SDI-12 COMPASS / INCLINATION SENSOR

The TBSCS1 is a 3D compass and inclination sensor with SDI-12 interface. It measures heading, roll angle and pitch angle.
The sensor is used in agricultural yield applications to monitor the operation of center pivot irrigation systems or the status of flood gates.

TBSCS1 SDI-12 compass / inclinometer

Features

- 3D Compass and inclination sensor
- Measurement range: 0° to 360°heading,
- -90° to +90° roll, -90° to +90° pitch
- Measurement response: 3 sec
- SDI-12 Standard V1.4
- Plug and Play
- 6 - 16V supply voltage
- Operating Temperature Range:
  - 40°C … + 80°C
- Weight: 80g

Target Applications

- Monitoring of flood gates
- Monitoring of center pivot irrigators

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1 Introduction

The TBSCS1 is a rugged compass sensor/inclinometer with SDI-12 interface. It is mounted inside an IP67 housing from Fibox.

Figure 1 – TBSCS1 board

1.1 Product specifications

- Compass heading range: 0 to 360°, ±3° accuracy
- Roll angle range: -90° to +90°, ±2° accuracy
- Pitch angle range: -90° to +90°, ±2° accuracy
- Measurement response: 3 sec
- SDI-12 Standard V1.4
- 6 - 16V supply voltage
- Operating Temperature Range: - 40°C … + 80°C
- Weight: 0,08kg
- Current consumption: active 17mA; idle 1.8mA.
- Standard cable length: 3m; any other length upon requirement

1.2 Calibration

The heading calculation relies on an accurate measurement of the magnetic field. However the measurement accuracy is impacted by both hard-iron and soft-iron phenomenons.

It is then required to proceed with a specific procedure that will measure the hard-iron and soft-iron corrections that will be automatically applied while measuring the heading.

In that case, M2! command shall be sent only once and at the place where TBSCS1 is used. This measurement procedure must be done again whenever TBSCS1 is moved to another place in order to ensure a suitable accuracy.

The hard-iron and soft-iron measurements procedure takes 20 seconds.

Upon execution of M2!, TBSCS1 shall be fully rotated:

- Around its 3 axis as defined by the industry standard NED (*North, East,* Down) coordinates system:

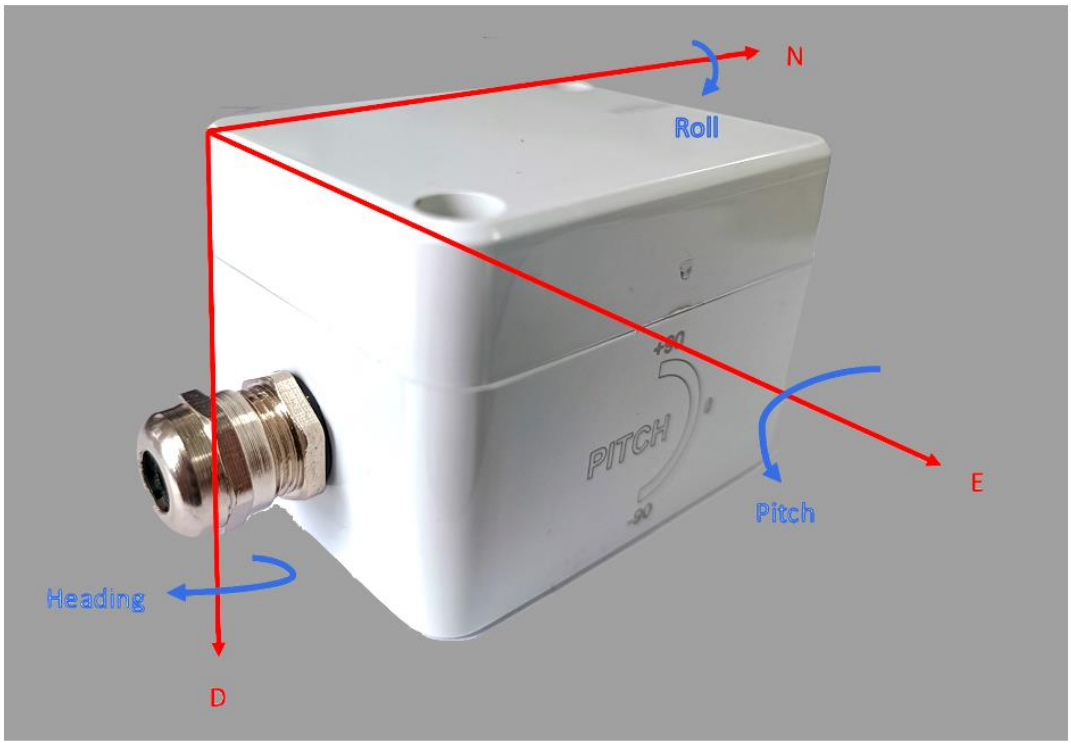

Figure 2 – TBSCS1 – Roll, Pitch and Heading axis

- And then for different pitch and roll positions.

Performing hard-iron and soft-iron measurement is only needed when TBSCS1 is used to calculate the heading. In case only the roll and pitch are measured, this procedure can be skipped.

Hard-iron and soft-iron correction parameters can be cleared with extended command **aXSHS,0!** meaning that no compensation will be applied while measuring the heading (which is not recommended since it will entail a significant error on the calculated heading).

1.3 Default parameters

TBSCS1 is shipped with following default parameters:

- SDI-12 address: 0
- Temperature unit: degree Celcius
- Hard-iron compensation: none (Mag_X, Mag_Y and Mag_Z offset: 0 mGauss)
- Soft-iron compensation: none (Mag_X, Mag_Y and Mag_Z scaling factor: 1)
- Magnetic declination: 0 degree.

1.4 Installation

The TBSCS1 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 and 3 of this datasheet. Chapter 2 refers to the electrical installation; chapter 3 refers to the mechanical drawings.

The TBSCS1 shall ideally be mounted in at least 1,5 meters distance from iron objects if the compass feature is used.

Figure 3 – terminal block pin assignment

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

TBSCS1 is SDI-12 v1.4 compliant.

2 Measurement

The TBSCS1 outputs compass heading, roll angle, pitch angle and board temperature.

2.1 Roll, pitch and heading measurement

TBSCS1 embeds an accelerometer that allows calculating the pitch and roll whereas the heading is calculated with the embedded magnetometer. The reported values are in degree.

With respect to heading measurement, TBSCS1 not only applies hard-iron and soft-iron compensation on the measured magnetic field (as described in the calibration procedure) but also includes an algorithm that automatically performs tilt compensation.

Above compensations are automatically carried out while issuing M! measurement command.

Due to TBSCS1 design, the sensor must be used in static conditions for full accuracy or in slow motion.

Supported measurement commands:

aM!	**aMC!**	**aC!**	**aCC!**	**roll angle, pitch angle, compass heading**

Notes:

- The angles are measured in degrees.
- The measured heading is magnetic heading pointed by the *Heading* arrow at the top of TBSCS1.

2.2 Temperature measurement

TBSCS1 3D accelerometer and magnetometer module provides an embedded temperature sensor. It shall be used for getting temperature indication rather than an precise measurement like with a PT1000.

Supported measurement commands:

aM1!	**aMC1!**	**aC1!**	**aCC1!**	**internal temperature**

The measurement unit is ℃ by default, but it can be configured to ℉ through extended SDI-12 command **XSTUC!/XSTUF!**.

2.3 Hard-iron and soft-iron compensation measurement

While performing the hard-iron and soft-iron measurements, M2! returns the calculated hard-iron offsets (Mag_X_HI, Mag_Y_HI, Mag_Z_HI in mGauss) and soft-iron scaling factor (Mag_X_SI, Mag_Y_SI, Mag_Z_SI).

Supported measurement commands:

aM2!	**aMC2!**	**aC2!**	**aCC2!**	**Mag_X_HI, Mag_Y_HI, Mag_Z_HI, Mag_X_SI, Mag_Y_SI, Mag_Z_SI**

These corrections can be reset to their default values with extended SDI-12 command **XSHS,0!**.

2.4 Magnetic declination compensation

The heading is measured vs the magnetic North. If the user needs to get the heading aligned with the true North or simply desires to set a custom reference direction, an offset can be applied to the final calculation through the extended command **aXSMD,sn!**.
Valid offset ranges from -90 to +90 degrees.

3 Application Examples

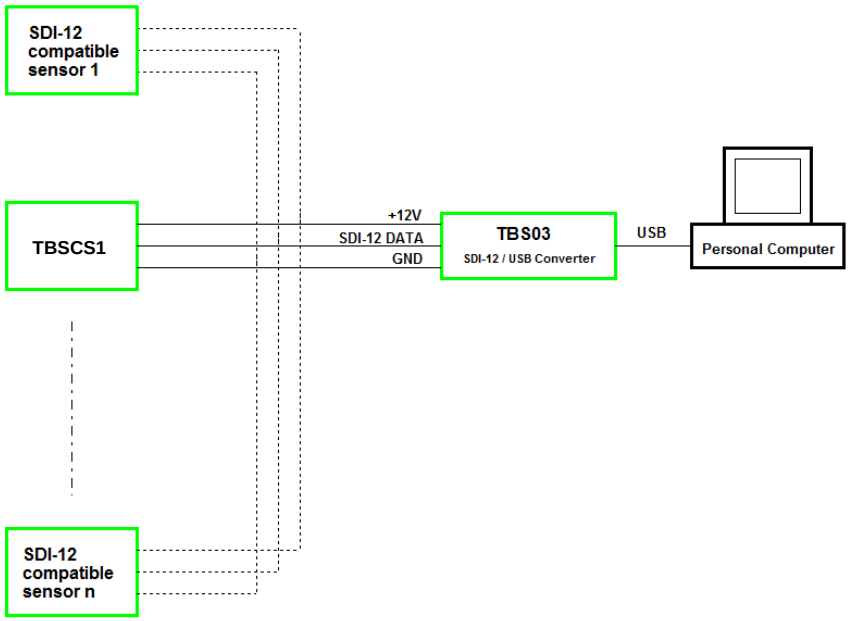

Figure 4 – TBSCS1 and other sensors with SDI-12 interface connected to TBS03 SDI-12 to USB converter; setup for controlling / testing sensors and for PC based data recording

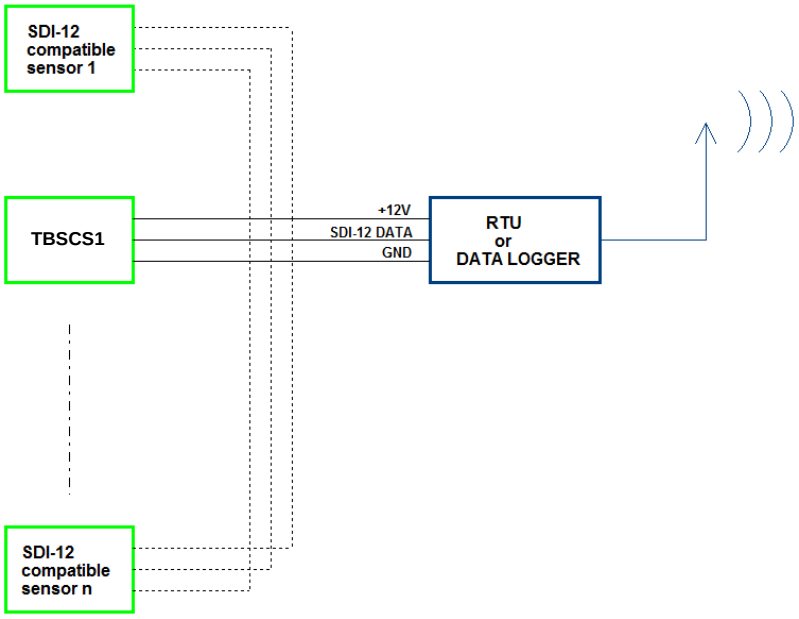

Figure 5 – TBSCS1 and other sensors with SDI-12 interface connected to Remote Telemetry Unit or Data Recorder

4 HARDWARE DESCRIPTION

Refer to Fibox website with respect to the mounting holes of the housing.

4.1 Cable Connection

Cable Color	Signal Assignment
Blue	SDI-12 Power
Yellow-Green	SDI-12 Data
Blue	GND
Black	GND

Table 1 – Cable Connection

5 SUPPORTED SDI-12 V1.3 COMMANDS

Following commands are supported by the TBSCS1:

Command	Description	Response
a!	Acknowledge Active	a<CR><LF>
aI!	Send Identification	a14TEKBOXVNTBSCS1rv<h><nnnnnn><fffffff><CR><LF> With: ○ <a>: SDI-12 address ○ <h>: HW revision (one letter) ○ <nnnnnn>: serial number (6 digits) ○ <fffffff>: firmware version (7 digits) Example: 014TEKBOXVNTBSCS1rvB1234561200101<CR><LF>
aAb!	Change Address	b<CR><LF> Changing the sensor address from a to b
?!	Address Query	a<CR><LF>
aM!	Start Measurement Measures roll, pitch and heading (in degrees)	a0033<CR><LF> Delay: (3) seconds and number of values (3)
aM1!	Additional Measurement Measures internal temperature	a0011<CR><LF> Delay: (1) seconds and number of values (1)
aM2!	Additional Measurement	a0206<CR><LF>

	Measures hard-iron and soft-iron parameters	Delay: (20) seconds and number of values (6)
aMC!	Start Measurement and request CRC Measures roll, pitch and heading (in degrees) and calculates CRC	a0033<CR><LF> Delay: (3) seconds and number of values (3)
aMC1!	Additional Measurement and request CRC Measures internal temperature and calculates CRC	a0011<CR><LF> Delay: (1) seconds and number of values (1)
aMC2!	Additional Measurement Measures hard-iron and soft-iron parameters and calculates CRC	a0206<CR><LF> Delay: (20) seconds and number of values (6)
aC!	Start Concurrent Measurement Measures roll, pitch and heading (in degrees)	a00303<CR><LF> Delay: (3) seconds and number of values (3)
aC1!	Start Concurrent Measurement Measures internal temperature	a00101<CR><LF> Delay: (1) seconds and number of values (1)
aC2!	Additional Measurement Measures hard-iron and soft-iron parameters	a02006<CR><LF> Delay: (20) seconds and number of values (6)
aCC!	Start Concurrent Measurement and request CRC Measures roll, pitch and heading (in degrees) and calculates CRC	a00303<CR><LF> Delay: (3) seconds and number of values (3)
aCC1!	Start Concurrent Measurement and request CRC Measures internal temperature and calculates CRC	a00101<CR><LF> Delay: (1) seconds and number of values (1)
aCC2!	Additional Measurement Measures hard-iron and soft-iron parameters and calculates CRC	a02006<CR><LF> Delay: (20) seconds and number of values (6)
aD0!	Get Measurement Result(s)	Upon issuing the aD0! Command, the TBSCS1 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 v1.3 commands

6 SUPPORTED SDI-12 V1.4 COMMANDS

Command	Description	Response
aIM!	aM! Identify Measurement Returns delay and number of parameters	a0033<CR><LF> Delay: (3) seconds and number of values (3)
aIMC!	aMC! Identify Measurement Returns delay and number of parameters	a0033<CR><LF> Delay: (3) seconds and number of values (3)
aIC!	aC! Identify Measurement	a00303<CR><LF>

	Returns delay and number of parameters	Delay: (3) seconds and number of values (3)
aICC!	aCC! Identify Measurement Returns delay and number of parameters	a00303<CR><LF> Delay: (3) seconds and number of values (3)
aIM1!	aM1! Identify Measurement Returns delay and number of parameters	a0011<CR><LF> Delay: (1) seconds and number of values (1)
aIMC1!	aMC1! Identify Measurement Returns delay and number of parameters	a0011<CR><LF> Delay: (1) second, number of values (1)
aIC1!	aC1! Identify Measurement Returns delay and number of parameters	a00101<CR><LF> Delay: (1) second and number of values (01)
aICC1!	aCC1! Identify Measurement Returns delay and number of parameters	a00101<CR><LF> Delay: (1) second, number of values (1)
aIM2!	aM2! Identify Measurement Returns delay and number of parameters	a0206<CR><LF> Delay: (20) seconds and number of values (6)
aIMC2!	aMC2! Identify Measurement Returns delay and number of parameters	a0206<CR><LF> Delay: (20) seconds and number of values (6)
aIC2!	aC2! Identify Measurement Returns delay and number of parameters	a02006<CR><LF> Delay: (20) seconds and number of values (6)
aICC2!	aCC2! Identify Measurement Returns delay and number of parameters	a02006<CR><LF> Delay: (20) seconds and number of values (6)
aIM_001!	aM! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,Roll,Degree(Angle);<CR><LF>
aIMC_001!	aMC! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,Roll,Degree(Angle);<CRC><CR><LF>
aIC_001!	aC! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,Roll,Degree(Angle);<CR><LF>
aICC_001!	aCC! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,Roll,Degree(Angle);<CRC><CR><LF>
aIM_002!	aM! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,Pitch,Degree(Angle);<CR><LF>
aIMC_002!	aMC! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,Pitch,Degree(Angle);<CRC><CR><LF>
aIC_002!	aC! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,Pitch,Degree(Angle);<CR><LF>
aICC_002!	aCC! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,Pitch,Degree(Angle);<CRC><CR><LF>
aIM_003!	aM! Identify Measurement	a,Yaw,Degree(Angle);<CR><LF>

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	Parameters (3rd) Returns parameter's identification and unit	
aIMC_003!	aMC! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,Yaw,Degree(Angle);<CRC><CR><LF>
aIC_003!	aC! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,Yaw,Degree(Angle);<CR><LF>
aICC_003!	aCC! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,Yaw,Degree(Angle);<CRC><CR><LF>
aIM1_001!	aM1! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,AirTemperature,*t_unit*;<CR><LF> (*)
aIMC1_001!	aMC1! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,AirTemperature,*t_unit*;<CRC><CR><LF> (*)
aIC1_001!	aC1! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,AirTemperature,*t_unit*;<CR><LF> (*)
aICC1_001!	aCC1! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,AirTemperature,*t_unit*;<CRC><CR><LF> (*)
aIM2_001!	aM2! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,MagneticHardIronX,mGauss;<CR><LF>
aIMC2_001!	aMC2! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,MagneticHardIronX,mGauss;<CRC><CR><LF>
aIC2_001!	aC2! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,MagneticHardIronX,mGauss;<CR><LF>
aICC2_001!	aCC2! Identify Measurement Parameters (1rst) Returns parameter's identification and unit	a,MagneticHardIronX,mGauss;<CRC><CR><LF>
aIM2_002!	aM2! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,MagneticHardIronY,mGauss;<CR><LF>
aIMC2_002!	aMC2! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,MagneticHardIronY,mGauss;<CRC><CR><LF>
aIC2_002!	aC2! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,MagneticHardIronY,mGauss;<CR><LF>
aICC2_002!	aCC2! Identify Measurement Parameters (2nd) Returns parameter's identification and unit	a,MagneticHardIronY,mGauss;<CRC><CR><LF>

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aIM2_003!	aM2! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,MagneticHardIronZ,mGauss;<CR><LF>
aIMC2_003!	aMC2! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,MagneticHardIronZ,mGauss;<CRC><CR><LF>
aIC2_003!	aC2! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,MagneticHardIronZ,mGauss;<CR><LF>
aICC2_003!	aCC2! Identify Measurement Parameters (3rd) Returns parameter's identification and unit	a,MagneticHardIronZ,mGauss;<CRC><CR><LF>
aIM2_004!	aM2! Identify Measurement Parameters (4th) Returns parameter's identification and unit	a,MagneticSoftIronX,none;<CR><LF>
aIMC2_004!	aMC2! Identify Measurement Parameters (4th) Returns parameter's identification and unit	a,MagneticSoftIronX, none;<CRC><CR><LF>
aIC2_004!	aC2! Identify Measurement Parameters (4th) Returns parameter's identification and unit	a,MagneticSoftIronX, none;<CR><LF>
aICC2_004!	aCC2! Identify Measurement Parameters (4th) Returns parameter's identification and unit	a,MagneticSoftIronX, none;<CRC><CR><LF>
aIM2_005!	aM2! Identify Measurement Parameters (5th) Returns parameter's identification and unit	a,MagneticSoftIronY, none;<CR><LF>
aIMC2_005!	aMC2! Identify Measurement Parameters (5th) Returns parameter's identification and unit	a,MagneticSoftIronY, none;<CRC><CR><LF>
aIC2_005!	aC2! Identify Measurement Parameters (5th) Returns parameter's identification and unit	a,MagneticSoftIronY, none;<CR><LF>
aICC2_005!	aCC2! Identify Measurement Parameters (5th) Returns parameter's identification and unit	a,MagneticSoftIronY, none;<CRC><CR><LF>
aIM2_006!	aM2! Identify Measurement Parameters (6th) Returns parameter's identification and unit	a,MagneticSoftIronZ, none;<CR><LF>
aIMC2_006!	aMC2! Identify Measurement Parameters (6th) Returns parameter's identification and unit	a,MagneticSoftIronZ, none;<CRC><CR><LF>
aIC2_006!	aC2! Identify Measurement Parameters (6th) Returns parameter's identification and unit	a,MagneticSoftIronZ, none;<CR><LF>
aICC2_006!	aCC2! Identify Measurement Parameters (6th)	a,MagneticSoftIronZ, none;<CRC><CR><LF>

	Returns parameter's identification and unit	

Table 3 – Standard SDI-12 v1.4 commands

(*) Where *t_unit* depends on the unit set with aXSTUn! (Celcius or Fahrenheit)

7 Supported Extended Commands

Execution of extended SDI-12 commands will return aX_FAIL<CR><LF> in case of error.

7.1 Setting engineering units

Command	Description	Response
aXSTUn!	Set temperature unit <n>: temperature unit ○ C: Celcius ○ F: Fahrenheit	aX_OK<CR><LF>
aXGTU!	Get temperature unit	a*n*<CR><LF> <*n*>: ○ C: Celcius ○ F: Fahrenheit

Table 4 – Extended SDI-12 Commands – Engineering Units

7.2 Initialization

Command	Description	Response
aXSDC!	Restore default configuration: ○ Degree Celcius ○ SDI-12 address: 0 ○ Hard-Iron X, Y, Z: 0mGauss ○ Soft-Iron X, Y, Z: 1 ○ Magnetic declination: 0 degree	aX_OK<CR><LF>
aXSHS,0!	Set default values for magnetic hard-iron and soft-iron compensation: ○ Magnetic Hard-Iron X, Y, Z: 0mGauss ○ Magnetic Soft-Iron X, Y, Z: 1	aX_OK<CR><LF>

Table 5 – Extended SDI-12 Commands - Initialization

7.3 Internal parameters

Command	Description	Response
aXSMD,sn!	Set magnetic declination offset <s>: ○ Sign, + or – <n>: ○ Magnetic declination in degree (range: -90;+90)	aX_OK<CR><LF>
aXGMD!	Get magnetic declination value (in degree)	a*sn*<CR><LF> <*s*>: ○ Sign, + or – <*n*>: Magnetic declination
aXGHS!	Get hard-iron (in mGauss) and soft-iron compensation values for (X, Y, Z) magnetic vector components	a*mhix,mhiy,mhiz,msix,msiy,msiz* <CR><LF> <*mhix*>: ○ Hard-iron compensation – X component <*mhiy*>: ○ Hard-iron compensation – Y component <*mhiz*>: ○ Hard-iron compensation – Z component <*msix*>: ○ Soft-iron compensation – X component <*msiy*>: ○ Soft-iron compensation – Y component <*msiz*>: ○ Soft-iron compensation – Z component All values in floating point format with 2 decimal digits.

Table 6 – Extended SDI-12 Commands – Internal parameters

8 Ordering Information

Part Number	Description
TBSCS1	TBSCS1, SDI-12 compass sensor / inclinometer with 3m cable

Please mention in your order, if you require a different cable length

Table 7 – Ordering Information

9 History

Version	Date	Author	Changes
V1.0	8.04.2015	Mayerhofer	Creation of the document
V1.1	8.08.2019	Thinh	Added zero positon command
V1.2	26.05.2021	Philippe Hervieu	Update calibration chapter
V1.3	13.12.2022	Philippe Hervieu	Update document following change of digital compass IC (HW rev B)
V1.4	09.05.2023	Philippe Hervieu	Update dead link.

Table 8 – History