

# apogee<sup>®</sup>

## INSTRUMENTS

OWNER'S MANUAL

# TEROS 12 SOIL MOISTURE SENSOR WITH MODBUS OUTPUT

Model: TEROS12-MB

Rev: 29-Dec-2025



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# DECLARATION OF CONFORMITY

## EU Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.  
721 W 1800 N  
Logan, Utah 84321  
USA

for the following product(s):

Models: TEROS12-MB  
Type: Soil Moisture Sensor

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Hazardous Substances (RoHS 2) Directive
2015/863/EU	Amending Annex II to Directive 2011/65/EU (RoHS 3)

Standards referenced during compliance assessment:

EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including lead (see note below), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), bis (2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP). However, please note that articles containing greater than 0.1 % lead concentration are RoHS 3 compliant using exemption 6c.

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but we rely on the information provided to us by our material suppliers.

Signed for and on behalf of:  
Apogee Instruments, October 2023



Bruce Bugbee  
President  
Apogee Instruments, Inc.



# DECLARATION OF CONFORMITY

## UK Declaration of Conformity

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Apogee Instruments, Inc.  
721 W 1800 N  
Logan, Utah 84321  
USA

for the following product(s):

Models: TEROS12-MB  
Type: Soil Moisture Sensor

The object of the declaration described above is in conformity with the relevant UK Statutory Instruments and their amendments:

2016 No. 1091	The Electromagnetic Compatibility Regulations 2016
2012 No. 3032	The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

Standards referenced during compliance assessment:

BS EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
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## INTRODUCTION

Volumetric Water Content (VWC) is the ratio of the volume of water to the total volume of a porous medium. It's a critical factor in plant growth, irrigation management, and environmental monitoring because it directly affects water availability, nutrient uptake, and soil health. Researchers, growers, and engineers may all track how much water is present in different soil layers over time.

Soil temperature influences underground biological and chemical processes, from root growth and nutrient uptake to microbial activity and decomposition. Tracking it helps researchers and growers understand how heat moves through the soil profile, evaluate plant stress, and manage conditions in both field and controlled environments.

Soil electrical conductivity (EC) reflects the concentration of dissolved ions in the soil solution, making it a useful indicator of salinity, fertilizer levels, and overall soil solution chemistry. EC sensors help identify zones with salt buildup, monitor nutrient movement under fertigation, and assess substrate performance in soilless systems.

The TEROS 12 combines moisture, temperature, and EC in a single probe. This provides a comprehensive view of the soil/porous growth medium being monitored. This sensor can be used to optimize irrigation and fertigation schedules, maintain consistent growing conditions, monitor soil water dynamics for hydrology studies, evaluate substrate performance in horticulture, optimize germination conditions, guide controlled climate strategies, and model soil energy balance. In research and production settings, EC data supports decisions about irrigation water quality, fertilizer dosing, and long-term soil health, helping prevent crop stress and maintain consistent growing conditions.

This sensor features a sealed epoxy body designed for durability in field environments and pointed, stainless steel needles that enable consistent soil contact during installation. Its 1.01 L volume of influence produces measurements representative of a soil zone — helpful when soil is spatially heterogeneous. The 70 MHz dielectric capacitance minimizes interference from soil salinity or texture. The sensor is built to be suitable for long-term deployment with minimal maintenance.

Apogee has made the TEROS 12 available with Modbus output. Rather than requiring a subscription to access data, Modbus communication protocol offers a straightforward way to stream calibrated measurements into controllers and data systems, making integration especially convenient for teams already using RS-232 or RS-485 networks. It supports multiple parameters on a single line, long cable runs, and provides noise-resistant communication in demanding environments.

Some information covered in this manual is from METER's TEROS 12 manual, which you can access at [https://publications.metergroup.com/Manuals/20587\\_TEROS11-12\\_Manual\\_Web.pdf](https://publications.metergroup.com/Manuals/20587_TEROS11-12_Manual_Web.pdf).

## THEORY

### Volumetric Water Content

TEROS 12 sensors use an electromagnetic field to measure the dielectric permittivity of the surrounding medium. The sensor supplies a 70-MHz oscillating wave to the sensor needles, which charge according to the dielectric of the material. The charge time is proportional to substrate dielectric, which is highly dependent on substrate VWC. The TEROS 12 microprocessor measures the charge time and outputs a raw value based on the substrate dielectric permittivity. The raw value is then converted to VWC by a calibration equation specific to the substrate, found in the Maintenance and Recalibration section).

### Temperature

The TEROS 12 uses a small thermistor mounted on the PCB near the lower needle. The TEROS 12 temperature measurement is optimized to be accurate when the TEROS 12 is fully buried in soil or substrate. Older models of TEROS 12 use a thermistor in the center needle to take temperature readings. The TEROS 12 sensors output temperature is in degrees Celsius unless otherwise stated in the data logger program.

### Electrical Conductivity

Electrical conductivity is the ability of a substance to conduct electricity and can be used to infer the amount of ions that are present in solution. EC is measured by applying an alternating electrical current to two electrodes and measuring the resistance between them. Bulk EC is derived by multiplying the inverse of the resistance (conductance) by the cell constant (the ratio of the distance between the electrodes to their area). TEROS 12 sensor bulk EC measurements are corrected to EC at 25 °C:

$$EC_{25} = \frac{EC_T}{1 + 0.019(T - 25)} \quad (1)$$

where

- $EC_{25}$  is the normalized EC at 25 °C
- $EC_T$  is the EC measured by the probe at temperature T
- T is the temperature at the time of measurement

The bulk EC measurement is factory calibrated to be accurate over the range found in the vast majority of soil and growth substrates.

EC measurements above 10 dS/m are sensitive to contamination of the electrodes by skin oils, etc. Follow cleaning instructions in the Maintenance and Recalibration section if measuring the EC of salty soils.

### Converting Bulk EC to Pore EC

For many applications, it is advantageous to know the EC of the solution contained in the soil pores ( $\sigma_p$ ), which is a good indicator of the solute concentration in the soil. Traditionally,  $\sigma_p$  is obtained by extracting pore water from the soil and measuring  $\sigma_p$  directly, a time consuming and labor-intensive process. The TEROS 12 sensor measures the EC of the bulk soil surrounding the sensors ( $\sigma_b$ ). A considerable amount of research has been conducted to determine the relationship between  $\sigma_b$  and  $\sigma_p$ . Hilhorst (2000) describes a linear relationship between  $\sigma_p$  and  $\sigma_b$  as

well as the soil bulk dielectric permittivity ( $\epsilon_b$ ). We use this relationship to convert  $\sigma_b$  to  $\sigma_p$ . The TEROS 12 sensor measures  $\epsilon_b$  and  $\sigma_b$  nearly simultaneously in the same soil volume. Therefore, the TEROS 12 is well suited to this method.

The pore water conductivity ( $\sigma_p$ ) is determined from this equation (see Hilhorst 2000 for derivation):

$$\sigma_p = \frac{\epsilon_p \sigma_b}{\epsilon_b - \epsilon_{\sigma_b=0}} \quad (2)$$

where

- $\sigma_p$  is the pore water EC (dS/m)
- $\epsilon_p$  is the real portion of the dielectric permittivity of the soil pore water (unitless)
- $\sigma_b$  is the bulk EC (dS/m) measured directly by the TEROS 12
- $\epsilon_b$  is the real portion of the dielectric permittivity of the bulk soil (unitless)
- $\epsilon_{\sigma_b=0}$  is the real portion of the dielectric permittivity of the soil when bulk EC is 0 (unitless)

METER testing indicates that the method for calculating  $\sigma_p$  results in good accuracy ( $\pm 20\%$ ) in moist soils and other growth media. In dry soils, where VWC is less than  $0.10 \text{ m}^3/\text{m}^3$ , the denominator of Equation 1 becomes very small, leading to potentially large errors. METER recommends that  $\sigma_p$  not be calculated in soils with  $\text{VWC} < 0.10 \text{ m}^3/\text{m}^3$  using this method.

Dielectric permittivity of the soil pore water ( $\epsilon_p$ ) is calculated from soil temperature using the following Equation:

$$\epsilon_p = 80.3 - 0.37 \times (T_{\text{soil}} - 20) \quad (3)$$

- where  $T_{\text{soil}}$  is the soil temperature (in Celsius) measured by the TEROS 12

Use Equation 8 (on page 18 in the Recalibration and Maintenance section) to calculate  $\epsilon_b$  from the raw sensor water content.

Finally,  $\epsilon_{\sigma_b=0}$  is an offset term loosely representing the dielectric permittivity of the dry soil. Hilhorst (2000) recommended that  $\epsilon_{\sigma_b=0} = 4.1$  be used as a generic offset. Hilhorst (2000) offers a simple and easy method for determining  $\epsilon_{\sigma_b=0}$  for individual soil types, which improves the accuracy of the calculation of  $\epsilon_p$  in most cases.

### Pore Water Versus Saturation Extract EC

As noted in above, pore water EC can be calculated from bulk EC using the sensor measured dielectric permittivity of the medium. However, pore water EC is not the same as saturation extract EC. Pore water EC is the EC of the water in the pore space of the soil. This is measured directly if the soil is placed under high pressure to force water out of the soil matrix. That water must be collected and tested for EC. Saturation extract EC is the EC of pore water removed from a saturated paste. Saturation extract EC can be measured directly if distilled water is used to wet the soil until the soil saturates. The soil is then placed on filter paper in a vacuum funnel and suction is applied. An EC measurement on the water extracted from the saturated sample will give the saturation extract EC. Theoretically, the pore water EC and saturation extract EC are related by the degree of saturation (VWC/total porosity) of the soil. The following example calculation illustrates this relationship:

*A soil is at  $0.1 \text{ m}^3/\text{m}^3$  VWC, has a pore water EC of  $0.7 \text{ dS/m}$ , and a dry bulk density of  $1.5 \text{ Mg/m}^3$ . The total porosity of the soil can be calculated using this equation:*

$$\begin{aligned}
 \phi &= 1 - \frac{\rho_b}{\rho_s} \\
 &= 1 - \frac{1.5}{2.65} \\
 &= 0.43
 \end{aligned}
 \tag{4}$$

The saturation extract EC can be calculated as illustrated below:

$$\begin{aligned}
 \text{Solution EC} &= \frac{\sigma_p \Theta + \sigma_d (\phi - \Theta)}{\phi} \\
 &= \frac{0.7(0.1) + 0}{0.43} \\
 &= 0.162
 \end{aligned}
 \tag{5}$$

Where

- $\phi$  is the porosity (unitless)
- $\rho_b$  is the soil dry bulk density ( $\text{Mg}/\text{m}^3$ )
- $\rho_s$  is the density of the minerals or particle density (assumed to be  $2.65 \text{ Mg}/\text{m}^3$ )
- $\sigma_p$  is the pore water EC ( $\text{dS}/\text{m}$ )
- $\sigma_d$  is the EC of distilled water ( $0 \text{ dS}/\text{m}$ )
- $\Theta$  is the VWC ( $\text{m}^3/\text{m}^3$ )

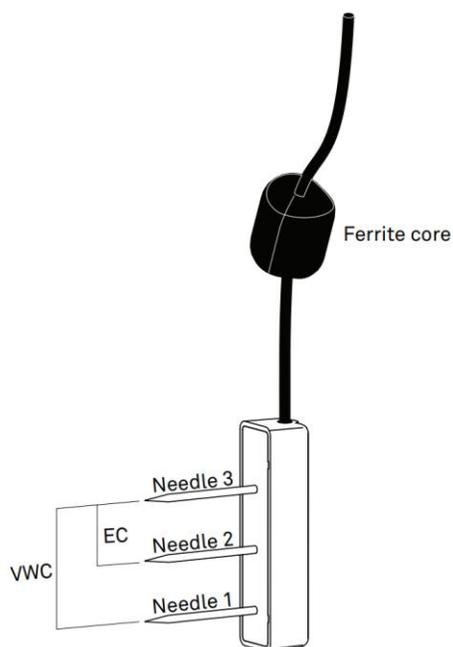
In practice, solution EC calculated from this method and solution EC taken from a laboratory soil test may not agree well because wetting soil to a saturated paste is very imprecise.

## SENSOR MODELS



A sensor's model number and serial number are located on a label near the pigtail leads on the sensor cable. If the manufacturing date of a specific sensor is required, please contact Apogee Instruments with the serial number of the sensor.

### Instrument Components



TEROS 11/12 sensors measure soil moisture by applying the 70 MHz signal to Needle 1 and using Needle 2 and Needle 3 as the reference for the measurement.

Temperature is measured with a thermistor on the PCB near needle 1.

EC is measured between Needle 2 and Needle 3

The ferrite core is positioned on the cable 7.6 cm (3 in) away from the sensor head. This isolates the sensor from any interference or noise in the system.

## SPECIFICATIONS

<b>TEROS12-MB</b>	
Input Voltage Requirement	5 to 24 V
RS-232 Current Draw	Minimum: 14.0 mA Typical: 14.6 mA Maximum: 37.0 mA
RS-485 Current Draw	Minimum: 9.0 mA Typical: 9.6 mA Maximum: 48.0 mA
Volumetric Water Content (VWC) Range	Mineral Soil Calibration: 0.00-0.70 m <sup>3</sup> /m <sup>3</sup> Soilless Media Calibration: 0.0-1.0 m <sup>3</sup> /m <sup>3</sup> Apparent Dielectric Permittivity ( $\epsilon_a$ ): 1 (air) to 80 (water)
VWC Resolution	0.0010 m <sup>3</sup> /m <sup>3</sup>
VWC Accuracy	Generic Calibration: $\pm 0.03$ m <sup>3</sup> /m <sup>3</sup> ( $\pm 3.00\%$ VWC) in mineral soils of solution EC <8,000 $\mu\text{S}/\text{cm}$ Medium Specific Calibration: $\pm 0.01$ – $0.02$ m <sup>3</sup> /m <sup>3</sup> in any porous medium Apparent Dielectric Permittivity ( $\epsilon_a$ ): 1–40 (soil range), $\pm 1 \epsilon_a$ (unitless) 40–80, 15% of measurement
Output	Modbus (RS-232 and RS-485)
Temperature Measurement Range	-40 to +60 °C
Temperature Accuracy	$\pm 1.0$ °C from -40 to 0 °C $\pm 0.5$ °C from 0 to +60 °C
Dielectric Measurement Frequency	70 MHz
Electrical Conductivity (EC) Accuracy	+/- (5% + 10 $\mu\text{S}/\text{cm}$ ) from 0–10,000 $\mu\text{S}/\text{cm}$ +/- 8% from 10,000–20,000 $\mu\text{S}/\text{cm}$
EC Resolution	0–20,000 $\mu\text{S}/\text{cm}$ (bulk)
EC Range	1 $\mu\text{S}/\text{cm}$
Volume of Influence	1010 mL
Measurement Duration	25 to 150 ms
Dimensions	Length: 9.4 cm (3.70 in) Width: 2.4 cm (0.95 in) Height: 7.5 cm (2.95 in), Needle Length: 5.5 cm (2.17 in)
Mass	
Operating Environment	-40 to +60 °C
Cable	5, 10, or 20 m of four conductor, shielded, twisted-pair wire; customized cable lengths available; TPR jacket (high water resistance, high UV stability, flexibility in cold conditions); pigtail lead wires

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## DEPLOYMENT AND INSTALLATION

### Installation Steps

Note: Do not touch the needles with an ungloved hand or bring them in contact with any source of oil or other nonconducting residue.

1. Create a hole to the desired installation depth.
2. In the sidewall of the hole, push the needles straight into the soil. Each needle should be horizontal to the ground (that way, the sensor body doesn't block water flow through the soil to the needles).
  - a. The sensor may be installed in any orientation along the Y axis. If the needles are aligned vertically, more soil depth is integrated in the soil moisture measurement. Aligning the needles horizontally provides measurements at a more discreet depth.
3. Plug the leads into your Modbus datalogger or controller. Check that the sensor is reading properly.
4. Return soil to the hole and pack it down to its native density. Be careful not to knock the sensor body or ferrite core, as that could loosen or remove it from its installed location.

### Best Practices

- Avoid large objects. Roots or rocks could potentially damage or bend the needles. Large rocks above the sensor location can also impact moisture reaching the needles compared to areas that are soil only, so keep that in mind when selecting a deployment location. The soil closest to the sensor has the strongest influence on readings, so install sensors in areas that well represent the soil you want to measure.
- Don't put metal between the sensor and the ferrite core (located on the cable 3 inches from the sensor). It can interfere with VWC measurement. Installation near large metal objects can also distort readings.
- Test the sensor before deployment in the field. To avoid inconvenience, there are a couple ways to double check sensor functionality prior to deployment. Plug the sensor into your measurement device to make sure it's functioning. To check that the sensor is reading within expected ranges, take a measurement in air and water. It should read around  $0.70 \text{ m}^3/\text{m}^3$  in water and a slightly negative value in air.
- Minimize air pockets around the sensor needles. Air gaps will result in low soil moisture readings. Avoid wiggling the sensor during installation, as that can widen the holes around the needles.
- Secure and protect cables. To minimize strain on connections, give the cables a little slack between the logger and the next secured point. Gather and secure excess cable. Protect cables with PVC casing or flexible conduits.
- Do not route a sensor cable along another sensor cable in the ground, as that can interfere with sensor readings. Sensors and ferrite cores should be at least 3 cm apart from each other. For best results, install sensors offset from each other instead of directly above and below each other.
- Even though the sensor head is white, in direct sunlight, the temperature measurement may read high. Take note of this when installing the sensor with the sensor head in the sun.

### Additional Information

There are many methods for digging to the installation depth. A shovel or excavator can be used to dig a trench. METER also offers borehole tool rentals that minimize soil disturbance at the measurement site. Visit <https://metergroup.com/products/teros-borehole-installation-tool/> to rent this tool.

## CABLE CONNECTORS

Apogee offers in-line cable connectors on some bare-lead sensors to simplify the process of removing sensors from deployment stations for calibration (the entire cable does **not** have to be removed from the station and shipped with the sensor).

The ruggedized M8 connectors are rated IP68, made of corrosion-resistant marine-grade stainless-steel, and designed for extended use in harsh environmental conditions.

### Instructions

**Pins and Wiring Colors:** All Apogee connectors have six pins, but not all pins are used for every sensor. There may also be unused wire colors inside the cable. To simplify datalogger connection, we remove the unused pigtail lead colors at the datalogger end of the cable.

If a replacement cable is required, please contact Apogee directly to ensure ordering the proper pigtail configuration.

**Alignment:** When reconnecting a sensor, arrows on the connector jacket and an aligning notch ensure proper orientation.

**Disconnection for extended periods:** When disconnecting the sensor for an extended period of time from a station, protect the remaining half of the connector still on the station from water and dirt with electrical tape or other method.

**Tightening:** Connectors are designed to be firmly finger-tightened only. There is an O-ring inside the connector that can be overly compressed if a wrench is used. Pay attention to thread alignment to avoid cross-threading. When fully tightened, 1-2 threads may still be visible.

Inline cable connectors are installed near the head



A reference notch inside the connector ensures proper alignment before tightening.



Finger-tighten firmly

## OPERATION AND MEASUREMENT

The TEROS12-MB utilizes Modbus output, where measurements are returned in digital format. This requires a measurement device with a Modbus interface that supports the Read Holding Registers (0x03) function.

### Wiring



The Green wire should be connected to Ground to enable RS-485 communication, or it should be connected to 12 V power for RS-232 communication. Text for the White and Blue wires above refers to the port that the wires should be connected to.

## Modbus Interface

The following is a brief explanation of the Modbus protocol instructions used in Apogee Teros12-MB sensors. For questions on the implementation of this protocol, please refer to the official serial line implementation of the Modbus protocol: [http://www.modbus.org/docs/Modbus\\_over\\_serial\\_line\\_V1\\_02.pdf](http://www.modbus.org/docs/Modbus_over_serial_line_V1_02.pdf) (2006) and the general Modbus protocol specification: [http://www.modbus.org/docs/Modbus\\_Application\\_Protocol\\_V1\\_1b3.pdf](http://www.modbus.org/docs/Modbus_Application_Protocol_V1_1b3.pdf) (2012). Further information can be found at: <http://www.modbus.org/specs.php>

### Overview

The primary idea of the Modbus interface is that each sensor exists at an address and appears as a table of values. These values are called Registers. Each value in the table has an associated index, and that index is used to identify which value in the table is being accessed.

### Sensor addresses

Each sensor is given an address from 1 to 247. Apogee sensors are shipped with a default address of 1. If using multiple sensors on the same Modbus line, the sensor's address will have to be changed by writing the Slave Address register.

### Register Index

Each register in a sensor represents a value in the sensor, such as a measurement or a configuration parameter. Some registers can only be read, some registers can only be written, and some can be both read and written. Each register exists at a specified index in the table for the sensor. Often this index is called an address, which is a separate address than the sensor address, but can be easily confused with the sensor address.

However, there are two different indexing schemes used for Modbus sensors, though translating between them is simple. One indexing scheme is called one-based numbering, where the first register is given the index of 1, and is thereby accessed by requesting access to register 1. The other indexing scheme is called zero-based numbering, where the first register is given the index 0, and is thereby accessed by requesting access to register 0. Apogee Sensors use zero-based numbering. However, if using the sensor in a system that uses one-based numbering, such as using a CR1000X logger, adding 1 to the zero-based address will produce the one-based address for the register.

### Register Format:

According to the Modbus protocol specification, Holding Registers (the type registers Apogee sensors contain) are defined to be 16 bits wide. However, when making scientific measurements, it is desirable to obtain a more precise value than 16 bits allows. Thus, several Modbus implementations will use two 16-bit registers to act as one 32-bit register. Apogee Modbus sensors use this 32-bit implementation to provide measurement values as 32-bit IEEE 754 floating point numbers.

Apogee Modbus sensors also contain a redundant, duplicate set of registers that use 16-bit signed integers to represent values as decimal-shifted numbers. It is recommended to use the 32-bit values, if possible, as they contain more precise values.

### Communication Parameters:

Apogee Sensors communicate using the Modbus RTU variant of the Modbus protocol. The default communication parameters are as follows:

Slave address: 1

Baudrate: 19200  
 Data bits: 8  
 Stop bits: 1  
 Parity: Even  
 Byte Order: Big-Endian (most significant byte sent first)

The baudrate and slave address are user configurable. **Valid slave addresses are 1 to 247. Since the address 0 is reserve as the broadcast address, setting the slave address to 0 will actually set the slave address to 1.**

## MODBUS REGISTERS

Note: Some integer registers return values that are scaled to maintain decimal precision. For example, a measurement normally expressed as 1.234 may be reported as 1234 (in other words, it was multiplied by 1000). In these cases, a scale factor is listed. Divide the received number by the listed factor to obtain the actual value.

Read Only Registers (function code 0x3)			
Float Registers		Integer Registers	
0	Calibrated Counts; Calibrated ADC counts for volumetric water content	50	Calibrated Counts; Calibrated ADC counts for volumetric water content
1			
2	Temperature °C Air temperature	51	Temperature °C Air temperature Factor: 10
3			
4	Electrical Conductivity $\mu\text{S}/\text{cm}$ Bulk electrical conductivity normalized to 25 °C	52	Electrical Conductivity $\mu\text{S}/\text{cm}$ Bulk electrical conductivity normalized to 25 °C
5			
6	VWCmineral	53	VWCmineral Factor: 1000
7			
8	VWCsoilless	54	VWCsoilless Factor: 1000
9			
10	VWCdielectric	55	VWCdielectric Factor: 1000
11			
12	Device status (1 means device is busy, 0 otherwise)	56	Device status (1 means device is busy, 0 otherwise)
13			
14	Firmware version	57	Firmware version Factor: 10
15			
16	Hardware version	58	Hardware version Factor: 10
17			
18	Sensor version	59	Sensor version Factor: 100
19			

Read/Write Registers (function codes 0x3 and 0x10)			
Float Registers		Integer Registers	
20	Slave address	60	Slave address
21			
22	Model number*	61	Model number*
23			
24	Serial number*	62	Serial number*
25			
26	baudrate (0 = 115200, 1 = 57600, 2 = 38400, <b>3 = 19200</b> , 4 = 9600) (Power Cycle Required after write)	63	baudrate (0 = 115200, 1 = 57600, 2 = 38400, <b>3 = 19200</b> , 4 = 9600) (Power Cycle Required after write)
27			
28	Parity (0 = none, 1 = odd, <b>2 = even</b> ) (Power Cycle Required after write)	64	Parity (0 = none, 1 = odd, <b>2 = even</b> ) (Power Cycle Required after write)
29			
30	Number of stopbits ( <b>1</b> or 2) (Power Cycle Required after write)	65	Number of stopbits ( <b>1</b> or 2) (Power Cycle Required after write)
31			

**\*Registers marked with an asterisk (\*) cannot be written to unless a specific procedure is followed. Contact Apogee Instruments to receive the procedure for writing these registers.**

#### Packet Framing:

Apogee sensors use Modbus RTU packets and tend to adhere to the following pattern:

Slave Address (1 byte), Function Code (1 byte), Starting Address (2 bytes), Number of Registers (2 bytes), Data Length (1 byte, optional) Data (n bytes, optional)

Modbus RTU packets use the zero-based address when addressing registers.

For information on Modbus RTU framing, see the official documentation at [http://www.modbus.org/docs/Modbus\\_Application\\_Protocol\\_V1\\_1b3.pdf](http://www.modbus.org/docs/Modbus_Application_Protocol_V1_1b3.pdf)

#### Example Packets:

An example of a data packet sent from the controller to the sensor using function code 0x3 reading register address 0. Each pair of square brackets indicates one byte.

[Slave Address][Function][Starting Address High Byte][Starting Address Low Byte][No of Registers High Byte][No of Registers Low Byte][CRC High Byte][CRC Low Byte]

0x01 0x03 0x00 0x00 0x00 0x02 0xC4 0x0B

An example of a data packet sent from the controller to the sensor using function code 0x10 writing a 1 to register 26. Each pair of square brackets indicates one byte.

[Slave Address][Function][Starting Address High Byte][Starting Address Low Byte][No of Registers High Byte][No of Registers Low Byte][Byte Count][Data High Byte][Data Low Byte][Data High Byte][Data Low Byte][CRC High Byte][CRC Low Byte]

0x01 0x10 0x00 0x1A 0x00 0x02 0x04 0x3f 0x80 0x00 0x00 0x7f 0x20

## MAINTENANCE AND RECALIBRATION

### Calibrations

Following is a list of the mineral soil, soilless media, and dielectric calibrations for TEROS 12, where  $\theta$  is the VWC (in  $\text{m}^3/\text{m}^3$ ), where  $\epsilon$  is dielectric, and where RAW is the raw sensor output.

The TEROS 12 is not sensitive to variation in soil texture and EC because it runs at a high measurement frequency. Therefore, its generic calibration equation should result in reasonable absolute accuracy;  $0.03 \text{ m}^3/\text{m}^3$  for most mineral soils up to 8 dS/m saturation extract. Its calibration equations are shown below for mineral soil, soilless growing media (i.e., potting soil, perlite, or peat moss), and dielectric permittivity. However, for added accuracy, customers are encouraged to perform soil specific calibrations.

For calibration services, visit <https://metergroup.com/resources/services/custom-calibration/>

### Calibration for Mineral Soils

According to METER tests, a single calibration equation will generally suffice for most mineral soil types with ECs from 0 dS/m to 8 dS/m saturation extract. VWC ( $\theta$ ) is given below:

$$\theta \left( \frac{\text{m}^3}{\text{m}^3} \right) = 3.879 \times 10^{-4} \times \text{RAW} - 0.6956 \quad (6)$$

A linear equation is used for the mineral soil calibration because it provides the best predictions of VWC in the range of VWC found in mineral soils, but this equation reaches a maximum at approximately  $0.70 \text{ m}^3/\text{m}^3$  in pure water. To display data on a scale from 0 to  $1.0 \text{ m}^3/\text{m}^3$ , VWC should be modeled with a quadratic equation (which would result in  $1.0 \text{ m}^3/\text{m}^3$  in water). However, METER does not recommend this for mineral soils because it often makes the calibration in the range of VWC found in mineral soil less accurate.

### Calibration for Soilless Media

TEROS 12 sensors are calibrated in potting soil, perlite, and peat. The goal is to create a generic calibration equation that will work in many non soil substrates with an accuracy of better than  $0.05 \text{ m}^3/\text{m}^3$ . For higher accuracy, performing a media-specific calibration should improve the accuracy to  $0.01$  to  $0.02 \text{ m}^3/\text{m}^3$ . The differences between mineral soil and soilless media calibrations are caused by high-air volume in the organic soils that lowers the starting (dry media) dielectric of the sensor. The calibration for several potting soils, perlite, and peat moss is shown below:

$$\theta \left( \frac{\text{m}^3}{\text{m}^3} \right) = 6.771 \times 10^{-10} \times \text{RAW}^3 - 5.105 \times 10^{-6} \times \text{RAW}^2 + 1.302 \times 10^{-2} \times \text{RAW} - 10.848 \quad (7)$$

### Apparent Dielectric Permittivity

Apparent dielectric permittivity ( $\epsilon_a$ ) can be used to determine VWC using external published equations such as the Topp equation (Topp et al. 1980). Dielectric permittivity is also used for calculating pore water EC. Dielectric permittivity is given by the equation below:

$$\epsilon = (2.887 \times 10^{-9} \times \text{RAW}^3 - 2.080 \times 10^{-5} \times \text{RAW}^2 + 5.276 \times 10^{-2} \times \text{RAW} - 43.39)^2 \quad (8)$$

**Cleaning**

If the sensor needles become contaminated with oils from contact with skin or another source, it is necessary to clean the needles to ensure accurate EC readings in salty soils with bulk EC greater than 10 dS/m. Do not touch the needles with an ungloved hand or bring them in contact with any source of oil or other nonconducting residue.

1. Clean each needle using a mild detergent such as liquid dish soap and a nonabrasive sponge or cloth. Avoid detergents that contain lotions or moisturizers.
2. Rinse the sensor and needles thoroughly with tap or deionized (DI) water.

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## TROUBLESHOOTING AND CUSTOMER SUPPORT

### Independent Verification of Functionality

If the sensor does not communicate with the datalogger, use an ammeter to check the current drain. It should be near 37 mA when the sensor is powered. Any current drain significantly greater than approximately 37 mA indicates a problem with power supply to the sensors, wiring of the sensor, or sensor electronics.

### Compatible Measurement Devices (Dataloggers/Controllers/Meters)

Any datalogger or meter with RS-232/RS-485 that can read/write float or integer values.

An example datalogger program for Campbell Scientific dataloggers can be found on the Apogee webpage at <http://www.apogeeinstruments.com/downloads/#datalogger>.

### Earth Ground

All Apogee sensors use shielded cable to minimize electromagnetic interference. For best communication, the shield wire must be connected to an earth ground. This is particularly important when using the sensor with long lead lengths in electromagnetically noisy environments.

### RS-232 Cable Length

If using an RS-232 serial interface, the cable length from the sensor to the controller should be kept short, no longer than 20 meters. For more information, see section 3.3.5 in this document:

[http://www.modbus.org/docs/Modbus\\_over\\_serial\\_line\\_V1\\_02.pdf](http://www.modbus.org/docs/Modbus_over_serial_line_V1_02.pdf)

### RS-485 Cable Length

If using an RS-485 serial interface, longer cable lengths may be used. The trunk cable can be up to 1000 meters long. The length of cable from the sensor to a tap on the trunk should be short, no more than 20 meters.

### Using Separate Power and Communication Devices

In differential signaling, a sufficiently high or low voltage must be reached in order to be detected as a valid signal. If there is not a common ground between the power and communication source when using RS-485, those thresholds may not be met. If you experience communication issues while using this set up, bridge a ground wire between the Modbus device and the communication system.

Similarly, if there is no ground connection between devices when using RS-232, there may still be communication failures. If this occurs, establish a ground connection between the sensor and the host device.

### Sensor Reading Too Low

- Check for air gaps around sensor needles. These could be produced below the surface of the substrate when the needle contacts a large piece of material and pushes it out of the way, or if the sensor is not inserted perfectly linear.
- Ensure the needles are not in contact with or very close to large, non-soil objects, like a plant pot wall.
- Ensure the calibration equation being used is appropriate for the media type. There are significant differences between substrate calibrations, so be sure to use the one specific to the substrate.

### Sensor Reading Too High

- Check to make sure that the media was not packed excessively or insufficiently during sensor installation. Higher density can cause sensor reading to be elevated.
- Ensure the calibration equation being used is appropriate for the media type. There are significant differences between calibrations, so be sure to use the one most suitable to the substrate, or consider developing a substrate-specific calibration for the particular medium.
- Some substrates have an inherently high dielectric permittivity (soils of volcanic origin or high titanium, for instance). If the substrate has a dry dielectric permittivity above 6, a custom calibration may need to be performed. Soils with a bulk EC greater than 10 dS/m require substrate specific calibrations (see the Maintenance and Recalibration section).

### Modbus Tips

- Make sure to use the green wire to select between RS-232 and RS-485.
- Make sure that the sensor is wired correctly (refer to wiring diagram).
- Make sure the sensor is powered by a power supply with a sufficient output (e.g., 12 V).
- Make sure to use the appropriate kind of variable when reading Modbus registers. Use a float variable for float registers and an integer variable for integer registers.
- Make sure the baudrate, stop bits, parity, byte order, and protocols match between the control program and the sensor. Default values are:
  - Baudrate: 19200
  - Stop bits: 1
  - Parity: Even
  - Byte order: ABCD (Big-Endian/Most Significant Byte First)
  - Protocol: RS-232 or RS-485

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## RETURN AND WARRANTY POLICY

### RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

### WARRANTY POLICY

#### What is Covered

All products manufactured by Apogee Instruments are warranted to be free from defects in materials and craftsmanship for a period of four (4) years from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated by Apogee.

Products not manufactured by Apogee are covered for a period of one (1) year, which applies to the following products:

- PS-series spectroradiometers
- MS-100 InSight
- SS-110 and SS-120 spectroradiometers
- MC-100 chlorophyll content meters
- EE08-SS humidity probes
- Brackets, rods, leveling plates, and adapters

Third-party accessories—like batteries, fans, and splitters—carry the original manufacturer’s warranty. **The Teros 12 comes with a 3 year warranty, the original manufacturer's warranty.**

Sensor wands have a 30-day warranty.

#### What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation, use, or abuse.
2. Operation of the instrument outside of its specified operating range.
3. Natural occurrences such as lightning, fire, etc.
4. Unauthorized modification.
5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

#### Who is Covered

This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

### What Apogee Will Do

At no charge Apogee will:

1. Either repair or replace (at our discretion) the item under warranty.
2. Ship the item back to the customer by the carrier of our choice. (If the customer elects to use different or expedited shipping methods, it will be at the customer's expense.)

### How To Return an Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise Authorization (RMA) number from our technical support department by submitting an online RMA form at [www.apogeeinstruments.com/tech-support-recalibration-repairs/](http://www.apogeeinstruments.com/tech-support-recalibration-repairs/). We will use your RMA number for tracking of the service item. Call (435) 245-8012 or email [techsupport@apogeeinstruments.com](mailto:techsupport@apogeeinstruments.com) with questions.
2. For warranty evaluations, send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration. **Note:** *When sending back sensors for routine calibration that have Apogee's standard stainless-steel connectors, you only need to send the sensor with the 30 cm section of cable and one-half of the connector. We have mating connectors at our factory that can be used for calibrating the sensor.*
3. Please write the RMA number on the outside of the shipping container.
4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.

**Apogee Instruments, Inc.**  
**721 West 1800 North Logan, UT**  
**84321, USA**

5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation to the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

## PRODUCTS BEYOND THE WARRANTY PERIOD

For issues with sensors beyond the warranty period, please contact Apogee at [techsupport@apogeeinstruments.com](mailto:techsupport@apogeeinstruments.com) to discuss repair or replacement options.

## OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of data, loss of wages, loss of time, loss of sales, accrual of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the

International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot be transferred or assigned. If any provision of this limited warranty is unlawful, void, or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

This warranty cannot be changed, assumed, or amended by any other person or agreement.

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## REFERENCES

Hilhorst, M. A. 2000. "A Pore Water Conductivity Sensor." *Soil Science Society of America Journal* 64, no. 6:1922–1925.

METER Group, Inc. 2018-2025. "TEROS 11/12 Manual."  
[https://publications.metergroup.com/Manuals/20587\\_TEROS11-12\\_Manual\\_Web.pdf](https://publications.metergroup.com/Manuals/20587_TEROS11-12_Manual_Web.pdf)

Topp, G. Clarke, J.L. Davis, and A. Peter Annan. 1980. "Electromagnetic Determination of Soil Water Content: Measurement in Coaxial Transmission Lines." *Water Resources Research* 16, no.3: 574–582.