DATALOGGER PROGRAMMING AND SENSORS CONNECTION
ADVANCED COURSE

Module

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Ministero dell'Università e della Ricerca

Italiadomani

Section 1 - Datalogger

1.1 General description

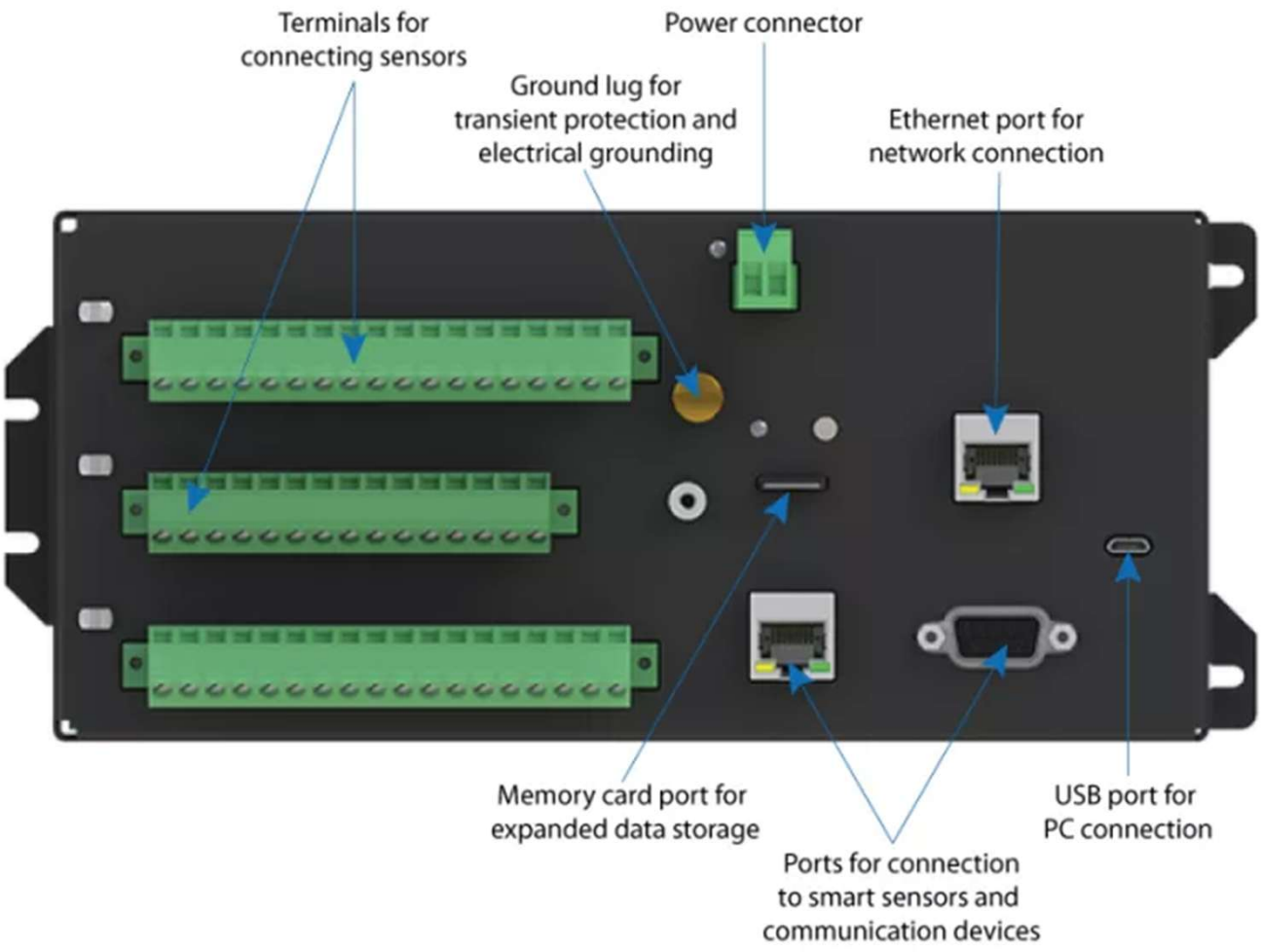
What is a datalogger

- Electronic device to **record data** from **sensors**
- **Programmable** to convert signals into physical units
- **Data storage** (flash memory, PC, clouds, etc.)
- **General purpose**

https://www.campbellsci.com/data-loggers

https://www.youtube.com/@CampbellScientific

Datalogger parts



Signal — *Section 2*

Calculations + conversions — *Section 3*

Storage

Datalogger models

		Operating Temperature Range	Maximum Scan Rate	Analog Inputs	Communication Protocols
CR3000 Measurement and Control Datalogger		❯ -40° to +85°C (extended) ❯ -25° to +50°C (standard) ❯ *Non-condensing environment* ❯ *Battery bases have different temperature ranges. The rechargeable base option has an operating temperature range of -40° to +60°C. The alkaline base option has a temperature range of -25° to +50°C.*	100 Hz	28 single-ended or 14 differential (individually configured)	PakBus, Modbus, DNP3, SDI-12, SDM
CR1000X Measurement and Control Datalogger Popular		❯ *Non-condensing environment* ❯ -55° to +85°C (extended) ❯ -40° to +70°C (standard)	1000 Hz	16 single-ended or 8 differential (individually configured) Two analog inputs can measure 4 to 20 mA or 0 to 20 mA natively. Four analog inputs can provide pulse/ digital I/O functions.	CPI, PakBus, SDM, SDI-12, Modbus, TCP, DNP3, UDP, NTCIP, NMEA 0183, I2C, SPI, and others
CR6 Measurement and Control Datalogger Popular		❯ *Non-condensing environment* ❯ -55° to +85°C (extended) ❯ -40° to +70°C (standard)	1000 Hz	Up to 12 single-ended or 6 differential (The CR6 has 12 universal [U] and 4 control [C] terminals that can be programmed for a variety of functions. The number of analog inputs, switched excitations, and digital ports assume all the ports are configured the same.)	CPI, PakBus, SDM, SDI-12, Modbus, TCP, DNP3, UDP, NTCIP, NMEA 0183, I2C, SPI, and others
CR300 Measurement and Control Datalogger Popular		❯ *Non-condensing environment* ❯ -40° to +70°C (standard)	10 Hz	6 single-ended or 3 differential (individually configured)	PakBus, Modbus, DNP3, SDI-12, TCP, UDP, and others
CR310 Measurement and Control Datalogger		❯ *Non-condensing environment* ❯ -40° to +70°C (standard)	10 Hz	6 single-ended or 3 differential (individually configured)	PakBus, Modbus, DNP3, SDI-12, TCP, UDP, and others

Datalogger models

Two new models

	Operating Temperature Range	*Maximum Scan Rate*	*Analog Inputs*	*Communications Protocols*
CR1000Xe Measurement and Control Datalogger 	› -40° to +70°C (standard) › -55° to +85°C (extended) › Non-condensing environment	1000 Hz	16 single-ended or 8 differential (individually configured). Two analog inputs can measure 4 to 20 mA or 0 to 20 mA natively.	CPI, PakBus, SDM, SDI-12, Modbus, TCP, DNP3 outstation, UDP, NTCIP, NMEA 0183, I2C, SPI, CampbellCloud HTTPS/MQTTS, and others
CR350 Measurement and Control Datalogger 	› -40° to +70°C › *Non-condensing environment*	10 Hz	4 single-ended or 2 differential (individually configured)	PakBus, PakBus Encryption, Modbus RTU/ASCII/TCP, DNP3, SDI-12, and others

Terminal types

- **Analog** inputs
- **Pulse** counters
- Switched voltage **excitation** outputs
- **Digital** I/O ports
- RS-232, RS-422, or RS-485 ports
- 5 V, 12 V and switched 12 V terminals

Section 1 - Datalogger

1.2 Specifications

Specs

https://s.campbellsci.com/documents/us/product-brochures/s_cr1000xe.pdf

Section 1 - Datalogger

1.3 Models comparison

Datalogger models

- Different per **size**, number of **channels,** communication, accuracy, etc.

		Operating Temperature Range	Maximum Scan Rate	Analog Inputs	Communication Protocols
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CR310 Measurement and Control Datalogger		❯ *Non-condensing environment* ❯ -40° to +70°C (standard)	10 Hz	6 single-ended or 3 differential (individually configured)	PakBus, Modbus, DNP3, SDI-12, TCP, UDP, and others

Datalogger models

Two new models

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Section 3 - Software di configurazione, gestione e controllo

3.1 – Device Configuration Utility

DCU - summary

Connect to a datalogger (cable or Ethernet)	***If USB -> 5 V!!!***
Date and time settings	***with PC time***
Send a programme	
Verify OS installed Verify update/upgrade OS	***Suggested when connected if outdated***
Status table	***See next slide***
File control and security	***Programme management***
Terminal	***Sensors settings, e.g. SDI-12***

Status

Record No	1,595
Time Stamp	5/21/2025 11:52:39 AM
OSVersion	CR1000X.Std.08.01
OSDate	09/23/2024
OSSignature	41,327
SerialNumber	70184
RevBoard	020.001.p.e
StationName	70184
RecipeStatus	
ProgName	CPU:temp_test_mod_v5.CR1X
StartTime	5/21/2025 11:12:55 AM
RunSignature	49,159
ProgSignature	36,336
WatchdogErrors	0
PanelTemp	24.47958
Battery	0
LithiumBattery	3.677859
Low12VCount	0
CompileResults	CPU:temp_test_mod_v5.CR1X -- Compiled in PipelineMode.
StartUpCode	65
ProgErrors	0
VarOutOfBound	0
SkippedScan	0
SkippedSystemScan	0
ErrorCalib	0
MemorySize	4,194,304
MemoryFree	57,628

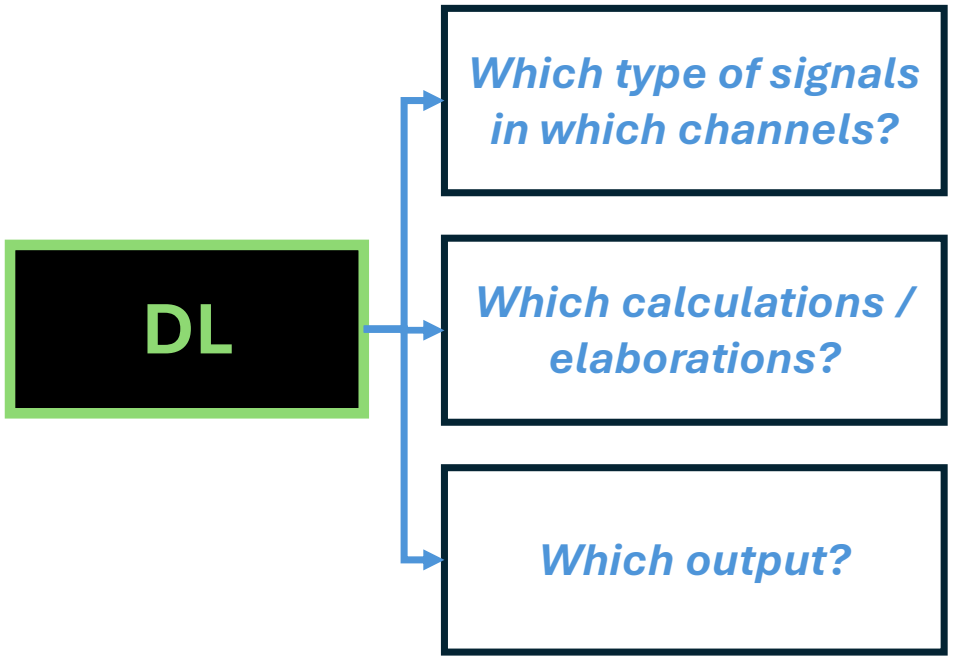
Record No	1,595
Time Stamp	5/21/2025 11:52:39 AM
OSVersion	CR1000X.Std.08.01
MemoryFree	57,628
CommsMemFree	305 100(99),92(91),199(198),100(96),15(14),25(23),14(12),1(1),0(0),0(0)
FullMemReset	0
CardStatus	No Card Present.
MeasureOps	194
MeasureTime	142,600
ProcessTime	787,784
MaxProcTime	789,854
BuffDepth	0
MaxBuffDepth	0
LastSystemScan	5/21/2025 11:53:00 AM
SystemProcTime	356
MaxSystemProcTime	360
PortStatus(1)	0
PortStatus(2)	0
PortStatus(3)	0
PortStatus(4)	0
PortStatus(5)	0
PortStatus(6)	0
PortStatus(7)	0
PortStatus(8)	0
PortConfig(1)	SDI-12
PortConfig(2)	Input
PortConfig(3)	RS485 A-
PortConfig(4)	RS485 B+
PortConfig(5)	Input

PortConfig(5)	Input
PortConfig(6)	Input
PortConfig(7)	Input
PortConfig(8)	Input
SW12Volts(1)	0
SW12Volts(2)	0
SW12CSIO	-1
PakBusRoutes	13,4089,4089,5000
Messages	
CalVolts(1)	8,000.158
CalVolts(2)	1,599.909
CalVolts(3)	319.7759
CalRefSlope(1)	-0.04259603
CalRefSlope(2)	-0.009371054
CalRefSlope(3)	-0.002777082
CalRefOffset(1)	2.554944
CalRefOffset(2)	0.5674039
CalRefOffset(3)	0.1750101
CalGain(1)	0.0006422554
CalGain(2)	0.0001267055
CalGain(3)	2.527439e-05
CalOffset(1)	-145
CalOffset(2)	-144
CalOffset(3)	-135
CalCurrent(1)	0.09999441
CalCurrent(2)	0.09999672

Section 3 - Software di configurazione, gestione e controllo

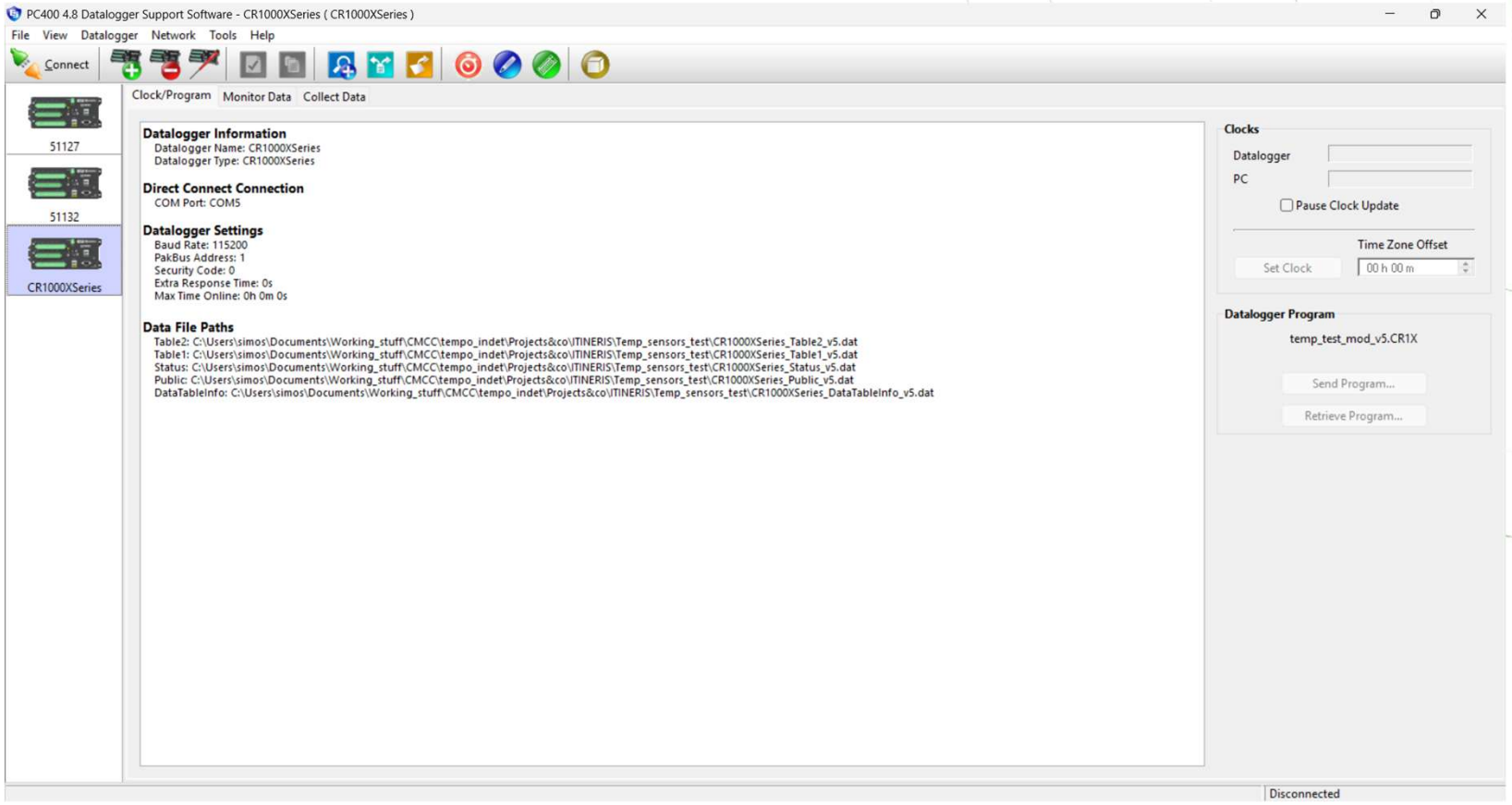
3.2. PC400

How to instruct the logger



Communication: PC400 (core, free) or LoggerNet (complete, at a cost)

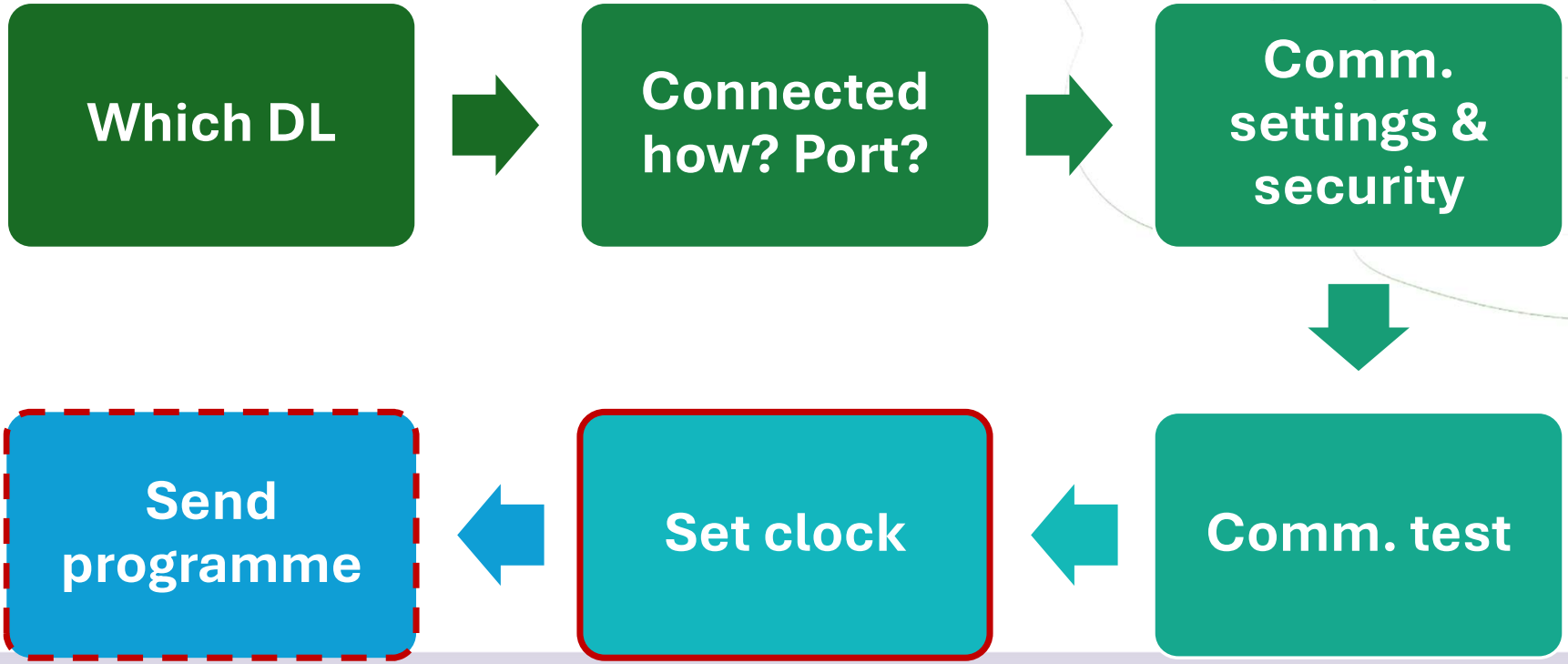
PC400


PC400 4.8 Datalogger Support Software - CR1000XSeries (CR1000XSeries)
File View Datalogger Network Tools Help
Connect
51127
51132
CR1000XSeries
Clock/Program Monitor Data Collect Data
Datalogger Information
Datalogger Name: CR1000XSeries
Datalogger Type: CR1000XSeries
Direct Connect Connection
COM Port: COM5
Datalogger Settings
Baud Rate: 115200
PakBus Address: 1
Security Code: 0
Extra Response Time: 0s
Max Time Online: 0h 0m 0s
Data File Paths
Table2: C:\Users\simos\Documents\Working_stuff\CMCC\tempo_indet\Projects&co\ITINERIS\Temp_sensors_test\CR1000XSeries_Table2_v5.dat
Table1: C:\Users\simos\Documents\Working_stuff\CMCC\tempo_indet\Projects&co\ITINERIS\Temp_sensors_test\CR1000XSeries_Table1_v5.dat
Status: C:\Users\simos\Documents\Working_stuff\CMCC\tempo_indet\Projects&co\ITINERIS\Temp_sensors_test\CR1000XSeries_Status_v5.dat
Public: C:\Users\simos\Documents\Working_stuff\CMCC\tempo_indet\Projects&co\ITINERIS\Temp_sensors_test\CR1000XSeries_Public_v5.dat
DataTableInfo: C:\Users\simos\Documents\Working_stuff\CMCC\tempo_indet\Projects&co\ITINERIS\Temp_sensors_test\CR1000XSeries_DataTableInfo_v5.dat
Clocks
Datalogger
PC
Pause Clock Update
Time Zone Offset
Set Clock
00 h 00 m
Datalogger Program
temp_test_mod_v5.CR1X
Send Program...
Retrieve Program...
Disconnected

PC400 – Datalogger setup

Wizard

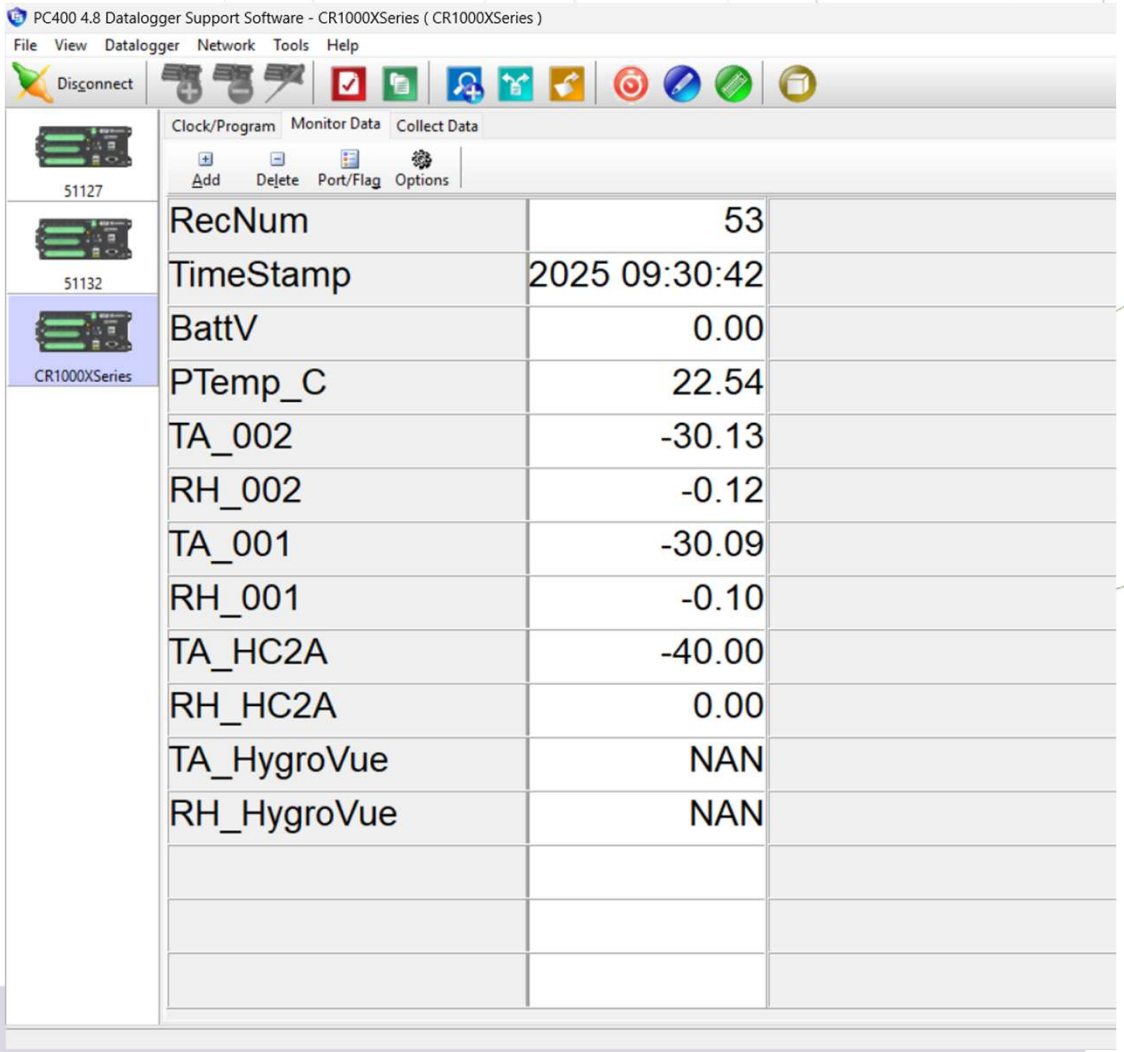
- Can be done also in DCU, LoggerNet
- Can be done also afterwards
- Can be done also in Short Cut



Data tables

PUBLIC

- Output are organized in **tables**
  - **Public** → at scan rate, real time
  - **Status**
  - **Custom** → usually one for battery and logger temp., one with measurements. Samples, averages, or simple aggregations at the desired interval
- Data monitor also in Dev. Config. and LoggerNet



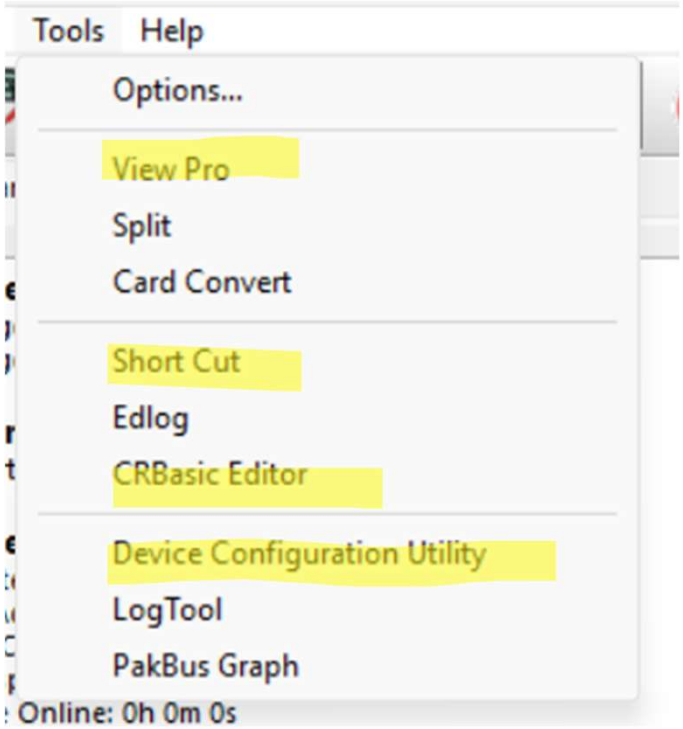
Data download

- Select **which data** you need
- Select the table and specify **destination** and **filename**
- **Save** to text files
- Files can be visualized
- No visualization of data (plots)

WARNING! Risk of data loss!

Same filename+all data → overwrites!
Check the filenames of all the tables you need!

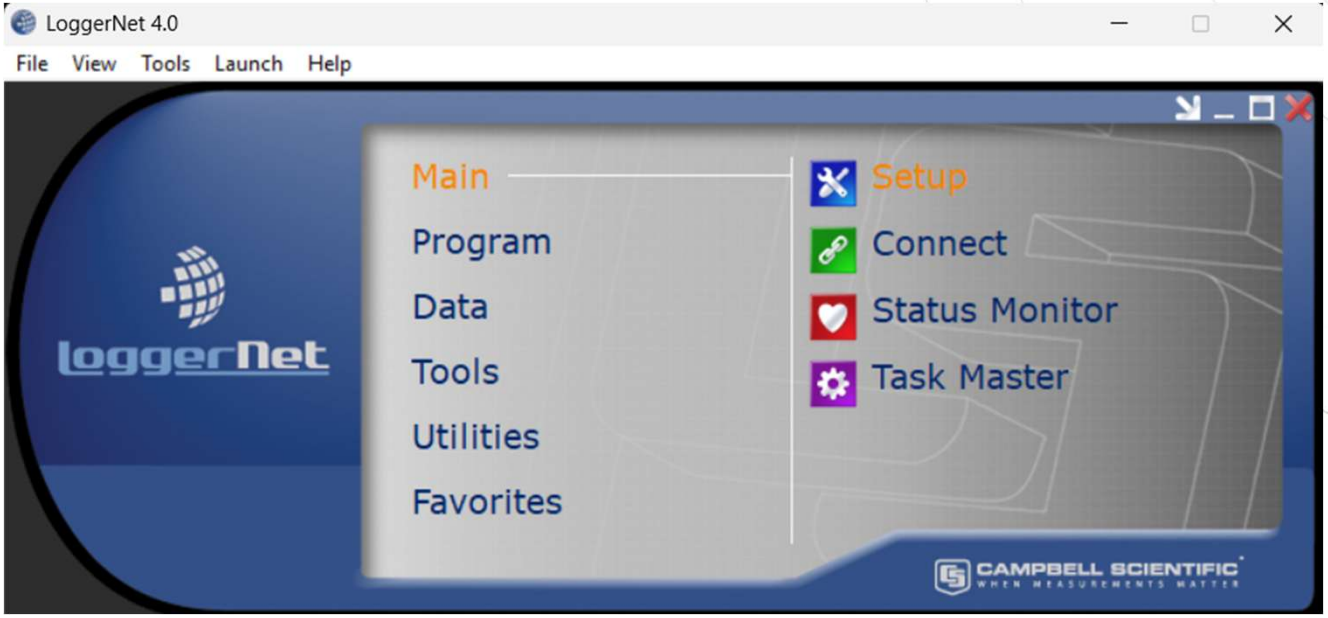
Other functionalities



Section 3 - Software di configurazione, gestione e controllo

3.3. LoggerNet

LoggerNet: a complete CS software



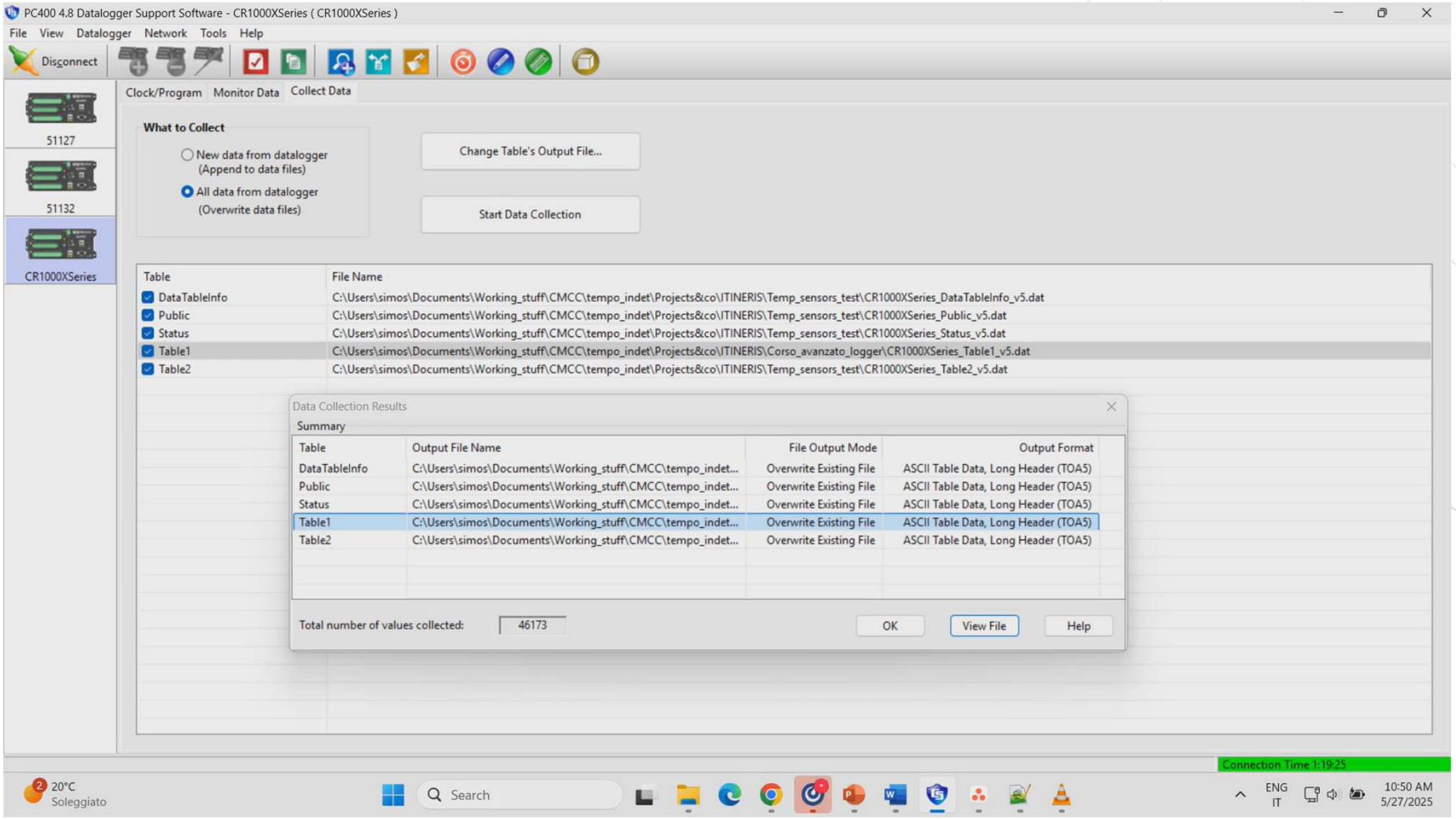
LoggerNet software

- Same functionalities as PC400 + dedicated utilities and more options
  - **Datalogger setup**
  - **Connect**
  - **Device configuration**
  - **Access to ViewPro and programming tools**
- Example of additional functionalities:
  - **Status Monitor**
  - **Plots**
  - **More options for data collection and more formats**
  - **Download scheduling**
  - **Remote connection**

Section 3 - Software di configurazione, gestione e controllo

3.4. ViewPro

Simple visualisation tool



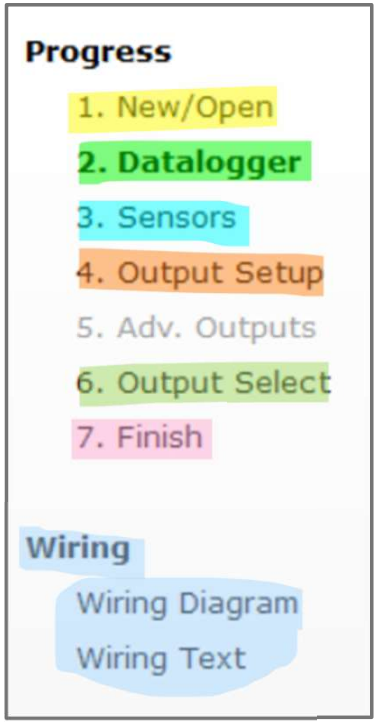
Text files downloaded

Section 3 - Software di configurazione, gestione e controllo

3.5. Short Cut

Short Cut

- The easiest and fastest way to **create** a programme
- Accessible via PC400, LoggerNet or directly (Windows)
- Few **steps**:



Create or edit

Associate a logger model

Select sensors from database and configure

Scan interval, output tables attributes (name, output interval)

Assign vars from sensors to tables, according to which operation

Save and send the programme to the logger

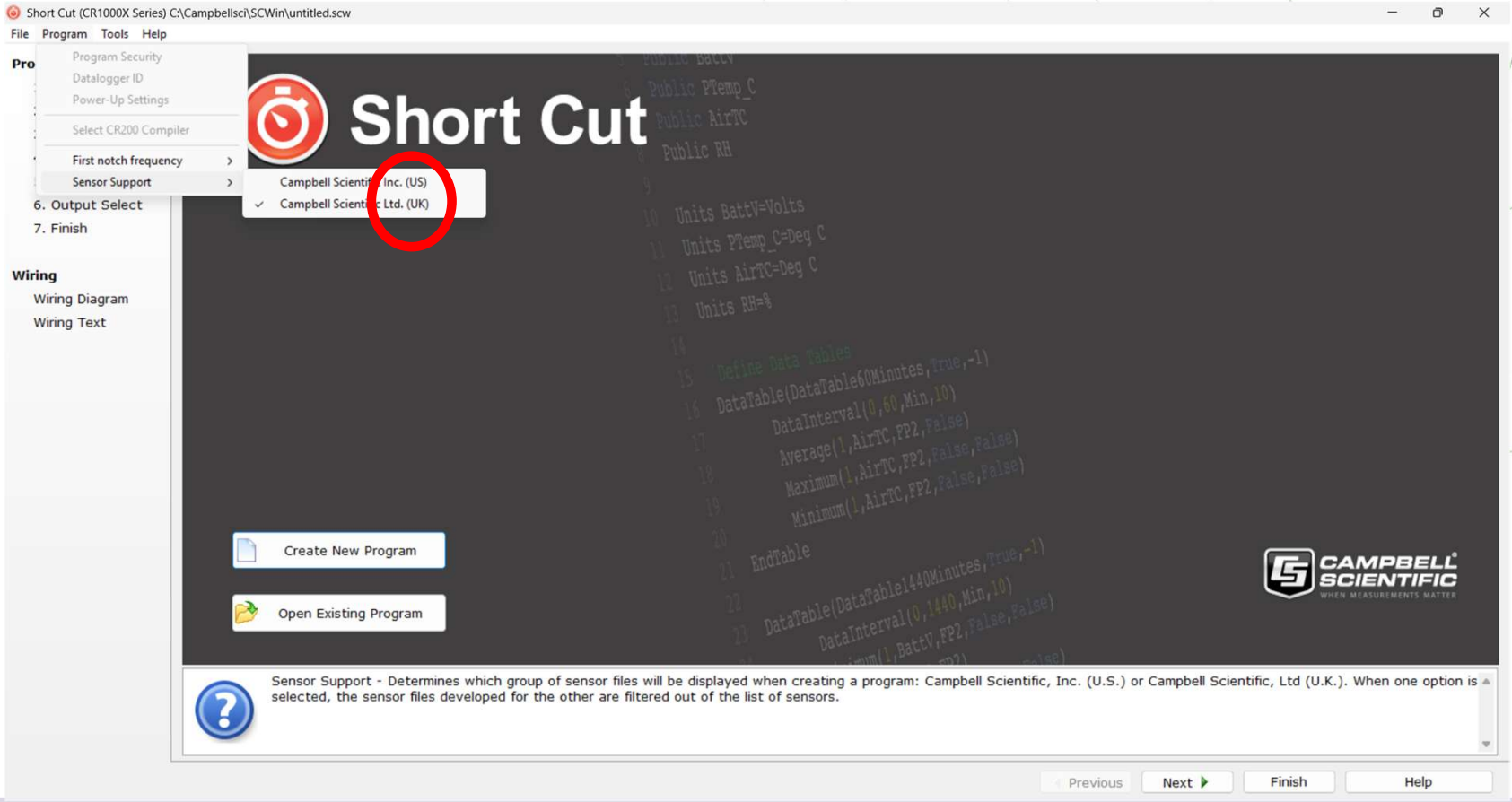
WARNING!

Colours may change!

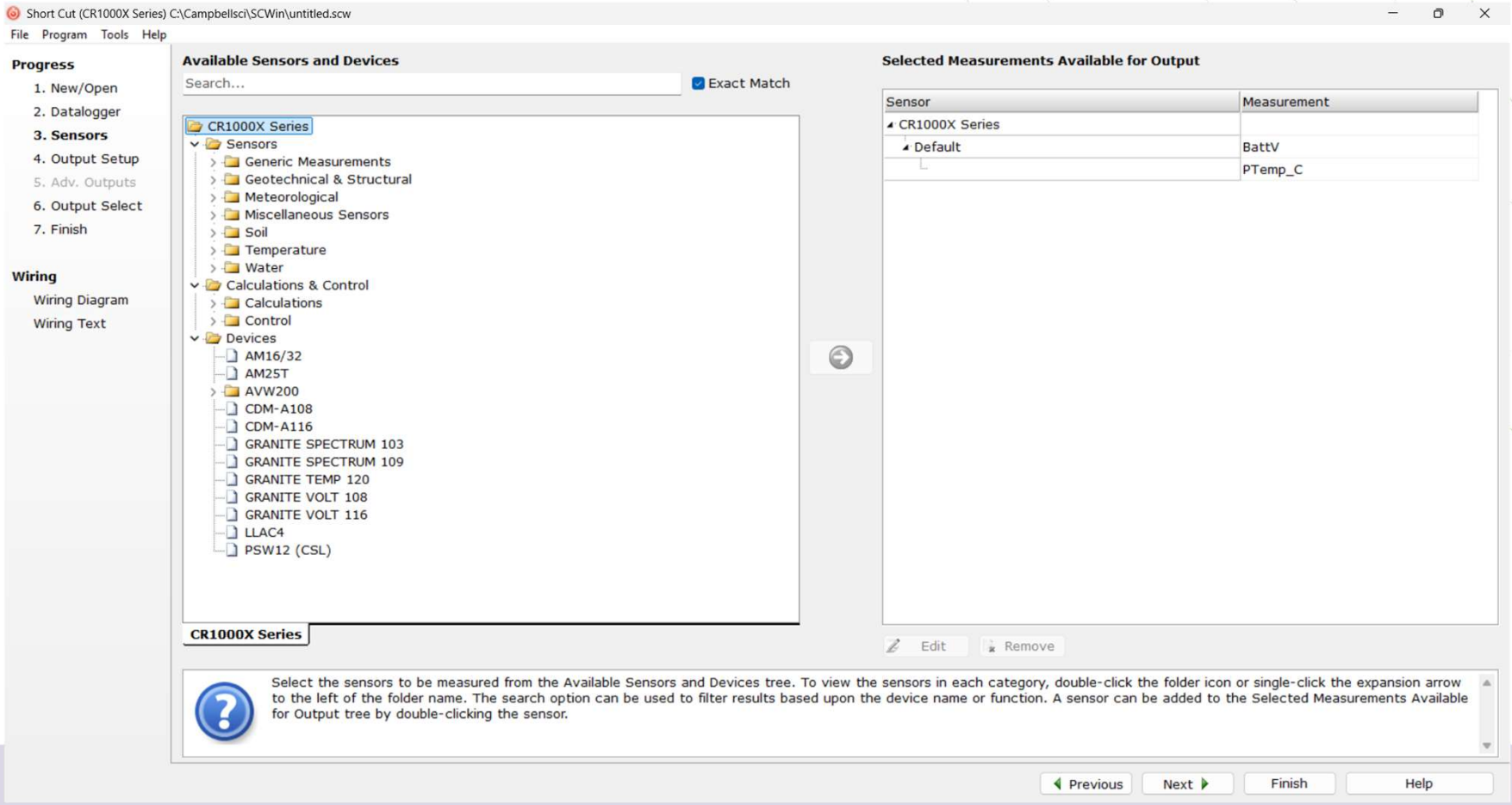
Wires colour	**Logger channel**

Select sensors from database and configure

- Two databases



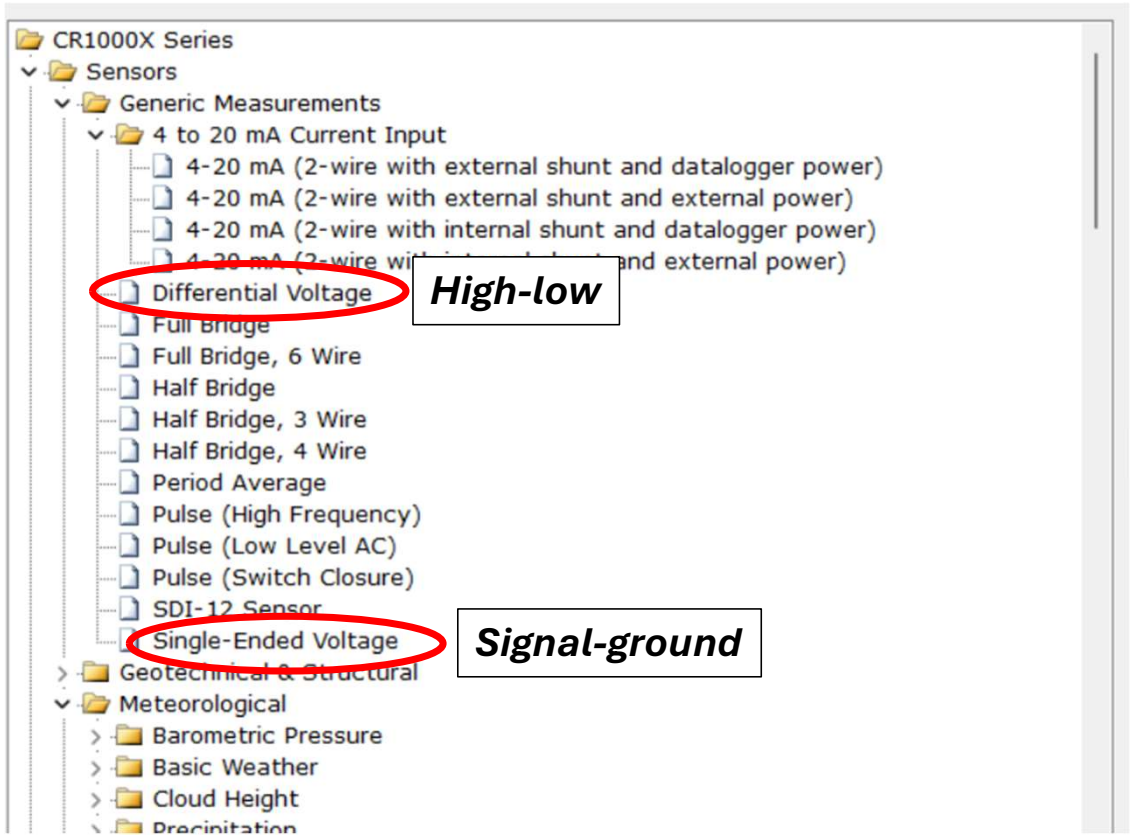
Select sensors from database and configure



What if my sensor is not on the lists?

- First check under “**miscellaneous**”
- Still possible to use the Short Cut if standard measure (single ended, differential – see sec. 2): **Generic Measurements**
- **Custom** sensors can be saved
- Some examples and special cases in the next slides

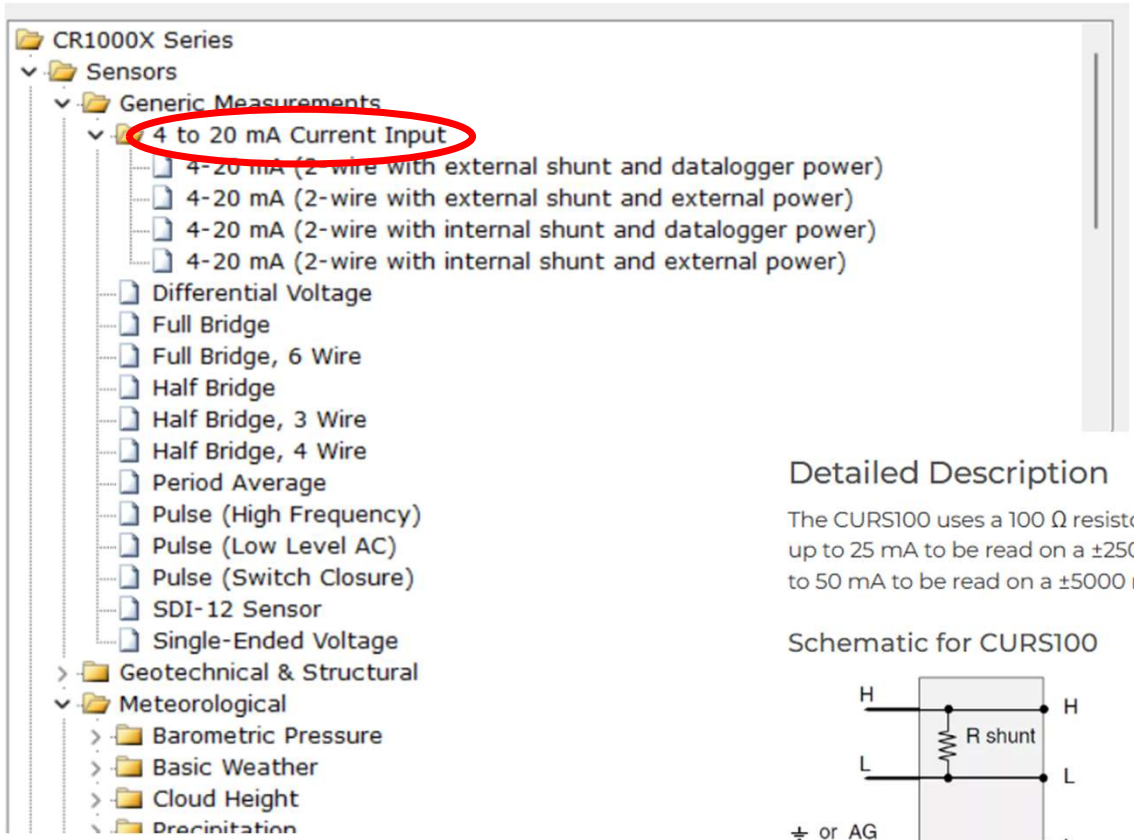
Analogue measurements



Linear relation with physical units → multiplier, offset

Analogue measurements

- Linear relation with physical units → multiplier, offset
- Convert to mV using a known precision (shunt) **resistance** (Ohm law *V=R*I*)
- Dedicated **module** from CS (CURS100)

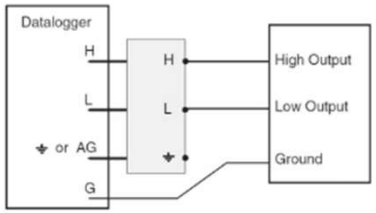


Detailed Description

The CURS100 uses a 100 Ω resistor for the current shunt that allows currents up to 25 mA to be read on a ±2500 mV range (CR10X, CR510) and currents up to 50 mA to be read on a ±5000 mV range.

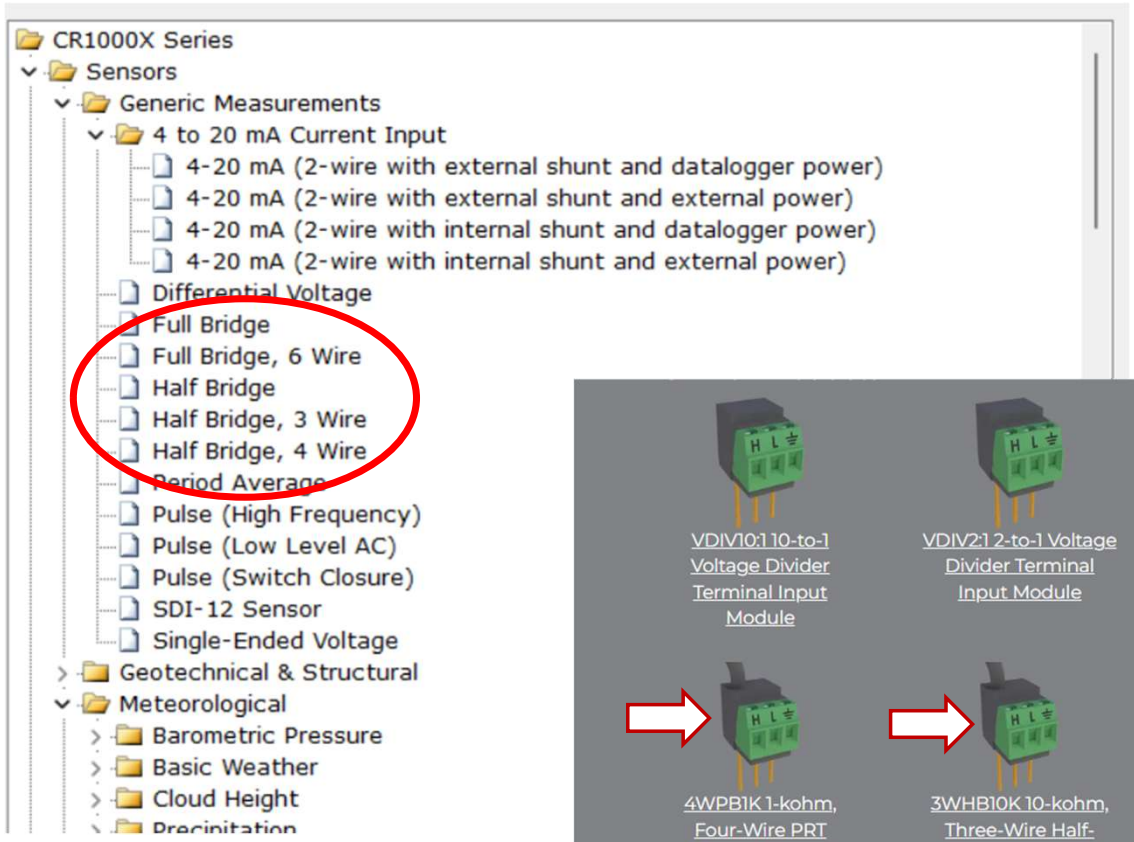
Schematic for CURS100

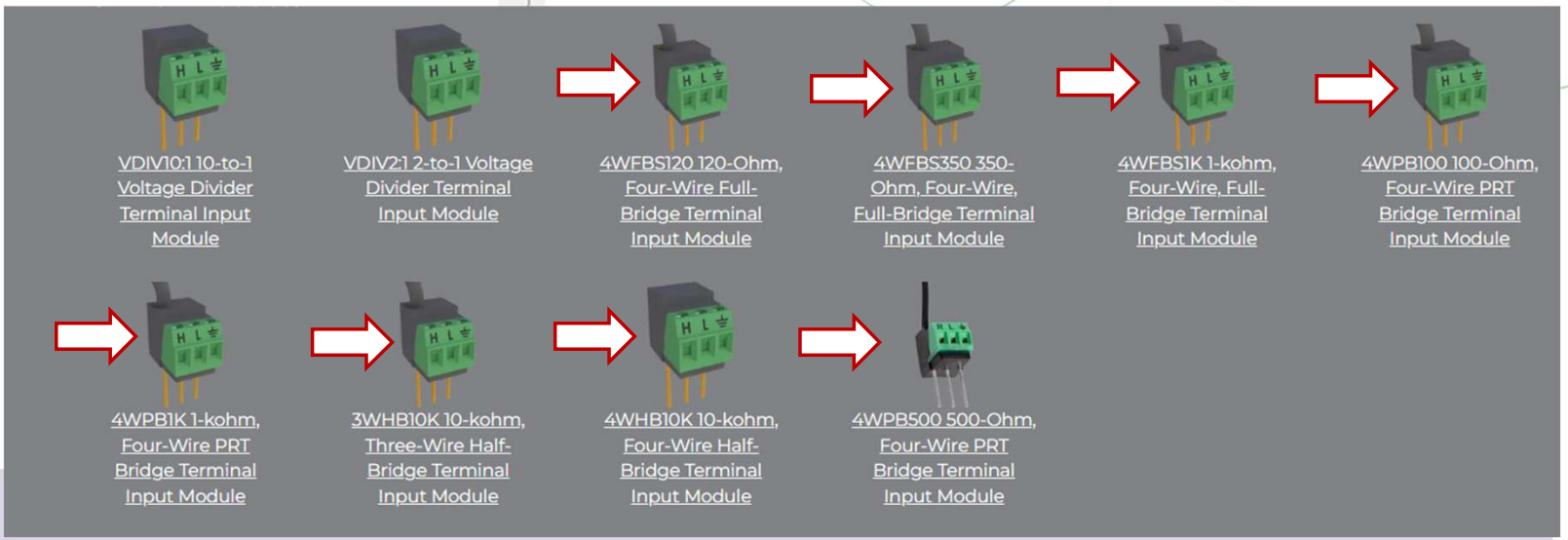
CURS100-to-Sensor Hookup



Bridge measurements

- **Resistance** measurements with Voltage excitation
- V drop across R of the sensor and one ore more known resistors.
- **Typical for PRT**
- CS selling dedicated terminal input **modules**

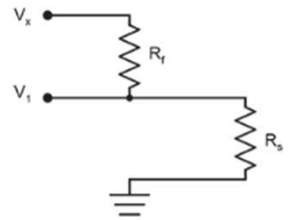
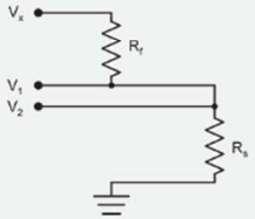
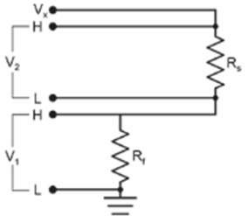




Bridge measurements

Half bridges

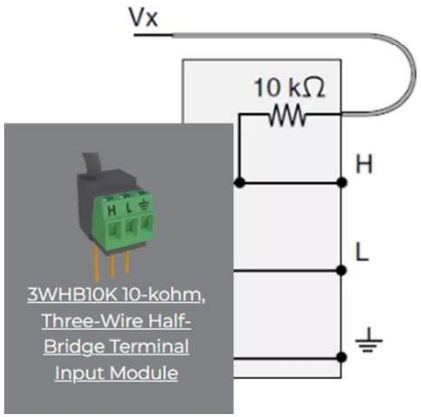
- Rs=sensing resistor
- Rf=fixed, known resistance
- Vx = excitation voltage
- V1, V2 = sensor return voltages
- From the V drop we can retrieve Rs, that scales with temperature

Resistive-bridge type and circuit diagram	CRBasic instruction and fundamental relationship	Relational formulas
Half Bridge[1] 	CRBasic Instruction: `BrHalf()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = \frac{V_1}{V_x} = \frac{R_s}{R_s+R_f}$	$R_s = R_f\frac{X}{1-X}$ $R_f = \frac{R_s(1-X)}{X}$
Three Wire Half Bridge[1,2] 	CRBasic Instruction: `BrHalf3W()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = \frac{2V_2-V_1}{V_x-V_1} = \frac{R_s}{R_f}$	$R_s = R_fX$ $R_f = \frac{R_s}{X}$
Four Wire Half Bridge[1,2] 	CRBasic Instruction: `BrHalf4W()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = \frac{V_2}{V_1} = \frac{R_s}{R_f}$	$R_f = \frac{R_s}{X}$ $R_s = R_fX$

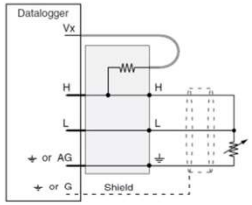
Bridge measurements

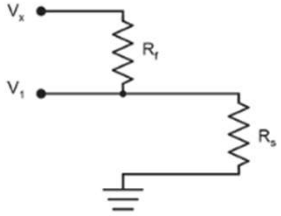
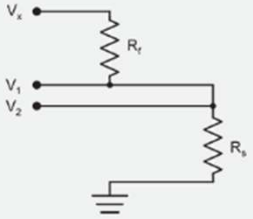
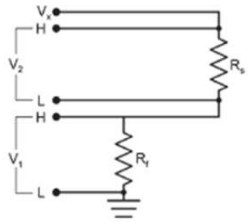
Detailed Description

3WHB10K Schematic



3WHB10K-to-Sensor Hookup

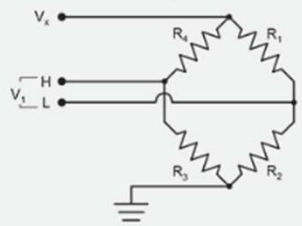
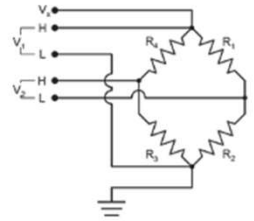


Resistive-bridge type and circuit diagram	CRBasic instruction and fundamental relationship	Relational formulas
Half Bridge[1] 	CRBasic Instruction: `BrHalf()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = \frac{V_1}{V_x} = \frac{R_s}{R_s+R_f}$	$R_s = R_f\frac{X}{1-X}$ $R_f = \frac{R_s(1-X)}{X}$
Three Wire Half Bridge[1,2] 	CRBasic Instruction: `BrHalf3W()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = \frac{2V_2-V_1}{V_x-V_1} = \frac{R_s}{R_f}$	$R_s = R_fX$ $R_f = \frac{R_s}{X}$
Four Wire Half Bridge[1,2] 	CRBasic Instruction: `BrHalf4W()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = \frac{V_2}{V_1} = \frac{R_s}{R_f}$	$R_f = \frac{R_s}{X}$ $R_s = R_fX$

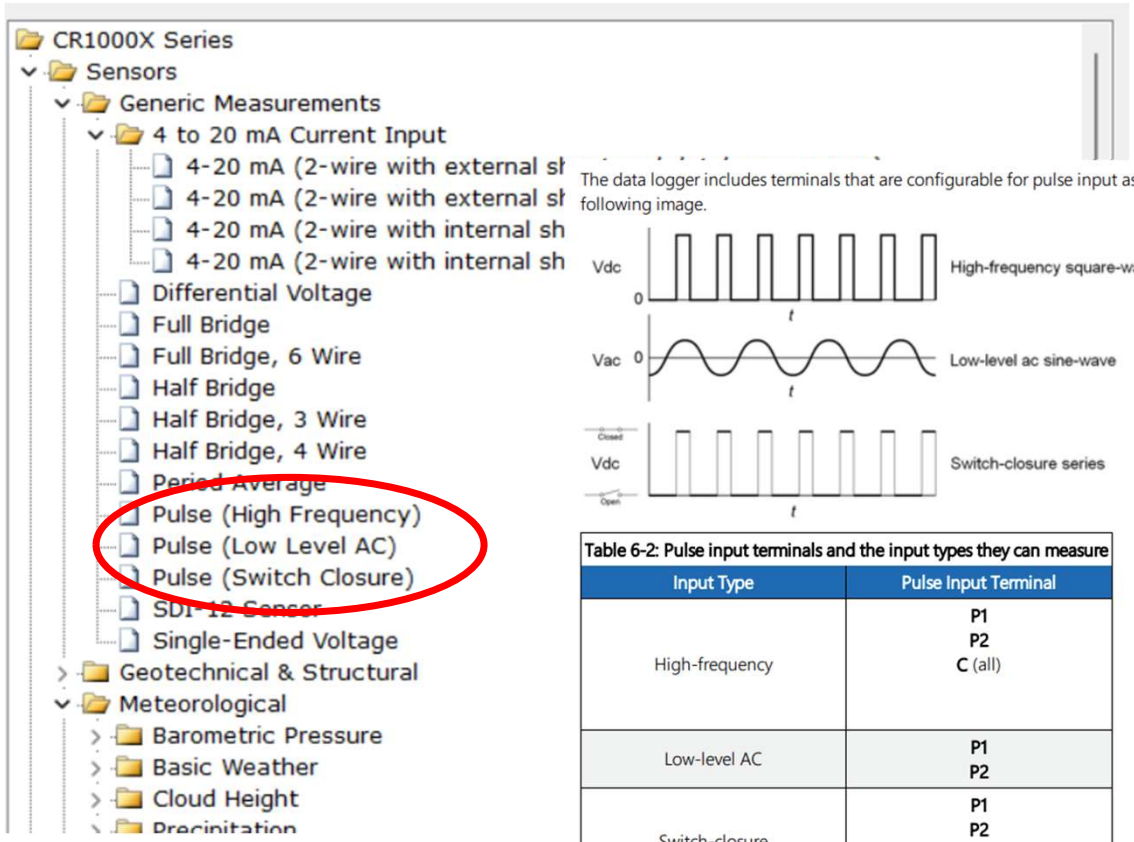
Bridge measurements

Full bridges

- More complex circuits, V drops across different combinations

Full Bridge[1,2]  	CRBasic Instruction: `BrFull()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = 1000\frac{V_1}{V_x} = 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	These relationships apply to `BrFull()` and `BrFull6W()` $R_1 = \frac{R_2(1-X_1)}{X_1}$ $R_2 = \frac{R_1 X_1}{1-X_1}$ where $X_1 = \frac{-X}{1000} + \frac{R_3}{R_3+R_4}$ $R_3 = \frac{R_4 X_2}{1-X_2}$ $R_4 = \frac{R_3(1-X_2)}{X_2}$ where $X_2 = \frac{X}{1000} + \frac{R_2}{R_1+R_2}$
Six Wire Full Bridge[1]  	CRBasic Instruction: `BrFull6W()` Fundamental Relationship: X = result w/mult = 1, offset = 0 $X = 1000\frac{V_2}{V_1} = 1000\left(\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right)$	

Pulse and Frequencies



The data logger includes terminals that are configurable for pulse input as shown in the following image.

Table 6-2: Pulse input terminals and the input types they can measure

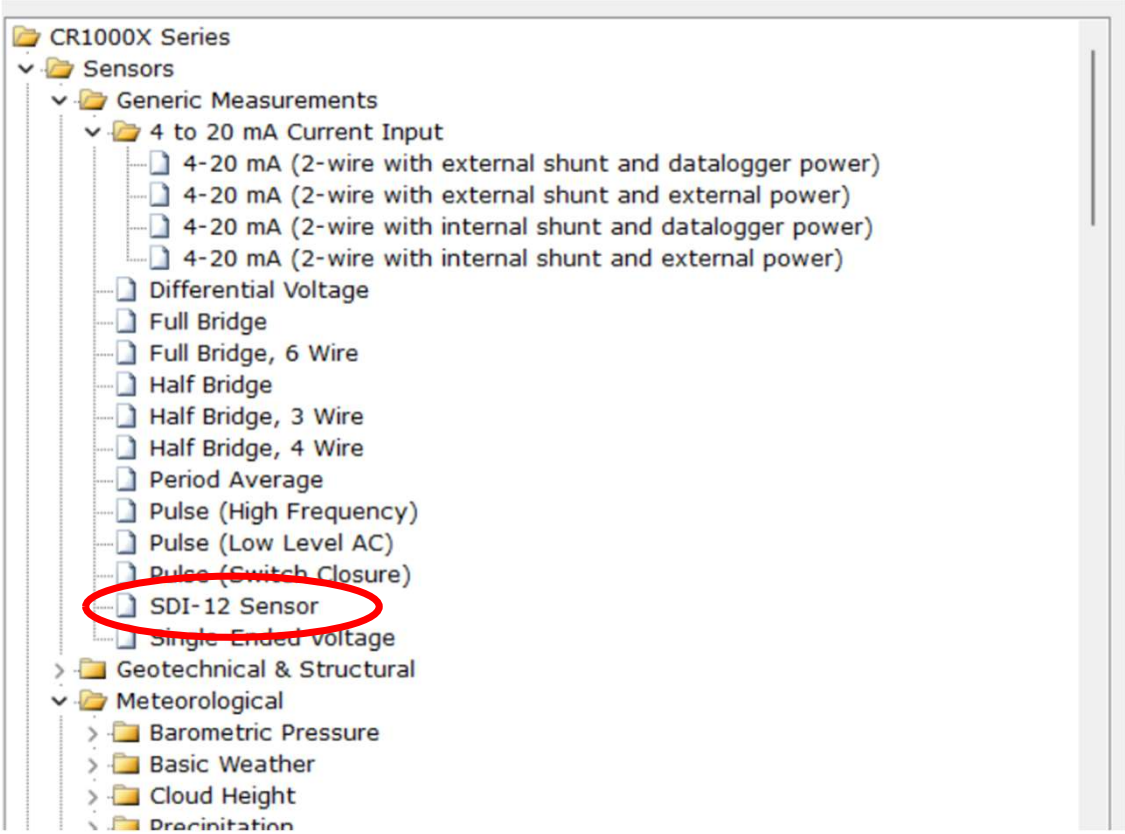
Input Type	Pulse Input Terminal
High-frequency	**P1** **P2** **C** (all)
Low-level AC	**P1** **P2**
Switch-closure	**P1** **P2** **C** (all)

Output signal = series of **voltage waves**.

"The sensor couples its output signal to the measured phenomenon by modulating wave frequency. The data logger detects the state transition as each wave varies between voltage extremes (high-to-low or low-to high). Measurements are processed and presented as counts, frequency, or timing data"

(from manual)

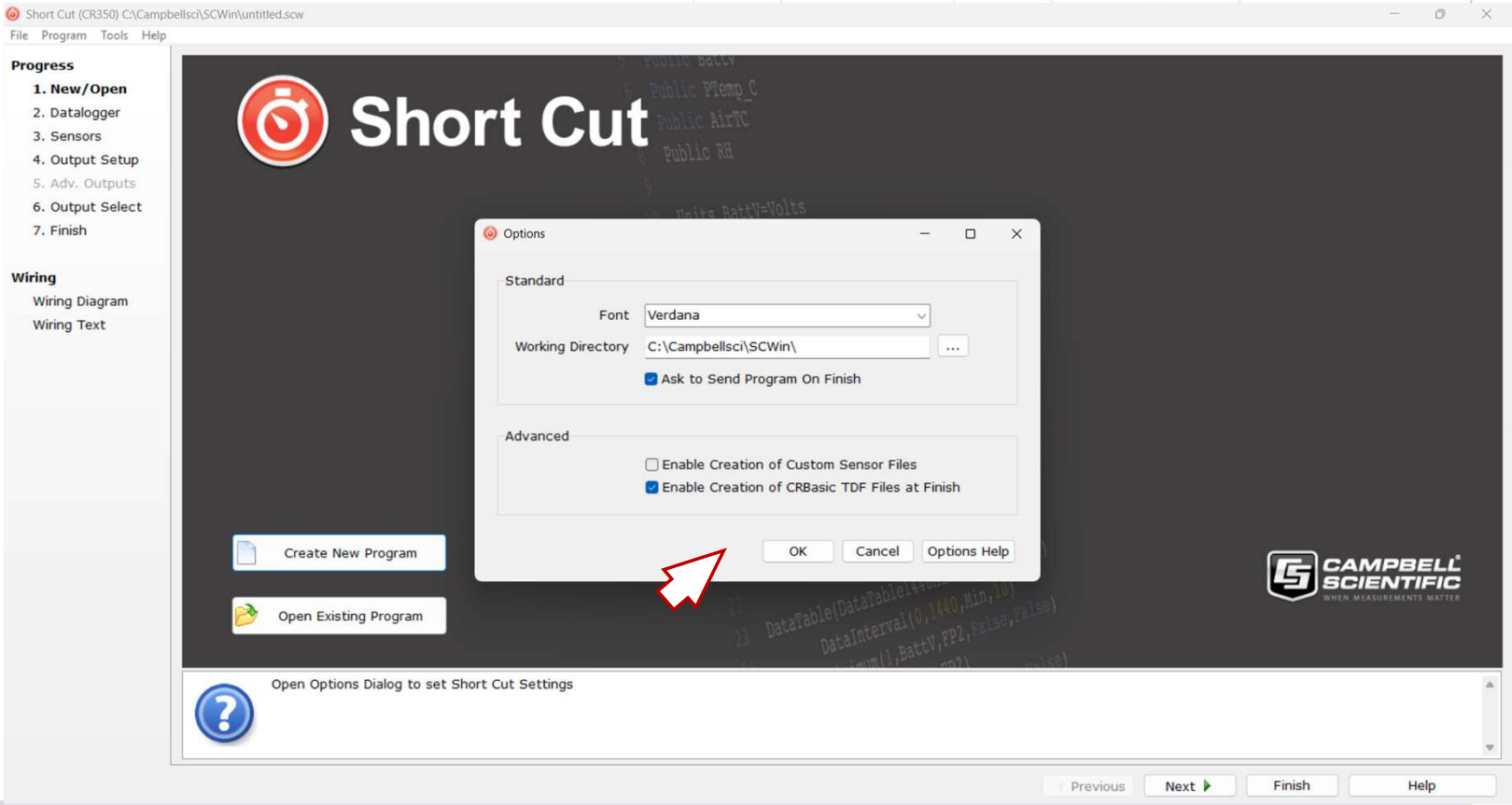
SDI-12



- Standard comm. protocol to transfer measurements taken by an intelligent sensor. Takes a measurement, computations, outputs **in engineering units**. (SDI-12 SG)
- Relatively slow communication (1200 BR)
- Battery powered data recorders with micro-processor-based sensors for environ. data
- Ports C1, C3, C5, and C7. All sensors in the same port → different addresses
- Transparent mode from terminal (DCU, PC400) → config
- Programmed mode (see Sect. 3.6)

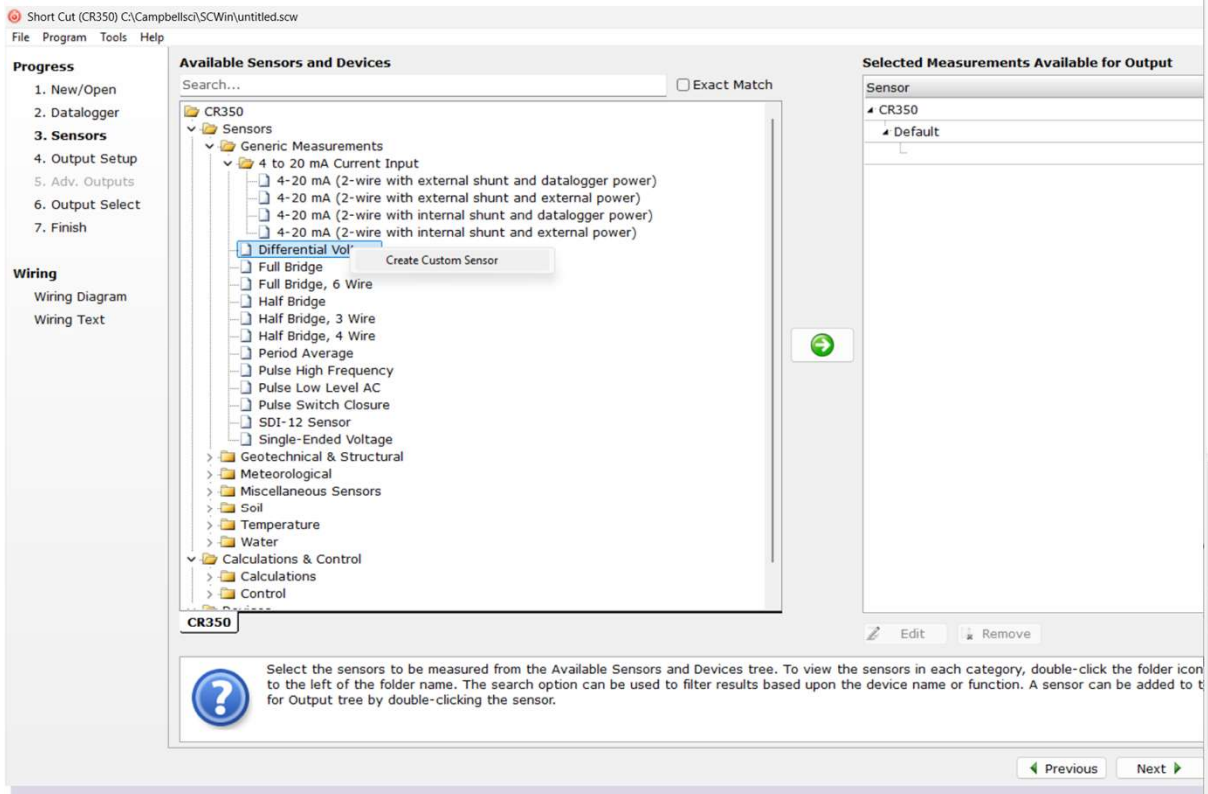
Custom sensors

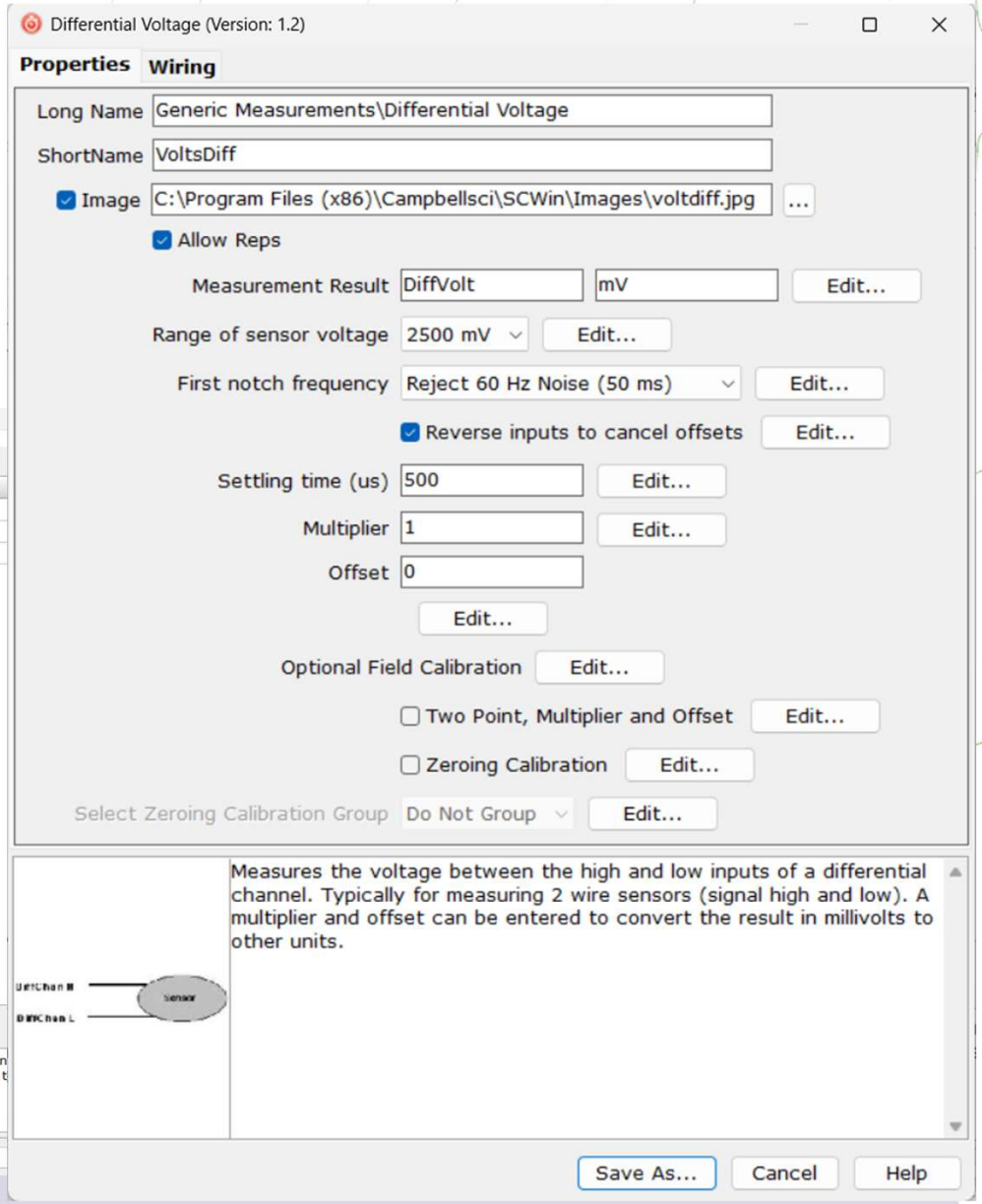
- Can be enabled from Tools→Options…



Custom sensors

- Right-click on one “close” sensor





Sensors for practice

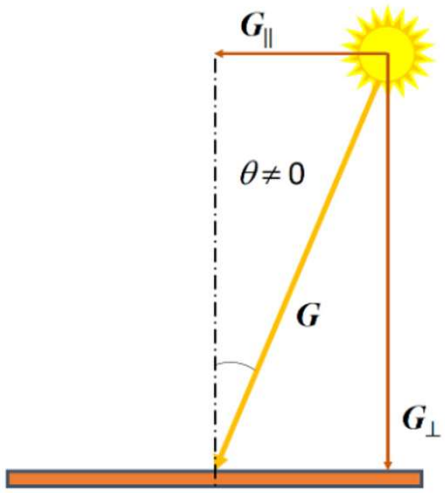
LICOR LI-190R

- Type of measurement: **analogue**
- What it measures: photosynthetic active radiation (**PAR** or **PPFD**)
- Technology: enhanced silicon **photodiode** mounted under a cosine-corrected acrylic diffuser, with a spectral filter (spectral response)
- Output: µA, directly proportional to hemispherical PAR.

Multiplier M to radiation (µmol s-1 m-2).

- 2290 millivolt adapter: known resistance -> mV ->

µmol m-2 s-1



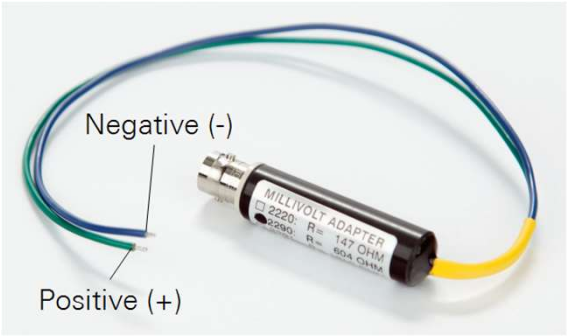
$$G_{\perp} = G\cos(\theta)$$

Figure 3.4: Evaluation of cosine effect on a horizonal surface based on the zenith angle.

Mark Fedkin

https://www.e-education.psu.edu/eme812/node/896

LICOR LI-190R



$$M = -1/(G * C)$$

Multiplier in µmol s^{-1} m^{-2} per mV

Resistance= 0.604 mV μA^{-1}

Calibration constant in µA per 1000 µmol s^{-1} m^{-2}

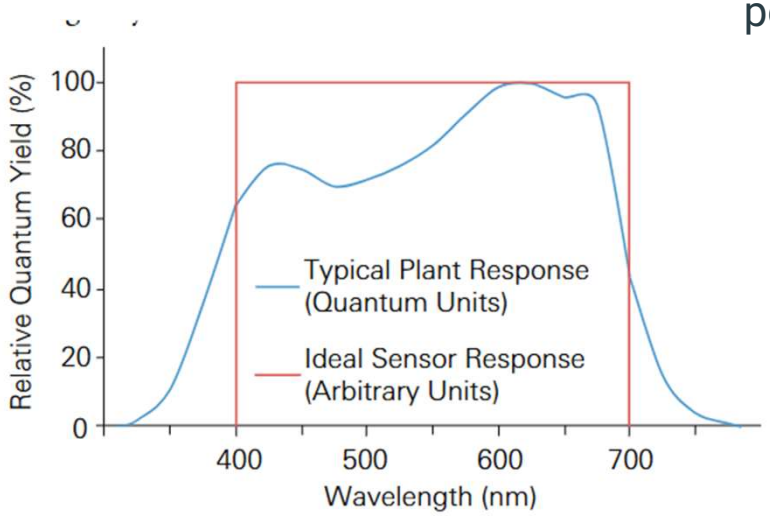
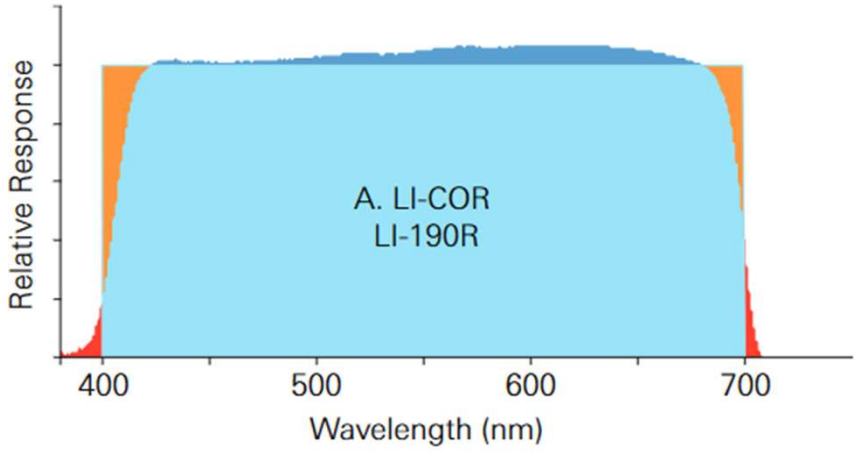


Figure 2. Ideal sensor response and response of a typical plant.

Photosynthetic rates normalized by light intensity in units of absorbed quanta (photons; relative quantum yield) at each wavelength.

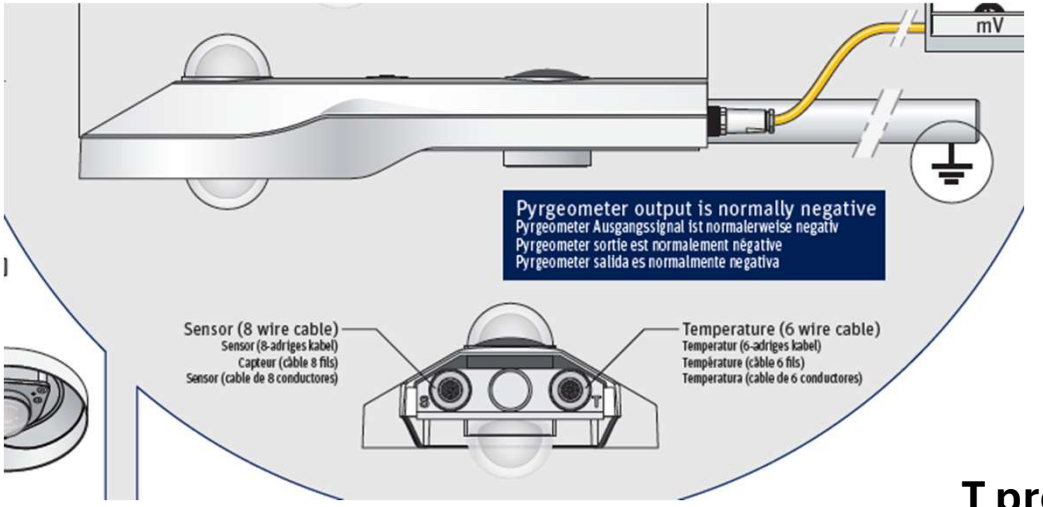


https://www.licor.com/support/LI-190R-and-LI-191R/topics/quantum-general-information.html

Kipp&Zonen CNR4

- Type of measurement: **analogue** (6 sensors – 4 radiometers, 2 temperature sensors)
- What it measures: short-wave and long-wave radiations + Temp.
- Technology: **thermopile** - irradiation is proportional to the difference between the temperature of the sun exposed area and the temperature of the shadow area.
- Output: µV. Sensitivity -> W m-2

Kipp&Zonen CNR4



$$E_{SW} = \frac{U_{emf}}{S} \qquad E_{LW} = \frac{U_{emf}}{S} + 5.67 \cdot 10^{-8} \cdot T_b^{\,4}$$

$U_{emf}\,[\mu V]$ = Output Voltage
Ausgangsspannung • Sortie tension • Voltaje de salida

$S\left[\frac{\mu V}{W/m^2}\right]$ = Sensitivity
Empfindlichkeit • Sensibilité • Sensibilidad

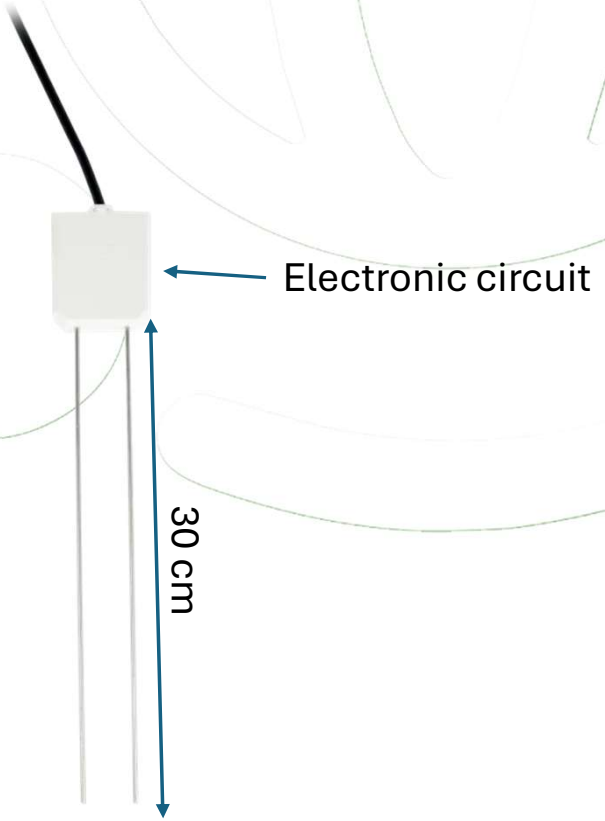
$T_b \quad [K]$ = Temperature
Temperatur • Température • Temperatura

T proportional to Resistance (PT100 or Thermistor)

(from sensor manual)

Campbell Scientific CS616

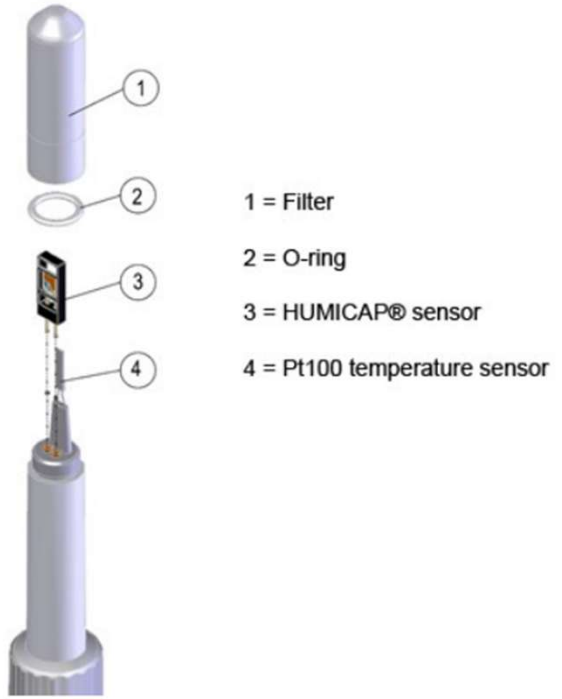
- Type of measurement: **digital** (frequency)
- What it measures: Soil water content (**SWC**)
- Technology: **time-domain** measurement (CS616 generates an electromagnetic pulse. The elapsed travel time and pulse reflection are used to calculate SWC).
- Output: megahertz oscillation frequency -> m3 m-3



(from sensor manual)

VAISALA HMP155A

- Type of measurement: **digital** (RS-485)
- What it measures: **Air temperature and RH**
- Technology: **capacitive** thin film polymer sensor (RH)
  – effect of humidity on the dielectric constant of a polymer. **PRT** (Temp) - platinum wire whose resistance is proportional to temperature
- Output: % and K or °C



(from sensor manual)

Campbell Scientific HygroVUE

- Type of measurement: **digital** (SDI-12)
- What it measures: **Air temperature and RH**
- Technology: single **chip** element
- Output: % and K or °C

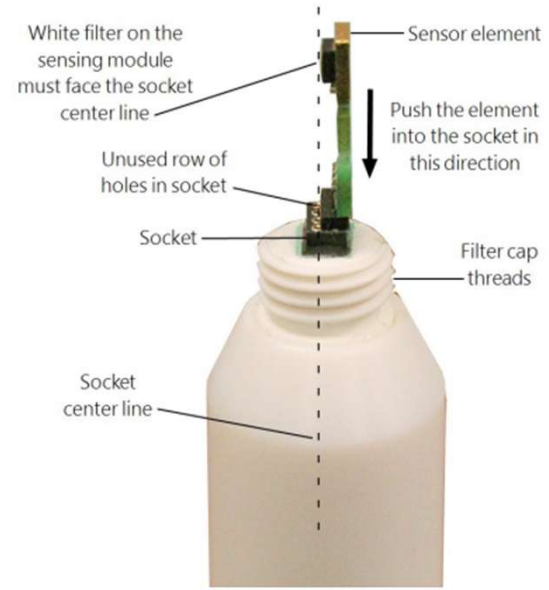


Figure 9-1. Correct fit of the 4-pin sensor element (side view)

(from sensor manual)

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THANKS!

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