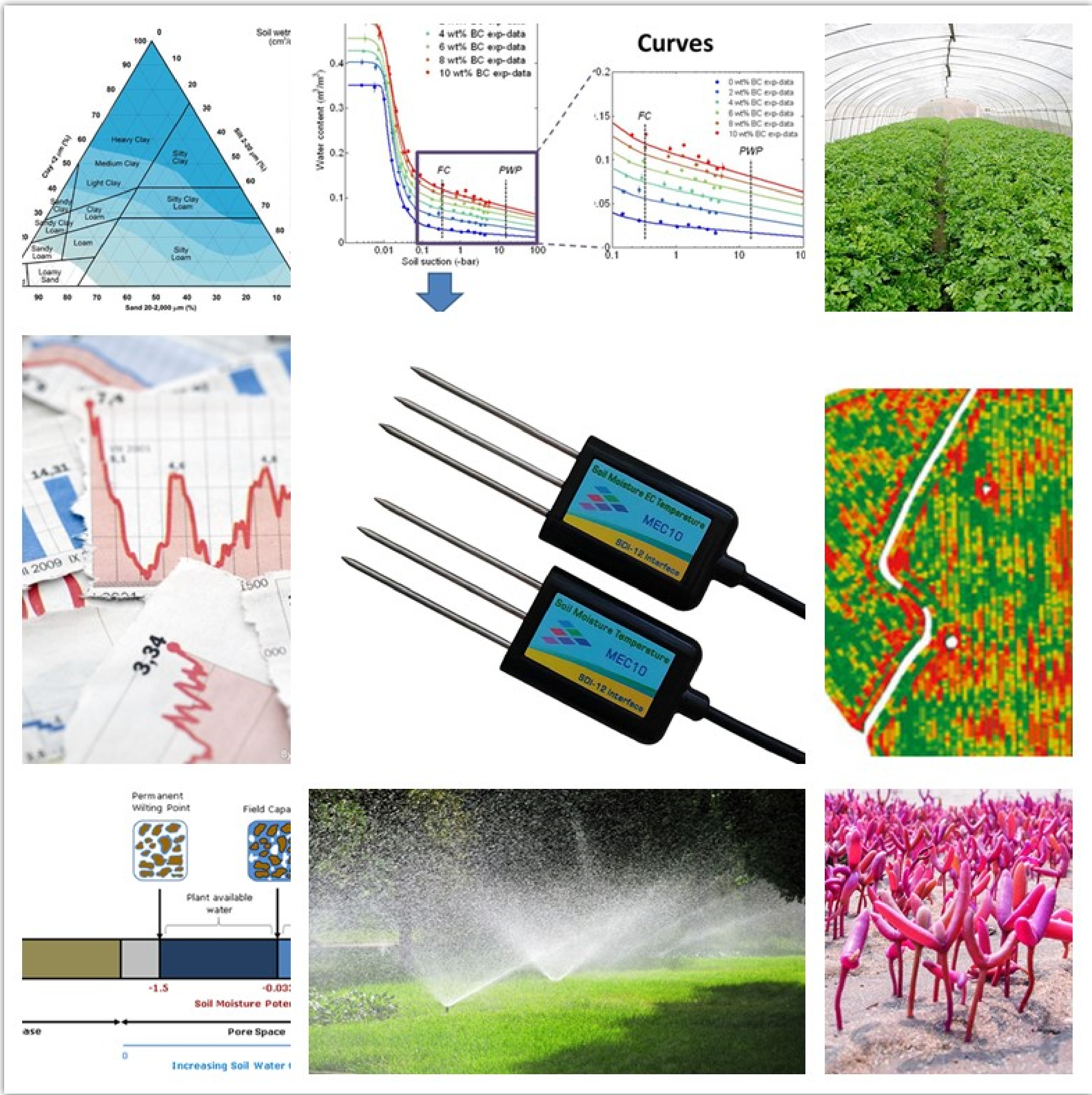
MEC10 (SDI-12 Interface)

Soil Moisture EC and Temperature Sensor (MEC10-J)

Soil Moisture and Temperature Sensor (MEC10-K)

User Manual



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Website

http://www.infwin.com

E-Mail

infwin@163.com

Telephone

+86-411-66831953, +86-4000-511-521

Fax

+86-411-66831953

2 Introduction

The MEC10 Substrate and Soil Moisture, Temperature, and Electrical Conductivity (EC) sensor is an accurate tool for monitoring volumetric water content (VWC), temperature in soil and soilless substrates, and electrical conductivity. It sealed with resin packaged plastic body with sensing rods which can be insert directly into the soil or substrate with long time stability.

The sensor is applicable for science research, irrigation, greenhouse, smart agriculture etc.

Features

- Integrated with Moisture, EC and Temperature measurement
- Digital sensor communicates over SDI-12 serial interface
- Low-input voltage requirements for power supply
- Low-power design supports battery-operated data loggers
- Low salinity sensitivity
- Robust epoxy encapsulation resists corrosive environments
- High accuracy with excellent stability
- Reverse power protection and Built-in TVS/ESD protection

Applications

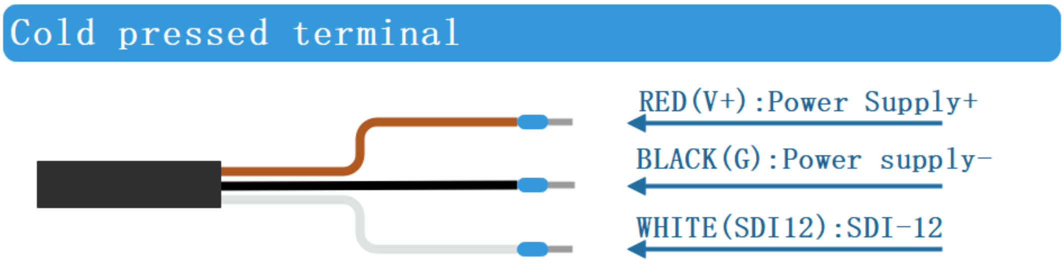
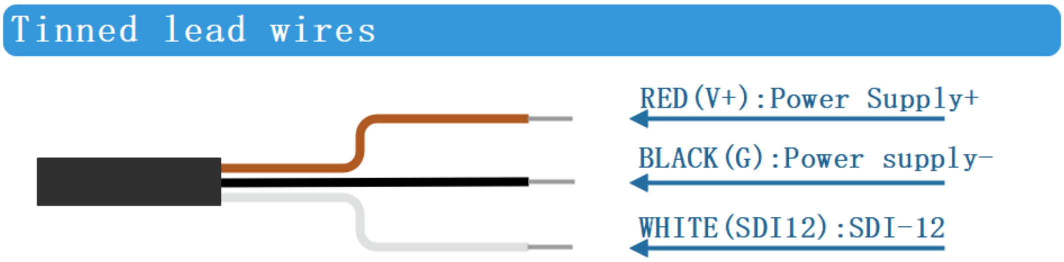
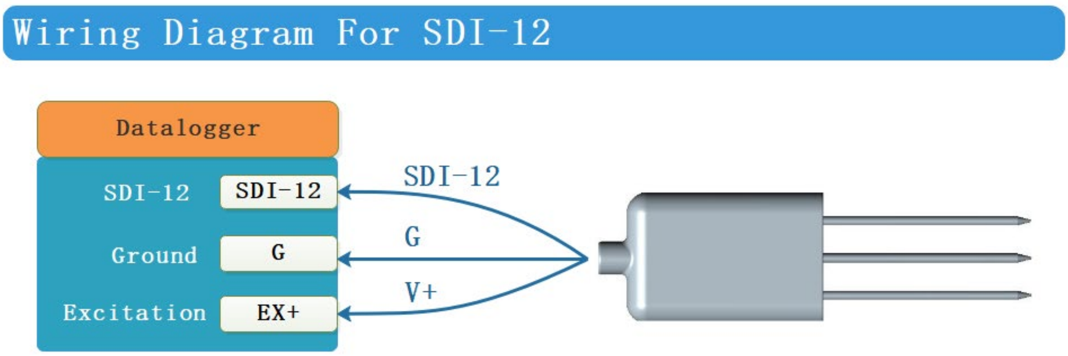
- Smart Agriculture, Hydroponic and Horticulture
- Greenhouse monitoring
- Soil/Substrate water balance
- Irrigation management
- Solute/fertilizer movement
- Reference evapotranspiration calculations

Specifications	
Output Interface	SDI-12, V1.3
Power Supply	3.9-28V/DC
Power Consumption	SDI-12: Quiescent Current : <30uA Measuring Current : <20mA during 150ms measurement
Moisture Measurement	Apparent dielectric permittivity: Range:1-81 (air - water), Resolution: 1-40.00: 0.1， 40.00-81.88: 0.5 Accuracy:1.00-40.00:+/-1.5, 40.00-81.00:+/-10% of Readings Volumetric Water Content (VWC): Range:0-100%, Resolution: 0.1% Accuracy: +/-3% The VWC range is dependent on the media the sensor is calibrated to. A custom calibration will accommodate the necessary ranges for most substrates.
EC Measurement	Range: 0-23.00ds/m; Resolution: 0.01ds/m; Accuracy: 0-7.00ds/m, 5%; 7.00-23.00ds/m, +/-15% of Readings Temperature compensation: 0-50°C
Temperature Measurement	Range: -40-80°C, Resolution:0.1°C, Accuracy:+/-0.5°C
IP Ratings	IP68
Operating Temperature	-40-80°C
Sensor Sealed	Epoxy resin
Installation	Surface or buried installation
Cable Length	2 meters or Customize
Dimension	46*15*146mm
Electrode Length	70mm

Electrical and Timing Characteristics			
Item	**Minimum**	**Typical**	**Maximum**
Supply Voltage (V+ to G), 3.9-28V DC	3.9 V DC	N/A	28 V DC
Digital Input Voltage (logic high) , SDI-12	3.0 V	3.3 V	5.0 V
Digital Input Voltage (logic low), SDI-12	-0.3 V	0.0 V	0.5 V
Digital Output Voltage (logic high) , SDI-12	N/A	3.3 V	3.6V
Power Line Slew Rate	1.0 V/ms	N/A	N/A
Current Drain (during measurement) , SDI-12	3.0 mA	3.6 mA	20mA
Current Drain (while asleep) , SDI-12	N/A	30 uA	N/A
Power-Up Time (ADI serial)	80 ms	N/A	100ms
Power-Up Time (SDI-12)	N/A	300 ms	N/A
Measurement Duration	N/A	150 ms	N/A

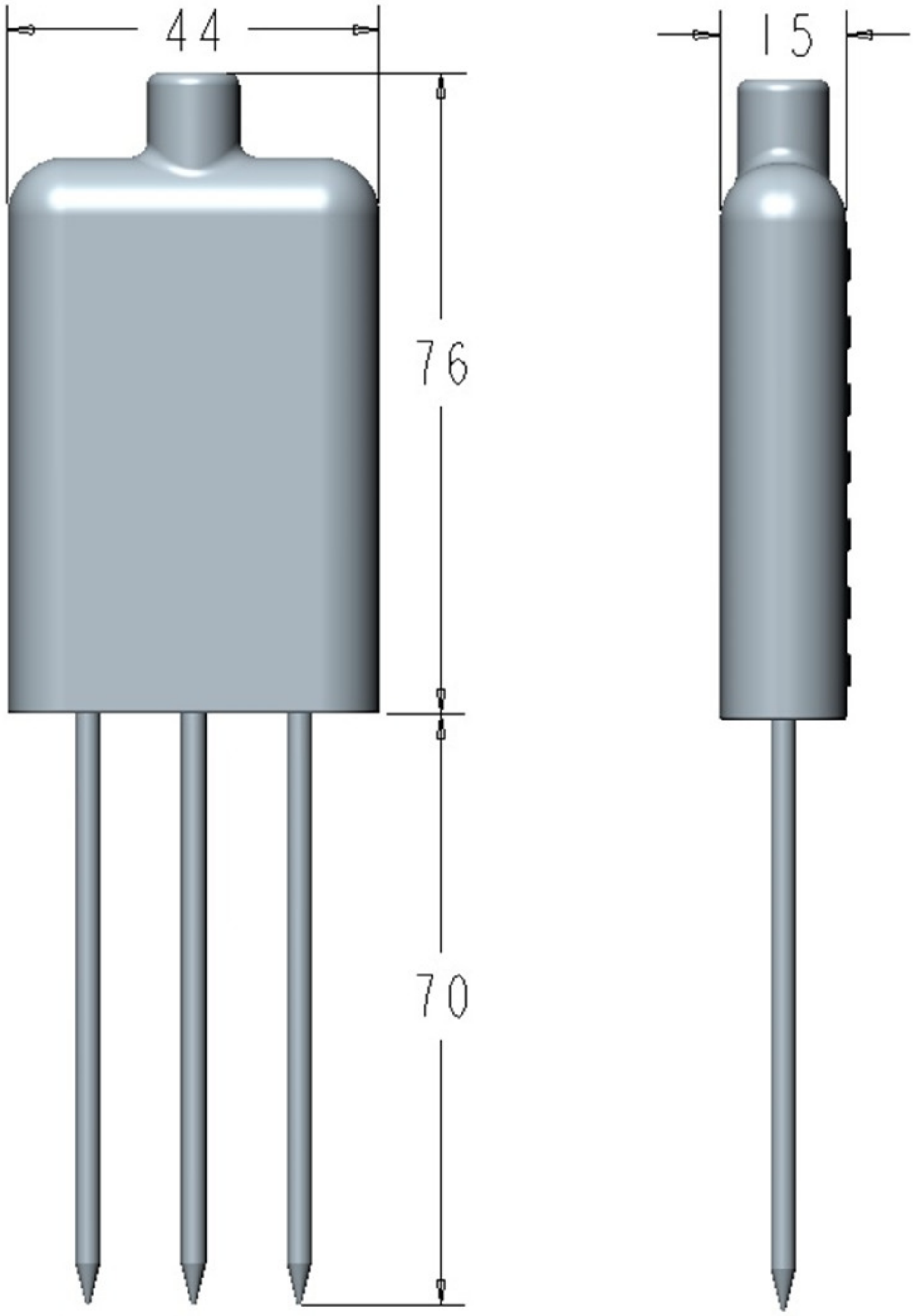
3 Wiring diagrams

3.1 SDI-12 Interface

Type	Wiring diagram
SDI-12 Interface	 
Connections	

4 Dimension and Ordering Infomation

4.1 Dimension



Unit: mm

4.2 Ordering Information

Parameters	Code	Comments
Code 1: Product Series	MEC10	MEC10 Soil Moisture, Temperature , (EC) Sensor
Code 2: Measuring Parameters	J K E F	Soil Moisture & Temperature & EC (Protocol compatible with Decagon 5TE) Soil Moisture & Temperature (Protocol compatible with Decagon 5TM) Soil Moisture & Temperature & EC (Protocol compatible with METER TEROS12) Soil Moisture & Temperature (Protocol compatible with METER TEROS11) Note: Please refer to separate user manual for Code E & F
Code 3: Soil Moisture Range	B	0-100%
Code 4: EC Range	C X	0-23.00ds/m No EC measurement
Code 5: Power Supply	F	3.9-28V DC
Code 6: Output Interface	F	SDI-12
Code 7: Connector	B C	Cold pressed terminal Stripped & tinned lead wires
Code 8: Cable Length	002 XXX	2 meters Customize, XXX is required cable length(Unit: meter)
Ordering Code Example: MEC10-JBCFFB002 Product Series: MEC10 Soil Moisture, Temperature , (EC) Sensor; Measuring Parameters: Soil Moisture & Temperature & EC (Protocol compatible with Decagon 5TE); Soil Moisture Range: 0-100%; EC Range: 0-23.00ds/m Power Supply: 3.9-28V DC Output Interface: SDI-12; Connector: Cold pressed terminal; Cable Length: 2 Meters		

5 Safty ,Care and Installation

5.1 Care and Safty

■ The rods of the Sensor are sharp for ease insertion. Care must be taken and handling precautions followed.
■ Avoid touching the rods or exposing them to other sources of static damage, particularly when powered up.
■ Do not pull the sensor out of the substrate by its cable.
■ If you feel any resistance when inserting the sensor into substrate, Stop pushing and re-insert at a new location.

5.2 Installation

■ Clear away any stones. Pre-form holes in very hard soil or substrate before insertion.
■ Push the sensor into the substrate until the rods are fully inserted. Ensure good substrate contact.
■ If you feel strong resistance when inserting the sensor, you have probably hit a stone. Stop, and re-insert at a new location.

6 SDI-12 Communication

The sensor has two type of serial interface and protocol, ADI protocol (Active Digital Interface) and SDI-12 Protocol.

6.1 SDI-12 Protocol (Decagon 5TE & 5TM compatible parts)

The description and terms used within this chapter are listed in table below:

Parameters	Unit	Description
+/-	-	Sign of the 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	Seconds	Maximum measurement time (fixed width of 3)
tttt	Seconds	Maximum measurement time (fixed width of 4)
<SPACE>	-	Space character
<CR>	-	Carriage return character
<LF>	-	Line feed character
<Checksum>	-	SUM Checksum
<CRC>	-	SDI-12 protocol CRC Checksum
<VERIFY_STATUS>	-	Sensor Verification status
<sensorType>	-	ASCII character denoting the sensor type For MEC10-J, the character is ‘g’ For MEC10-K, the character is ‘h’
<±SubstrateTemp>	°C °F	Substrate Temperature, the value unit depends on the temperature unit setting. Range: -40.0 - +80.0°C
<+SubstrateECBulk(ds/m)>	ds/m	Substrate Bulk EC normalized to 25 °C. Range: +0 - +23.00ds/m
<+SubstrateEpsilon>, ξ_a	-	Substrate Apparent Epsilon of volumetric water content. Range:0.00-200.00

6.1.1 Protocol

Request	Response	Comment
a!	a<CR><LF> Acknowledge Active a: Sensor address	**Example:** Request: 0! Response: 0<CR><LF>
aI!	allccccccccmmmmmmvvvxxxxxxxxxxxxxx<CR><LF> Send Identification	**Example (MEC10-J):** Request: 0I! Response: 013INFWIN MEC10J8.1MEC10-J-44000

	a: Sensor address ll:SDI-12 Version Number cccccccc: 8 characters vendor identification mmmmmm: 6 characters specifying the sensor model number vvv: 3 characters specifying the sensor version xxxxxxxxxxxxx: 13 characters serial number <CR><LF>: terminates the response	**Example (MEC10-K):** Request: 0I! Response: 013INFWIN MEC10K8.1MEC10-K-44000
?!	a<CR><LF> Sensor Address Query a:Sensor address	**Example:** Request: ?! Response: 0<CR><LF>
aAb!	b<CR><LF> Change Sensor address a:Current Sensor address b:New Sensor address	**Example:** Request: 0A1! Response: 1<CR><LF>
aM!, aMC!	**MEC10-J:** a0013<CR><LF> a:Sensor address 001: Measurement data will be ready in 001 seconds 3: Number of measurement data returned by aD0! <CR><LF>:terminates the response aD0! Response data format： a<+SubstrateEpsilon><+SubstrateECBulk(ds/m)><±SubstrateTemp>[<CRC>]<CR><LF> **MEC10-K:** a0012<CR><LF> a:Sensor address 001: Measurement data will be ready in 001 seconds 2: Number of measurement data returned by aD0! <CR><LF>:terminates the response aD0! Response data format： a<+SubstrateEpsilon><±SubstrateTemp>[<CRC>]<CR><LF>	**Example (MEC10-J):** Request: 0M! Response: 00013<CR><LF> Response: 0<CR><LF> Request: 0D0! Response: 0+23.53+2.60+17.6<CR><LF> **Example (MEC10-K):** Request: 0M! Response: 00012<CR><LF> Response: 0<CR><LF> Request: 0D0! Response: 0+18.96+18.0<CR><LF>
aC!, aCC!	**MEC10-J:**	**Example (MEC10-J):**

	a00103<CR><LF> a:Sensor address 001: Measurement data will be ready in 001 seconds 03: Number of measurement data returned by aD0! <CR><LF>:terminates the response aD0! Response data format： a<+SubstrateEpsilon><+SubstrateECBulk(ds/m)><±SubstrateTemp>[<CRC>]<CR><LF> **MEC10-K:** a00102<CR><LF> a:Sensor address 001: Measurement data will be ready in 001 seconds 02: Number of measurement data returned by aD0! <CR><LF>:terminates the response aD0! Response data format： a<+SubstrateEpsilon><±SubstrateTemp>[<CRC>]<CR><LF>	Request: 0C! Response: 000103<CR><LF> Request: 0D0! Response: 0+23.53+2.60+17.6<CR><LF> **Example (MEC10-K):** Request: 0C! Response: 000102<CR><LF> Request: 0D0! Response: 0+18.96+18.0<CR><LF>
aD0!	a[<saaaa>][<sbbbb>][<scccc>][<CRC>]<CR><LF>	Send Data Command, The sensor responds by sending the data The data returned depends on the command you send most recently. [<saaaa>]: data 1 [<sbbbb>]: data 2 [<scccc>]: data 3 [<CRC>]: Optional 3 characters CRC checksum, <CR><LF>:terminates the response
aR0!, aRC0!	**MEC10-J:** Response data format： a<+SubstrateEpsilon><+SubstrateECBulk(ds/m)><±SubstrateTemp>[<CRC>]<CR><LF> **MEC10-K:** Response data format： a<+SubstrateEpsilon><±SubstrateTemp>[<CRC>]<CR><LF>	**Example (MEC10-J):** Request: 0R0! Response: 0+23.53+2.60+17.6<CR><LF> **Example (MEC10-K):** Request: 0R0! Response: 0+18.96+18.0<CR><LF>
aR3!, aRC3!	Response data format：	**Example (MEC10-J):**

aR4!, aRC4!	a<SPACE><EPSILONraw><SPACE><ECraw><SPACE><Traw><CR><sensorType><Checksum><CR><LF> Note: For MEC10-K, the <ECraw> will always be 0.	Request: 0R3! Response: 0<SPACE>2499<SPACE>127<SPACE>587<CR>z]<CR><LF> Request: 0R4! Response: 0<SPACE>2499<SPACE>127<SPACE>587<CR>z]<CR><LF> **Example (MEC10-K):** Request: 0R3! Response: 0<SPACE>2499<SPACE>0<SPACE>587<CR>x1<CR><LF> Request: 0R4! Response: 0<SPACE>2499<SPACE>0<SPACE>587<CR>x1<CR><LF>

6.1.2 Data Conversion

- **Water Content Conversion for Soil**

Using following conversion formula for VWC calculation.

$$VWC = 4.3*10^{-6}*\xi_a^3 - 5.5*10^{-4}*\xi_a^2 + 2.92*10^{-2}*\xi_a - 5.3*10^{-2}$$

- **Water Content Conversion for Non-soil substrate**

Using following conversion formula for VWC calculation.

- **Potting Soil**

$$VWC = 2.25*10^{-5}*\xi_a^3 - 2.06*10^{-3}*\xi_a^2 + 7.24*10^{-2}*\xi_a - 0.247$$

- **Rockwool**

$$VWC = -1.68*10^{-3}*\xi_a^2 + 6.56*10^{-2}*\xi_a + 0.0266$$

- **Perlite**

$$VWC = -1.07*10^{-3}*\xi_a^2 + 5.25*10^{-2}*\xi_a - 0.0685$$

6.2 SDI-12 Protocol (Extension parts)

The description and terms used within this chapter are listed in table below:

Parameters	Unit	Description

<CR>	-	Carriage return character
<LF>	-	Line feed character

6.2.1 Protocol

Request	Response	Comment
aXR_TUNIT!	aTUNIT=<X><CR><LF> <X> is temperature unit: C: Degrees Centigrade F: Degrees Fahrenheit	**Query temperature unit** **Example:** Request: 0XR_TUNIT! Response: 0TUNIT=C<CR><LF>
aXW_TUNIT_<X>!	aTUNIT=<X><CR><LF>	**Configure temperature unit** **Example:** Request: 0XW_TUNIT_C! Response: 0TUNIT=C<CR><LF>
aXR_SUBSTRATETYPE!	aSUBSTRATETYPE=<X><CR><LF> <X> is substrate type: 0: Soil 1: Soilless 2: UDF(User Defined Curve) The substrate type is only used for <SubstrateVWC> calculation based on different formula.	**Query substrate type** **Example:** Request: 0XR_SUBSTRATETYPE! Response: 0SUBSTRATETYPE=0<CR><LF>
aXW_SUBSTRATETYPE_<X>!	aSUBSTRATETYPE=<X><CR><LF>	**Configure substrate type** **Example:** Request: 0XW_SUBSTRATETYPE_0! Response: 0SUBSTRATETYPE=0<CR><LF>
aXR_ADIEN!	aADIEN=<v><CR><LF> <v>: ADI output enable on sensor start up, when SDI12 is 0 on sensor start up: <v>=0 the sensor will output data in ADI format. <v>=0 the sensor will not output data in ADI format.	**Query ADI output enable** **Example:** Request: 0XR_ADIEN! Response: 0ADIEN=1<CR><LF>
aXW_ADIEN_<v>!	aADIEN=<v><CR><LF>	**Set ADI output enable** **Example:** Request: 0XW_ADIEN_0! Response: 0ADIEN=0<CR><LF>
aXR_SN!	aSN=<ssssssss><CR><LF> <ssssssss> is 8-digits serial number	**Query serial number** **Example:** Request: 0XR_SN! Response: 0SN=12345678<CR><LF>

aXW_SN_<ssssssss>!	aSN=<ssssssss><CR><LF>	**Configure serial number** **Example:** Request: 0XW_SN_ABCDEFGH! Response: 0SN=ABCDEFGH<CR><LF>

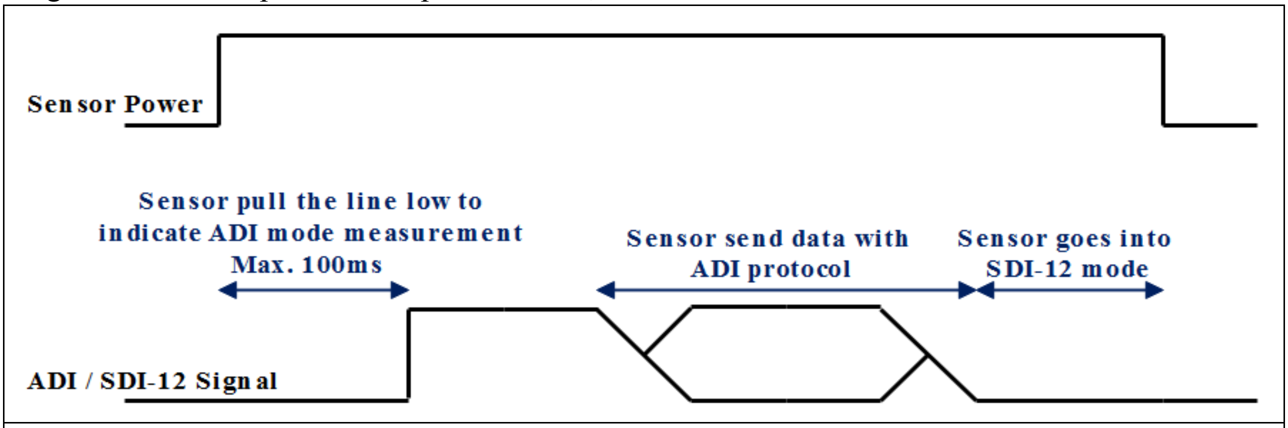
6.3 ADI Interface and Protocol

The description and terms used within this chapter are listed in table below:

Parameters	Unit	Description
<SPACE>	-	Space character
<CR>	-	Carriage return character
<LF>	-	Line feed character
<Checksum>	-	SUM Checksum
<sensorType>	-	ASCII character denoting the sensor type For MEC10-J, the character is 'g' For MEC10-K, the character is 'h'
<EPSILONraw>	-	ADI output raw value for Epsilon. Range: 0 - 4095
<Traw>	-	ADI output raw value for Temperature. Range:0-1022
<ECraw>	-	ADI output raw value for EC Range:0-1022

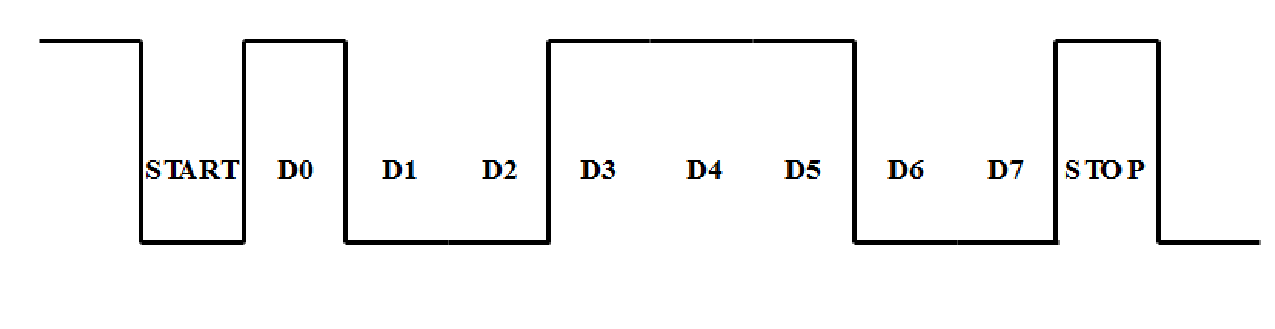
6.3.1 ADI Interface

ADI interface protocol(TTL signal),ADI is short for Active Digital Interface. Each time when sensor power up with SDI-12 address 0,the sensor firstly enter into the ADI mode and pull down the SDI-12 signal line for 100ms to indicating the measurement in processing,then release the SDI-12 signal line and output the ADI protocol data, and then enter into the SDI-12 interface mode.



ADI protocol logic

ADI interface is TTL compatiable standard(0-3.6V),protocol data stream is encoded in ASCII,Baudrate 1200bps,None parity,8 data bits,1 stop bit.The sensor enter into SDI-12 standby mode after the ADI output.You'll need to re power up the sensor again for another ADI output.ADI interface transmission bit diagram is as following.



Transmission bit diagram of the ASCII character‘9’(0x39)

6.3.2 Protocol

ADI protocol format:
“<EPSILONraw><SPACE><ECraw><SPACE><Traw><CR><sensorType><Checksum><CR><LF>”

Parameters	Description
<EPSILONraw>	ADI output raw value for Epsilon
<SPACE>	Space Character
<ECraw>	ADI output raw value for EC Note: This output is only available on MEC10-J
<SPACE>	Space Character
<Traw>	ADI output raw value for Temperature
<CR>	Carriage return character
<sensorType>	ASCII character denoting the sensor type For MEC10-J, the character is ‘z’ For MEC10-K, the character is ‘x’
<Checksum>	SUM Check from <EPSILONraw> to <sensorType>
<CR>	Carriage return character
<LF>	Line feed character

The data stream protocol including 3 raw measurement data with space delimited, and terminated by the carriage return.

The first data is Epsilon raw value. The second data is EC raw value(will be always 0 for those sensors without EC measurement),The third data is Temperature raw value. Those raw data can be converted to the measurement values by following formulas:

- Epsilon ξ_a

Epsilon raw value ranges from 0~4094 (and 4095 to indicate the error),and can be converted to epsilon value ξ_a 0.00~81.88 :

ξ_a = <EPSILONraw>/50.00

- EC(bulk)

<ECraw> value ranges from 0~1022(and 1023 to indicate the error),and can be converted to $EC_{(bulk)}$ 0.00~23.10ds/m :

When "<ECraw>"≤700 then $EC_{(bulk)}$ = ECraw/100

When "<ECraw>">700 then $EC_{(bulk)} = \frac{700 + 5\,(ECraw - 700)}{100}$

The unit of EC is:ds/m

- Temperature

<Traw> value ranges from 0~1022(and 1023 to indicate the error),when temperature in -40.0~50.0°C, resolution is 0.1°C;when temperature in 50.5~111.0°C, resolution is 0.5°C :

When "<Traw>"≤900 then $T_{Raw2} = T_{Raw}$

When "<Traw>">900 then $T_{Raw2} = 900 + 5\,(T_{Raw} - 900)$

Temperature T(°C)= $\frac{(TRaw2 - 400)}{10}$

Example: Data stream sent by sensor,"56 432 645<0D>zG<0D><0A>"

Parameters	Comment
56	ξ_a =EPSILONraw/50.00 = 56/50=1.12,and then using proper formula to convert ξ_a to VWC
Space	data delimiter
432	For MEC10-J: ECraw=432≤700, then EC(bulk) = Ecraw/100 = 432/100=4.32ds/m. For MEC10-K: this value is always 0.
Space	data delimiter
645	Traw=645≤900 then TRaw2 = TRaw = 645 And then temperature T(°C)= $\frac{(TRaw2 - 400)}{10} = \frac{(645 - 400)}{10}$ =24.5°C
<0D>	Carriage return
z	Sensor type indicator. 'z'is MEC10-J 'x'is MEC10-K
G	Checksum of string "56 432 645<0D>z" for transmission validation.
<0D><0A>	Carriage return,is the data stream terminator

ADI Interface checksum calculation:

```
char CalcADIChecksum(char * Response)
{
    int length, sum = 0, i, crc;
    // stream data length
    length = strlen(Response);
    // checksum calculation
    for( i = 0; i < length; i++ )
        sum += Response[i];
    // convert to printable character
    crc = sum % 64 + 32;
    return crc;
}
```

Using"56 432 645<0D>z"as function parameters "char * Response" and you will get a checksum 'G'

Appendix A SDI-12 Sensor Testing and Settings

The user can test the communication or set the parameters with the SDI-12 sensors in the following method.

■ Use any kind of master device that supports the SDI-12 interface (such as data acquisition device, data logger, etc.) to communicate with the sensor or set the parameters.

■ Use a computer to communicate with the sensor through the SDI-12 converter (such as the SDI12ELF20 converter) and to set the parameters.

This chapter mainly introduces the communication or parameter setting on a computer for sensor through the SDI-12 converter (SDI12ELF20).

A.1 Testing SDI-12 Sensors with SDI12ELF20 Converter

SDI12ELF20 is a communication converter between USB master device and SDI-12 sensor. It supports bidirectional transparent transmission of SDI-12 communication data and is used to control or test SDI-12 compatible sensors or devices. The USB master device can be a computer, Raspberry PI and other hosts that support USB interface.

SDI12ELF20 Converter User Manual
https://www.infwin.com/sdi12elf20-sdi-12-to-usb-converter/

In this example, a computer is used as a USB host to connect the sensor through the SDI12ELF20 converter for SDI-12 communication test.

Installation steps:

■ Install USB Virtual COM port driver on PC, laptop or other USB master device. The converter uses the CH340C as the USB bridge chip. Download and install the CH340C driver and install it. After the converter is connected to the PC, a COM port is added to the system port. Use this port number in the debugging software to debug the communication with the converter.

Driver Download
https://www.infwin.com/resource-usb-to-serial-port-driver-ch340-series

■ Connect the converter to a PC, laptop or other USB master device through USB port

■ Connect the sensor of the SDI-12 port to the converter

■ The sensor can be powered by the power output that comes with the converter or by an external power supply which has common POWER GROUND with the converter power supply

■ Users can use any serial communication software for SDI-12 communication, such as Terminal, The default communication parameters of SDI12ELF20 is 9600bps, none parity, 8 data bits, 1 stop bit. Please use ASCII mode to send and receive data.

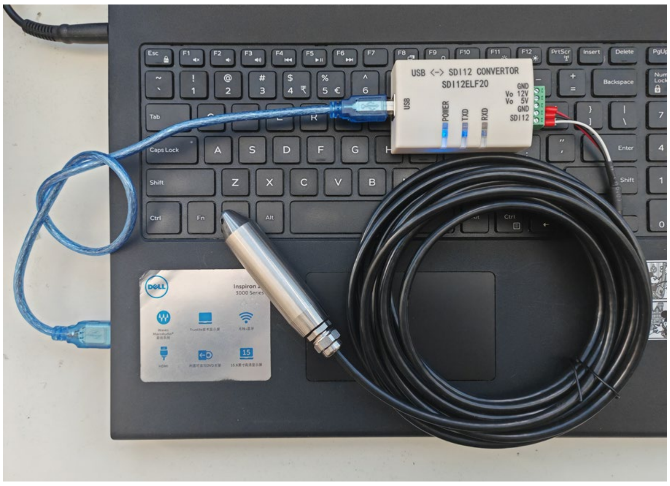
Testing Software Download	
Terminal (universal serial port debugging tool)	https://www.infwin.com/resource-serial-port-com-development-tool/
SensorOneSetSDI12 (SDI-12 sensor configuration utility)	https://www.infwin.com/resource-sensoronesetsdi12-configuration-utility-for-sdi-12-sensors/

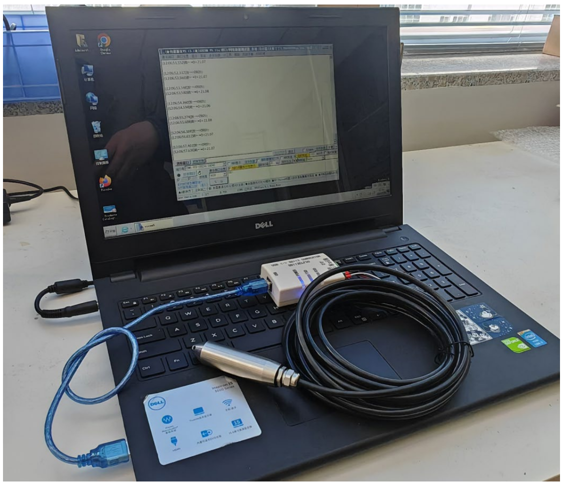
A.2 Testing Example

In this example, we use the SDI12ELF20 converter to communicate between a computer and the rugged temperature sensor DigiTEMP, The power supply of DigiTEMP is also provided by SDI12ELF20.

DigiTEMP Rugged Temperature Sensor User Manual
https://www.infwin.com/digitemp-rugged-digital-temperature-sensor-sdi12-rs485-modbus/

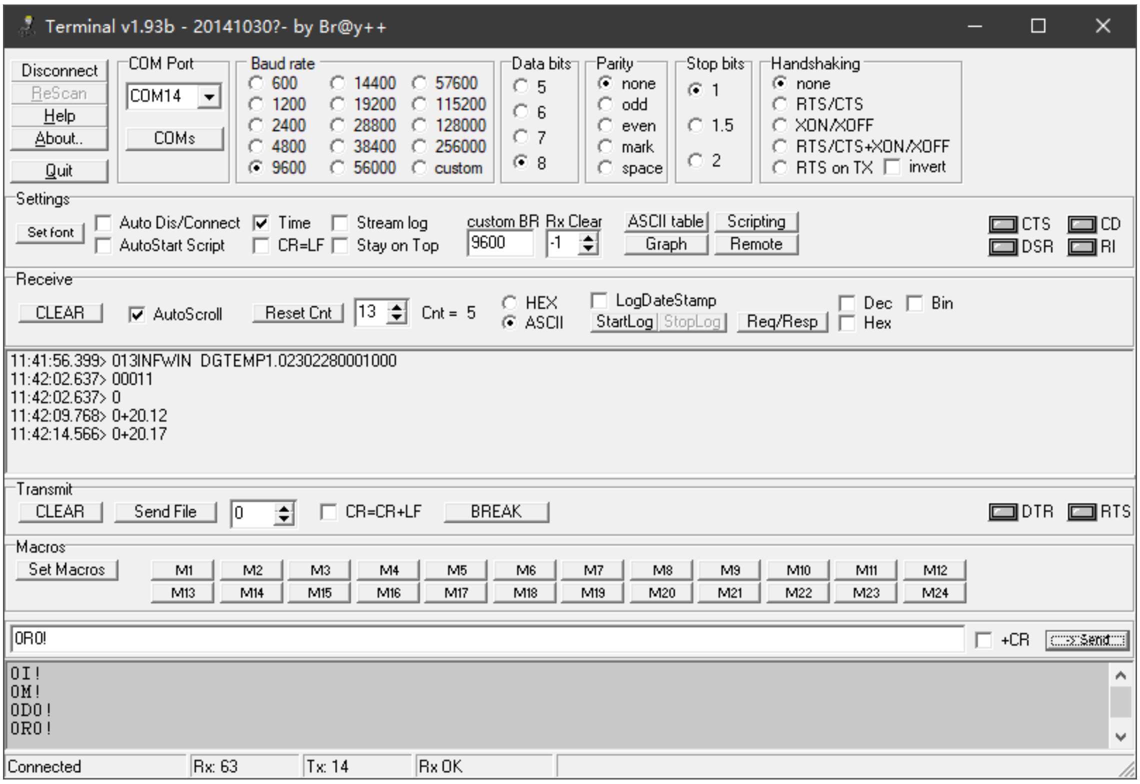
■ **Connections**





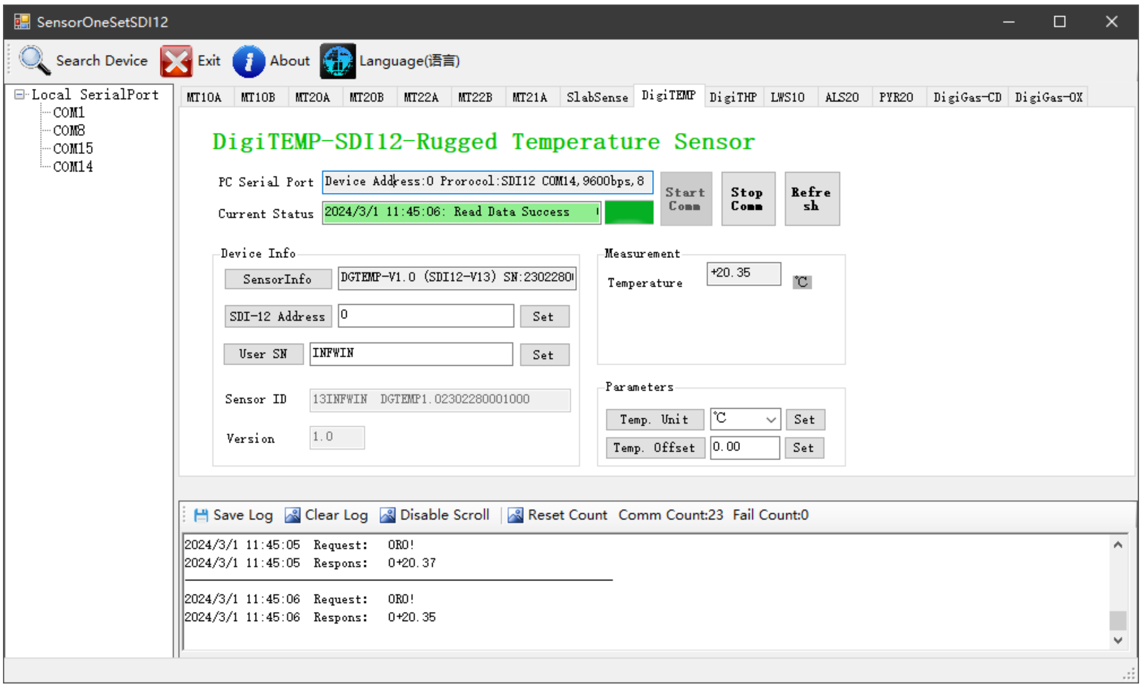
■ **Testing with serial port utility "Terminal"**

Take "Terminal" as an example, when debugging, please select the corresponding serial port number, baudrate is set to 9600bps, none parity, 8 data bits, 1 stop bit (the default communication Settings of SDI12ELF20), open the serial port and input the SDI-12 command and send. Please note that the ASCII format should be used for data communication.



■ **Testing with SDI-12 sensor configuration utility "SensorOneSetSDI12"**

Start up the application, select the corresponding product page DigiTEMP, click "start communication" and choose the proper serial port number, 9600bps, none parity, 8 data bits, 1 stop bit (SDI12ELF20 default communication Settings) and start communication.



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Version Control

Date	Version	Comment	Updated by
2024-02-11	V1.0	Initial Creation	sl51930