MAS-1

4-20 mA Soil Moisture Sensor

Operator's Manual

Decagon Devices, Inc.

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Trademarks

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1 Introduction

Thank you for choosing the MAS-1 4-20 mA Soil Moisture Sensor. This innovative sensor enables you to monitor soil moisture accurately and affordable with a standard 2-wire, 4-20 mA analog interface for use with many data acquisition and control systems. The MAS-1 cannot be used with the standard Decagon data loggers.

1.1 Customer Support

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.

1.2 About This Manual

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

1.3 Warranty

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

Note: The one year service plan activates when Decagon ships the instrument and not at the time of purchase.

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 the date of receipt of equipment.

Note: We do not consider the results of ordinary wear and tear, neglect, misuse, or 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 the MAS-1

The MAS-1 measures the dielectric constant of the soil in order to find its volumetric water content. Since the dielectric constant of water is much higher than that of air or soil minerals, the dielectric constant of the soil is a sensitive measure of water content. The MAS-1 supplies a 70 MHz oscillating wave to the sensor prongs that induces an electromagnetic field in the medium (soil) surrounding the sensor. The charging and discharging of the sensor is controlled by the dielectric of the surrounding soil.

A microprocessor on the MAS-1 measures the charging of the sensor, and therefore the dielectric constant of the soil which is related to the water content of the soil. The microprocessor makes a dielectric measurement and updates the transmitted current once per second. The transmitted 4-20 mA current can be converted to the water content of the soil using a simple calibration function.

We designed the MAS-1 to be used with standard 4-20 mA controllers and monitoring systems. It cannot be used with Decagon logging systems. For more information about using Decagon logging systems please contact Decagon's customer support representatives.

2.1 Specifications

Electrical

- Interface: Standard 4-20 mA, 2-wire analog transmitter
- Supply voltage: 12 to 32 VDC continuous
- Output current: 4-20 mA
- Overvoltage protection: Yes
- Reverse polarity protection: Yes
- Settling time: 4 seconds
- Wiring:

1. Red wire: (+) supply
2. Black wire: (-) output
3. Shield: Not connected

Measurement

- Type: Volumetric water content (VWC)
- Range: 0 to 100% VWC typical
- Resolution: Depends on current measurement (data acquisition) device
- Accuracy: ±6% VWC with generic calibration for supported growing media up to 65% VWC, above which accuracy lessens. Increased accuracy can be achieved with a medium specific calibration. For more information on how to perform your own media specific calibration, or to have Decagon's calibration service perform one for you, visit us online at http://www.decagon.com
- Output: 4-20 mA current proportional to VWC
- Sensor measurement interval: 1 second
- **Operating Environment**
- Temperature: −40 to 60 °C
  Sensors can be used at higher temperatures under some conditions. Contact Decagon for more details

Physical Properties

- Dimensions: 8.9 cm x 1.8 cm x 0.7 cm
- Cable: 2 m or 5 m (standard), 3 wire (22 AWG tinned Red and Black wires, 24 AWG tinned bare wire); (Custom cable length available upon request)

3 Integrating the MAS-1

A 4-20 mA system generally consists of a sensor, transmitter, power supply, and device to read the current being transmitted through the current loop. The MAS-1 is an integrated sensor and 4-20 mA transmitter. When the MAS-1 is powered by the Power Supply, it transmits a current though the loop that is proportional to the soil dielectric permittivity and therefore the soil volumetric water content. In figure 1, the current loop is shown by the dotted line labeled I=4-20 mA the arrows indicate the direction of the current.

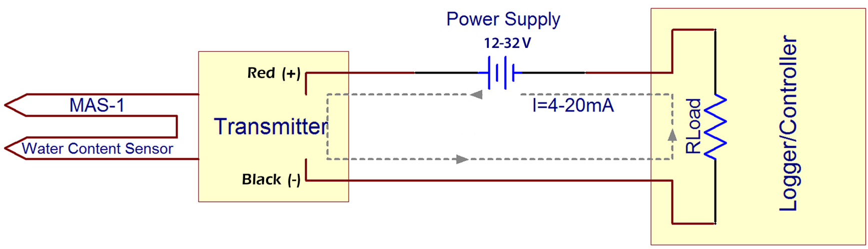

Figure 1: 4-20mA current loop diagram

The MAS-1 uses a microcontroller to regulate the interval at which it takes measurements. It takes one second from the time it is powered up to take its first measurement and transmit current though the loop. The transmitted current will reach a stable value within four seconds of power up. After the initial four second startup, measurements are taken every one second, while the current in the loop is continuously maintained. Since the measurement intervals are controlled by the MAS-1 itself, there is no need to pulse the excitation voltage. A constant supply voltage should be applied in order for the MAS-1 to function properly.

3.1 Wiring

Conventional (PLC)

A Programmable Logic Controller (PLC) is typically used to read the current transmitted though the MAS-1. The red wire (see Figure 2) of the MAS-1 is connected to a voltage output terminal that is able to supply 12 to 32 VDC. The black wire is connected to an input terminal that accepts a current input ranging from 4 mA to 20 mA. For the MAS-1 to function properly, the voltage drop from the red to the black lead must be 12 V or greater.

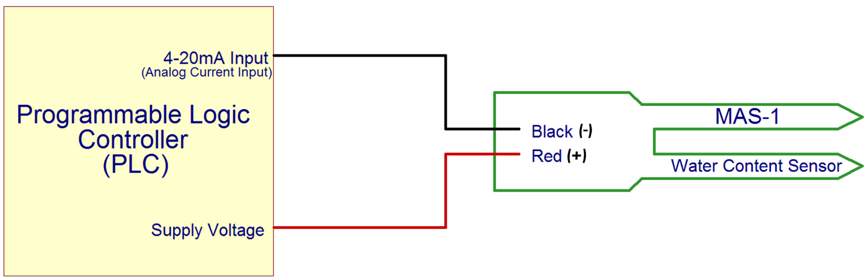

Figure 2: Typical Wiring Connection

Non-Conventional

When using a device, such as a data logger, that does not have an input capable of measuring current a pickoff resistor can be used as shown in figure 3. Assuming that the single ended input has an input impedance, or resistance, much larger that of R_{Volt}, then all of the current in the 4-20 mA loop passes through R_{Volt}. If the data logger can measure the voltage drop over the R_{Volt}, then the current can be calculated as:

$$I = \frac{V_{measured}}{R_{Volt}} \tag{1}$$

where I (mA) is the 4-20 mA current, R_{Volt} (ohms) is the resistance of the pickoff resistor, and $V_{measured}$ (mV) is the voltage drop over R_{Volt}.

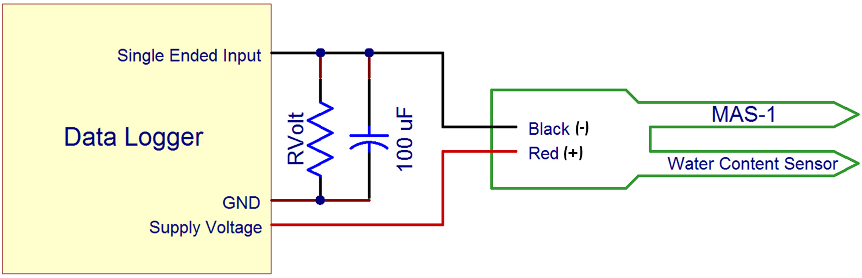

Figure 3: Wiring Connection for Devices Without Current

The optional 100 uF capacitor shown in parallel with the R_{Volt} reduces measurement noise. It should have a voltage rating higher than the largest supply voltage. Be sure to observe correct polarity.

The MAS-1 requires a voltage of at least 12 V. This limits the value of R_Volt since part of the total voltage drop will be across the resistor. Equation 2 can be used to determine the maximum value for R_Volt. Table 1 shows time resistance values.

$$V_{supply} - 12 = 0.02 R_{VoltMax} \tag{2}$$

Table 1: Maximum resistance values for R_{Volt} at specified voltages

Supply Voltage	Load
13 V	50 ohms
24 V	600 ohms
32 V	1000 ohms

The MAS-1 sensor has several advantages over voltage-output sensors, even for voltage-input data loggers.

1. The MAS-1 supply voltage does not need to be regulated for the sensor to work properly; it can be any value between 12 and 32 volts, without affecting sensor output.
2. When using a current-based sensor like the MAS-1, the signal is not affected by electrical resistance in the cable, so the sensor output is not affected by cable length or wire gauge.

3. The MAS-1 requires only two conductors, so long lines are both lower in noise and less expensive.
4. With the MAS-1 sensor the source impedance is small, and a current loop is highly immune to noise on the line.
5. Measured voltage can be tailored to a particular data acquisition system simply by adjusting the value of R_{Volt}. A typical application might be to use a MAS-1 with a 12 volt supply and a R_{Volt} value of 1 ohm. The output voltage range is the product of the current and the resistance (Equation 1), so for 4-20 mA it would be 4 to 29 mV.

3.2 Testing the Sensor

After integrating the MAS-1 into your PLC or other data acquisition system, it is always a good idea to test the sensor output to verify that it is functioning correctly with your system. Two convenient test conditions are surrounding the sensor with air or water. To test in air, suspend the sensor form the cable, making sure that it is at least six inches from any object. To test in water, place the sensor in a bucket of tap water (do not use deionized or distilled water). The entire sensor (prongs + black plastic electronics portion) should be immersed in water, and should be at least two inches from any container surface. Under these conditions, the sensor should transmit in the following ranges (approximate). The air between 3.4 to 4.7 mA and tap water: 18.1 to 22.4 mA.

Note: Sensor output can go above 20 mA and below 4 mA.

4 Installing the MAS-1

When selecting a site for installation, it is important to understand 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 sensor electromagnetic field and adversely affect the sensor readings. Because the MAS-1 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 prong will break if you use excessive sideways force when inserting them.

4.1 Procedure

1. The MAS-1 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 are buried completely up to the black overmolding. 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.

   Note: Never pound the sensor into the ground.

2. Carefully backfill the hole to match the bulk density of the surrounding soil. Be careful to no over stress the cable or overmold by bending when installing the sensor.

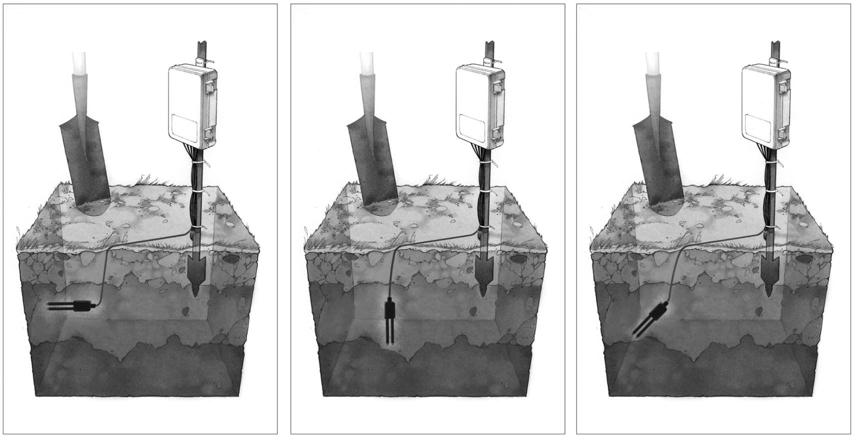

Figure 4: Installation Orientation

4.2 Orientation

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

4.3 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.

5 Calibration

The current transmitted by the MAS-1 is proportional to the dielectric permittivity of the medium surrounding the sensor, and therefore the volumetric water content (VWC) of the medium. We can calculate the VWC by applying a calibration equation to the current transmitted by the MAS-1. The following are generic calibration equations for common growth media. Applying these equations will generally result in accuracy of ±6% VWC as long as the electrical conductivity of the medium is less than 8 dS/m. If you wish to use the MAS-1 in a medium that is not listed below, if you need better than ±6% accuracy, or if you are working in a high salinity material, then you should develop a custom calibration for your particular medium. See www.decagon.com for step by step instructions on developing a custom calibration. Decagon can also develop a custom calibration for your medium; contact Decagon for more details on the calibration service.

5.1 Mineral Soils

A single calibration equation will generally result in good accuracy for all mineral soil types with electrical conductivity < 8 dS/m. VWC is given by

$$VWC = 0.00328 * mA^2 - 0.0244 * mA - 0.00565 \tag{3}$$

If your data acquisition system is not capable of higher order mathematical operations, the mineral soil calibration can be approximated by the following linear model. This will result in slightly worse accuracy at low VWC, with errors becoming large above 35% VWC.

$$VWC = 0.0479 \times mA - 0.391 \tag{4}$$

5.2 Potting Soil/Peat

The following equation can be used to covert MAS-1 transmitted current into VWC in potting soil and peat potting mixes. Please note that different potting soil types are quite variable, so this calibration equation may not result in good accuracy in your particular mix (although precision should still be good). We recommend a custom calibration for best accuracy when using the MAS-1 in potting soils.

$$VWC = 0.00531 \times e^{(0.29*mA)} \tag{5}$$

5.3 Rockwool

The MAS-1 was calibrated in Grodan Expert^{TM} rockwool at several electrical conductivities. VWC can be calculated as:

$$VWC = 0.00446 * mA^2 - 0.0359 * mA + 0.0741 \tag{6}$$

6 Troubleshooting

If you encounter problems with the MAS-1, they will usually be caused by one of two situations

- If the MAS-1 readings in air and/or water are outside the ranges given in Section 3.2, then there is likely a problem with the connection to the PLC or other data acquisition system. Check the wiring and make sure that the supply voltage is in the specified range.
- If the MAS-1 is reading a negative value for VWC while it is inserted into the soil, make sure that you have good sensor-to-soil contact. When inserted, the MAS-1 should be completely covered up past the black overmolding. Removing and re-installing the full length of the sensor with better sensor-to-soil contact should remedy this problem.

If problems persist, contact Decagon for assistance.

7 Declaration of Conformity

Application of Council Directive:	2004/208/EC and 2011/65/EU
Standards to which conformity is declared:	EN61326-1:2013 EN62321:2009
Manufacturer's Name:	Decagon Devices, Inc. 2365 NE Hopkins Court Pullman, WA 99163 USA
Type of Equipment:	Data Collection System
Model Number:	MAS-1
Year of First Manufacture:	2008

This is to certify that the MAS-1 dielectric soil moisture sensors, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meet or exceed 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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