Starting up and operating the soil moisture sensor PMD EM M-30 LR

User manual

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1 For your safety

Read this manual carefully and keep it for future reference.

1.1 Identification of warning notes

This symbol indicates hazards that could lead to personal injury.

There are three signal words indicating the severity of a potential injury.

DANGER
Indicates a hazard with a high risk level. If this hazardous situation is not avoided, it will result in death or serious injury.

WARNING
Indicates a hazard with a medium risk level. If this hazardous situation is not avoided, it could result in death or serious injury.

CAUTION
Indicates a hazard with a low risk level. If this hazardous situation is not avoided, it could result in minor or moderate injury.

This symbol together with the **NOTE** signal word warns the reader of actions that might cause property damage or a malfunction.

Here you will find additional information or detailed sources of information.

1.2 Qualification of users

The use of products described in this manual is oriented exclusively to qualified application programmers and software engineers. The users must be familiar with the relevant safety concepts of automation technology as well as applicable standards and other regulations.

1.3 Field of application of the product

1.3.1 Intended use

The soil moisture sensor measures the volumetric water content in the soil. To do this, the measuring probes of the sensor are inserted into the soil.

As a LoRaWAN® device, the soil moisture sensor is designed for use in a LoRaWAN® network. The sensor transmits the acquired measured data via a wireless LoRa® interface to a LoRaWAN® gateway.

1.3.2 Product changes

Modifications to hardware and firmware of the device are not permitted.

Incorrect operation or modifications to the device can endanger your safety or damage the device. Do not repair the device yourself. If the device is defective, please contact Phoenix Contact.

1.4 Safety notes

- Observe the country-specific installation, safety, and accident prevention regulations.

WARNING: Risk of injury from measuring probes
There is a risk of injury if you fall onto or trip over the sensor measuring probes.

- Do not put the sensor down with the measuring probes facing upwards.

NOTE: Electrostatic discharge
Electrostatic discharge can damage or destroy components. When handling the device, observe the necessary safety precautions against electrostatic discharge (ESD) in accordance with EN 61340-5-1 and IEC 61340-5-1.

1.5 Legal notes

LoRaWAN® and LoRa® are marks used under license from the LoRa Alliance®.

2 Description of the soil moisture sensor

2.1 General description

The soil moisture sensor measures the volumetric water content in the soil and provides the measured value as a percentage. In addition, a temperature sensor is integrated in the sensor head, which measures the temperature near the soil. The measured values are made available via a LoRaWAN® network.

Selecting the location and determining the soil type

Before mounting and starting up the sensor, you must select a location with good connectivity to the LoRaWAN® gateway.

Determining the soil type at the selected location is required for parameterizing the sensor.

Information on location selection and soil type determination can be found in Section 3.

To parameterize the sensor, select a predefined soil type that is most similar to the soil type at your location. An overview of the predefined soil types can be found in “Soil texture triangle” on page 11. The exact compositions of the predefined soil types are listed in Section “Appendix: Soil types” on page 27.

Parameterizing the sensor

In order to parameterize the sensor for the relevant soil type, an input payload for the predefined soil types is available on the LoRaWAN® server application. The payload is downloaded via the LoRaWAN® network and transmitted to the sensor.

For information on sensor parameterization, please refer to Section 6.

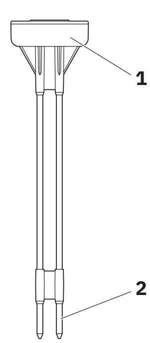
Decoding the measured data

The acquired measured data is transmitted to the LoRaWAN® network via an uplink. For decoding the measured data, a JavaScript file is available that can be integrated in your LoRaWAN® server application.

Information on decoding can be found in Section 7.

2.2 Components of the device

Figure 2-1 Components of the device



1 Sensor head (with integrated temperature sensor)

2 Measuring probes

3 Selecting the location and determining the soil type

3.1 Selecting the location for the sensor

Size and heterogeneity of the area

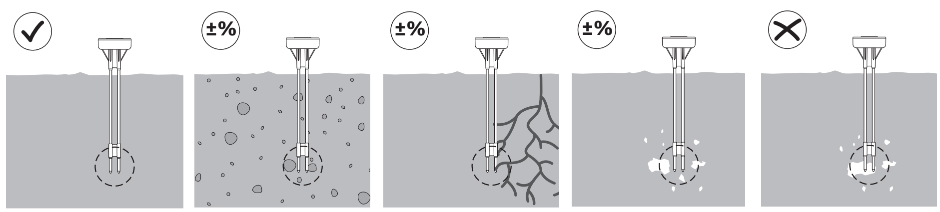
When selecting a location, please note that geographical features such as slopes or dips influence the water content of the soil, even if the area consists of the same type of soil.

However, larger areas may also have different types of soil.

If you want to monitor the soil moisture of a larger area, we therefore recommend using multiple sensors at different locations across the area.

Measurements can be impaired by stones, roots, or entrapped air in the soil. If you use multiple sensors in the same soil type and acquire significantly different measured data for a sensor, move this sensor to another position.

Figure 3-1 Stones, roots, or air at the measuring probes

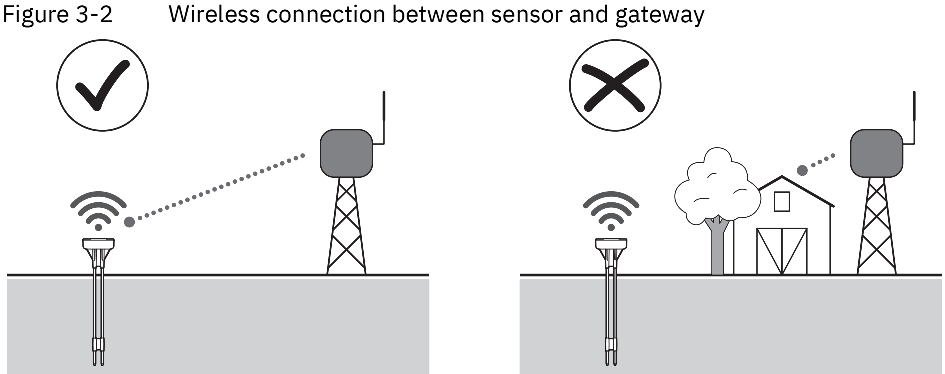


Pure soil | Stones | Roots | Air (around the probes) | Air (directly at the probes)

Connectivity in the LoRaWAN® network

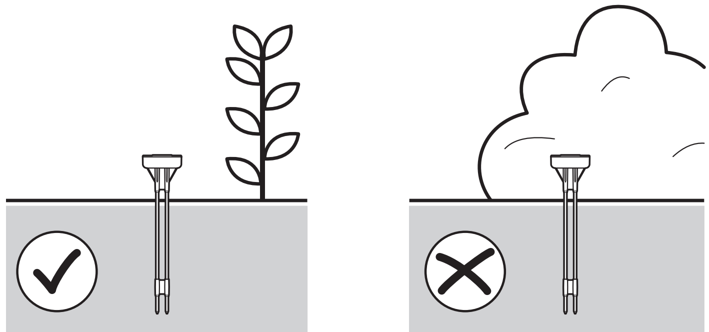
The sensor communicates the measured data via a wireless LoRa® interface to a LoRaWAN® gateway. There should be a clear line of sight between the sensor and the antenna of the gateway. Buildings, trees, or similar between the sensor and gateway can affect the wireless signal.

Figure 3-2 Wireless connection between sensor and gateway



Even smaller plants and leaves next to or above the sensor can affect the wireless signal. If the sensor has problems establishing the wireless connection, increase the distance between the sensor and the plant so that nothing is in the way above the sensor.

Figure 3-3 Free-standing sensor



In the event of a poor wireless connection, it can also be helpful to increase the distance between the soil and the sensor head. However, make sure that the sensor is still secure in the soil and stable. See Figure 4-3.

3.2 Determining the soil type at the location

The water retention capacity of the soil depends to a large extent on the soil type, i.e., the grain size composition of the soil. It is therefore important to determine the soil type at the sensor location and to parameterize the sensor accordingly.

If you do not know the soil type at the sensor location, there are several options for determining it:

- Professional laboratory analysis of the soil.
- Various tests you can perform yourself. Instructions on how to do this can be found on the Internet.
- Using the soilgrids.org website of the International Soil Reference and Information Center (ISRIC).

Soil texture triangle

The soil texture triangle on page 11 shows different predefined soil types. To parameterize the sensor, select the soil type shown in the soil texture triangle that comes closest to your soil type.

Ideal soil moisture range

Each type of soil has its ideal moisture range in which sufficient water is available for the plants.

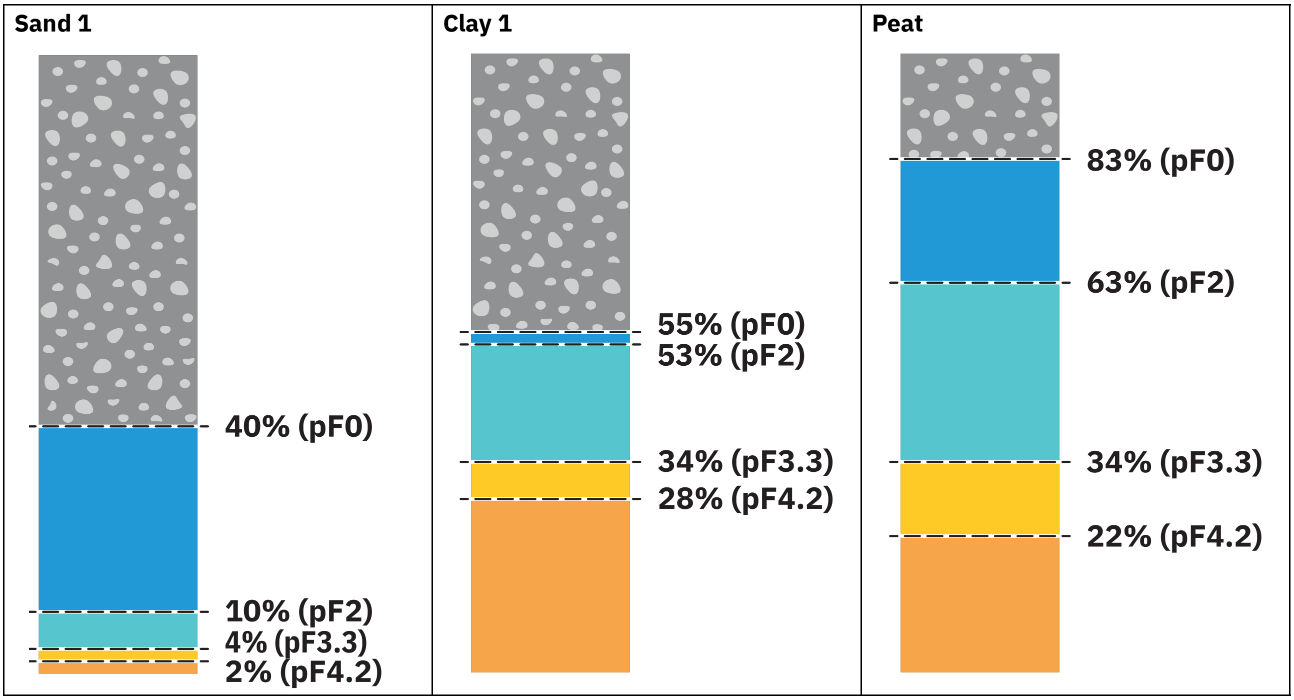
The upper limit of this ideal range is indicated by the field capacity (pF2). Above the field capacity, overwatering occurs; this washes out nutrients and deprives the plant roots of air. At the saturation point (pF0), all pores of the soil are filled with water.

The lower limit value of the ideal range is the watering point (pF3.3). Below the watering point, there is not enough water available to the plants. Below the permanent wilting point (pF4.2), the plants will wilt irreversibly.

Figure 3-4 uses the example of sand 1, clay 1, and peat to determine the limit values for the relevant soil type.

The percentages in the figure indicate the volumetric water content (VWC) and correspond to the limit values for each soil type.

Figure 3-4 Soil moisture limits of different soil types



Key:

pF0	Saturation point
	Too wet
pF2	Field capacity
	Healthy
pF3.3	Watering point
	Stress
pF4.2	Permanent wilting point
	Too dry

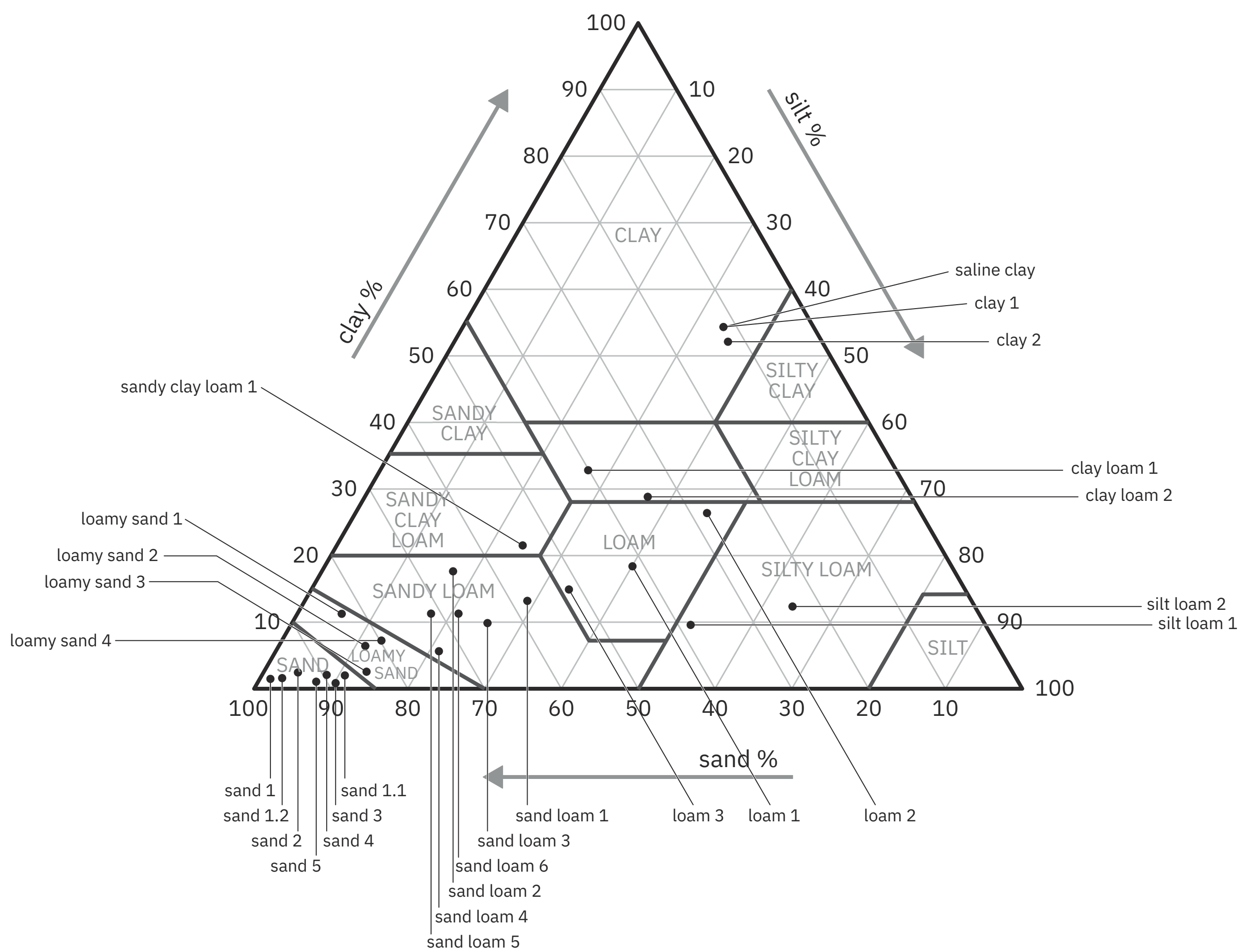
For the required limit values of all soil types shown in the triangle, please refer to "Appendix: Soil types".

3.3 Selecting the soil type for parameterization

The soil texture triangle in Figure 3-5 shows different soils according to their grain size composition, i.e., the content of clay, silt, and sand.

- To parameterize the sensor, select the soil type from the soil texture triangle that comes closest to the soil at your sensor location.

Figure 3-5 Soil texture triangle



The soil types shown are based on the soil texture classifications of the U.S. Department of Agriculture (USDA). On the USDA website, you can download the soil texture calculator, which you can use to locate your soil composition in the triangle: www.nrcs.usda.gov

The description of the shown soil types with their properties and necessary parameters can be found in “Appendix: Soil types”.

Additional soil types

The following soils are not listed in the soil texture triangle, but are still available as parameterizable soil types:

– Peat, coco peat, mineral wool, substrate with vegetable carbon, see page 33

4 Startup

Requirements for startup:

– You have determined a location for the sensor that provides good connectivity to the LoRaWAN® gateway.
– You have determined the soil type at the location.
– You have access to your LoRaWAN® server application.

For sensor installation, you need the following:

– The sensor
– If necessary, a mobile device with a GPS receiver for recording the position data at the sensor location
– For hard soil, a rubber hammer and/or a shovel, if necessary

4.1 Safety notes

- Observe the country-specific installation, safety, and accident prevention regulations.

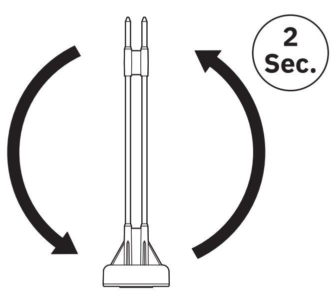
WARNING: Risk of injury from measuring probes
There is a risk of injury if you fall onto or trip over the sensor measuring probes.
- Do not put the sensor down with the measuring probes facing upwards.

4.2 Activating the sensor

- To activate the sensor, turn it upside down for two seconds.

↪ The built-in motion sensor activates the sensor and therefore connection establishment to the LoRaWAN® network.

Figure 4-1 Activating the sensor

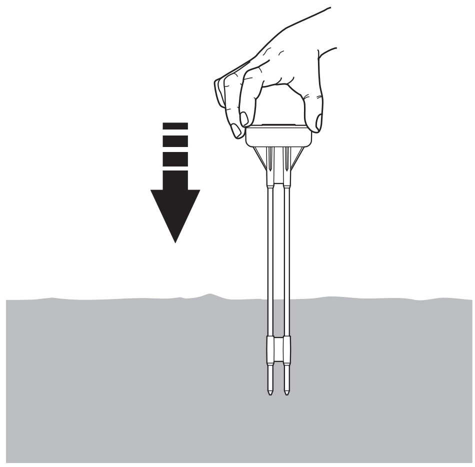


In normal operation, the sensor performs a measurement once an hour and sends the data to the gateway.

After one hour, you can check whether the first measured data has been sent to the network. In individual cases, however, this can take up to 48 hours.

4.3 Installing the sensor

Figure 4-2 Installing the sensor



In the event of soft soil:

- Insert the measuring probes of the sensor into the ground.

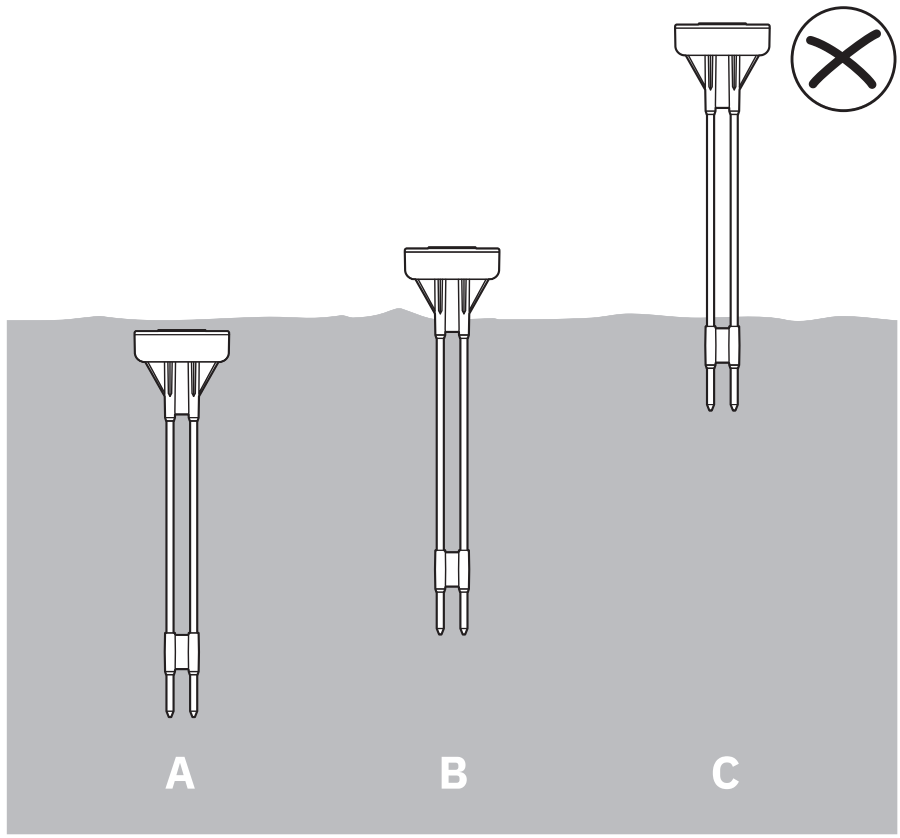
In the event of hard soil:

- If the top layer of the soil is dried out or stony, remove a few centimeters of the soil until you reach softer, moister soil.
- Then insert the sensor into the ground or, if necessary, carefully hit it in using a rubber hammer.
  (!) **NOTE:** To avoid damaging the sensor, make sure that the sensor head is hit in the center and do not use a metal hammer.

In the event of very hard soil:

- If the soil is still too hard after removing the upper layer, dig a hole that is slightly wider and deeper than the sensor.
- Loosen the removed earth and pour it back into the hole.
- Lightly press the loosened earth back on with your hands or feet.
- Then insert the sensor into the loosened soil.
  (i) It may take some time until the loosened earth has the properties of the surrounding soil again.

Figure 4-3 Installation depth of the sensor in the soil



Limited connectivity possible

Recommended installation depth

Too high (unstable)

NOTE: Damage to sensor
If mechanical harvesting is to be carried out, remove the sensor from the soil first.

Recommended:
If you want to integrate the exact location data of the sensor into your application, use a mobile device with a GPS receiver to acquire the location.

4.4 Registering the sensor with the LoRaWAN® server

The sensor is registered with the LoRaWAN® server using over-the-air activation (OTAA).

Unique key

Each sensor has unique keys that are required for the activation process and for registering the device with the LoRaWAN® server:

– DevEUI
– AppEUI
– AppKey

Please note:
The keys that are actually required depend on the LoRaWAN® server used. If you use the LPWAN service from Phoenix Contact, you only need DevEUI and AppKey.

The required keys can be found on the label provided with the device packaging. There is also a QR code printed on the label. When you read the QR code, the unique keys of the device are displayed.

NOTE: Unauthorized access
The keys are printed on the label in plain text. Unauthorized persons can use the keys to intercept the LoRaWAN® connection of the device or to redirect the device to another LoRaWAN® server.

- Make sure that only authorized persons have access to the keys.
- Keep the label in such a way that it is protected against unauthorized access.

Figure 4-4 Example of label with device-specific keys

Entering the keys on the server

- Enter the required keys of the sensor in the corresponding input fields on the LoRaWAN® server.
- Apply your entries.

↪ The sensor is now registered as a LoRaWAN® device with the LoRaWAN® server.

Now you can parameterize the sensor.

5 Relative soil moisture values

Uncalibrated data

The sensor is not parameterized for a specific soil type in its delivery state. It provides uncalibrated data, which can nevertheless provide insights into the behavior of soil moisture.

For example, you can observe relative changes in soil moisture values or compare the data with other data sources that also provide relative data.

However, note the following limitation: In the uncalibrated state, the sensor only provides relative values in the range from 0 to 100. These values are not directly related to the volumetric moisture content. The variation in the values between two measurements can be very low for certain soils or situations. For example, the difference between a dry and a wet soil can result in a difference of just 5 points.

In order to obtain precise data, it is therefore important to determine the soil type and to parameterize the sensor accordingly. The parameterization is described in Section 6.

Restoring the delivery state

If you want to reset the sensor to the delivery state after parameterization, use the payload 030000000000000000_{hex} for sensor parameterization.

6 Parameterization

In general, the sensor works in all types of soil. However, in order to obtain the most accurate measured data possible, you must determine the soil type at the selected sensor location and parameterize the sensor accordingly.

The parameterization can be transmitted using a payload from the LoRaWAN® server to the sensor via a downlink. A payload in hexadecimal format is available for each predefined soil types.

You will find the soil-specific payloads for parameterization in “Appendix: Soil types”.

Requirement for parameterization:

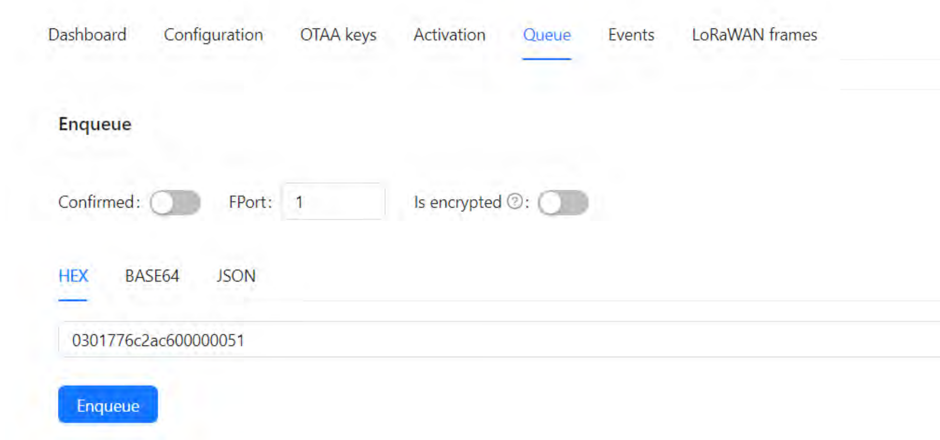
– The sensor is registered with the LoRaWAN® server, see Section 4.4.

To parameterize the sensor, proceed as follows:

- Open your LoRaWAN® server application.
- Send the payload to the sensor via **FPort1** and a downlink.

Figure 6-1 shows an example entry of a soil type-specific payload on a ChirpStack V4-based LoRaWAN® server.

Figure 6-1 Example: Entering a payload



Please note the method of operation of class A sensors:
Under certain circumstances, it may take more than an hour until the sensor transmits the first measured data via an uplink to the LoRaWAN® network. The sensor is a class A LoRaWAN® device and transmits data once an hour by default. A class A sensor can only receive a downlink within a specific time slot directly after an uplink. This means that the first uplink always contains measured data from the unparameterized delivery state of the sensor and the sensor can only receive the parameterization in the following downlink time slot.

For decoding of the measured data, a JavaScript file is available, see “Decoding the measured data” on page 19. Alternatively, you can manually decode the measured data.

7 Decoding the measured data

The uplink payload of the sensor always consists of 9 bytes (72 bits) and is sent via FPort 11.

It contains the following data:

– 6 soil moisture measurements as volumetric water content in % (current measurement plus 5 previous, stored measurements)
– The current temperature at the sensor head
– A flag that indicates that the saturation point (pF0) has been exceeded.
  ℹ The volumetric water content of a soil cannot be higher than the saturation point. If the measured water content is higher than the saturation point, an error in the parameterization is likely.

There are two options for decoding the uplink payload:

1. "Decoding with JavaScript file" on page 20
2. "Decoding without JavaScript file" on page 22

7.1 Decoding with JavaScript file

A decoder in the form of a JavaScript file is available for decoding the measured data transmitted by the sensor via an uplink.

The file can be found under “Downloads” on the product page:

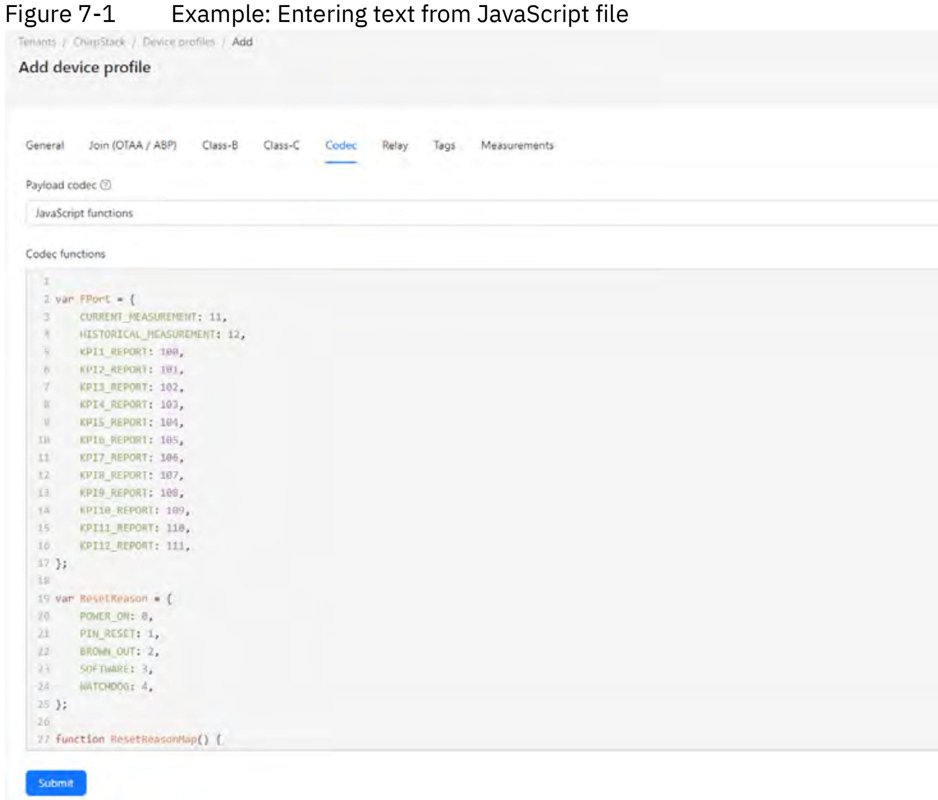
www.phoenixcontact.com/product/1646045.

To integrate the decoder in your LoRaWAN® server application, proceed as follows:

- Download the “Decoder.js” file.
- Open the file in a text editor and copy the complete text from the file to the clipboard.
- On the LoRaWAN® server, add the text in the corresponding area and confirm the entry.

For ChirpStack-based LoRaWAN® servers, for example, this is the “Codec” area in the corresponding device profile, see Figure 7-1.

Figure 7-1 Example: Entering text from JavaScript file



Example of an uplink payload:

Example: Uplink payload	Description
▸ txInfo: {} 3 keys adr: true dr: 5 fCnt: 48 fPort: 11	
data: "U0whhRRSSOEf" ▾ objectJSON: {} 4 keys ▾ data: {} 2 keys ▾ readings: [] 7 items	data: Coded payload
▾ 0: {} 4 keys error_flag: false type: "volumetric_moisture" unit: "%" value: 8.3	0: Current soil moisture measurement (t)
▾ 1: {} 4 keys error_flag: false type: "volumetric_moisture" unit: "%" value: 8.3	1: Previous measurement (t-1)
▾ 2: {} 4 keys error_flag: false type: "volumetric_moisture" unit: "%" value: 8.2	2: Measurement (t-2)
▾ 3: {} 4 keys error_flag: false type: "volumetric_moisture" unit: "%" value: 8.2	3: Measurement (t-3)
▾ 4: {} 4 keys error_flag: false type: "volumetric_moisture" unit: "%" value: 8.2	4: Measurement (t-4)
▾ 5: {} 4 keys error_flag: false type: "volumetric_moisture" unit: "%" value: 8.2	5: Measurement (t-5)
▾ 6: {} 4 keys error_flag: false type: "temperature" unit: "°C" value: 21	6: Temperature in the sensor head
saturation_point_overshot: false errors: null type: "Measurement" warnings: null	saturation _point_overshot: Flag for current measurement

7.2 Decoding without JavaScript file

The uplink payload of the sensor is structured as follows:

Table 7-1 Structure of the uplink payload

Total data length	Position	Length (bit)	Value range	Resolu-tion	Description
9 bytes (72 bits)	0	10	0 … 100	0.1	Current soil moisture measurement (t) in %
	10	10	0 … 100	0.1	Previous measurement (t-1) in %
	20	10	0 … 100	0.1	Measurement (t-2) in %
	30	10	0 … 100	0.1	Measurement (t-3) in %
	40	10	0 … 100	0.1	Measurement (t-4) in %
	50	10	0 … 100	0.1	Measurement (t-5) in %
	60	10	-30 … 70	0.1	Temperature in °C
	70	1	0 … 1	1	Parameter error (saturation point exceeded)
	71	1	0 … 1	1	Reserved

Representation of measured values

Table 7-2 Volumetric water content (positions 0 … 50; 10 bits each)

dec	hex	bin	Measured value in %
0	0	0	0
333	14D	0101001101	33.3
666	29A	1010011010	66.6
1000	3E8	1111101000	100
1001 … 1022	3E9 … 3FE	-	Reserved
1023	3FF	1111111111	Read error

Table 7-3 Temperature (position 60; 10 bits)

dec	hex	bin	Measured value in °C (offset -30 K)
0	0	0	≤ -30
1	001	0000000001	-29.9
250	0FA	0011111010	-5
300	12C	0100101100	0
600	258	1001011000	30
1020	3FC	1111111100	72
1021	3FD	1111111101	> 72
1022	3FE	1111111110	Reserved
1023	3FF	1111111111	Read error

Table 7-4 Parameter error (position 70; 1 bit)

bin	Meaning
0	Saturation point not exceeded
1	Saturation point exceeded (parameter error)

Example of decoding an uplink payload

Table 7-5 Example: Decoding an uplink payload

Uplink payload									Data
65 5A E6 BA 28 8A 13 04 B0 hex									Length: 9 bytes (72 bits)
0110 0101 0101 1010 1110 0110 1011 0101 0010 1000 1000 1010 0001 0011 0000 0100 1011 0000 bin									
0110010101	0110101110	0110101110	1000101000	1000101000	0100110000	0100101100	0	0	
195	1AE	1AE	228	228	260	12C	0	0	hex
405	430	430	552	552	608	300	0	0	dec
40.5	43.0	43.0	55.2	55.2	60.8	0	0	0	Measured value
Measured value 1 (current (t))	Measured value 2 (t-1)	Measured value 3 (t-2)	Measured value 4 (t-3)	Measured value 5 (t-4)	Measured value 6 (t-5)	Tempera-ture (offset -30)	Parameter error	Reserved	Meaning
Volumetric water content									

8 Maintenance, storage, and disposal

8.1 Maintenance

NOTE: Damage to sensor
If mechanical harvesting is to be carried out, remove the sensor from the soil first.

Removing the sensor

- Pull the sensor out of the soil.

Cleaning the sensor

- You can clean the sensor, if required and after use:
  - Use an alcoholic cleaning agent for the measuring probes.
  - You can clean the sensor head with soap.

8.2 Decommissioning and storage

- If the sensor is not in use, remove it from the soil, see “Removing the sensor”.
- Store the sensor in a cool and dry place.

If the sensor does not detect any soil over a longer period of time, it is set to storage mode. In storage mode, the sensor only performs one measurement per day. This protects the battery.

As soon as the sensor detects a resistance during the daily measurement, it is reactivated and performs one measurement once an hour. Alternatively, you can reactivate the sensor as described in Section “Activating the sensor”.

Please note:
If the LoRaWAN® gateway is not operating, the sensor should also be stopped, otherwise the sensor will continue to attempt to establish a LoRa® wireless connection. This would use battery of the sensor unnecessarily and shorten the battery service life.

8.3 Disposal

Device disposal

The symbol with the crossed-out trash can indicates that this item must be collected and disposed of separately from other waste. Phoenix Contact or public collection sites will take the item back for free disposal. For information on the available disposal options, visit phoenixcontact.com.

Disposing of the packaging

- Dispose of packaging materials that are no longer needed (cardboard packaging, paper, bubble wrap sheets, etc.) with household waste in accordance with the currently applicable national regulations.

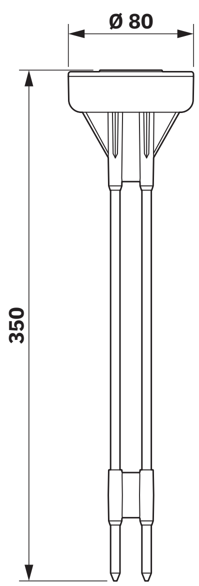
9 Ordering data and technical data

9.1 Ordering data

Description	Type	Item no.	Pcs./Pkt.
Soil moisture sensor, LoRaWAN® device (class A), measuring depth: 30 cm, volumetric water content in %, degree of protection: IP67	PMD EM M-30 LR	1646045	1

9.2 Technical data

Dimensions	



Height	350 mm
Diameter	80 mm

General data	
Weight	265 g
Degree of protection	IP67

Ambient conditions	
Ambient temperature (operation)	-20 °C ... 60 °C

Supply: Battery	
Battery type	Lithium battery
Battery voltage	3 V
Service life of battery	5 years ... 8 years (at a transmission speed of 1 x per hour)

Sensor characteristics: Soil moisture sensor	
Measuring depth	30 cm
Measuring volume	6.2 cm^3
Measured value representation	Volumetric water content (VWC%)
Measured value resolution	up to 0.1% accuracy
Measuring range	From 0% to 100%, where 100% represents the maximum water capacity of the soil in relation to the total volume. The maximum value is e.g., 53% for clay or 40% for sand.
Tolerance, relative	± 1.5 %
Measured value memory	yes (6 measurements)

Sensor characteristics: Temperature sensor	
Measured value resolution	up to 0.1°C accuracy
Measuring range	-30 °C ... 70 °C

Wireless interface	
Number	1
Frequency	868 MHz (Europe EU868)
Wireless standard	LoRaWAN®
Frequency range	863 MHz ... 870 MHz
Transmission power	≤ 14 dBm
Transmission physics	LoRa®
Class	A
Transmission rate	1x per hour (Default)
Security	128-bit AES encryption
Protocols supported	LoRaWAN® 1.0.4 (ADR and OTAA-capable)

Approvals and manufacturer's declarations	
The latest documents can be found at:	www.phoenixcontact.com/product/1646045

A Appendix: Soil types

In this section, you will find the following details for each soil type shown in the soil texture triangle on page 11:

- Composition of the soil type
- Payload for parameterization of the sensor
- Volumetric water content (VWC) at the following limit values:
  - Saturation point (pF0)
  - Field capacity (pF2)
  - Watering point (pF3.3)
  - Wilting point (pF4.2)

In addition, the following soils, which are not shown in the soil texture triangle, are listed on page 33:

- Peat
- Coco peat
- Mineral wool
- Substrate with vegetable carbon

A 1 Clay and saline clay

Table A-1 Composition and payload

Composition	Clay 1	Clay 2	Saline clay
Clay	55%	53%	55%
Silt	35%	36%	35%
Sand	10%	11%	10%
Organic material	0%	12.4%	0%
Salt content, EC	-	-	5 mS/cm[1]
Payload (hex)	03012468acc4333be052	03018a6bb0c400000053	On request

1 Salt content of 5 mS/cm corresponding to highly saline watering or intensive use of fertilizers

Table A-2 Volumetric water content (VWC)

Limit value		VWC in %		
		Clay 1	Clay 2	Saline clay
pF0	**Saturation point**	55	56	55
pF2	**Field capacity**	53	50	53
pF3.3	**Watering point**	34	40	34
pF4.2	**Wilting point**	28	34	28

A 2 Sandy clay loam

Table A-3 Composition and payload

Composition	Sandy clay loam 1
Clay	20%
Silt	26%
Sand	53%
Organic material	12.2%
Payload (hex)	030122607ec10000a052

Table A-4 Volumetric water content (VWC)

Limit value		VWC in %
		Sandy clay loam 1
pF0	**Saturation point**	53
pF2	**Field capacity**	43
pF3.3	**Watering point**	31
pF4.2	**Wilting point**	25

A 3 Clay loam

Table A-5 Composition and payload

Composition	Clay loam 1	Clay loam 2
Clay	32%	29%
Silt	28%	38%
Sand	40%	33%
Organic material	0.2%	4.1%
Payload (hex)	03014d64fbc300008052	03019264cdc49a404052

Table A-6 Volumetric water content (VWC)

Limit value		**VWC in %**	
		Clay loam 1	**Clay loam 2**
pF0	**Saturation point**	52	50
pF2	**Field capacity**	46	40
pF3.3	**Watering point**	38	30
pF4.2	**Wilting point**	30	20

A 4 Loam

Table A-7 Composition and payload

Composition	Loam 1	Loam 2	Loam 3
Clay	19%	26%	15%
Silt	41%	47%	33%
Sand	40%	28%	52%
Organic material	12.1%	3%	2.6%
Payload (hex)	0301b45faac22a4a0053	030170681fc4333b0052	On request

Table A-8 Volumetric water content (VWC)

Limit value		**VWC in %**		
		Loam 1	**Loam 2**	**Loam 3**
pF0	**Saturation point**	55	48	48
pF2	**Field capacity**	45	38	34
pF3.3	**Watering point**	32	23	18
pF4.2	**Wilting point**	25	16	12

A 5 Sandy loam

Table A-9 Composition and payload

Composition	Sandy loam 1	Sandy loam 2	Sandy loam 3	Sandy loam 4	Sandy loam 5	Sandy loam 6
Clay	13%	17%	10%	7%	11%	11%
Silt	28%	18%	26%	18%	15%	21%
Sand	59%	65%	64%	75%	74%	68%
Organic material	2.3%	7.2%	3.2%	4.4%	6.8%	26%
Payload (hex)	On request	0301706526c4d93c0052	030170704dc5cd3c0052	0301c06ed1c400008051	03011d6b7ac40000e051	0301f4601fc2b9460054

Table A-10 Volumetric water content (VWC)

Limit value		VWC in %					
		Sandy loam 1	Sandy loam 2	Sandy loam 3	Sandy loam 4	Sandy loam 5	Sandy loam 6
pF0	**Saturation point**	47	48	48	44	47	64
pF2	**Field capacity**	33	36	33	28	33	49
pF3.3	**Watering point**	16	22	16	13	18	34
pF4.2	**Wilting point**	9	17	10	8	12	26

A 6 Loamy sand

Table A-11 Composition and payload

Composition	Loamy sand 1	Loamy sand 2	Loamy sand 3	Loamy sand 4
Clay	12%	3%	2%	7%
Silt	6%	14%	13%	12%
Sand	82%	83%	85%	81%
Organic material	0.6%	2.5%	3.2%	4.9%
Payload (hex)	On request	0301c7668fc300006051	030171665ac300006051	03010a6926c400008051

Table A-12 Volumetric water content (VWC)

Limit value		**VWC in %**			
		Loamy sand 1	**Loamy sand 2**	**Loamy sand 3**	**Loamy sand 4**
pF0	**Saturation point**	39	43	43	44
pF2	**Field capacity**	18	22	23	27
pF3.3	**Watering point**	6	8	8	12
pF4.2	**Wilting point**	3	4	4	7

A 7 Sand

Table A-13 Composition and payload

Composition	Sand 1	Sand 1.1	Sand 1.2	Sand 2	Sand 3	Sand 4	Sand 5
Clay	1%	0%	0%	2%	1%	1%	1%
Silt	1%	12%	2%	6%	12%	9%	10%
Sand	91%	88%	98%	92%	87%	90%	89%
Organic material	0%	0%	0%	0.9%	5.7%	12%	7.7%
Payload (hex)	0301177b0ac700000051	0301e37bd5c500000051	On request	On request	On request	0301cc5cdcc100008052	03013261bdc100002052

Table A-14 Volumetric water content (VWC)

Limit value		VWC in %						
		Sand 1	Sand 1.1	Sand 1.2	Sand 2	Sand 3	Sand 4	Sand 5
pF0	**Saturation point**	40	40	40	40	47	**52**	**49**
pF2	**Field capacity**	10	10	10	10	28	36	31
pF3.3	**Watering point**	4	4	4	4	11	18	13
pF4.2	**Wilting point**	2	2	2	2	6	12	8

A 8 Silt loam

Table A-15 Composition and payload

Composition	Silt loam 1	Silt loam 2
Clay	9%	12%
Silt	51%	65%
Sand	40%	23%
Organic material	2.4%	4.7%
Payload (hex)	03011f7033c500006051	On request

Table A-16 Volumetric water content (VWC)

Limit value		VWC in %	
		Silt loam 1	Silt loam 2
pF0	**Saturation point**	43	49
pF2	**Field capacity**	32	39
pF3.3	**Watering point**	15	21
pF4.2	**Wilting point**	9	14

A 9 Peat, coco peat, mineral wool, substrate with vegetable carbon

Table A-17 Composition and payload

Composition	Peat	Coco peat	Mineral wool	Substrate with vegetable carbon
Clay	0%	0%	0%	8%
Silt	0%	0%	0%	32%
Sand	0%	0%	0%	60%
Organic material	100%	100%	0%	2%
Payload (hex)	030142698ac300003055	03010a6b33c40000a055	0301d4788bc60000f055	0301f565c0c40041a051

Table A-18 Volumetric water content (VWC)

Limit value		VWC in %			
		Peat	Coco peat	Mineral wool	Substrate with vegetable carbon
pF0	**Saturation point**	83	89	95	45
pF2	**Field capacity**	63	75	74	30
pF3.3	**Watering point**	34	32	8	13
pF4.2	**Wilting point**	22	23	7	7

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