



**METER**

## ECH<sub>2</sub>O GS3 INTEGRATOR GUIDE

### SENSOR DESCRIPTION

The ECH<sub>2</sub>O GS3 sensor is a low-cost, accurate tool for monitoring electrical conductivity (EC), volumetric water content (VWC), and temperature in soil and soilless substrates. All three measurements are made independently. As with all ECH<sub>2</sub>O sensors, the GS3 determines VWC by measuring the dielectric constant of the media using capacitance/frequency domain technology. The sensor uses a 70-MHz frequency, which minimizes textural and salinity effects, making the GS3 accurate in most soils and soilless substrates. The GS3 measures temperature using an onboard thermistor and electrical conductivity using a stainless steel electrode array. For a more detailed description of how this sensor makes measurements, refer to the [GS3 User Manual](#).

### APPLICATIONS

- Greenhouse substrate monitoring
- Volumetric water content (VWC) measurement
- Electrical conductivity (EC) measurement
- Soil/substrate water balance
- Irrigation management
- Salt management
- Fertilizer movement
- Soil/substrate temperature measurement
- Modeling processes that are affected by temperature

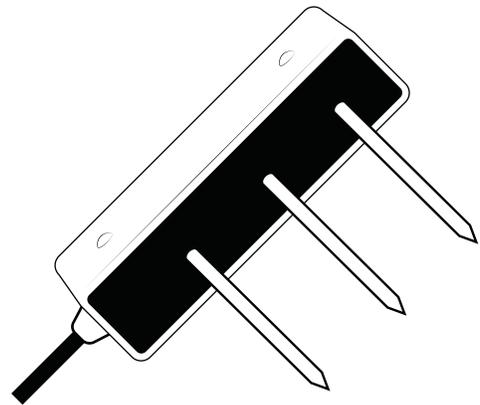


Figure 1 GS3 sensor

### ADVANTAGES

- Robust thermistor for accurate temperature measurements
- Two-probe electrical conductivity (EC) measurement
- Robust epoxy encapsulation and stainless steel needles to resist corrosive environments
- Three-wire sensor interface: power, ground, and data
- Digital sensor communicates multiple measurements over a serial interface
- Low-input voltage requirements
- Low-power design supports battery-operated data loggers
- Supports SDI-12 or DDI serial communications protocols
- Modern design optimized for low-cost sensing

### PURPOSE OF THIS GUIDE

METER provides the information in this integrator guide to help GS3 customers establish communication between the sensors and their data acquisition equipment or field data loggers. Customers using data loggers that support SDI-12 sensor communications should consult the data logger user manual. METER sensors are fully integrated into the METER system of plug-and-play sensors, cellular-enabled data loggers, and data analysis software. For more information about METER-integrated systems, please contact [Customer Support](#).

### COMPATIBLE FIRMWARE VERSIONS

This guide is compatible with firmware versions 4.02 or newer.

## SPECIFICATIONS

### MEASUREMENT SPECIFICATIONS

Volumetric Water Content (VWC)		Dielectric Measurement Frequency	
Range		70 MHz	
Mineral soil calibration	0.0–1.0 m <sup>3</sup> /m <sup>3</sup>	<b>Temperature</b>	
Soilless media calibration	0.0–1.0 m <sup>3</sup> /m <sup>3</sup>	Range	–40 to +60 °C
Apparent dielectric permittivity ( $\epsilon_a$ )	1 (air) to 80 (water)	Resolution	0.1 °C
Resolution	0.1 $\epsilon_a$ (unitless) from 1–20 <0.75 $\epsilon_a$ (unitless) from 20–80 0.002 m <sup>3</sup> /m <sup>3</sup> from 0.0–0.4 m <sup>3</sup> /m <sup>3</sup> 0.001 m <sup>3</sup> /m <sup>3</sup> for >0.4 m <sup>3</sup> /m <sup>3</sup>	Accuracy	±1 °C
Accuracy		<b>NOTE: Temperature measurement, for applicable sensors, may not be accurate if sensor is not fully immersed in the medium of interest, due to longer equilibration time.</b>	
Generic calibration	±0.03 m <sup>3</sup> /m <sup>3</sup> typical	<b>Bulk Electrical Conductivity</b>	
Medium-specific calibration	±0.01–0.02 m <sup>3</sup> /m <sup>3</sup>	Range	0–25 dS/m
Apparent dielectric permittivity ( $\epsilon_a$ )	1–40 (soil range), ±1 $\epsilon_a$ (unitless) 40–80, 15% measurement	Resolution	0.001 dS/m from 0–25 dS/m
		Accuracy	±5% from 0–5 dS/m ±10% from 5–25 dS/m Custom calibration required 10–25 dS/m

### COMMUNICATION SPECIFICATIONS

Output	Data Logger Compatibility
DDI serial or SDI-12 communication protocol	Any data acquisition system capable of 3.6- to 15-VDC power and serial or SDI-12 communication

### PHYSICAL SPECIFICATIONS

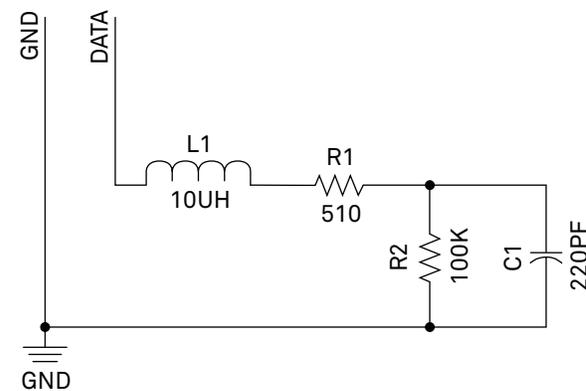
Dimensions	Cable Length	
Length	9.3 cm (3.7 in)	5 m (standard) 75 m (maximum custom cable length)
Width	2.4 cm (0.9 in)	<b>NOTE: Contact <a href="#">Customer Support</a> if a nonstandard cable length is needed.</b>
Height	6.5 cm (2.6 in)	<b>Connector Types</b>
<b>Needle Length</b>	5.5 cm (2.2 in)	3.5-mm stereo plug connector or stripped and tinned wires
<b>Operating Temperature Range</b>		
Minimum	–40 °C	
Typical	NA	
Maximum	+60 °C	
<b>NOTE: Sensors may be used at higher temperatures under certain conditions; contact <a href="#">Customer Support</a> for assistance.</b>		

## ELECTRICAL AND TIMING CHARACTERISTICS

Supply Voltage (VCC to GND)		Current Drain (while asleep)	
Minimum	3.6 VDC	Minimum	NA
Typical	NA	Typical	0.03 mA
Maximum	15.0 VDC	Maximum	NA
Digital Input Voltage (logic high)		Power-Up Time (DDI serial)	
Minimum	2.8 V	Minimum	NA
Typical	3.0 V	Typical	NA
Maximum	3.9 V	Maximum	100 ms
Digital Input Voltage (logic low)		Power-Up Time (SDI-12)	
Minimum	-0.3 V	Minimum	100 ms
Typical	0.0 V	Typical	150 ms
Maximum	0.8 V	Maximum	200 ms
Power Line Slew Rate		Measurement Duration	
Minimum	1.0 V/ms	Minimum	NA
Typical	NA	Typical	150 ms
Maximum	NA	Maximum	200 ms
Current Drain (during measurement)		COMPLIANCE	
Minimum	0.5 mA	Manufactured under ISO 9001:2015	
Typical	3.0 mA	EM ISO/IEC 17050:2010 (CE Mark)	
Maximum	30.0 mA		

## EQUIVALENT CIRCUIT AND CONNECTION TYPES

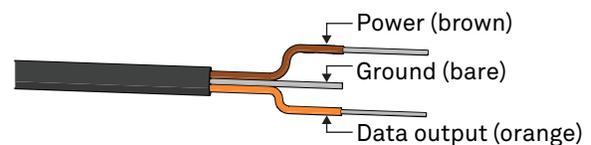
Refer to [Figure 2](#) and [Figure 3](#) to connect the GS3 to a data logger. [Figure 2](#) provides a low-impedance variant of the recommended SDI-12 specification.



NOTE: This is a low-impedance variant of the recommended SDI-12 specification. This allows as many as 62 sensors to be maintained on a bus.

Figure 2 Equivalent circuit diagram

### PIGTAIL CABLE



NOTE: Some early GS3 units may have the older Decagon wiring scheme where the power supply is white, the digital out is red, and the bare wire is ground.

### STEREO CABLE

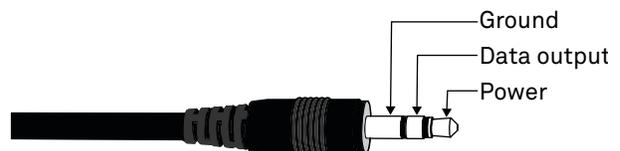


Figure 3 Connection types

## ⚠ PRECAUTIONS

METER sensors are built to the highest standards, but misuse, improper protection, or improper installation may damage the sensor and possibly void the warranty. Before integrating sensors into a sensor network, follow the recommended installation instructions and implement safeguards to protect the sensor from damaging interference.

## **SURGE CONDITIONS**

Sensors have built-in circuitry that protects them against common surge conditions. Installations in lightning-prone areas, however, require special precautions, especially when sensors are connected to a well-grounded third-party logger.

Read the application note [Lightning surge and grounding practices](#) on the METER website for more information.

## **POWER AND GROUNDING**

Ensure there is sufficient power to simultaneously support the maximum sensor current drain for all of the sensors on the bus. The sensor protection circuitry may be insufficient if the data logger is improperly powered or grounded. Refer to the data logger installation instructions. Improper grounding may affect the sensor output as well as sensor performance.

For METER data loggers visit [metergroup.com](http://metergroup.com). Read the application note [Lightning surge and grounding practices](#) on the METER website for more information.

## **CABLES**

Improperly protected cables can lead to severed cables or disconnected sensors. Cabling issues can be caused by many factors, including rodent damage, driving over sensor cables, tripping over the cable, not leaving enough cable slack during installation, or poor sensor wiring connections. To relieve strain on the connections and prevent loose cabling from being inadvertently snagged, gather and secure the cable traveling between the GS3 and the data acquisition device to the mounting mast in one or more places. Install cables in conduit or plastic cladding when near the ground to avoid rodent damage. Tie excess cable to the data logger mast to ensure cable weight does not cause sensor to unplug.

## **SENSOR COMMUNICATIONS**

METER digital sensors feature a serial interface with shared receive and transmit signals for communicating sensor measurements on the data wire ([Figure 3](#)). The sensor supports two different protocols: SDI-12 and DDI serial. Each protocol has implementation advantages and challenges. Please contact [Customer Support](#) if the protocol choice for the desired application is not obvious.

### **SDI-12 INTRODUCTION**

SDI-12 is a standards-based protocol for interfacing sensors to data loggers and data acquisition equipment. Multiple sensors with unique addresses can share a common 3-wire bus (power, ground, and data). Two-way communication between the sensor and logger is possible by sharing the data line for transmit and receive as defined by the standard. Sensor measurements are triggered by protocol command. The SDI-12 protocol requires a unique alphanumeric sensor address for each sensor on the bus so that a data logger can send commands to and receive readings from specific sensors.

Download the [SDI-12 Specification v1.3](#) to learn more about the latest SDI-12 protocol.

### **DDI SERIAL INTRODUCTION**

The DDI serial protocol is the method used by METER data loggers for collecting data from the sensor. This protocol uses the data line configured to transmit data from the sensor to the receiver only (simplex). Typically, the receive side is a microprocessor UART or a general-purpose I/O pin using a bitbang method to receive data. Sensor measurements are triggered by applying power to the sensor.

### **INTERFACING THE SENSOR TO A COMPUTER**

The serial signals and protocols supported by the sensor require some type of interface hardware to be compatible with the serial port found on most computers (or USB-to-serial adapters). There are several SDI-12 interface adapters available in the marketplace; however, METER has not tested any of these interfaces and cannot make a recommendation as to which adapters work with METER sensors. METER data loggers and the ProCheck hand-held device can operate as a computer-to-sensor interface for making on-demand sensor measurements. For more information, please contact [Customer Support](#).

## METER SDI-12 IMPLEMENTATION

METER sensors use a low-impedance variant of the SDI-12 standard sensor circuit (Figure 2). During the power-up time, the sensors output some sensor diagnostic information and should not be communicated with until the power-up time has passed. After the power-up time, the sensors are compatible with all commands listed in the [SDI-12 Specification v1.3](#).

Out of the factory, all METER sensors start with SDI-12 address 0 and print out the DDI serial startup string during the power-up time. This can be interpreted by non-METER SDI-12 sensors as a pseudo-break condition followed by a random series of bits.

The GS3 will omit the DDI serial startup string (sensor identification) when the SDI-12 address is nonzero. Changing the address to a nonzero address is recommended for this reason.

## SENSOR BUS CONSIDERATIONS

SDI-12 sensor buses require regular checking, sensor upkeep, and sensor troubleshooting. If one sensor goes down, that may take down the whole bus even if the remaining sensors are functioning normally. Power cycling the SDI-12 bus when a sensor is failing is acceptable, but METER does not recommend scheduling power cycling events on an SDI-12 bus more than once or twice per day. Many factors influence the effectiveness of the bus configuration. Visit [metergroup.com](http://metergroup.com) for articles and virtual seminars containing more information.

## SDI-12 CONFIGURATION

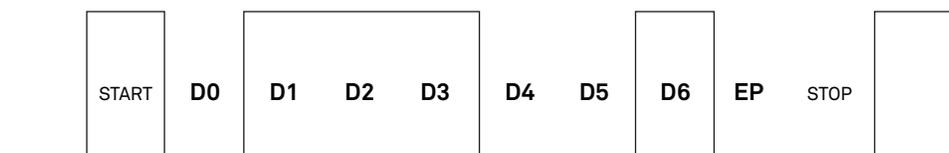
Table 1 lists the SDI-12 communication configuration.

**Table 1 SDI-12 communication configuration**

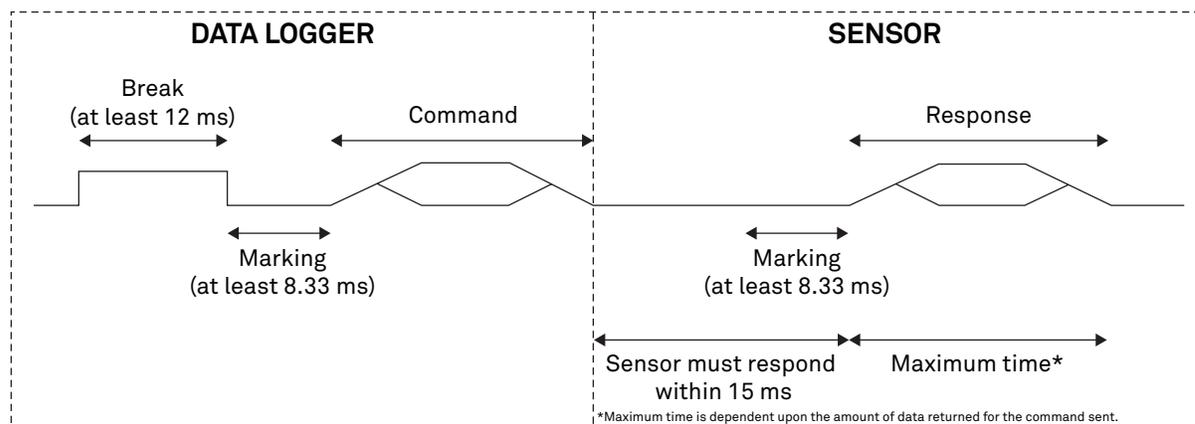
Baud Rate	1200
Start Bits	1
Data Bits	7 (LSB first)
Parity Bits	1 (even)
Stop Bits	1
Logic	Inverted (active low)

## SDI-12 TIMING

All SDI-12 commands and responses must adhere to the format in Figure 4 on the data line. Both the command and response are preceded by an address and terminated by a carriage return and line feed combination (<CR><LF>) and follow the timing shown in Figure 5.



**Figure 4 Example SDI-12 transmission of the character 1 (0x31)**



**Figure 5 Example data logger and sensor communication**

## COMMON SDI-12 COMMANDS

This section includes tables of common SDI-12 commands that are often used in an SDI-12 system and the corresponding responses from METER sensors. All command responses are followed by a <CR><LF>.

### IDENTIFICATION COMMAND (aI!)

The Identification command can be used to obtain a variety of detailed information about the connected sensor. An example of the command and response is shown in [Example 1](#), where the command is in **bold** and the response follows the command.

**Example 1** **1I!**113DECAGON \_GS3 \_ \_ \_337631800001

<u>Parameter</u>	<u>Fixed Character Length</u>	<u>Description</u>
<b>1I!</b>	3	Data logger command. Request to the sensor for information from sensor address 1.
1	1	Sensor address. Prepended on all responses, this indicates which sensor on the bus is returning the following information.
13	2	Indicates that the target sensor supports <a href="#">SDI-12 Specification v1.3</a> .
DECAGON _	8	Vendor identification string. (DECAGON and one space _)
GS3 _ _ _	6	Sensor model string. This string is specific to the sensor type. For the GS3, the string is GS3.
402	3	Sensor version. This number divided by 100 is the METER sensor version (e.g., 402 is version 4.02).
631800001	≤13, variable	Sensor serial number. This is a variable length field. It may be omitted for older sensors.

**NOTE:** In the event that the fixed length is longer than the parameter, the trailing characters will be populated with space characters.

### CHANGE ADDRESS COMMAND (aAB!)

The Change Address command is used to change the sensor address to a new address. All other commands support the wildcard character as the target sensor address except for this command. All METER sensors have a default address of 0 (zero) out of the factory. Supported addresses are alphanumeric (i.e., a–z, A–Z, and 0–9). An example output from a METER sensor is shown in [Example 2](#), where the command is in **bold** and the response follows the command.

**Example 2** **1A0!0**

<u>Parameter</u>	<u>Fixed Character Length</u>	<u>Description</u>
<b>1A0!</b>	4	Data logger command. Request to the sensor to change its address from 1 to a new address of 0.
0	1	New sensor address. For all subsequent commands, this new address will be used by the target sensor.

## ADDRESS QUERY COMMAND (?!)

While disconnected from a bus, the Address Query command can be used to determine which sensor is currently being communicated with. Sending this command over a bus will cause a bus contention where all the sensors will respond simultaneously and corrupt the data line. This command is helpful when trying to isolate a failed sensor. [Example 3](#) shows an example of the command and response, where the command is in **bold** and the response follows the command. The question mark (?) is a wildcard character that can be used in place of the address with any command except the Change Address command.

### Example 3 ?!0

<u>Parameter</u>	<u>Fixed Character Length</u>	<u>Description</u>
?!	2	Data logger command. Request for a response from any sensor listening on the data line.
0	1	Sensor address. Returns the sensor address to the currently connected sensor.

## COMMAND IMPLEMENTATION

The following tables list the relevant Measurement (M) and Data (D) commands when necessary.

### MEASUREMENT COMMAND IMPLEMENTATION

Measurement (M) commands are sent to a single sensor on the SDI-12 bus and require that subsequent Data (D) commands are sent to that sensor to retrieve the sensor output data before initiating communication with another sensor on the bus.

Please refer to [Table 2](#) and for an explanation of the command sequence and see [Table 6](#) for an explanation of response parameters.

**Table 2 aM! measurement command sequence**

<b>Command</b>	<b>Response</b>
This command reports instantaneous values.	
<b>aM!</b>	attn
<b>aD0!</b>	a+<dielectricPermittivity>±<temperature>+<electricalConductivity>

**NOTE:** The measurement and corresponding data commands are intended to be used back to back. After a measurement command is processed by the sensor, a service request a <CR><LF> is sent from the sensor signaling the measurement is ready. Either wait until *ttt* seconds have passed or wait until the service request is received before sending the data commands. See the [SDI-12 Specifications v1.3](#) document for more information.

### CONCURRENT MEASUREMENT COMMANDS IMPLEMENTATION

Concurrent Measurement (C) commands are typically used with sensors connected to a bus. C commands for this sensor deviate from the standard C command implementation. First, send the C command, wait the specified amount of time detailed in the C command response, and then use D commands to read its response prior to communicating with another sensor.

Please refer to [Table 3](#) for an explanation of the command sequence and see [Table 7](#) for an explanation of response parameters.

**Table 3 aC! measurement command sequence**

Command	Response
This command reports instantaneous values.	
aC!	atttnn
aD0!	a<dielectricPermittivity>±<temperature>+<electricalConductivity>

NOTE: This command does not adhere to the SDI-12 concurrent command requirements. See [METER SDI-12 Implementation](#) for more information.

NOTE: The measurement and corresponding data commands are intended to be used back to back. After a measurement command is processed by the sensor, a service request a <CR><LF> is sent from the sensor signaling the measurement is ready. Either wait until ttt seconds have passed or wait until the service request is received before sending the data commands. See the [SDI-12 Specifications v1.3](#) document for more information.

## CONTINUOUS MEASUREMENT COMMANDS IMPLEMENTATION

Continuous Measurement (R) commands trigger a sensor measurement and return the data automatically after the readings are completed without needing to send a D command.

Please refer to [Table 4](#) and [Table 5](#) for an explanation of the command sequence and see [Table 7](#) for an explanation of response parameters.

**Table 4 aR0! measurement command sequence**

Command	Response
This command reports instantaneous values.	
aR0!	a<dielectricPermittivity>±<temperature>+<electricalConductivity>

NOTE: This command does not adhere to the SDI-12 response timing. See [METER SDI-12 Implementation](#) for more information.

**Table 5 aR3! measurement command sequence**

Command	Response
This command reports instantaneous values.	
aR3!	a<TAB><dielectricPermittivity> <temperature> <electricalConductivity><CR><sensorType><Checksum>

NOTE: This command does not adhere to the SDI-12 response format or timing. See [METER SDI-12 Implementation](#) for more information.

## PARAMETERS

[Table 6](#) lists the parameters, unit measurement, and a description of the parameters returned in command responses for GS3.

**Table 6 Parameter Descriptions**

Parameter	Unit	Description
±	—	Positive or negative sign denoting sign of the next value
a	—	SDI-12 address
n	—	Number of measurements (fixed width of 1)
nn	—	Number of measurements with leading zero if necessary (fixed width of 2)
ttt	s	Maximum time measurement will take (fixed width of 3)
<TAB>	—	Tab character
<CR>	—	Carriage return character
<LF>	—	Line feed character
<dielectricPermittivity>	ε	Dielectric permittivity
<temperature>	°C	Air temperature

**Table 6 Parameter Descriptions (continued)**

Parameter	Unit	Description
<electricalConductivity>	μS/cm	Bulk electrical conductivity normalized to 25 °C
<sensorType>	—	ASCII character denoting the sensor type For GS3, the character is w
<Checksum>	—	METER serial checksum

NOTE: Electrical conductivity is output in μS/cm. To convert to dS/m, divide electrical conductivity by 1,000.

NOTE: To convert apparent dielectric to VWC for mineral soils, METER recommends the following calibration equation:

$$\theta = 5.89 \times 10^{-6} \times \epsilon_a^3 - 7.62 \times 10^{-4} \times \epsilon_a^2 + 3.67 \times 10^{-2} \times \epsilon_a - 7.53 \times 10^{-2}$$

## DDI SERIAL COMMUNICATION

The DDI serial communications protocol is ideal for systems that have dedicated serial signaling lines for each sensor or use a multiplexer to handle multiple sensors. The serial communications are compatible with many TTL serial implementations that support active-high logic levels using 0.0 to 3.6 VDC signal levels. When the sensor is first powered, it automatically makes measurements of the integrated transducers then outputs a response over the data line. Systems using this protocol control the sensor excitation to initiate data transfers from the sensor. This protocol is subject to change as METER improves and expands the line of digital sensors and data loggers.

For GS3 sensors with firmware version 3.37 and newer, the startup string is omitted when the SDI-12 address is nonzero.

NOTE: Out of the factory, all METER sensors start with SDI-12 address 0 and print out the startup string when power cycled. On sensors with firmware version 3.37 and newer the startup string is omitted when the address is nonzero.

## DDI SERIAL TIMING

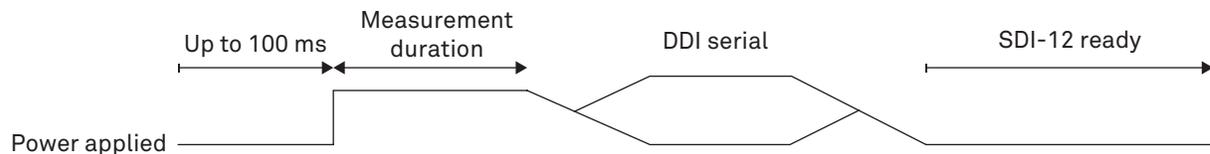
Table 7 lists the DDI serial communication configuration.

**Table 7 DDI serial communication configuration**

Baud Rate	1200
Start Bits	1
Data Bits	8 (LSB first)
Parity Bits	0 (none)
Stop Bits	1
Logic	Standard (active high)

At power up, the sensor will pull the data line high within 100 ms to indicate that the sensor is taking a reading (Figure 6). When the reading is complete, the sensor begins sending the serial signal out the data line adhering to the format shown in Figure 7. Once the data is transmitted, the sensor goes into SDI-12 communication mode. To get another serial signal, the sensor must be power cycled.

NOTE: Sometimes the signaling from the sensor can confuse typical microprocessor UARTs. The sensor holds the data line low while taking measurements. The sensor raises the line high to signal the logger that it will send a measurement. Then the sensor may take some additional measurements before starting to clock out the first data byte starting with a typical start bit (low). Once the first start bit is sent, typical serial timing is valid; however, the signal transitions before this point are not serial signaling and may be misinterpreted by the UART.



**Figure 6 Data line DDI serial timing**

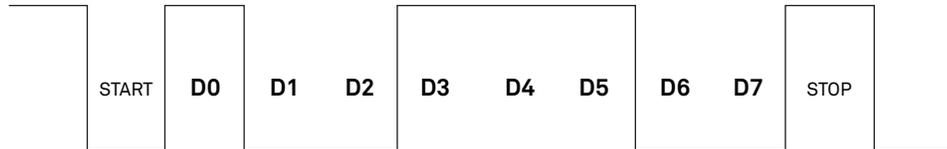


Figure 7 Example DDI serial transmission of the character 9 (0x39)

## DDI SERIAL RESPONSE

Table 8 details the DDI serial response.

Table 8 DDI serial response

COMMAND	RESPONSE
NA	<TAB><dielectricPermittivity> <temperature> <electricalConductivity><CR><sensorType><Checksum>

NOTE: There is no actual command. The response is returned automatically upon power up.

## DDI SERIAL CHECKSUM

These checksums are used in the continuous commands R3 and R4 as well as the DDI serial response. The legacy checksum is computed from the start of the transmission to the sensor identification character, excluding the sensor address.

Legacy checksum example input is <TAB>1.91 22.6 1<CR>w and the resulting checksum output is / (forward slash).

```
uint8_t LegacyChecksum(const char * Response)
{
    uint16_t length;
    uint16_t i;
    uint16_t sum = 0;

    // Finding the length of the response string
    length = strlen(response);

    // Adding characters in the response together
    for( i = 0; i < length; i++ )
    {
        sum += response[i];
        if(response[i] == '\r')
        {
            // Found the beginning of the meta data section of the response
            break;
        }
    }

    // include the sensor type into the checksum
    sum += response[++i];

    // Convert checksum to a printable character
    sum = sum % 64 + 32;

    return sum;
}
```

## CUSTOMER SUPPORT

### NORTH AMERICA

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 7:00 am to 5:00 pm Pacific time.

**Email:** [support.environment@metergroup.com](mailto:support.environment@metergroup.com)  
[sales.environment@metergroup.com](mailto:sales.environment@metergroup.com)

**Phone:** +1.509.332.5600

**Fax:** +1.509.332.5158

**Website:** [metergroup.com](http://metergroup.com)

### EUROPE

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 8:00 to 17:00 Central European time.

**Email:** [support@metergroup.de](mailto:support@metergroup.de)  
[sales@metergroup.de](mailto:sales@metergroup.de)

**Phone:** +49 89 12 66 52 0

**Fax:** +49 89 12 66 52 20

**Website:** [metergroup.de](http://metergroup.de)

If contacting METER by email, please include the following information:

Name	Email address
Address	Instrument serial number
Phone number	Description of problem

**NOTE:** For products purchased through a distributor, please contact the distributor directly for assistance.

## REVISION HISTORY

The following table lists document revisions.

Revision	Date	Compatible Firmware	Description
01	4.30.2019	4.02	Updated Customer Support information.
00	5.17.2018	4.02	Rebranded document for METER.