Modbus Master to SDI 12 Slave Converter

The TBS09S is a converter to connect SDI-12 sensors to a Modbus master. It can control multiple SDI12 sensors in parallel by individually addressing the connected SDI-12 sensors.

TBS09S Modbus Master to SDI 12 Slave Converter

Features

- Modbus Master to SDI 12 Slave Converter
- Multiple SDI-12 sensors can be connected
- SDI-12 Standard V1.3
- Modbus RTU, 19200 baud
- Switched sensor supply voltage output
- 5 - 16V supply voltage
- 6mA current consumption when active
- 20µA in idle, 4mA in active mode
- Operating Temperature Range:
  - 40°C … + 80°C

Target Applications

- SDI-12 sensor networks with Modbus controller

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Modbus Master to SDI-12 Slave Converter

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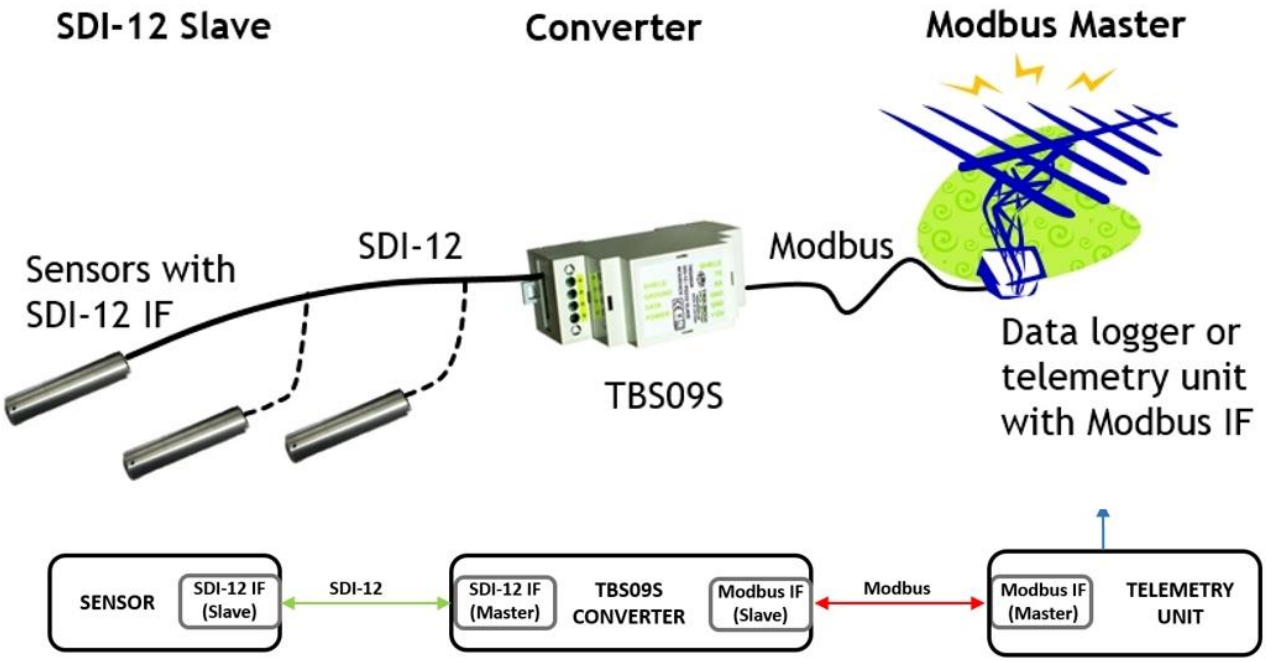
Modbus Master to SDI-12 Slave Converter

1 Introduction

The TBS09S is a converter to connect one or multiple SDI-12 sensors to a Modbus device such as a data logger or telemetry unit. The converter is inserted in between the data logger or RTU with Modbus interface and the sensor(s) with SDI-12 interface. The designation Modbus Master to SDI-12 Slave is ambiguous. Looking purely at the converter, the device got a Modbus slave interface on one side and a SDI-12 master output at the other side. However looking at its application, the device is a converter between a Modbus master (data logger, RTU, etc.) and a SDI-12 slave (sensor with SDI-12 interface).

The following diagrams describe a typical use of TBS09S module that bridges a Modbus telemetry unit with a SDI-12 sensor and highlight how the internal TBS09S Modbus/SDI-12 layers interact with them.



TBS09S application

2 Product specification

- Application: converter used to interface Modbus master devices (eg RTU) with SDI-12 slave devices (eg sensors)
    - The converter embeds a Modbus slave and a SDI-12 master modules
- SDI-12 compatibility:
    - Version: v1.3
    - SDI-12 commands not supported: aI!, a!, aV!, aRx!, aRCx!
    - Data command supports up to 10 measurements maximum
- Modbus compatibility:

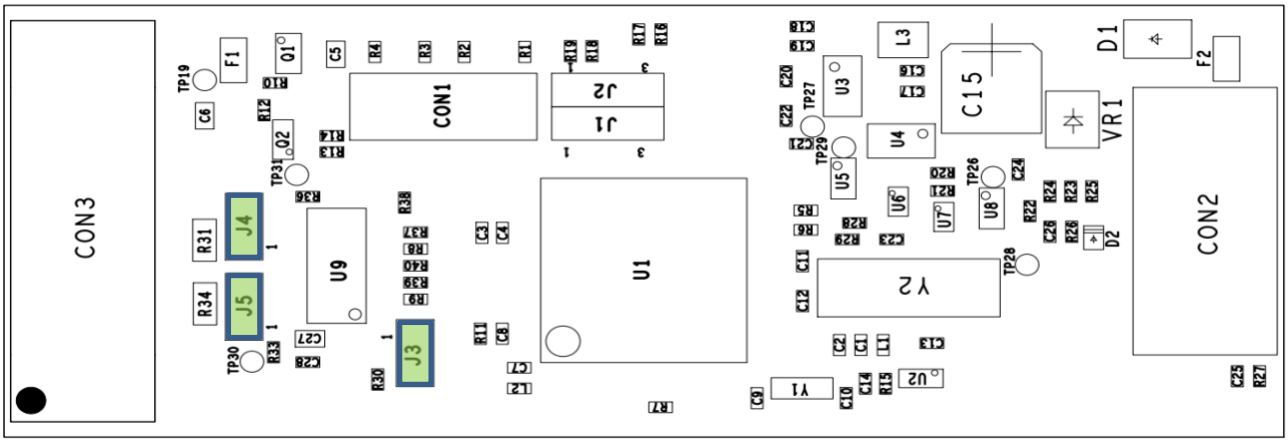
  - Modbus RTU
  - Baud rate: 19200
  - Half or full duplex (configurable)
  - 120 Ω termination (configurable)
- Supply voltage: 5 – 16 V
- Power consumption
  - Active mode: 4 mA
  - Idle mode: 20µA
- Form factor: DINRAIL

3 Calibration and settings

TBS09S doesn't require any calibration.

It comes factory-configured to operate by default in half duplex with no termination.

This configuration can be changed by the user by setting related jumpers J3/J4/J5 after lifting the housing:



Communication mode:

Configuration	J3
Half Duplex	✓
Full Duplex	×

Modbus termination:

Configuration	J4 – J5
120 Ω termination	✓
No termination	×

Modbus Master to SDI-12 Slave Converter

4 Connections

TBS09S provides one 4 slots connector (SDI-12) and one 6 slots connector (RS485):

SDI-12 terminal assignment, from top to bottom:

Slot name	Description	Comment
Shield	Cable shield	Connect to sensor's cable shield
Ground	Ground	Connect to ground
Data	SDI-12 data line	Connect to SDI-12 sensor data line
Power*	TBS09S supply voltage input	Connect to +12V external power supply

RS485 terminal assignment, from top to bottom:

Slot name	Description	Comment
T+	TXD+ output	Connect to Modbus master RXD+
T-	TXD- output	Connect to Modbus master RXD-
R+	RXD+ input	Connect to Modbus master TXD+ ***(full duplex operation only – must be left unconnected in half duplex)***
R-	RXD- input	Connect to Modbus master TXD- ***(full duplex operation only – must***

		be left unconnected in half duplex)
G	Ground	Connect to ground
P*	SDI-12 sensor supply voltage output (+12V, connected to the converter supply line through a high side FET switch)	Connect to SDI-12 sensor power line.

*The crossed connectivity is caused by the same converter hardware being used for both the Modbus master to SDI-12 slave converter and the SDI-12 master to Modbus slave converter. This is subject to being changed in a future hardware revision.

5 Sending SDI-12 commands through TBS09S

SDI-12 commands are encapsulated by Modbus which acts as a communication layer.

Executing a SDI-12 command over Modbus requires sending 2 Modbus requests:

- One request with function code 6 to send the SDI-12 command
- One request with function code 4 to get the result of the executed SDI-12 command.

5.1 Supported SDI-12 commands

TBS09S supports only a subset of SDI-12 commands vs SDI-12 v1.3 specification and has a limitation with respect to Send Data command.

The following commands are supported:

Address Query	?!
Change Address	aAb!
Start Measurement	aM!
Start Measurement and Request CRC	aMC!
Additional Measurements	aM1! … aM9!
Additional Measurements and Request CRC	aMC1! ... aMC9!
Start Concurrent Measurement	aC!
Start Concurrent Measurement and Request CRC	aCC!
Additional Concurrent Measurements	aC1! … aC9!
Additional Concurrent Measurements and Request CRC	aCC1! ... aCC9!
Send Data (*)	aD0! … aD9!

Supported SDI-12 address range is aligned with SDI-12 v1.3 specification:

- 0 – 9

- a – z
- A – Z

(*): Send Data aD0!...aD9! supports only up to 10 measurements irrespective of the maximum number of characters that can be returned (75 for a concurrent measurement command, 35 otherwise).

5.2 Modbus default configuration and frames format

5.2.1 Default configuration

TBS09S uses following Modbus configuration:

- Protocol: Modbus RTU
- Baud rate: 19200, Parity: none
- Modbus slave address: 1 (default). It is configurable via Modbus Address Change request within 0x01-0xFF range

5.2.2 Modbus master to TBS09S: Modbus request format

All Modbus requests sent by the Modbus master (Modbus data logger, Modbus RTU) to TBS09S must be formatted as described in following table as per Modbus specification.

Each field represents one byte in hexadecimal:

Modbus Master request
Slave Address
Function
Starting Address Hi
Starting Address Lo
Data Hi
Data Lo
Error Check Lo (CRC)
Error Check Hi (CRC)

TBS09S uses only Modbus requests with function codes 4 or 6 depending on the command's purpose.

The CRC must be calculated as per Modbus RTU standard (please note the less significant CRC byte is stored first and followed by the most significant CRC byte).

Online calculators can be used for this, like https://www.lammertbies.nl/comm/info/crc-calculation and selecting hexadecimal input type.

5.2.3 TBS09S to Modbus master: Modbus response format

Each field in below tables represents one byte.

Generic response to a Modbus request with function code 4

Modbus Slave response (TBS09S)
Slave Address *(TBS09S Modbus address)*
04
Byte Count *(2*N, N is the number of Input Registers)*
Input Register 1 Hi
Input Register 1 Lo
…
Input Register N Hi
Input Register N Lo
Error Check Lo (CRC)
Error Check Hi (CRC)

Generic response to a Modbus request with function code 6

Modbus Slave response (TBS09S)
Slave Address *(TBS09S Modbus address)*
06
Register Address Hi
Register Address Lo
Register Value Hi
Register Value Lo
Error Check Lo (CRC)
Error Check Hi (CRC)

Note: in this case, the response is the mirror of the corresponding request.

5.3 TBS09S Modbus registers mapping

All available SDI-12 commands that can be sent over Modbus are mapped over a set of registers.

The following table lists all TBS09S Modbus registers with their associated commands ('a' refers to SDI-12 address as per SDI-12 standard and is subsequently used as is in this document):

Register Address	Command	Description
Modbus configuration commands		
0xB000	Modbus slave address change	Change TBS09S Modbus address
SDI-12 commands		
0xA000	?!	Address Query command
0xA100	aAb!	Change Address command
0x0010	aM!	Start Measurement
0x0011	aM1!	Additional Measurements
0x0012	aM2!	Additional Measurements

0x0013	aM3!	Additional Measurements
0x0014	aM4!	Additional Measurements
0x0015	aM5!	Additional Measurements
0x0016	aM6!	Additional Measurements
0x0017	aM7!	Additional Measurements
0x0018	aM8!	Additional Measurements
0x0019	aM9!	Additional Measurements
0x0020	aMC!	Additional Measurements and Request CRC
0x0021	aMC1!	Additional Measurements and Request CRC
0x0022	aMC2!	Additional Measurements and Request CRC
0x0023	aMC3!	Additional Measurements and Request CRC
0x0024	aMC4!	Additional Measurements and Request CRC
0x0025	aMC5!	Additional Measurements and Request CRC
0x0026	aMC6!	Additional Measurements and Request CRC
0x0027	aMC7!	Additional Measurements and Request CRC
0x0028	aMC8!	Additional Measurements and Request CRC
0x0029	aMC9!	Additional Measurements and Request CRC
0x0030	aC!	Start Concurrent Measurements
0x0031	aC1!	Additional Concurrent Measurements
0x0032	aC2!	Additional Concurrent Measurements
0x0033	aC3!	Additional Concurrent Measurements
0x0034	aC4!	Additional Concurrent Measurements
0x0035	aC5!	Additional Concurrent Measurements
0x0036	aC6!	Additional Concurrent Measurements
0x0037	aC7!	Additional Concurrent Measurements
0x0038	aC8!	Additional Concurrent Measurements

0x0039	aC9!	Additional Concurrent Measurements
0x0040	aCC!	Additional Concurrent Measurements and Request CRC
0x0041	aCC1!	Additional Concurrent Measurements and Request CRC
0x0042	aCC2!	Additional Concurrent Measurements and Request CRC
0x0043	aCC3!	Additional Concurrent Measurements and Request CRC
0x0044	aCC4!	Additional Concurrent Measurements and Request CRC
0x0045	aCC5!	Additional Concurrent Measurements and Request CRC
0x0046	aCC6!	Additional Concurrent Measurements and Request CRC
0x0047	aCC7!	Additional Concurrent Measurements and Request CRC
0x0048	aCC8!	Additional Concurrent Measurements and Request CRC
0x0049	aCC9!	Additional Concurrent Measurements and Request CRC

5.4 TBS09S Modbus requests detailed description

Following tables show each defined Modbus requests and the corresponding response format along with an example.

All fields represent a byte coded in hexadecimal.

5.4.1 Modbus slave address change

Register address	Command		Description
0xB000	Modbus slave address change		Change TBS09S Modbus address
Modbus Master request format	Example: change TBS09S Modbus address from 1 to 2		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
06	06	06	06
B0	B0	B0	B0
00	00	00	00
00	00	00	00
New TBS09S Modbus Address	02	02	New TBS09S Modbus Address

Range: 0x01 – 0xFF			
Error Check Lo (CRC)	2E	2E	Error Check Lo (CRC)
Error Check Hi (CRC)	CB	CB	Error Check Hi (CRC)

5.4.2 Query sensor's SDI-12 address (SDI-12 command: ?!)

Send SDI-12 ?! command

Register address	Command		Description
0xA000	Query sensor's SDI-12 address		Sends ?! SDI-12 command
Modbus Master request format	Example: returned sensor's SDI-12 address is 2		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
06	06	06	06
A0	A0	A0	A0
00	00	00	00
00	00	00	00
00	00	00	00
Error Check Lo (CRC)	AB	AB	Error Check Lo (CRC)
Error Check Hi (CRC)	CA	CA	Error Check Hi (CRC)

Read returned SDI-12 address

Register address	Command		Description
0xA000	Read ?! response		Read sensor's SDI-12 address
Modbus Master request format	Example: returned sensor's SDI-12 address is 2		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
04	04	04	04
A0	A0	02	02
00	00	32 *(ASCII code: 0x32 => SDI-12 address=2)*	SDI-12 Address *(represented by its ASCII code)*
00	00	00	00
01	01	AC	Error Check Lo (CRC)
Error Check Lo (CRC)	13	50	Error Check Hi (CRC)
Error Check Hi (CRC)	CA		

5.4.3 Change sensor's SDI-12 address (SDI-12 command: aAb!)

Send SDI-12 aAb! Command

Register address	Command		Description
0xA100	Change sensor's SDI-12 address		Sends aAb! SDI-12 command
Modbus Master request format	Example: change SDI-12 address from 3 to 4		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
06	06	06	06
A1	A1	A1	A1
00	00	00	00
Current SDI-12 Address *(represented by its ASCII code)*	33 *(ASCII code: 0x33 => SDI-12 address=3)*	33	Current SDI-12 Address *(represented by its ASCII code)*
New SDI-12 Address *(represented by its ASCII code)*	34 *(ASCII code: 0x34 => SDI-12 address=4)*	34	New SDI-12 Address *(represented by its ASCII code)*
Error Check Lo (CRC)	BF	BF	Error Check Lo (CRC)
Error Check Hi (CRC)	11	11	Error Check Hi (CRC)

5.4.4 SDI-12 Measurement (SDI-12 commands: aM!/aMC!/aMx!/aMCx!/aC!/aCC!/aCCx!)

The procedure is similar to a regular SDI-12 communication to get sensor's measurements, except that the SDI-12 commands are sent over Modbus.

This implies:

- Send a SDI-12 measurement command (aM!/aMC!/aMx!/aMCx!/aC!/aCC!/aCCx!)
- Get the specified time (ttt) and the number of measurement values (n / nn)
- Send the SDI-12 data command (aD0! … aD9!)
- Retrieve the measurements

Step 1 – Send a Measurement Command to the SDI-12 sensor:

TBS09S can transmit any of the following measurement commands to a SDI-12 sensor: aM!...aM9, aMC!…aMC9!, aC!..aC9!, aCC!..aCC9!

Note: refer to TBS09S Modbus registers mapping for a complete list of supported SDI-12 commands and the corresponding register address.

- *Send SDI-12 measurement command*(aM!/aMC!/aMx!/aMCx!/aC!/aCC!/aCCx!)

Register address	Command		Description
SDI-12 register address	SDI-12 Measurement Command		aM!/aMC!/aMx!/aMCx!/aC!/aCC!/aCCx!
Modbus Master request format	Example: send SDI-12 command bM!		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
06	06	06	06
SDI-12 command register address Hi	00 *(M! register address Hi)*	00	SDI-12 command register address Hi
SDI-12 command register address Lo	10 *(M! register address Lo)*	10	SDI-12 command register address Lo
00	00	00	00
SDI-12 address *(represented by its ASCII code)*	62 *(ASCII code: 0x62 => SDI-12 address=b)*	62	SDI-12 address *(represented by its ASCII code)*
Error Check Lo (CRC)	09	09	Error Check Lo (CRC)
Error Check Hi (CRC)	E6	E6	Error Check Hi (CRC)

Step 2 – Get the specified time and the number of measurements

As per SDI-12 standard, the measurements commands will return the specified time and the number of measurement values:

- M!/MC!/M1!...M9!/MC1!...MC9!
  - Specified time: ttt
  - Number of measurement values: n
- C!/CC!/C1!...C9!/CC1!...CC9!
  - Specified time: ttt
  - Number of measurement values: nn

Register address	Command		Description
0xmm10 (mm: SDI-12 address ASCII code)	Read SDI-12 measurement command response		Read Specified time (ttt) and Number of Measurements (n/nn)
Modbus Master request format	Example: time=1s and 2 measurement values		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
04	04	04	04
SDI-12 address *(represented by its ASCII code)*	62 *(ASCII code 0x62 =>*	04	04

	SDI-12 address=b)		
10	10	00	00
00	00	01	Specified time ttt
02	02	00	00
Error Check Lo (CRC)	6F	02	Number of measurements n/nn
Error Check Hi (CRC)	B6	2B	Error Check Lo (CRC)
		85	Error Check Hi (CRC)

Step 3 - Send SDI-12 Data Command to the SDI-12 sensor

Send the data command (any of aD0!...aD9!):

Register address	Command		Description
0x00Dm (m: 0 to 9)	Send SDI-12 Data command		Send aDm! (m: 0 to 9)
Modbus Master request format	Example: send SDI-12 data command bD0!		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
06	06	06	06
00	00	00	00
SDI-12 Data Command *(D0! To D9! Coded as 0xD0 to 0xD9)*	D0 *(0xD0 => D0! Data command)*	D0	SDI-12 Data Command *(D0! To D9! Coded as 0xD0 to 0xD9)*
00	00	00	00
SDI-12 address *(represented by its ASCII code)*	62 *(ASCII code: 0x62 => SDI-12 address=b)*	62	SDI-12 address *(represented by its ASCII code)*
Error Check Lo (CRC)	09	09	Error Check Lo (CRC)
Error Check Hi (CRC)	DA	DA	Error Check Hi (CRC)

Step 4 – Retrieve the measurements

The Send Data command is implemented in TBS09S so it can handle up to 10 values (this is a limitation vs SDI-12 v1.3 standard).

aDx! Will then return a maximum of 10 measurements as follows:

a<Value0><Value1><Value2><Value3><Value4><Value5><Value6><Value7><Value8><Value9>

Each value is identified by its index:

Value	Value0	Value1	Value2	Value3	Value4	Value5	Value6	Value7	Value8	Value9
Index	0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09

and is stored in hexadecimal floating point over 4 bytes (0x*Byte3Byte2Byte1Byte0*) and must be then individually fetched with a specific modbus request.

Retrieve a measurement

Register address	Command	Description
0xmmii mm: SDI-12 address ASCII code, ii: value index (0x00-0x09)	Retrieve aDx! Value	Return aDx! Value at index

Modbus Master request format	Example: retrieve the 6th value returned by bD0!		Modbus Slave response format
	Modbus Master request	Modbus Slave (TBS09S) response	
TBS09S Modbus Address	01	01	TBS09S Modbus Address
04	04	04	04
SDI-12 address *(represented by its ASCII code)*	62 *(ASCII code 0x62 => SDI-12 address=b)*	04	04
Value Index *(00x00 to 0x09)*	05 *(0x05 => index of the 6th value returned by bD0!)*	41	Value – Byte3
00	00	CF	Value – Byte 2
02	02	1E	Value – Byte 1
Error Check Lo (CRC)	7E	B8	Value – Byte 0
Error Check Hi (CRC)	72	D6	Error Check Lo (CRC)
		55	Error Check Hi (CRC)

The above example shows how to read the 6th measurement from a temperature sensor with SDI-12 interface.

The hexadecimal floating point value is 0x41CF1EB8; once converted to decimal representation this results in +25.89℃.

Online hexadecimal floating point to decimal converters can be used to make the measurement readable like https://www.h-schmidt.net/FloatConverter/IEEE754.html

5.5 TBS09S / SDI-12 sensor communication flow example

The below example shows how to measure and read the soil moisture and soil temperature over Modbus by using SDI-12 TBSMP03 Tekbox sensor (https://www.tekbox.com/product/tbsmp03-sdi-12-soil-moisture-temperature-probe/) connected to TBS09S.

With this test setup:

- TBS09S Modbus slave address is 1
- TBSMP03 SDI-12 address is 0
- TBSMP03 returns 2 parameters, soil temperature first and then the soil moisture

[Modbus Master]	**01 06 00 11 00 30 D9 DB**	**Modbus Master sends 0M1! To the sensor**
[TBS09S]	01 06 00 11 00 30 D9 DB	TBS09S responds with ACK
[Modbus Master]	**01 04 30 10 00 02 7F 0E**	**Modbus Master reads ttt and n**
[TBS09S]	01 04 04 00 01 00 02 2B 85	TBS09S returns ttt=1s and n=2 values
Modbus Master waits 1s		
[Modbus Master]	**01 06 00 D0 00 30 88 27**	**Modbus Master sends 0D0! To the sensor**
[TBS09S]	01 06 00 D0 00 30 88 27	TBS09S responds with ACK
[Modbus Master]	**01 04 30 00 00 02 7E CB**	**Modbus Master reads 1st parameter (moisture)**
[TBS09S]	01 04 04 41 2D 99 99 8B FF	TBS09S response data = 41,2D,99,99 =10.85
[Modbus Master]	**01 04 30 01 00 02 2F 0B**	**Modbus Master reads 2nd parameter (temperature)**
[TBS09S]	01 04 04 41 DB 70 A4 F8 FF	TBS09S response data = 41,DB,70,A4 = 27.43

6 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 V1.4 which dates from Jan 10th, 2019. The standard is available on the website of the SDI-12 Support Group.

7 History

Version	Date	Author	Changes
V1.0	9.8.2018	Thinh	Creation of the document
V1.1	9.19.2019	Thinh	Update new command
V1.5	24.6.2020	Hoa Hoang	Updated naming to Modbus Master to SDI 12 Slave Converter
V1.6	15.7.2020	Mayerhofer	Complete rework of the document
V1.7	17.7.2020	Philippe	Updated link in 5.5
V1.8	2.4.2021	Mayerhofer	Updated drawing in chapter 1
V1.9	22.07.2021	Philippe	Fix typo in 5.4.2 (Read returned SDI-12 address)