PRODUCT MANUAL

Sensor

MS-80SH

Class A Digital Pyranometer with SDI-12 and Modbus Output

Revision: 04/2025

RELIABLE MONITORING SINCE 1974

Campbell SCIENTIFIC®

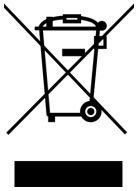
Please read first

About this manual

Please note that this manual was produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this. In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users. Differences include the U.S. standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. Please note, however, *that when a power supply adapter is ordered from Campbell Scientific it will be suitable for use in your country*.

Reference to some radio transmitters, digital cell phones and aerials (antennas) may also not be applicable according to your locality. Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered.

Recycling information for countries subject to WEEE regulations 2012/19/EU



At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the products life should be removed from the product and also be sent to an appropriate recycling facility, per The Waste Electrical and Electronic Equipment (WEEE) Regulations 2012/19/EU. Campbell Scientific can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories. For further support, please contact Campbell Scientific, or your local agent.

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1. Introduction

The MS-80SH, manufactured by EKO Instruments, is an ISO 9060:2018 Class A pyranometer inspired by the combination of latest technologies and state-of-the-art thermopile sensor with an unprecedented, low zero-offset behavior; fast sensor response; Modbus RTU 485 or SDI-12 output; and a five-year warranty and recalibration interval. The MS-80SH has a dome heater, internal temperature and humidity sensors, and a tilt sensor. These internal sensors monitor the stability of the irradiance sensors and ensures proper installation and maintenance.

Features:

- Controllable dome heater function for dew and frost mitigation
- Response time [<0.5s at 95%, <1s at 99%]
- Low power consumption (<0.2 W without heater, <1.4 W with heater)
- Built in tilt / roll sensor to check the sensor position over time
- Temperature and humidity sensors to monitor the inside temperature of the pyranometer and condition of the drying agent (silica gel) inside the pyranometer body
- Excellent temperature response over a wide temperature range (–20 to +50 °C)
- Compatible with SDI-12 and Modbus controllers including Campbell Scientific GRANITE-series, CR6, CR1000X, CR350-series, CR300-series, CR1000, and CR800-series data loggers

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, contact Campbell Scientific.
- Although the MS-80SH is rugged, it should be handled as a precision scientific instrument.

3. Initial inspection

- Upon receipt of the MS-80SH, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the correct product and cable length are received.

4. Specifications

ISO 9060 classification:	Class A (secondary standard)
Output:	Modbus 485 RTU / SDI-12
Default Modbus address:	Last two digits of serial number
Default SDI-12 address:	0
Response time 95%:	< 0.5 s
Zero offset A:	< 1 W/m^2 (response to 200 W/m^2 net thermal radiation)
Zero offset B:	±1 W/m^2 (5 K/hr)
Non-stability:	±0.5% change in 5 years
Non-linearity:	±0.2% (1000 W/m^2)
Directional response:	±10 W/m^2 (1000 W/m^2)
Spectral selectivity:	±3% (0.35 to 1.5 µm)
Spectral range:	285 to 3000 nm
Operating temperature range:	–40 to 80 °C
Temperature response:	± 0.5% (–20 to 50 °C)
Tilt response:	±0.2% (1000 W/m^2)
Power consumption:	< 1.4 W
Supply voltage:	8 to 30 VDC
Irradiance range:	0 to 4000 W/m^2

Dimensions	
Diameter (including sun screen):	9.6 cm (3.8 in)
Body height:	7.3 cm (2.9 in)
Dome height:	1.2 cm (0.5 in)
Leveling screw height:	1.6 cm (0.6 in)
Weight:	0.41 kg (0.90 lb)
Compliance documents:	View at: www.campbellsci.com/ms-80sh-l

5. Installation

This section discusses the following:

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5.1 Wiring

Figure 5-1 (p. 4) shows Campbell Scientific connectors, pin numbers, and wire colors. Figure 5-2 (p. 4) shows EKO pin numbers and wire colors. Table 5-1 (p. 4) shows SDI-12 wiring and Table 5-2 (p. 5) shows Modbus wiring.

Figure 5-1. Campbell Scientific connectors, pin numbers, and wire colors

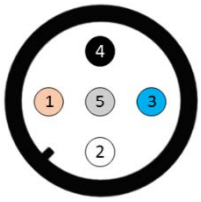


Figure 5-2. EKO pin numbers and wire colors

Table 5-1: SDI-12 pin-out, wire color, function, and data logger connection

Campbell Scientific wire color	EKO wire color	Pin number	Function	Data logger connection
Yellow	Gray	5	SDI-12 signal	**C**, **SDI-12**, or **U** configured for SDI-12[1]
Red	Brown	1	Power in (12 V)	**12V**
Black	White	2	Power ground	**G**
Clear	Clear	N/C	Shield	⏚ (analog ground)
White	Blue	3	Not used	
Green	Black	4	Not used	

[1] **U** and **C** terminals are automatically configured by the measurement instruction.

If multiple SDI-12 sensors are connected to a data logger, Campbell Scientific recommends using separate terminals when possible. However, multiple SDI-12 sensors can connect to the same data logger control or **U** terminal. Each must have a unique SDI-12 address. Valid addresses are 0 through 9, a through z, and A through Z.

For the CR6 and CR1000X data loggers, triggering conflicts may occur when a companion terminal is used for a triggering instruction such as `TimerInput()`, `PulseCount()`, or `WaitDigTrig()`. For example, if the MS-80SH is connected to **C3** on a CR1000X, then **C4** cannot be used in the `TimerInput()`, `PulseCount()`, or `WaitDigTrig()` instructions.

Table 5-2: Modbus pin-out, wire color, function, and data logger connection

Campbell Scientific wire color	EKO wire color	Pin-out	Function	Data logger connection[1]
Green	Black	4	RS-485–	**A–**, **C** (odd)
White	Blue	3	RS-485+	**B+**, **C** (even)
Red	Brown	1	Power in (12 V)	**12V**
Black	White	2	Power ground	**G**
Clear	Clear	N/C	Shield	⏚ (analog ground)
Yellow	Gray	5	Not used	

[1] Assumes the sensor directly connects to the data logger.

5.2 Programming

Output from the MS-80SH is measured using either Modbus or SDI-12. The following sections describe CRBasic programming for those outputs.

5.2.1 SDI-12 CRBasic programming

The `SDI12Recorder()` MS-80SH instruction can be used to measure an MS-80SH. This instruction sends a request to the sensor to make a measurement and then retrieves the measurement from the sensor. See Table 6-1 (p. 9) for more information.

For most data loggers, the `SDI12Recorder()` instruction has the following syntax:

```
SDI12Recorder(Destination, SDIPort, SDIAddress, "SDICommand", Multiplier, Offset,
FillNAN, WaitonTimeout)
```

For the **SDIAddress**, alphabetical characters need to be enclosed in quotes (for example, **"A"**). Also enclose the **SDICommand** in quotes as shown. The **Destination** parameter must be an array. The required number of values in the array depends on the command (see Table 6-1 [p. 9]).

FillNAN and **WaitonTimeout** are optional parameters (refer to ***CRBasic Editor*** Help for more information).

5.2.2 Modbus CRBasic programming

The RS-485 output can be directly read by a MeteoPV, CR6-series, CR1000X, or Modbus RTU RS-485 network. Other Campbell Scientific data loggers can use an MD485 multidrop interface to read the RS-485 output (refer to the MD485 manual). Refer to www.campbellsci.com/videos/meteopv for information about using the MeteoPV.

A CR6 or CR1000X data logger programmed as a Modbus client can retrieve the values stored in the input registers. To do this, the CRBasic program requires a `SerialOpen()` instruction followed by the `ModbusClient()` instruction.

> NOTE:
> `ModbusClient()` was formerly `ModbusMaster()`. Campbell Scientific, in conjunction with the Modbus Organization, is now using "client-server" to describe Modbus communications. The Modbus client(s) initiates communications and makes requests of server device(s). Server devices process requests and return an appropriate response (or error message). See https://modbus.org for more information. Existing programs that use the old Modbus terminology will still compile in the data logger.

The `SerialOpen` instruction has the following syntax:

```
SerialOpen (ComPort, Baud, Format, TXDelay, BufferSize, Mode)
```

The `Format` is typically set to logic 1 low; even parity, one stop bit, 8 data bits. The `Mode` parameter should configure the ComPort as RS-485 half-duplex, transparent. The `ModbusClient()` instruction has the following syntax:

```
ModbusClient (Result, ComPort, Baud, Addr, Function, Variable, Start, Length,
Tries, TimeOut, [ModbusOption])
```

The `Addr` parameter must match the sensor Modbus address. To collect all of the values, the `Start` parameter needs to be 1 and the `Length` parameter needs to correspond with the register count (see MS-80SH register map [p. 11]). `ModbusOption` is an optional parameter described in the *CRBasic Editor* Help.

5.3 Siting

The solar radiation sensor is usually installed horizontally, but can also be installed at any angle, including an inverted position. Site the sensor to allow easy access for maintenance, but avoid locations with obstructions or reflections above the plane of the sensing element. It is important to mount the sensor such that a shadow or a reflection will not be cast on it at any time. If this is not possible, try to choose a site where any obstruction over the azimuth range between earliest

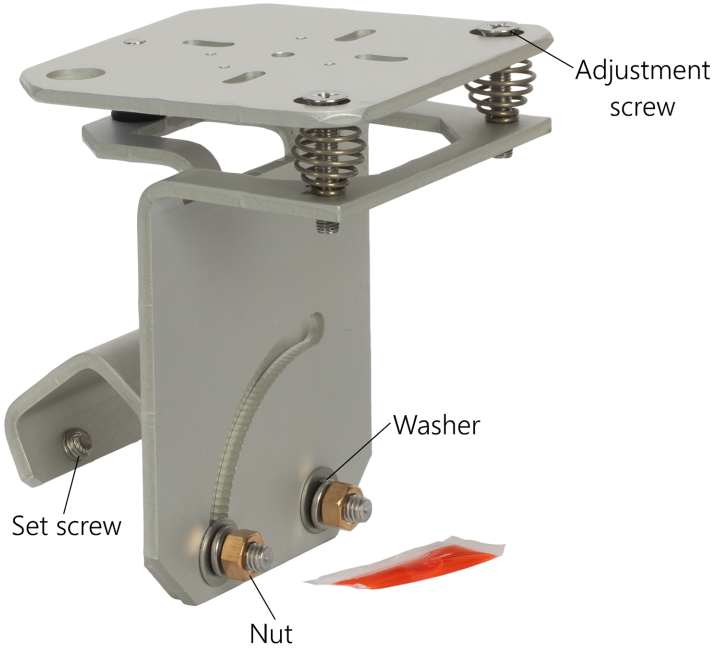
sunrise and latest sunset has an elevation not exceeding 5°. Diffuse solar radiation is less influenced by obstructions near the horizon. The sensor should be mounted with the cable pointing towards the nearest magnetic pole. For example, in the northern hemisphere, point the cable toward the North Pole.

5.4 Mounting procedure

Required tools:

- Solar compass
- 8 mm (5/16-inch) open-end wrench or hex key wrench for U-bolt nuts
- CM256 mounting bracket

1. On a level surface, level the solar radiation sensor using the leveling feet on the sensor.
2. Secure the solar radiation sensor to the mounting bracket.
3. Using a diopter in combination with a solar compass, install and orient the crossarm on the tripod or the mast. If installing the mounting bracket on a vertical pole, ensure the pole is truly vertical.
4. Use the two set screws to secure the bracket to the crossarm or pole as shown in the following figure. For pyranometers mounted horizontally, ensure the mounting bracket is horizontal in two dimensions. For pyranometers mounted at an angle, set the mounting bracket angle to the desired angle prior to tightening the mounting hardware.



5. Verify mounting hardware is firmly tightened, and that the mounting bracket is at the desired angle.

6. Operation

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6.1 SDI-12 commands

The MS-80SH supports the commands listed in Table 6-1 (p. 9). When using an **M!** command, the data logger waits for the time specified by the sensor, sends the **D0!** command, pauses its operation, and waits until either it receives the data from the sensor or the sensor timeout expires. If the data logger receives no response, it will send the command a total of three times, with three retries for each attempt, or until a response is received.

A **C!** command follows the same pattern as an **M!** command with the exception that it does not require the data logger to pause its operation until the values are ready. Rather, the data logger picks up the data with the **D0!** command on the next pass through the program. Another measurement request is then sent so that data is ready on the next scan.

As measurement data is transferred between the MS-80SH and data logger digitally, no offset errors are incurred with increasing cable length as seen with analog sensors. However, an increase in cable length does reach a point when digital communications break down, resulting in either no response or excessive SDI-12 retries and incorrect data due to noise problems. (Using SDI-12 commands such as **MC!**, which add a cyclic redundancy check [CRC], can significantly improve incorrect data issues.)

The **R0!** command directly reads the sensor measurements and outputs all of its values.

Table 6-1: SDI-12 commands	
SDI-12 command[1]	Values returned or function
*a*M!, *a*C!, *a*MC!, *a*CC!, *a*R0!, or *a*RC0!	Request the device with address number a to execute measurement.
*a*D0!	Irradiance (W/m^2) 1 digit after decimal point
*a*D1!	1. Sensor output voltage (mV) 4 digits after decimal point 2. Sensor temperature (Celsius) 2 digits after decimal point
*a*D2!	1. X-axis tilt angle (degree) 1 digit after decimal point, forward/backward with connector facing back, positive value when back is up 2. Y axis tilt angle (degree) 1 digit after decimal point, left/right with connector facing back, negative value when left is down
*a*D3!	1. Internal temperature of pyranometer body (°C), 1 digit after the decimal point 2. Humidity inside the enclosure (% RH ,) 1 digit after the decimal point.
*a*D4!	Indicates whether the internal humidity and dome heating conditions are normal 0 = normal condition 1 = abnormal condition

Table 6-1: SDI-12 commands	
SDI-12 command[1]	Values returned or function
*a*I!	Returns information. <Response example> 'a14EKOINST_ MS 80SH V3220000001<CR><LF> Where a = SDI-12 address 14: SDI-12 version (represents version 1.4) EKOInst: Company name (8 characters) MS-80SH : Sensor model name (6V32: Sensor version (3 characters) 20000001: Serial number (8 characters)
?!	Returns the SDI-12 address
[1]*a* is the SDI-12 address. In the SDI12Recorder() CRBasic instruction, the command parameter does not include the SDI-12 address because the address is a separate parameter.	

6.2 SDI-12 extended commands

Enter the following SDI-12 extended commands using the transparent mode while the computer is communicating with the data logger through a terminal emulator program. It is accessed through Campbell Scientific ***Device Configuration Utility*** software or other terminal emulator programs. Data logger keyboards and displays cannot be used. Refer to SDI-12 transparent mode (p. 19) for more information.

Table 6-2: SDI-12 extended commands	
SDI-12 command[1]	Values returned or function
*a*XSE!	Read the sensitivity constant of this device. Two digits after the decimal point.
*a*XCD!	Read the calibration date of this device. YYYY: year, MM: month, DD: day.
*a*XHT!	Reads the dome heating function status. ON :1, OFF:0

Table 6-2: SDI-12 extended commands	
SDI-12 command[1]	Values returned or function
*a*XHT1!	Change the dome heating function setting to ON.
*a*XHT0!	Change the dome heating function setting to OFF.
[1]*a* is the sensor address.	

6.3 RS-485 default configuration

The default RS-485 settings are: 19200 baud rate, 8 data bits, even parity, one stop bit. This configuration is used for most Modbus networks.

6.4 MS-80SH register map

Table 6-3 (p. 11) provides the register map for the most commonly used values. A comprehensive register map is available in the EKO manual.

Table 6-3: RS-485 register map				
Starting register number	Register count	Data format	Units	Description
8	2	Float	°C	Sensor temperature (measured by Pt100)
14	2	Float	°	X-axis tilt angle
16	2	Float	°	Y-axis tilt angle
18	2	Float	W/m^2	Intensity of solar radiation before correction
20	2	Float	mV	Sensor output voltage
22	2	Float	mV	Sensor voltage output with three decimals
22	2	Float	°C	Internal temperature
24	2	Float	% RH	Internal humidity

Table 6-3: RS-485 register map

Starting register number	Register count	Data format	Units	Description
26	2	Unsigned 32bit Integer		Alerts for abnormal internal humidity of the pyranometer. Normal: 0 Abnormality occurs: 1
28	2	Unsigned 32bit Integer		Alerts for abnormalities in the dome heating function of the pyranometer. Normal: 0 Abnormality occurs: 1

7. Maintenance and troubleshooting

The MS-80SH has no service items that require scheduled replacement. There is no accessible desiccant cartridge to maintain. Use pure alcohol or distilled water and a lint-free cloth to clean the dome, removing smears and deposits. Local conditions and application dictate a cleaning interval. Sophisticated research applications require daily cleaning. For typical PV applications, clean once per week, bi-monthly, or monthly. The MS-80SH should be recalibrated following industry-standard best practices such as ASTM G167, ISO 9846, ASTM E824 or ASTM G207 by an accredited lab. The recommended recalibration interval is two years. Contact Campbell Scientific for more information.

Unexpected results typically occur because of improper wiring or programming, electromagnetic radiation, or damaged cables. Ensure that the data logger program includes the correct parameters for the measurement instructions. Check for the presence of strong sources of electromagnetic radiation. Check the cable for damage and ensure that it is properly connected to the data logger.

Appendix A. SDI-12 sensor support

Serial Data Interface at 1200 baud (SDI-12) is a protocol developed to simplify sensor and data logger compatibility. Only three wires are necessary—serial data, ground, and 12 V. With unique addresses, multiple SDI-12 sensors can connect to a single SDI-12 terminal on a Campbell Scientific data logger.

This appendix discusses the structure of SDI-12 commands and the process of querying SDI-12 sensors. For more detailed information, refer to version 1.4 (January 2019) of the SDI-12 protocol, available at www.sdi-12.org.

For additional information, refer to the SDI-12 Sensors | Transparent Mode and SDI-12 Sensors | Watch or Sniffer Mode videos.

A.1 SDI-12 command basics

SDI-12 commands have three components:

- **Sensor address (a)** – a single character and the first character of the command. Use the default address of zero (0) unless multiple sensors are connected to the same port.
- **Command body** – an upper case letter (the "command"), optionally followed by one or more alphanumeric qualifiers.
- **Command termination (!)** – an exclamation mark.

An active sensor responds to each command. Responses have several standard forms and always terminate with <CR><LF> (carriage return and line feed). Standard SDI-12 commands are listed in Table A-1 (p. 13).

Table A-1: Campbell Scientific sensor SDI-12 command and response sets

Name[1]	Command	Response
Acknowledge active	a!	a<CR><LF>
Send identification	aI!	allccccccccmmmmmmmvvvxxx...xx<CR><LF>
Address query	?!	a<CR><LF>

Table A-1: Campbell Scientific sensor SDI-12 command and response sets

Name[1]	Command	Response
Change address	aAb!	b<CR><LF>
Start measurement	aM! aM1!...aM9!	atttn<CR><LF>
Start measurement and request CRC	aMC! aMC1!...aMC9!	atttn <CR><LF>
Start concurrent measurement	aC! aC1!...aC9!	atttnn<CR><LF>
Start concurrent measurement and request CRC	aCC! aCC1!...aCC9!	atttnn<CR><LF>
Send data	aD0!...aD9!	a<values><CR><LF> or a<values><CRC><CR><LF>
Continuous measurement	aR0!...aR9!	a<values><CR><LF>
Continuous measurement and request CRC	aRC0!...aRC9!	a<values><CRC><CR><LF>

[1] Information on each of these commands is given in the following sections.

A.1.1 Acknowledge active command (a!)

The acknowledge active command (a!) is used to test a sensor on the SDI-12 bus. An active sensor responds with its address.

A.1.2 Send identification command (aI!)

Sensor identifiers are requested by issuing command aI!. The reply is defined by the sensor manufacturer but usually includes the sensor address, SDI-12 version, manufacturer's name, and sensor model information. Serial number or other sensor specific information may also be included.

Command: aI!

Response: *allccccccccmmmmmmvvv<CR><LF>*

Where

a = sensor address

ll = SDI-12 version number (indicates compatibility)

cccccccc = 8-character vendor identification

mmmmmm = sensor model

vvv = 3 characters specifying the sensor version (operating system)

<*CR*><*LF*> = terminates the response

A.1.3 Address query command (?!)

Command **?!** requests an address of the connected sensor. The sensor responds to the query with the address, *a*. This command should only be used with one sensor on the SDI-12 bus at a time.

A.1.4 Change address command (aAb!)

Multiple SDI-12 sensors can connect to a single SDI-12 terminal on a data logger. Each device on a single terminal must have a unique address.

A sensor address is changed with command **aAb!**, where *a* is the current address and *b* is the new address. For example, to change an address from *0* to *2*, the command is **0A2!**. The sensor responds with the new address *b*, which in this case is 2.

> **NOTE:**
> Only one sensor should be connected to a particular terminal at a time when changing addresses.

A.1.5 Start measurement commands (aM!)

A measurement is initiated with the **M!** command. The response to each command has the form *atttn*<*CR*><*LF*>, where

a = sensor address

ttt = time, in seconds, until measurement data is available; when the data is ready, the sensor notifies the data logger, and the data logger begins issuing **D** commands.

n = the number of values returned when one or more subsequent **D** commands are issued; for the **aM!** command, *n* is an integer from 0 to 9.

When the **aM!** command is issued, the data logger pauses its operation and waits until either it receives data from the sensor or the time (*ttt*) expires. Depending on the scan interval of the data logger program and the response time of the sensor, this may cause skipped scans to occur. To avoid this, ensure that the scan interval is greater than the longest measurement time (*ttt*).

Table A-2: Example aM! sequence	
0M!	The data logger makes a request to sensor 0 to start a measurement.
00352<CR><LF>	Sensor 0 immediately indicates that it will return two values within the next 35 seconds.
0<CR><LF>	Within 35 seconds, sensor 0 indicates that it has completed the measurement by sending a service request to the data logger.
0D0!	The data logger immediately issues the first **D** command to collect data from the sensor.
0+.859+3.54<CR><LF>	The sensor immediately responds with the sensor address and the two values.

A.1.6 Start concurrent measurement commands (aC!)

A concurrent measurement (**aC!**) command follows the same pattern as the **aM!** command with the exception that it does not require the data logger to pause its operation, and other SDI-12 sensors may take measurements at the same time. The sensor will not issue a service request to notify the data logger that the measurement is complete. The data logger will issue the **aD0!** command during the next scan after the measurement time reported by the sensor has expired. To use this command, the scan interval should be 10 seconds or less. The response to each command has the form *atttn<CR><LF>*, where

a = the sensor address

ttt = time, in seconds, until the measurement data is available

nn = the number of values to be returned when one or more subsequent **D!** commands are issued.

See the following example. A data logger has three sensors wired into terminal **C1**. The sensors are addresses **X**, **Y**, and **Z**. The data logger will issue the following commands and receive the following responses:

Table A-3: Example aC! sequence	
XC!	The data logger makes a request to sensor X to start a concurrent measurement.
X03005<CR><LF>	Sensor X immediately indicates that it will have 5 (05) values ready for collection within the next 30 (030) seconds.

Table A-3: Example aC! sequence	
YC!	The data logger makes a request to sensor Y to start a concurrent measurement.
Y04006<CR><LF>	Sensor Y immediately indicates that it will have 6 (06) values ready for collection within the next 40 (040) seconds.
ZC!	The data logger makes a request to sensor Z to start a concurrent measurement.
Z02010<CR><LF>	Sensor Z immediately indicates that it will have 10 values ready for collection within the next 20 (020) seconds.
ZD0!	After 20 seconds have passed, the data logger starts the process of collecting the data by issuing the first **D** command to sensor Z.
Z+1+2+3+4+5+6+7+8+9+10<CR><LF>	Sensor Z immediately responds with the sensor address and the 10 values.
XD0!	10 seconds later, after a total of 30 seconds have passed, the data logger starts the process of collecting data from sensor X by issuing the first **D** command.
X+1+2+3+4+5<CR><LF>	The sensor immediately responds with the sensor address and the 5 values.
YD0!	Ten seconds later, after a total of 40 seconds have passed, the data logger starts the process of collecting data from sensor Y by issuing the first **D** command.
Y+1+2+3+4+5+6<CR><LF>	The sensor immediately responds with the sensor address and the 6 values.

A.1.7 Start concurrent measurement commands (aC!)

Error checking is done by using measurement commands with cyclic redundancy checks (**aMC!** or **aCC!**). This is most commonly implemented when long cable lengths or electronic noise may impact measurement transmission to the data logger. When these commands are used, the data returned in response to **D!** or **R!** commands must have a cyclic redundancy check (CRC) code

appended to it. The CRC code is a 16-bit value encoded within three characters appended before the <CR><LF>. This code is not returned in the data table but is instead checked by the data logger as it comes. The code returned is based on the SDI-12 protocol. See the SDI-12 communication specification for version 1.4 version 1.4 (January 2019) available at www.sdi-12.org to learn more about how the CRC code is developed.

A.1.8 Continuous measurement command (aR0! ... aR9!)

Sensors that are able to continuously monitor the phenomena to be measured can be read directly with the **R!** commands (**R0!** ... **R9!**). The response to the **R!** commands mirrors the Send Data command (**aD0!**). A maximum of 75 characters can be returned in the <*values*> part of the response to the **R!** command.

A.1.9 Send data command (aD0! ... aD9!)

The send data command (**aD!**) requests data from the sensor. It is issued automatically with every type of measurement command (**aM!**, **aMC!**, **aC!**, **aCC!**). When the measurement command is a**M!** or a**MC!**, the data logger issues the **aD0!** command once a service request has been received from the sensor or the reported time has expired. When the data logger is issuing concurrent commands (**aC!** or **aCC!**), the send data command is issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode (see SDI-12 transparent mode [p. 19]), the user asserts this command to obtain data.

Depending on the type of data returned and the number of values a sensor returns, the data logger may need to issue **aD0!** up to **aD9!** to retrieve all data. A sensor may return up to 35 characters of data in response to an **aD!** command that follows an **aM!** or **aMC!** command. A sensor may return up to 75 characters of data in response to a **aD!** command that follows an **aC!** or **aCC!** command. Data values are separated by plus or minus signs.

Command: **aD0!** (**aD1!** ... **aD9!**)

Response: *a*<*values*><*CR*><*LF*> or *a*<*values*><*CRC*><*CR*><*LF*>

where

a = the sensor address

<*values*> = values returned with a polarity sign (+ or –)

<*CR*><*LF*> = terminates the response

<*CRC*> = 16-bit CRC code appended if data was requested with **aMC!** or **aCC!**.

A.1.10 Extended commands

Many sensors support extended SDI-12 commands. An extended command is specific to a make of sensor and tells the sensor to perform a specific task. They have the following structure. Responses vary from unit to unit. See the sensor manual for specifics.

Command: **aXNNNN!**

The command will start with the sensor address (**a**), followed by an **X**, then a set of optional letters, and terminate with an exclamation point.

Response: *a<optional values><CR><LF>*

The response will start with the sensor address and end with a carriage return/line feed.

A.2 SDI-12 transparent mode

System operators can manually interrogate and enter settings in probes using transparent mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with probes. Data logger security may need to be unlocked before activating the transparent mode.

Transparent mode is entered while the computer is communicating with the data logger through a terminal emulator program. It is accessed through Campbell Scientific data logger support software or other terminal emulator programs. Data logger keyboards and displays cannot be used.

The terminal emulator is accessed through Campbell Scientific *Device Configuration Utility* software.

Watch videos/sdi12-sensors-transparent-mode from our website.

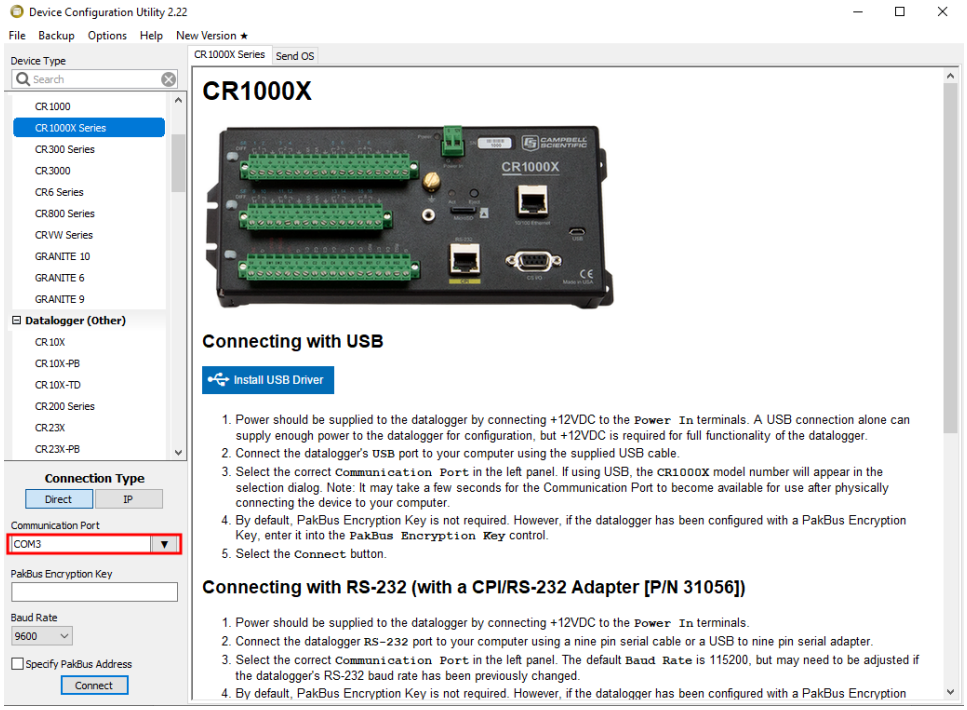
Data loggers from other manufacturers will also have a transparent mode. Refer to those manuals on how to use their transparent mode.

The following examples show how to enter transparent mode and change the SDI-12 address of an SDI-12 sensor. The steps shown in Changing an SDI-12 address (p. 19) are used with most Campbell Scientific data loggers.

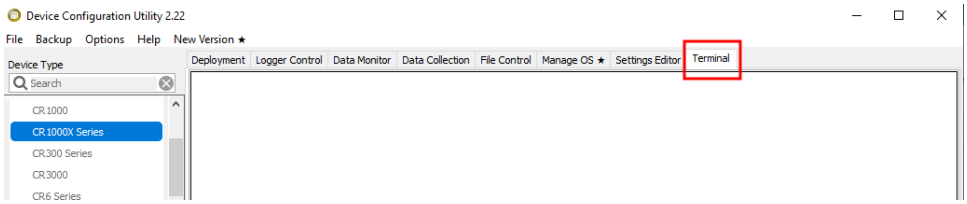
A.2.1 Changing an SDI-12 address

This example was done with a CR1000X, but the steps are only slightly different for Granite-series, CR6, CR800-series, CR300-series data loggers.

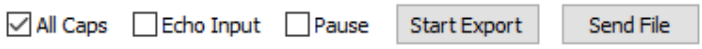
1. Connect an SDI-12 sensor to the CR1000X.
2. Open *Device Configuration Utility*.
3. Under **Device Type**, type the data logger model and double-click on the model type. This example uses a CR1000X directly connected to the computer USB port.
4. Select the correct **Communication Port** and click **Connect**.



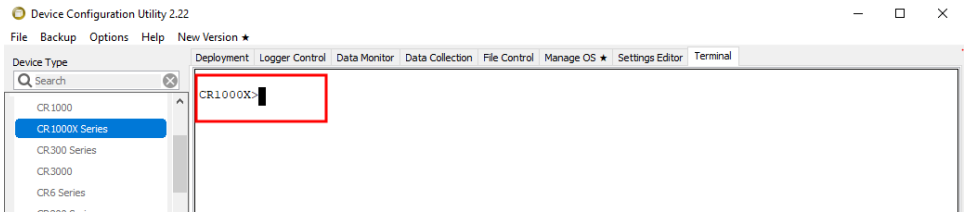
5. Click the **Terminal** tab.



6. Select **All Caps Mode**.



7. Press **Enter** until the data logger responds with the data logger (**CR1000X>**) prompt.



8. Type **SDI12** and press Enter.
9. At the **Select SDI12 Port** prompt, type the number corresponding to the control port where the sensor is connected and press **Enter**. In this example the sensor is connected to C3. The response **Entering SDI12 Terminal** indicates that the sensor is ready to accept SDI-12 commands.

```
CR1000X>
CR1000X>SDI12
1: C1
2: C3
3: C5
4: C7
Select SDI12 Port: 2
```

10. To query the sensor for its current SDI-12 address, type **?!** and press **Enter**. The sensor responds with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply type **SDI12** again, press **Enter**, and type the correct control port number when prompted.

```
?!
0
```

11. To change the SDI-12 address, type **aAb!**, where **a** is the current address from the previous step and **b** is the new address. Press **Enter**. The sensor changes its address and responds with the new address. In the following example, the sensor address is changed from 0 to B.

```
SDI12
SDI12>0AB!B
```

12. To exit SDI-12 transparent mode, click **Close Terminal**.

NOTE:
The transparent mode for the Granite-series, CR6, CR3000, CR800-series, CR300-series data loggers is similar to that shown for the CR1000X.

Limited warranty

Covered equipment is warranted/guaranteed against defects in materials and workmanship under normal use and service for the period listed on your sales invoice or the product order information web page. The covered period begins on the date of shipment unless otherwise specified. For a repair to be covered under warranty, the following criteria must be met:

1. There must be a defect in materials or workmanship that affects form, fit, or function of the device.

2. The defect cannot be the result of misuse.

3. The defect must have occurred within a specified period of time; and

4. The determination must be made by a qualified technician at a Campbell Scientific Service Center/ repair facility.

The following is not covered:

1. Equipment which has been modified or altered in any way without the written permission of Campbell Scientific.

2. Batteries; and

3. Any equipment which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country. For directions on how to return equipment, see Assistance.

Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.

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MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Campbell Scientific hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the products, whether express, implied, or statutory, other than those expressly provided herein.

Campbell Scientific will, as a default, return warranted equipment by surface carrier prepaid. However, the method of return shipment is at Campbell Scientific's sole discretion. Campbell Scientific will not reimburse the claimant for costs incurred in removing and/or reinstalling equipment. This warranty and the Company's obligation thereunder is in lieu of all other

warranties, expressed or implied, including those of suitability and fitness for a particular purpose. Campbell Scientific is not liable for consequential damage.

In the event of any conflict or inconsistency between the provisions of this Warranty and the provisions of Campbell Scientific's Terms, the provisions of Campbell Scientific's Terms shall prevail. Furthermore, Campbell Scientific's Terms are hereby incorporated by reference into this Warranty. To view Terms and conditions that apply to Campbell Scientific, Logan, UT, USA, see Terms and Conditions. To view terms and conditions that apply to Campbell Scientific offices outside of the United States, contact the regional office that serves your country.

Assistance

Products may not be returned without prior authorization. Please inform us before returning equipment and obtain a **return material authorization (RMA) number** whether the repair is under warranty/guarantee or not. See Limited warranty for information on covered equipment.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country.

When returning equipment, a RMA number must be clearly marked on the outside of the package. Please state the faults as clearly as possible. Quotations for repairs can be given on request.

It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment. In support of this policy, when equipment is returned to Campbell Scientific, Logan, UT, USA, it is mandatory that a "Declaration of Hazardous Material and Decontamination" form be received before the return can be processed. If the form is not received within 5 working days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. For details on decontamination standards specific to your country, please reach out to your regional Campbell Scientific office.

> NOTE:
> All goods that cross trade boundaries may be subject to some form of fee (customs clearance, duties or import tax). Also, some regional offices require a purchase order upfront if a product is out of the warranty period. Please contact your regional Campbell Scientific office for details.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a hardhat and eye protection, and take other appropriate safety precautions while working on or around tripods and towers.
- Do not climb tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- You can be killed or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in contact with overhead or underground utility lines.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, whichever is greater, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.

- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

Use and disposal of batteries

- Where batteries need to be transported to the installation site, ensure they are packed to prevent the battery terminals shorting which could cause a fire or explosion. Especially in the case of lithium batteries, ensure they are packed and transported in a way that complies with local shipping regulations and the safety requirements of the carriers involved.
- When installing the batteries follow the installation instructions very carefully. This is to avoid risk of damage to the equipment caused by installing the wrong type of battery or reverse connections.
- When disposing of used batteries, it is still important to avoid the risk of shorting. Do not dispose of the batteries in a fire as there is risk of explosion and leakage of harmful chemicals into the environment. Batteries should be disposed of at registered recycling facilities.

Avoiding unnecessary exposure to radio transmitter radiation

- Where the equipment includes a radio transmitter, precautions should be taken to avoid unnecessary exposure to radiation from the antenna. The degree of caution required varies with the power of the transmitter, but as a rule it is best to avoid getting closer to the antenna than 20 cm (8 inches) when the antenna is active. In particular keep your head away from the antenna. For higher power radios (in excess of 1 W ERP) turn the radio off when servicing the system, unless the antenna is installed away from the station, e.g. it is mounted above the system on an arm or pole.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

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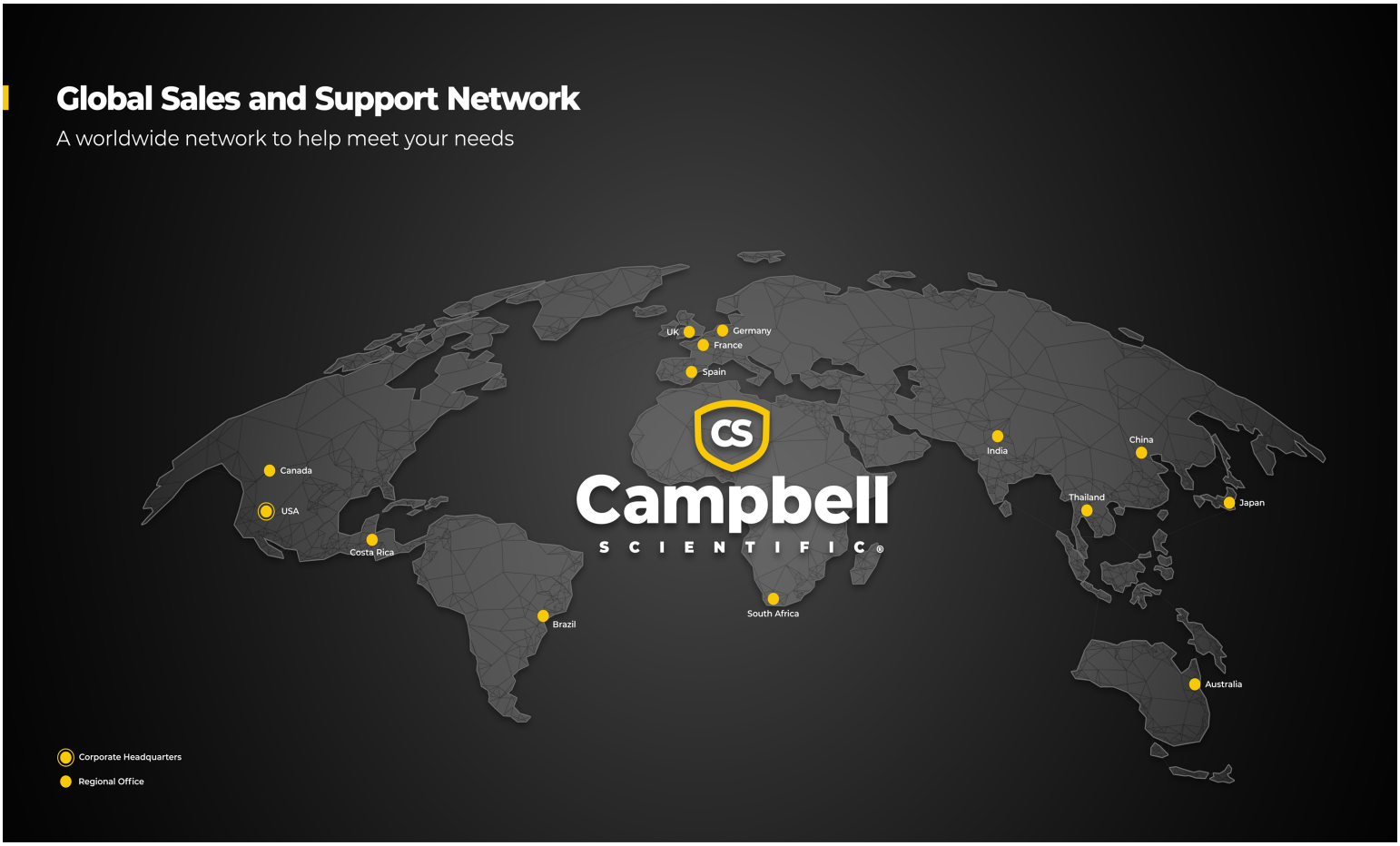

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