SPA-2

Snow pack analyzer

Manual

Setup version 3.10 (Firmware 2.20)

22.09.2021

Sommer Messtechnik

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Validity

This manual applies to the Snow pack analyzer with the setup version 3.10, including all its sub-versions.

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EU conformity

CE

This product is in conformity with the following standards:

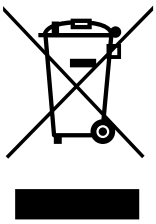
EMC	2014/30/EU	EN 301 489-1 V1.9.2
LVD	2014/35/EU	EN 62311:2008
		EN 62368-1:2014
RoHS II	2011/65/EU	
RoHS III	2015/863/EU	

Safety information

Please read this manual carefully before installing or operating this equipment. Non-compliance with the instructions given in this manual can result in failure or damage of the equipment or may put people at risk by injuries through electrical or mechanic impact.

- Make sure that the personnel responsible for installation, configuration and maintenance is familiar with the applicable regulations and standards!
- Do not perform any installations in bad weather conditions, e.g. thunderstorms.
- Prior to installation of equipment inform the owner of the measurement site or the authority responsible for it. Upon completion, secure the installation from trespassers.
- Maintenance and repair must be performed by trained personnel or an engineer of Sommer Messtechnik. Only replacement parts supplied by Sommer Messtechnik should be used for repairs.
- Make sure that NO power is connected to the equipment during installation and wiring!
- Only use a power supply that complies with the power rating specified for this equipment!
- Keep equipment dry during wiring and maintenance!
- If applicable, it is recommended to use accessories of Sommer Messtechnik with this equipment.

Disposal



After this device has reached the end of its lifetime, it must not be disposed of with household waste! Instead, dispose of the device by returning it to a designated collection point for the recycling of waste electrical and electronic equipment.

Feedback

Should you come across any error in this manual, or if you miss information to handle and operate the SPA-2 we are pleased to receive your feedback to office@sommer.at.

Content

1 What is the SPA-2? 10
2 Unpacking 11
3 Get started 12
3.1 Connect the SPA-2 to your PC 12
3.2 Configure the SPA-2 13
3.3 Acquire measurements 13
4 How the SPA-2 works 14
5 Components 16
5.1 Terminals 16
6 Specifications 19
7 Installation 20
7.1 Site selection 20
7.2 Things to consider for installation 20
7.2.1 Power supply 20
7.2.2 Signal cables 20
7.2.3 Lightning protection 21
7.3 Required tools and equipment 21
7.4 Mounting 21
7.4.1 General 21
7.4.2 Supporting frame 23
7.4.3 Mast with tilted SPA-2-sensor and USH-9 26
7.4.4 Tilted SPA-ribbon-sensor 32
7.4.5 Horizontal SPA-2-ribbon-sensor 34
7.4.6 Control cabinet 37
7.4.7 Sensor wiring 38
7.5 Wiring to a data acquisition system 40
7.5.1 RS-232 wiring 40
7.5.2 SDI-12 wiring 40
7.6 Calibration of SPA-2-ribbon-sensors 41
7.6.1 Zero test and adjustment 41
7.6.2 Span test and adjustment 43

7.7 Adjustment of snow depth measurement 44
7.8 Start-up 45
8 Operation 46
8.1 Connect device to PC 46
9 Maintenance 47
10 Support software Commander 48
10.1 Software features 48
10.2 System requirements 48
10.3 Installation of Commander 48
10.4 Working with connections 53
10.4.1 Establish a connection with the Communication assistant 53
10.4.2 Establish a connection manually 54
10.4.3 Create a new connection 54
10.5 Working with stations 54
10.5.1 Create a station with the Communication assistant 54
10.5.2 Create a station manually 59
10.6 Working with measurements 59
10.6.1 Poll continuous measurements 59
10.6.2 Record measurements 60
10.7 Working with data 61
10.7.1 View live data 61
10.8 Working with setups 61
10.8.1 Download setup 61
10.8.2 Open a setup file 62
10.8.3 Edit setup 62
10.8.4 Upload new setup file 62
10.9 Update firmware 63
11 Configuration of the SPA-2 65
11.1 Software tools 65
11.2 Configuration with Commander support software 65
11.3 Configuration with a terminal program 68
11.4 General settings 69
11.4.1 Measurement trigger 69
11.4.2 Language/Sprache 70
11.4.3 Decimal character 70
11.4.4 Units and decimals 70
11.4.5 Output protocol (OP) 70
11.4.6 OP, information 71
11.5 USH-9 serial communication 71
11.5.1 USH-9 71
11.5.2 SPA-2 72

12 Communication ... 73
12.1 Communication protocols ... 73
12.2 Data output ... 73
12.2.1 Output values ... 73
12.2.2 Exception values ... 74
12.3 RS-485 ... 75
12.3.1 What is RS-485? ... 75
12.3.2 What can I do with it? ... 75
12.3.3 Configuration ... 75
12.3.4 Data output options ... 77
12.3.5 Sommer protocol ... 77
12.3.6 Standard protocol ... 80
12.3.7 Sommer old protocol ... 82
12.3.8 RS-485 commands ... 83
12.3.9 Sommer CRC-16 ... 85
12.4 SDI-12 ... 86
12.4.1 What is SDI-12? ... 86
12.4.2 What can I do with it? ... 86
12.4.3 Configuration ... 86
12.4.4 Data structure ... 86
12.4.5 SDI-12 commands ... 87
12.5 Modbus ... 91
12.5.1 What is Modbus? ... 91
12.5.2 What can I do with it? ... 92
12.5.3 Wiring ... 92
12.5.4 Configuration ... 92
12.5.5 Modbus commands and registers ... 98
12.5.6 Reactivate Sommer protocol ... 107
12.5.7 PLC integration ... 113
13 Parameter definitions ... 114
A Measurement trigger ... 114
B Measurement Interval ... 114
C Measurement table ... 115
D Snow depth adjust ... 118
E Snow depth test ... 118
F Technics ... 118
F-A Language/Sprache ... 118
F-B Decimal character ... 118
F-C Sleep mode ... 119
F-D Warm-up time ... 119
F-E Sommer ID ... 119

F-F SPA, sensor table ... 120
F-G SDI-12 service ... 121
F-G-A SDI-12 address ... 121
F-G-B SDI12 'M'-response ... 121
F-G-C SDI-2 maximal duration ... 122
F-G-D SDI-2 sensor search ... 122
F-G-E SDI-2 change sensor address ... 122
F-G-F SDI-2 ask for a sensor address ... 123
F-H RS-485-2 Port ... 123
F-H-A Baud rate ... 123
F-H-B Parity, stop bits ... 123
F-H-C Minimum response time ... 124
F-H-D Transmitter warm-up time ... 124
F-H-E Flow control ... 124
F-H-F Sending window ... 125
F-H-G Receiving window ... 125
F-H-H Trig, polling ... 125
F-H-I Trig, timeout ... 125
F-H-J Trig, sleep while timeout ... 126
F-H-K Network scan extension ... 126
F-H-L Polling delay ... 126
F-H-M Transparency to RS485-2 ... 126
F-I RS-485-1 Protocol ... 127
F-I-A Device number ... 127
F-I-B System key ... 127
F-I-C Output protocol (OP) ... 127
F-I-D OP, measurement output ... 128
F-I-E OP, information ... 128
F-I-F OP, wake-up sequence ... 128
F-I-G OP, prefix holdback ... 129
F-I-H MODBUS, set default ... 129
F-I-I MODBUS, device address ... 130
F-J RS-485-1 Port ... 130
F-J-A Baud rate ... 130
F-J-B Parity, stop bits ... 131
F-J-C Minimum response time ... 131
F-J-D Transmitter warm-up time ... 131
F-J-E Flow control ... 131
F-J-F Sending window ... 132
F-J-G Receiving window ... 132
G Special functions ... 132
G-A Device status ... 132
G-B View setup ... 132

G-C Set factory default 133
G-D Temp. load factory default 133
G-E Relaunch program 133
Appendix N Troubleshooting 134
N.1 Devices 134
N.1.1 The SPA-2 is not responding or returns unreadable characters 134
N.1.2 The SPA-2 reboots repeatedly 135
N.2 Measurement data 135
N.2.1 Measurement data are not updated 135
N.3 Firmware & software 136
N.3.1 Commander loads wrong setup 136
N.3.2 Firmware update via RS-485 is aborted 136
N.4 RS-485 136
N.4.1 Configuration via terminal shows unexpected behavior 136
N.5 SDI-12 137
N.5.1 The SPA-2 is not detected by a SDI-12 master device 137
N.5.2 Data logger receives no SDI-12 data 137
N.6 Analog output 138
N.6.1 The 4-20 mA output is wrong 138
Appendix O CRC-16 array 139

1 What is the SPA-2?

Determination of snowpack-properties can be very challenging as they vary significantly in space and time. The SPA-2 snow pack analyzer measures the volumetric contents of ice and water within a snowpack, and together with the snow depth calculates the snow water equivalent (SWE) and snow density.

By measuring the complex impedance along multiple, 4.8 m long, ribbon-shaped sensors, the SPA-2 acquires area-averaged data about the snowpack at different depth. Other than that, the snow height is precisely measured with the contact-free ultrasonic level sensor USH-9. This sensor-combination provides an automatic measurement system to continuously monitor the snowpack development for hydrological, agricultural and other applications.

2 Unpacking

When unpacking your SPA-2 sensor box please make sure that the following items are present:

Qty	Name
1	SPA-2 in the required version
1	Manual and Commander Software on USB stick

In case of missing or damaged items please contact your Sommer Messtechnik sales partner.

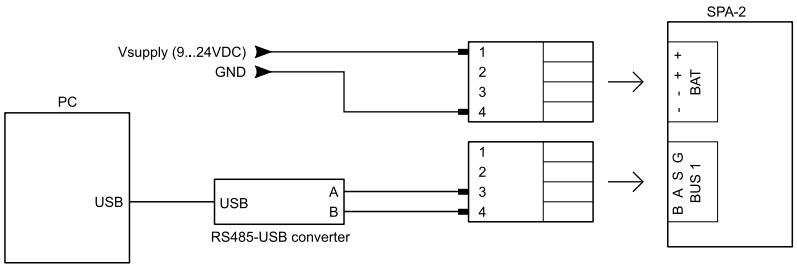
3 Get started

Follow the steps described below to set the basic configurations and to acquire the first measurement results.

NOTE Perform the first start-up in your lab or office before installing the equipment in the field!

3.1 Connect the SPA-2 to your PC

1. Install the Commander support software (see Installation of Commander)
2. Connect the yellow and gray wire of the sensor cable to the USB to RS485 isolated converter cable and plug it into your PC as illustrated in the figure below.
3. Connect the RS-232 to USB converter cable to the SPA-2 and a USB port on your PC.
4. Connect a 9...28 VDC power supply to the SPA-2
5. Start the Commander software.
6. Click on Communication assistant on the right-hand side of the Commander window and follow the instructions. During this procedure the communication assistant will search for connected devices. Upon successful completion, the new connection is added to the connections list (tab Connections (F8)).
7. In the Communication Section at the right-hand side of the Commander window select Mode Connection and the previously created connection from the drop-down list.
8. Click Connect to establish a connection with the SPA-2. If the connection was successful a green icon is displayed at the top-right corner of the Commander window.
9. Select the tab Parameters (F2) and click Download parameters from device on the left side of the Commander-window. The complete parameter list is transferred from the sensor to your PC and displayed in the Parameter window.

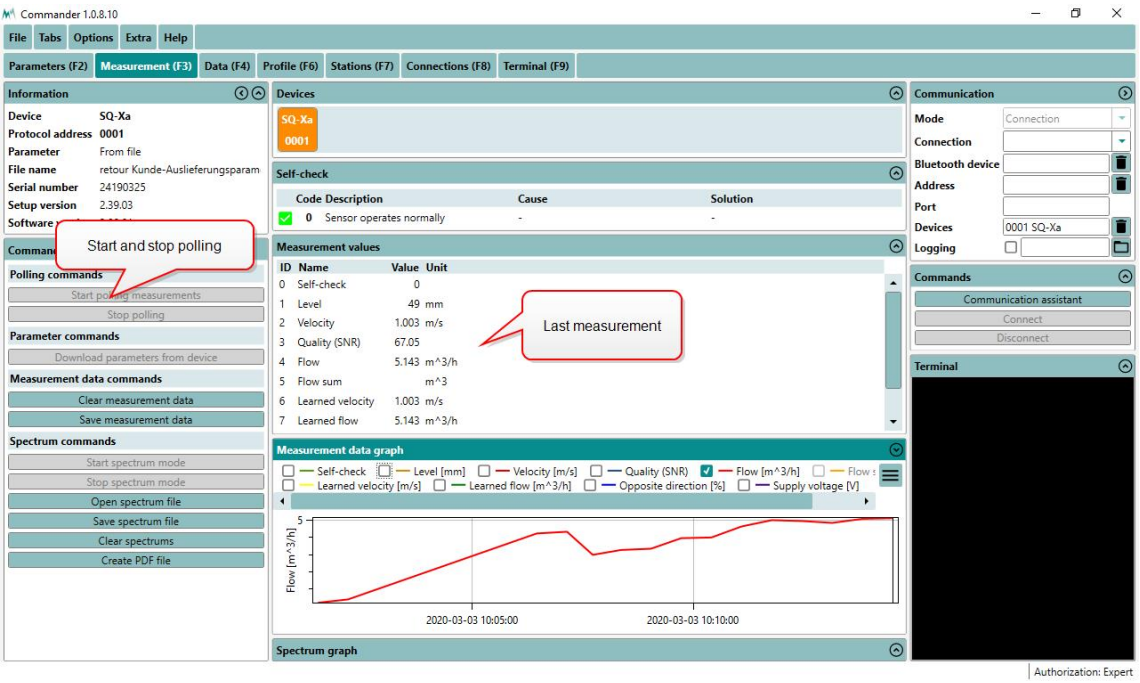


3.2 Configure the SPA-2

1. Select language and decimal character (see General settings)
2. Select the measurement trigger and measurement interval (see General settings)
3. Define the scope and structure of the data output (see General settings)
4. Calibrate the SPA-2 by measuring the capacities of the ribbon sensors in air (see Calibration of SPA-2-ribbon-sensors)
5. Optional: measure the capacities of the ribbon sensors with a reference plate (see Calibration of SPA-2-ribbon-sensors))
6. Send any modifications to the SPA-2 by clicking Upload modified parameters to device.

3.3 Acquire measurements

1. Establish a connection to your device as described in Working with connections.
2. Download the setup of your device as described in Download setup.
3. Select the Measurement (F3) tab.
4. In the Commandssection click Start polling measurement. Now, the Commander will trigger measurements of the SPA-2 without any delays between measurements. The results are displayed Measurement values and plotted in the Measurement data graph.
5. To finish polling mode click Stop polling.



4 How the SPA-2 works

A snowpack has strong spatial variability and transforms considerably over time. The evaluation of snow properties and the assessment of snow conditions mostly relies on spot observations. The snow pack analyzer SPA-2 breaks this limitation and provides information about the snow pack by measuring the dielectric properties of a large snow volume. It provides all relevant snow properties like snow depth, snow density, snow water equivalent as well as the contents of liquid water and ice.

Snow consists of ice, water and air, which have distinctly different dielectric properties. By measuring the complex impedance along a ribbon sensor (SPA-sensor) at two different frequencies, ice, water and air can be distinguished and their relative volume contents can be determined. From these fractions the snow density is deduced.

Additionally, snow depth is measured with a USH-9, Sommer's ultrasonic level sensor. With this information, the snow water equivalent (SWE) can be calculated. In Figure 1 the cross section of SPA-sensor and its surrounding electric field is illustrated.

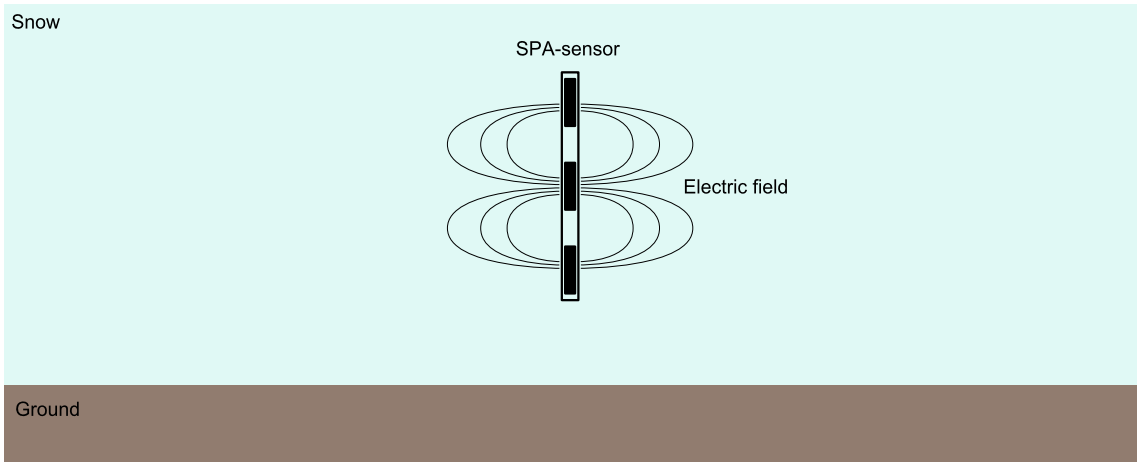


Figure 1 Measurement principle of SPA-sensor

The SPA-sensors are 60 mm wide, reinforced rubber ribbons containing three parallel copper wires. As soon as an alternating current flows through the wires, an electric field builds up that penetrates up to 4 cm into the surrounding snowpack.

The 4.8-m long ribbons are stretched onto a supporting frame at different heights either horizontally or in a sloping angle.

The USH-9 ultrasonic level sensor is mounted on the mast of the supporting frame to record the snow height, which is required to determine the snow coverage of the tilted SPA-sensor and to calculate the snow water equivalent.

While the tilted ribbons sensor provides average values of the snow properties, the horizontal sensors return the properties of individual layers. Figure 2 illustrates the determination of the SWE-values at different snow depths.

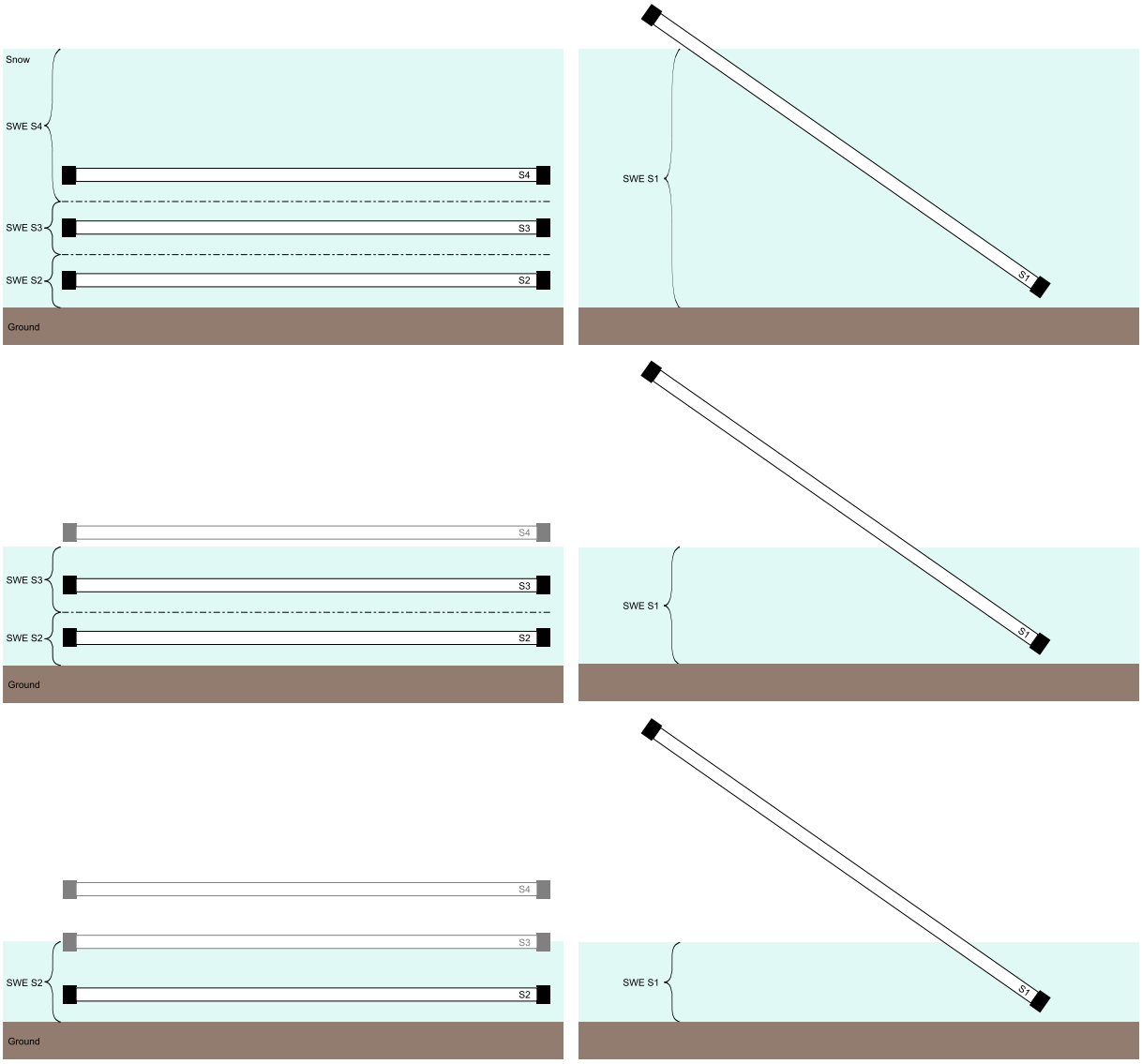


Figure 2 SWE-values at different snow depths

5 Components

5.1 Terminals

The pin-layout of the SPA-2 is shown in Figure 3 and the terminals are listed in Table 1.

ATTENTION Do not connect voltages >30 V to any terminal! Excess voltages can impair the functioning of the SPA-2, destroy the device and may lead to injuries.

ATTENTION Serial port BUS 2 is reserved for the USH-9 snow depth input!

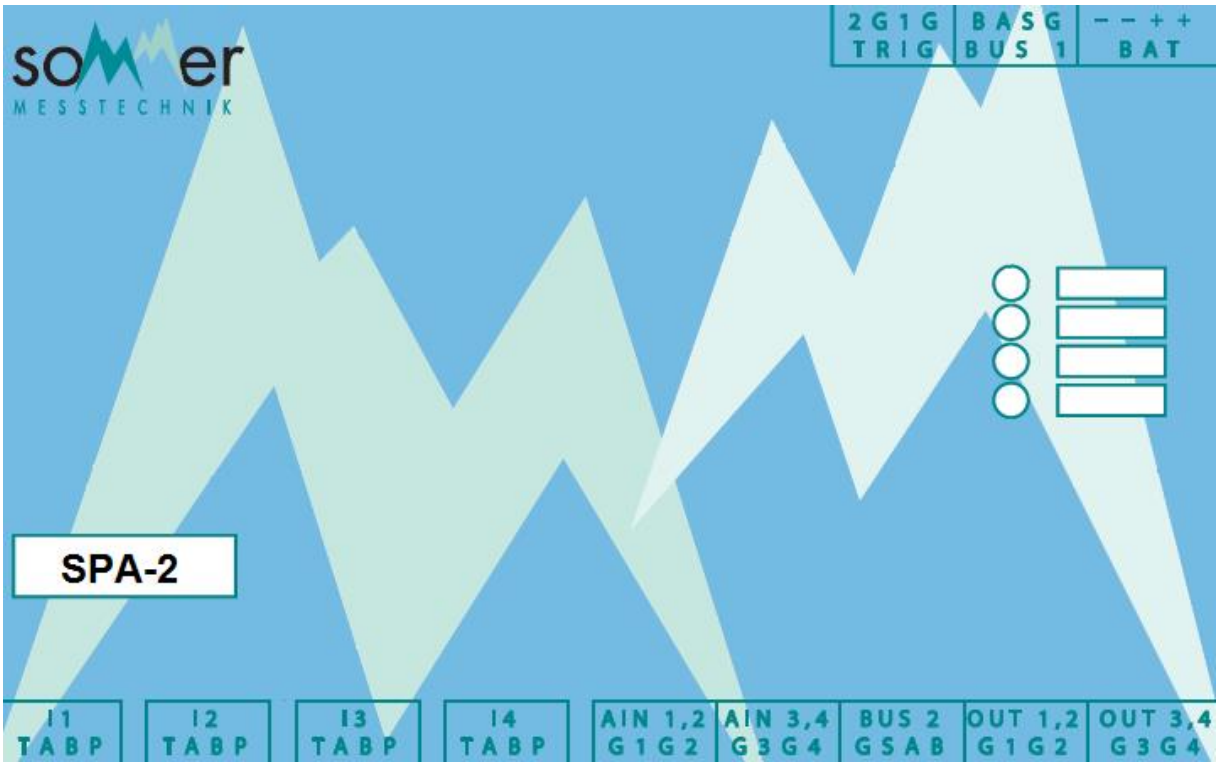


Figure 3 Connection terminals of SPA-2

Terminal	PIN	Description
TRIG	2	Trigger input 2 (not available)
	G	Ground
	1	Trigger input 1
	G	Ground
BUS 1	B	RS-485 B (to data acquisition device)
	A	RS-485 A (to data acquisition device)
	S	SDI-12 (to data acquisition device)
	G	Ground
BAT	-	Supply voltage (-)
	-	Supply voltage (-)
	+	Supply Voltage (+), 9.0 to 24.0 VDC
	+	Supply Voltage (+), 9.0 to 24.0 VDC
I1	T	Optional temperature input
	A	SPA-ribbon sensor 1
	B	SPA-ribbon sensor 1
	P	Shield of SPA-ribbon sensor 1
I2	T	Optional temperature input
	A	SPA-ribbon sensor 2
	B	SPA-ribbon sensor 2
	P	Shield of SPA-ribbon sensor 2
I3	T	Optional temperature input
	A	SPA-ribbon sensor 3
	B	SPA-ribbon sensor 3
	P	Shield of SPA-ribbon sensor 3

Terminal	PIN	Description
I4	T	Optional temperature input
	A	SPA-ribbon sensor 4
	B	SPA-ribbon sensor 4
	P	Shield of SPA-ribbon sensor 4
AIN 1,2	G	Ground
	1	Analog input 1
	G	Ground
	2	Analog input 2
AIN 3,4	G	Ground
	3	Analog input 3
	G	Ground
	4	Analog input 4
BUS 2	G	Ground
	S	SDI-12 (from sensor)
	A	RS-485 A (from USH-9)
	B	RS-485 B (from USH-9)
OUT 1,2	G	Ground
	1	Switched supply voltage 1: reserved for USH-9
	G	Ground
	2	Switched supply voltage 2
OUT 3,4	G	Ground
	3	Switched supply voltage 3
	G	Ground
	4	Switched supply voltage 4

Connection terminals of SP-2 controller

Table 1 Connection terminals

6 Specifications

Physical and environmental	
Power supply	9...28 VDC; Reverse voltage protection, overvoltage protection
Power consumption at 12 VDC	max. 65 mA active 1mA in sleep mode
Outputs	RS-485 SDI-12 Analog output 4...20 mA (14 bit, max. load 200 Ω) Digital output (low: 0V, high: V_{supply}, max. 30 mA at V_{supply}-0.5 V)
Operating temperature	-35…60 °C (-31…140 °F)
Storage temperature	-35…60 °C (-31…140 °F)
Rel. humidity	0...100 %
Protection rating	Sensors IP 66 Controller IP 54 (IP 66 if contained in electrical cabinet)
Lightning protection	Integrated protection against indirect lightning with a discharge capacity of 6 kA Ppp
Housing material	Aluminium
Size L x W x H	2.5-m version: 6360 x 1100 x 3700 mm (250.39 x 43.31 x 145.67 in) 5.0-m version: 6360 x 1100 x 5700 mm (250.39 x 43.31 x 224.41 in)
Weight	2.5-m version: 110 kg (242.5 lb) 5.0-m version: 115 kg (253.5 lb)

7 Installation

7.1 Site selection

The selection of a suitable site is crucial to gain information of the snowpack that is representative of the monitored area. Several aspects have to be considered when choosing a measurement site:

1. The selected site should be flat with no dips and rises.
2. The measurement spot should be representative of the monitored area.
3. There should be no boulders, trees, fences or other objects in the vicinity of the measurement spot. Any obstacle can cause snow drift and thus affect the measurement results.
4. If feasible, the SPA-2 should be installed in the direction of the main wind. This minimizes disturbances by snow drifts.
5. The site must be safe from avalanches.

7.2 Things to consider for installation

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7.2.1 Power supply

The SPA-2 is designed for extreme environmental conditions at remote sites and with no grid connection. The sensor switches automatically into standby-mode between measurements and thus consumes only approx. 0.2 Ah per day which can be supplied by a 12V-solar-generator mounted to the mast.

7.2.2 Signal cables

Maximum cable length

Please consider the maximum cable lengths for the applied transmission protocol:

Protocol	Max. cable length [m]
SDI-12	60
RS-485	300

Table 2 Maximum cable lengths

NOTE Cable lengths longer than 60 m require a heavier gauge wire if the power supply drops below 11 V.

7.2.3 Lightning protection

If the underground at the measurement site permits sufficient current dissipation it is strongly recommended to equip the sensor support or mast with properly dimensioned lightning protection. Consult an expert for advice.

The SPA-2 is protected against overvoltage. If a data logger is mounted to the mast, its ground lug must be properly connected to earth ground.

7.3 Required tools and equipment

Prepare the following tools and equipment to install the SPA-2:

Qty	Tool
1	Flat spanner 19 mm
2	Flat spanner 17 mm
2	Flat spanner 13 mm
1	Flat spanner 7 mm
1	Allen-key 3mm
1	Allen-key 6 mm
1	Allen-key 8 mm
1	Wire cutter
1	Folding-rule

7.4 Mounting

7.4.1 General

The SPA-2 system consists of a frame that supports the SPA-ribbon sensors and an USH-9 level sensor.

ATTENTION To avoid erroneous measurements, the SPA-2 must be installed on firm ground. If there is a risk of subsiding ground, reinforce the surface with logs or concrete slabs and install the SPA-2 on top of it.

The parts of the SPA-2 structure are marked at their mounting positions where relevant. For example, the label 3/13 indicates that the frame parts 3 and 13 are joined (see Figure 4 for an example). The part-numbers are listed in the parts list inScope of delivery and are also indicated in Figure 5.

As the SPA-2 structure is asymmetric, some parts are also labelled L (left) and R (right). The left and right sides are indicated in Figure 5.

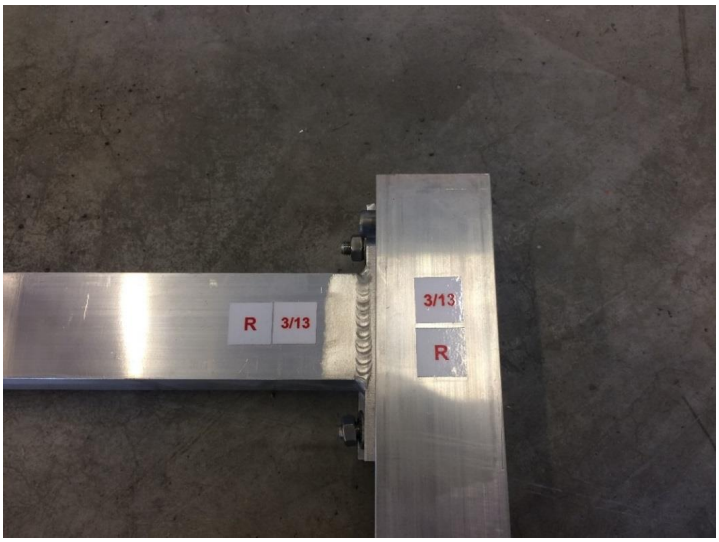


Figure 4 Labelling of parts

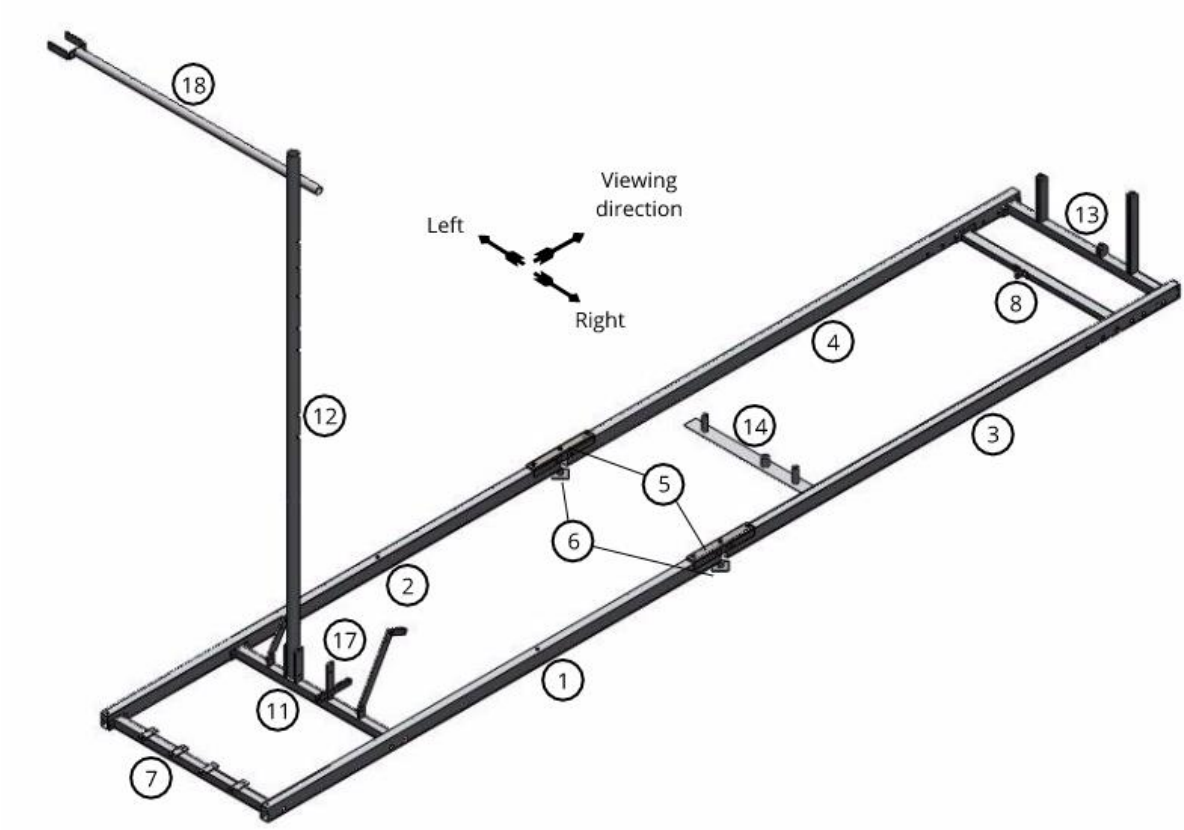


Figure 5 Assembled SPA-frame

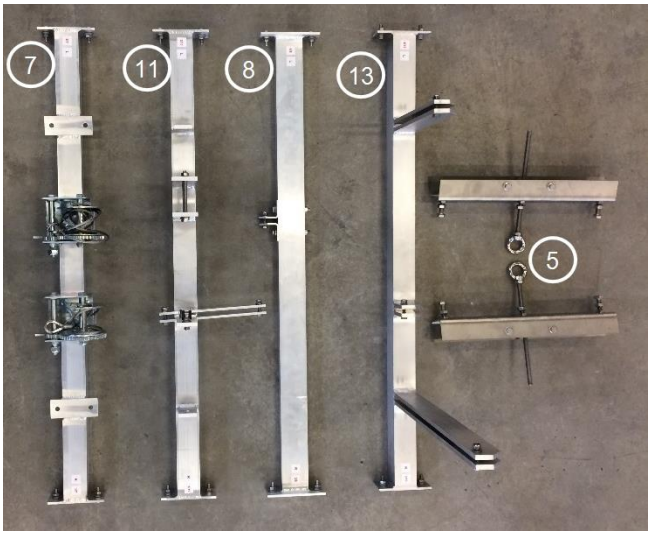


Figure 6 Cross-profiles

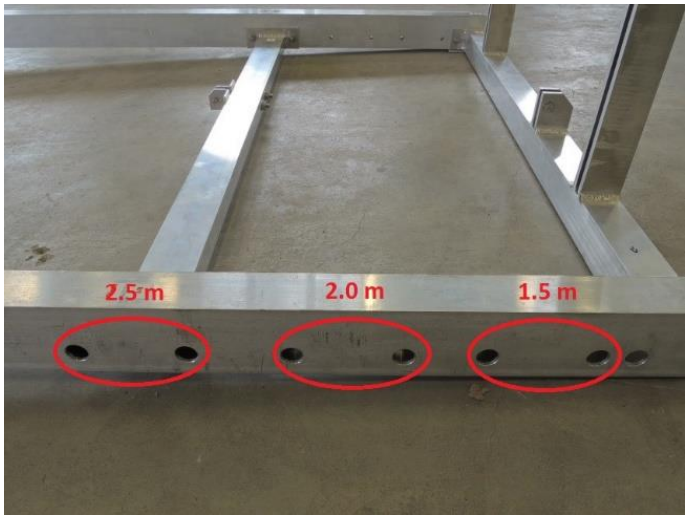
7.4.2 Supporting frame

Follow the steps below to assemble the supporting frame:

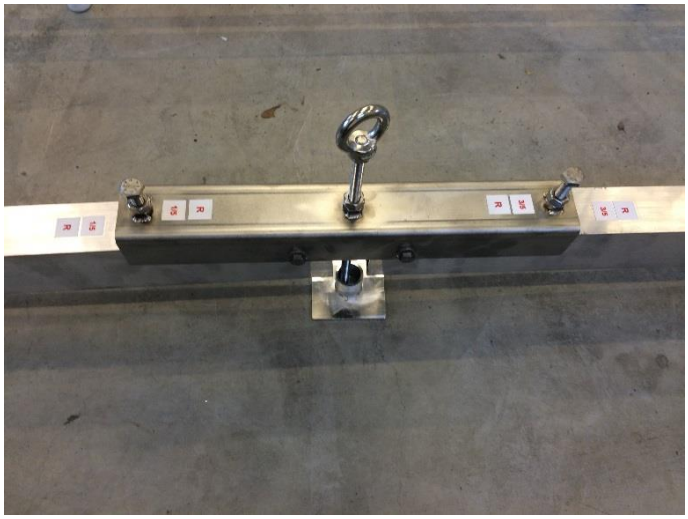
1. Lay out the base-profiles nr. 1…4 and the cross-profiles 7, 11 and 13 as shown in Figure 5. Consider the viewing direction and the position of the cross-arm supporting the USH-9!
2. When you have verified the correct mounting position, join the base- and cross-profiles with the provided bolts as shown in the following example. Use the proper Allen-key to slide the bolts through the holes of the outer side of the base-profiles. Make sure that the knurled side of the washer faces the head of the bolt and the nut, respectively.

3. Join cross-profile nr. 8 to base-profiles nr. 3 and 4. This profile can be mounted in three different positions as shown in the figure below. The position depends on the expected snow height and the mounting height of the tilted SPA-sensor. By default, the profile is joined at position 2.5 m.

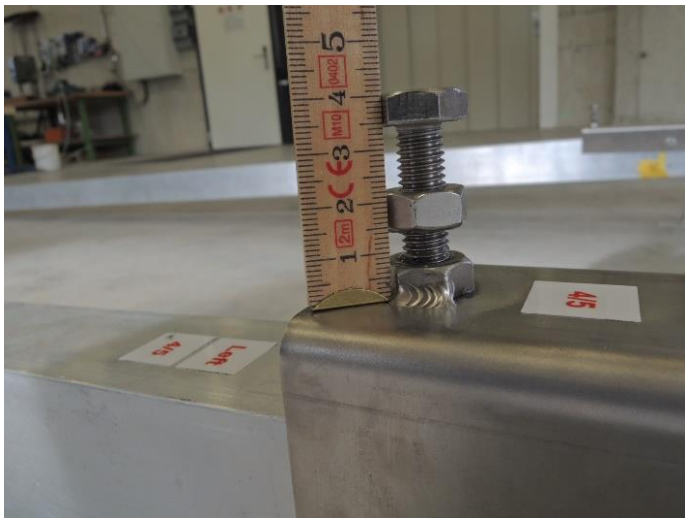
> **ATTENTION** The position of cross-profile nr. 8 has to match the mounting position of the tilted SPA-sensor on the mast (see also Mast with tilted SPA-2-sensor and USH-9)!



4. Place the U-profiles Nr. 5 between the base-profiles nr.1 and 3, and nr. 2 and 4 using the horizontal bolts mounted to the profiles.

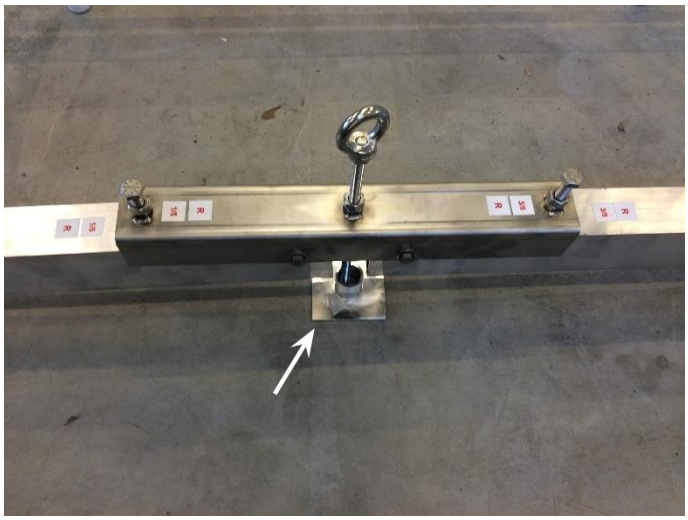


5. Adjust the bolts on each end of the U-profile so that they protrude 4 cm from the surface. You may need to lift the end of the base-profiles by a few cm to adjust the bolts. Tighten the lock-nuts.

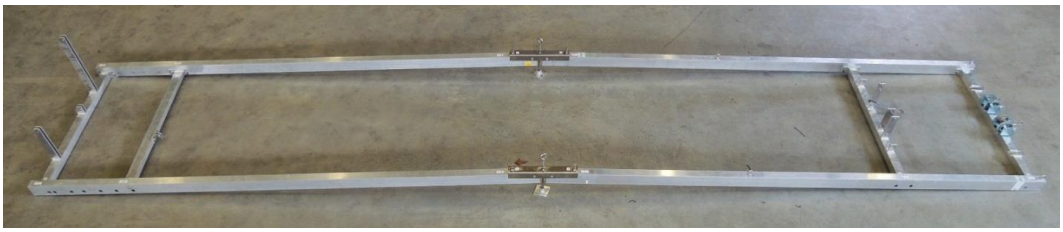


6. Adjust the center bolt of each U-profile so that it protrudes 8.5 cm from the surface (measured below the ring nut). Tighten the lock-nuts.

7. Place the base plates nr. 6 underneath the center bolts of the U-profiles.



The base-profiles are now not level with the ground; this is required to be able to tighten the SPA-ribbon sensors.

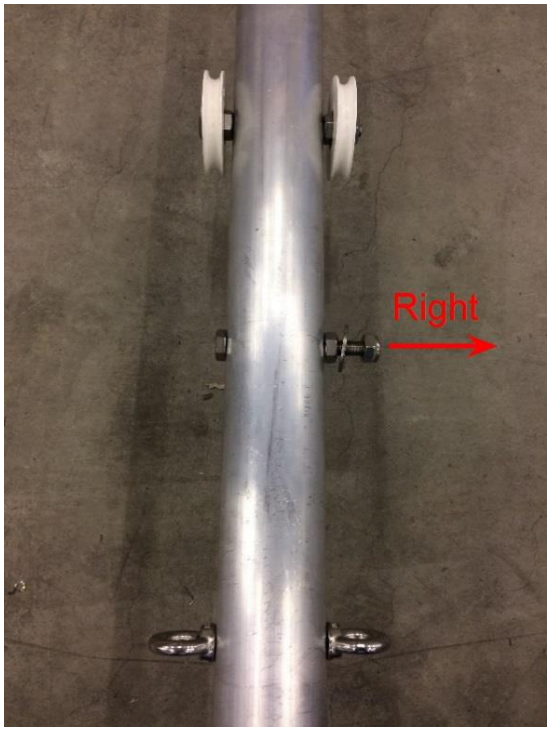


7.4.3 Mast with tilted SPA-2-sensor and USH-9

Follow the steps below to set up the mast. It is recommended to attach all required items while the mast is lying on the ground. In this way no ladder or step is needed.

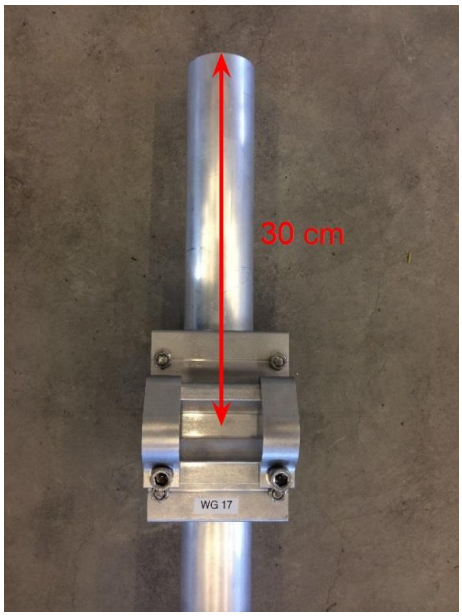
1. Remove the bolts of the mast bracket on cross-profile nr. 11 and slide the bottom end of the mast into the bracket.

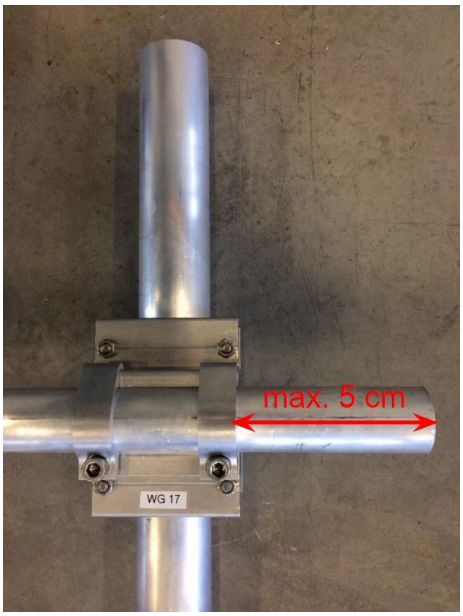
2. Turn the mast so that the protruding end of the attached bolt is facing to the right.



3. Fix the mast with the upper bolt of the mast bracket on cross-profile nr. 11.

4. Slide the bracket for the cross-arm approx. 30 cm over the top of the mast and tighten it loosely.



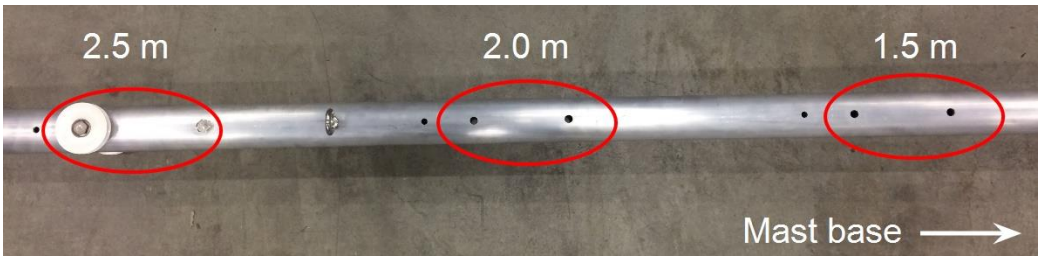


5. Slide the cross-arm into the bracket so that the short end protrudes max. 5 cm and tighten it. Make sure that the cross-arm is pointing perpendicular to the length of the supporting frame when it is standing upright! Now, tighten the 4 bolts of the bracket embracing the mast.
6. Mount the USH-9 with its bracket to the cross-arm. Make sure that the USH-9 is pointing towards the ground and that it is parallel to the mast when erected.

> **ATTENTION** The tilt of the USH-9 sensor should be less than ±6° off the vertical axis!

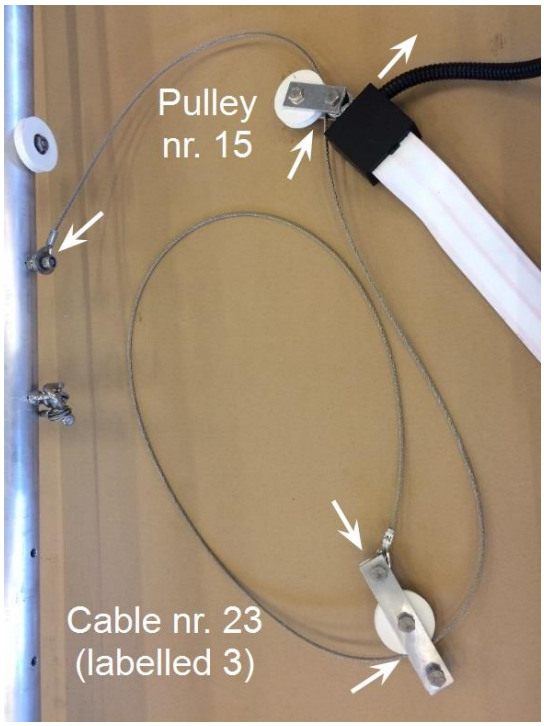
7. Plug the sensor cable to the USH-9 and fix it along the cross-arm and mast with cable ties. Coil up the excess sensor cable and attach it to the mast to avoid damage during the remaining installation steps.
8. Verify that the pulleys attached to the mast match the mounting position of cross-profile nr. 8. The default position is 2.5 m (see next figure).

> **ATTENTION** The pulleys on the mast can be mounted in three different positions, depending on the expected snow height. As illustrated in the figure below, the available positions are 1.5, 2.0 and 2.5 m. The selected position must match the mounting position of cross- profile nr. 8 described in the previous section.

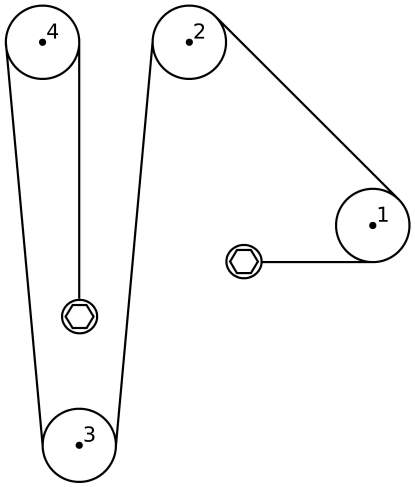


9. Attach the loop of cable nr. 23 (labelled 3) to the bolt below the pulley of the mast as shown in the next figure.
10. Attach pulley nr. 15 to the ring nut of the tilted SPA-ribbon-sensor. Run cable nr. 23 between the pulley and the ring nut. Make sure to attach the pulley to the ribbon end with the cable out-put and in the position shown in the figure below!
11. Fasten the other end of cable nr. 23 to the second pulley as shown in the figure below.

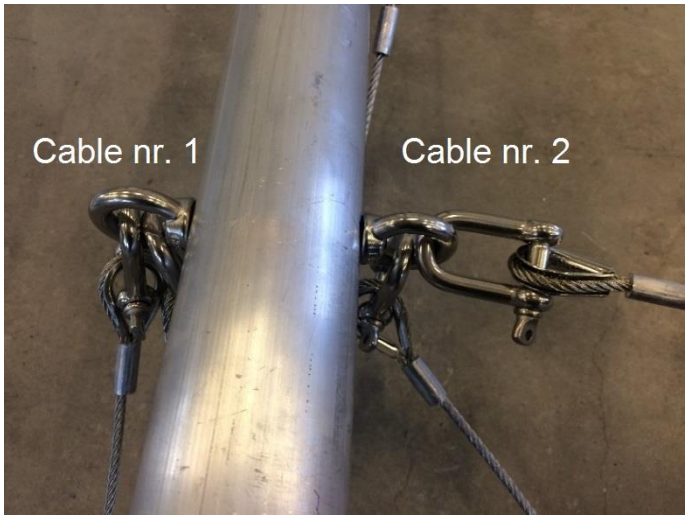
12. Run the cable nr. 23 through the second pulley as shown below.



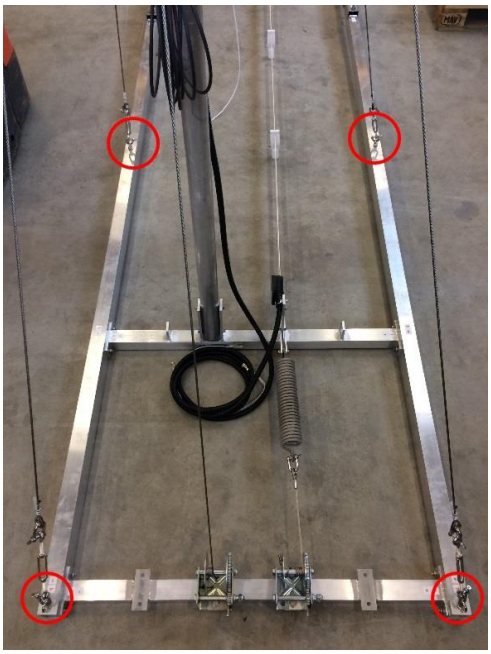
13. Fix cable nr. 23 with a cable tie to the mast as shown below. Make sure to run the cable around the pulleys exactly as shown in the figure. Only then the hoist to tighten the SPA ribbon sensor will work properly.



14. Attach the guy cables nr. 21 (labelled 1) with the shackles to the ring nut on the left side of the mast.
15. Attach the guy cables nr. 22 (labelled 2) with the shackles to the ring nut on the right side of the mast.



16. Push up the mast into its upright position and fix it with the second bolt on cross-profile nr. 1

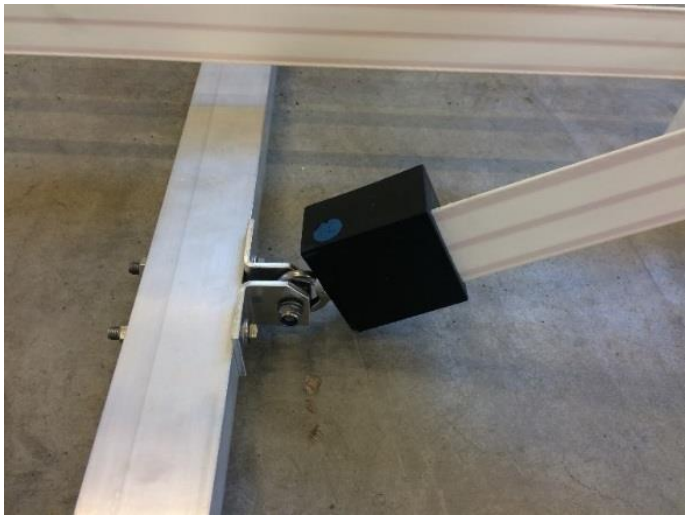


17. Secure the mast with the four guy cables to the base frame. The turnbuckles of cables nr. 21 (labelled 1) are mounted to the ring nuts on base-profile nr. 2 (left), and the buckles of cables nr. 22 (labelled 2) to the ring nuts on base-profile nr. 1 (right).

> **ATTENTION** Tighten the four guys equally! The mast must point exactly upright for proper operation of the snow level sensor!

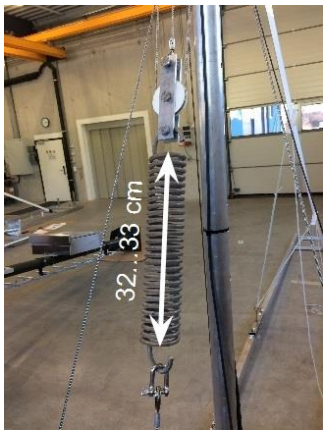
7.4.4 Tilted SPA-ribbon-sensor

1. Fasten the open end of the ribbon-sensor to the bracket on profile nr. 8. Make sure the ribbon is not twisted and that the ring-nut can turn in the bracket-gap!



2. Hinge one of the tension springs nr. 20 into the clamp of pulley nr. 23.

3. Hinge the loop of the cable fixed to the left winch on cross-profile nr. 7 into the other end of the tension spring as shown above.
4. Remove the temporary cable tie that held the hinge on the mast.
5. Tighten the spring to a length of 32…33 cm by operating the winch in clockwise direction.



NOTE The winch is self-locking and does not need to be secured!

7. Attach the 2 plastic clips onto the ribbon-sensor with the supplied bolts. The clips should be placed approx. 1 m from each end of the ribbon. Make sure the thickened edges of the ribbon are placed in the notches of the clips.

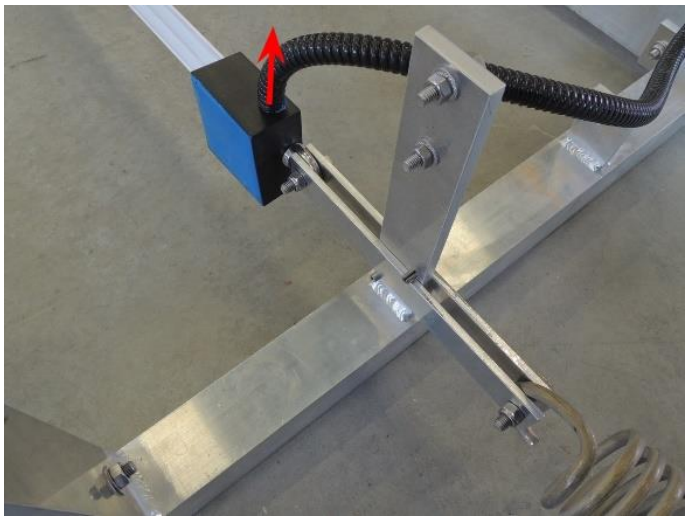
8. Secure the tilted SPA-ribbon by running the provided rope through the clips on the ribbon and the ring nuts on the supporting frame. Fasten the rope with a Fisherman's knot, which allows

repeated tightening.

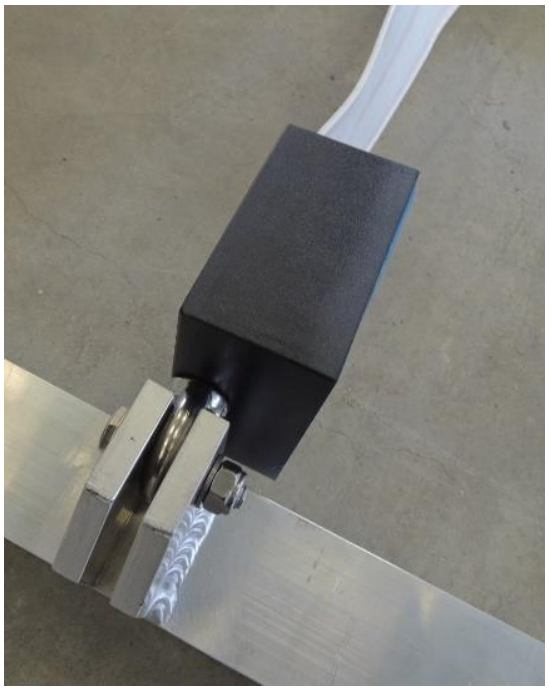
7.4.5 Horizontal SPA-2-ribbon-sensor

1. Roll out the ribbon-sensor in such a way that the end with the sensor cable lies next to the mast.
2. Attach the near end of the ribbon-sensor to the sliding clamp on profile nr. 11. Make sure that

the sensor cable is pointing upwards and that the ring-nut can turn in the clamp-gap!

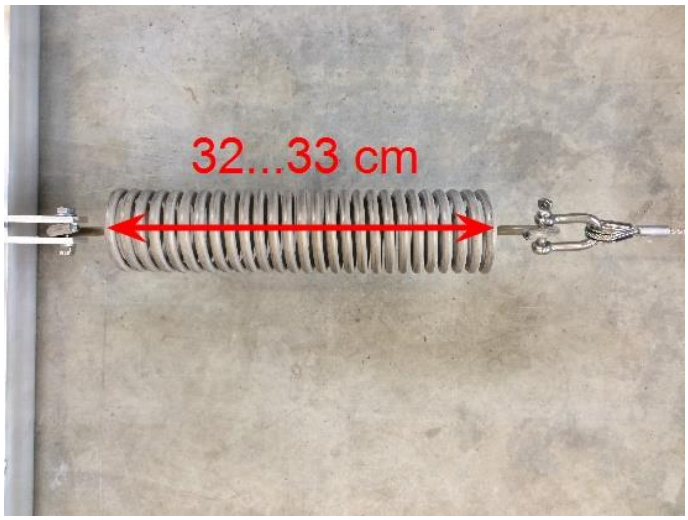


3. Attach the far end of the ribbon-sensor to the lowest clamp of profile nr. 13. Make sure that the ribbon is not twisted and that the ring-nut can turn in the bracket-gap!



4. Hook the tension spring nr. 20 into the other end of the sliding clamp on cross profile nr.11.
5. Hinge the loop of the cable fixed to the right winch on cross-profile nr. 7 into the other end of

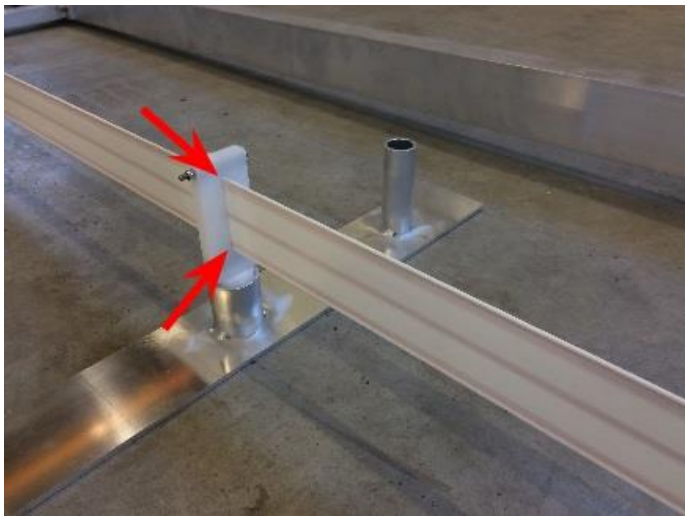
the tension spring.



6. Tighten the spring to a length of 32…33 cm by operating the winch in clockwise direction.
7. Secure the sensor cable with the provided clamp as illustrated in the figure below.

9. Attach the 5 plastic clips onto the ribbon-sensor with the supplied bolts. The spaces between the clips should be equal along the ribbon. Make sure the thickened edges of the ribbon are

placed in the notches of the clips.

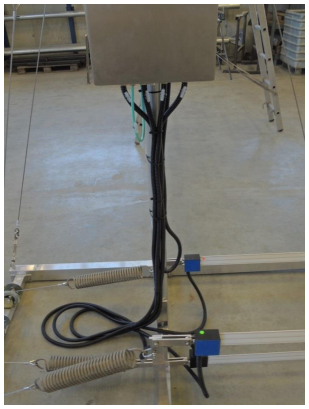


10. Slide the plastic cylinders over the clips and place them in the positioning supports nr. 14 (see figure above).

7.4.6 Control cabinet

1. Mount the control cabinet to the mast with the provided U-bolts. The cabinet should be attached sideways below the tension spring of the tilted SPA-sensor. Secure the cabinet with locknuts.

2. Feed the sensor cables of the SPA-sensors through the cable glands into the cabinet and secure them with the provided nuts. The cable of the tilted SPA-sensor should be fed through the left gland.

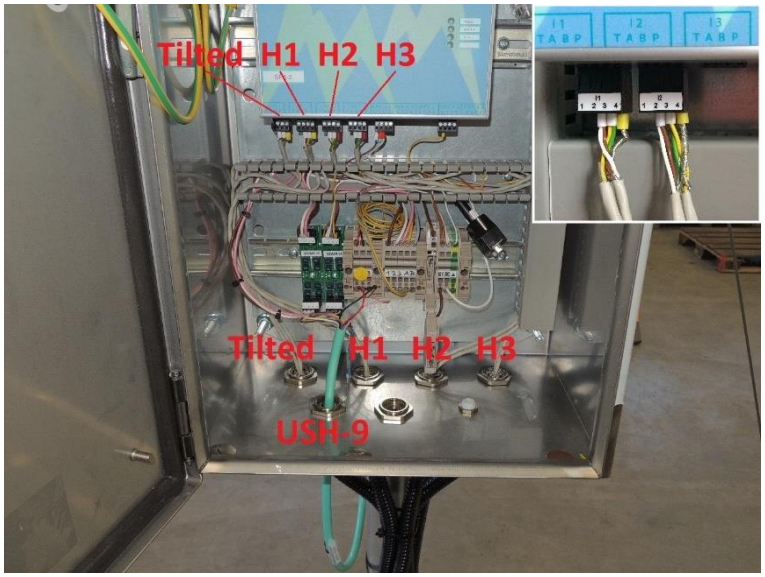


ATTENTION Do not coil up and attach the sensor cables to the mast! Ice might build up and stress the cable connections!

3. Feed the sensor cable of the USH-9 through the left-most gland. Shorten a cable if it is too long. The cable should not touch the ground!

7.4.7 Sensor wiring

1. Verify that the SPA and USH-9 sensor cables are fed through the base of the cabinet as illustrated below.



2. Connect the SPA-sensor cables to the controller in the order shown above. The sensor wires are connected to the SPA-2 controller as illustrated below.

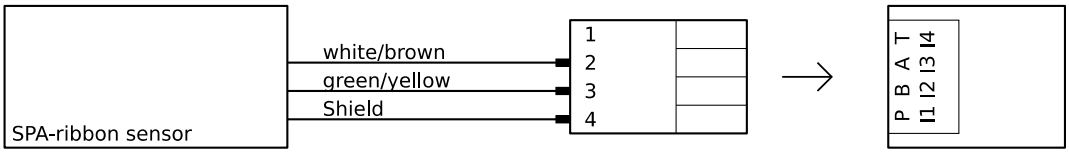
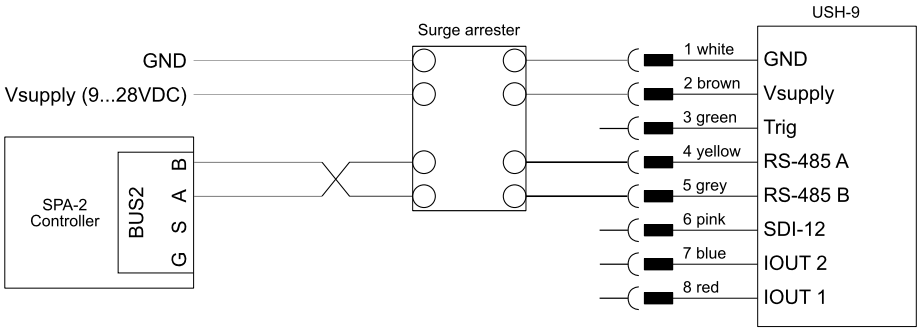


Figure 7 Wiring of SPA-ribbon sensor

Wire color	Pin	Function	Description
-	1	-	not connected
white/brown	2	Receive	Received signal
green/yellow	3	Transmit	Transmitted signal
shield	4	-	cable shield

Connection wires of SPA-ribbon sensor

3. Connect the wires of the USH-9 as shown in and the figure below.



Wire color	Pin	Function	Description
white	1	GND	Ground
brown	2	Vsupply	9...27 VDC
green	3	Trigger	low: 0...0.6 V, high: 2...27 V
red	4	IOUT1	Level (4...20 mA)

Wire color	Pin	Function	Description
yellow	-	RS-485 A	RS-485 (1200…115200 Baud)
grey	-	RS-485 B	
rosa	-	SDI-12	SDI-12 (1200 Baud)
blau	-	IOUT2	Temperature (4…20 mA)

Connection wires of USH-9

7.5 Wiring to a data acquisition system

7.5.1 RS-232 wiring

Connect the SPA-2 to a data acquisition system according to the figure below.

This is a placeholder snippet for wiring diagrams. Add images here.

7.5.2 SDI-12 wiring

Connect the SPA-2 to a data logger by SDI-12 according to the figure below.

SDI-12 uses a shared bus with a ground wire, a data wire (indicated as SDI-12) and an optional +12 V wire.

NOTE The connection with the 12 V power supply is optional and depends on the connected SDI-12 master device (typically a data logger).

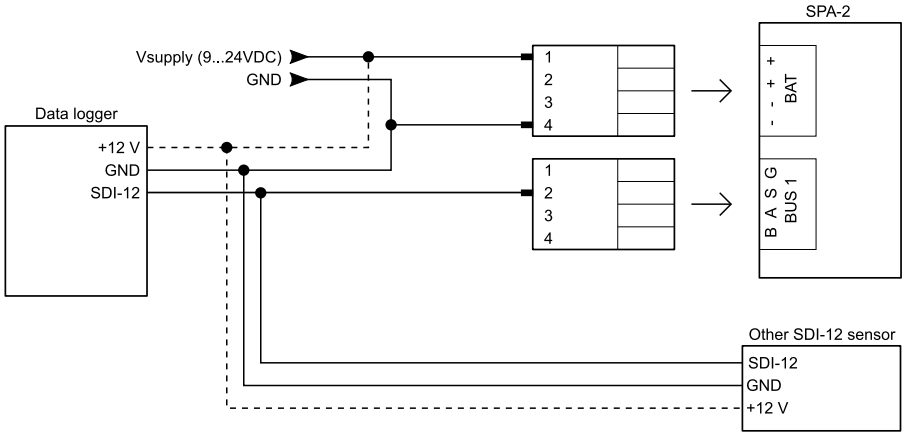


Figure 8 Wiring of the SPA-2 with a data logger via SDI-12

7.6 Calibration of SPA-2-ribbon-sensors

The SPA-ribbon-sensors are calibrated by measuring the complex capacities in dry air (zero) and with an attached reference plate that simulates a certain water content (span). Sommer Messtechnik only ships calibrated SPA-ribbon sensors and generally, a regular zero-check of the sensors is sufficient. If required, the reference plate can be obtained from Sommer Messtechnik.

ATTENTION

During calibration the SPA-ribbon-sensor must be dry and free of snow and ice!

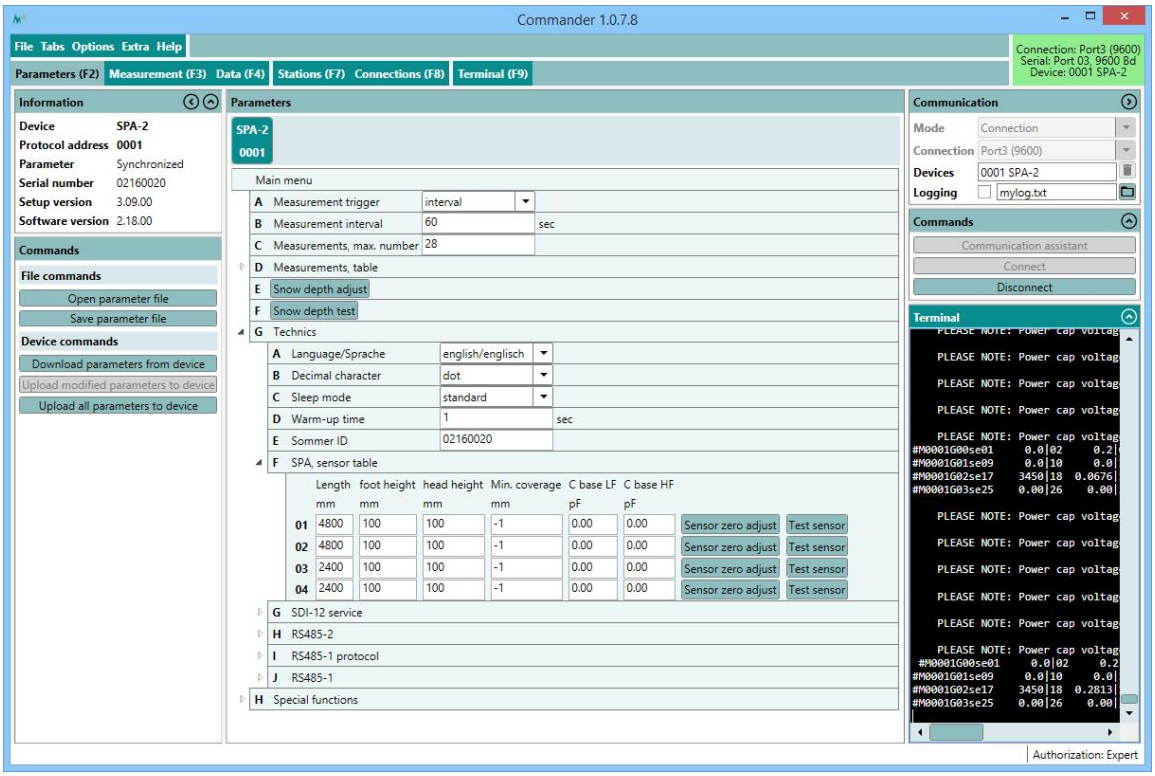
All sensors must be connected and active during calibration!

7.6.1 Zero test and adjustment

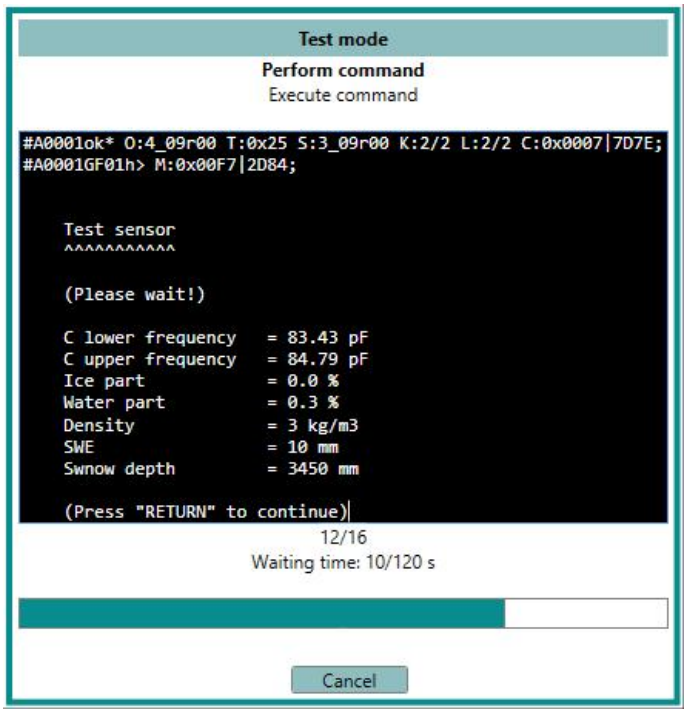
Follow the instructions below to perform a zero-test and -adjustment:

1. Install the SPA-2 as described in Section Installation.
2. Connect the SPA-2 controller to your PC and a power-supply with the specified rating.
3. Open the Commander software and establish a connection to the SPA-2 as described in Establish a connection with the Communication assistant.

4. Download the parameter list and open SPA, sensor table in the Technics menu.



5. For each sensor click Test sensor. The SPA-2 performs a measurement and displays the results in a pup-up window.



The C-values at both frequencies should be 17.4 pF per meter sensor, i.e. 84 ±5 pF for a 4800 mm long sensor. The fractions of ice and water as well as the density should be zero. If the C-values are within these limit, no calibration needs to be performed. If the C-values are outside the limits specified above, perform a zero-adjustment by clicking Sensor zero adjust. After the adjustment, test the sensors again.

7.6.2 Span test and adjustment

Follow the instructions below to perform a span-test for each SPA-2-ribbon sensor:

1. Mount the reference plate to the SPA-ribbon sensor as shown in Figure 9: loosen the knurled bolts and attach the plates to the ribbon.

> **ATTENTION** Make sure the thickened edges of the SPA-ribbon are aligned along the grooves of the reference plate. Fasten the bolts by hand.

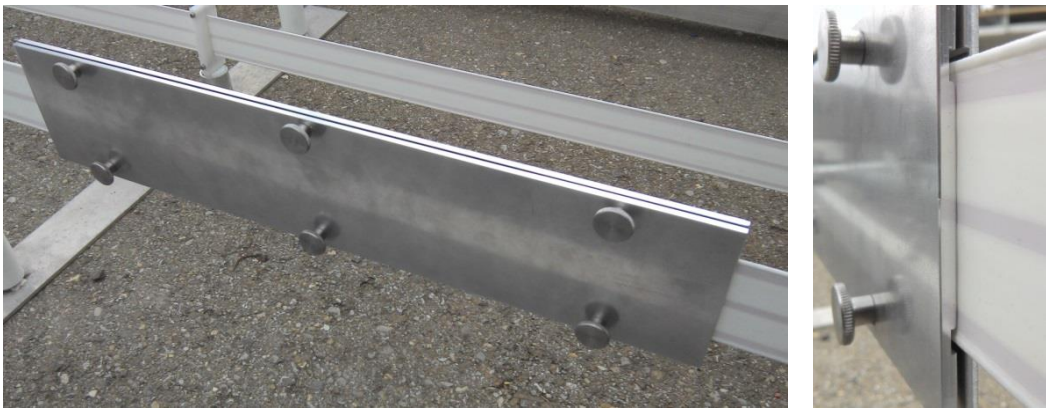
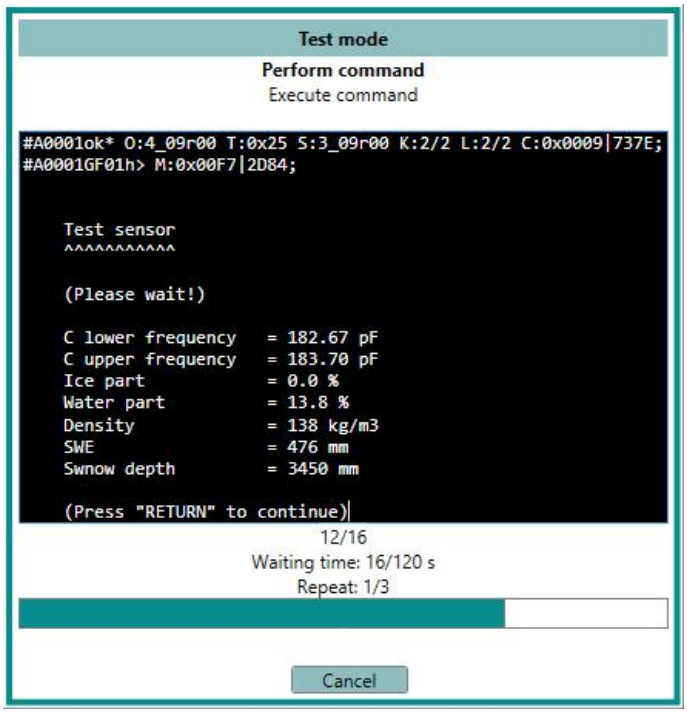


Figure 9 Reference plate

2. In the Commander open SPA, sensor table in the Technics menu.
3. Click Test sensor. The SPA-2 performs a measurement and displays the results in a pup-up win-

dow.



The C-values at both frequencies should increase by 100 ±10 pF, i.e. reach 183 pF. The fraction of water must remain at 0%!

If the C-values are outside these limits, perform a zero-adjustment and repeat the measurement with the reference plate. Should the C-values still deviate too much please contact Sommer Messtechnik.

NOTE The measurement of the capacities with the reference plate is highly sensitive to the mounting of the plate and any interfering capacities SPA-2, e.g. sensor cables.

7.7 Adjustment of snow depth measurement

With the function Snow depth test the current snow depth measurement of the ultrasonic level sensor can be tested. In case the result of this test deviates from the real snow depth, it can be adjusted with Snow depth adjust. This function initiates a measurement and then requests the actual level.

ATTENTION It is recommended to adjust the snow depth measurement at a time without a snow cover.

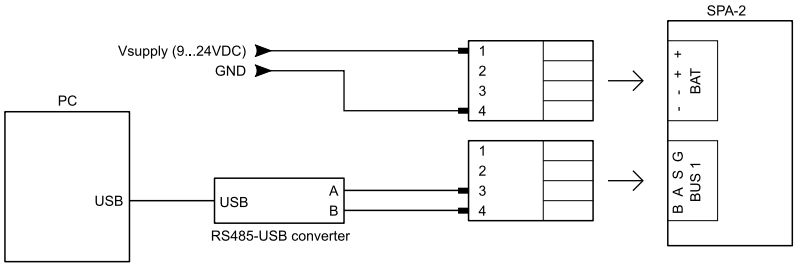
7.8 Start-up

After successful testing, verify that the measurement data are recorded by your data acquisition system and check the data transmission to the remote server if applicable.

8 Operation

8.1 Connect device to PC

1. Install the Commander support software (see Installation of Commander)
2. Connect the yellow and gray wire of the sensor cable to the USB to RS485 isolated converter cable and plug it into your PC as illustrated in the figure below.
3. Connect the RS-232 to USB converter cable to the SPA-2 and a USB port on your PC.
4. Connect a 9...28 VDC power supply to the SPA-2
5. Start the Commander software.
6. Click on Communication assistant on the right-hand side of the Commander window and follow the instructions. During this procedure the communication assistant will search for connected devices. Upon successful completion, the new connection is added to the connections list (tab Connections (F8)).
7. In the Communication Section at the right-hand side of the Commander window select Mode Connection and the previously created connection from the drop-down list.
8. Click Connect to establish a connection with the SPA-2. If the connection was successful a green icon is displayed at the top-right corner of the Commander window.
9. Select the tab Parameters (F2) and click Download parameters from device on the left side of the Commander-window. The complete parameter list is transferred from the sensor to your PC and displayed in the Parameter window.



To activate the communication between your device and the Commander software follow the steps described in Working with connections.

9 Maintenance

The SPA-2 generally does not require any special maintenance. However, we recommend to check the following:

- Sits the installation firmly on the ground?
- Is the mast in the upright position?
- Are the SPA-ribbon sensors damaged and tightly stretched? Are the clips in the upright position?
- Are the wires between the sensors and tension springs tight?
- Are the sensor cables and their protection tubing broken, e.g. damage by rodents?

10 Support software Commander

10.1 Software features

The Commander is a multipurpose software tool to configure and operate any Sommer Messtechnik device. It offers the following functions:

- Communication with Sommer Messtechnik sensors and data loggers via serial connection, modem, socket, IP-call and Bluetooth®
- Management of connections and stations
- Configurations of sensors and data loggers
- Live data monitoring and storage
- Data management including download from data loggers and transmission to MDS (Measurement Data server)
- Terminal window to check data transfer and to access device settings directly

10.2 System requirements

The Commander software supports 32- and 64-bit versions of Windows 7 SP1, Windows 8, Windows 8.1 and Windows 10.

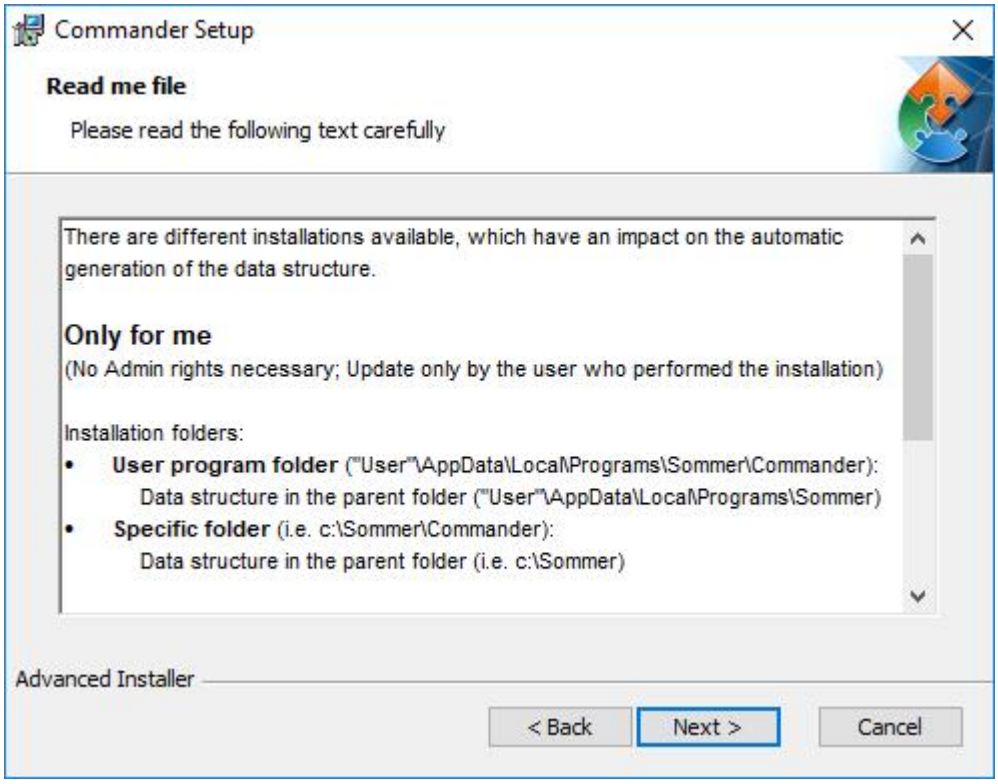
For correct operation Microsoft® .NET Framework 4.5 or later must be installed.

10.3 Installation of Commander

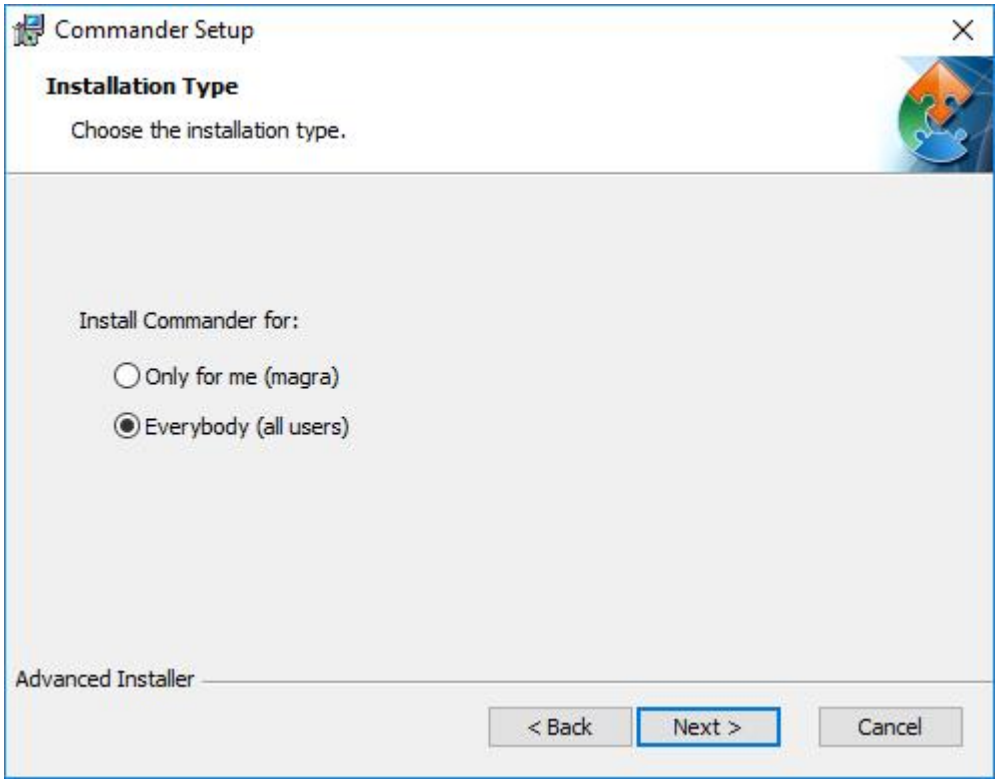
Follow the steps below to install the Commander software:

1. Plug the USB stick shipped with the device into your PC.
2. Double-click the commander.msi installer file on the USB drive.
3. Click Next on the pop-up window

4. Read the instructions and click Next



5. Select the installation type and click Next



NOTE

Two installation types are available. Depending on the selection, the access rights and the folder structure differ:

Only for me

No admin rights are required. Updates are only available to the user who installed the software.

Installation folders:

- User program folder:
  Users\User\AppData\Local\Programs\Sommer\Commander
  Data structure:
  Users\User\AppData\Local\Programs\Sommer
- Specific folder (default):
  C:\Sommer\Commander
  Data structure (default):
  C:\Sommer

Everybody

Admin rights are required. Updates may only be performed by system administrators.

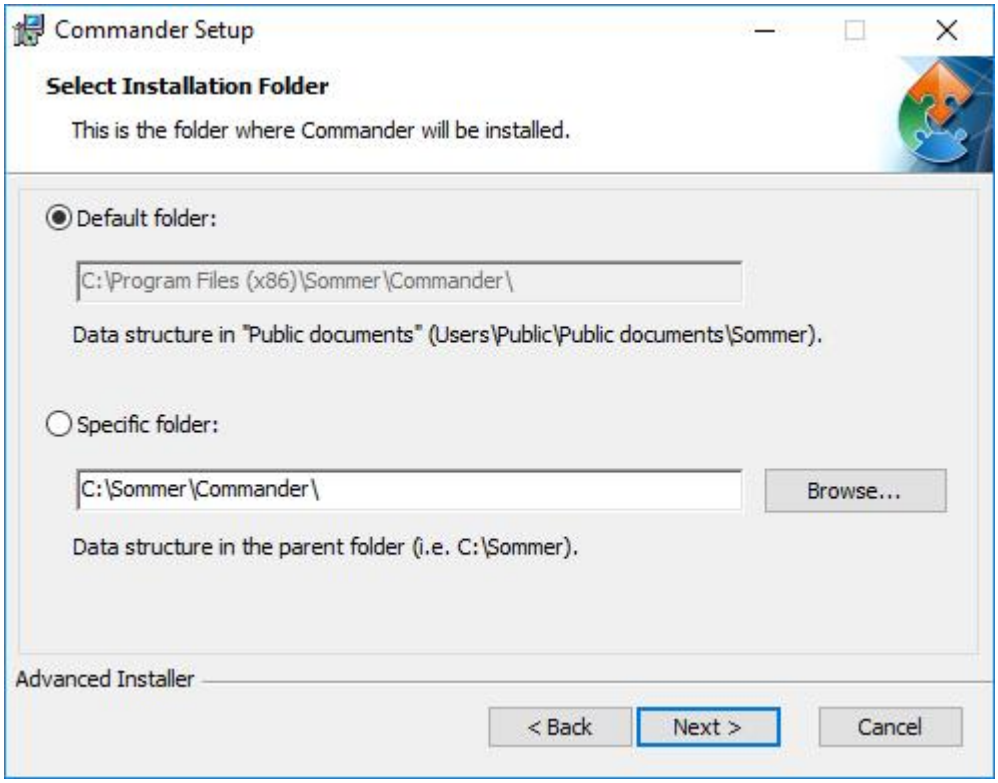
Installation folders:

- Standard program folder:
  Program Files (x86)\Sommer\Commander

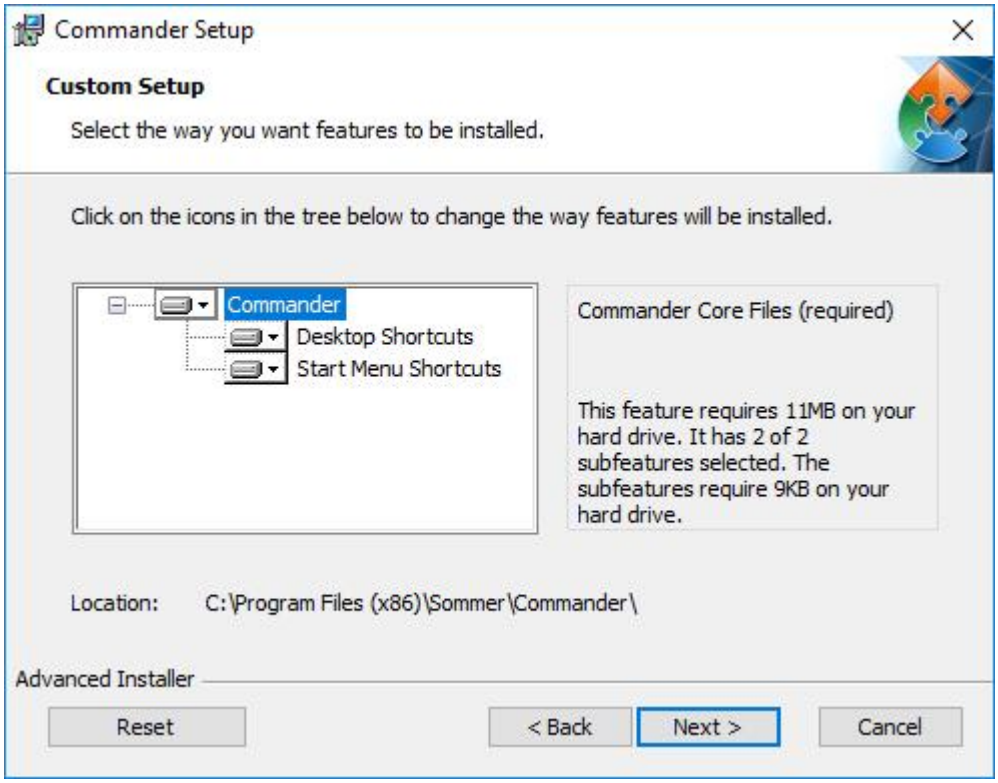
Data structure:
Users\Public\Public documents\Sommer

- Specific folder (default):
  C:\Sommer\Commander
  Data structure (default):
  C:\Sommer

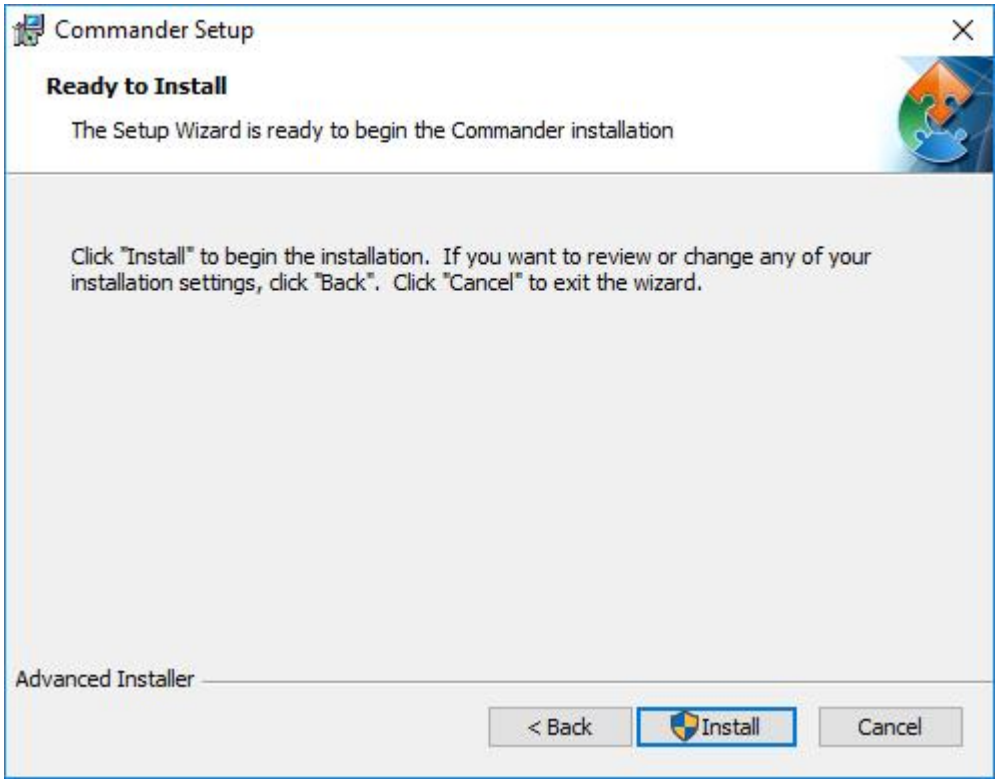
6. Select the installation directory and click Next.



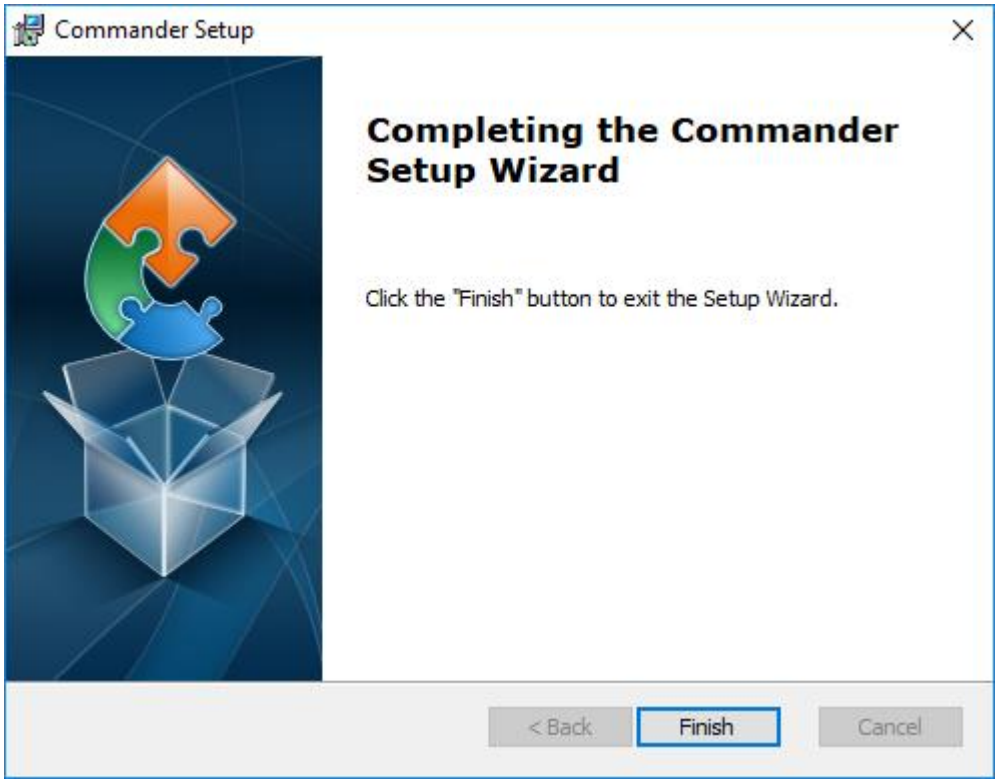
7. Select the features to be installed and click Next.



8. Click Install to start the installation.



9. Click Finish to complete the installation.



10.4 Working with connections

10.4.1 Establish a connection with the Communication assistant

1. Install the Commander support software as described in Installation of Commander.
2. Connect the device to your PC according to Connect the SPA-2 to your PC.
3. Start the Commander software on your PC.
4. Click on Communication assistant on the right-hand side of the Commander window and follow the instructions. During this procedure the communication assistant will search for connected devices. Upon successful completion, the new connection is added to the connections list (tab Connections (F8)).
5. In the Communication Section at the right-hand side of the Commander window select Mode Connection and the previously created connection from the drop-down list.
6. Click Connect to establish a connection with the SPA-2. If the connection was successful a green icon is displayed at the top-right corner of the Commander window.

To view the settings of the connected device or to read the current measurements, follow the steps described in Download setup and Record measurements.

10.4.2 Establish a connection manually

1. Install the Commander support software as described in Installation of Commander.
2. Connect the device to your PC according to Connect the SPA-2 to your PC.
3. Start the Commander software on your PC.
4. Select the required connection in the Connections list of the Connections (F8) tab and click Connect. If the connection was successful a green icon is displayed at the top-right corner of the Commander window.
   If you don't have the required connection available in the Connections list, create a new connection as described in Create a new connection.

To view the settings of the connected device or to read the current measurements, follow the steps described in Download setup and Record measurements.

10.4.3 Create a new connection

1. Select the Connections (F8) tab in the Commander.
2. Click New connection.
3. In the section Connection settings enter a name of the new connection, e.g. *Serial-com1-9600*, and the connection type, e.g. *Serial connection*.
4. Enter the required information for the selected connection type.
   If your SPA-2 is wired to your PC with a RS-485 to USB converter cable, select the port where the device is connected and select a Baud rate of 9800.

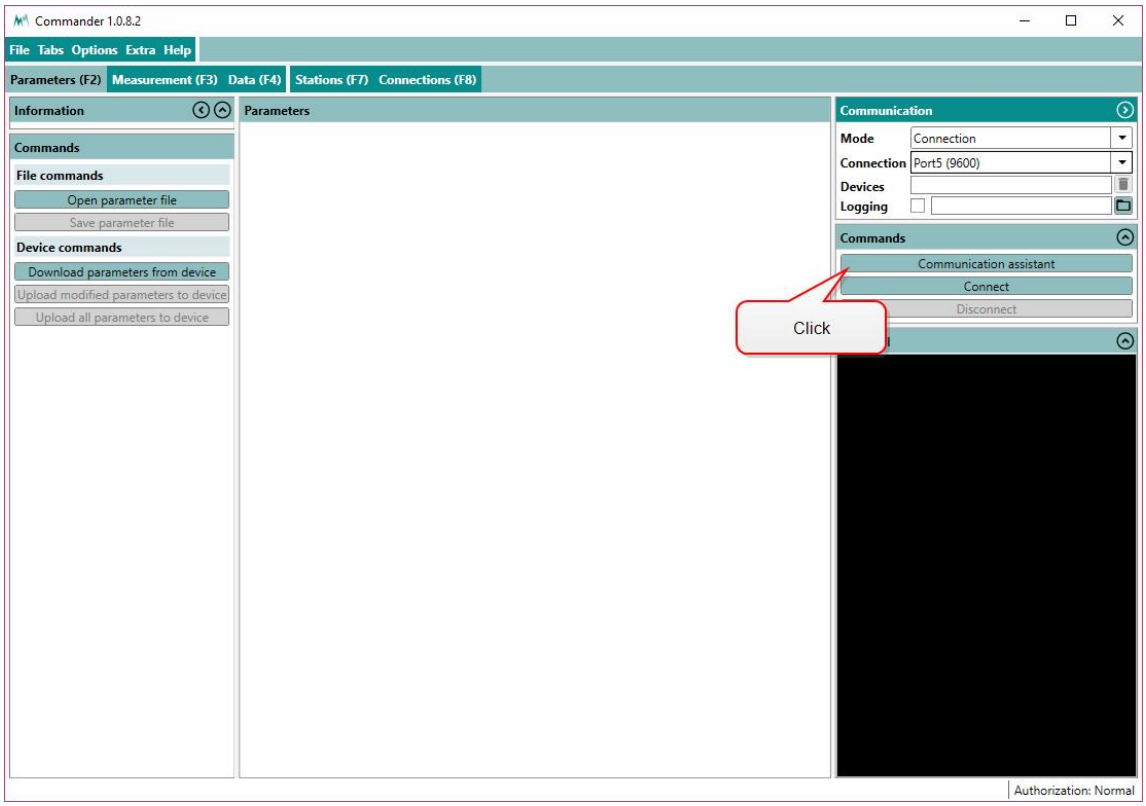
10.5 Working with stations

10.5.1 Create a station with the Communication assistant

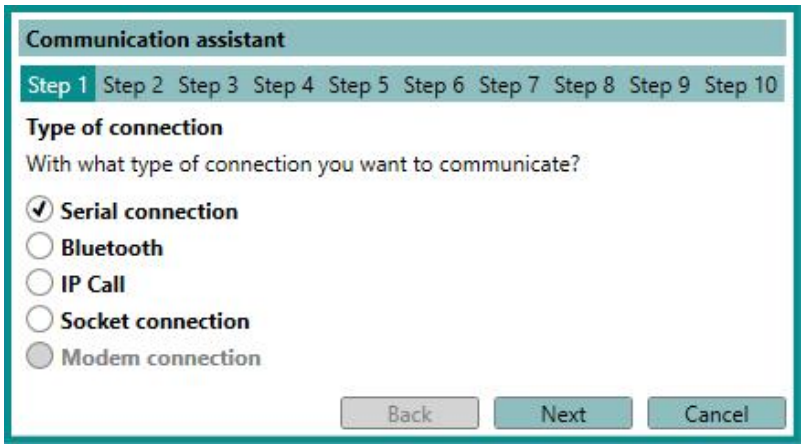
In order to manage several data loggers, to connect to a data logger via IP-call and to download data, stations can be created in the Commander software. To view a list of all stations select the tab Stations (F7).

Perform the following steps to create a new station with the Communication assistant:

1. Click on Communication assistant in the Commander-window

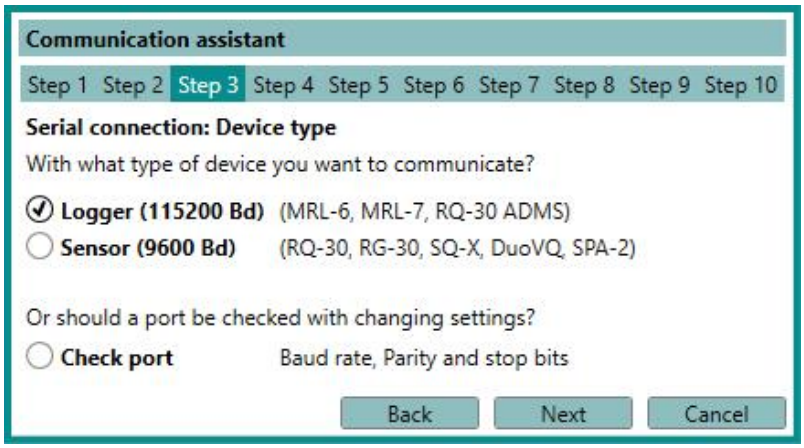


2. In the pop-up window choose the required connection and click Next.

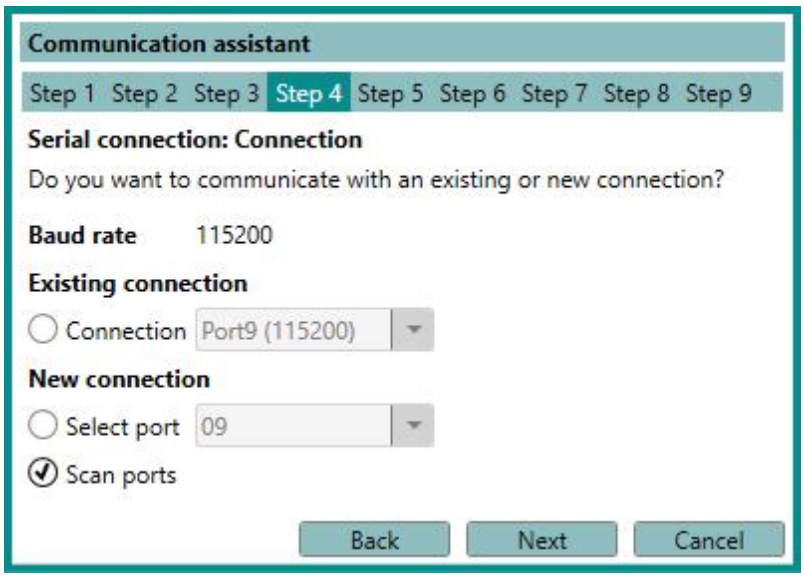


3. Verify that the SPA-2 is connected to your PC and a power supply. Click Next.

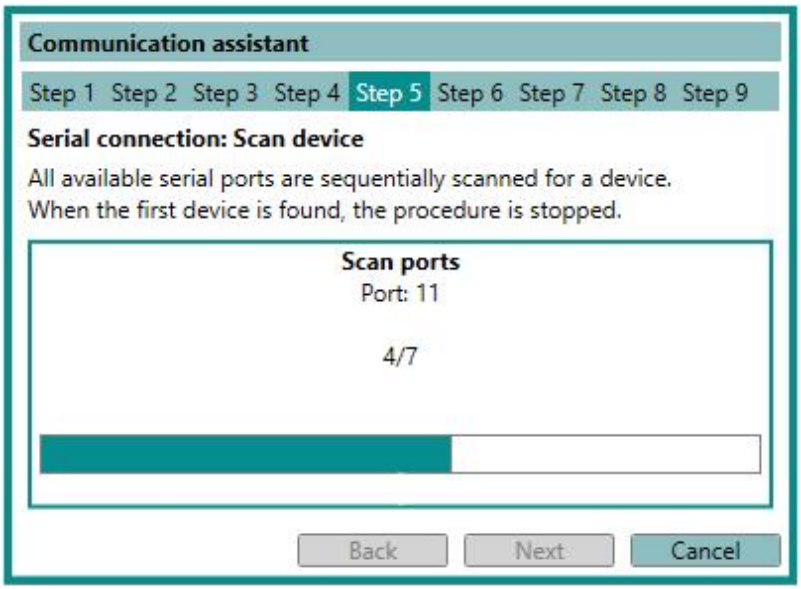
4. Select *Logger (115200 Bd)* and click Next.



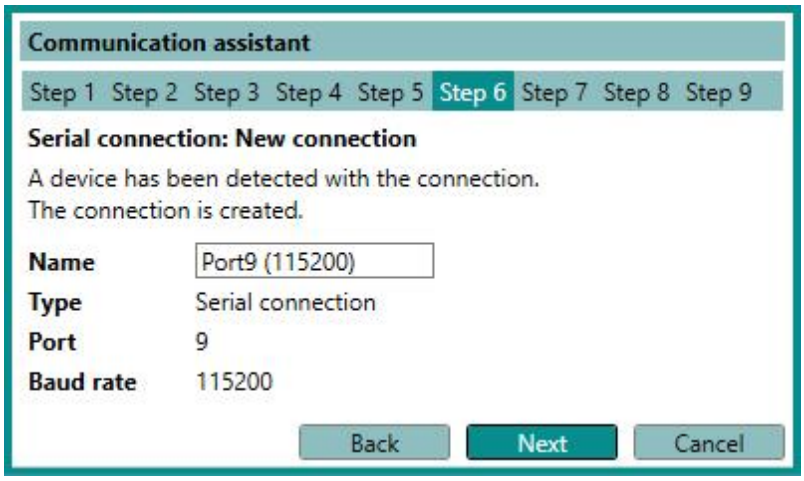
5. Select *Scan ports* and click Next.



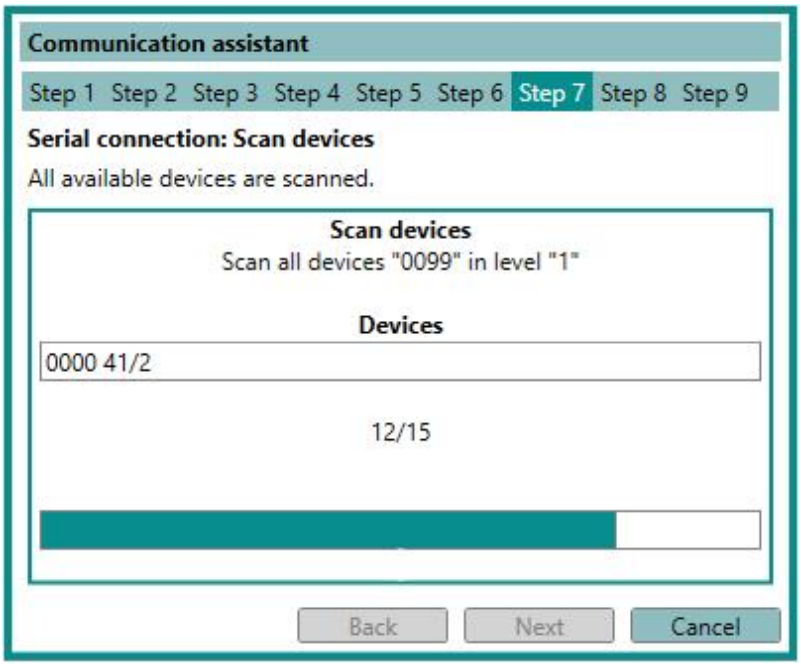
6. The Commander now scans all available ports.



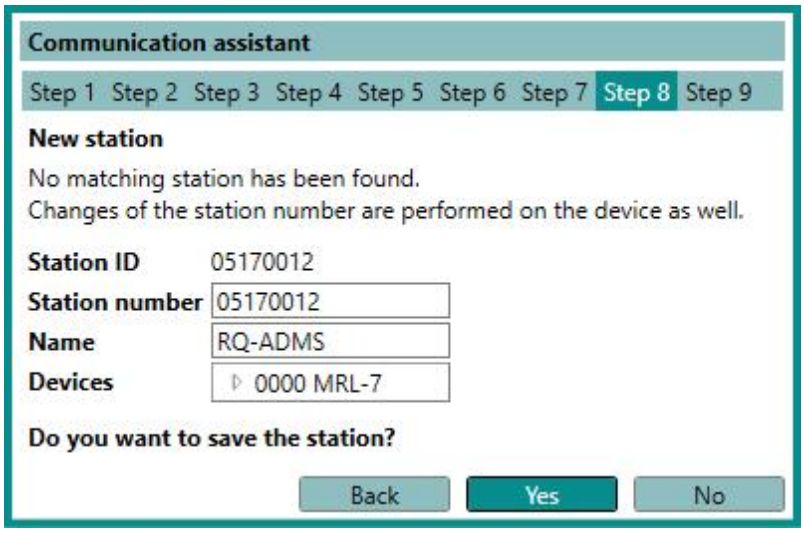
7. Adopt the *Name* provided by the communication assistant. Click Next.



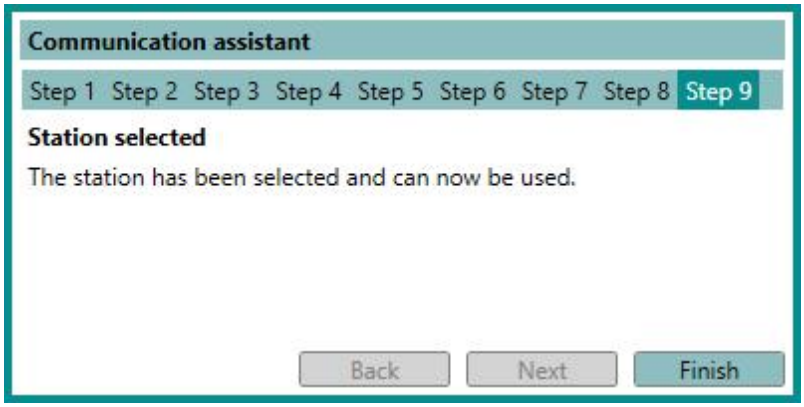
8. The Commander now scans the selected port for connected devices.



9. Adopt the *Name* of the new station or enter a new name. Click Next.



10. A new station has now been created. Click Finish.



11. The newly created station can now be selected in the Communication section of the Commander. Click Connect to activate the connection to your device.

10.5.2 Create a station manually

In order to manage several data loggers, to connect to a data logger via IP-call and to download data, stations can be created in the Commander software. To view a list of all stations select the tab Stations (F7).

Perform the following steps to create a new station:

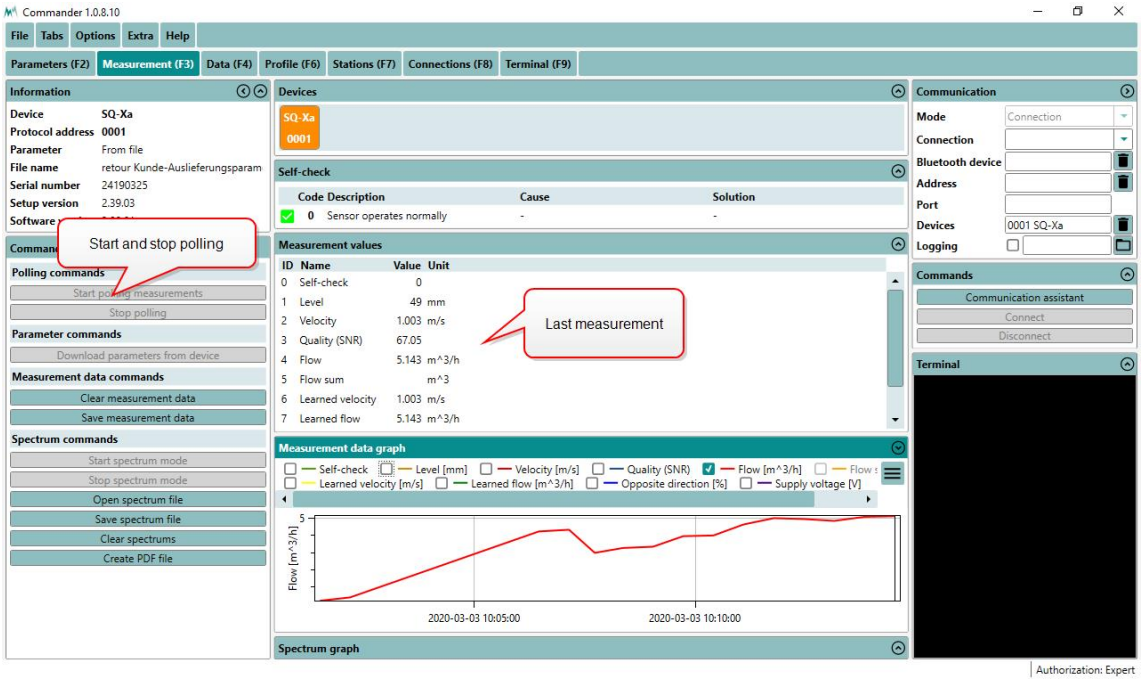
1. In the tab-menu Stations (F7) click New station.
2. Under Station settings enter the Station number and Sommer ID. By default both settings are set to the device's serial number (visible on the SPA-2 housing).
3. Select the Connections used for the station. Multiple selections are possible; the default connection can be selected by ticking the circular field.
4. Depending on the connection type, enter the additional information, e.g. Address for a Bluetooth connection or IMSI number for an IP call.
5. Enter the settings for Data management.When data are downloaded from a connected SPA-2 they are stored in an archive-file by default. Each archive-file contains the data of a year or month, as selected in Archive type. Selection *None* will save all data in one file.The default location for data files is C:\Users\Public\Documents\Sommer\Data\.
6. Save the newly created station with the button Save station.

10.6 Working with measurements

10.6.1 Poll continuous measurements

1. Establish a connection to your device as described in Working with connections.
2. Download the setup of your device as described in Download setup.

3. Select the Measurement (F3) tab.
4. In the Commandssection click Start polling measurement. Now, the Commander will trigger measurements of the SPA-2 without any delays between measurements. The results are displayed Measurement values and plotted in the Measurement data graph.
5. To finish polling mode click Stop polling.



NOTE The polling mode stops automatically after 30 minutes.

10.6.2 Record measurements

1. Establish a connection to your device as described in Working with connections.
2. Download the setup of your device as described in Download setup.
3. Select the Measurement (F3) tab.
4. If the connection with your device is active, the data will now be displayed in the measurement table and updated at the interval specified in the setup. Also, the incoming data strings are displayed in the Terminal.
5. Click Save measurement data in the Commands section to save the recorded measurements. The data are saved as a *.csv file in the SommerXF format.

10.7 Working with data

10.7.1 View live data

Follow the steps below to view live data acquired from your device:

1. Establish a direct or remote connection with the SPA-2 using the Commander. Use an existing Commander-connection or -station if available.
2. In the Parameters (F2) tab download the parameters of the SPA-2.
3. Now, there are two options to view the measurement data:
    1. If OP, measurement output is set to *measured automatic*, data are displayed in the Measurement (F3) tab in the specified measurement interval.
    2. Open the Measurement (F3) tab and click Start polling measurements. With this option measurements are triggered in the fastest possible sequence and the results are displayed instantly. This measurement mode can be stopped by clicking Stop polling, or it is finished automatically after 30 minutes.

10.8 Working with setups

10.8.1 Download setup

1. Establish a connection to your device as described in Working with connections.
2. Select the Parameters (F2) tab in the Commander software.
3. In the Commands section click Download parameters from device.
   The Commander now downloads the setup currently active on the SPA-2. This may take some time if you are downloading the setup for the first time to your PC. Consecutive downloads of a setup with the same version number are usually faster.

You can now save the setup file by clicking Save parameter file, or edit the settings as described in Edit setup.

TIP Save the setup on your PC before you make any changes!

10.8.2 Open a setup file

1. Start the Commander on your PC and connect to your SPA-2 either directly with the USB to RS485 isolated converter cable or, if available, the optional Bluetooth connection.
2. Open the Parameters (F2) tab and click Open parameter file. Select the required file (extension .xmld or .xmla).
3. Verify the new settings and click Upload all parameters to device. After completion the new settings are active on your data logger.

10.8.3 Edit setup

1. Open the setup file as described in Open a setup file or download it from your device as described in Download setup.
2. Adapt the values of the settings in question and press Enter after each. After you have changed a value, its text box will turn red.

> **NOTE** If you have entered a value outside the data range of the setting, it will be forced to the next valid value! The valid range of each setting is listed in the Parameter definitions.

3. After you have adapted all required settings save the setup file and/or upload the setup to your device by clicking Upload modified parameters to device.
   Once the setup has been saved or uploaded, the modified red text boxes will turn white again, indicating that the settings have been saved/applied.

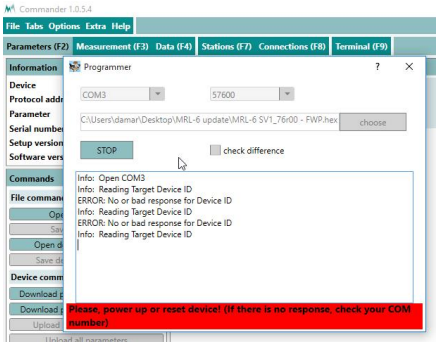
10.8.4 Upload new setup file

1. Establish a connection to your device as described in Working with connections.
2. Select the Parameters (F2) tab.
3. Download the setup currently on the SPA-2 as described in Download setup and save it by clicking Save parameter file. This step is recommended to have the latest setup available for documentation.
4. Click Open parameter file and select the required setup file (*.xlmp) on your PC.
5. Click Upload all parameters to device. This transfers the current setup to the SPA-2.
6. To verify the correct upload click Dowanload parameters from device. This will display the present setup of the SPA-2.

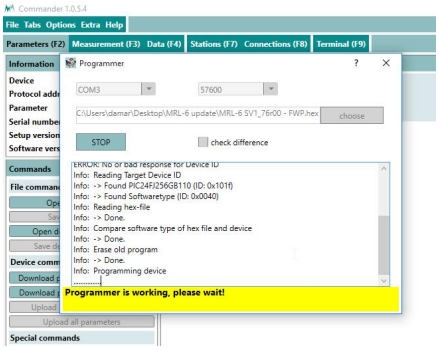
10.9 Update firmware

1. Connect the SPA-2 to your PC with the USB to RS485 isolated converter cable and make sure the device is powered.
2. Click on the menu item Extra and select Start Programmer.
3. Select the firmware file (*.hex) provided by SOMMER Messtechnik. Make sure the file is stored on your PC and not on a USB or network drive.
4. Choose the COM-port the data logger is connected to and a Baud-rate of 57'600.
5. Perform the following three steps in short sequence:
   - Click Program
   - Unpower the data logger
   - Wait 3…5 seconds
   - Repower the data logger

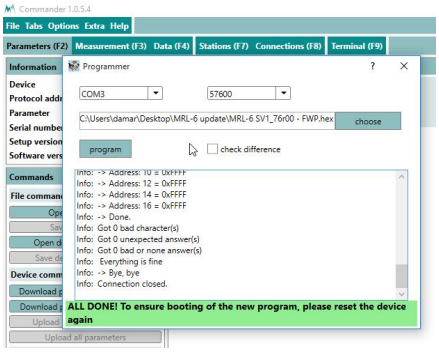
   The firmware currently present on the data logger is now erased and the new one copied to the data logger. During the update process the pop-up window may show the following messages:



The programmer is not ready; power needs to be on.



The programmer is active.



The firmware update has finished.

6. Close the programmer-window as soon as the firmware update has finished.
7. Switch off and repower the data logger again.
8. Open the Parameters (F2) tab.
9. Click Download parameters from device. The download of the new parameter list might take a few minutes. After completion the new firmware and setup versions will be displayed in the Information section.

11 Configuration of the SPA-2

11.1 Software tools

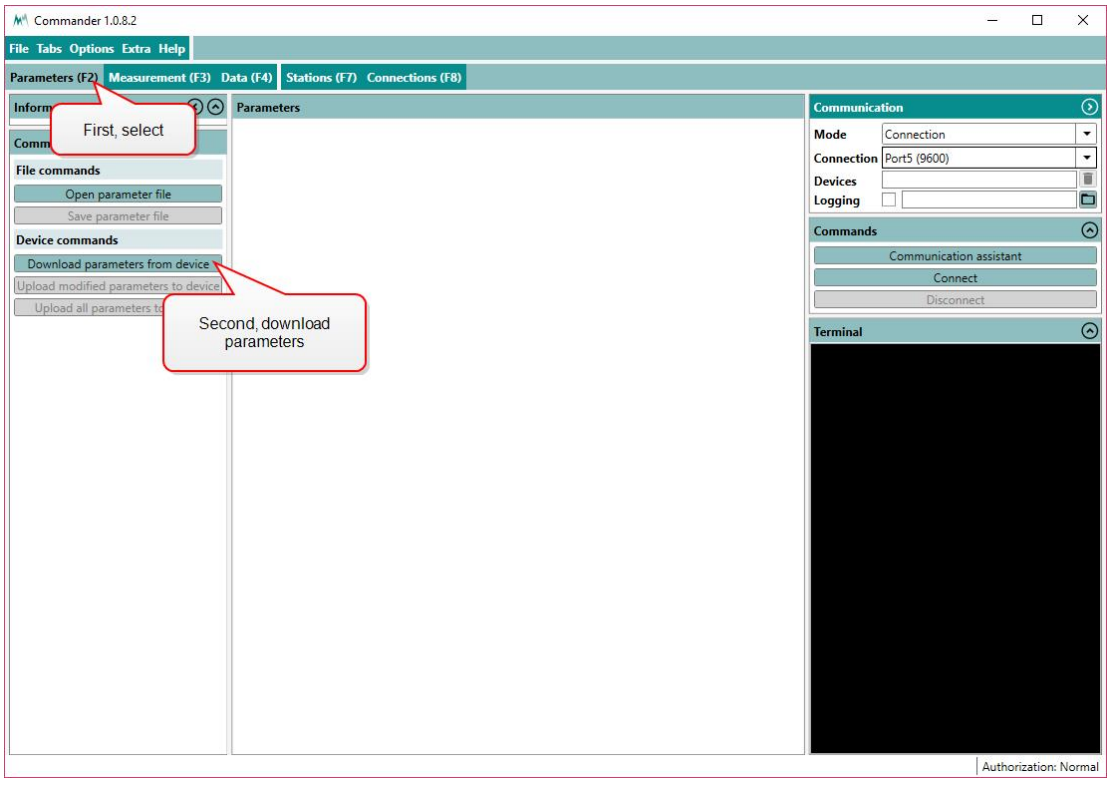
The SPA-2 can be configured with one of the following tools:

- Configuration with Commander support software
- Configuration with a terminal program

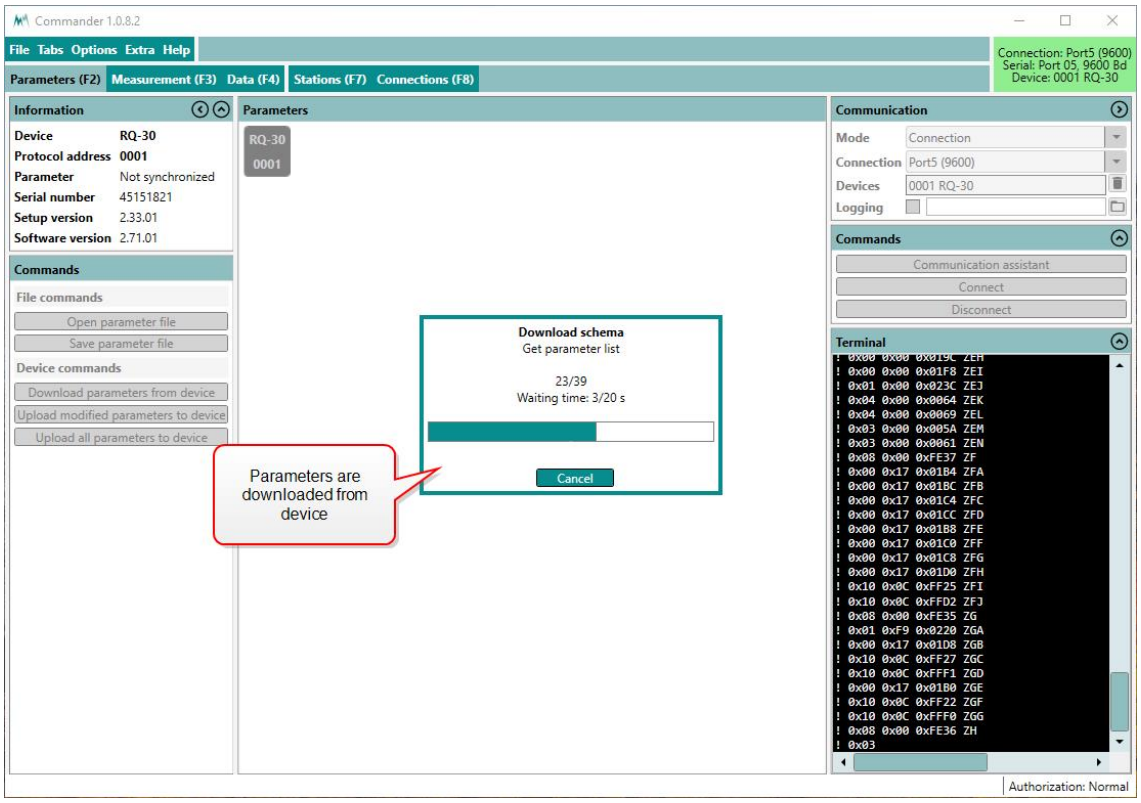
11.2 Configuration with Commander support software

Follow the steps below to modify the configuration parameters of the SPA-2:

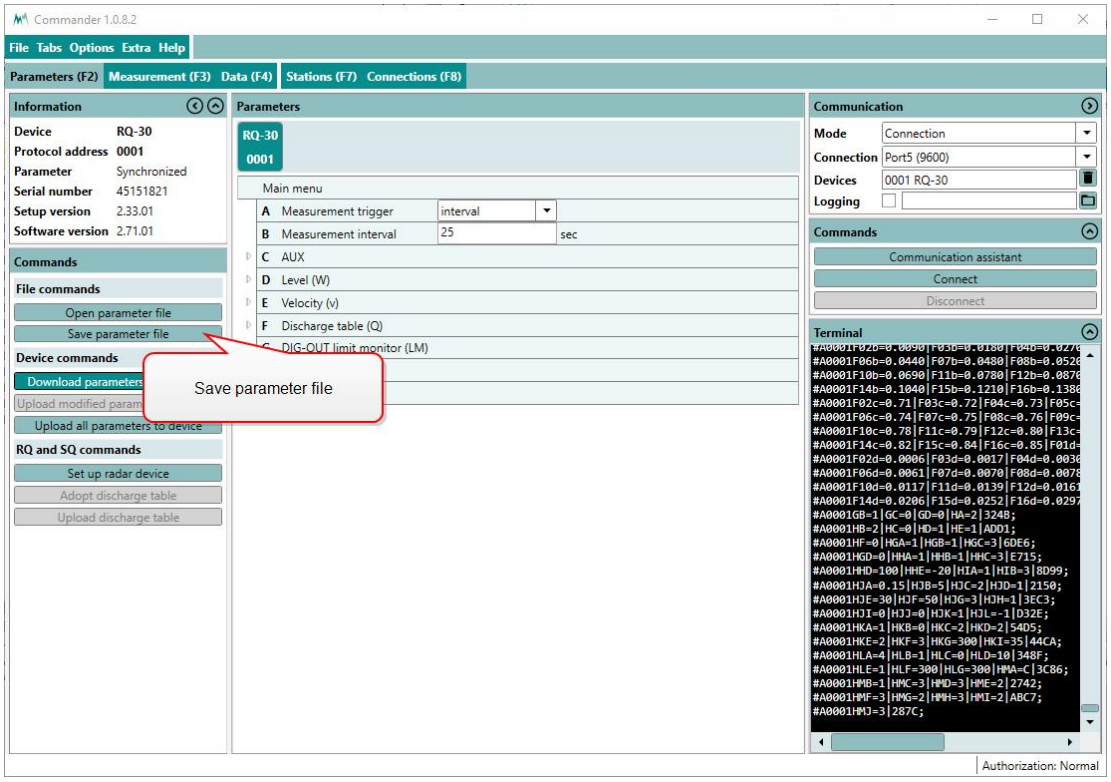
1. Establish a connection between your PC and the SPA-2 as described in Connect the SPA-2 to your PC.
2. Select the tab Parameters (F2) and click Download parameters from device. The complete parameter list is transferred from the sensor to your PC and displayed in the Parameter window.



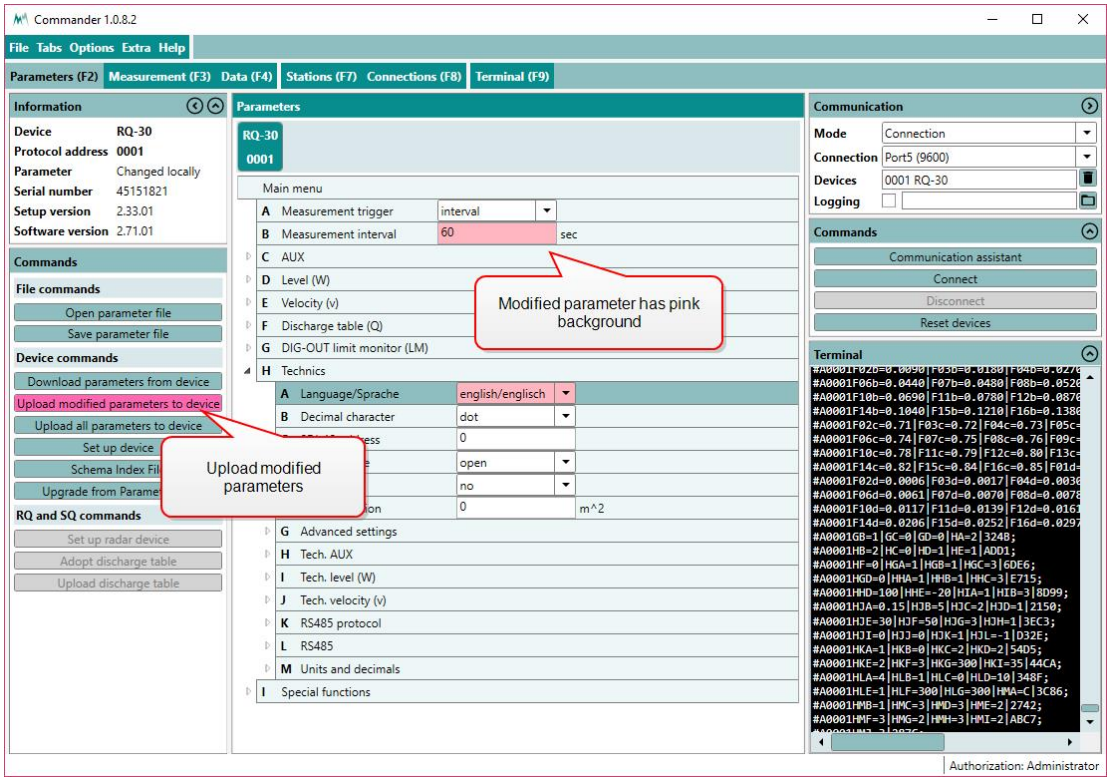
NOTE The first download of the parameter list may take a few minutes. After that the device is known to the PC and consecutive downloads are much faster.



3. Save the parameter file to your PC by clicking Save parameter file. This step is recommended to track any configuration changes.



4. Adapt the parameters required for your application. Changed values are displayed with a pink background.



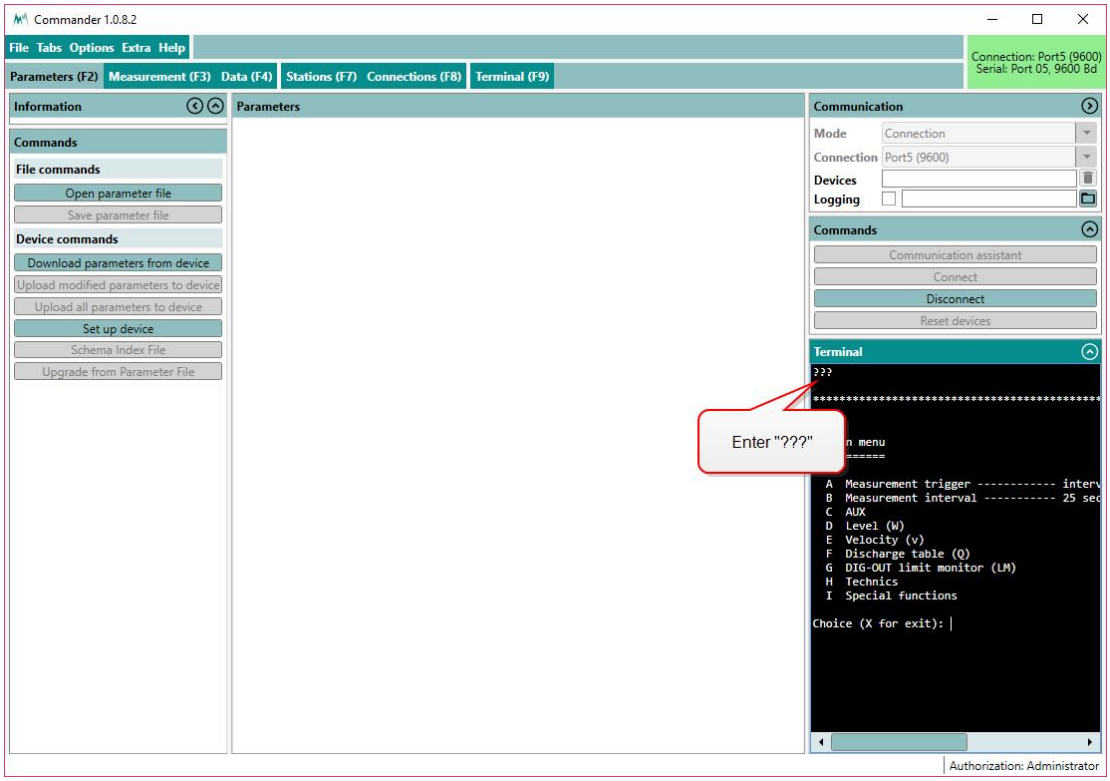
5. Send the modifications to the SPA-2 by clicking Upload modified parameters to device. Upon successful upload the pink backgrounds disappear again.

11.3 Configuration with a terminal program

The Commander software ships with an integrated terminal program. However, communication with the SPA-2 can be performed with any terminal program.

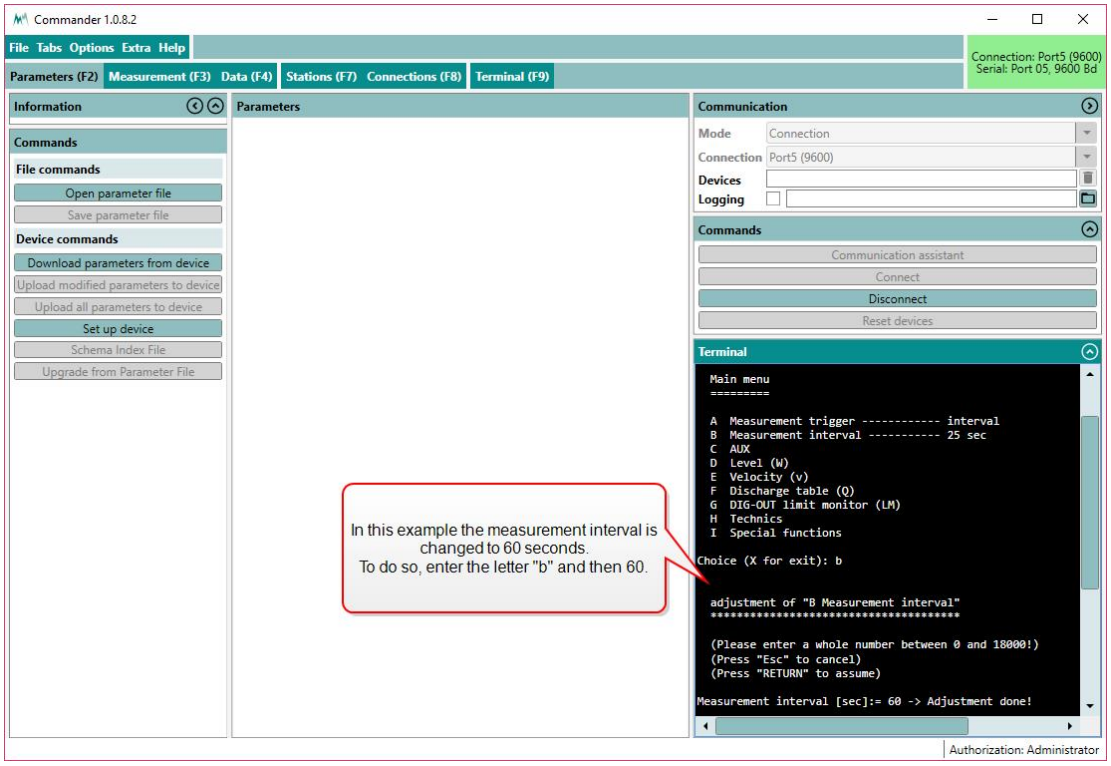
Follow the steps below to modify the configuration parameters of the SPA-2:

1. Establish a connection between your PC and the SPA-2.
2. In the terminal window enter three question marks (`???`) in quick succession. The main parameter menu is displayed in response.



NOTE As an unwanted switching into the menu mode has to be avoided the timing of the three question marks `???` is very restrictive and must never be finished with Return/Enter. This is especially important for command line tools, which may automatically send a closing "Carriage return".

3. Read or modify the required parameters: The menu items can be selected by entering the letter assigned to each item. Upon selection a submenu is opened or the selected parameter is displayed with its unit. Changes to values are confirmed with Return/Enter or discarded with Esc. Menus are closed with X. After closing the main menu with X the sensor performs an initialization.



11.4 General settings

When first setting-up a SPA-2 at a measurement site, the parameters described below may need to be adapted.

11.4.1 Measurement trigger

Measurements are initiated by one of the options listed in the table below.

The commands to trigger measurements via RS-485 and SDI-12 are described in Communication.

Measured data are either returned directly after the measurement or can be requested by commands via the RS-485 or SDI-12 interface. The format of the returned data can be configured in the sub-menu Output protocol (OP).

ID	Option	Description
1	Interval (default)	Measurements are initiated in a specified interval.
2	TRIG input	Measurements are triggered by the positive edge of a DC-voltage signal applied to the TRIG input (low: 0 ... 0.6 V, high: 2.2 ... 28 V, pulse duration must be ≥500 ms, delay between pulses must be ≥500 ms)
3	SDI-12/RS-485	Measurements are externally triggered by commands via RS-485 or SDI-12 from ,e.g. a data logger.
4	all allowed	Measurement is triggered by all options mentioned above.

An internal measurement interval can be set for the SPA-2. If selected in menu item Measurement trigger, measurements are performed in the defined interval. However, a measurement is always completed before a new one is initiated.

11.4.2 Language/Sprache

The menu language.

11.4.3 Decimal character

The character used as decimal separator in the values of the settings and in serial data strings.

11.4.4 Units and decimals

The units and number of decimal digits. These have to be set prior to all other settings as all values are saved internally in this format. They are set in the parameter menu Units and decimals.

ATTENTION If units or decimals are changed, related parameters may need to be adjusted.

11.4.5 Output protocol (OP)

The type of the serial output protocol. The following options are available:

ID	Option	Description
1	Sommer (default)	Sommer protocol; data values are returned with an index starting at 1
2	Standard	Standard protocol; data values are returned without an index
3	MODBUS	Modbus protocol

11.4.6 OP, information

The main measurement values are always included in the data output string. Additionally, special and analysis values can be included.

ID	Option	Description
1	main values	Only the main values are returned.
2	& special values (default)	Main values and special values are returned.
3	& analysis values	Main, special and analysis values are returned.

11.5 USH-9 serial communication

Generally, the USH-9 snow depth sensor of the SPA-2 is shipped pre-configured. In case the SPA-2 or the USH-9 need to be rewired, their setups need to have the following settings:

11.5.1 USH-9

Index	Setting	Value
A	Measurement trigger	*SDI-12/RS485*
C-F	Moving filter, duration	*1800 s*
D-F-A	Output status	*off*
D-I-D	OP, measurement output	*after measurement*

11.5.2 SPA-2

Index	Setting	Value
D	Measurement, table	Set data line 51 to the values shown in the screenshot below.
G-H-E	Flow control	*XOFF-XON blocking*
G-H-H	Trigger polling	*on*
G-H-I	Trigger, timeout	*60s*
G-H-K	Network scan extension	*on*

12 Communication

12.1 Communication protocols

The SPA-2 provides the following communication protocols:

- RS-485
- Modbus
- SDI-12

12.2 Data output

The SPA-2 includes a RS-485 and a SDI-12 interface for communication and data output. The measurement values returned by one of these ports are arranged in a fixed sequence and are identified by the index in Measurement table. By default the following variables are recorded by the SPA-2:

12.2.1 Output values

Index	Variable	Unit	Description
01	snow depth	mm	Snow depth measured by SPA-2
02	ice content S1	%	Ice content of SPA-sensor 1
03	water content S1	%	Water content of SPA-sensor 1
04	density S1	kg/m^3	Density of SPA-sensor 1
05	SWE S1	mm	Snow water equivalent of SPA-sensor 1
06	ice content S2	%	Ice content of SPA-sensor 2
07	water content S2	%	Water content of SPA-sensor 2
08	density S2	kg/m^3	Density of SPA-sensor 2
09	SWE S2	mm	Snow water equivalent of SPA-sensor 2
10	ice content S3	%	Ice content of SPA-sensor 3
11	water content S3	%	Water content of SPA-sensor 3

Index	Variable	Unit	Description
12	density S3	kg/m^3	Density of SPA-sensor 3
13	SWE S3	mm	Snow water equivalent of SPA-sensor 3
14	ice content S4	%	Ice content of SPA-sensor 4
15	water content S4	%	Water content of SPA-sensor 4
16	density S4	kg/m^3	Density of SPA-sensor 4
17	SWE S4	mm	Snow water equivalent of SPA-sensor 4
18	Analog 2		Variable acquired by analog input 2
19	Analog 3		Variable acquired by analog input 3
20	Analog 4		Variable acquired by analog input 4
21	C_LF S1	pF	Capacity of SPA-sensor 1 at low frequency
22	C_HF S1	pF	Capacity of SPA-sensor 1 at high frequency
23	C_LF S2	pF	Capacity of SPA-sensor 2 at low frequency
24	C_HF S2	pF	Capacity of SPA-sensor 2 at high frequency
25	C_LF S3	pF	Capacity of SPA-sensor 3 at low frequency
26	C_HF S3	pF	Capacity of SPA-sensor 3 at high frequency
27	C_LF S4	pF	Capacity of SPA-sensor 4 at low frequency
28	C_HF S4	pF	Capacity of SPA-sensor 4 at high frequency

Measurement table

Table 3 Output values

12.2.2 Exception values

Measurement data may be returned with the following exception values:

Value	Description
9999.998	Initial value: No measurement has been performed yet (position of decimal character is irrelevant).
9999.997	Conversion error: Caused by a technical problem (position of decimal character is irrelevant)
9999999	Positive overflow
-9999999	Negative overflow

Table 4 Exception values

12.3 RS-485

12.3.1 What is RS-485?

RS-485 is a serial communication method for computers and devices. It is currently a widely used communication interface in data acquisition and control applications where multiple nodes communicate with each other.[1]

12.3.2 What can I do with it?

RS-485 communication is primarily used to trigger measurements and read their results. It also permits to change parameters of the SPA-2.

12.3.3 Configuration

The SPA-2 has serial RS-485 communication enabled by default. If the device is integrated into a RS-485 network or connected to a stand-alone data acquisition system, e.g. a data logger, the parameters listed in RS-485-1 Protocol may need to be adapted.

System key and device number

The system key and device number are used to identify a SPA-2 in a bus system. This is essential if multiple devices (SPA-2 and data loggers) are operated within the same system.

[1]https://www.lammertbies.nl/comm/info/RS-485.html

System key

The system key separates different conceptual bus systems. This may be necessary if the remote radio coverage of two measurement systems overlap. In general, the system key should be set to *00*.

Device number

The device number is a unique number that identifies a device in a bus system.

OP, measurement output

The serial data output can be triggered in the following ways:

ID	Option	Description
1	just per command	The output is only requested by commands via the RS-485 or SDI-12 interface.
2	measured values push	Data are returned automatically after each measurement.

NOTE If OP, measurement output is set to *pos. TRIG slope*, the data are returned with a delay of 200 ms after the trigger has been set. Make sure that your data acquisition system takes account of this lag to ensure that it receives the most recent data.

Operation modes

The selected combination of measurement trigger and output time determines the following operation modes:

	Mode		
Parameter	**Pushing**	**Polling**	**Apparent polling**
Measurement trigger	internal	TRIG input SDI-12/RS485	TRIG input SDI-12/RS485
OP, measurement output	after measurement	just per command	after measurement

Waking-up a connected data logger

The SPA-2 supports wake-up of a connected data logger that is in standby mode. Generally, this feature is only used in pushing mode and can be set under OP, wake-up sequence.

Sync sequence

The sync sequence is the string `UU~?~?` and is sent directly before a command. It is used to synchronize the receiving UART.

Prefix

The prefix is an arbitrary character; the SPA-2 uses a blank. This character is sent prior to any communication. Then the time of the OP, prefix holdback is waited and the command is sent afterwards. With this procedure the receiving device has time to wake-up.

Output protocols

For data output via RS-485 different protocols are available, which can be selected under Output protocol (OP).

12.3.4 Data output options

Data are returned in two different formats, selectable in Output protocol (OP):

- Sommer protocol
- Standard protocol

12.3.5 Sommer protocol

The data string of the Sommer protocol has the following format:

EXAMPLE `#M0001G01se01 1461|02 1539|03 25.25|04 0|3883;`

Header

The header (`#M0001G00se`) identifies the data by system key, device number and string number.

Parameter	Format	Description
Start character	#	
Identifier	M	M identifies an output string
System key	dd	
Device number	dd	
Command ID	G	G defines an output string with string number
String number	dd	01 Output values
Command	se	se identifies automatically sent values

Table 5 Header of the Sommer protocol

Measurement value

A measurement value (02 1539|) has a length of 8 digits and is returned together with its index. If the measurement value is a decimal number, one digit is reserved for the decimal character. Values are returned right-aligned, so blanks may occur between index and value.

Parameter	Format	Description
Index	dd	2 numbers
Value	xxxxxxxx	8 character right-aligned
Separator	|	

Table 6 Values in Sommer protocol

End sequence

The data string is terminated with a CRC-16 in hex format (3883) followed by an end character and <CR><LF>. The CRC-16 is described in Sommer CRC-16.

Parameter	Format	Description
CRC-16	Hhhh	4-digit hex number
End character	;	
Control characters	<CR><LF>	Carriage return and Line feed

Table 7 End sequence of the Sommer protocol

Example Sommer protocol

Output values

The acquired data are returned as in the following example:

EXAMPLE

```
#M0001G00se01     0.3|02     1.2|03       1|04
3|05     0.5|06     1.3|07       0|08       0|3762;

#M0001G01se09     0.5|10     1.2|11       0|12
0|13     0.0|14     0.0|15       0|16       0|5E2A;

#M0001G02se17     480|18  0.0735|19  0.0705|20
0.0764|21   58.45|22   58.22|23    0.00|24
0.00|944D;

#M0001G03se25    92.3|26    90.8|27    0.00|28
0.00|8536;
```

#M0001G00se	Header with system key 00, device number 01 and string number 00
01 0.3|	Ice content of SPA-sensor 1
02 1.2|	Water content of SPA-sensor 1
…	
3762;	Closing sequence
#M0001G01se	Header with system key 00, device number 01 and string number 01

09 0.5|	Ice content of SPA-sensor 3
10 1.2|	Water content of SPA-sensor 3
…	
5E2A;	Closing sequence
#M0001G02se	Header with system key 00, device number 01 and string number 02
17 480|	Snow depth measured by SPA-2
18 0.0735|	Variable acquired by analog input 2
…	
944D;	Closing sequence
#M0001G03se	Header with system key 00, device number 01 and string number 03
25 92.3|	Capacity of SPA-sensor 3 at low frequency
26 90.8|	Capacity of SPA-sensor 3 at high frequency
…	
8536;	Closing sequence

Measurement values returned by Sommer protocol

Table 8 Output values in Sommer protocol

12.3.6 Standard protocol

The data string of the Standard protocol has the following format:

EXAMPLE `M_0001 1461 1359 25.38 0`

Header

The header (`M_0001`) identifies the data by system key and device number.

Parameter	Format	Description
Identifier	X_	M_ Measurement values
System key	Dd	
Device number	Dd	

Table 9 Header of the Standard protocol

Measurement values

Measurement values are returned in sequence and are separated by a blank. A measurement value has a length of 8 digits. If the measurement value is a decimal number, one digit is reserved for the decimal character. Values are returned right-aligned, so additional blanks may be returned between values.

Parameter	Format	Description
Separator	[blank]	blank
Value	xxxxxxxx	8 character right-aligned

Table 10 Values in Standard protocol

End sequence

The data string is terminated with <CR><LF>.

Example Standard protocol

Output values

The acquired data are returned as in the following example:

EXAMPLE

```
M00_0001      0.3      1.2        1        3      0.0
 0.0        0        0
```

```
M01_0001      0.5      1.2        0        0      0.0
 0.0        0        0

M02_0001      480   0.0735   0.0711   0.0771    58.45
 58.21     0.00     0.00

M03_0001     92.3     90.8     0.00     0.00
```

M00_0001	Header with identifier for measurement values
0.3	Ice content of SPA-sensor 1
1.2	Water content of SPA-sensor 1
…	
M01_0001	Header with identifier for measurement values
0.5	Ice content of SPA-sensor 3
1.2	Water content of SPA-sensor 3
…	
M02_0001	Header with identifier for measurement values
480	Snow depth measured by SPA-2
0.0735	Variable acquired by analog input 2
…	
M03_0001	Header with identifier for measurement values
92.3	Capacity of SPA-sensor 3 at low frequency
90.8	Capacity of SPA-sensor 3 at high frequency
…	

Measurement values returned by Standard protocol

Table 11 Output values in Standard protocol

12.3.7 Sommer old protocol

The data string of the Sommer old protocol has the following format:

EXAMPLE `#M0001G00se00 -17.4|01 0.535|02 0.000|03 -1.89|04 0.0|05 0|B11D;`

This protocol is identical with the Sommer protocol except that the index of the measurement values starts at 0 instead of 1.

This protocol has been implemented for compatibility reasons: When a Sommer device with firmware < 2.0 is updated to version 2.x the protocol is automatically set to Sommer old. Thus, the setup of a connected data logger does not have to be adjusted.

12.3.8 RS-485 commands

Command structure

The structure of serial commands and answers (`#W0001$mt|BE85;`) is described in the following table:

Parameter	Format	Description
Start character	#	
Identifier	X	W SPA-2 returns a confirmation on receipt. This command type demands a closing sequence with a valid CRC-16. S SPA-2 does not acknowledge the receipt of the command. This command type demands no closing sequence and therefore no CRC-16. R SPA-2 returns the requested measurement value or parameter. This command type demands a closing sequence with a valid CRC-16. T Write a volatile setting and receive a confirmation A Answer of device to read or write command
System key	dd	
Device number	dd	
Command	xxx	See RS-485 commands

Parameter	Format	Description
Separator	|	
CRC-16	hhhh	4-digit hex number
End character	;	

Table 12 Structure of Sommer bus commands and answers

Commands

The following commands can be used with the SPA-2:

Command	Description
$mt	Trigger a measurement
$pt	Return measurement values
XX	Read a parameter with identifier XX
XX=xxxx	Write a parameter with identifier XX and the value xxx

Table 13 List of Sommer bus commands

Trigger a measurement

The command $mt triggers a complete measurement sequence as in the following example:

EXAMPLE #W0001$mt|BE85; Answer: #A0001ok$mt|4FA9;

Read a parameter value

Read measurement interval (in the example below the menu item B):

EXAMPLE #R0001B|228E; Answer: #A0001B=300|F8B3;

Request a complete data string

The command `$pt` requests a data string as in the following example:

EXAMPLE `#S0001$pt|` Answer: none

The data string is returned as soon as the SPA-2 has processed the command.

Request a single measurement value

The reading command `R` together with the index of the requested measurement returns a single measurement value. In the following example the measurement value with index `01` (in this example a water level) is requested:

EXAMPLE

`#R0001_010cv|EA62;`

Answer: `#A0001ok_010cv1461 |07EB;`

12.3.9 Sommer CRC-16

The CRC-16 (cyclic redundancy check) used in data transmission of Sommer devices is based on the ZMODEM protocol. When data are exchanged between two devices the receiving device calculates the CRC-value. This value is compared to the CRC value sent by the other device to check if the data were transmitted correctly. Please refer to technical literature or contact Sommer for calculation of CRC-16 values.

You can here calculate the CRC of a command online .

If you need to compute CRCs automatically, you can implement the following script in your data logger or controller software:

Computation CRC-16 in C/C++

```
1  crc16 = crc16tab[(unsigned char)(crc16>>8)] ^ (crc16<<8) ^ (unsigned int)(c);
```

The `crc16tab` array is listed in CRC-16 array.

12.4 SDI-12

12.4.1 What is SDI-12?

SDI-12 (Serial Data Interface at 1200 Baud) is a serial data communication standard for interfacing multiple sensors with a single data recorder. For a detailed description on SDI-12 communication please refer to www.sdi-12.org.

12.4.2 What can I do with it?

The SPA-2 listens to standard SDI-12 commands as listed in the SDI-12 specifications of version 1.3, e.g., to trigger a measurement or retrieve measurement results. Additionally, a set of extended SDI-12 commands is implemented in all SOMMER sensors for instrument configuration.

12.4.3 Configuration

The SPA-2 has SDI-12 communication enabled by default. When setting up a SDI-12 network take the following considerations into account:

- Each device in the SDI-12 network must have a unique address, e.g. data logger address *0*, SPA-2 address *1*.
- If the SPA-2 operates in polling mode (Measurement trigger set to *SDI-12/RS-485*), measurements are triggered by `M!` commands and data are retrieved by `D!` commands.
- If the SPA-2 operates in pushing mode (Measurement trigger set to *interval*), data are retrieved by the `R!` commands.
- When multiple sensors are connected to the same network, data acquisition should be done in sequence, i.e., data should have been received from the first sensor before triggering the measurement of the second sensor.
- Most data loggers control the timing of messages (marking and spacing) automatically. If this is not the case, please refer to www.sdi-12.org.

12.4.4 Data structure

The answer from the SDI-12 device is a string containing the sensor address, the requested data and a terminating carriage return/line feed.

In a string containing measurement data, the measurements are returned in the same order as listed by the index in Data output.

EXAMPLE

0+2591+706+25.53+62<CR><LF>

Value	Content
0	Sensor address
2591	Measurement with index 01
706	Measurement with index 02
25.53	Measurement with index 03
62	Measurement with index 04

If a device returns more than 9 measurement values, or if the values are returned in groups (see also Request results) the measurement index increments in the next group.

EXAMPLE

0D0! Answer: 0+2591+706+25.53+62<CR><LF>

0D0! Answer: 0+56.2+125+12.32<CR><LF>

Value	Content
0	Sensor address
2591	Measurement with index 01
706	Measurement with index 02
25.53	Measurement with index 03
62	Measurement with index 04
0	Sensor address
56.2	Measurement with index 05
125	Measurement with index 06
12.32	Measurement with index 07

12.4.5 SDI-12 commands

The following tasks can be performed with standard and extended SDI-12 commands.

Extended SDI-12 commands are non-standard commands implemented by SOMMER to enable device configuration via SDI-12.

NOTE After any changes, the settings have to be adopted with the command `aXW_ts|!`, with `a` the sensor address.

Command structure

A standard SDI-12 command starts with the sensor address and ends with an exclamation mark, e.g., `0M!` to trigger a measurement.

Configuration commands contain additional information; see the sections below for details.

Identify device

The identification of a SDI-12 device is requested with the command `aI!`, with `a` the sensor address.

EXAMPLE

`0I!` Answer `013Sommer  USH   140r90 USH-9    <CR><LF>`

The answer contains the following information:

`0`	SDI-12 address
`1`	SDI-12 version prior to the point
`3`	SDI-12 version after the point
`Sommer`	Description of the company (6 characters and 2 blanks)
`USH`	Description of the firmware (5 characters and 2 blanks)
`140r90`	Firmware version (6 characters and 2 blanks)
`SPA-2`	Device designation (max. 13 characters)

Acquire measurements

To acquire a measurement from a sensor, two individual SDI-12 commands – trigger a measurement and request measurement values – need to be sent.

EXAMPLE

`0M!` Answer: `00084<CR><LF>` and `0<CR><LF>` after 8 seconds

0D0! Answer: 0+2591+706+25.53+0<CR><LF>

The first values in the response to the aDn! command is the sensor address.

Trigger measurement

The command aM! with sensor address a triggers a measurement as in the example below.

The response states the measurement duration and the number of measurement values (see example below). After completion of the measurement, the device will return an additional a<CR><LF>, with a the sensor address.

EXAMPLE

0M! Answer: 00084<CR><LF> and 0<CR><LF> after 8 seconds

The answer contains the following information:

0 SDI-12 address

008 Duration of the measurement in seconds

4 Number of measurement values

Request results

After each measurement, results are requested with the command aDn!, with a the sensor address and n the index of the returned data string.

EXAMPLE 0D0! Answer: 0+2591+706+25.53+0<CR><LF>

The leading 0 of the response is the sensor address.

Generally, the command aD0! is sufficient to request up to 9 measurement values. If more than 9 values need to be read, or if the values are returned in groups, the commands aD1!, aD2!,… may need to be issued after aD0!. For example, if a measurement returns 8 values in two groups of 4, the commands aD0! and aD1! need to be issued to receive all values.

Acquire continuous measurements

If the SDI-12 device is operating in continuous measurement mode (not polled by SDI-12), the command aR0! will request and return the current reading of the sensor. The values within the data

string follow the order listed in the measurement table. The first values in the response to the aRn! command is the sensor address.

EXAMPLE

0R0! Answer: 0+2591+706+25.53+0<CR><LF>

If more than 9 values need to be read, or if the values are returned in groups, the commands aR1!, aR2!,… may need to be issued after aR0!. For example, if a measurement returns 8 values in two groups of 4, the commands aR0! and aR1! need to be issued to receive all values.

Configure parameter

The configuration parameters of a SOMMER sensor are read with the command aXRpp! and written with the command aXWpp=vvv!, with a the sensor address, pp the parameter identifier and vvv the value of the parameter.

Read and write a parameter

EXAMPLE

Reading of measurement interval (in this example menu item B)

0XRB|! Answer: 0B=300|<CR><LF>

Setting of measurement interval to 60 s (in this example menu item B)

0XWB=60|! Answer: 0B=60|<CR><LF>

Read and write a selector-parameter

Changing the measurement trigger (in the following example menu item A) from *interval* to *SDI-12/RS485*:

EXAMPLE

0XRA|! Answer: 0A=1|<CR><LF>

0XWA=3|! Answer: 0A=3|<CR><LF>

Read and write a parameters of a table

Some SOMMER sensors are equipped with multiple transducers and their settings are listed in a table (see example below). A value within such a table is addressed by its row-index (01, 02 …) and column-index (A, B …). A corresponding SDI-command has the following format:

EXAMPLE

In this example of a snow scale the value in row 01 and column B of the parameter D-D-E is changed to -1.4.

`0XWDDE01B=-1.4|!` Answer: `0DDE01b=-1.4|<CR><LF>`

	Identifier	offset zero kg	gain	zero default kg	gain default
01	Load Cell 1	-1.4	0,997787	0,000	0,997787
02	Load Cell 2	0,000	0,997787	0,000	0,997787
03	Load Cell 3	0,000	0,997787	0,000	0,997787
04	Load Cell 4	0,000	0,997787	0,000	0,997787

Adopt settings

Some settings need to be adopted with the command `aXW_ts|!`, with `a` the sensor address. It is recommended to issue `aXW_ts|!` after each configuration change.

12.5 Modbus

12.5.1 What is Modbus?

Modbus is a serial communication protocol used for transmitting information over serial lines between electronic devices. The device requesting the information is called the Modbus Master and the devices supplying information are Modbus Slaves. In a standard Modbus network, there is one Master and up to 247 Slaves, each with a unique Slave Address from 1 to 247. The Master can also write information to Slaves.

Modbus has become a standard communication protocol in industry, and is now the most commonly available means of connecting industrial electronic devices. It is often used to connect a supervisory computer with a remote terminal unit (RTU) in supervisory control and data acquisition (SCADA)

systems. Versions of the Modbus protocol exist for serial lines (Modbus RTU and Modbus ASCII) and for Ethernet (Modbus TCP).[1]

12.5.2 What can I do with it?

Modbus-communication with SPA-2 allows reading of measurement values and device information by a Modbus master. Additionally, the basic RS-485 port settings can be written to the SPA-2.

12.5.3 Wiring

For Modbus communication the SPA-2 is wired according to the table below.

Modbus	Connector MAIN	Connection wire	Description
Common	Pin 1	White	GND
D1 - B/B	Pin 4	Yellow	RS-485 A
D0 - A/A	Pin 5	Grey	RS-485 B

Table 14 Modbus wiring

NOTE
Please note that different signal notations are in use for RS-485 connections:

TX+/RX+ or D+ or D1 as alternative for B

TX−/RX− or D− or D0 as alternative for A

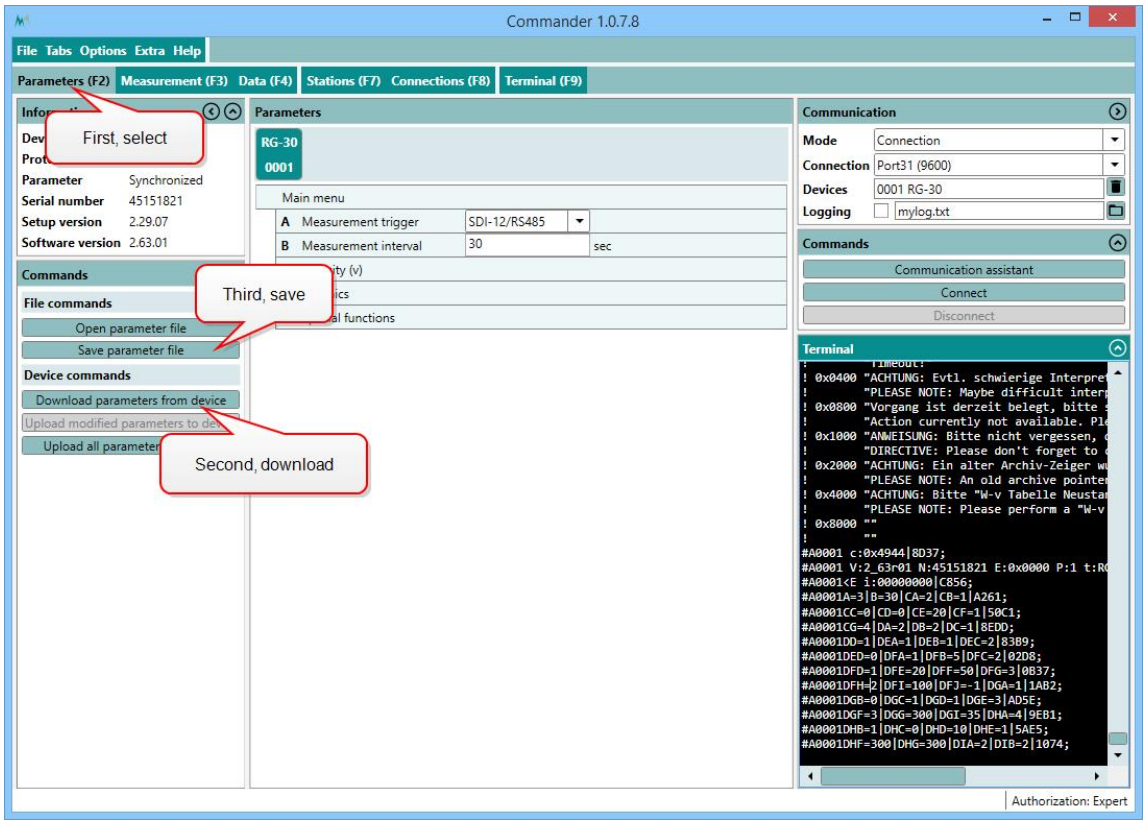
NOTE If the SPA-2 is operated with multiple Modbus devices within the same network, termination resistors may be required. Please contact Sommer Messtechnik for details.

12.5.4 Configuration

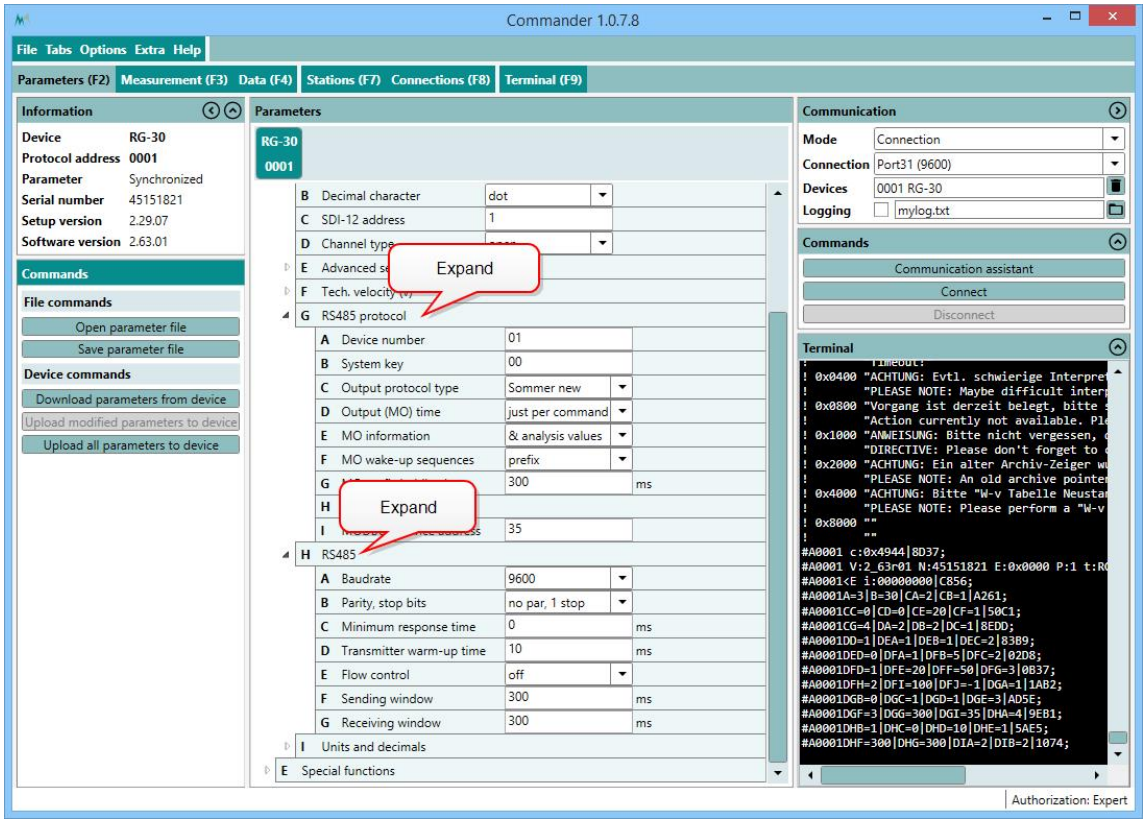
Follow the instructions below to change the communication of a Sommer-device (in this example a RG-30) to Modbus:

[1]http://www.simplymodbus.ca/FAQ.htm

1. Connect the USB to RS-485 converter to the data cable of the Sommer-device and a USB port on your PC.
2. Connect the sensor to a power supply with the specified rating.
3. Start the Commander software on your PC.
4. Establish a connection to the Sommer-device.
5. Download the sensor's parameters in the Parameters (F2) tab and save the parameter list on your PC.



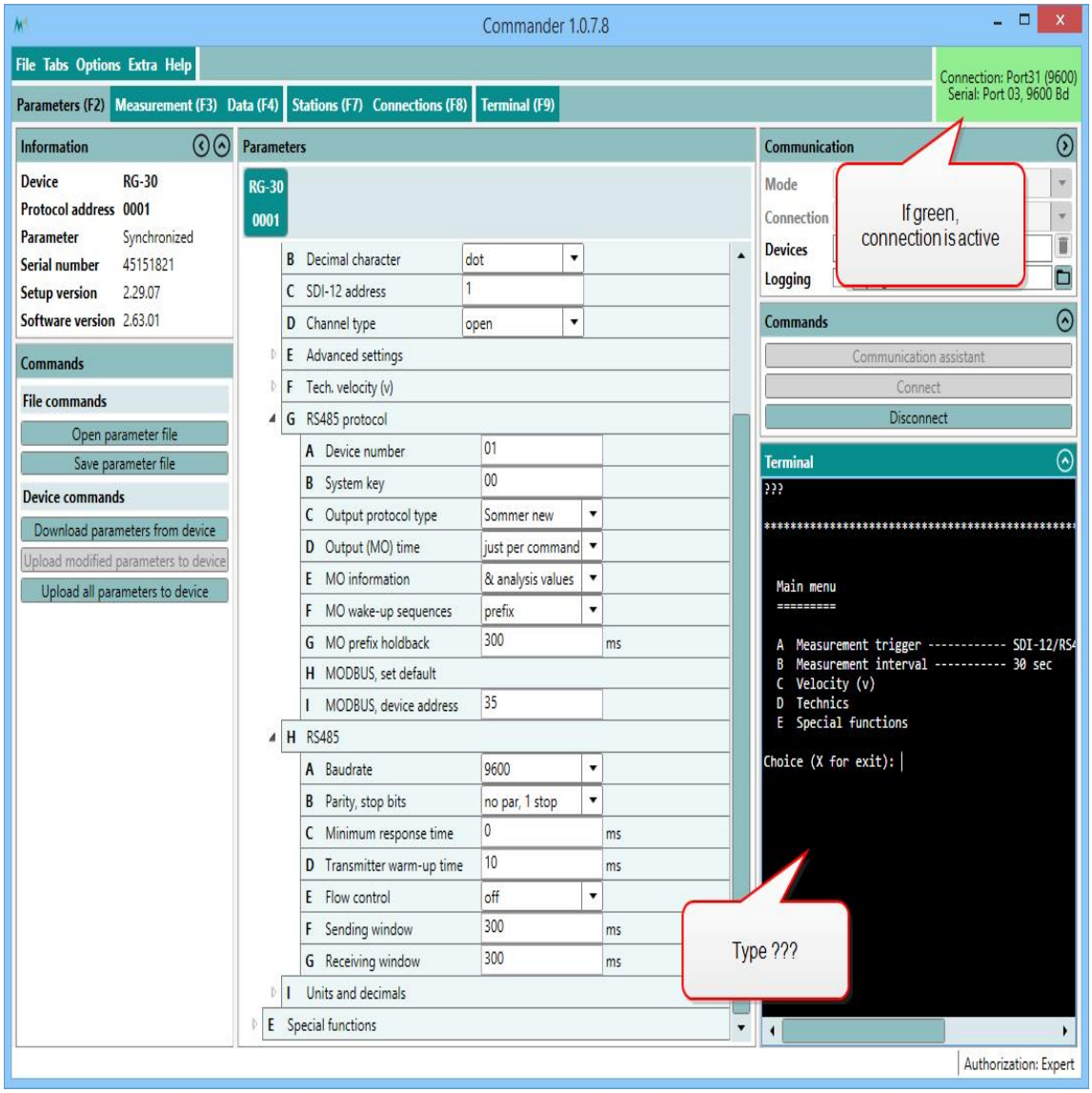
6. In the parameter list navigate to Technics and open the menus RS-485 protocol and RS485 and take a screenshot of the associated parameters. This and the previous step are helpful if you need to switch back to the standard communication mode at a later time.



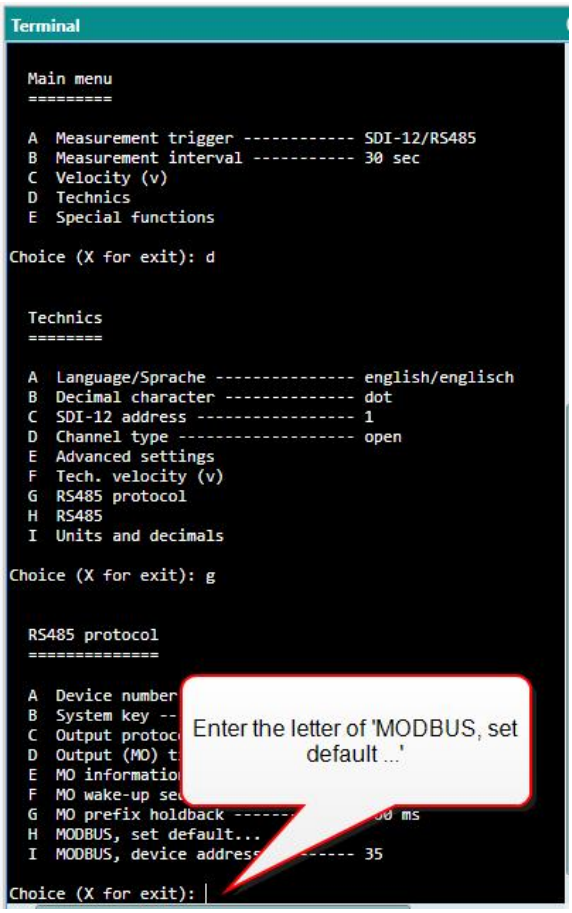
7. Set Measurement trigger to one of the following options:
   A. *Interval*, if measurements are triggered internally by the device.
   B. *SDI-12/RS-485*, if measurements are triggered by SDI-12.
   C. *TRIG input*, if measurements are triggered by a trigger input.
   D. *all allowed*, if measurements are triggered by one of the previous options.

> **NOTE** Modbus cannot trigger measurements! Make sure to use the trigger option suitable for your application!

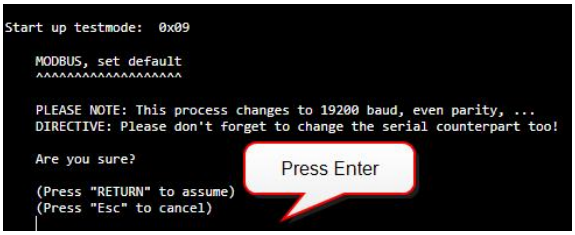
8. Verify that the connection to the Sommer-device is active and click into the Terminal window. Type ??? to enter the sensor-menu.



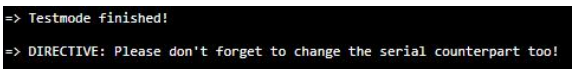
9. Navigate to *RS485 protocol* and select *MODBUS, set default…* Please note, that the index-letters might be different for your Sommer-device!



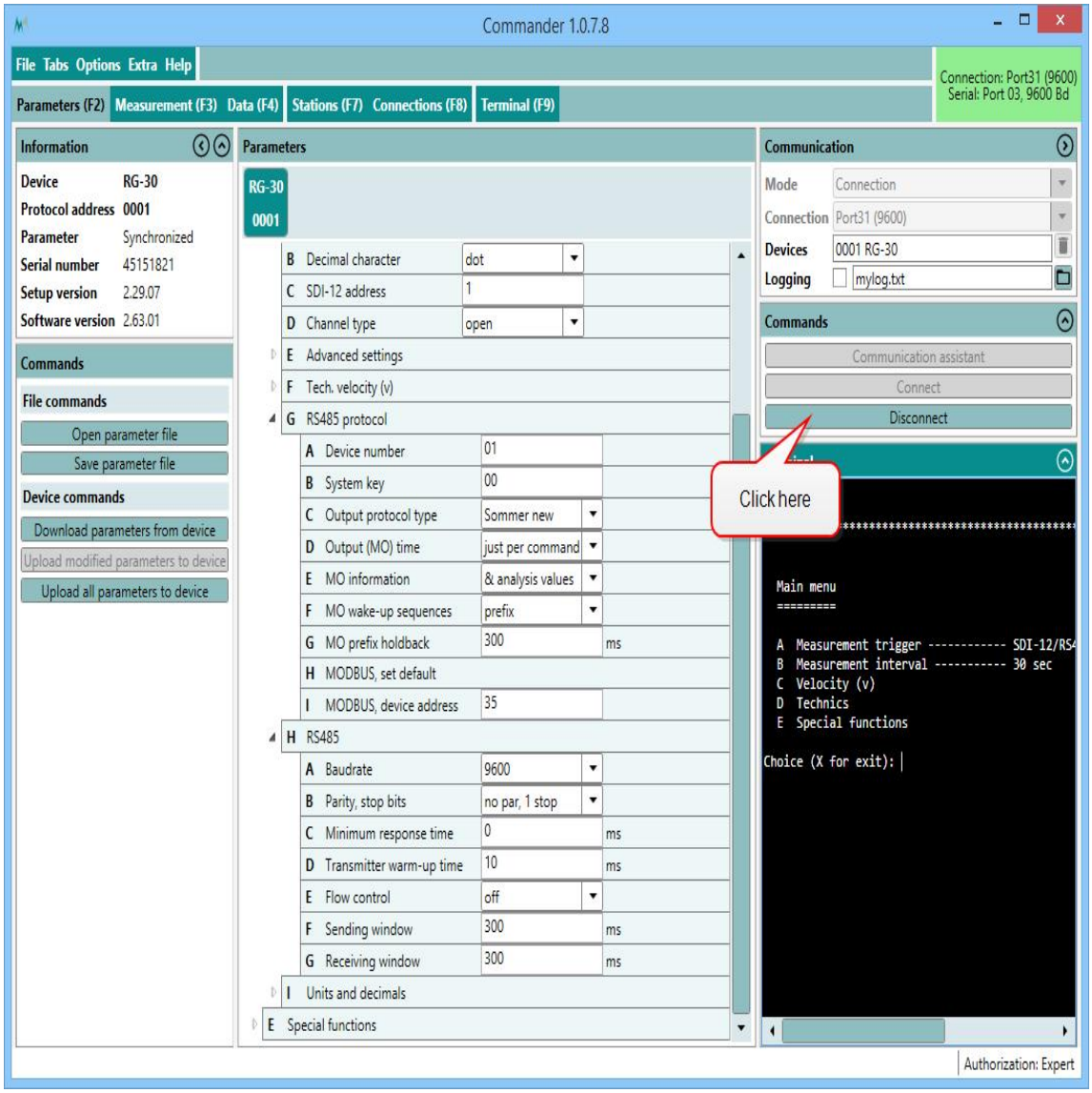
10. Acknowledge the safety-note.



11. After completion the following message will be displayed:



12. Enter X until you get back to the main menu. The Sommer-device is now restarted and available for Modbus-communication. As the connection-parameters have been changed to Modbus, the connection to the sensor is lost. Press Disconnect for completion.



NOTE

By switching communication to Modbus with MODBUS, set default the following parameters are changed:

Parameter	Modbus setting
OP, measurement output	just per command
Output protocol (OP)	Modbus
MODBUS, device address	35
Sleep mode	Modbus, slow
Parity, stop bits	even par, 1 stop
Baud rate	19200
Flow control	off

Parameter	Modbus setting
Transmitter warm-up time	10 ms
Minimum response time	30 ms

12.5.5 Modbus commands and registers

Read input registers

Input registers contain measurement values. The content of these registers is updated after each measurement.

	Index	Register address	Variable	Unit / value	Bytes	Format
Test value		0	Hardcoded test value	2.7519...	4	float

	Index	Register address	Variable	Unit / value	Bytes	Format
Main values	01	2	snow depth	mm	4	float

	Index	Register address	Variable	Unit / value	Bytes	Format
	02	4	ice content S1	%		

	Index	Register address	Variable	Unit / value	Bytes	Format
	03	6	water content S1	%		

	Index	Register address	Variable	Unit / value	Bytes	Format
	04	8	density S1	kg/m^3		

	Index	Register address	Variable	Unit / value	Bytes	Format
	05	10	SWE S1	mm		
	06	12	ice content S2	%		
	07	14	water content S2	%		
	08	16	density S2	kg/m^3		
	09	18	SWE S2	mm		
	10	20	ice content S3	%		
	11	22	water content S3	%		
	12	24	density S3	kg/m^3		
	13	26	SWE S3	mm		
	14	28	ice content S4	%		
	15	30	water content S4	%		
	16	32	density S4	kg/m^3		
	17	34	SWE S4	mm		
	18	36	Analog 2	-		
	19	38	Analog 3	-		
	20	40	Analog 4	-		
	21	42	C_LF S1	pF		
	22	44	C_HF S1	pF		
	23	46	C_LF S2	pF		
	24	48	C_HF S2	pF		
	25	50	C_LF S3	pF		
	26	52	C_HF S3	pF		
	27	54	C_LF S4	pF		
	28	56	C_HF S4	pF		

	Index	Register address	Variable	Unit / value	Bytes	Format
Device info	-	65533	Device type and configuration	3701	2	unsigned int
	-	65534	Software version	XYYZZ	2	
	-	65535	Modbus version	10100	2	

Table 15 Input registers

Read and write holding registers

Holding resisters are mainly used to configure the Modbus adapter communication. Configuration settings are read with function 03 (read holding registers) and written with function 06 (write single registers).

NOTE Restart the Modbus adapter after changing the configuration!

	Register address	Variable	Range	Bytes	Format
Config values	0	Modbus default[1]	0 - 1…read 1…write	2	unsigned int
	1	Modbus device address	1 to 247		
	2	RS-485 baud rate	1…1200 baud 2…2400 baud 3…4800 baud 4…9600 baud 5…19200 baud 6…38400 baud 7…57600 baud 8…115200 baud		
	3	RS-485 parity/ stop bits	1…no parity, 1 stop bit 2…no parity, 2 stop bits 3…even parity, 1 stop bit 4…odd parity, 1 stop bit		

[1]Writing "1" sets the Modbus default settings.

Table 16 Holding registers

Report slave ID

The Modbus function 17 (report slave ID, read only) can be used to read basic information of the SPA-2. The following example shows the response of function 17 of a RG-30 sensor, which is received in hex-format:

EXAMPLE 23 11 26 53 FF 27 74 20 53 6F 6D 6D 65 72 20
20 52 47 2D 33 30 20 20 20 32 5F 37 31 72 30 31 20 34
35 31 35 31 38 32 31 00 BB D4

			Example	
	Content	**Length (Bytes)**	**HEX-value**	**Decimal, ASCII**
PDU* response	Slave address	1	23	35
	Function code	1	11	17
	Number of bytes (excl. slave-address, function code, NUL and CRC)	1	26	38
	Slave ID	1	53	"S"
	Run status (0=inactive; FF=active)	1	FF	255
	Modbus implementation version	2	27 74	10100
	Separator	1	20	" "
	Vendor string	7	53 6F 6D 6D 65 72 20	"Sommer "
	Separator	1	20	" "
	Device configuration	7	52 47 2D 33 30 20 20	“RG-30 “
	Separator	1	20	" "
	Software version	7	32 5F 37 31 72 30 31	2_71r01
	Separator	1	20	" "
	Serial number	8	34 35 31 35 31 38 32 31	45151821
	NUL	1	00	
	CRC	2	BB D4	

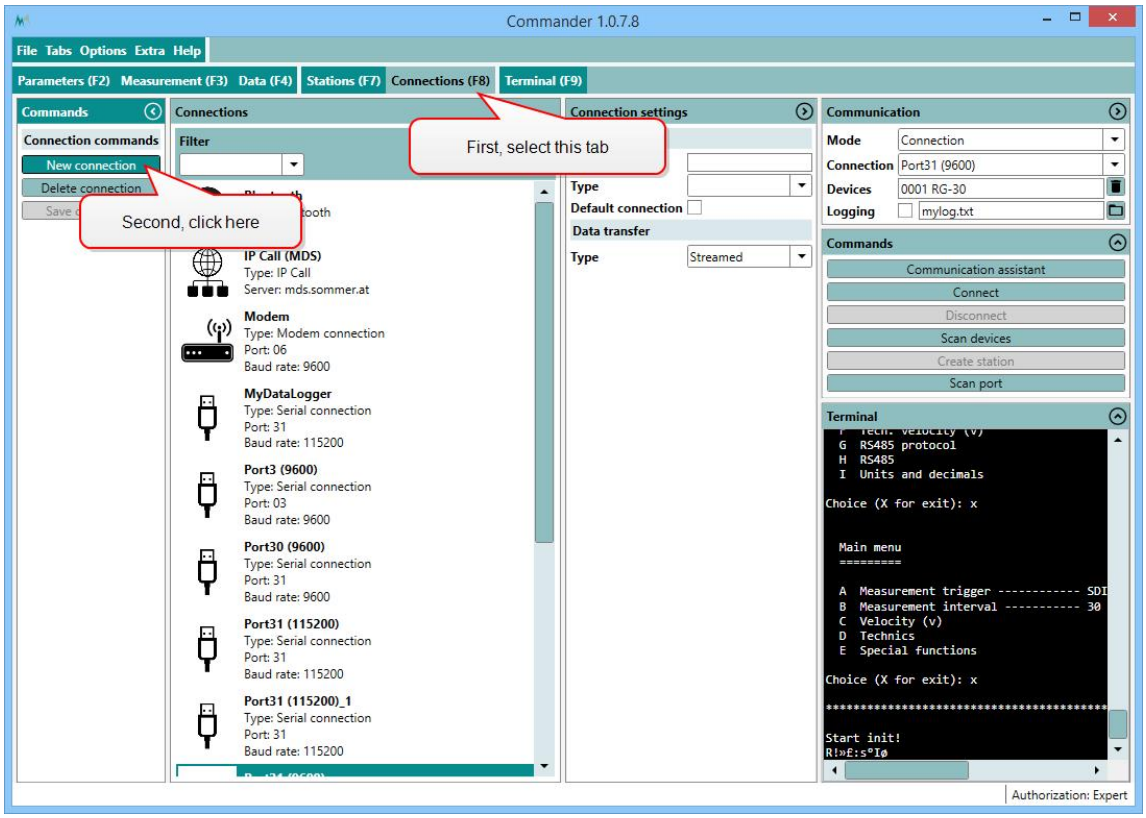
*Protocol Data Unit

Table 17 Slave ID

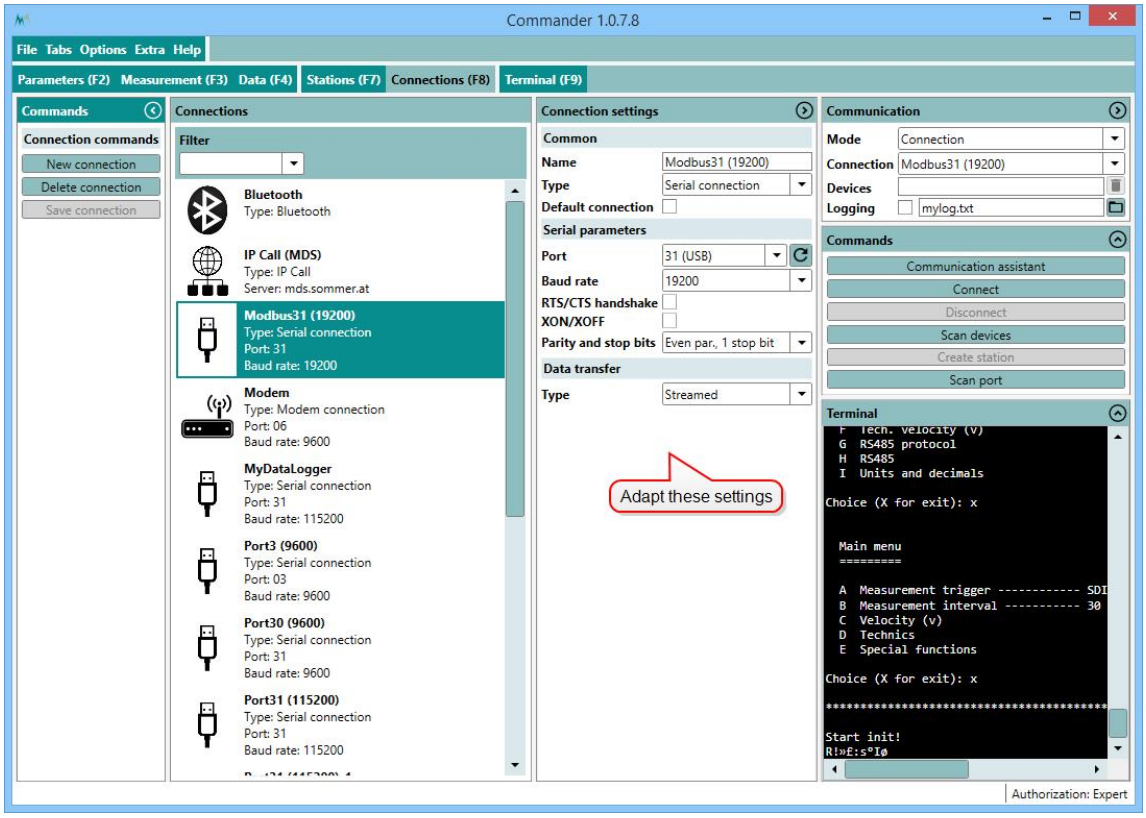
12.5.6 Reactivate Sommer protocol

Follow the instructions below to change the data output back to Sommer-protocol:

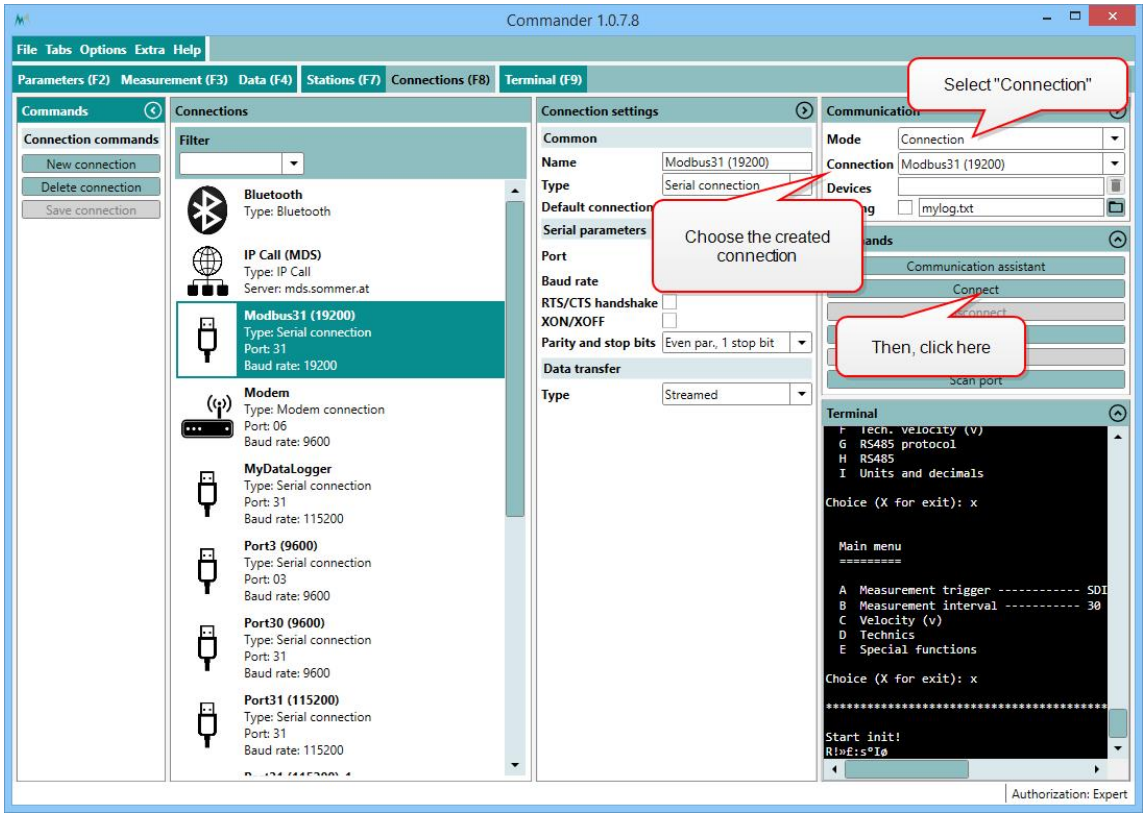
1. Open the Connections (F8) tab and click New connection.



2. Enter the Name of the new connection. We recommend to use a meaningful name for later recognition, e.g. Modbus31 (19200) to indicate port 31 and Baud-rate 19200. Select the Type Serial connection and choose the Port your sensor is connected to, set the Baud-rate to *19200* and the Parity/stop bits to *Even par., 1 stop bit*.



3. Click Save connection.
4. In the Communication window select Mode Connection and choose the Connection you have created. Then click Connect.

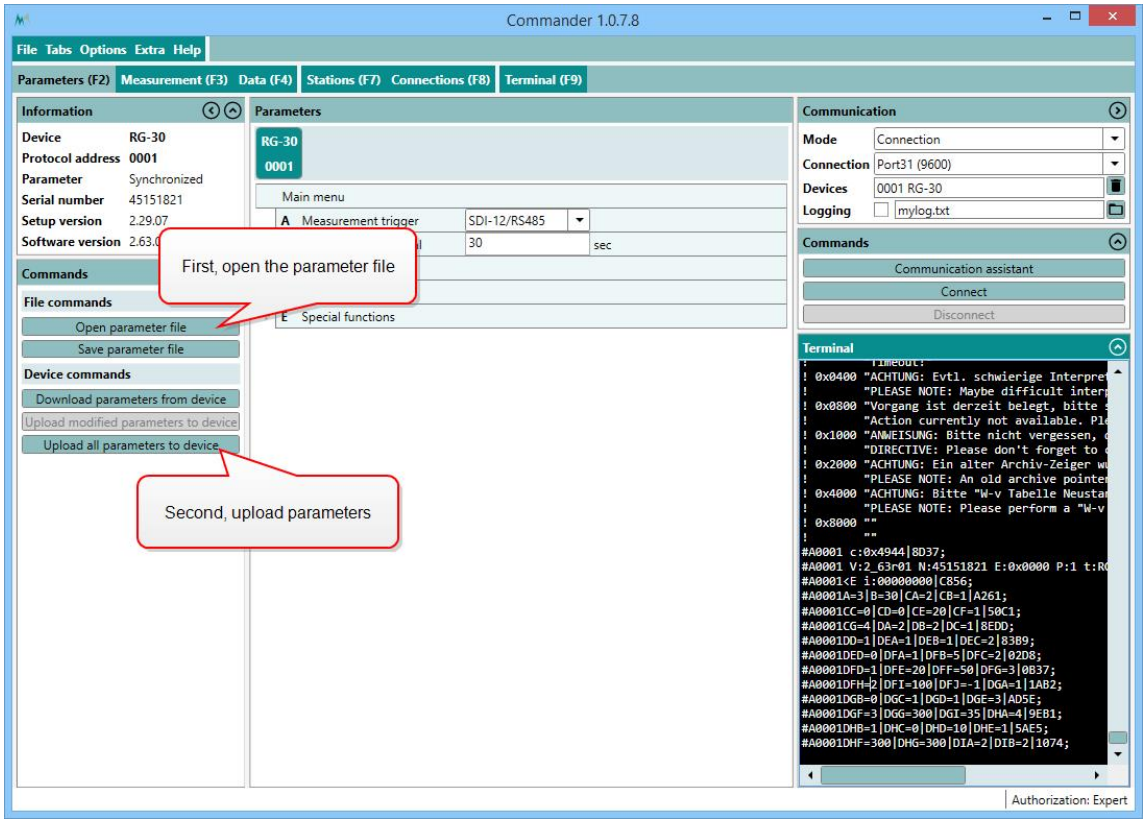


5. Download the parameters and save the parameter file as described in Configuration.

> **TIP** Save the parameter file for future use and to document configuration changes!

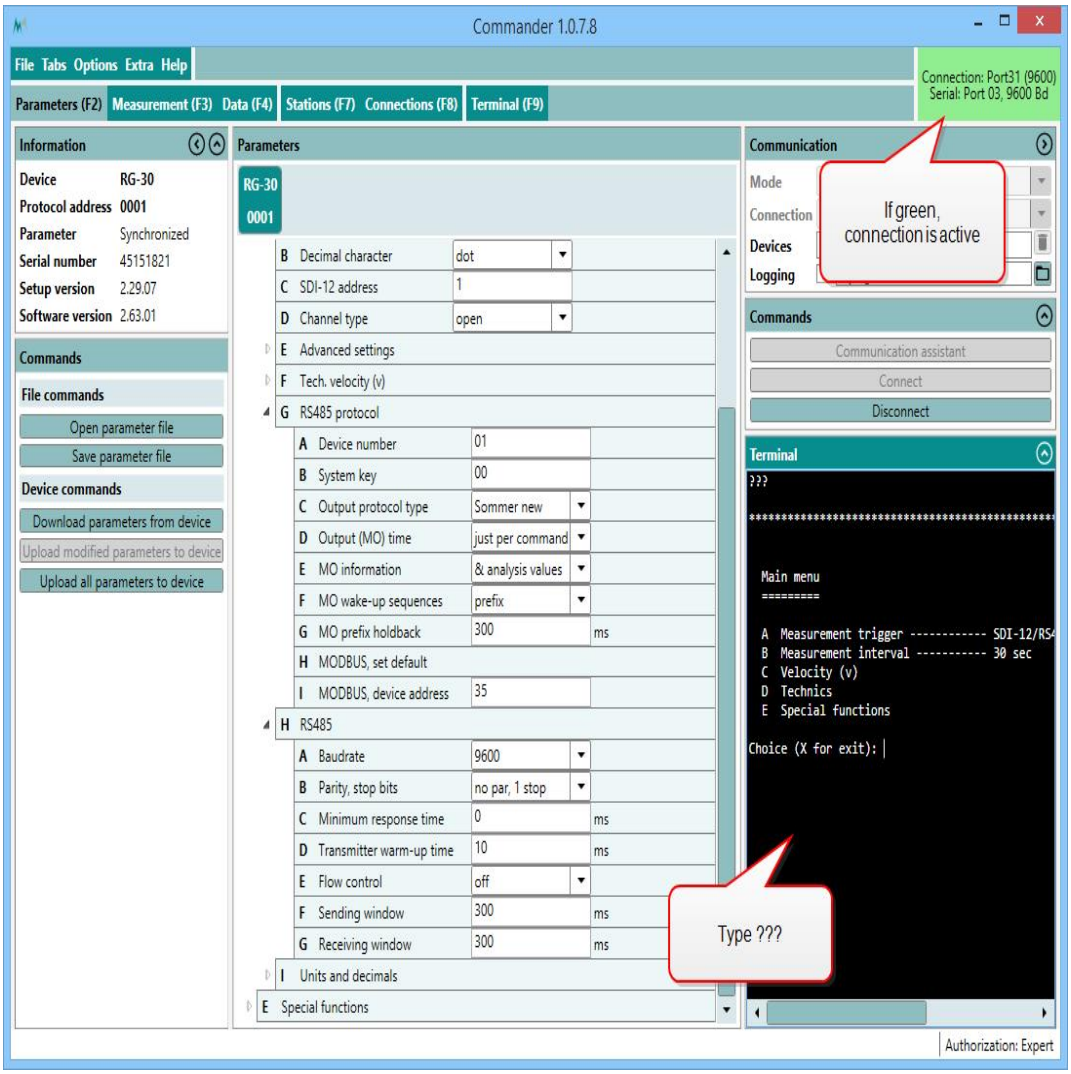
6. Now, two options are available to revert communication back to the Sommer-protocol:

A. If a parameter file is available that has the Sommer-protocol enabled, the file can be loaded by clicking Open parameter file, selecting the respective file and uploading the parameters to the device by clicking Upload all parameters to device.

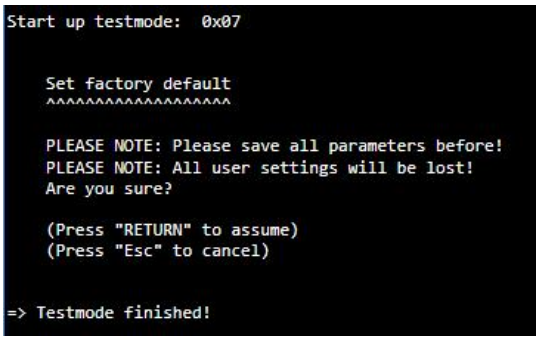


B. If no parameter file is available, the device has to be reset to its default configuration:

1. Click into the Terminal window and type ??? to enter the sensor-menu.



2. Navigate to Special functions and select Set factory default…
3. Acknowledge the safety-note.



4. Enter X until you get back to the main menu. The Sommer-sensor is now restarted and available in its initial configuration. As the connection-parameters have been changed to the default settings, the connection to the sensor is lost. Press Disconnect for

completion.

7. Establish the original connection to the Sommer-sensor as described in Configuration.
8. Download the sensor's parameters in the Parameters (F2) tab, adapt the required parameters, or upload your originally saved parameter file to the SPA-2.

12.5.7 PLC integration

The SPA-2 can be integrated into a PLC system as a slave device. It supports the PROFIBUS, PROFINET, EtherCAT and CANopen protocols. This requires an additional serial converter, e.g. Anybus Communicator.

13 Parameter definitions

A Measurement trigger 114
A Measurement Interval 114
B Measurement table 115
C Snow depth adjust 118
D Snow depth test 118
E Technics 118
F Special functions 132
G

A Measurement trigger

generic-measurement-trigger

Measurements are initiated by one of the options listed in the table below.

The commands to trigger measurements via RS-485 and SDI-12 are described in Communication.

Measured data are either returned directly after the measurement or can be requested by commands via the RS-485 or SDI-12 interface. The format of the returned data can be configured in the sub-menu Output protocol (OP).

ID	Option	Description
1	Interval (default)	Measurements are initiated in a specified interval.
2	TRIG input	Measurements are triggered by the positive edge of a DC-voltage signal applied to the TRIG input (low: 0 ... 0.6 V, high: 2.2 ... 28 V, pulse duration must be ≥500 ms, delay between pulses must be ≥500 ms)
3	SDI-12/RS-485	Measurements are externally triggered by commands via RS-485 or SDI-12 from ,e.g. a data logger.
4	all allowed	Measurement is triggered by all options mentioned above.

B Measurement Interval

generic-measurement-interval

An internal measurement interval can be set for the SPA-2. If selected in menu item Measurement trigger, measurements are performed in the defined interval. However, a measurement is always completed before a new one is initiated.

Value range	Default	Units
00:00:01 ... 12:00:00	00:01:00	-

C Measurement table

generic-measurement-table

In the measurement table the recorded variables are selected. By default, the measurement table contains the following variables:

Index	Variable	Unit	Description
01	snow depth	mm	Snow depth measured by SPA-2
02	ice content S1	%	Ice content of SPA-sensor 1
03	water content S1	%	Water content of SPA-sensor 1
04	density S1	kg/m^3	Density of SPA-sensor 1
05	SWE S1	mm	Snow water equivalent of SPA-sensor 1
06	ice content S2	%	Ice content of SPA-sensor 2
07	water content S2	%	Water content of SPA-sensor 2
08	density S2	kg/m^3	Density of SPA-sensor 2
09	SWE S2	mm	Snow water equivalent of SPA-sensor 2
10	ice content S3	%	Ice content of SPA-sensor 3
11	water content S3	%	Water content of SPA-sensor 3
12	density S3	kg/m^3	Density of SPA-sensor 3
13	SWE S3	mm	Snow water equivalent of SPA-sensor 3
14	ice content S4	%	Ice content of SPA-sensor 4
15	water content S4	%	Water content of SPA-sensor 4
16	density S4	kg/m^3	Density of SPA-sensor 4
17	SWE S4	mm	Snow water equivalent of SPA-sensor 4
18	Analog 2		Variable acquired by analog input 2
19	Analog 3		Variable acquired by analog input 3
20	Analog 4		Variable acquired by analog input 4

Index	Variable	Unit	Description
21	C_LF S1	pF	Capacity of SPA-sensor 1 at low frequency
22	C_HF S1	pF	Capacity of SPA-sensor 1 at high frequency
23	C_LF S2	pF	Capacity of SPA-sensor 2 at low frequency
24	C_HF S2	pF	Capacity of SPA-sensor 2 at high frequency
25	C_LF S3	pF	Capacity of SPA-sensor 3 at low frequency
26	C_HF S3	pF	Capacity of SPA-sensor 3 at high frequency
27	C_LF S4	pF	Capacity of SPA-sensor 4 at low frequency
28	C_HF S4	pF	Capacity of SPA-sensor 4 at high frequency

Measurement table

Each entry of the measurement table is configured by the parameters described below:

Identifier

`generic-measurement-table-identifier`

User defined variable name.

Unit

`generic-measurement-table-unit`

The unit of the selected variable.

Decimals

`generic-measurement-table-decimals`

The number of decimal places assigned to the selected variable. The following options are available:

ID	Decimals	Description
1	`1…5`	number of decimal places assigned to the selected variable
2	`none`	no decimal places
3	`as S`	the number of decimal places of the source is adopted

Scale

`generic-measurement-table-scale`

The slope applied to the selected variable. Only available if Decimals is set to 1…5 or none. If Decimals is set as S (as source), no scaling is applied.

Offset

`generic-measurement-table-offset`

The offset applied to the selected variable.

Adjustment (Correction)

generic-measurement-table-adjustment

A measurement of the selected variable is triggered and the result displayed in the terminal window. If the measured value deviates from the correct value, the correct value can be entered. This adjusts the value in Offset. The factor in Scale is not affected by this correction.

Test

generic-measurement-table-test

A measurement of the selected variable is triggered and the result displayed in the terminal window.

S-TYP

generic-measurement-table-s-typ

One of the following sensor (or source) types:

This is a placeholder snippet. Edit and remove link to global project.

S-TYP	Description and S-MEA options

S-NUM

generic-measurement-table-s-num

The number of the selected SDI-12 or SPA-S sensor, e.g. 3.

S-MEA

generic-measurement-table-s-mea

The number of the SPA-2 sensor variable or an internal system variable, the connection port of the selected analog sensor, or the position of the measurement value within the string returned by a connected SDI-12 sensor. See S-TYP for the available options.

S-ADD

generic-measurement-table-s-add

Contains additional commands which are sent with a standard request to a sensor (or source), or which provide additional options for controlling measurements and handling results. The available commands depend on the settings in S-TYP:

This is a placeholder snippet. Edit and remove link to global project.

Function	S-TYP	S-ADD	Description

TIP Multiple commands can be entered by separating them with a space, e.g. `D+ SY`.

D Snow depth adjust

Function to adjust the snow depth measurement (see Section Adjustment of snow depth measurement).

E Snow depth test

Function to test the snow depth measurement.

F Technics

F-A Language/Sprache 118
F-B Decimal character 118
F-C Sleep mode 119
F-D Sommer ID 119
F-E SPA, sensor table 120
F-F SDI-12 service 121
F-G RS-485-2 Port 123
F-H RS-485-1 Protocol 127
F-J RS-485-1 Port 130

F-A Language/Sprache

`generic-language`

The menu language.

ID	Option	Description
1	german/deutsch	German language
2	english/englisch (default)	English language

F-B Decimal character

`generic-decimals-character`

The character used as decimal separator in the values of the settings and in serial data strings.

ID	Option	Description
1	comma	-
2	dot (default)	-

F-C Sleep mode

generic-sleep-mode

Defines the behavior of the SPA-2 between two measurements, provided the measurement interval is longer than the time of the measurement itself. The following options are available:

ID	Option	Description
1	MODBUS, fast	For MODBUS applications. The SPA-2 stays in normal mode. This option permits high data transmission rates, but increases power consumption.
2	MODBUS, slow	For MODBUS applications. The SPA-2 goes into idle mode and can be woken up by a command via the RS-485 interface with a low baud rate. This option reduces power consumption at lower data transmission rates.
3	Standard (default)	The SPA-2 goes into sleep mode and can be woken up by a command via the RS-485 interface only with a time delay. Option with the lowest power consumption.

F-D Warm-up time

generic-warm-up-time

The time between the power-supply is switched on and the first measurement.

Value range	Default	Units
0…255	0	sec

F-E Sommer ID

generic-sommer-id

The Sommer ID is used to define stations within the Commander software. The ID is preset in the device and corresponds to its serial number.SOMMER suggests not to change the ID, except if a SPA-2 device is replaced. In such a case it can be practical to change the ID of the new device to the ID of the replaced device to guarantee data consistency.

F-F SPA, sensor table

The installation and base-measurement settings for the installed SPA-ribbon sensors. By default, the sensors are configured as follows:

	Length [mm]	Foot height [mm]	Head height [mm]	Min. Coverage [mm]	C base LF [pF]	C base HF [pF]
01	4800	80	2580	-1	-	-
02	4800	100	100	-1	-	-
03	4800	300	300	-1	-	-
04	4800	500	500	-1	-	-

Sensor length
Length of SPA-ribbon sensor.

Foot height
Mounting height at the lower end of a tilted sensor (see Figure 10). For horizontally mounted sensors Foot height and Head height are equal.

Head height
Mounting height at the upper end of a tilted sensor (see Figure 10). For horizontally mounted sensors Foot height and Head height are equal.

Min. Coverage
The minimum length the sensor has to be covered in snow to yield valid measurements.

C base LF
Sensor adjustment value.

C base HF
Sensor adjustment value.

Sensor zero adjust
Function to perform a zero adjustment of the sensor (see Section Calibration of SPA-2-ribbon-sensors for details).

Test sensor
Function to perform a test measurement of the selected SPA-sensor.

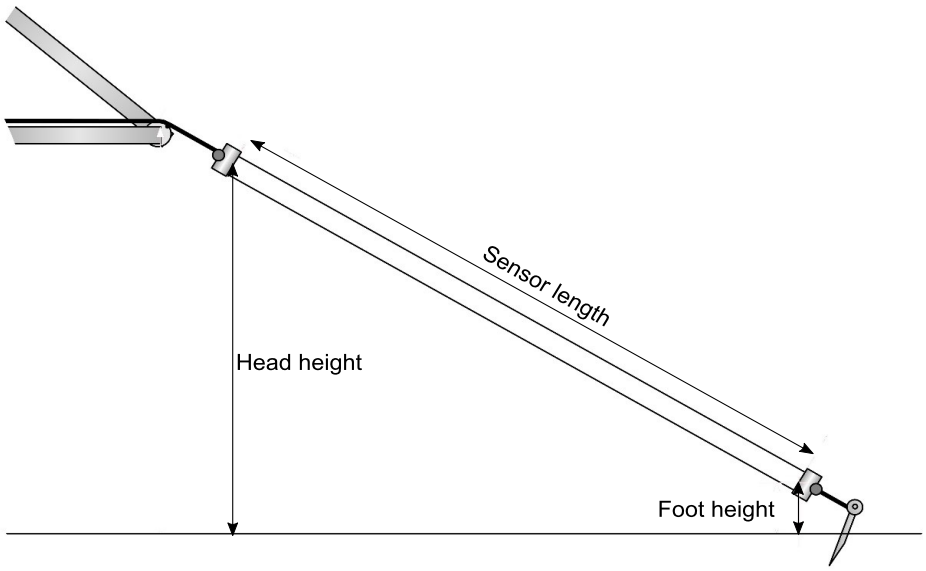


Figure 10 Dimensions of tilted SPA-sensor

F-G SDI-12 service

F-G-A SDI-12 address 121
F-G-B SDI12 'M'-response 121
F-G-C SDI-2 maximal duration 122
F-G-D SDI-2 sensor search 122
F-G-E SDI-2 change sensor address 122
F-G-F SDI-2 ask for a sensor address 123

F-G-A SDI-12 address

generic-sdi-12-address

The address is a unique identifier of the sensor within a SDI-12 bus system.

Value range	Default	Units
0…9, a…z, A…Z	0	-

F-G-B SDI12 'M'-response

generic-sdi-12-m-response

Defines how an SDI-12 M-command received by the SPA-2 is answered if the requested number of measurement values exceeds 9. The following options are available:

ID	Parameter	Description
1	expand address	This option should only be used with SDI-12 standard V1.0. The measurement values can be requested with the commands `aD0!`, `aD1!`,…, with `a` the sensor address. Max. 9 values are returned for each command.
2	just expand output	The `M`-request received by the SPA-2 is answered according to SDI-12 standard V1.3, which supports transmitting more than 9 measurement values per answer.
3	as at 'C' request	The M-request received by the SPA-2 is answered as if several `C`-requests were sent.
4	M1, M2, M3 split (default)	The M-request received by the SPA-2 is answered as if several `Mk`-commands were sent, with k depending on the number of measurement values to be transmitted (`M1` returns the first 9 measurement values, `M2` the second nine values, etc).

F-G-C SDI-2 maximal duration

`generic-sdi-12-max-measurement-duration`

The timeout for commands sent to SDI-12 devices connected to the SPA-2. If a SDI-12 device does not respond to a command within this time the device returns an error.

Value range	Default	Units
0…255	20	sec

F-G-D SDI-2 sensor search

`generic-sdi-12-sensor-search`

Searches for connected SDI-12 sensors and lists their identification and sensor address in the terminal window.

F-G-E SDI-2 change sensor address

`generic-sdi-12-change-sensor-address`

Changes the SDI-12 address of a connected sensor.

F-G-F SDI-2 ask for a sensor address

generic-ask-sensor-address

Reads the SDI-12 address and its identification of a single SDI-12 sensor connected to the SPA-2.

F-H RS-485-2 Port

The RS-485-2 interface is used to read data from connected digital sensors. The following parameters are available to configure it.

F-H-A Baud rate 123
F-H-B Parity, stop bits 123
F-H-C Minimum response time 124
F-H-D Transmitter warm-up time 124
F-H-E Flow control 124
F-H-F Sending window 125
F-H-G Receiving window 125
F-H-H Trig. polling 125
F-H-I Trig. timeout 125
F-H-J Trig. sleep while timeout 126
F-H-K Network scan extension 126
F-H-L Polling delay 126
F-H-M Transparency to RS485-2 126

F-H-A Baud rate

generic-rs-485-port-baud-rate

The following transmission rates in bps (baud) can be selected:

ID	Option	Description
1	1'200	-
2	2'400	-
3	4'800	-
4	9'600 (default)	-
5	19'200	-
6	38'400	-
7	57'600	-
8	115'200	-

F-H-B Parity, stop bits

generic-rs-485-port-parity-stop-bits

The following combinations of parity and stop bits can be selected:

ID	Option	Description
1	no par, 1 stop (default)	No parity and 1 stop bit
2	no par, 2 stop	No parity and 2 stop bits
3	even par, 1 stop	Even parity and 1 stop bit
4	odd par, 1 stop	Odd parity and 1 stop bit

F-H-C Minimum response time

`generic-rs-485-port-minimum-response-time`

Setting of this parameter avoids interference of communication at the RS-485 interface. For this purpose the response to a command is delayed by the selected time. Additionally, the response is kept compact.

Value range	Default	Units
0…2'000	10	ms

F-H-D Transmitter warm-up time

`generic-rs-485-port-transmitter-warm-up-time`

The transmitter warm-up time defines the time before data is sent.

Value range	Default	Units
0…2'000	10	ms

F-H-E Flow control

`generic-rs-485-port-flow-control`

The XOFF-XON flow control can be activated with this setting.

ID	Option	Description
1	Off (default)	no flow control
2	XOFF-XON blocking	XOFF-XON flow control, especially adapted for half-duplex systems

F-H-F Sending window

generic-rs-485-port-sending-window

If XON-XOFF flow control is activated data are transmitted in blocks with the defined length.

Value range	Default	Units
200...5'000	300	ms

F-H-G Receiving window

generic-rs-485-port-receiving-window

If XON-XOFF flow control is activated transmission of blocks is delayed by the specified time.

Value range	Default	Units
200...5'000	300	ms

F-H-H Trig, polling

generic-rs-485-port-trig-polling

Sets the polling of connected digital sensors.

ID	Setting	Description
1	off (default)	Continuous polling is inactive.
2	on	Continuous polling is active.

F-H-I Trig, timeout

generic-rs-485-port-trig-timeout

The time the SPA-2 is waiting until expected commands/answers are received via the RS485-2 interface.

Value range	Default	Units
3 ... 250	60	s

F-H-J Trig, sleep while timeout

generic-rs-485-port-trig-sleep-timeout

To reduce power consumption the SPA-2 can switch to a sleep mode between measurements.

ID	Setting	Description
1	off (default)	SPA-2 remains activated between measurements, i.e. during Trig, timeout
2	on	SPA-2 is inactive between initialization of measurement and reception of measurement data. The connected sensor must send a Prefix command to wake up the SPA-2 for data transmission.

F-H-K Network scan extension

generic-rs-485-port-network-scan-extension

Optional detection of connected SOMMER sensors with the Commander software.

ID	Setting	Description
1	off (default)	Detection of SOMMER devices connected to RS485-2 is deactivated.
2	on	Detection of SOMMER devices connected to RS485-2 is activated.

F-H-L Polling delay

generic-rs-485-polling-delay

Time by which polling of multiple digital sensors is delayed. Used to poll sensors in sequence to avoid communication conflicts.

Value range	Default	Unit
0 ... 20	2	sec

F-H-M Transparency to RS485-2

generic-rs-485-port-transparency-rs-485-2

Only available in terminal mode. After activation, direct communication with a connected sensor is enabled, i.e. commands and theirs answers are exchanged over the RS485-2 interface of the SPA-2. With this mode the settings of a connected digital sensor can be read or changed.

F-I RS-485-1 Protocol

The RS-485-1 interface is used to read acquired data and to configure the SPA-2. The following parameters are available to configure the protocol; the port settings are defined in RS-485-1 Port.

F-I-A Device number 127
F-I-B System key 127
F-I-C Output protocol (OP) 127
F-I-D OP, measurement output 128
F-I-E OP, information 128
F-I-F OP, wake-up sequence 128
F-I-G OP, prefix holdback 129
F-I-H MODBUS, set default 129
F-I-I MODBUS, device address 130

F-I-A Device number

`generic-rs-485-protocol-device-number`

The device number is used for the unique identification of the device in a bus system.

Value range	Default	Units
0…98	0 (default)	-

F-I-B System key

`generic-rs-485-protocol-system-key`

The system key defines the bus system of the device. Thus, different conceptual bus systems can be separated. Interfering bus systems occur if the remote radio coverage of two measurement systems overlap. In general, the system key should be set to 00.

Value range	Default	Units
0…99	0	-

F-I-C Output protocol (OP)

`generic-rs-485-protocol-output-protocol`

The type of the serial output protocol. The following options are available:

ID	Option	Description
1	Sommer (default)	Sommer protocol; data values are returned with an index starting at 1
2	Standard	Standard protocol; data values are returned without an index
3	MODBUS	Modbus protocol

NOTE For MODBUS applications run MODBUS, set default to get the appropriate communication settings.

F-I-D OP, measurement output

`generic-rs-485-protocol-measurement-output`

Specifies the timing of the serial data output.

ID	Option	Description
1	just per command	The output is only requested by commands via the RS-485 or SDI-12 interface.
2	measured values push	Data are returned automatically after each measurement.

F-I-E OP, information

`generic-rs-485-protocol-information`

The main measurement values are always included in the data output string. Additionally, special and analysis values can be included.

ID	Option	Description
1	main values	Only the main values are returned.
2	& special values (default)	Main values and special values are returned.
3	& analysis values	Main, special and analysis values are returned.

F-I-F OP, wake-up sequence

`generic-rs-485-protocol-wake-up-sequence`

Serial data can be transmitted to a recording device automatically without a request. However, many devices demand a wake-up sequence before they can receive and process data. The SPA-2 has the option to send a sync sequence and a prefix before data are transmitted (see Waking-up a connected data logger). The following options are available:

ID	Option	Description
1	off	No wake-up sequence
2	sync	The sync sequence UU~?~? is sent before the output string.
3	prefix (default)	A blank with a time delay is sent before the output string.
4	prefix & sync	A blank with a time delay and the sync sequence UU~?~? is sent before the output string.

F-I-G OP, prefix holdback

`generic-rs-485-protocol-prefix-holdback`

The hold-back time defines the time delay between the prefix and the data string.

Value range	Default	Units
0…5'000	300	ms

F-I-H MODBUS, set default

`generic-rs-485-protocol-modbus-set-default`

Sets all parameters required for Modbus communication automatically. The following settings are adapted:

Parameter	Modbus setting
OP, measurement output	just per command
Output protocol (OP)	Modbus
MODBUS, device address	35
Sleep mode	Modbus, slow
Parity, stop bits	even par, 1 stop
Baud rate	19200
Flow control	off

Parameter	Modbus setting
Transmitter warm-up time	10 ms
Minimum response time	30 ms

F-I-I MODBUS, device address

generic-rs-485-protocol-modbus-device-address

Unique device address for the Modbus protocol.

Value range	Default	Units
1…247	35	-

F-J RS-485-1 Port

F-J-A Baud rate 130
F-J-B Parity, stop bits 131
F-J-C Minimum response time 131
F-J-D Transmitter warm-up time 131
F-J-E Flow control 131
F-J-F Sending window 132
F-J-G Receiving window 132

F-J-A Baud rate

generic-rs-485-port-baud-rate

The following transmission rates in bps (baud) can be selected:

ID	Option	Description
1	1'200	-
2	2'400	-
3	4'800	-
4	9'600 (default)	-
5	19'200	-
6	38'400	-
7	57'600	-
8	115'200	-

F-J-B Parity, stop bits

generic-rs-485-port-parity-stop-bits

The following combinations of parity and stop bits can be selected:

ID	Option	Description
1	no par, 1 stop (default)	No parity and 1 stop bit
2	no par, 2 stop	No parity and 2 stop bits
3	even par, 1 stop	Even parity and 1 stop bit
4	odd par, 1 stop	Odd parity and 1 stop bit

F-J-C Minimum response time

generic-rs-485-port-minimum-response-time

Setting of this parameter avoids interference of communication at the RS-485 interface. For this purpose the response to a command is delayed by the selected time. Additionally, the response is kept compact.

Value range	Default	Units
0…2'000	10	ms

F-J-D Transmitter warm-up time

generic-rs-485-port-transmitter-warm-up-time

The transmitter warm-up time defines the time before data is sent.

Value range	Default	Units
0…2'000	10	ms

F-J-E Flow control

generic-rs-485-port-flow-control

The XOFF-XON flow control can be activated with this setting.

ID	Option	Description
1	Off (default)	no flow control
2	XOFF-XON blocking	XOFF-XON flow control, especially adapted for half-duplex systems

F-J-F Sending window

generic-rs-485-port-sending-window

If XON-XOFF flow control is activated data are transmitted in blocks with the defined length.

Value range	Default	Units
200...5'000	300	ms

F-J-G Receiving window

generic-rs-485-port-receiving-window

If XON-XOFF flow control is activated transmission of blocks is delayed by the specified time.

Value range	Default	Units
200...5'000	300	ms

G Special functions

G-A Device status 132
G-B View setup 132
G-C Set factory default 133
G-D Temp. load factory default 133
G-E Relaunch program 133

G-A Device status

generic-special-functions-device-status

Displays information about the sensor and the software version.

G-B View setup

generic-special-functions-view-setup

All parameters of the SPA-2 are listed in the terminal window.

G-C Set factory default

generic-special-functions-set-factory-default

All parameters are reset to factory defaults. Only available in terminal-mode.

G-D Temp. load factory default

generic-special-functions-temp-load-factory-default

Loads factory default values temporarily. Only available in terminal mode.

G-E Relaunch program

generic-special-functions-relaunch-program

The device is restarted. Powering the sensor off and on again is equivalent.

Appendix N Troubleshooting

N.1 Devices 134
N.1.1 The SPA-2 is not responding or returns unreadable characters 134
N.1.2 The SPA-2 reboots repeatedly 135
N.2 Measurement data 135
N.2.1 Measurement data are not updated 135
N.3 Firmware & software 136
N.3.1 Commander loads wrong setup 136
N.3.2 Firmware update via RS-485 is aborted 136
N.4 RS-485 136
N.4.1 Configuration via terminal shows unexpected behavior 136
N.5 SDI-12 137
N.5.1 The SPA-2 is not detected by a SDI-12 master device 137
N.5.2 Data logger receives no SDI-12 data 137
N.6 Analog output 138
N.6.1 The 4-20 mA output is wrong 138

N.1 Devices

N.1.1 The SPA-2 is not responding or returns unreadable characters

Reason	Solution
The power supply is not connected or turned off.	Check if the power supply is connected and on.
The polarity of connected power supply wires is wrong.	Check the polarity of connected wires.
The power supply does not provide enough current.	Use a power supply that provides more current than listed in the Specifications.
The power supply voltage is out of range.	Adjust the power supply to match the specified voltage range.
The polarity of the connected RS-485-A and RS-485-B wires is wrong.	Reverse the polarity of the connected RS-485-A and RS-485-B wires.
The port settings of the SPA-2 and the data acquisition system do not match.	Use the CommanderCommunication assistant or adapt port settings on your device. **NOTE** Sommer Messtechnik devices require the following Baud rates: ● Sensor: 9600 ● Data logger: 115200 ● Modbus: 19200 In case of doubt use the function Check port in the Communication assistant.

Reason	Solution
A sensor wire is not connected firmly to the terminal of the data acquisition device.	Check the firm connection of the sensor wires.
A pin of the connector plug is bent or broken.	Verify that all connector pins are straight.
The sensor cable is damaged.	Replace the sensor cable.
The COM-port has not assigned correctly to the USB converter.	1. Make sure to use a Sommer Messtechnik USB converter. Third party converters are not supported. 2. Check the COM-port number using Windows Device Manager. 3. Plug in the USB converter first, then start Commander.
The USB converter is faulty.	Replace the USB converter.
The USB port on your PC is not working.	Use another USB port.
The driver of the USB converter was incorrectly installed	Reinstall the driver of the USB converter.

N.1.2 The SPA-2 reboots repeatedly

Reason	Solution
The power supply has not enough current to start the SPA-2.	Verify that the power supply provides enough current. A SPA-2 consumes up to 140 mA @ 12 V. If required, power the SPA-2 by an additional or alternative supply.

N.2 Measurement data

N.2.1 Measurement data are not updated

The device is connected to the Commander, but the data are not updated.

Cause	Solution
Data traffic conflict	Reboot the device by interrupting the power supply.

N.3 Firmware & software

N.3.1 Commander loads wrong setup

If the setup is reloaded from the device the Commander seems to display an old version.

Cause	Solution
The device has been connected to the same PC before and several different setup files have been loaded.	Delete the setup files of the device that have been downloaded by Commander to the folder *C:\Users\Public\Documents\Sommer\Setup*. The respective files can be identified by the serial number in the file name and the file date.

N.3.2 Firmware update via RS-485 is aborted

Reason	Solution
USB to RS-485 converter cable is damaged or can only operate on 9600 baud.	Replace USB to RS-485 converter cable. The programmer requires 57600 baud.

N.4 RS-485

N.4.1 Configuration via terminal shows unexpected behavior

Accessing the parameter menus in the terminal leads to unexpected behavior, e.g. after entering a menu character the terminal displays repeated error messages or jumps out of the parameter menu.

Reason	Solution
The sensor, power supply and PC/laptop do not share the same ground.	Verify that all equipment is connected to the same ground.

N.5 SDI-12

N.5.1 The SPA-2 is not detected by a SDI-12 master device

Reason	Solution
The SPA-2 and the SDI-12 master have different grounds.	Verify that the SPA-2 and the SDI-12 master are connected by a ground (GND) wire.

N.5.2 Data logger receives no SDI-12 data

Reason	Solution
The sensor is set to Measurement trigger *interval*, but the data logger sends a `M!` command, i.e. the data logger polls data.	If data are polled from the sensor, Measurement interval must be set to *SDI-12/RS485*.
The sensor is set to Measurement trigger *SDI-12/RS485*, but the data logger sends an `R!` command, i.e. the sensor pushes data.	If the sensor pushes data, Measurement interval must be set to *interval*.
Multiple sensors are connected to the data logger and two or more sensors have the same SDI-12 address.	If multiple sensors are connected to the same data logger, each sensor must be assigned a unique SDI-12 address.
Some third-party sensors may not issue a service request when they have completed a measurement.	If a sensor does not issue a service request after a measurement, a `C!` command instead of a `M!` command must be sent to start a measurement. Otherwise the data logger runs into a timeout or is waiting indefinitely for a service request.
The timing of the data logger between triggering a measurement and data request may be too tight.	Verify that the timing between triggering and data request is sufficient. Upon a measurement request, e.g. by an `M!` command, the sensor returns the required measurement duration. See Acquire measurements for details.

N.6 Analog output

N.6.1 The 4-20 mA output is wrong

Reason	Solution
Analog output settings incorrect.	1. Check analog output settings. 2. Run Simulate current output and verify the correct output.
Sensor and data acquisition system have different grounds.	Verify that sensor and data acquisition system have the same ground.
The 4-20 mA output is delayed by approx. 150 ms. If the output is read before, a wrong value is acquired.	Sample the 4-20 mA output with a delay of more than 150 ms.

Appendix O CRC-16 array

CRC-16 array

```
crc16tab[] =
{
0x0000, 0x1021, 0x2042, 0x3063, 0x4084, 0x50A5, 0x60C6, 0x70E7,
0x8108, 0x9129, 0xA14A, 0xB16B, 0xC18C, 0xD1AD, 0xE1CE, 0xF1EF,
0x1231, 0x0210, 0x3273, 0x2252, 0x52B5, 0x4294, 0x72F7, 0x62D6,
0x9339, 0x8318, 0xB37B, 0xA35A, 0xD3BD, 0xC39C, 0xF3FF, 0xE3DE,
0x2462, 0x3443, 0x0420, 0x1401, 0x64E6, 0x74C7, 0x44A4, 0x5485,
0xA56A, 0xB54B, 0x8528, 0x9509, 0xE5EE, 0xF5CF, 0xC5AC, 0xD58D,
0x3653, 0x2672, 0x1611, 0x0630, 0x76D7, 0x66F6, 0x5695, 0x46B4,
0xB75B, 0xA77A, 0x9719, 0x8738, 0xF7DF, 0xE7FE, 0xD79D, 0xC7BC,
0x48C4, 0x58E5, 0x6886, 0x78A7, 0x0840, 0x1861, 0x2802, 0x3823,
0xC9CC, 0xD9ED, 0xE98E, 0xF9AF, 0x8948, 0x9969, 0xA90A, 0xB92B,
0x5AF5, 0x4AD4, 0x7AB7, 0x6A96, 0x1A71, 0x0A50, 0x3A33, 0x2A12,
0xDBFD, 0xCBDC, 0xFBBF, 0xEB9E, 0x9B79, 0x8B58, 0xBB3B, 0xAB1A,
0x6CA6, 0x7C87, 0x4CE4, 0x5CC5, 0x2C22, 0x3C03, 0x0C60, 0x1C41,
0xEDAE, 0xFD8F, 0xCDEC, 0xDDCD, 0xAD2A, 0xBD0B, 0x8D68, 0x9D49,
0x7E97, 0x6EB6, 0x5ED5, 0x4EF4, 0x3E13, 0x2E32, 0x1E51, 0x0E70,
0xFF9F, 0xEFBE, 0xDFDD, 0xCFFC, 0xBF1B, 0xAF3A, 0x9F59, 0x8F78,
0x9188, 0x81A9, 0xB1CA, 0xA1EB, 0xD10C, 0xC12D, 0xF14E, 0xE16F,
0x1080, 0x00A1, 0x30C2, 0x20E3, 0x5004, 0x4025, 0x7046, 0x6067,
0x83B9, 0x9398, 0xA3FB, 0xB3DA, 0xC33D, 0xD31C, 0xE37F, 0xF35E,
0x02B1, 0x1290, 0x22F3, 0x32D2, 0x4235, 0x5214, 0x6277, 0x7256,
0xB5EA, 0xA5CB, 0x95A8, 0x8589, 0xF56E, 0xE54F, 0xD52C, 0xC50D,
0x34E2, 0x24C3, 0x14A0, 0x0481, 0x7466, 0x6447, 0x5424, 0x4405,
0xA7DB, 0xB7FA, 0x8799, 0x97B8, 0xE75F, 0xF77E, 0xC71D, 0xD73C,
0x26D3, 0x36F2, 0x0691, 0x16B0, 0x6657, 0x7676, 0x4615, 0x5634,
0xD94C, 0xC96D, 0xF90E, 0xE92F, 0x99C8, 0x89E9, 0xB98A, 0xA9AB,
0x5844, 0x4865, 0x7806, 0x6827, 0x18C0, 0x08E1, 0x3882, 0x28A3,
0xCB7D, 0xDB5C, 0xEB3F, 0xFB1E, 0x8BF9, 0x9BD8, 0xABBB, 0xBB9A,
0x4A75, 0x5A54, 0x6A37, 0x7A16, 0x0AF1, 0x1AD0, 0x2AB3, 0x3A92,
0xFD2E, 0xED0F, 0xDD6C, 0xCD4D, 0xBDAA, 0xAD8B, 0x9DE8, 0x8DC9,
0x7C26, 0x6C07, 0x5C64, 0x4C45, 0x3CA2, 0x2C83, 0x1CE0, 0x0CC1,
0xEF1F, 0xFF3E, 0xCF5D, 0xDF7C, 0xAF9B, 0xBFBA, 0x8FD9, 0x9FF8,
0x6E17, 0x7E36, 0x4E55, 0x5E74, 0x2E93, 0x3EB2, 0x0ED1, 0x1EF0
}
```

Glossary

Index

M

Modbus 71, 91-92, 98, 105-106, 128-130, 134

R

RS-485 17, 19-20, 40, 54, 69, 73, 75-77, 83, 86, 92-93, 105, 114, 119, 123-124, 127-128, 130-131, 134, 136

S

SDI-12 17, 19-20, 40, 69, 71, 73, 76, 86-90, 94, 114, 117, 121-123, 128, 137