MPS-2 & MPS-6

Dielectric Water Potential Sensors

Operator's Manual

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Trademarks

Contents

1   Introduction

Thank you for choosing the Dielectric Water Potential Sensor, model MPS-2 or MPS-6, for measuring soil water potential and temperature. This manual helps you to understand the sensor features and how to use it successfully.

Note: The engineering community commonly uses the term soil suction instead of soil water potential. Soil water potential is simply the negative of soil suction and appears as such throughout this manual.

1.1   Customer Support

There are several ways to contact Decagon if you ever need assistance with your sensors or if you have questions or feedback. We have customer service representatives available to speak with you Monday thru Friday, between 8am and 5pm Pacific time.

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

E-mail:
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.

1.2   Specifications

Water Potential

Range: -9 to $-100,000$ kPa (pF 1.96 to pF 6.01)[1]

Resolution: 0.1 kPa

Accuracy:
    MPS-6: $\pm$(10% of reading + 2 kPa) from -9 to -100 kPa[1]
    MPS-2: $\pm$(25% of reading + 2 kPa) from -9 to -100 kPa[1]

Temperature

Range: -40 °C to 60 °C

Resolution: 0.1 °C

Accuracy: $\pm$1 °C

General

Operating Temperature: -40 to 60 °C,[2] 0 to 100% RH

Operating Temperature: 0 to 60 °C (no water potential measurement below 0 °C)

Power Requirements: 3.6 to 15 VDC, 0.03 mA quiescent, 10 mA max during 150 ms measurement

Dimensions: 9.6 cm (L) x 3.5 cm (W) x 1.5 cm (D)

Sensor Diameter: 3.2 cm

Dielectric Measurement Frequency: 70 MHz

Measurement Time: 150 ms (milliseconds)

Output: RS232 (TTL) with 3.6 volt levels or SDI-12 communication protocol

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[1]Please see Section 4.1 of this manual for more detailed information on range and accuracy at lower water potentials.

[2]Customers may use sensors at higher temperatures under certain conditions, please contact Decagon for assistance.

Connector Types: 3.5 mm (stereo) plug or stripped & tinned lead wires (3)

Cable Length: 5 m standard; maximum cable length of 75 m. Please contact Decagon if you need longer cable lengths

Data Logger Compatibility (not exclusive):

Decagon: Em50, Em50R, Em50G (rev 2.13+)

Campbell Scientific: Any logger with serial I/O including CR10X, CR23X, any CRBasic type logger (CR850, 1000, 3000, etc.)

Other: Any data acquisition system capable of 3.6 to 15 V excitation and serial or SDI-12 communication

Handheld Reader Compatability: ProCheck (rev 1.53+)

Software Compatibility: ECH2O Utility (rev 1.71+) and DataTrac 3 (rev 3.9+)

1.3 Warranty Information

The Dielectric Water Potential Sensor has a 30-day satisfaction guarantee and a one-year warranty.

1.4 Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not to be considered a defect); but Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts F.O.B. 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 the MPS-2 & MPS-6

The MPS-2 and MPS-6 measure the water potential and temperature of soil and other porous materials. These sensors have a low power requirement which makes them ideal for permanent burial in the soil and continuous reading with a data logger or periodic reading with a handheld reader.

The only functional difference between the MPS-2 and MPS-6 is the amount of effort spent calibrating the sensor. Each MPS-2 has a two point calibration that results in a fair degree of accuracy, while the MPS-6 has a six point calibration that results in research-grade accuracy.
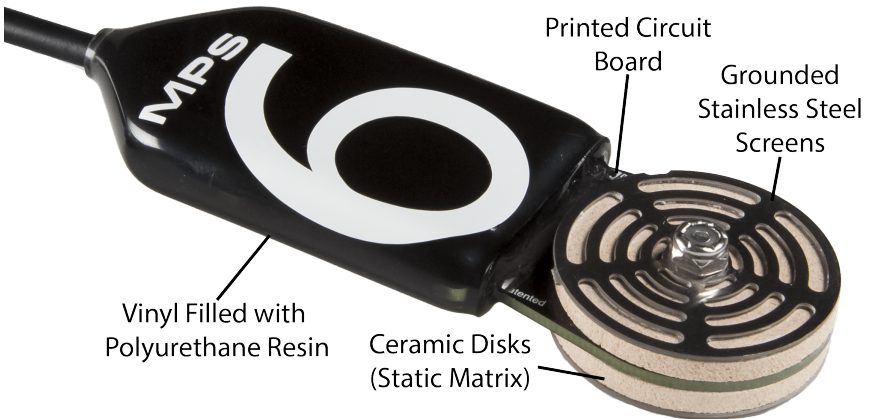

Figure 1: MPS-2 & MPS-6 Components

3   Theory

3.1   Water Potential Measurement

There are two basic parameters that describe the state of water in soil: one is soil water content, or the amount of water per unit of soil, and the other is soil water potential, or the energy state of water in the soil. Although water content is useful when trying to describe the water balance of a soil, i.e. how much water is moving in, out, or being stored, water potential is often preferred over water content because it determines how water moves in a soil or from the soil to the plant. In addition, you can use water potential to determine plant availability of water, schedule irrigation, or determine the mechanical stress state of soil.

All soil water potential measurement techniques measure the potential energy of water in equilibrium with water in the soil. The Second Law of Thermodynamics states that connected systems with differing energy levels move toward an equilibrium energy level. When an object comes into hydraulic contact with the soil, the water potential of the object comes into equilibrium with the soil water potential. For example, tensiometers make use of this principal to measure the potential energy of a liquid water reservoir in equilibrium with the soil water (liquid equilibration), and psychrometers/dew point hygrometers measure the potential energy of water vapor in equilibrium using soil water (vapor equilibration).

Another category of water potential sensors use a solid matrix equilibration technique to measure the water potential of the soil. This technique introduces a known material with a static matrix of pores into the soil and allows it to come into hydraulic equilibrium according to the Second Law of Thermodynamics. Because the two are in equilibrium, measuring the water potential of the solid matrix gives the water potential of the soil. Historically, instruments have measured the thermal conductivity or electrical conductivity of the solid matrix to determine its water potential with varying degrees of success.

The MPS-2 and MPS-6 use the same principle, but instead measure the dielectric permittivity of a solid matrix – porous ceramic discs – to determine its water potential. The dielectric permittivity of air, the solid ceramic, and water are 1, 5, and 80 respectively. So, the dielectric permittivity of the porous ceramic discs depends on the amount of water present in the ceramic disc pore spaces. Measuring the dielectric permittivity of the ceramic discs allows you to resolve a wide range of water content measurements .

Water content and water potential are related by a relationship unique to a given material, called the moisture characteristic curve. The ceramic used with the MPS-2 and MPS-6 has a wide pore size distribution and is consistent between discs, giving each disc the same moisture characteristic curve. Thus, you infer the water potential with the moisture characteristic curve after measuring the water content of the ceramic.

Equation 1 represents the component variables for determining total soil water potential (Ψ_t):

$$\Psi_t = \Psi_p + \Psi_g + \Psi_o + \Psi_m \tag{1}$$

The subscripts p, g, o, and m are pressure, gravitational, osmotic, and matric respectively. Of these four components, only Ψ_o and Ψ_m are significant and often measured in soil. Ψ_o arises from dissolved salts in the soil, and only becomes important if a semi permeable barrier is present that prevents ionic movement (e.g. plant roots, cell membranes). Ψ_m arises from the attraction of water to the soil particles and is the most important component of water potential in all but the most salt affected soils. The MPS-2 and MPS-6 both measure the matric potential of the soil (Ψ_m). In highly salt affected soils, it may be necessary to quantify Ψ_o independently if you take measurements of soil water potential relating to biological activity.

3.2   Temperature Measurement

The MPS-2 and MPS-6 use a surface-mounted thermistor to take temperature readings. The thermistor is located underneath the sensor overmold. The MPS-2 and MPS-6 output temperature readings

in °C unless otherwise stated in your preferences file in either the DataTrac 3 or ECH2O Utility programs. If the black plastic over-mold of the sensor is in direct sunshine, the temperature measure-ment may read high. Exposure of the overmold to solar radiation also drastically decreases the life expectancy of the sensor. We do not recommend installing the sensor with the overmold in the sun.

4   Range and Accuracy

4.1   Measurement Range

The MPS-2 and MPS-6 measure the water content of porous ceramic discs and convert the measured water content to water potential using the moisture characteristic curve of the ceramic.(See Section 3) It is important for sensor function that the ceramic drains over a wide water potential range.(See Figure 2) The size of the pore determines the water potential at which a pore drains (the air entry potential or bubble pressure), so the ideal ceramic would have pores that range from very small to relatively large. Decagon specially designed the ceramic discs to approach this ideal, but they have a total pore volume that is weighted toward the larger pores, which drain at water potentials within the plant-available range. However, the MPS-2 and MPS-6 measurement range extends all the way to air-dry ($-100{,}000$ kPa).

As the sensor dries past the plant-available range, the total pore volume that drains at a given water potential decreases. At these low water potentials, the measured water potential can become somewhat noisy because small changes in measured water content of the ceramic translate into large changes in water potential. This phenomenon is most pronounced when the sensor is air-dry. It is expected that the measured water potential of an open air and dry sensor can jump around throughout the range of $-50{,}000$ kPa to $-100{,}000$ kPa. The noise level is much lower when the sensor is installed in the soil, even at air-dry water potential.
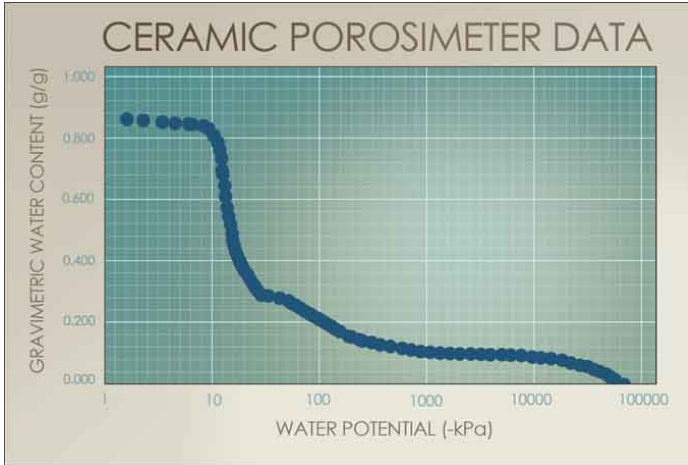
Figure 2:   Moisture characteristic curve derived from mercury porosimeter data for MPS-2 and MPS-6 ceramic

The air entry potential of the largest pores in the ceramic is about −9 kPa. However, the ceramic disc must have access to air for the large pores to begin draining and the response of the sensor to change. If the soil around the sensor has an air entry potential less (drier) than −9 kPa, air will not reach the sensor until reaching the air entry potential of the soil. So, in this scenario, the air entry potential of the soil limits the wet end range, rather than the ceramic discs themselves. This is generally only an issue when using the sensor in poorly structured soils with high clay content.

4.2   Measurement Accuracy

Wet end

The MPS-2 and MPS-6 sensors are identical in construction, with the only difference between the two sensor types being the calibration method applied. We calibrate the MPS-2 and MPS-6 at a vacuum saturated state (0 kPa), and at an air-dry state (−100,000 kPa). These calibration techniques result in accuracy of $\pm$(25% of reading + 2 kPa) over the range of −9 to −100 kPa. The MPS-6 has an additional four calibration points between 0 and −100 kPa, resulting

in accuracy of $\pm(10\%$ of reading $+$ 2 kPa) over the range of -9 to -100 kPa.

Dry end

At water potentials drier than -100 kPa, both the MPS-2 and MPS-6 rely on the linear relationship between water content and the logarithm of water potential that is a fundamental characteristic of soils and the MPS-2 or MPS-6 ceramic disc. Laboratory evaluations have shown good accuracy and low sensor-to-sensor variability to at least -1500 kPa (plant permanent wilting point). Field evaluations have shown low sensor-to-sensor variability to -4500 kPa.(See Figures 3 and 4) Good accuracy should theoretically be achievable to this level, and well beyond, but evaluation against accurate, independent water potential measurements low water potential levels is problematic.
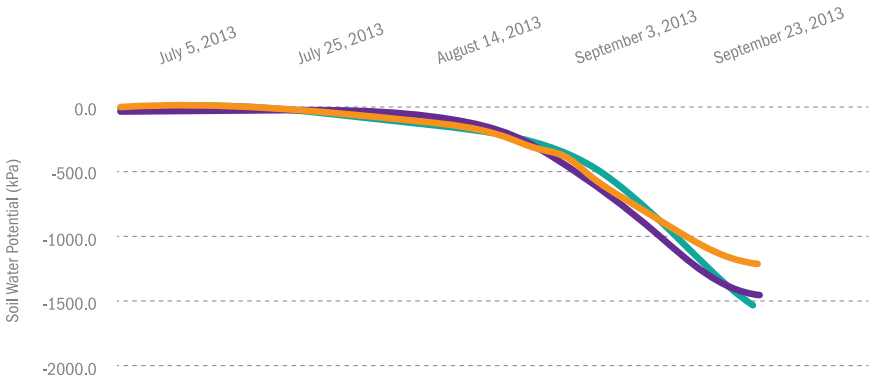

Figure 3: Time series MPS water potential data collected at 80 cm depth under a Beech forest in Switzerland. Note the excellent sensor agreement down to permanent wilting point (-1,500 KPa).[3]
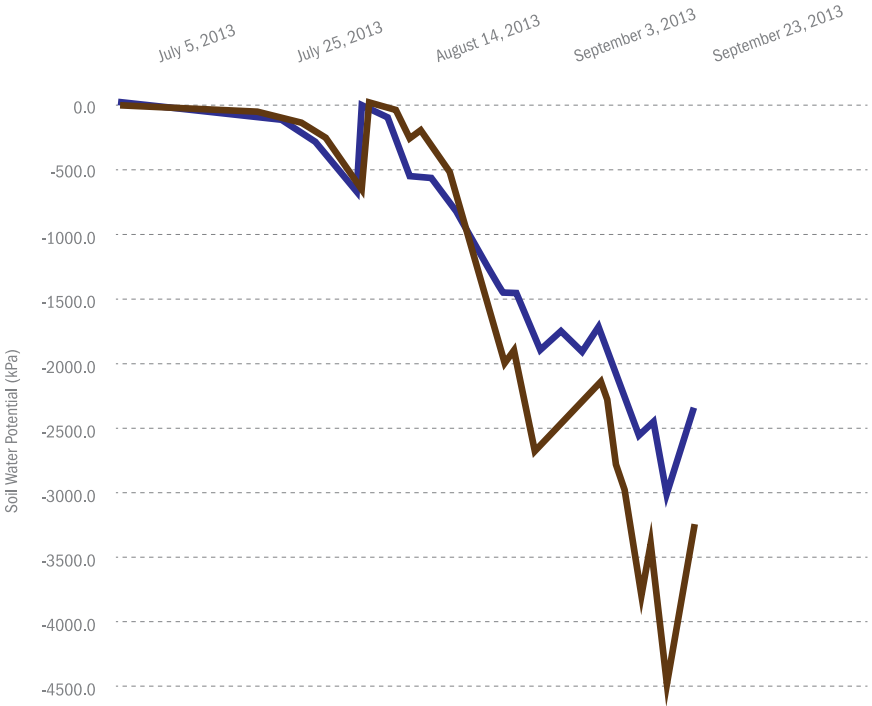
Figure 4: Time series MPS water potential data collected at 20 cm under a dry oak forest in Switzerland. Note the range extends well beyond permanent wilting point.[3]

4.3   Calibration

Wet End

We calibrate each MPS-2 and MPS-6 sensor at an air-dry and vacuum saturated state at Decagon Devices. This two-point calibration results in the accuracy stated above. Although better wet-end accuracy can be achieved through user calibration of the MPS-2 sensor, it is more cost-effective and convenient to simply order MPS-6 sensors that are fully calibrated in the wet end at Decagon.

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[3]Figures 3 and 4 reproduced with permission from Walthert, L. (2013): Soil as a site factor in Swiss forests(project title). Swiss Federal Institute for Forest, Snow, and Landscape Research WSL

Dry End

As described in the section above, both the MPS-2 and MPS-6 rely
the linear relationship between water content and the logarithm of
water potential for calibration in the dry end. Lab testing and field
evaluations have shown that additional calibrations in this region are
not necessary, but could improve accuracy some.

Decagon strongly discourages dry end calibrations in the pressure
plate apparatus. Our early attempts to improve MPS-1 and MPS-2
sensor dry-end performance in the pressure plate apparatus actually
decreased accuracy, likely because of pressure plate dry end equilib-
rium issues pointed out in the literature.[4]

4.4   Soil Type Dependence

The MPS-2 and MPS-6 calibration is not affected by soil type because
the sensors only measure the water potential of the ceramic discs in
equilibrium with the soil. The MPS-2 and MPS-6 work in any soil
type or other porous media as long as you install them correctly
with adequate hydraulic contact (to ensure timely water potential
equilibrium between the sensor and the medium of interest).

4.5   Hysteresis

The amount of water that a soil holds at a given water potential is
greater if the material is dried to that water potential than if the ma-
terial is wet up to that water potential; a phenomenon known as hys-
teresis. Because the MPS-2 and MPS-6 essentially make a dielectric
measurement of water content and convert that to water potential,
sensor measurements have some hysteresis. In most situations, soil
undergoes brief periods of wet up (precipitation or irrigation events)
followed by longer dry down periods where water potential measure-
ments are most useful. We perform MPS-2 and MPS-6 calibration
on the drying leg of the hysteresis loop, so the measurements are

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[4]e.g. Campbell (1998), Gee et al. (2002), Bittelli and Flury (2009), and
Frydman and Baker (2009)

most accurate as the soil dries. Measurements as the soil wets up are slightly drier (more negative water potential) than the true water potential of the soil. Our wetting and drying tests show the magnitude of the hysteresis error is less than 10 kPa in the -20 kPa to -100 kPa range.

5   Connecting to a Logger

The MPS-2 and MPS-6 sensors operate with Decagon's Em50, Em50R, and Em50G data loggers or the ProCheck handheld reader. The standard sensor (with 3.5 mm stereo connector) quickly connects to and is easily configured within a Decagon logger or selected in ProCheck.

The MPS-2 and MPS-6 sensors incorporate several features that also make them excellent for use with third party loggers. Customers have the option to purchase the sensor with stripped and tinned wires (pigtail) for terminal connections.

Extending Sensor Cables

The MPS-2 and MPS-6 sensors come standard with a five meter cable. Customers may purchase custom cable lengths for an additional per-meter fee. This option eliminates the need for splicing the cable. If you do need to extend the cable, please be sure to adequately waterproof the cable splices as inadequately waterproofed cable splices are a major failure point. Visit our website for detailed suggestions on waterproofing cable splices.

5.1   Connecting to Em50/Em50R/Em50G logger

The MPS-2 and MPS-6 work best with the Em50 data logger series. Simply plug the 3.5 mm "stereo plug" connector directly into one of the five sensor ports. Next, configure your logger port for the MPS-2 or MPS-6 and set the measurement interval, this may be done using either ECH2O Utility or DataTrac 3 (see respective manuals). Please check your software and firmware versions to ensure they support the MPS-2 and MPS-6 sensors. To update to the latest version, please visit Decagon's software download site: http://www.decagon.com/support.

The following software/firmware supports the MPS-2 and MPS-6 sensors.

 ECH2O Utility version 1.71 or greater

DataTrac 3 version 3.9 or greater
Em50 version 2.13 or greater
ProCheck readers version 1.53 or greater

Use ECH2O Utility or DataTrac 3 to download data from a Decagon
logger to your computer.

Figure 5: 3.5 mm Stereo Plug Wiring

5.2   Connecting to a Non-Decagon Logger

You may purchase the MPS-2 and MPS-6 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. See Sec-
tion 5.3 for more information on connecting the MPS-2 and MPS-6
sensors to non-Decagon loggers or visit http://www.decagon.com/su
pport/mps-2-and-mps-6-integrator-s-guide/ for the complete Integra-
tor's guide.

Figure 6: Pigtail End Wiring

Connect the wires to the data logger as shown, with the supply wire
(white) connected to the excitation, the digital out wire (red) to a
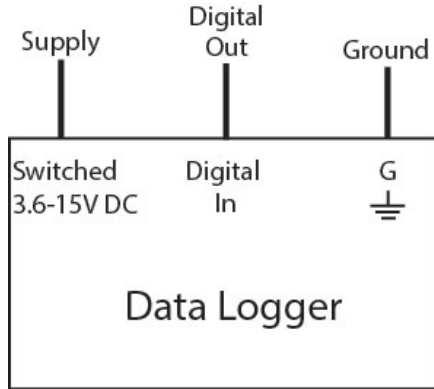digital input, the bare ground wire to ground as illustrated below.

Figure 7: Wire Illustration

Note: The acceptable range of excitation voltages is from 3.6 to 15 VDC. If you wish to read the MPS-2 or the MPS-6 with the Campbell Scientific Data Loggers, you need to power the sensors off of the 5 V, 12 V, or switched 12 V port.

If your sensor is equipped with the standard 3.5 mm plug, and you wish 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, you cannot easily use it 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.

5.3   Using Non-Decagon Loggers

The MPS-2 and MPS-6 sensors communicate using two different methods, Serial (TTL) and SDI-12. This chapter discusses the specifics of each of these communication methods. Please see the complete Integrator's guide for more detailed explanations and instructions.

5.4   Communication

Serial Communication

When you apply excitation voltage, the sensor makes a measurement. Within about 40 ms of excitation, two measurement values transmit to the data logger as a serial stream of ASCII characters.

The serial out is 1200 baud asynchronous with 8 data bits, no parity, and one stop bit. The voltage levels are 0 to 3.6 V and the logic levels are TTL (active low). The power must be removed and reapplied to transmit a new set of values.

The ASCII stream contains two numbers separated by spaces. The stream terminates with the carriage return character. The first number output is water potential in kilopascals. The second number is the temperature in degrees Celsius.

SDI-12 Communication

The sensor can also communicate using the SDI-12 protocol, a three-wire interface where all sensors are powered (white wire), grounded (bare wire), and communicate (red wire) on shared wires (for more info, go to http://www.sdi-12.org). Below is a brief description of SDI-12 for communication. If you plan on using SDI-12 for communication with the sensor, please see our Integrator's guide under the support tab on the MPS-2 and MPS-6 product pages at http://www.decagon.com.

There are several benefits and drawbacks regarding the SDI-12 protocol. One benefit is that you can connect up to 62 sensors to the

same 12 V supply and communication port on the data logger. This simplifies wiring because no multiplexer is necessary. The drawback to using multiple sensors on one bus is that a problem with a single sensor can bring down the entire array (through a short circuit, etc.). To avoid this problem, we recommend the user make an independent junction box with wire harnesses where all sensor wires are wired to wire lugs so sensors can be disconnected if a problem arises. A single three-wire bundle can be run from the junction box to the data logger.

Address

The SDI-12 protocol requires that all sensors have a unique address. MPS-2 and MPS-6 sensors come from the factory with an SDI-12 address of 0. To add more than one SDI-12 sensor to a bus, the sensor address must be changed. Address options include 0...9, A...Z, a...z.

The best and easiest way to change an address is to use Decagon's ProCheck (if the ProCheck does not have this option, please upgrade your firmware to the latest version). SDI-12 addressing can be accessed in the "CONFIG" menu by selecting "SDI-12 Address." Addresses may then be changed by simply pressing the up or down arrows until you see the desired address and pushing "Enter."

Power

Customers can power the sensor with any voltage from 3.6 to 15 VDC, but 12 V is the optimal voltage. When using the sensor as part of an SDI-12 bus, we recommended you excite the sensors continuously to avoid issues with initial sensor startup interfering with the SDI-12 communications.

Reading

SDI-12 communication allows communication of many parameters at once. This allows you to see information such as the sensor model, SDI-12 version, temp, etc. Reading the sensor in SDI-12 mode requires function calls.

The water potential in kilopascals is the first number output by the sensor. The second number is temperature in Celsius.

The SDI-12 communication protocol is supported in Campbell Scientific data loggers like the CR10X, CR200, CR1000, CR3000, etc. Direct SDI-12 communication is supported in the "Terminal Emulator" mode under the "Tools" menu on the "Connect" screen. Detailed information on setting the address using CSI data loggers can be found on our website at http://www.decagon.com/support.

5.5   Installing the Sensors

Because the MPS-2 and MPS-6 measure water potential, they are not as sensitive to air gaps or soil disturbance as water content sensors. The MPS-2 and MPS-6 need good hydraulic contact with the surrounding soil. The preferred method for installing the sensor is to take some native soil, wet it, and pack it in a ball around the entire sensor, making sure that the moist soil is in contact with all surfaces of the ceramic. The sensor and moist soil are then packed into the soil at the desired depth.

In sandy soils, the soil may not adhere to the sensor even when wet. In this case the sensor can be packed into soil at the bottom of a hole dug to the desired installation depth. Again, take care to pack the sandy soil around the sensor with good contact to all ceramic surfaces.

After installing the sensor and moist soil, the hole that was excavated to bury the sensor at depth should be back-filled with care taken to pack the soil back to its native bulk density. Leave at least six inches of sensor cable beneath the soil before bringing the cable to the surface. The cable should never be bent in a tight radius as it leaves the sensor body. At least four inches of cable should exit the sensor body in a straight line before bending the cable.

5.6   Campbell Scientific Programs

Because the sensors use digital rather than analog communication, they require special considerations when connecting to a Campbell Scientific data logger. Please visit our website at http://www.decagon .com/support to view sample Campbell Scientific programs.

6   Maintenance and Troubleshooting

The MPS-2 and MPS-6 sensors measure the water potential of two engineered ceramic discs sandwiched between stainless steel screens and the circuit board. The ceramic discs are somewhat brittle and can chip or crack if abused. The metal screens afford the discs some amount of protection, but sharp trauma on the disc edges or massive impact (such as dropping the sensor onto a hard surface) can cause the ceramic to break. One or two small chips on the edge of the disc does not affect the sensor accuracy significantly. However, a cracked ceramic disc creates a loss of accuracy.

For the MPS-2 and MPS-6 to accurately measure water potential, the ceramic discs must readily take up water. If you expose the ceramic discs to oils or other hydrophobic substances, it compromises the ability of the discs to take up water from the soil. This inability to take up water leads to slow equilibration times and loss of accuracy. We recommend you minimize exposure of the ceramic material to skin oils and that you do not handle the discs with greasy hands, or expose the discs to synthetic oils or other hydrophobic compounds.

6.1   MPS-2 & MPS-6 in Frozen Soils

The MPS-2 and MPS-6 measure the dielectric permittivity of two ceramic discs to measure their water content and then derive their water potential. The dielectric permittivity of water in the ceramic discs is 80 compared to a dielectric permittivity of $\sim$5 for the ceramic material, and 1 for air. When water freezes to ice, the dielectric permittivity drops to 5 at the frequency of the sensor measurement meaning that the MPS-2 or MPS-6 can no longer accurately measure the water in the ceramic. The MPS-2 and MPS-6 do not accurately measure the water potential of soil in frozen soil conditions. However, you can measure the water potential of the soil under frozen soil conditions by measuring the soil temperature accurately (Koopmans and Miller, 1966). For each 1 °C decrease in temperature below 0 °C, the water potential in the soil decreases by $\sim$1200 kPa. Spaans and Baker (1996) showed that this relationship is valid in field soils for water potentials below about -50 kPa.

Rigorous testing indicates that repeated freeze-thaw cycles do not affect the ceramic discs. Several sensors were equilibrated in saturated soil, and then subjected to numerous freeze thaw cycles in a temperature control chamber. The freezing rate of the soil containers was at least an order of magnitude faster than could be achieved in field soil under natural conditions. At several points during the test, and at the end of the test, the ceramic discs were evaluated for damage due to repeated rapid freezing with pore spaces full of water. None of the ceramic discs showed any signs of physical damage, and none of the sensors showed any significant change in output due to the freezing tests.

6.2   Troubleshooting

If you encounter problems with the MPS-2 or MPS-6 sensor, they most likely manifest themselves in the form of incorrect or erroneous readings. Review these troubleshooting suggestions before contacting Decagon about the sensor.

Data Logger

1. Check to make sure the connections to the data logger are both correct and secure.

2. Ensure that your data logger batteries are not dead or weakened.

3. Check the configuration of your data logger in ECH2O Utility or DataTrac 3 to make sure you have selected MPS-2 or MPS-6.

4. Ensure that you are using the most up to date software and firmware.

Sensors

1. Ensure that your sensors are installed according to section 5.5 "Installation" of this manual.

2. Check sensor cables for nicks or cuts that could cause a malfunction.

3. Check the ceramic disc for damage or contamination.

7   References

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Spaans, E. J. A., and J. M. Baker, 1996. The soil freezing characteristic: Its measurement and similarity to the soil moisture characteristic, *Soil Sci. Soc. Am. J.*, 60, 1319, 1996.

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: Water Potential and Tempera-
ture Sensors

Model Number: MPS-2 & MPS-6

Year of First Manufacture: 2011

This is to certify that the MPS-2 and MPS-6 dielectric water poten-
tial sensors, manufactured by Decagon Devices, Inc., a corporation
based in Pullman, Washington, USA meet or exceeds the standards
for CE compliance as per the the aforementioned Council Directives.
All instruments are built at the factory at Decagon and pertinent
testing documentation is freely available for verification.

Index