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SLF SNOWPRO – USER MANUAL

SNOWPRO-17 SENSOR

SNOWPRO-4040 SENSOR

SNOWPRO-2525 SENSOR

SLF
WSL-Institut für Schnee- und Lawinenforschung SLF

CONTENTS

CONTROLLER OVERVIEW

The controller device consists of a graphical display, user buttons and connector to attach different types of snow sensors. This device is especially developed for use in harsh environment and environmental conditions that occur during field measurements. It has internal non-volatile storage for up to 2728 measurements, which can be read out using a USB cable for further data processing on a computer. The low temperature limit of -25°C is given by the graphical display. The absolute limit is -40°C but in that case the display will react extremely slow, however, measurements are still possible.

1) Graphical Display (102x64 with Backlight)
2) Abort Button
3) Enter Button
4) Navigation Buttons
5) Power Button
6) Connection to Sensor or Computer (USB)
7) Battery Compartment (back side)
8) Sensing area (back side)
9) Connection to Control Unit

CONTROLLER SPECIFICATION

Parameter	Value	
Battery run time	>10	hrs
Temperature range	-25 to +60	°C
Memory size	2728	samples
Battery	3 x 1,5V	AAA cells*
Data download	via USB	
Display	102 x 64 px with backlight	

* We recommend using Energizer Ultimate Lithium or Varta Litium batteries for best performance at low temperatures.

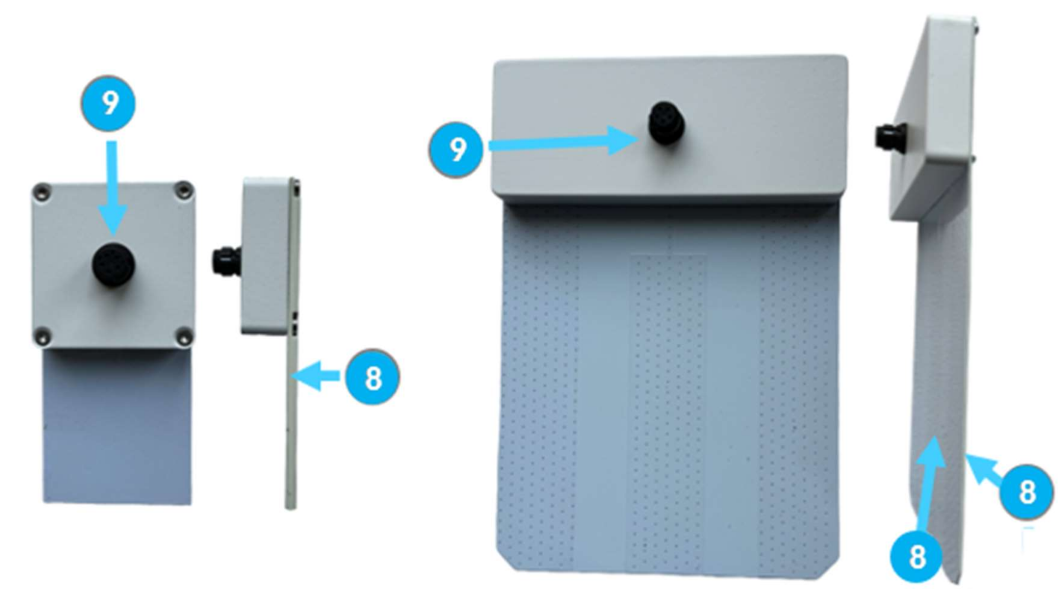
SENSOR WORKING PRINCIPLE

The SLF Snow Sensor device measures the density (ρ) or the liquid water content (LWC) of snow with a capacitive sensor, which generates an electrical field permeating the snow. Depending on the fractions of ice, air and water within the permeated snow volume, the measured capacitance changes, as ice, air and water have different dielectric properties. For dry snow (absence of liquid water) the snow density can be directly deduced. To determine the LWC, the ice fraction (dry snow density) of the snow must be known. Rather by a density measurement before the snow has started to melt or by approximation (e.g. for machine made snow). The capacitive sensor forms an oscillator together with a quartz crystal. A change of the capacitance forces a frequency change in the oscillator.

Below table shows the different types of snow sensors that are available. The SLF Snow Sensor -17 is applied on top of the snow and penetrating only 17 mm into the snow. On the other hand, the -4040 and -2525 sensors are inserted into the snow and penetrating into top and bottom direction and well suited for snow profile measurements.

SENSOR SPECIFICATION

SLF SnowPro	**-17**	**-4040**	**-2525**	
Snow density range	0..917	0..917	0..917	kg / m³
Snow moisture range	0..20	0..20	0..20	vol. %
Meas. Frequency	20	20	20	MHz
Application	Snow surface	Snow profiles	Snow profiles	
Measurement footprint	45 x 95	117 x 130	117 x 130	mm
Penetration depth	Bot: 17	Top/Bot: 40	Top/Bot: 25	mm
Measurement volume	72	1.216	608	cm³



SLF SNOWPRO-17

SLF SNOWPRO-4040
SLF SNOWPRO-2525

SENSOR CALIBRATION

<u>SLF SnowPro-4040 and SnowPro-2525</u>

These sensors are using the same dimensions and structure as the probes originally designed and studied by A. Denoth [1]. He obtained relations between permittivity ϵ and snow density ρ and liquid water content LWC that are well accepted in the researcher community. For snow profiles which are clearly below 0°C the density of dry snow ρ_{dry} is calculated using the following empirical formula (Denoth, 1989 [1]):

$$\rho\ [\mathrm{kg/m^3}] = \frac{1000}{0.88} \times \left(-1.92 + \sqrt{1.92^2 - 4 \times 0.44(1-\epsilon)}\right) \qquad (1)$$

For temperatures above 0°C LWC is calculated using below empiric formula (Denoth, 1989 [1]), including the average dry snow density ρ_{dry}:

$$\mathrm{LWC}\ [\mathrm{vol.\%}] = \frac{-0.206}{0.0092} \times \frac{\sqrt{0.206^2 - 4 \times 0.046 \times \left(0.44 \times \rho_{dry}{}^2 + 1.92 \times \frac{\rho_{dry}}{1000} + 1 - \epsilon\right)}}{0.092^2} \qquad (2)$$

The sensor is calibrated using an empiric ϵ - Δf relation from measurements on four materials (air ϵ_{air} = 1, polytetrafluoroethylene ϵ_{PTFE} = 2.1, polymethylmethacrylate ϵ_{PMMA} = 2.7 and phenolic resin $\epsilon_{PR} = 5.5$) with known permittivity. Calibration measurements at 0 °C and 27 °C revealed no relevant influence of temperature on the dielectric properties of the materials.

In [7] the SnowPro-4040 was compared against the original device from A. Denoth and snow cutter and found identical in terms of measurement accuracy and stability.

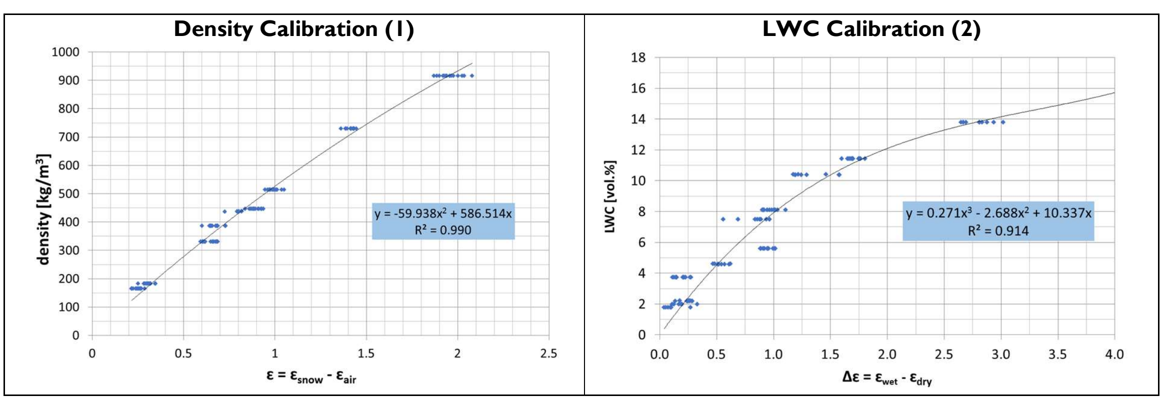
<u>SLF SnowPro-17</u>

Since this sensor has much different dimensions than the original sensor from A. Denoth and is only applied on top of the snow, we had to derive our own relations between permittivity ϵ and snow density ρ and liquid water content LWC.

As a first step measurements on materials with known dielectric properties (air, PTFE) provide the linear ε – Δf relation represented by the calibration factor *k*. Reference measurements (weighted volumes, LWC dilution method) on snow with varying densities and wetness give the ρ – ε relation function (Eq. 3) as well the LWC – Δε relation function (Eq. 4) expressing the increase of ε by liquid water within snow of a certain density.

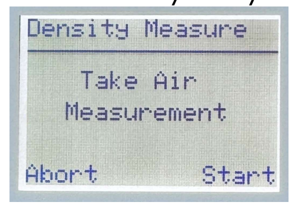
$$\rho\ [\mathrm{kg/m^3}] = -59.938\ \varepsilon^2 + 586.514\ \varepsilon \qquad (3)$$

$$\mathrm{LWC}\ [\mathrm{vol.\%}] = 0.271\ \Delta\varepsilon^3 - 2.688\ \Delta\varepsilon^2 + 10.337\ \Delta\varepsilon \qquad (4)$$



SNOW DENSITY MEASUREMENT

0) Verify the absence of liquid water in the snow (T_{snow} < 0 °C). The density measurement works only for dry snow.



FOLLOW THE DENSITY MEASUREMENT MENU:

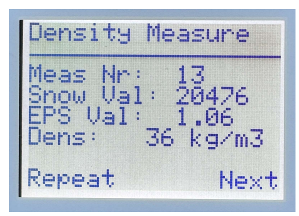
1) Start “Density” menu

2) Air measurement: Make sure the sensor is clean of water droplets or snow and is not hold at the capacitors area. Start the measurement by pressing the ENTER button.

3) Snow measurement using SnowPro-17: Use a scrapper like tool to flatten uneven snow surfaces. Put (don’t press) the sensor on a flat snow surface and start the measurement by pressing the ENTER button. Due to the inherent variability of the snow density but also due to imperfections of the snow surface preparation, at least 3 to 5 repetitions are recommended.

   Snow measurement using SnowPro-4040 or -2525: Insert the snow sensor into the snow. The enclosure acts as a stopper and must not be forced into the snow. Make sure that when using the -4040 sensor that the snow layer surrounding the sensor is at least 40 mm thick, ideally 60-80 mm to avoid any influence from wet soil or air. For the -2525 sensor the snow layer thickness should be at least 25 mm.

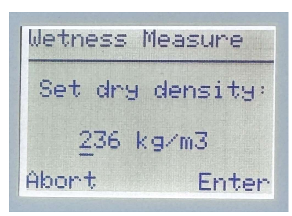
   Prevent the sensor of heating up causing melting while in contact with the snow.



4) Save measurement: After snow measurement is confirmed, the density value is immediately calculated based on ρ – ε relation that is stored in each snow sensor. Each measurement is assigned to a constantly increased measurement number that is stored in memory and can be transferred over USB to the computer. The remaining memory space is shortly displayed after the measurement is saved. For consecutive measurements the device uses the same air value until the density measurement menu is left. Pressing the repeat button, the snow measurement will be repeatetd and overwritten.

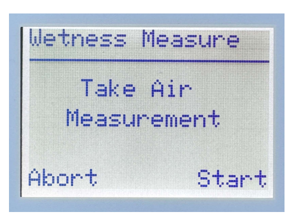
SNOW MOISTURE MEASUREMENT (LIQUID WATER CONTENT)

0) Verify the possible existence of liquid water in the snow (T_{snow} = 0 °C).



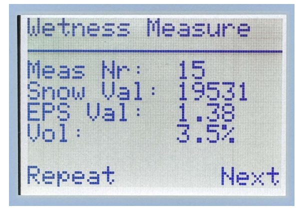
FOLLOW THE LWC MEASUREMENT MENU:

1) Start “Wetness LWC” menu



2) To calculate the LWC value it is required to know the dry snow density which describes the fraction of ice in a wet snow volume. Therefore, the first step is to enter the snow density. The snow density value can be either derived by
   a. performing a measurement forehand (e.g. early morning) if T_{snow} < 0 °C
   b. manually entering a value for the density that can be an estimate or from reported values for typical snow types in the literature [e.g. Fierz et al., 2009; Wolfsperger et al., 2018].

c. or calculated based on measuring the weight of a well-defined snow volume. This will introduce a small error since measuring the weight also includes the weight of the water. Since the ε of water (~90) is much larger than that of ice (~3), measured LWC is largely dominated by water content rather than snow density. E.g. at LWC = 14% snow density is overestimated by 30% resulting in ε_{snow_dry} increase of just 0.3. Optionally, the obtained LWC value can be used to manually calculate the mass of water and in multiple iterations an accurate density estimation can be obtained.



3) Follow the on-screen guidance to measure the air and snow values. Start the measurement by pressing the ENTER button and follow the same procedure as for the dry snow measurement regarding sensor handling. Prevent the sensor of heating up causing additional melting while in contact with the snow. The LWC value is immediately calculated based on LWC – Δε relation that is stored in each snow sensor using the previosuly entered snow density.

CONFIGURATION MENU

Show Info

Displays information regarding control unit and snow sensor:

1) Software version of control unit. “512k” refers to the non-volatile memory size and results in 2728 samples. The first batch of controllers are supplied with 64k memory and therefore store only 340 samples.
2) Serial number of snow sensor
3) Firmware-Version of snow sensor
4) Snow sensor calibration values
5) Current date and time that is used for timestamps. Can be changed if during power-up the POWER button is pressed.

Enter Mess Nr

Allows to set the continuously increase measurement number to any value

Service

Service menu to set calibration constants of snow sensor and LWC- / density relation functions. Only accessible with password.

TX Over USB

See below

DATA TRANSFER TO COMPUTER

1) Disconnect snow sensor

2) Go to Config Menu and start “TX over USB”

3) Connect USB adapter cable between computer and control unit.

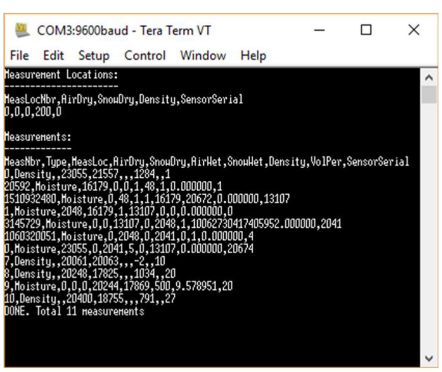
4) On Windows Computer:

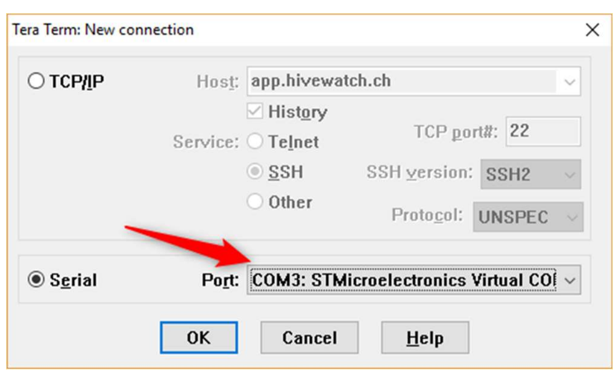
a. Windows 10 should recognize "STMicroelectronics Virtual COM Port" and start installing driver if not already present. For old Windows versions driver can be downloaded on [ST.com website](ST.com).
b. Open Terminal Window (e.g. Tera Term) and connect to virtual COM port.
c. Press "Start TX" Button.

5) On Apple Computer:
   a. MacOSX recognizes virtual COM port without any extra driver.
   b. Open terminal application.
   c. Check if the device is visible to your computer. The name is always "usbmodem???".
      $ ls -l /dev/.usb**
      crw-rw-rw- 1 root wheel 21, 11 Oct 23 09:24 /dev/cu.usbmodemFD131
      crw-rw-rw- 1 root wheel 21, 10 Oct 23 09:24 /dev/tty.usbmodemFD131
   d. Now open the "tty" device for the transfer.
      $ screen /dev/tty.usbmodemFD131
   e. Press "Start TX" Button
   f. The data are transferred now and shown on the terminal.

6) On Linux Computer:
   a. Open terminal and check if the device is visible:
      *sudo ls -la /dev/tty**
   b. The most recent device belongs to the sensor, e.g.
      0 crw-rw---- 1 root 166, 0 Jan 22 16:32 /dev/ttyACM0
   c. Make sure you have the following line in your ~/.screenrc configuration file, it will prevent the screen window to shutdown as the process terminates (either variant will work based on your Linux configuration):
      Variant A: *zombie kr*
      Variant B: *termcapinfo * ti=:te=*
   d. Open the device for transfer
      sudo screen /dev/ttyACM0
   e. Press "Start TX" Button
   f. The data are transferred now and shown on the terminal.

7) Copy and paste comma delimited data to spreadsheet (e.g. Excel).
8) After USB download memory can be deleted if desired and measurement index set back to zero.





LITERATURE

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[7] Wolfsperger, F., Geisser, M., Ziegler, S., Löwe, H., 2023: A NEW HANDHELD CAPACITIVE SENSOR TO MEASURE SNOW DENSITY AND LIQUID WATER CONTENT, International Snow Science Workshop 2023 at Bend, Oregon, US.

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