



Datasheet-Manual TBS12B/TBS12S LoRaWAN RTU for SDI-12 nodes

V1.20

The TBS12B/TBS12S SDI-12 to LoRaWAN RTU bring LoRa wireless connectivity to SDI-12 compliant sensors to achieve long range communication. These RTU embed a low power LoRaWAN certified modem, with dual antennas connectors to operate on low (434MHz/470MHz) and high (868MHz/915MHz) ISM bands. They also integrate a fully SDI-12 compatible data logger, that sends configurable SDI-12 commands to the sensors and transmits the measurements over LoRa. TBS12B and TBS12S share the same features but differ at power supply side: integrated solar panel and rechargeable battery (TBS12S) or batteries powered only (TBS12B). They offer low current consumption, small footprint and easy integration with SDI-12 sensors.

The TBS12B/TBS12S have been engineered specifically for applications where cost, performance, range, time to market and ease of integration are prime considerations.



Features

- LoRaWAN 1.02 Class A – ABP/OTAA
- SDI-12 Standard V1.3
- Selectable frequency schemes: EU, US, AU, AS, CN, Custom
- Easy configuration with PC tool through TBS12's UART port
- Low quiescent current
- TBS12S: integrated solar panel with 3.6V rechargeable battery
- TBS12B: 3*D cells batteries powered
- More than 15km range with clear line of sight
- Configurable measurements and transmission intervals.

- Operating Temperature Range: -40°C - +85°C

Target Applications

- Any usual agricultural application (eg crop yield optimization, precision irrigation, etc...) where deploying SDI-12 cables is an issue.
- Acts as a range extender for SDI-12 (up to 15km instead of 60m)
- SDI-12 sensors network capacity increase (thousands of nodes can be deployed with only one gateway).

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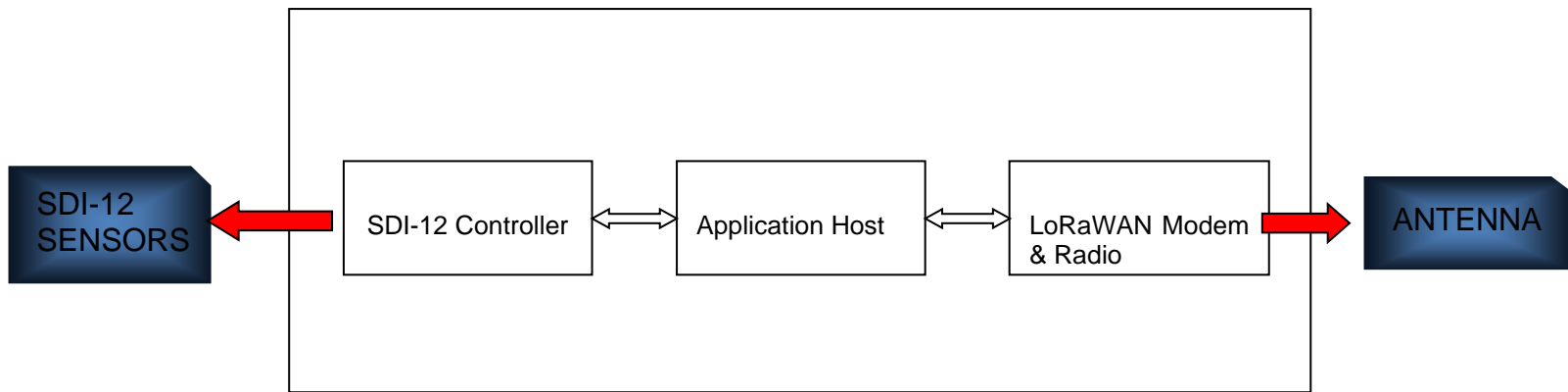
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1 Platform overview

1.1 Module overview

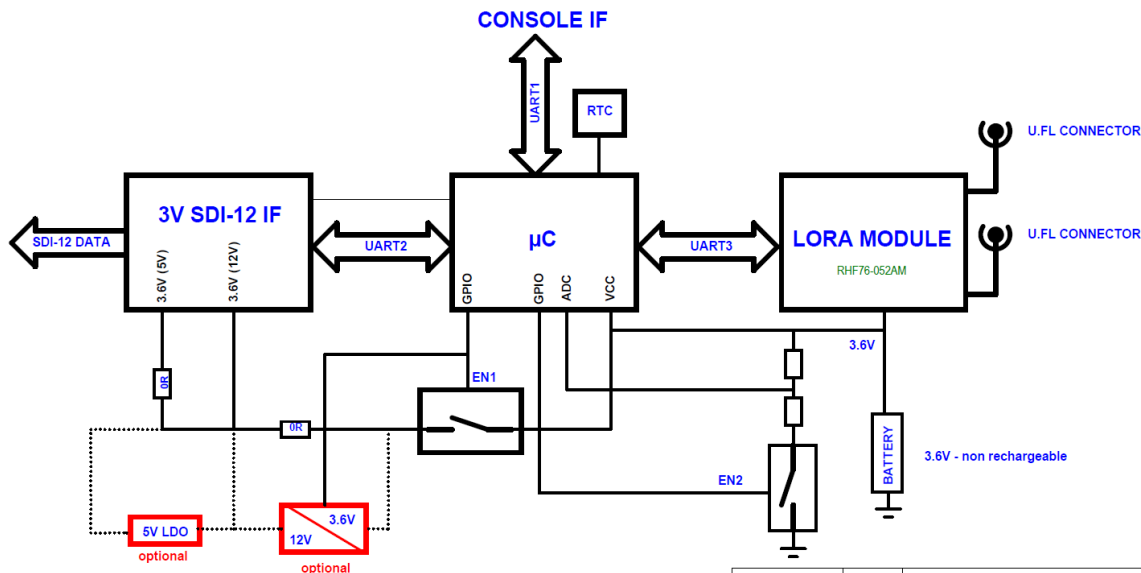
The TBS12B/TBS12S RTU implement three main components:

- A SDI-12 controller, used to control SDI-12 sensors and send back measurements to internal host
- A LoRaWAN modem, used to transmit the SDI-12 measurements to the remote application server over LoRa.
- An application host, that controls:
 - SDI-12 commands configuration
 - SDI-12 measurements
 - LoRaWAN transmission
 - Measurement and transmission intervals
 - Measurements storage
 - Power management



TBS12B/TBS12S functional block diagram

LoRaWAN RTU for SDI-12 sensors



1.2 Variants overview

The RTU based on that design exists in 2 variants depending on the power supply:

- TBS12B
 - LoRaWAN RTU for SDI-12 sensors, powered by batteries
- TBS12S
 - LoRaWAN RTU for SDI-12 sensors powered by rechargeable battery and solar panel

1.2.1 TBS12B variant



TBS12B: front view and rear view with fixture

LoRaWAN RTU for SDI-12 sensors

1.2.2 TBS12S variant

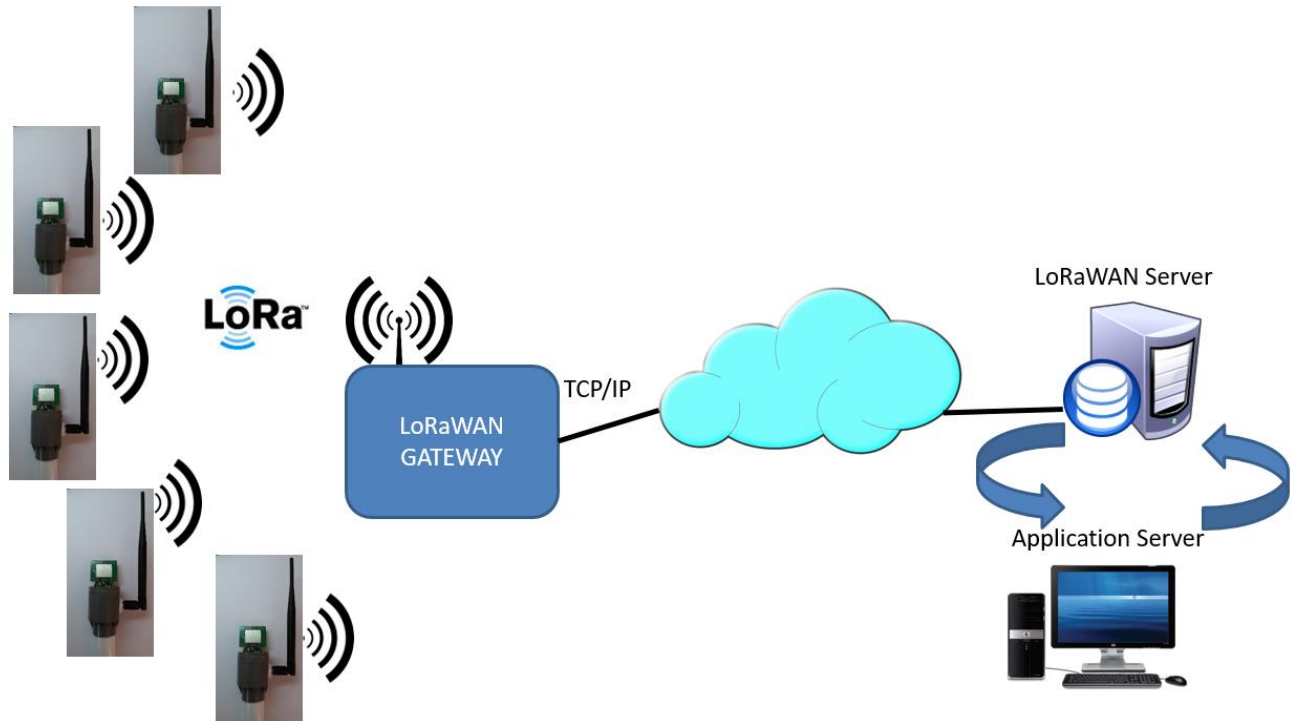


TBS12S front view and rear view with fixture

2 System overview

TBS12B/TBS12S integrate within a typical LoRaWAN ecosystem: each TBS12B/TBS12S LoRaWAN RTU is seen as a unique end node within a LoRaWAN private network (ie including at least one LoRaWAN gateway and a LoRaWAN server).

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Deployment of a private LoRaWAN network

Before being used, TBS12B/TBS12S must go through a configuration and provisioning phase to initialize system, SDI-12 and LoRaWAN parameters.

Device configuration is achieved by connecting TBS12B/TBS12S to a PC and running the configuration tool provided along with this product. Further details pertaining to TBS12B/TBS12S configuration are found in [configuration chapter](#).

2.1 HW specification

The TBS12B/TBS12S are based on a low power controller and LoRaWAN modem, and a robust SDI-12 interface hardware.

2.1.1 Platform characteristics

Feature	Description	Additional information
Sensors		
SDI-12	V1.3	Refer to Sensors support for further information.
Modem		

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Modem	LoRaWAN	Refer to wireless modem section for further information.
Platform		
Platform reset	Internally: reset button Externally: reed switch	Not accessible for outdoor use Hover a magnet over reed switch
Power supply (**)		
Power supply	TBS12S	Outdoor use only
	Solar panel	Integrated to the unit
	Rechargeable battery	Not provided
	TBS12B	Indoor/Outdoor use
	Non rechargeable batteries	Not provided
Current in idle mode	TBS12B: 5-7 μ A TBS12S: 35 μ A	
Connectors		
Connectors	3 pins (UART (RX, TX, GND) internal connector	Used for TBS12B/TBS12S configuration (requires TBS12 PC configuration tool)
	1 * 7 pins external connector	LLT-M14BMF07 For SDI-12 sensors connection
Antenna	Suitable for LoRaWAN communication	Provided (868 – 915 MHz) <i>For 433/470MHz contact sales@tekbox.com</i>
Mechanical details		
Housing	<p>TBS12B: IP67 aluminium housing: SP-AG-FA3-1 family, single piece gasket, IP67, TNC antenna connector, Gore-Tex vent, IP67 circular panel connector</p> <p>TBS12S: Takachi enclosure, IP67 UV-Protect ASA plastic box</p>	Suitable for outdoor use.
Operating temperature range	-40 to +85°C	

2.1.2 Sensors support

Sensor	Support	Electrical characteristics	Additional information
SDI-12	Yes 1 port available	12V, 1200 baud SDI-12 data interface with transient protection	SDI-12 v1.3 compliant <i>Limitation: aRx! not supported</i> More sensors can be connected by using a SDI-12 junction box (TBS04)

LoRaWAN RTU for SDI-12 sensors

2.1.3 LoRaWAN modem

Modem	Frequencies	Protocol	Additional information
LoRa	EU868 US915 US915HYBRID CN779 EU433 AU915 CN470 AS923 KR920 IN865	LoRaWAN 1.02B Class A	Contact sales@tekbox.com for 433 MHz band support.

2.1.4 Power supply

TBS12B	
Use	Indoor / Outdoor
Maximum delivered current	3.2 A
Non rechargeable battery	
Type	3 * 1.5V D cells (ex. Duracell Ultra Alkaline D battery)
Included	No

TBS12S	
Use	Outdoor
Maximum delivered current	3.2 A
Solar panel	
Included	Yes (integrated to the housing)
Rechargeable battery	
Type	3.7V Lilon Size must fit the battery holder 0.72" Dia * 2.56" H (18.2mm * 65.0mm)
Capacity	2000-3000 mAh
Included	No

3 Platform connectivity

TBS12B/TBS12S provide following connectivity:

- 1 UART to control SDI-12 sensor
- 1 UART port for PC connection
- 1 SWIM port for FW update and connection to an emulator
- 1 slot for battery (form factor is variant dependant)
- 1 port for solar panel (TBS12S only – embedded on the housing)
- 2 internal antenna connectors (low and high LoRaWAN frequencies) linked to external antenna.

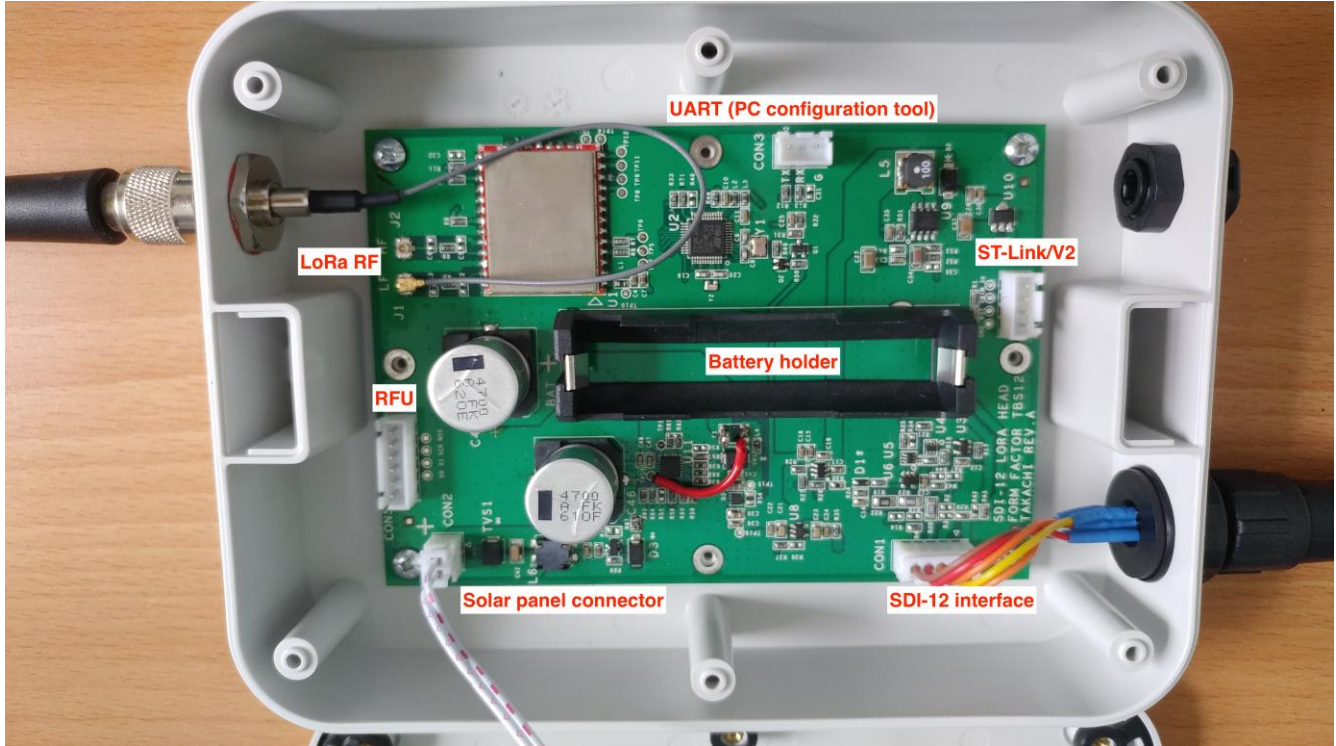
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3.1 TBS12S connectivity



TBS12S – Housing closed

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*TBS12S – Lid open*

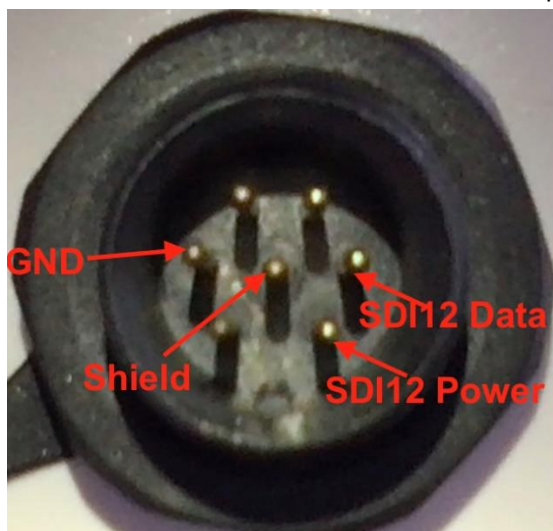
LoRaWAN RTU for SDI-12 sensors

3.2 TBS12B connectivity



3.3 SDI-12 connector

Both TBS12B and TBS1S have an external 7 pins connector to connect SDI-12 sensor:



LoRaWAN RTU for SDI-12 sensors

Pin	Description
GND (Pin 2)	Ground <i>To SDI-12 sensor GND</i>
SDI-12 Data (Pin 5)	SDI-12 data line <i>To SDI-12 sensor data line</i>
SDI-12 Power (Pin 6)	SDI-12 power <i>To SDI-12 sensor power line</i>
Shield (Pin 7)	Cable's shield (optional) <i>To be connected to SDI-12 sensor cable shield if any</i>

4 Functional Description

4.1 Interface function

4.1.1 SDI-12

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 generated by the data recorder/controller firmware. The TBS12B/TBS12S are connected to the TX output of the data recorder controller UART and converts the command strings to the logic levels and baud rate specified by the SDI-12 standard. Furthermore, TBS12B/TBS12S module handles breaks, marks and all other details of the SDI-12 protocol.

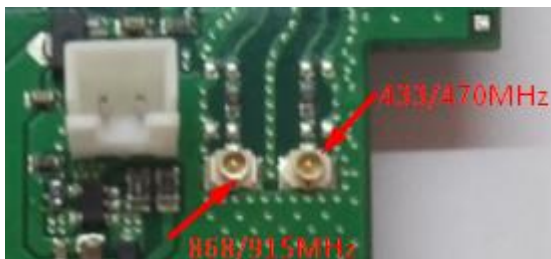
- **Note: aRx! Commands are not supported by TBS12B and TBS12S.**

Upon receiving data or status information originated by a Sensor, TBS12B/TBS12S extract the corresponding ASCII strings and presents it to the RX input of the data recorder controller UART.

4.1.2 LoRa modem and radio

TBS12B/TBS12S embed a LoRaWAN compatible modem and a dual band LoRa radio.

Depending on the frequency plan that is used (country specific), either low or high ISM band will be needed. It is therefore crucial to connect the antenna to the right connector:



LoRaWAN RTU for SDI-12 sensors

As LoRaWAN uses free ISM bands, useable frequencies are subject to local regulation, and TBS12B/TBS12S must be configured accordingly:

- To use supported LoRaWAN frequency plans for countries where this has been defined
- To use custom plans for other countries

Refer to latest LoRaWAN specification on www.lora-alliance.org

TBS12B/TBS12S must be then used along with a LoRaWAN gateway that operates on the same frequency band: for example, if they are deployed in Europe, both RTU and gateway must be configured to use EU868 frequency plan.

The following LoRaWAN parameters are fully configurable:

- Device activation: ABP / OTAA
- Frequency plans: EU868 US915 US915HYBRID CN779 EU433 AU915 CN470 AS923 KR920 IN865; configurable frequencies and data rates.
- Uplink communication – selectable confirmed or unconfirmed messages, repeat feature
- Downlink communication: not supported.
- Reconfigurable LoRaWAN parameters: identifiers (DevAddr, DevEUI) and security keys (NwkSKey, AppSKey, AppKey)

Both TBS12B and TBS12S have a UART port used to connect to a PC that runs the configuration tool. For further information about the configuration process refer to the documentation embedded within the PC configuration tool delivered by Tekbox.

4.2 System

TBS12B/TBS12S act as a RTU: they are designed to trigger SDI-12 measurements on a regular basis, and transmit the measurements over LoRa to application server on defined time interval.

SDI-12 measurements are stored inside the RTU internal memory until they're transmitted.

All of these parameters are configurable:

- Fully configurable set of SDI-12 commands to be executed (up to 40 Measurement/Data commands pairs)
- Programmable measurement and transmission intervals (from 1 minute to 24 hours)
- Configurable battery information reporting interval
- Configurable transmission delay: allow to stagger the transmission of multiple TBS12B/TBS12S units deployed in the same vicinity, contributing then to reduce the collision rate.
- 2 modes of operation while connected to TBS12 PC application:
 - Logging mode: TBS12B/TBS12S operates normally but outputs debug information to the PC tool
 - Console mode: TBS12B/TBS12S is in configuration mode, its system, SDI-12 and LoRaWAN parameters can be checked and updated. Moreover, it is possible to directly access connected SDI-12 sensors and LoRaWAN modem by sending any supported SDI-12 commands/LoRaWAN modem AT command (this is an advanced diagnosis feature).

LoRaWAN RTU for SDI-12 sensors

4.2.1 Time intervals

Three different time intervals are defined in the system:

- Measurement interval
 - o Period in minutes to perform SDI-12 measurements and store data into internal memory.
- Transmission interval
 - o Period in minutes to transmit measurements stored in the RTU internal memory over LoRa
- Monitoring interval
 - o Period in minutes to transmit monitoring information (eg battery level) over LoRa to the application server. This must be a multiple of the Transmission Interval.

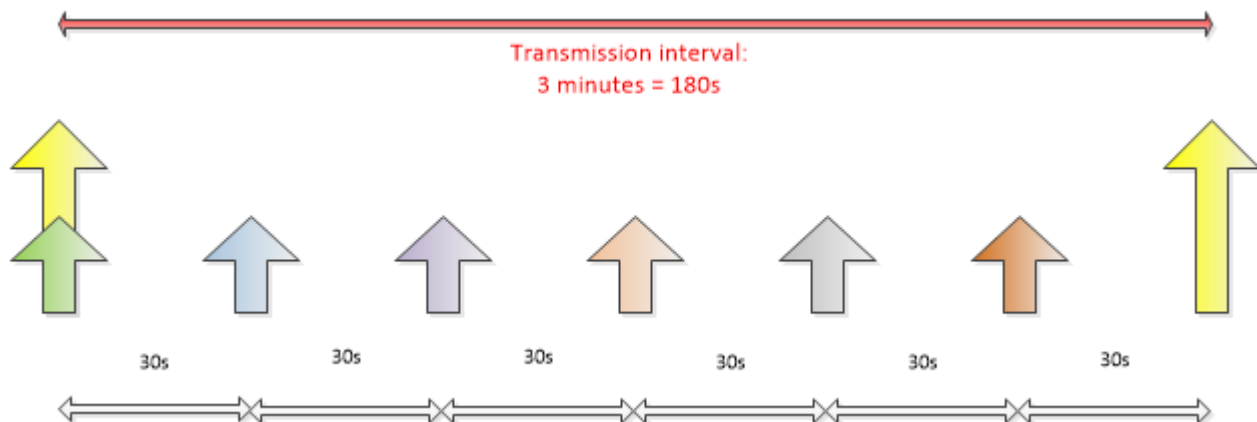
These parameters are configured with the TBS12 Configuration Tool.

Intervals are set in minutes from 1min to 1440 minutes (ie 24 hours).

A transmission delay can be set in case multiple RTU are deployed in the same area. Having several RTU sending data at the same time will result in numerous packets collisions, therefore staggering the transmission of each units over the transmission interval will help reducing this effect.

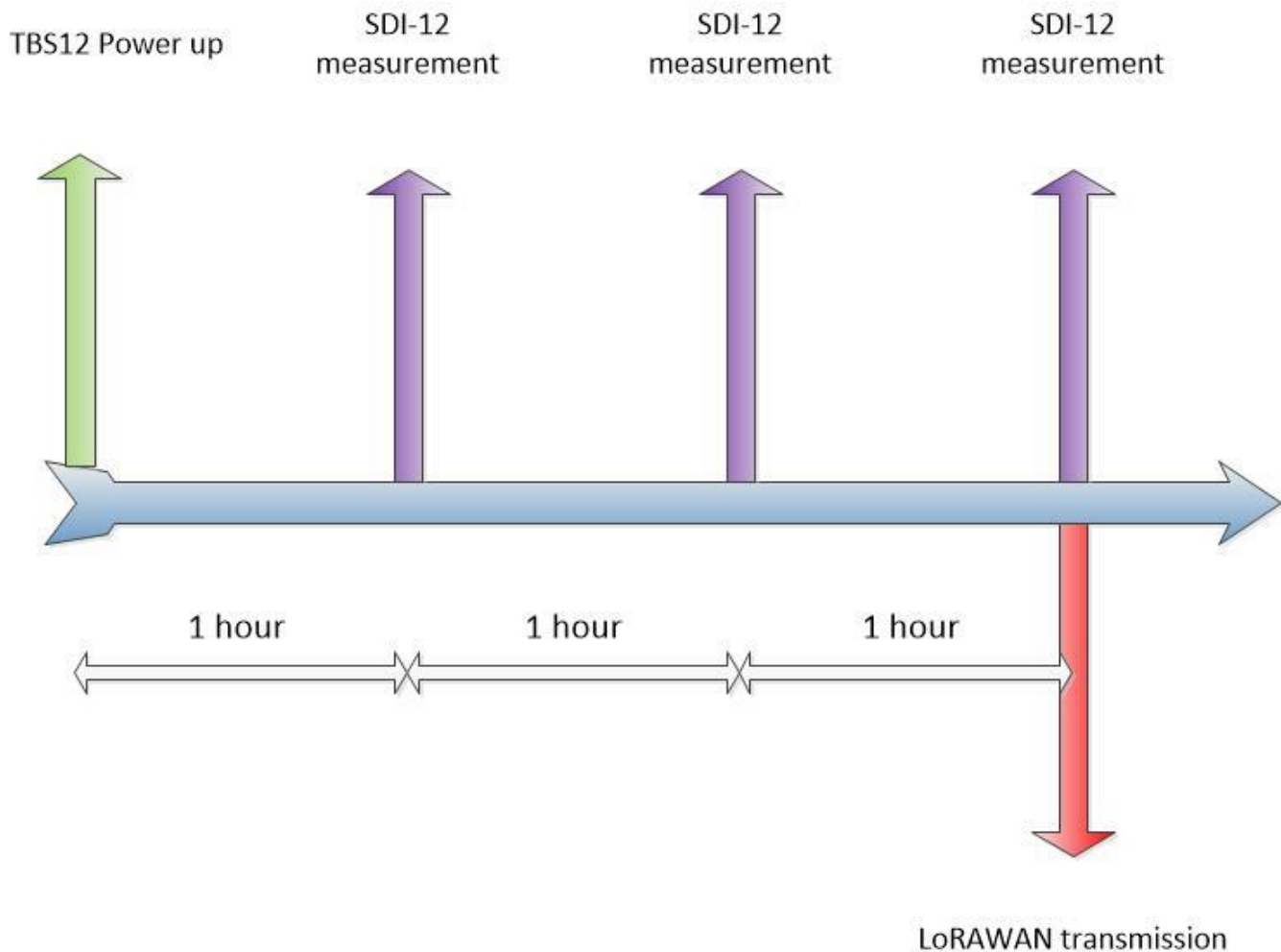
The staggering delay should be carefully chosen so there's no overlap with the next transmission interval.

Following sequence shows 6 TBS12B/TBS12S units transmitting their data on a 30s slot basis spread over a 6 minutes transmission interval:



Below diagram shows how TBS12B/TBS12S operate with a 1 hour measurement interval and 3 hours transmission interval:

LoRaWAN RTU for SDI-12 sensors



Note: it is strongly recommended to use same interval for both measurements and transmission (e.g. each 15 minutes) to ensure smooth operation of the RTU.

4.2.2 Communication outage

Communication outage situations can be mitigated by using LoRaWAN confirmed messages and setting the retry counter accordingly to minimize the risk of not getting the ACK from the LoRaWAN server.

Alternatively unconfirmed messages can be used while setting the repeat counter to lower the risk of packet loss. Both methods have overhead on the air transmission and power consumption so it shall be tuned depending on the actual situation.

4.2.3 Data format

Each measurement stored in internal memory is time stamped, and one packet of data corresponds to one sensor. As an example, if 5 SDI-12 sensors are connected to TBS12B/TBS12S, 5 packets of data are stored in memory upon each measurement interval.

LoRaWAN RTU for SDI-12 sensors

TBS12B/TBS12S transmits 4 types of messages:

- Measurement message
- Battery reporting message
- Common reporting message
- LinkCheckReq

Measurement message

This message is a string formatted as follows:

PSYY:MM:DD:HH:MM:00<Sensor_ID><SubSensor_ID><Nb_values> <Value1> <Value2> ... <ValueN>

Where:

- <PS>: packet header for SDI-12 parameters
- <YY:MM:DD> is the date with <YY> being the last 2 digits of the year, <MM> the month number and <DD> the date. For example, <18:06:01> is the 1st of June 2018.
- <HH:MM:00> is the time represented as hours/minutes/seconds, eg 16:25:00.
 - Note: time is 24h format (ie no AM/PM representation)
 - Number of seconds is always 00 (time alignment with round hour).
- <Sensor_ID>: virtual ID corresponding to a physical sensor that has its own specific SDI-12 address.
- <SubSensor_ID>: index of the SDI-12 commands that is executed for a specific Sensor_ID.
- <Nb_values>: number of measurements returned by the SDI-12 sensor, coded over 2 bytes.
- Space character: separator
- <Value1>... <ValueN>: SDI-12 measurements formatted as per SDI-12 standard (pd.d) and separated by a space character.

Example:

A TBS12S has 4 SDI-12 sensors attached, the following tables shows the programmed SDI-12 commands and the Sensor_ID/SubSensor_ID allocation (automatically handled by the platform):

SDI-12 command index	SDI-12 command	Sensor_ID	SubSensorID
0	0M!	0	0
1	0C!	0	1
2	1M!	1	0
3	1C1!	1	1
4	3M1!	2	0
5	eM!	3	0
6	eM1!	3	1
7	eC!	3	2

PS18:06:01:16:25:003202 +37.37 +29.65

- Time stamp: 1st of June 2018 (date) 16:15:00 (time)
- '3': Sensor_ID is 3
- '2': SubSensor_ID is 2

LoRaWAN RTU for SDI-12 sensors

- '02': 2 SDI-12 measurements returned by the sensor
- SDI-12 measurements: +37.37 and +29.65

Battery measurement message

This message is a string formatted as follows:

PBY:MM:DD:HH:MM:00 <Battery_voltage>Where:

- <PB>: packet header for battery voltage parameter
- <YY:MM:DD> is the date with <YY> being the last 2 digits of the year, <MM> the month number and <DD> the date. For example, <18:06:01> is the 1st of June 2018.
- <HH:MM:00> is the time represented as hours/minutes/seconds, eg 16:25:00.
 - Note: time is 24h format (ie no AM/PM representation)
- Space character: separator.
- <Battery_voltage>: battery voltage in V coded over 5 digit including the decimal separator.

Example:

PB18:06:01:17:00:00 3.600

- Time stamp: 1st of June 2018 (date) 17:00:00 (time)
- Battery voltage: 3.6V

Common reporting message

This message is a string formatted as follows:

CYY:MM:DD:HH:MM:SS<BoardID><FW><PowerID><SensorsNb><Status> <RSSI> Where:

- <C>: packet header for common reporting message
- <YY:MM:DD> is the date with <YY> being the last 2 digits of the year, <MM> the month number and <DD> the date. For example, <20:08:19> is the 19th of August 2020
- <HH:MM:SS> is the time represented as hours/minutes/seconds, eg 16:25:00.
 - Note: time is 24h format (ie no AM/PM representation)
- <BoardID>: board ID coded over 8 characters
- <FW>: FW version coded over 8 characters
- <PowerID>: power supply identifier, set to 0 (reserved for future use)
- <SensorsNb>: number of connected sensors
- <Status>: TBS12x status, 'S': startup, 'R': running
- Space character: separator
- <RSSI>: signed RSSI value

Example:

C20:08:18:22:12:00000001010200010705R -105

C: common reporting message

Date: 18th of August 2020

Time: 22:12:00 (10:12PM)

BoardID: 00000101

FW version: 02.00.01.07

PowerID: 0

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Number of connected sensors: 5

TBS12S status: Running ('R')

RSSI: -105 dB

LinkCheckReq

This message doesn't hold any payload as this is a LoRaWAN MAC layer command.

It is used by the platform to measure the RSSI and check the connectivity with the LoRaWAN gateway.

4.2.4 Uplink Javascript payload parser implementation example

A portable way to parse uplink payload which is almost not language related is to use regular expressions (regex).

The below sample code is written in Javascript but could be easily adapted for other languages (a good regex online tester and verifier is [Regex101](#)).

The subsequent sections lists all Javascript regular expressions needed to extract required fields from the payload. They are provided for information only and shall be modified based on user's needs.

4.2.4.1 Sample code

The following sample code parses *payload* string and extracts the message type into *msgtype* capturing group. The result is displayed to the console.

```

1 // SDI-12 payload
2 const payload = 'PS20:03:12:02:45:000208 +0.317 +0.64 +0.559 +0.459 +0.666 +0.881 +0.611 +0.654';
3
4 // Regular expression to extract the message type
5 const regex_filter = /^(?<msgtype>PS|PB|PA|PP|C).*/;
6
7 // Execute the regular expression over the payload string
8 const result = regex_filter.exec(payload);
9
10 // Display the capturing group msgtype to the console
11 console.log(result.groups.msgtype);

```

This code can be easily customized depending on the payload type by using following regular expressions to extract required fields.

4.2.4.2 Message type

Get message type: PS/PB/C:

```
/(?<msgtype>PS|PB|C).*/
```

4.2.4.3 Time stamp

Extract the year, month, day, hour and minutes from the time stamp:

LoRaWAN RTU for SDI-12 sensors

```
/^(\?:\D{0,1})(?<year>\d\d)(?:\:)(?<month>\d\d)(?:\:)(?<day>\d\d)(?:\:)(?<hour>\d\d)(?:\:)(?<min>\d\d)(?:\:)(?<sec>\d\d)?$/
```

4.2.4.4 Sensor ID

Get the sensor index, only applicable to PS message type.

```
/^(\?:PS)(?:\.{17})(?<sensor>\d)(?:.*)$/
```

4.2.4.5 Sub-Sensor ID

Get the sub-sensor index, only applicable to PS message type.

```
/^(\?:PS)(?:\.{18})(?<subsensor>\d)(?:.*)$/
```

4.2.4.6 Battery level

Battery level is extracted from PB message.

```
/^(\?:PB)(?:\.{18})(?<battery>.*)/
```

4.2.4.7 RSSI

RSSI is extracted from C message.

```
/^(\?:C)(?:\.{37})(?<rssi>.*)/
```

4.2.4.8 Number of measurements (PS)

Get number of measurements for a PS message.

```
/^(\?:PS)(?:\.{19})(?<number>\d\d)(?:.*)$/
```

4.2.4.9 Measurements (PS)

Get all measurements held by a PS message.

```
/^(\?:PS)(?:\.{22})(?<payload_temp>.*)/
```

Regex expressions to get the first 10 measurements one by one (*val1* to *val10*):

```
/^(\?:PS)(?:\.{22})(?<val1>[\s]{1,9})(?:.*)$/
```

```
/^(\?:PS)(?:\.{22})(?:([\s]+\s){1})(?<val2>[\s]{1,9})(?:.*)$/
```

```
/^(\?:PS)(?:\.{22})(?:([\s]+\s){2})(?<val3>[\s]{1,9})(?:.*)$/
```

```
/^(\?:PS)(?:\.{22})(?:([\s]+\s){3})(?<val4>[\s]{1,9})(?:.*)$/
```

```
/^(\?:PS)(?:\.{22})(?:([\s]+\s){4})(?<val5>[\s]{1,9})(?:.*)$/
```

LoRaWAN RTU for SDI-12 sensors

```
/^(:PS)(?:{22})(?:([\s]+\s){5})(?<val6>[\s]{1,9})(?:.*)/
```

```
/^(:PS)(?:{22})(?:([\s]+\s){6})(?<val7>[\s]{1,9})(?:.*)/
```

```
/^(:PS)(?:{22})(?:([\s]+\s){7})(?<val8>[\s]{1,9})(?:.*)/
```

```
/^(:PS)(?:{22})(?:([\s]+\s){8})(?<val9>[\s]{1,9})(?:.*)/
```

```
/^(:PS)(?:{22})(?:([\s]+\s){9})(?<val10>[\s]{1,9})(?:.*)/
```

5 TBS12B/TBS12S configuration

Before being used, TBS12B/TBS12S must be configured:

- With ad hoc LoRaWAN ID and ciphering keys to operate on the selected LoRaWAN service provider.
- With LoRa frequencies and data rates corresponding to the area where the RTU is deployed (subject to local regulation and as per LoRaWAN standard)
- With optional LoRaWAN parameters like ADR, confirmed/unconfirmed messages, ...
- With measurement and transmission intervals

TBS12B/TBS12S configuration is achieved through a PC application that accesses the device through its external UART port.

When the RTU is connected to PC application, its internal date and time are automatically updated. TBS12B/TBS12S are designed so they can't operate until its date and time have been set through the PC application.

A maximum of 16 SDI-12 commands can be programmed.

Refer to the TBS12B/TBS12S PC configuration tool user guide for further information.

6 Power Management strategy

TBS12B/TBS12S integrate automatic power management feature. When the device neither measures nor transmits, the MCU goes to deep sleep mode, SDI-12 HW stage is disabled and LoRaWAN modem is in ultra low power mode.

Following screenshot mirrors the current consumption in a typical TBS12B/TBS12S operating sequence, where measurement and transmission intervals occur at the same time: the platform wakes up from sleep mode, then performs SDI-12 measurements, and finally transmit all measurements stored since last transmission over LoRa.

LoRaWAN RTU for SDI-12 sensors



7 Technical references

7.1 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 meters of 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 standard is available on the web site of the SDI-12 Support Group. More information on SDI-12 is presented in chapter 6.

7.2 LoRaWAN

LoRaWAN is a MAC layer radio protocol for LoRa (technology owned by Semtech, www.semtech.com) developed and maintained by LoRa Alliance:

LoRaWAN RTU for SDI-12 sensors

www.lora-alliance.org

LoRa™ Alliance

2400 Camino Ramon, #375

San Ramon, CA 94583

Phone: +1 925-275-6611

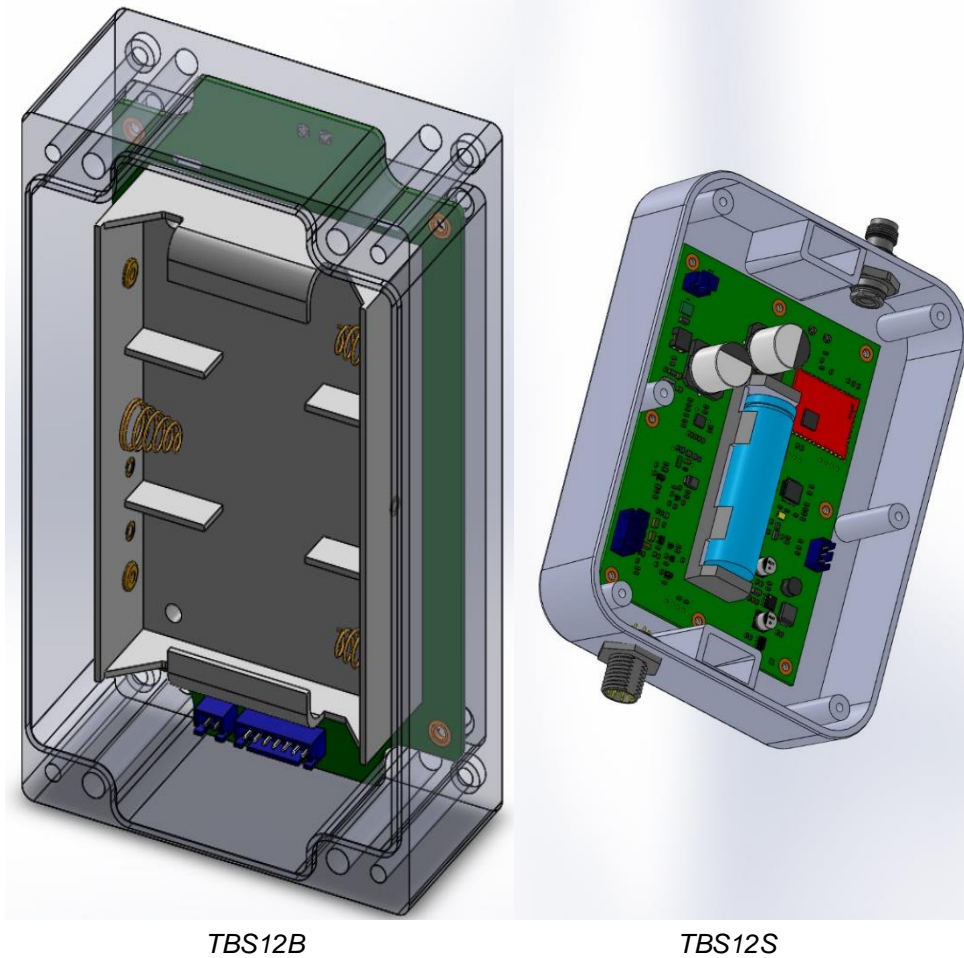
Fax: +1 925-275-6691

“**LoRaWAN™** is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things in a regional, national or global network. LoRaWAN targets key requirements of Internet of Things such as secure bi-directional communication, mobility and localization services. The LoRaWAN specification provides seamless interoperability among smart Things without the need of complex local installations and gives back the freedom to the user, developer, businesses enabling the roll out of Internet of Things.”

Further details available on LoRa Alliance website (<https://www.lora-alliance.org/What-Is-LoRa/Technology>).

LoRaWAN RTU for SDI-12 sensors

8 Mechanical Specifications



Product	Dimensions	Weight
TBS12B	100*160*60 mm	0.9 kg
TBS12S	130*175*45 mm	0.5 kg

9 SDI-12 Basics

SDI-12 is a serial data communication standard for interfacing multiple sensors with a data recorder. The 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”.

LoRaWAN RTU for SDI-12 sensors

A sensor typically can 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 are 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, a SDI-12 compatibility number, company name, sensor model number, sensor version number and sensor serial number.

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

Example:

Start Measurement Command **0M1!**

Sensor 0 might respond 00302 which means the measurement will take 30 seconds and deliver 2 values.

After min. 30 seconds, the data recorder can send the Read Data Command **0D0!** To which Sensor 0 might reply 0+27+1050. +27+1050 is the two measurement results which may be 27°C and 1050 milibar.

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.

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10 LoRaWAN network basics

10.1 Overview

This section provides TBS12B/TBS12S user a basic understanding of LoRaWAN key features, so they can be integrated smoothly in such ecosystem.

LoRa Alliance describes a LoRaWAN network as follows:

LoRaWAN RTU for SDI-12 sensors

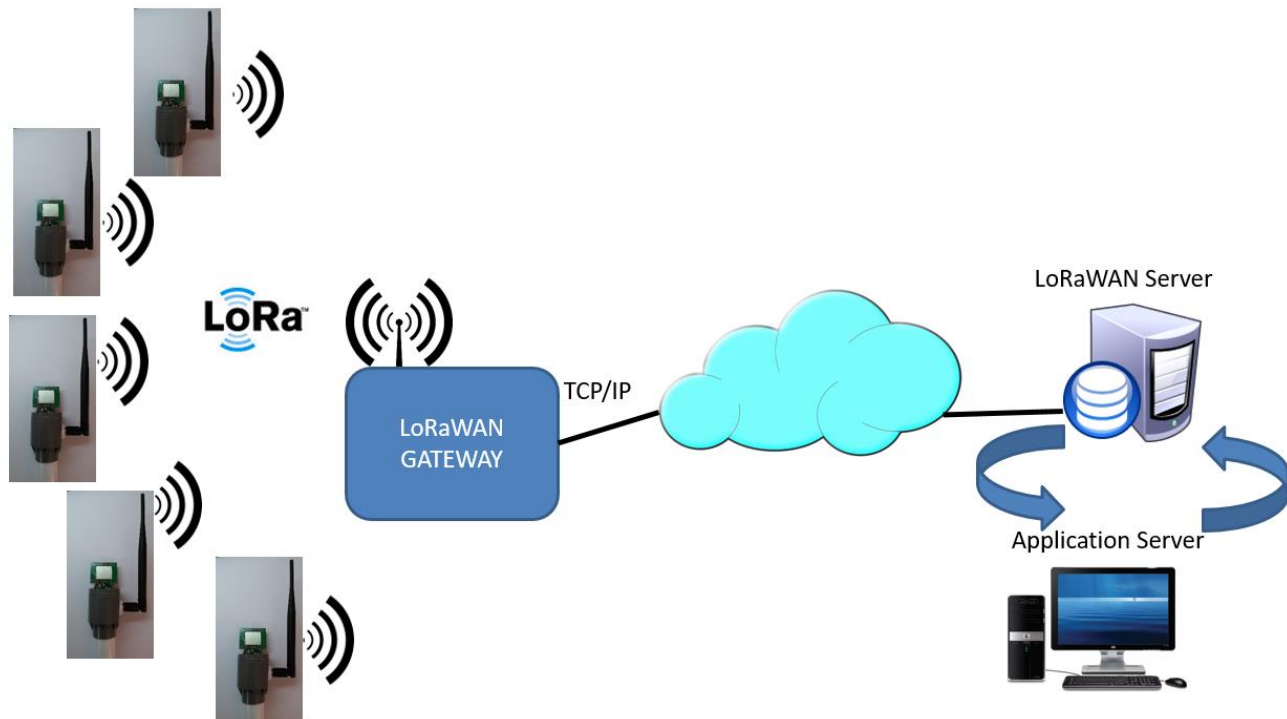
“

LoRaWAN network architecture is typically laid out in a star-of-stars topology in which **gateways** is a transparent bridge relaying messages between **end-devices** and a central **network server** in the backend. Gateways are connected to the network server via standard IP connections while end-devices use single-hop wireless communication to one or many gateways. All end-point communication is generally bi-directional, but also supports operation such as multicast enabling software upgrade over the air or other mass distribution messages to reduce the on air communication time.

Communication between end-devices and gateways is spread out on different **frequency channels** and **data rates**. The selection of the data rate is a trade-off between communication range and message duration. Due to the spread spectrum technology, communications with different data rates do not interfere with each other and create a set of “virtual” channels increasing the capacity of the gateway. LoRaWAN data rates range from 0.3 kbps to 50 kbps. To maximize both battery life of the end-devices and overall network capacity, the LoRaWAN network server is managing the data rate and RF output for each end-device individually by means of an **adaptive data rate** (ADR) scheme.

“

This leads then to a network where each TBS12B/TBS12S is a unique end node communicating with a gateway as highlighted in below schematics:



Several components are involved in the LoRaWAN network:

- End nodes: this is any end-user device integrating a LoRaWAN modem and communicating with a LoRaWAN gateway. With respect to this, TBS12B/TBS12S are end nodes.
- Gateway: it acts as a packet forwarder between end nodes and LoRaWAN server. It communicates through LoRa radio with end nodes, and through a TCP/IP connection with LoRaWAN server (depending on the gateway capability, this can be achieved with an Ethernet, wifi or cellular connection). One gateway

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can accommodate thousands of end nodes, and typical range is 2km in urban areas and around 15km in rural areas with clear line of sight.

- LoRaWAN server: this is a service provided by a 3rd party company (hence the user needs to subscribe to such service). As LoRaWAN packets are encrypted, the LoRaWAN server proceeds with deciphering of LoRaWAN packets and make them available to user's application server through various communication protocols (this is totally dependant on the LoRaWAN service provider, but HTTPS, WebSocket and REST are widely used protocols besides direct integration with IoT platforms like Microsoft Azure or AWS IoT). An API is then provided to access deciphered data, device EUI and other radio parameters (usually in JSON or XML format).

10.2 Integrating TBS12B/TBS12S in a LoRaWAN ecosystem

To build a private network of TBS12B/TBS12S, it is first required to choose a LoRaWAN gateway (eg www.kerlink.com, www.multitech.com, ...) and a LoRaWAN services provider (eg www.loriot.io, ...).

TBS12B/TBS12S are compatible with any LoRaWAN certified gateway and network service provider.

This choice is dependant on several criteria:

- Geographic area where the sensors will be deployed: this determines the LoRaWAN frequency plan to be used. The gateway must then have required HW to support these frequencies (eg 868MHz, 915MHz, etc...)
- Gateway connectivity: depending on where the gateway will be installed, next options need to be considered,
 - o Indoor / outdoor model
 - o Connectivity: Ethernet, cellular, wifi
- The LoRaWAN service provider:
 - o Needs to support the chosen gateway (because it will be programmed to access the selected LoRaWAN service provider)
 - o Must support the frequency plans required by the user
 - o Must support the LoRaWAN features required by the user (eg LoRaWAN downlink, Class C, OTAA, etc...)
 - o Provides a suitable interface for the user so the application server can collect deciphered data (eg JSON/XML API reachable through Websocket, REST, etc...)
 - o Must be ideally located in the same region where end nodes are deployed, to avoid latencies (eg end nodes in Vietnam, LoRaWAN server in Singapore but not in Germany)
 - o Support of multiple applications/accounts, scalability of the server, ...
 - o Pricing model: subscription based, billing per gateway and end nodes, etc...

The next step is to activate each end node so they are identified and can communicate with the LoRaWAN network.

LoRaWAN standard defines 2 ways of activating end nodes:

- Activation By Personalization (ABP): with this configuration, the end node is bound to a specific LoRaWAN network. This mode is supported by default in TBS12B/TBS12S, and can be compared to a smartphone that is SIM-locked to a specific cellular network.
- Over the Air Activation (OTAA): this configuration is optional on TBS12. It gives the end node the "roaming" capability, ie the end node is not bound to a specific network, and can be re-activated on different

LoRaWAN RTU for SDI-12 sensors

LoRaWAN network through OTAA procedure. TBS12 implements an auto join mechanism that ensures the device will systematically try to (re)join whenever this is required by the LoRaWAN network server.

Both activation modes require following identifiers & keys configuration:

Mode	ID/EUI	Key
ABP	DevAddr	NwkSKey, AppSKey
OTAA	AppEUI, DevEUI	AppKey

Note: the generation of DevAddr in ABP mode is dependant on the LoRaWAN service provider. It can be any random value generated by the user, or can be generated from EUI (or other mean) by the LoRaWAN service provider.

Good practice is to define an EUI for an end node, whether it is activated by ABP or OTAA.

10.3 Deploying TBS12B/TBS12S on the field

It is key having the gateway installed as high as possible to get increased communication range.

There may be situations where TBS12B/S has been fully configured but needs to be stored for some time until it is deployed on the field (typically during winter time). In order to minimize as much as possible the power consumption while allowing an easy deployment, TBS12 can be left in logging mode (once fully configured) without the matching SDI-12 sensors connected. In this case it will detect the SDI-12 sensors are missing hence not performing any SDI-12 measurement nor LoRaWAN transmission.

Once ready for deployment, it's just needed to connect the SDI-12 sensors and TBS12B/S will resume measuring and transmitting.

11 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
	Humidity level	Ta=60°C; no condensation	-	95	% R.H

Table 1 – Environmental Specifications

12 ESD Safety

TBS12B/TBS12S are static-sensitive electronic devices. Do not operate or store near strong electrostatic fields. Follow guidelines as per EIA/JESD22-A115-A.

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13 RoHS Compliance

TBS12B/TBS12S modules are compliant with the European Union Directive 2002/95/EC Restriction on the Use of Hazardous Substances (RoHS). All designated products have Pb-free terminals.

14 Ordering Information

Part Number	Description
TBS12B	LoRaWAN RTU for SDI-12 sensors
TBS12S	LoRaWAN RTU for SDI-12 sensors + integrated solar panel
TBSBR02	Mounting bracket for TBS12B
TBSBR03	Mounting bracket for TBS12S

Contact: sales@tekbox.com

15 History

Version	Date	Author	Changes
V1.0	02.11.2016	Philippe Hervieu	Creation of the document
V1.1	03.11.2016	Philippe Hervieu	Remove soldering profile and packaging chapters / Update power management, Electrical specifications and Mechanical Specification sections.
V1.2	06.02.2017	Philippe Hervieu	Battery information updated
V1.3	06.02.2017	Philippe Hervieu	Details about date and time programming in the unit
V1.4	03.08.2017	Philippe Hervieu	Update current consumption in sleep mode
V1.5	02.10.2017	Philippe Hervieu	Add Tekbox/Takachi variants descriptions
V1.6	10.04.2018	Philippe Hervieu	Update products names
V1.7	01.06.2018	Philippe Hervieu	Update power consumption section and messages format
V1.8	25.06.2018	Philippe Hervieu	Add TBS12S connectivity
V1.9	24.08.2018	Philippe Hervieu	Update TBS12 variants
V1.10	02.10.2018	Philippe Hervieu	Update configuration section.
V1.11	18.10.2018	Philippe Hervieu	Recommendation about using same measurement and transmission intervals.
V1.12	19.11.2018	Philippe Hervieu	Update PS message format (size of returned parameters).
V1.13	19.08.2020	Philippe Hervieu	Add C message description
V1.14	03.09.2020	Philippe Hervieu	Update UART speed for PC-TBS12x communication
V1.15	04.09.2020	Philippe Hervieu	Fix typo in packets frame format / Add LinkCheckReq description
V1.16	09.11.20	Philippe Hervieu	Update communication outage chapter
V1.17	27.11.20	Philippe Hervieu	Remove LoRaWAN head

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V1.18	14.01.21	Philippe Hervieu	Rework HW description and remove LoRaWAN head.
V1.19	02.07.21	Philippe Hervieu	Javascript regex and minor updates
V1.20	26.04.22	Philippe Hervieu	OTAA autojoin and power saving