

EC-5

Soil Moisture Sensor

Operator's Manual



Decagon Devices, Inc.

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1 Introduction

Thank you for choosing Decagon's EC-5 Volumetric Water Content sensor. This manual can help you understand the sensor features and ensure successful sensor operation. We hope you find the contents of this manual useful in understanding your instrument and maximizing its benefit to you.

There are several ways to contact Decagon if you ever need assistance with your product, have any questions, or feedback. Decagon has Customer Service Representatives available to speak with you Monday through Friday, between 7am and 5pm Pacific time.

Note: If you purchased your sensor through a distributor, please contact them for assistance.

Email:

support@decagon.com or **sales@decagon.com**

Phone:

509-332-5600

Fax:

509-332-5158

If contacting us by email or fax, please include as part of your message your instrument serial number, your name, address, phone, fax number, and a description of your problem or question.

Please read these instructions before operating your sensor to ensure that it performs to its full potential.

1.1 Warranty

The sensor has a 30-day satisfaction guarantee and a one-year warranty on parts and labor. Your warranty automatically validates upon receipt of the instrument.

1.2 Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from the date of receipt of equipment.

Note: We do not consider the results of ordinary wear and tear, neglect, misuse, accident as defects.

The Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts "freight on board" the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

2 About EC-5

The EC-5 determines volumetric water content (VWC) by measuring the dielectric constant of the media using capacitance and frequency domain technology. The 70 MHz frequency minimizes salinity and textural effects, making this sensor accurate in almost any soil or soilless media. It arrives with factory calibration for mineral soils, potting soils, rockwool, and perlite included in this Operator's Manual.

The two-prong design and higher measurement frequency allows the EC-5 to measure VWC from 0 to 100% (VWC of saturated soils is generally 40 to 60% depending on the soil type) and allows accurate measurement of all soils and soilless medias with a wide range of salinities.

2.1 Specifications

Measurement Time: 10 ms (milliseconds)

Accuracy: at least $0.03 \text{ m}^3/\text{m}^3$ typical soils, up to 8 dS/m
With soil-specific calibration: $\pm 0.02 \text{ m}^3/\text{m}^3$ ($\pm 2\%$)

Resolution: $0.001 \text{ m}^3/\text{m}^3$ VWC in mineral soils, 0.25% in growing media

Power Requirements: 2.5 VDC to 3.6 VDC @ 10 mA

Output: 10 to 40% of excitation voltage (250 to 1,000 mV at 2,500 mV excitation)

Operating Environment: 0 to 50°C ¹

Range of Measurement: 0 to 100%

Sensor dimensions: $8.9 \text{ cm} \times 1.8 \text{ cm} \times 0.7 \text{ cm}$

Connector Types: 3.5 mm (stereo) plug or stripped & tinned lead wires (Pigtail)

¹Sensors can be used at higher temperatures under certain conditions. Please contact Decagon for assistance.

Cable Length: 5 m standard; custom cable lengths up to 40 m available upon request

Data logger Compatibility (not exclusive):

- Decagon: Em50, Em50R, and Em50G
- Campbell Scientific: Any logger with serial I/O (CR10X, CR850, 1000, 3000, etc.)

3 Installing the Sensors

When selecting a site for installation, it is important to remember that the soil adjacent to the sensor surface has the strongest influence on the sensor reading and that the sensor measures the volumetric water content.

Therefore any air gaps or excessive soil compaction around the sensor can profoundly influence the readings. Also, do not install the sensors adjacent to large metal objects such as metal poles or stakes. This can attenuate the sensors electromagnetic field and adversely affect output readings. Because the EC-5 has gaps between its prongs, it is also important to consider the size of the media you are inserting the sensor into. It is possible to get sticks, bark, roots or other material stuck between the sensor prongs, which will adversely affect readings. Finally, be careful when inserting the sensors into dense soil, as the prongs will break if excessive sideways force is used when pushing them in.

Installation Procedure

When installing the EC-5, it is best to maximize contact between the sensor and the soil.

- If you are installing sensors in a lightning prone area with a grounded data logger, please see our Application Note at www.decagon.com/lightning.
- Decagon advises that you test the sensors with your data logging device and software before going to the field.

The EC-5 sensor was designed for easy installation into the soil. After digging a hole to the desired depth, push the prongs on the sensor into undisturbed soil at the bottom of the hole or into the sidewall of the hole. Make sure that the prongs and black overmolding are buried completely as shown below. *Note: The sensor may be difficult to insert into extremely compact or dry soil. If you have difficulty inserting the sensor, try loosening the soil somewhat or wetting the soil. Never pound the sensor into the soil*

Carefully backfill the hole to match the bulk density of the surrounding soil. Be careful not to bend the black overmolding connecting the sensor to the cable.

To watch a video on proper installation of the sensor go to www.decagon.com/install.

Orientation

The sensor can be oriented in any direction. However, orienting the flat side perpendicular to the surface of the soil will minimize effects on downward water movement.

Removing the Sensor

When removing the sensor from the soil, do not pull it out of the soil by the cable! Doing so may break internal connections and make the sensor unusable.

3.1 Wiring



Figure 1: 3.5 mm Stereo Plug

The following software support the EC-5 sensor:

- ECH2O Utility 1.12 or greater
- ECH2O DataTrac 2.77 or greater

Connecting to a non-Decagon Logger

Customers may purchase EC-5 sensors for use with non-Decagon data loggers. These sensors typically come configured with stripped and tinned (pigtail) lead wires for use with screw terminals. Refer to your distinct logger manual for details on wiring. Our Integrator's Guide gives detailed instructions on connecting the EC-5 sensor to non-Decagon loggers. Please visit www.decagon.com/support/literature for the complete Integrator's Guide.



Figure 2: Pigtail End Wiring

Pigtail End Wiring

Connect the wires to the data logger as Figure 3 shows, with the supply wire (white) connected to the excitation, the analog out wire (red) to a analog input, the bare ground wire to ground as illustrated in Figure 2.

Note: The acceptable range of excitation voltages is from 2.5 to 3.6 VDC.

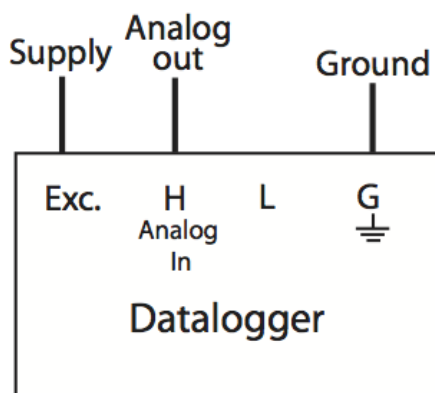


Figure 3: Connections

If your EC-5 is equipped with the standard 3.5 mm plug and you want to connect it to a non-Decagon data logger, you have two options. First, you can clip off the plug on the sensor cable, strip and tin the wires, and wire it directly into the data logger. This has the advantage of creating a direct connection with no chance of the sensor becoming unplugged; however, it cannot be easily used in the future with a Decagon readout unit or data logger.

The other option is to obtain an adapter cable from Decagon. The 3-wire sensor adapter cable has a connector for the sensor jack on one end, and three wires on the other end for connection to a data logger (this type of wire is often referred to as a “pigtail adapter”). Both the stripped and tinned adapter cable wires have the same termination as seen above; the white wire is excitation, red is output, and the bare wire is ground.

4 Connecting Sensors

Decagon designed the EC-5 sensor for use with our Em50 series data loggers, the Em5b data loggers, or the ProCheck handheld reader. The standard sensor (with a 3.5 mm “stereo plug” connector) quickly connects to and is easily configured within a Decagon logger or ProCheck.

The EC-5 sensor incorporates several features that also make it an excellent sensor for use with third party loggers. Customers may purchase the sensor with stripped and tinned wires (pigtail) for terminal connections.

The EC-5 sensor comes standard with a five meter cable. Customers may purchase sensors with custom cable lengths for an additional fee (on a per-meter fee basis). Obtaining custom length cables eliminates the need for splicing the cable (a possible failure point). The EC-5 is accurate with cable lengths up to 40 m.

Connecting to an Em50/Em50R Logger/Em50G/em5b

Decagon designed the EC-5 to work specifically with the Em50 data logger. Simply plug the 3.5 mm stereo plug connector directly into one of the five sensor ports. Next, configure the logger port for the EC-5 and set the measurement interval.

Connecting to ECH2O Utility

Please check your software version to ensure it will support the EC-5. To update your software to the latest version, please visit Decagon’s software download site at www.decagon.com/support/downloads.

Note: You must use the ECH2O Utility, DataTrac 3 or a terminal program on your computer to download data from the logger to your computer.

5 Collecting Data

5.1 Data Logger Requirements

The EC-5 sensor is designed to work most efficiently with Decagon's 5-channel Em5b, Em50, or ProCheck handheld readout. All Decagon readout devices use a 3.0 V excitation.

The sensors however, may be adapted for use with other data loggers, such as those from Campbell Scientific, Inc., for example. The EC-5 requires an excitation voltage in the range of 2.5 to 3.6 V. The sensors produce an output voltage that depends on the dielectric constant of the medium surrounding the sensor, and ranges between 10 and 50% of the excitation voltage. Any data logger which can produce a 2.5 to 3.6 V excitation with approximately 10 millisecond duration and read a volt level signal with 12-bit or better resolution should be compatible with the EC-5 sensor. The current requirement for the EC-5 is 10 mA at 2.5 V.

We designed the EC-5 sensor for use with data loggers and readout devices that provide short excitation pulses, leaving the sensors turned off most of the time. Continuous excitation not only wastes battery power, but may, under certain circumstances, cause the sensor to exceed government specified limits on electromagnetic emissions. Do not continuously power the EC-5 sensor.

5.2 Sample Program

The following program is an example that can be used with the Campbell Scientific CR10X data logger and our EC-5 sensor at a 2,500 mV excitation:

```
;{CR10X}  
; Example ECH20 Data Logger Program for CR10X  
  
; Wiring:
```

```

; White: Excitation Channel 1
; Red: Input Single Ended Channel 1
; Black: Ground

*Table 1 Program
01: 1      Execution Interval (seconds)

; Factory calibration equations for ECH20
; probes convert mV output of ECH20 to
; volumetric water content (VWC, m3/m3)

; EC-5:  VWC = 0.00119 * mV - 0.400

1:  Excite-Delay (SE) (P4)
  1: 1      Reps
  2: 5      2500 mV Slow Range
  3: 1      SE Channel
  4: 1      Excite all reps w/Exchan 1
  5: 1      Delay (0.01 sec units)
  6: 2500 mV Excitation
  7: 1      Loc [ Probe_VWC ]
  8: .00119 Multiplier
  9: -.4    Offset

```

```

*Table 2 Program
02: 0.0000 Execution Interval (seconds)

```

```

*Table 3 Subroutines

```

```

End Program

```

5.3 SCWin (Short Cut) Directions

The following are instructions for using the Campbell Scientific SCWin (Short Cut) program to read the EC-5 soil moisture sensor.

1. Download EchoCSI.zip from <http://www.decagon.com/appnotes/EchoCSIappnote.pdf>.

2. Unzip the folder EchoCSI.zip.
3. Locate the file containing SCWin.exe. It should be in C:\Program Files\Campbellsci\SCWin. Place the following files from the unzipped EchoCSI.zip folder into the folder with SCWin.exe.
 - AM1632Z.MUX
 - AM416Z.MUX
 - EC10.SCS
 - EC101632.SCS
 - EC10416.SCS
 - EC20.SCS
 - EC201632.SCS
 - EC20416.SCS
 - EC5.SCS
 - EC5632.SCS
 - EC5416.SCS
 - SCWIN-DECAGON.CNT
 - SCWIN-DECAGON.HLP

Note: If you are not able to find this directory path, search for the folder that contains SCWIN.exe and place the files into that folder.

4. Open up SCWin.exe (Short Cut). If you are using a V.3 copy of LoggerNet, there is a tab for SCWin (Short Cut) on the tool bar.
5. Select New to start a new program to read the EC-5.
 - (a) Select the data logger you will be using to read the sensors.
 - (b) Select the measurement interval (a shorter measurement interval, i.e. 1 sec., is sometimes desirable when testing the sensor).

6. Click on Sensors (this should open a new page with a file tree on it).
7. Under the “Sensors” file tree, double-click on “Meteorological” and then select “Soil Moisture.”
8. Choose “EC-5” Sensor.

5.4 Removing the Sensor

When removing the sensor from the soil, do not pull it out of the soil by the cable. Doing so may break internal connections and make the sensor unusable.

6 Calibration

Decagon's ECH2O Utility and DataTrac3 automatically apply factory calibrations to the sensor output data. However, this general calibration may not be applicable for all soil types. For added accuracy we encourage our customers to perform soil-specific calibrations.

Which calibration equation you use depends on where you use it. If you use it with sensors connected to a non-Decagon data logger you will need to use the calibration appropriate to your excitation voltage. If you use any Decagon software (DataTrac3, ECH2O Utility, etc.) or the user calibration menu in the ProCheck, you must use the RAW calibration. The difference between the two is the slope constant. To increase the resolution of the sensor output, Decagon uses all available increments of the 12-bit number (value of 4096) where the measurement is stored. Thus, the output of the sensors read by the ProCheck and Decagon loggers must be multiplied by 0.61 and the 2,500 mV slope to give the right value.

6.1 Sensor Calibration Values

Following is a list of the both the millivolt and RAW calibration values for the EC-5, where ϵ is the volumetric water content, mV is the millivolt output of the sensor, and where x is the RAW sensor output.

The EC-5 is much less sensitive to variation in texture and electrical conductivity because it runs at a much higher measurement frequency. Therefore, its general calibration equation should apply for all mineral soils up to 8 dS/m saturation extract. Its calibration equations are shown below for mineral soil, potting soil, and rock-wool growing media.

Dielectric Permittivity

Dielectric permittivity can be used to determine volumetric water content using external published equations such as the Topp equa-

tion. Dielectric permittivity is given by:

$$\varepsilon = 1/(-1.10570 \times 10^{-9} * RAW^3 + 3.575 \times 10^{-6} * RAW^2 - 3.9557 \times 10^{-3} * RAW + 1.53153) \quad (1)$$

where RAW is the output from the Decagon data logger using 3V excitation. If you are using a non-Decagon data logger, dielectric permittivity is given by

$$\varepsilon = 1/(-3.3326 \times 10^{-9} * mV^3 + 7.0218 \times 10^{-6} * mV^2 - 5.11647 \times 10^{-3} * mV + 1.30746) \quad (2)$$

Mineral Soils

According to our tests, a single calibration equation will generally suffice for all mineral soil types with electrical conductivities from 0.1 dS/m to 10 dS/m saturation extract. Volumetric water content (ϕ) is given by:

$$\phi = 8.5 \times 10^{-4} * RAW - 0.48 \quad (3)$$

where RAW is the output from the Decagon data logger using 3 V excitation. If you are using a non-Decagon data logger, VWC is given by:

$$\phi = 11.9 \times 10^{-4} * mV - 0.401 \quad (4)$$

where mV is the output of the sensor when excited at 2,500 mV. Please note that the equation will reach a maximum at $\sim 60\%$ volumetric water content (VWC) in pure water. To display data on a scale from 0 to 100%, VWC should be modeled with a quadratic equation (which would result in a 100% VWC in water), but a linear equation fits the mineral soil VWC range as well as the quadratic, and linear equations are easier to deal with, especially since mineral soil typically saturates at ~ 40 to 50% VWC.

Potting soil

The following equations can be used to convert EC-5 output to water content in potting soil. We tested several types of potting soil (Sunshine mix, Miracle Grow Potting Mix, and Custom Nursery soil) at

several salinities and found that VWC is given by:

$$\phi = 1.3 \times 10^{-3} * RAW - 0.696 \quad (5)$$

for a Decagon data logger or

$$\phi = 2.11 \times 10^{-3} * mV - 0.675 \quad (6)$$

for a data logger with 2,500 mV excitation.

Rockwool

We calibrate the EC-5 in Grodan Master rockwool with solution electrical conductivities of 0.2, 1.0, 1.5, 2.0, and 4.5 dS/m. Volumetric water content can be calculated using

$$\phi = 6.28 \times 10^{-7} * RAW^2 + 1.37 \times 10^{-4} * RAW - 0.183 \quad (7)$$

for a Decagon data logger or

$$\phi = 2.63 \times 10^{-6} * mV^2 + 5.07 \times 10^{-4} * mV - 0.0394 \quad (8)$$

for a data logger with 2,500 mV excitation.

Note: These calibration constants only apply to 2,500 mV excitations; use of these numbers with any other excitation voltage will result in erroneous readings!

7 Maintenance and Troubleshooting

If you encounter problems with the EC-5, they most likely will manifest themselves in the form of incorrect or erroneous readings. Before contacting Decagon about the sensor, do the following:

- Check to make sure the connections to the data logger are both correct and secure.
- Ensure that your data logger batteries are not dead or weakened.

If you encounter problems that are not due to the data logger, please contact Decagon at (509) 332-5600 or at support@decagon.com.

8 Declaration of Conformity

Application of Council Directive: 2004/108/EC and 2011/65/EU

Standards to which conformity is
declared: EN 61326-1:2013 and
EN 50581:2012

Manufacturer's Name: Decagon Devices, Inc. 2365 NE
Hopkins Ct. Pullman, WA 99163
USA

Type of Equipment: Soil Moisture Sensor

Model Number: EC-5

Year of First Manufacture: 2001

This is to certify that the EC-5 ECH2O soil moisture sensor, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

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