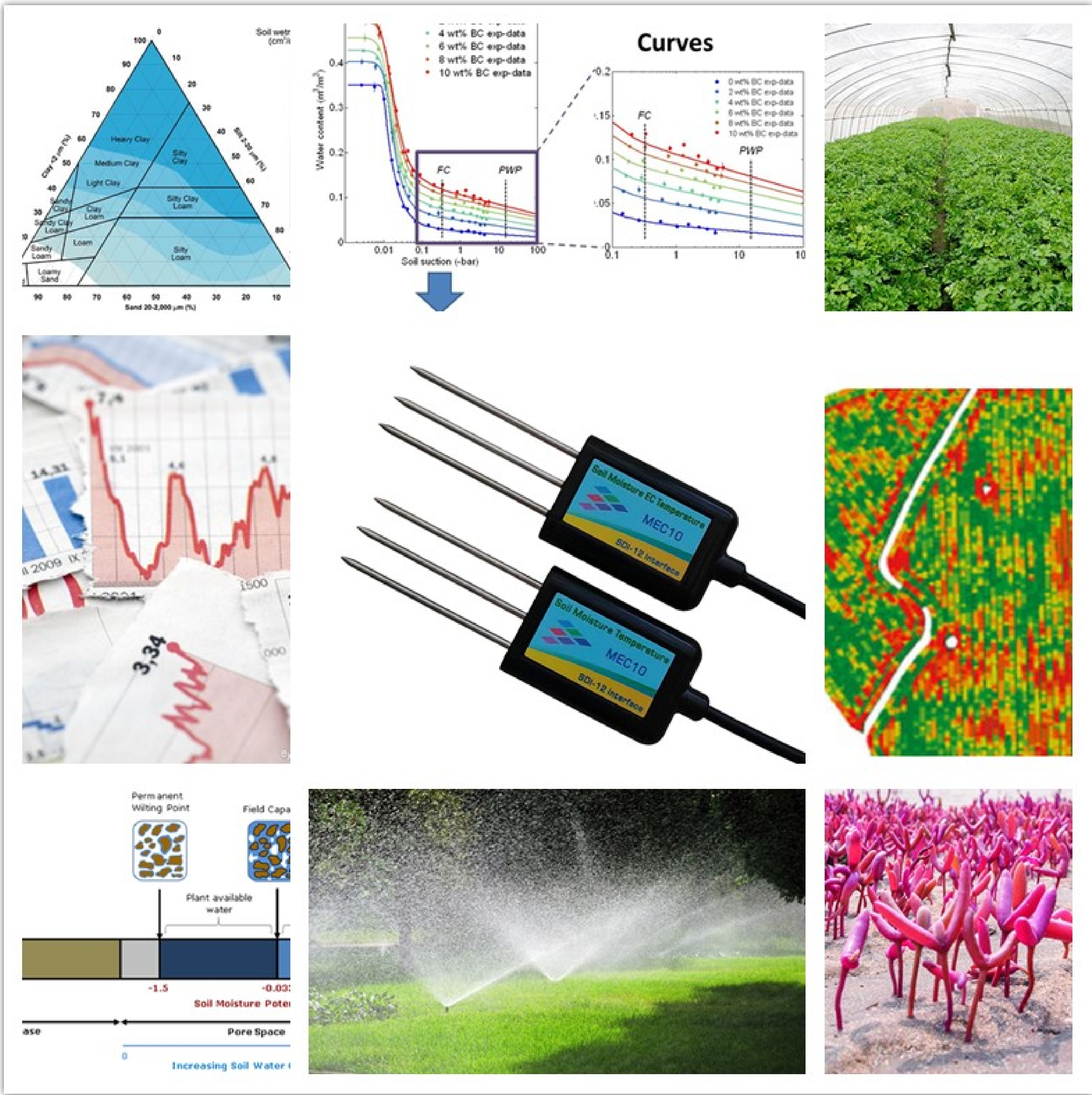
MEC10 (SDI-12 Interface)

Soil Moisture EC and Temperature Sensor (MEC10-E)

Soil Moisture and Temperature Sensor (MEC10-F)

User Manual



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1 Customer Support

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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

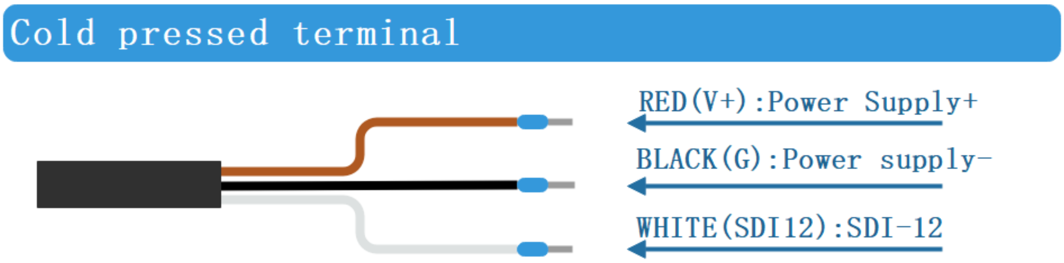
- Smart Agriculture, Hydroponic and Horticulture
- Greenhouse monitoring
- Soil/Substrate water balance
- Irrigation management
- Solute/fertilizer movement
- Reference evapotranspiration calculations

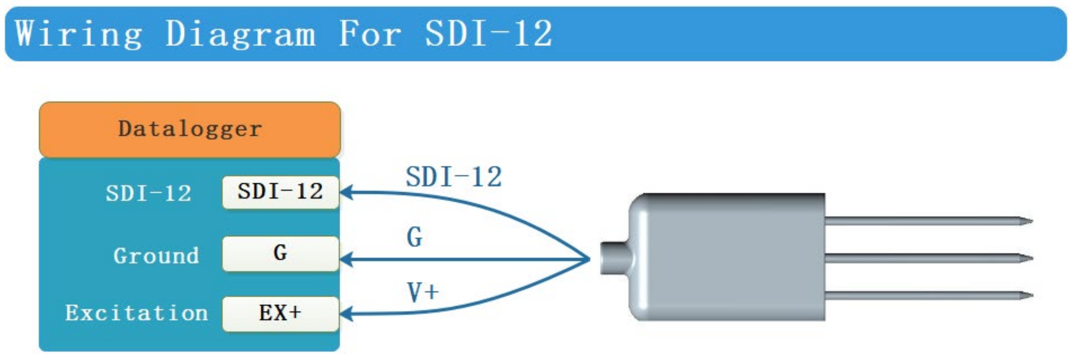
Specifications	
Output Interface	SDI-12, V1.3
Power Supply	3.9-28V/DC
Power Consumption	SDI-12: Quiescent Current : <30uA Measuring Current : <20mA during 150ms measurement
Moisture Measurement	Apparent dielectric permittivity: Range:1-81 (air - water), Resolution: 1-40.00: 0.1， 40.00-81.88: 0.5 Accuracy:1.00-40.00:+/-1.5, 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: 0-23000us/cm; Resolution: 10us/cm; Accuracy: 0-7000us/cm, 5%; 7000-23000us/cm, +/-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

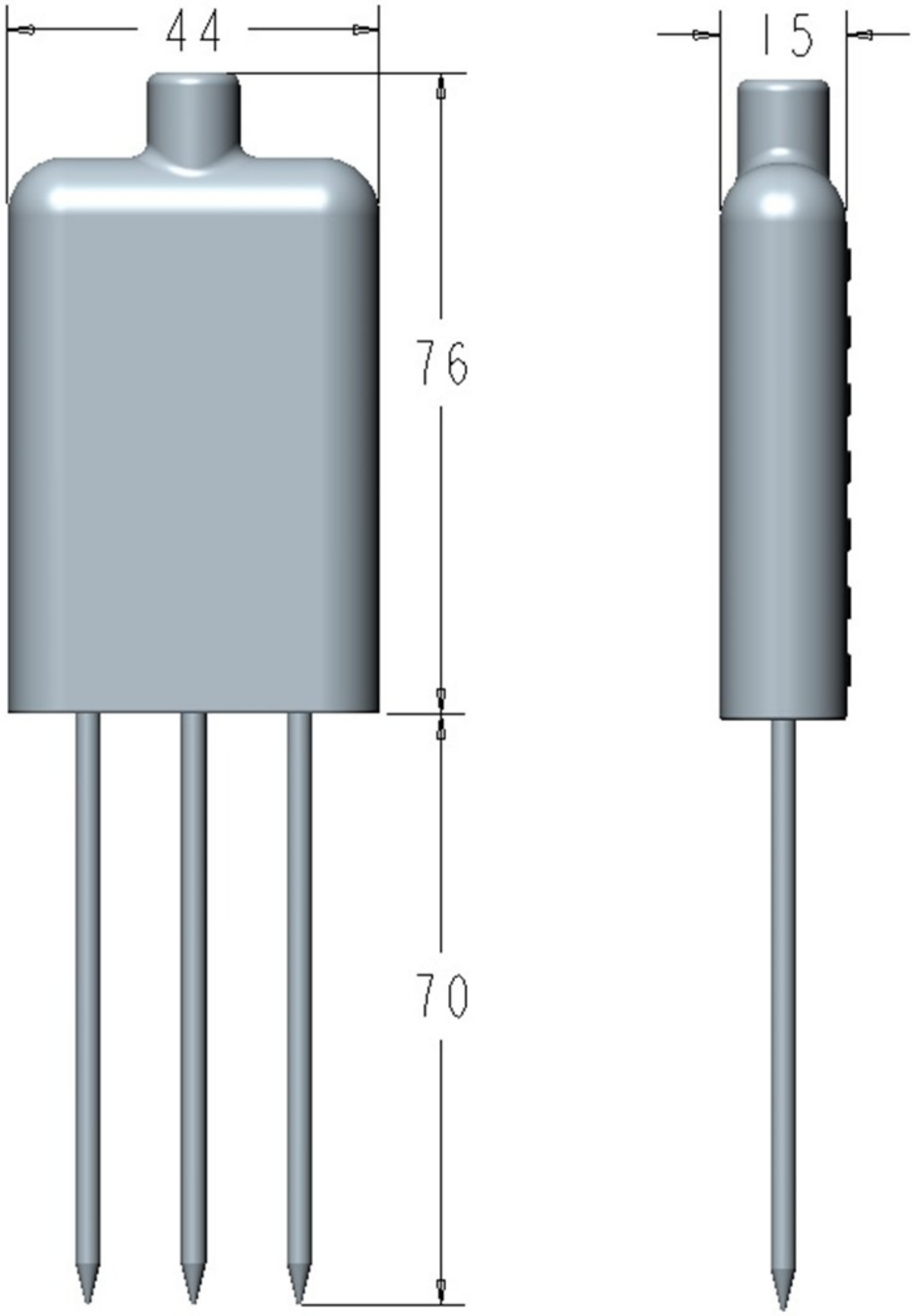
3.1 SDI-12 Interface

<table>
<tr><th>Type</th><th>Wiring diagram</th></tr>
<tr><td>SDI-12 Interface</td><td>


</td></tr>
<tr><td>Connections</td><td>
</td></tr>
</table>

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	E F J K	Soil Moisture & Temperature & EC (Protocol compatible with METER TEROS12) Soil Moisture & Temperature (Protocol compatible with METER TEROS11) Soil Moisture & Temperature & EC (Protocol compatible with Decagon 5TE) Soil Moisture & Temperature (Protocol compatible with Decagon 5TM) Note: Please refer to separate user manual for Code J & K
Code 3: Soil Moisture Range	B	0-100%
Code 4: EC Range	C X	0-23000us/cm 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-EBCFFB002 Product Series: MEC10 Soil Moisture, Temperature , (EC) Sensor; Measuring Parameters: Soil Moisture & Temperature & EC (Protocol compatible with METER TEROS12); Soil Moisture Range: 0-100%; EC Range: 0-23000us/cm 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. 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)
<TAB>	-	Tab character
<SPACE>	-	Space character
<CR>	-	Carriage return character
<LF>	-	Line feed character
<Checksum>	-	SUM Checksum
<CRC_ADI>		ADI protocol CRC Checksum
<CRC>	-	SDI-12 protocol CRC Checksum
<VERIFY_STATUS>	-	Sensor Verification status
<sensorType>	-	ASCII character denoting the sensor type For MEC10-E, the character is ‘g’ For MEC10-F, the character is ‘h’
<±SubstrateTemp>	°C °F	Substrate Temperature, the value unit depends on the temperature unit setting.
<+SubstrateVWC>	%	Substrate Volumetric Water Content
<+SubstrateECBulk>	us/cm	Substrate Bulk EC normalized to 25 °C
<+SubstrateCalibratedRawCounts> or <RAW>	-	Substrate Calibrated Raw Counts of volumetric water content
<+SubstrateEpsilon>	-	Substrate Apparent Epsilon of volumetric water content
<+SubstrateECPore>	us/cm	Substrate Pore EC normalized to 25 °C

The following error value will be responded as measurement value when there is error：

Error Value	Description
-999	Sensor Broken
-996	Not Supported Value

6.1 Data Conversion

Output Interface	Parameters	Range
ADI Interface	<SubstrateCalibratedRawCounts> or <RAW>	+0.00 - +4095.00
	<SubstrateTemp>	-40.0 - +80.0℃
	<SubstrateECBulk>	+0 - +23000 us/cm
SDI-12 Interface	<SubstrateCalibratedRawCounts > or <RAW>	+0.00 - +4095.00
	<SubstrateTemp>	-40.0 - +80.0℃
	<SubstrateEpsilon>	0.00 - +200.00
	<SubstrateVWC>	0.00 - +100.00%
	<SubstrateECBulk>	+0 - +23000 us/cm
	<SubstrateECPore>	+0 - +32000 us/cm
Customize	Please contact us for more info	

Note: VWC can be calculated by <calibratedCountsVWC> using formula below.

6.1.1 Water Content Conversion for Mineral Soil

Linear equation below can be used for soil from 0% to statured%. And VWC reaches a maximum at approximately 70% in pure water:

$$\mathrm{VWC} = 3.879 * 10^{-4} * \mathrm{RAW} - 0.6956$$

Using equation below can reaches a maximum at approximately 100% in pure water:
When RAW<3200

$$\mathrm{VWC} = 1.1033765 * 10^{-10} * \mathrm{RAW}^3 - 7.7895464 * 10^{-7} * RAW^2 + 2.1949004 * 10^{-3} * RAW \ - 2.0970717$$

When RAW>=3200:

$$\mathrm{VWC} = 4.0263182 * 10^{-8} * \mathrm{RAW}^3 - 3.8868517 * 10^{-4} * RAW^2 + 1.2516687 * RAW \ - 1343.9820$$

VWC:Volumetric Water Content 0-100%，RAW:Calibrated ADC for volumetric water content.

6.1.2 Water Content Conversion for Non-soil substrate

The VWC of non-soil substrate can be calculated from formula below, this is a generic equation can be used in most non-soil substrate with an accuracy better than 5%. For higher accuracy, perform a media specific calibration should improve the accuracy better than 2%. The calibration for several potting soils, perlite, peat moss, rockwool and cocopeat is shown:

$$VWC = 6.771 * 10^{-10} * RAW^3 - 5.105 * 10^{-6} * RAW^2 + 1.302 * 10^{-2} * RAW - 10.848$$

VWC:Volumetric Water Content 0-100%，RAW:Calibrated ADC for volumetric water content.

6.1.3 Epsilon Calculation

Dielectric permittivity (ξ_a) can be used to determine VWC using equations such as the Topp equation.

$\xi_a = (2.887*10^{-9}*RAW^3 - 2.080*10^{-5}*RAW^2 + 5.276*10^{-2}*RAW - 43.39)^2$， Where:

ξ_a :Epsilon， RAW:Calibrated ADC for volumetric water content.

6.2 SDI-12 Interface and Protocol

6.2.1 SDI-12 Interface

Please refer to SDI-12 standard user manual V1.3.

6.2.2 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 a: Sensor address ll:SDI-12 Version Number cccccccc: 8 characters vendor identification mmmmmm: 6 characters specifying	**Example (MEC10-E):** Request: 0I! Response: 013INFWIN MEC10E8.1MEC10-E-44000 **Example (MEC10-F):** Request: 0I! Response: 013INFWIN MEC10F8.1MEC10-F-4400

	the sensor model number vvv: 3 characters specifying the sensor version xxxxxxxxxxxxx: 13 characters serial number <CR><LF>: terminates the response	0
?!	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-E:** 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<+SubstrateCalibratedRawCounts><±SubstrateTemp><+SubstrateECBulk>[<CRC>]<CR><LF> **MEC10-F:** 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<+SubstrateCalibratedRawCounts><±SubstrateTemp>[<CRC>]<CR><LF>	**Example (MEC10-E):** Request: 0M! Response: 00013<CR><LF> Response: 0<CR><LF> Request: 0D0! Response: 0+2888.55+24.1+1620<CR><LF> **Example (MEC10-F):** Request: 0M! Response: 00012<CR><LF> Response: 0<CR><LF> Request: 0D0! Response: 0+2888.55+24.1<CR><LF>
aM1!, aMC1! aM6!, aMC6! aM9!, aMC9!	a0016<CR><LF> a:Sensor address 001: Measurement data will be ready in 001 seconds 6: Number of measurement data ret	**Example (MEC10-E):** Request: 0M1! Response: 00016<CR><LF> Response: 0<CR><LF> Request: 0D0!

	urned by aD0!, aD1! <CR><LF>:terminates the response aD0! Response data format: a<±SubstrateTemp><+SubstrateVWC><+SubstrateECBulk>[<CRC>]<CR><LF> aD1! Response data format: a<+SubstrateCalibratedRawCounts><+SubstrateVWCEpsilon><+ SubstrateECPore>[<CRC>]<CR><LF> **Note:** For MEC10-F, <+SubstrateECBulk> and <+ SubstrateECPore> will always be 0.	Response: 0+24.1+40.50+1620<CR><LF> Request: 0D1! Response: 0+2888.77+25.47+5972<CR><LF> **Example (MEC10-F):** Request: 0M1! Response: 00016<CR><LF> Response: 0<CR><LF> Request: 0D0! Response: 0+24.1+40.50+0<CR><LF> Request: 0D1! Response: 0+2888.77+25.47+0<CR><LF>
aC!, aCC!	**MEC10-E:** 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<+SubstrateCalibratedRawCounts><±SubstrateTemp><+SubstrateECBulk>[<CRC>]<CR><LF> **MEC10-F:** 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<+SubstrateCalibratedRawCounts><±SubstrateTemp> [<CRC>]<CR><LF>	**Example (MEC10-E):** Request: 0C! Response: 000103<CR><LF> Request: 0D0! Response: 0+2888.55+24.1+1620<CR><LF> **Example (MEC10-F):** Request: 0C! Response: 000102<CR><LF> Request: 0D0! Response: 0+2888.55+24.1<CR><LF>
aC1!, aCC1! aC6!, aCC6!	a00106<CR><LF> a: Sensor address	**Example (MEC10-E):** Request: 0C1!

aC9!, aCC9!	001: Measurement data will be ready in 001 seconds 06: Number of measurement data returned by aD0!, aD1! <CR><LF>:terminates the response aD0! Response data format： a<±SubstrateTemp><+SubstrateVWC><+SubstrateECBulk>[<CRC>]<CR><LF> aD1! Response data format： a<+SubstrateCalibratedRawCounts><+SubstrateVWCEpsilon><+ SubstrateECPore>[<CRC>]<CR><LF> **Note:** For MEC10-F, <+SubstrateECBulk> and <+ SubstrateECPore> will always be 0.	Response: 000106<CR><LF> Request: 0D0! Response: 0+24.1+40.50+1620<CR><LF> Request: 0D1! Response: 0+2888.77+25.47+5972<CR><LF> **Example (MEC10-F):** Request: 0C1! Response: 000106<CR><LF> Request: 0D0! Response: 0+24.1+40.50+0<CR><LF> Request: 0D1! Response: 0+2888.77+25.47+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-E:** Response data format： a<+SubstrateCalibratedRawCounts><±SubstrateTemp><+SubstrateECBulk>[<CRC>]<CR><LF> **MEC10-F:** Response data format： a<+SubstrateCalibratedRawCounts><±SubstrateTemp> [<CRC>]<CR><LF>	**Example (MEC10-E):** Request: 0R0! Response: 0+2888.55+24.1+1620<CR><LF> **Example (MEC10-F):** Request: 0R0! Response: 0+2888.55+24.1<CR><LF>
aR1!, aRC1! aR6!, aRC6! aR9!, aRC9!	Response data format： a<±SubstrateTemp><+SubstrateVWC><+SubstrateECBulk><+SubstrateCalibratedRawCounts><+SubstrateVWCEpsilon><+ SubstrateECPore>[<CRC>]<CR><LF>	**Example (MEC10-E):** Request: 0R1! Response: 0+24.1+40.50+1620+2888.77+25.47+5972<CR><LF> **Example (MEC10-F):**

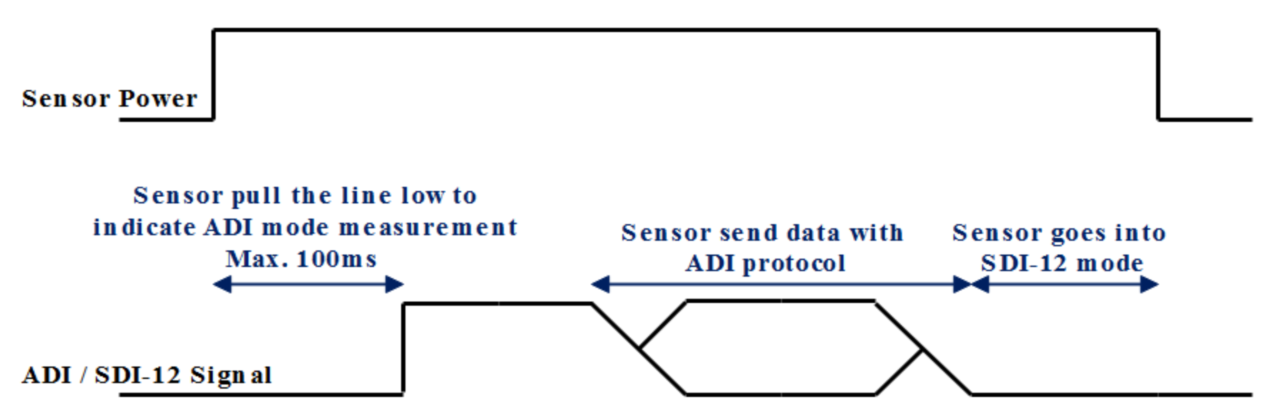
	Note: For MEC10-F, <+SubstrateECBulk> and <+ SubstrateECPore> will always be 0.	Request: 0R1! Response: 0+24.1+40.50+0+2888.77+25.47+0<CR><LF>
aR3!, aRC3! aR4!, aRC4!	**MEC10-E:** Response data format: a<TAB><SubstrateCalibratedRawCounts><SPACE><±SubstrateTemp><SPACE><SubstrateECBulk><CR><sensorType><Checksum><CRC_ADI><CR><LF> **MEC10-F:** Response data format: a<TAB><SubstrateCalibratedRawCounts><SPACE><±SubstrateTemp><CR><sensorType><Checksum><CRC_ADI><CR><LF>	**Example (MEC10-E):** Request: 0R3! Response: 0<TAB>2749.0<SPACE>23.8<SPACE>660<CR>g8o<CR><LF> Request: 0R4! Response: 0<TAB>2749.0<SPACE>23.8<SPACE>660<CR>g8o<CR><LF> **Example (MEC10-F):** Request: 0R3! Response: 0<TAB>3193.8<SPACE>19.4<CR>h@k<CR><LF> Request: 0R4! Response: 0<TAB>3193.8<SPACE>19.4<CR>h@k<CR><LF>
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>	**Query ADI output enable**

	<v>: ADI output enable on sensor start up, when SDI12 is 0 on sens or start up: <v>=0 the sensor will output data i n ADI format. <v>=0 the sensor will not output d ata in ADI format.	**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_<sss sssss>!	aSN=<ssssssss><CR><LF>	**Configure serial number** **Example:** Request: 0XW_SN_ABCDEFGH! Response: 0SN=ABCDEFGH<CR><LF>

6.3 ADI Interface and Protocol

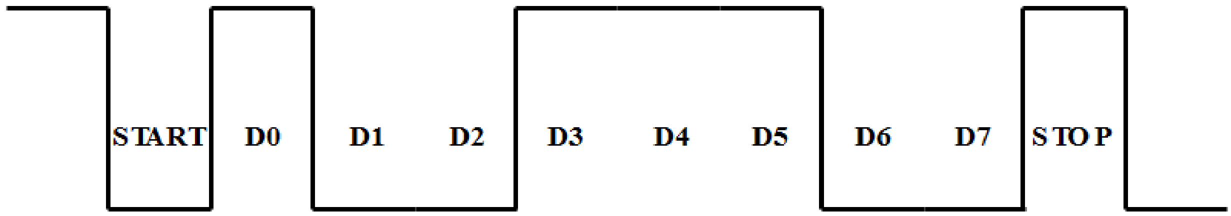
6.3.1 ADI Interface

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:

<TAB><calibratedCountsVWC><SPACE><temperature><SPACE><electricalConductivity><CR><sensorType><Checksum><CRC_ADI>

Parameters	Description
<TAB>	Tab Character
<calibratedCountsVWC>	Calibrated ADC for volumetric water content
<SPACE>	Space Character
<temperature>	Temperature
<SPACE>	Space Character
<electricalConductivity>	Bulk electrical conductivity normalized to 25 °C Note: This output is only available on MEC10-E
<CR>	Carriage return character
<sensorType>	ASCII character denoting the sensor type For MEC10-E, the character is ‘g’ For MEC10-F, the character is ‘h’
<Checksum>	SUM Check from <TAB> to <sensorType>
< CRC_ADI >	ADI protocol CRC Check from <TAB>to < Checksum>

Example: “<TAB>2749.0<SPACE>23.8<SPACE>660<CR>g8o”

Parameters	Description
<TAB>	Tab Character
2749.0	Calibrated ADC for volumetric water content 2749.0
<SPACE>	Space Character
23.8	Temperature 23.8°C
<SPACE>	Space Character
660	conductivity 660us/cm
<CR>	Carriage return character
g	sensor type
8	SUM Check

o	ADI protocol CRC Check

ADI Interface <Checksum> calculation:
Using "**<TAB>2749.0<SPACE>23.8<SPACE>660<CR>g**" as function parameters "char * response" and you will get the <Checksum> '8'

```
uint8_t CalcADIChecksum(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 metadata 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;
}
```

ADI Interface <CRC_ADI> calculation:
Using "**<TAB>2749.0<SPACE>23.8<SPACE>660<CR>g8**" as function parameters "char * response" and you will get the <CRC_ADI> 'o'

```
uint8_t CRC6_Offset(const char *buffer)
{
    uint16_t byte;
    uint16_t i;
    uint16_t bytes;
    uint8_t bit;
    uint8_t crc = 0xfc; // Set upper 6 bits to 1's
    // Calculate total message length—updated once the metadata section is found
    bytes = strlen(buffer);
    // Loop through all the bytes in the buffer
    for(byte = 0; byte < bytes; byte++)
    {
        // Get the next byte in the buffer and XOR it with the crc
```

```
            crc ^= buffer[byte];
            // Loop through all the bits in the current byte
            for(bit = 8; bit > 0; bit--)
            {
                // If the uppermost bit is a 1...
                if(crc & 0x80)
                {
                    // Shift to the next bit and XOR it with a polynomial
                    crc = (crc << 1) ^ 0x9c;
                }
                else
                {
                    // Shift to the next bit
                    crc = crc << 1;
                }
            }
            if(buffer[byte] == '\r')
            {
                // Found the beginning of the metadata section of the response
                // both sensor type and legacy checksum are part of the crc6
                // this requires only two more iterations of the loop so reset
                // "bytes"
                // bytes is incremented at the beginning of the loop, so 3 is added
                bytes = byte + 3;
            }
        }
        // Shift upper 6 bits down for crc
        crc = (crc >> 2);
        // Add 48 to shift crc to printable character avoiding \r \n and !
        return (crc + 48);
}
```

7. Substrate Volumetric Water Content User Calibration

The sensor support user calibration for volumetric water content, you can perform a calibration to achieve best accuracy for specific substrate. Please refer to application note “substrate volumetric water content user calibration procedure”.

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.

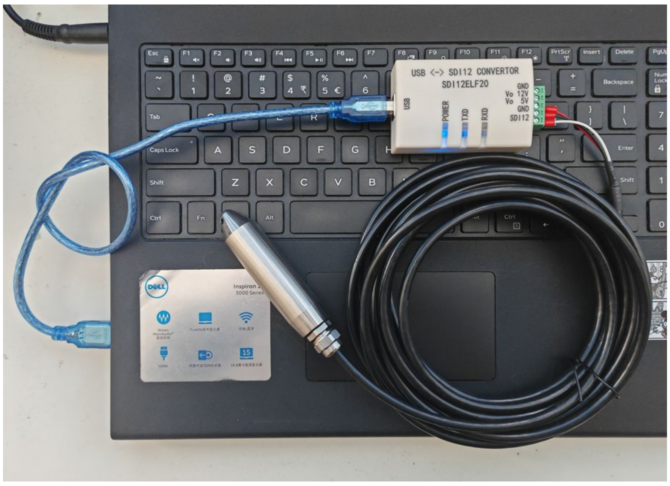
Testing Software Download	
Terminal (universal serial port debugging tool)	https://www.infwin.com/resource-serial-port-com-development-tool/
SensorOneSetSDI12 (SDI-12 sensor configuration utility)	https://www.infwin.com/resource-sensoronesetsdi12-configuration-utility-for-sdi-12-sensors/

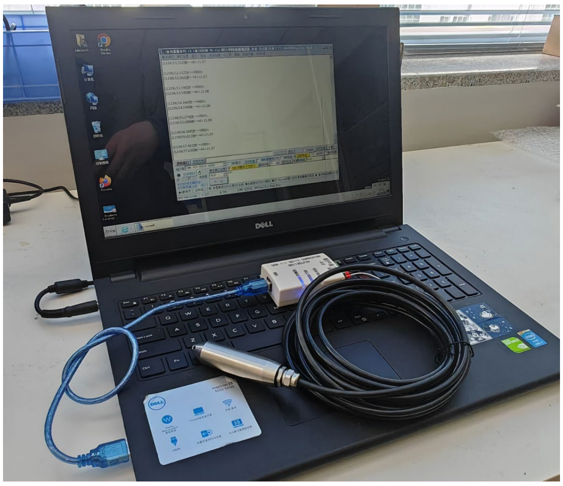
A.2 Testing Example

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/

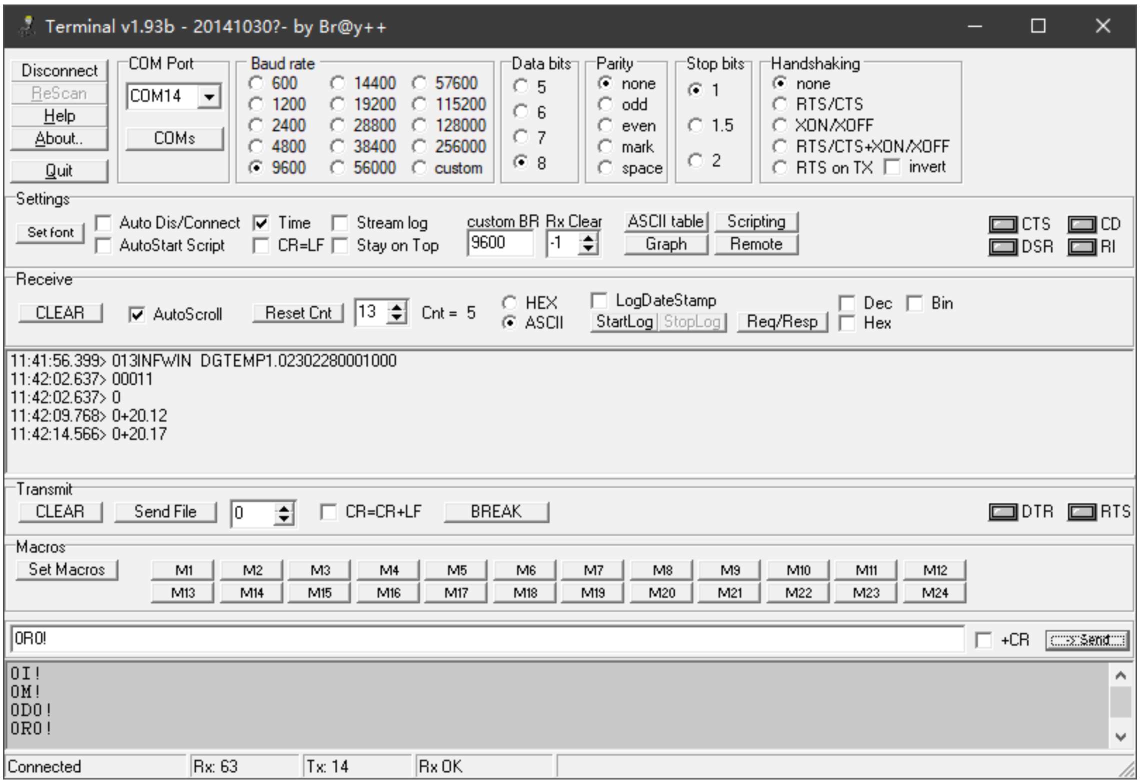
■ **Connections**





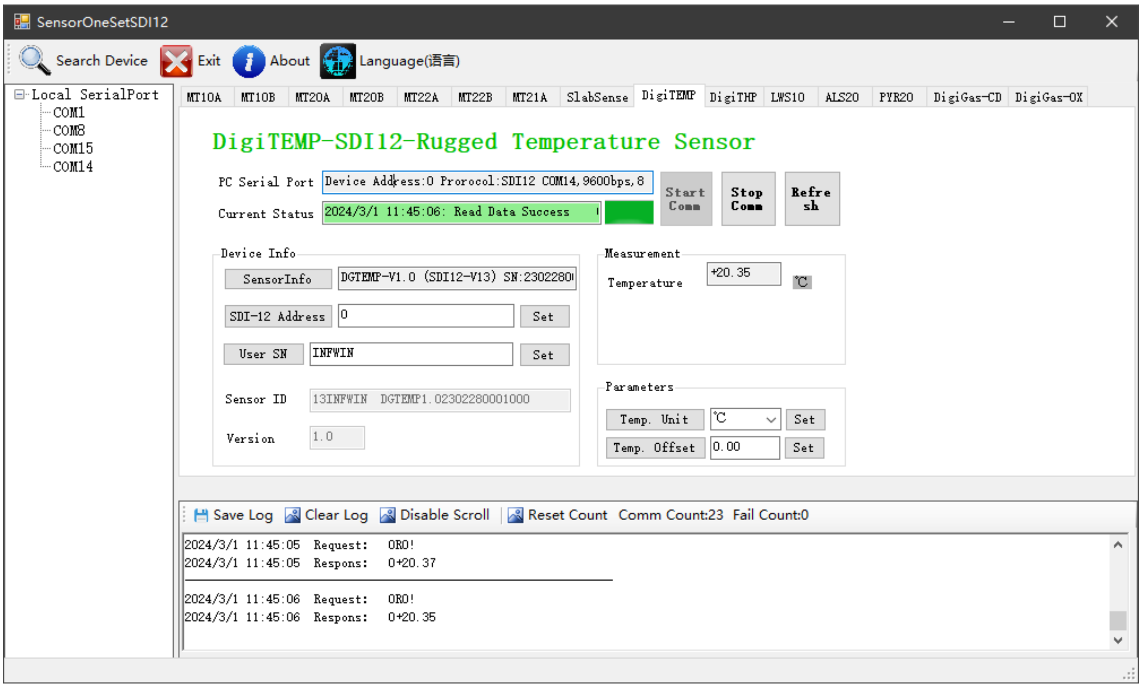
■ **Testing with serial port utility "Terminal"**

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