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CAMPBELL SCIENTIFIC, INC.
RMA#____
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Logan, Utah 84321-1784

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General

- 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 hard hat 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, 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.

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.

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.
1. Introduction

The SR05, manufactured by Hukseflux Thermal Sensors, is an ISO 9060 second class pyranometer designed for general solar radiation measurements in agricultural and meteorological networks and PV monitoring. Both analog output and Modbus over RS-485 are supported.

2. Specifications

- **ISO 9060:2018 classification:** Second class
- **Digital output:** Modbus over 2-wire RS-485
- **Voltage output:** 0 to 1 V
- **Analog output range:** 0 to 1600 W/m²
- **Default Modbus address:** 53
- **Response time (95 %):** 18 s
- **Calibration uncertainty:** < 1.8 % (k = 2)
- **Zero offset A:** < 15 W/m² (unventilated) response to 200 W/m² net thermal radiation
- **Zero offset B:** < ± 4 W/m² response to 5 K/h change in ambient temperature
- **Spectral range:** 285 to 3000 nm
- **Operating temperature range:** –40 to 80 °C
- **Temperature response:** < ± 0.4 % (–30 to 50 °C)
- **Operating voltage range:** 5 to 30 VDC
- **Power consumption:** < 75 mW at 12 VDC
- **Weight:** 0.35 kg (12.34 oz)
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 while ideally avoiding any 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.

4. Mounting procedure

Required tools:

- Diopter
- Solar compass
- 8 mm (5/16-inch) open-end wrench for U-bolt nuts

1. On a level surface, level the solar radiation sensor using the leveling feet on the sensor. Alternatively, remove the sensor leveling feet to allow it to be mounted directly to the mounting bracket.

2. Secure the solar radiation sensor to the mounting bracket. The blue dots in the following figure indicate the mounting holes used for this pyranometer.
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. Secure the mounting bracket to the crossarm or vertical pole using the hardware included with the mounting bracket. The CM255 uses one U-bolt, nuts, flat washers, and lock washers to mount the bracket, as shown in the following figure.

![Diagram showing the CM255 mounting bracket with hardware components labeled: U-bolt, Crossarm, Washer, Nut,Spacer.]

5. For the CM255LS bracket, 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.
6. Verify mounting hardware is firmly tightened, and that the mounting bracket is at the desired angle. The CM255LS includes leveling bolts for additional adjustment.

5. Wiring

Table 5-1 (p. 4) provides RS-485 wiring and Table 5-2 (p. 5) provides analog wiring.

### Table 5-1: RS-485 wire color, function, and data logger connection

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Function</th>
<th>Data logger connection(^1)</th>
<th>MeteoPV connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>RS485 A+</td>
<td>C (odd)</td>
<td>A-</td>
</tr>
<tr>
<td>White</td>
<td>RS485 B-</td>
<td>C (even)</td>
<td>B+</td>
</tr>
<tr>
<td>Red</td>
<td>Power in (12 V)</td>
<td>12V</td>
<td>12V</td>
</tr>
<tr>
<td>Black</td>
<td>Power ground</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Clear</td>
<td>Shield</td>
<td>☩ (analog ground)</td>
<td>☩ (analog ground)</td>
</tr>
</tbody>
</table>

\(^1\) Assumes the sensor directly connects to the data logger.
### Table 5-2: Analog wire color, function and data logger connection

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Function</th>
<th>Data logger connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Pyranometer signal high</td>
<td>U configured for differential input¹, DIFF H (differential high, analog-voltage input)</td>
</tr>
<tr>
<td></td>
<td>Pyranometer signal reference</td>
<td>U configured for differential input¹, ², DIFF L (differential low, analog-voltage input)²</td>
</tr>
<tr>
<td>Red</td>
<td>Power in (12 V)</td>
<td>12V</td>
</tr>
<tr>
<td>Black</td>
<td>Ground</td>
<td>☲ (analog ground)</td>
</tr>
<tr>
<td>Clear</td>
<td>Shield</td>
<td>☲ (analog ground)</td>
</tr>
</tbody>
</table>

¹ U channels are automatically configured by the measurement instruction.
² Jumper to ☲ with user-supplied wire.

## 6. Register map

Table 6-1 (p. 5) provides the register map for the most commonly used values. A comprehensive register map is available in the Hukseflux manual.

### Table 6-1: RS-485 register map

<table>
<thead>
<tr>
<th>Starting register number</th>
<th>Register count</th>
<th>Data format</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Signed 16 bit integer</td>
<td>Modbus address</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Signed 32 bit integer</td>
<td>mW/m²</td>
<td>Irradiance (temperature compensated signal)</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>Signed 16 bit integer</td>
<td>0.01 °C</td>
<td>Sensor body temperature</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Signed 16 bit integer</td>
<td>x 0.1 Ω</td>
<td>Sensor electrical resistance</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>Signed 16 bit integer</td>
<td>Scaling factor irradiance</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Signed 16 bit integer</td>
<td>Scaling factor temperature</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>Signed 32 bit integer</td>
<td>nV</td>
<td>Sensor voltage output</td>
</tr>
<tr>
<td>41</td>
<td>1</td>
<td>Signed 16 bit integer</td>
<td>Serial number</td>
<td></td>
</tr>
</tbody>
</table>
### Table 6-1: RS-485 register map

<table>
<thead>
<tr>
<th>Starting register number</th>
<th>Register count</th>
<th>Data format</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>2</td>
<td>Float</td>
<td>µV/W/m²</td>
<td>Sensor sensitivity</td>
</tr>
<tr>
<td>47</td>
<td>2</td>
<td>Signed 32 bit integer</td>
<td>Calibration date</td>
<td></td>
</tr>
</tbody>
</table>

### 7. RS-485 programming

The RS-485 output can be directly read by a MeteoPV, CR6-series, CR1000X-series, 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).

A CR6 or CR1000X data logger programmed as a Modbus Master can retrieve the values stored in the Input Registers. To do this, the CRBasic program requires a `SerialOpen()` instruction followed by the `ModbusMaster()` instruction.

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 `ModbusMaster()` instruction has the following syntax:

```
ModbusMaster (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 Register map (p. 5)). `ModbusOption` is an optional parameter described in the CRBasic Editor Help. Refer to Example programs (p. 7) for more information.

### 8. Analog programming

The pyranometer outputs a low level voltage that is measured using either the `VoltDiff()` CRBasic instruction or `VoltSE()` CRBasic instruction.
CAUTION:
Nearby AC power lines, electric pumps, or motors can be a source of electrical noise. If the sensor or data logger is located in an electrically noisy environment, the measurement should be made with the 60 or 50 Hz rejection integration option as shown in the example programs.

If measurement time is not critical, the autorange option can be used in the `VoltDiff()` or `VoltSE()` instruction; the autorange adds a few milliseconds to the measurement time. Otherwise, select the input range as follows:

1. Estimate the maximum expected input voltage by multiplying the maximum expected irradiance (in W•m⁻²) by the calibration factor (in μV / W•m⁻²). Divide the answer by 1000 to give the maximum in millivolt units.
2. Select the smallest input range that is greater than the maximum expected input voltage.

If electromagnetic radiation can be a problem, use an \( f_{N1} \) of 50 or 60 Hz. The multiplier converts the millivolt reading to engineering units. Table 8-1 (p. 7) provides the calculations required for the various units. The offset will normally be fixed at zero (see Example programs (p. 7)).

### Table 8-1: Multipliers required for flux density and total fluxes

<table>
<thead>
<tr>
<th>Units</th>
<th>Multiplier</th>
<th>Output processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>W•m⁻²</td>
<td>M</td>
<td>Average</td>
</tr>
<tr>
<td>MJ•m⁻²</td>
<td>M • t • 0.000001</td>
<td>Totalize</td>
</tr>
<tr>
<td>kJ•m⁻²</td>
<td>M • t • 0.001</td>
<td>Totalize</td>
</tr>
<tr>
<td>cal•cm⁻²</td>
<td>M • t • 0.0239 • 0.001</td>
<td>Totalize</td>
</tr>
<tr>
<td>cal • cm⁻² • min⁻¹</td>
<td>M • 1.434 • 0.001</td>
<td>Average</td>
</tr>
<tr>
<td>W • hr • m⁻²</td>
<td>M • t / 3600</td>
<td>Totalize</td>
</tr>
</tbody>
</table>

\( M = 1000/c \), where \( c \) is the sensor output in μV / W•m⁻²

\( t \) = data logger program execution interval in seconds

### 9. Example programs

Table 9-1 (p. 8) provides wiring for the example programs. CRBasic Example 1 (p. 8) uses Modbus over RS-485 and CRBasic Example 2 (p. 11) uses analog voltage measurements.
### Table 9-1: Connections for example programs

<table>
<thead>
<tr>
<th>Wire color</th>
<th>Function</th>
<th>RS-485 program CR1000X connections</th>
<th>Analog program CR1000X connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>RS485A</td>
<td>C5</td>
<td>N/C</td>
</tr>
<tr>
<td>White</td>
<td>RS485B</td>
<td>C6</td>
<td>N/C</td>
</tr>
<tr>
<td>Red</td>
<td>Power in (12 V)</td>
<td>12V</td>
<td>12V</td>
</tr>
<tr>
<td>Black</td>
<td>Power ground</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Blue</td>
<td>Pyranometer signal high</td>
<td>N/C</td>
<td>1H</td>
</tr>
<tr>
<td></td>
<td>Pyranometer signal reference</td>
<td>N/C</td>
<td>Jumper 1L to ⬇️ with user-supplied wire</td>
</tr>
<tr>
<td>Clear</td>
<td>Shield</td>
<td>⬇️ (analog ground)</td>
<td>⬇️ (analog ground)</td>
</tr>
</tbody>
</table>

### CRBasic Example 1: CR1000X program using Modbus over RS-485 to measure the SR05

```crbasic
'CR1000X Series Datalogger
'HukseFlux SR2005 Pyranometer
'SR05 is an ISO 9060 Second Class pyranometer
',
Public CheckSensorID As Boolean

Dim SR05(15) As Long

Public SR05_IRR_TC 'Temperature compensated x 0.01 W/M^2
Public SR05_INR 'Uncompensated x 0.01 W/M^2
Public SR05_BodyTemp As Float
Public SR05_SerialNumber As Float
Public SR05_CalDate As Long
Public SR05_Humidity As Float
Public SR05_ScaleFactor_IRR As Long
Public SR05_ScaleFactor_BodyTemp As Long
Public SR05_ElecResistance As Long
Public SR05_VoltageOut As Float

Public MBResult_IRR_TC
Public MBResult_INR
Public MBResult_BodyTemp
Public MBResult_SN
Public MBResult_CalDate
Public MBResult_Humidity
Public MBResult_SFIRR
Public MBResult_SRTemp
```

SR05 Second Class Pyranometer with Various Outputs 8
CRBasic Example 1: CR1000X program using Modbus over RS-485 to measure the SR05

Public MBResult_ElecRes
Public MBResult_VoltOut

Units SR05_IRR = W/m^2
Units SR05_IRR_TC = W/m^2
Units SR05_BodyTemp = DegC
Units SR05_Humidity = %
Units SR05_ElecResistance = Ohm
Units SR05_VoltageOut = uV

DataTable (OneMin,1,-1)
  DataInterval (0,1,Min,10)
  Average (1,SR05_IRR,IEEE4,False)
  Average (1,SR05_IRR_TC,IEEE4,False)
  Maximum (1,SR05_IRR_TC,IEEE4,False,False)
  Minimum (1,SR05_IRR_TC,IEEE4,False,False)
  StdDev (1,SR05_IRR_TC,IEEE4,False)
  Average (1,SR05_BodyTemp,IEEE4,False)
EndTable

DataTable (SR05_MetaData,1,-1)
  Sample (1,SR05_ElecResistance,IEEE4)
  Sample (1,SR05_VoltageOut,IEEE4)
  Sample (1,SR05_Humidity,IEEE4)
EndTable

DataTable (SR05_SensorID,1,100)
  Sample (1,SR05_SerialNumber,FP2)
  Sample (1,SR05_CalDate,Long)
  Sample (1,SR05_ScaleFactor_IRR,FP2)
  Sample (1,SR05_ScaleFactor_BodyTemp,FP2)
EndTable

BeginProg

  SerialOpen (ComC5,19200,2,0,50,4)
  CheckSensorID = True
  Scan (1,Sec,0,0)
  If CheckSensorID = True Then
    'Serial Number
    ModbusMaster(MBResult_SN,ComC5,19200,62,4,SR05(1),41,1,1,100,3)
    SR05_SerialNumber = SR05(1)
  
    'Cal Date
    ModbusMaster(MBResult_CalDate,ComC5,19200,62,4,SR05(2),47,1,1,100,2)
    SR05_CalDate = SR05(2)

EndProg
CRBasic Example 1: CR1000X program using Modbus over RS-485 to measure the SR05

'Scaling Factor IRR
ModbusMaster(MBResult_SFIRR,ComC5,19200,62,4,SR05(3),9,1,1,100,3)
SR05_ScaleFactor_IRR = SR05(3)

'Scaling Factor Temp
ModbusMaster(MBResult_SRTemp,ComC5,19200,62,4,SR05(4),10,1,1,100,3)
SR05_ScaleFactor_BodyTemp = SR05(4)

'Electrical Resistance
ModbusMaster(MBResult_ElecRes,ComC5,19200,62,4,SR05(10),7,1,1,100,1)
SR05_ElecResistance = SR05(10)/10

'Voltage output
ModbusMaster(MBResult_VoltOut,ComC5,19200,62,4,SR05(11),3,2,1,100,2)
SR05_VoltageOut = SR05(11)

'Humidity
ModbusMaster(MBResult_Humidity,ComC5,19200,62,4,SR05(13),99,1,1,100,3)
SR05_Humidity = SR05(13)/100
CheckSensorID = False

CallTable SR05_SensorID
EndIf

'Irradiance temperature compensated
ModbusMaster(MBResult_IRR_TC,ComC5,19200,62,4,SR05(5),3,2,1,100,2)
SR05_IRR_TC = SR05(5)/SR05_ScaleFactor_IRR

'Irradiance uncompensated
ModbusMaster(MBResult_IRR,ComC5,19200,62,4,SR05(7),3,2,1,100,2)
SR05_IRR = SR05(7)/SR05_ScaleFactor_IRR

'Body Temp
ModbusMaster(MBResult_BodyTemp,ComC5,19200,62,4,SR05(9),7,1,1,100,1)
SR05_BodyTemp = SR05(9)/SR05_ScaleFactor_BodyTemp

CallTable OneMin

NextScan

SlowSequence
Scan (6,Hr,0,0)

'Electrical Resistance
ModbusMaster(MBResult_ElecRes,ComC5,19200,62,4,SR05(10),7,1,1,100,1)
SR05_ElecResistance = SR05(10)/10

'Voltage output
CRBasic Example 1: CR1000X program using Modbus over RS-485 to measure the SR05

```crbasic
ModbusMaster(MBResult_VOLTOut,ComC5,19200,62,4,SR05(11),3,2,1,100,2)
SR05_VOLTageOut = SR05(11)

'Humidity
ModbusMaster(MBResult_Humidity,ComC5,19200,62,4,SR05(13),99,1,1,100,3)
SR05_Humidity = SR05(13)/100

CallTable SR05_MetaData
NextScan
EndProg
```

CRBasic Example 2: CR1000X program using analog voltage to measure the SR05

```crbasic
'CR1000X Series Datalogger
'Hukseflux SR2005 Pyranometer
'SR05 is an ISO 9060 Second Class pyranometer

Public SR05_Analog_IRR

DataTable (OneMin,1,-1)
  Average (1,SR05_Analog_IRR,IEEE4,False)
  Maximum (1,SR05_Analog_IRR,IEEE4,False,False)
  Minimum (1,SR05_Analog_IRR,IEEE4,False,False)
  StdDev (1,SR05_Analog_IRR,IEEE4,False)
EndTable

BeginProg
  Scan (1,Sec,0,0)

  'Irradiance uncompensated (Analog)
  VoltDiff (SR05_Analog_IRR,1,mV1000,1,True ,0,60,1.6,0)

  CallTable OneMin
  NextScan
  EndProg
```
10. Maintenance and troubleshooting

The SR05 has no service items requiring 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 cleaning interval. Sophisticated research applications require daily cleaning. For typical PV applications, clean once per week, bi-monthly, or monthly. The SR05 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 and use the 50 or 60 Hz integration option in the data logger program if electromagnetic radiation can be a problem. Check the cable for damage and ensure that it is properly connected to the data logger.
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- Location: São Paulo, SP Brazil
- Phone: 11.3732.3399
- Email: vendas@campbellsci.com.br
- Website: www.campbellsci.com.br

**Canada**
- Location: Edmonton, AB Canada
- Phone: 780.454.2505
- Email: dataloggers@campbellsci.ca
- Website: www.campbellsci.ca

**China**
- Location: Beijing, P. R. China
- Phone: 86.10.6561.0080
- Email: info@campbellsci.com.cn
- Website: www.campbellsci.com

**Costa Rica**
- Location: San Pedro, Costa Rica
- Phone: 506.2280.1564
- Email: info@campbellsci.cc
- Website: www.campbellsci.cc

**France**
- Location: Vincennes, France
- Phone: 0033.0.1.56.45.15.20
- Email: info@campbellsci.fr
- Website: www.campbellsci.fr

**Germany**
- Location: Bremen, Germany
- Phone: 49.0.421.460974.0
- Email: info@campbellsci.de
- Website: www.campbellsci.de

**South Africa**
- Location: Stellenbosch, South Africa
- Phone: 27.21.8809960
- Email: sales@campbellsci.co.za
- Website: www.campbellsci.co.za

**Southeast Asia**
- Location: Bangkok, Thailand
- Phone: 66.2.719.3399
- Email: thitipongc@campbellsci.asia
- Website: www.campbellsci.asia

**Spain**
- Location: Barcelona, Spain
- Phone: 34.93.2323938
- Email: info@campbellsci.es
- Website: www.campbellsci.es

**UK**
- Location: Shepshed, Loughborough, UK
- Phone: 44.0.1509.601141
- Email: sales@campbellsci.co.uk
- Website: www.campbellsci.co.uk

**USA**
- Location: Logan, UT USA
- Phone: 435.227.9120
- Email: info@campbellsci.com
- Website: www.campbellsci.com