Leaf Sensor

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Leaf-&-Air-Temperature
Conifer type (LAT-C)

For measuring needles & local air temperature

User Manual

Version 1.0

1. Introduction

Thank you for purchasing an Ecomatik Leaf Temperature Sensor type LAT-C. The LAT-C sensor is a highly precise sensor for the continuous measurements of leaf and air temperature, under both indoor and outdoor conditions.

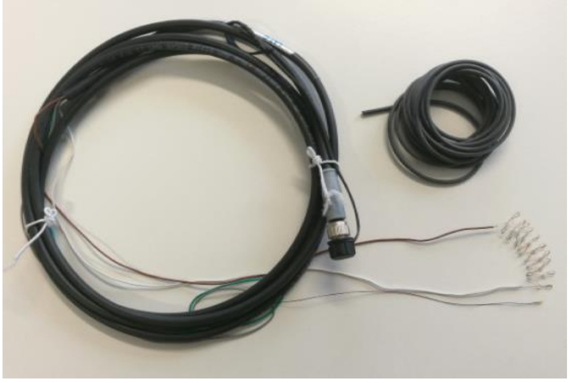
This manual is written to help you install and operate your LAT-C sensor without difficulty and to achieve the most desirable results. Please read it carefully before installing the sensor, and refer back to it if you should have any difficulty with the sensor in the future.

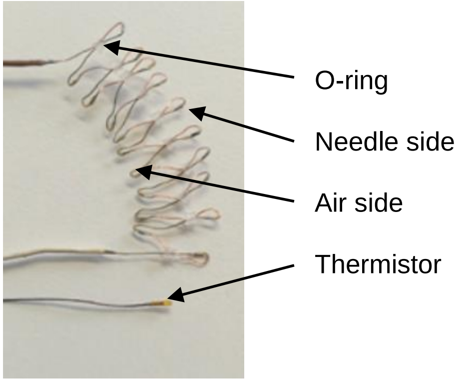
The LAT-C is the sensor part of the measuring system. This means that the LAT-C sensor must be installed onto a leaf of the experimental plant, and connected to a data logger for continuous data recording. The LAT-C sensor is compatible with a range of available data loggers.

2. Product Description

As shown below, a standard version of the LAT-C sensor consists of:

- 1 Sensor with 5 m cable. The cable length can be extended up to max. 50 m.
- 2 m rubber band for fixing and pull relief the sensor cable at the plant.





LAT-C sensor

Please contact us should you miss anything of these items.

The sensor can be ordered in standard configuration or with cable extension:

- Standard: 0.5 m until plug connector + 4.5 m extension cable connected to sensor via a weatherproof 4-pin plug connector.
- Optional extensions instead of the standard 4.5 m extension are 9.5 m, 14.5 m, 19.5 m

3. Safety Information

Important!

To avoid damage to the sensor and to ensure a high degree of measurement accuracy, it is very important to keep the original shape of the thermocouple chain. Please handle it with care and avoid any excessive distortion (turning, bending etc.)

When positioning the sensor please ensure an adequate distance to neighboring branches and objects. The position should be chosen such, that even under windy conditions no objects (e.g. branches, fruits or other plant parts) can hit the sensor. Otherwise, the sensor may get out of place, or can even be damaged.

Never pull the cable from the sensor and avoid any tension between the cable and sensor during handling, set up and operation.

Pay attention to connections to data logger. Wrong connections will provide wrong readings.

4. Installation

4.1 Required tools

A pair of scissors, a pair of edgeless tweezers, cable strips.

4.2 Choosing the measuring position

Depending on the specific research question, the sensor can be installed onto a fully sun exposed needles (to record temperature extremes) or onto several, differently exposed positions within the plant (to record variability and mean leaf temperature within the plant, a number of sensors is necessary).

4.3 Mounting

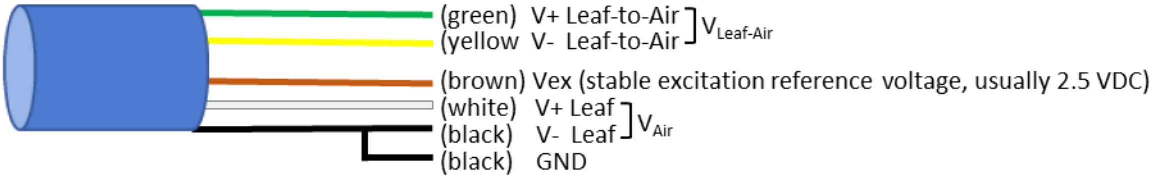
1. First, use the rubber band to fix and pull relief the sensor cable at the plant.
2. The zigzag-formed thermocouple chain of the sensor has two functional sides. One side, which has to be installed on the needles (slings, measuring needle surface temperature) and the other side which has to be just in air contact (measuring air temperature). Single needles have to be inserted into the slings between thermocouple wire and O-ring and tightened carefully via moving the respective O-ring.
3. Before attaching the sensor to the needles, carefully open the slings by gently sliding the O-rings some millimeters towards the air-side of the thermoelement chain.
4. Progressively insert single needles in each of the 10 slings and tighten the sling around the needle, by gently pushing the O-ring towards the needle.
5. Please ensure good thermal contact between each thermoelement sling (solder joints) and its respective needle (otherwise measurement results will be affected). Gaining some practice in advance to the real installation may be helpful, to achieve this satisfactorily without damaging the needles.
6. After tightening all needle slings, gently bend the air-sided thermoelement contacts away from surrounding needles.
7. Place the thermistor in the same position as the air side of the thermocouple chain.
8. Please ensure that there is NO thermal contact between none of the air-sided thermoelement contacts (solder joints) and surrounding needles (otherwise measurement results will be affected).

Please note: In case you need further assistance for installation, please do not hesitate to contact us. Additionally to this short description we will provide you a detailed video documentation of the mounting procedure.

5. Wiring and Logger Configuration

The LAT-B1 sensor is compatible with a range of available data loggers. However note that suitable loggers have to provide the possibility to measure positive and negative electric currents within a range of ± 10 mV, at a measurement resolution of at least 10 bits.

Furthermore, the provision of a precise and stable, switched (sensor should only be powered 100ms before and during measurements) excitation voltage of usually 2500 mV is required. In the following section we describe the connection with the widely used Campbell data logger CR1000. If you use another data logger, contact us in case you need further assistance.



Campbell Data Logger (CR1000)

The LAT-C sensor must be measured in differential voltage mode, measurement range must be set to 7.5 mV. One CR1000 can record 4 LAT-C sensors in differential mode.

Differential Voltage Mode (3 LAT-C sensors)

Connection		
	Cable Color	Input Port
1st LAT-B sensor	Yellow	1H
	Green	1L
	Brown	Vx1
	White	2H
	Black	2L and Signal Ground
2nd LAT-B sensor	Yellow	3H
	Green	3L
	Brown	Vx1
	White	4H
	Black	4L and Signal Ground
3rd LAT-B sensor	Yellow	5H
	Green	5L
	Brown	Vx1
	White	6H
	Black	6L and Signal Ground

Program Syntax (for one sensor)

VoltDiff(DeltaTC,1,mV7_5,1,True,0,_50Hz,2.456,0)
VoltDiff(AirTC,1,mV2500,2,True,0,_50Hz,1,0)
*AirTC=(2500-AirTC)/AirTC*20000*
*AirTC=1/(0,001130756+0,000233897*LN(AirTC)+0,000000088*LN(AriTC)^3)-273.15*

“ DeltaTC = Leaf-to-Air temperature difference in °C
“ AirTC= Air Temperature in °C

6. Data Calculation

According to its two electronic components, thermopile and thermistor, the sensor has two analog output signals:

Thermopile (Leaf-to-Air temperature difference):

Signal ranges within ± 10mV. This range covers temperature differences between the leaf surface and the surrounding air of over ± 20°C. If wired as indicated in section 5., a negative sensor signal indicates a lower, a positive sensor signal a higher leaf surface temperature, as compared to air temperature. Under temperature conditions between -10 and +50°C the factor 2.456 applies to convert the analog output signal from mV into °C:

$\Delta T_{Leaf-Air}$ (°C) = V_{therm}(mV) * 2.456

(**Please note:** if operation temperature largely exceeds the above stated temperature range, contact us to receive the adequate conversion factor)

Thermistor (Air temperature, absolute):

The employed miniature thermistor for absolute measurements of air temperature, is characterized by a very fast response time and a high thermal coefficient. The native analog output signal is resistance, ranging between 130307.6 Ω @ -25°C and 1751.6 Ω @ +70°C. In the standard version the sensor includes a bridge circuit with a 20 kΩ reference resistor, to enable also for voltage measurements. Voltage measurements are supported by most data loggers, whereas resistance measurements are supported only by few data loggers. For the voltage measurement method a precise and stable excitation voltage of usually 2500 mV has to be supplied.

The following function applies to convert back the analog output signal from mV into Ω:
R=(Vex-Vtc)/Vtc*Rref

where:
R: resistance corresponding to the respective mV measurement signal
Vex: excitation Voltage, usually 2500 mV
Vtc: sensor output signal in mV
Rref: reference resistor, with a resistance of 20000 Ω

The following function applies to convert the analog output signal from Ω into °C:
T = 1/(a + b(Ln R) + c(Ln R)^3) (Steinhart-Hart equation)

where:
T: temperature in Kelvin R: resistance at temperature T
a: coefficient = 1.13075635 E-03
b: coefficient = 2.33896902 E-04
c: coefficient = 8.82996895 E-08

7. Adjustment and maintenance

When positioning the sensor please ensure enough distance to neighboring branches such, that even under windy conditions no branches, fruits or other plant parts may hit the sensor.

If the sensor is installed onto a measurement leaf that is still expanding, the installation has to be adjusted progressively until expansion growth has terminated.

When the sensor is correctly installed, it will function under outdoor conditions without the need for further maintenance.

In regions with a pronounced winter season, the sensor should be deinstalled before snow fall.

8. Technical Specifications

Name	**LAT-C : Leaf-&-Air Temperature Sensor, conifer type(*)**
Application position, suitable for leaf size	Needle surface, standard size for needles > 5 mm length
Range of the sensor **- thermopile (ΔTleaf-to-air)** **- thermistor (Tair)**	ΔT = +/- 20°C Tair = -40 to 125°C
Accuracy **- thermopile (ΔTleaf-to-air)** **- thermistor (Tair)**	CR1000: +/-(0.06%*reading+0.01°C) CR1000: +/- 0.2 °C
Resolution **- thermopile (ΔTleaf-to-air)** **- thermistor (Tair)**	Theoretically infinite, depends on data logger. (e.g. CR1000-Logger with 1 µV resolution within a Signal range of +/- 7.5 mV: 0.0025°C) Theoretically infinite, depends on data logger (e.g. CR1000-Logger with 667 µV resolution within a Signal range of +/- 2500mV: 0.1°C)
Sensor weight	< 1 g
Output signal type **- thermopile (ΔTleaf-to-air)** **- thermistor (Tair)**	At a ΔT range of +/- 20°C signal ranges within ± 8.5 mV Supplied with 2500 mV, output signal is 0 to 2500mV
Power supply **- thermopile (ΔTleaf-to-air)** **- thermistor (Tair)**	Not required Excitation voltage Vex usually switched 2500 mV, power up 100ms max. Power consumption negligible.
Operating conditions	Air temperature: -25 to 70 °C, air humidity: 0 to 100%

(*) patent pending