# Leaf Sensor

**ECOMATIK GmbH**
Muenchner Str. 23
D-85221 Dachau/Germany
Tel.: +49 8131 260 738
Fax: +49 8131 260 736
e-mail: info@ecomatik.de
website: www.ecomatik.de

## Leaf-&-Air-Temperature
## Broadleaf type (LAT-B3)

For measuring leaf & local air temperature

User Manual

**Version 2022**

# 1. Introduction

Thank you for purchasing the Ecomatik Leaf Temperature Sensor type LAT-B3. The LAT-B3 sensor is a highly precise two-probe-sensor for the continuous measurements of leaf and air temperature. Sensor-individual matching of the two probes, ensures high precision measurements of leaf ($T_{Leaf}$), air ($T_{Air}$) and the difference of leaf-to-air temperature ($\Delta T_{Leaf-Air}$). The sensor is designed for both, indoor and outdoor conditions.

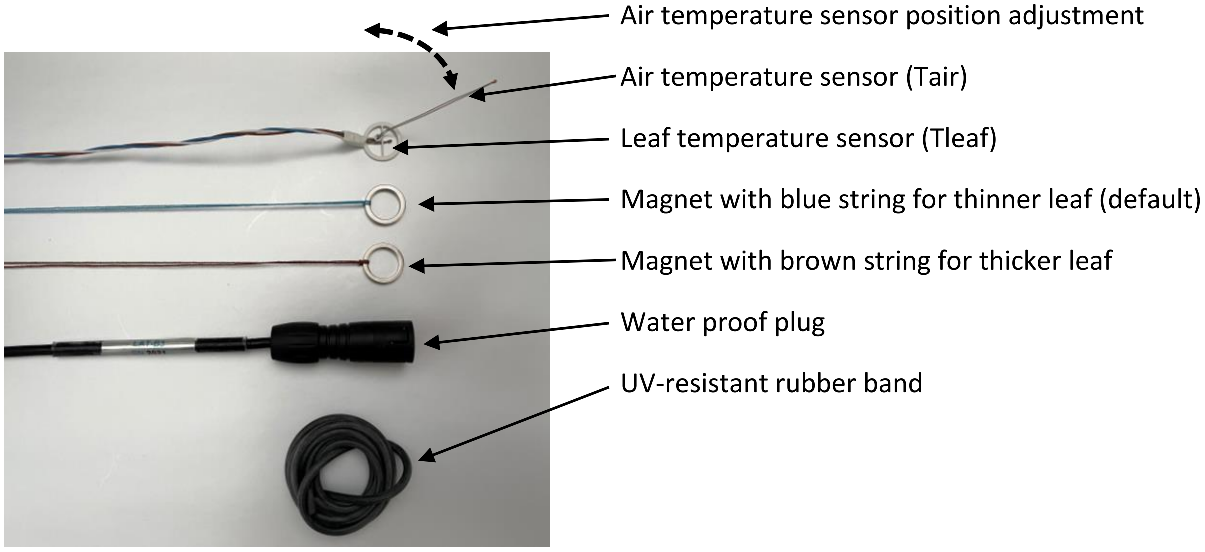
This manual is written to help you install and operate your LAT-B3 sensor without difficulty and to achieve the most desirable results. Please read it carefully before installing the sensor, and refer back to it if you should have any difficulty with the sensor in the future.

The LAT-B3 is the sensor part of the measuring system. This means that the LAT-B3 sensor must be installed onto a leaf of the experimental plant, and connected to a data logger or IoP Interface for continuous data recording. The LAT-B3 sensor is compatible with a range of available data loggers and ECOMATIK Multi-Interface and the IoP LoRa node.

# 2. Product Description

As shown below, a standard version of the LAT-B3 sensor consists of:

- 1x Sensor with pluggable 5 m cable. The cable length can be extended up to max. 50 m.
- 2x ring magnets for fixing the sensor on the leaf
- 1x Pieces UV-resistant rubber band (50cm, reusable) to fix the sensor cable at the branch/stem for strain relief.




**LAT-B3 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 e.g. 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 sensor. Please handle it with care and only touch the sensor by the small handle at the side of the sensor cable. 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 for sensor installation on the leaf

- none -

## 4.2 Choosing the measuring leaf

Depending on the specific research question, the sensor can be installed onto a fully sun exposed leaf (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. Use the rubber band to fix and pull relief the sensor cable at the plant.
2. Installation of the sensor with the temperature probes on the upper leaf surface is recommend. This way both temperature probes (leaf surface and surrounding air) are sun exposed, avoiding an artificial temperature offset, due to an unequal direct insolation of the two sensor parts.
3. The sensor is supplied with two ring magnets with different magnetic strengths (on the blue thread: normal magnetic force for thin and normal leaves; on the brown thread: strong magnetic force for thick leaves). By default, the sensor is equipped with the magnet with normal magnetic force.

   First, use the standard attached, standard strength magnet on the blue string for installation.
4. Place the sensor carefully at the measuring point on the leaf, at the same time place the magnetic ring on the opposite side.

   Gently position the sensor to avoid damaging the leaf and make **absolutely sure that the sensor and magnet are exactly opposite to each other.**
5. To verify that the sensor is firmly attached to the leaf, shake the instrumented blade as hard as you would expect under the prevailing environmental conditions (e.g. wind).

If the sensor stays in place, the magnet strength is sufficient and suitable for the thickness of the instrumented blade. If the sensor moves or falls off, the stronger magnet ring with the brown string has to be used. Please exchange the magnet rings as illustrated here.

6. Move the rearmost O-ring at the cable side of the sensor towards the edge of leaf, so that the string does not hang.
7. Gently pull the air temperature sensor up to the position where you want to measure the air temperature.

**You need further assistance?**

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-B3 sensor is compatible with our DL 18 data logger, as well as with a wide range of other available data loggers. However, note that suitable loggers have to provide a precise and stable, switched (sensor should only be powered 100ms before and during measurements) excitation voltage ($V_{ex}$) of usually 2500 mV. Furthermore, a measurement resolution within the signal range of 0 – $V_{ex}$ (e.g. 2500 mV) of at least 10 bits (resolution of <0.2 °C within the temperature range of -20 to +50°C), recommended are 12 bits (resolution of <0.05 °C). The sensor can be connected either in differential (wiring diagram a), or in single-ended (wiring diagram b) mode.

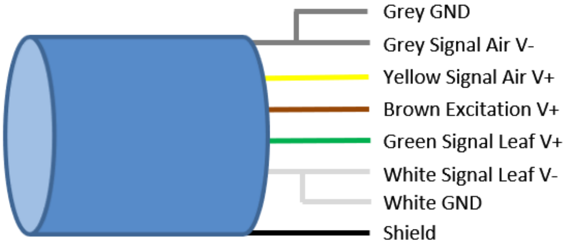



**Figure A: Differential wiring**

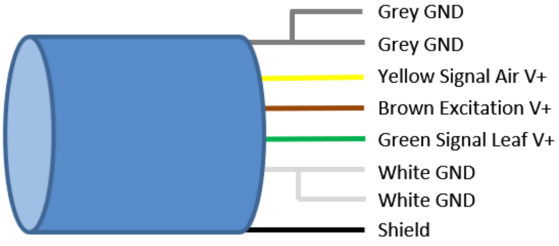



**Figure B: Single-ended wiring**

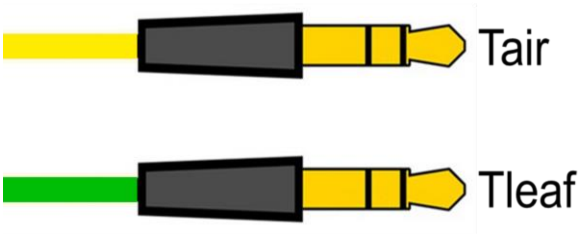



**Figure C: Stereo plug connector for DL 18 logger**

## Wiring Examples:

## Campbell Data Logger (CR1000)

This section describes how to connect the LAT-B3 sensor to the widely used Campbell data logger CR1000. If you use another data logger, contact us in case you need further assistance. The LAT-B3 sensor can be measured in differential voltage as well as in single-ended voltage mode, measurement range must be set to 2500 mV. One CR1000 can record 4 LAT-B3 sensors in differential mode, or 8 LAT-B3 sensors in single-ended mode.

### Differential Voltage Mode (2 LAT-B3 sensors)

| **Connection** | | | |
|---|---|---|---|
| Cable Color | | | Input Port |
| 1st LAT-B3 sensor | Vair | Brown | Vx1 |
| | | Yellow | 1H |
| | | Grey | 1L and Signal Ground |
| | Vleaf | Brown | Vx1 |
| | | Green | 2H |
| | | White | 2L and Signal Ground |
| 2nd LAT-B3 sensor | Vair | Brown | Vx1 |
| | | Yellow | 3H |
| | | Grey | 3L and Signal Ground |
| | Vleaf | Brown | Vx1 |
| | | Green | 4H |
| | | White | 4L and Signal Ground |

**Program Syntax (exemplifying for one sensor, including conversion of raw signal in °C)**

```
VoltDiff(T_Air(),4,mV2500,1,True,0,_50Hz,1,0)
T_Air()=(2500-T_Air())/T_Air()*20000
T_Air()=1/(0.00084906823733471+0.00026092929546095 *LN(T_Air())+0,00000013016564067
*LN(T_Air())^3)-273.15

T-Air1=T_Air(1)
T-Leaf1=T_Air(2)

T-Air2=T_Air(3)
T-Leaf2=T_Air(4)
```

### Single-ended Voltage Mode (2 LAT-B3 Sensors)

| **Connection** | | | |
|---|---|---|---|
| Cable Color | | | Input Port |
| 1st LAT-B3 sensor | Vair | Brown | Vx1 |
| | | Yellow | 1H |
| | | Grey | Signal Ground |
| | Vleaf | Brown | Vx1 |
| | | Green | 1L |
| | | White | Signal Ground |
| 2nd LAT-B3 sensor | Vair | Brown | Vx1 |
| | | Yellow | 2H |
| | | Grey | Signal Ground |
| | Vleaf | Brown | Vx1 |
| | | Green | 2L |
| | | White | Signal Ground |

**Program Syntax (exemplifying for one sensor, including conversion of raw signal in °C)**

```
VoltSe(T_Air(),4,mV2500,1,True,0,_50Hz,1,0)
T_Air()=(2500-T_Air())/T_Air()*20000
T_Air()=1/(0.00084906823733471+0.00026092929546095 *LN(T_Air())+0.00000013016564067
*LN(T_Air())^3)-273.15

T-Air1=T_Air(1)
T-Leaf1=T_Air(2)

T-Air2=T_Air(3)
T-Leaf2=T_Air(4)
```

### DL 18 data logger

Ordered with stereo plug connector, the LAT-B3 is compatible with our DL 18 data logger. Each of the two sensor parts requires one of the four channels and up to two LAT-B3 sensors can be connected to one DL 18 logger. The plug connector of the air sided temperature probe is marked blue and it is recommended to use odd-numbered channels for air, even-numbered channels for leaf temperature. For further information on DL 18 configuration for LAT-B3 sensors, please refer to our DL18 manual.

Configured correctly, sensor signals will be stored in V. Values in °C can be calculated from stored measurement values as described in the following section (Excel program for data calculation available on request).

## 6. Manual Data Calculation

In case that the used logger does not support complex conversion procedures of the raw measurement values, stored values have to be converted manually after data download from the logger (e.g. Dl 18 logger). According to its two temperature sensors (micro thermistors, NTC) the LAT_B3 has two analog output signals. The employed miniature NTCs for absolute measurements of leaf and air temperature, are characterized by a very fast response time and a high thermal coefficient. The native analog output signal is resistance ($R_{ntc}$), ranging between 93.246 kΩ @ -25°C and 2.182 kΩ @ +70°C. In the standard version the head of the sensor cable includes two inbuild bridge circuits with 20 kΩ reference resistors ($R_{ref}$), 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, switched excitation voltage of usually 2.5 V has to be supplied.

**Leaf and Air temperature, absolute:**

The following function applies for both, leaf- and air-sided thermistor, to convert back their analog output signal from V into Ω:

$R_{ntc}=(V_{ex}-V_{out})/V_{out}*R_{ref}$

where:

$R_{ntc}$: NTC resistance in Ω corresponding to the respective mV measurement signal

$V_{ex}$: excitation Voltage in V (e.g. for DL 18 logger $V_{ex}$ = 2.5 V)

$V_{out}$: measured sensor output signal in V, ranging between 0 and $V_{ex}$

$R_{ref}$: reference resistor in Ω, with a resistance of 20000 Ω

The following function applies to convert the analog output signal of both, leaf- and air-sided thermistor, from Ω into °C:

$T (°C)= 1/(a + b(Ln R_{ntc}) + c(Ln R_{ntc})^3)-273.15$ (Steinhart-Hart equation)

where:

T: temperature in °C R: NTC resistance in Ω at temperature T

a: coefficient = 8.4906823733471 E-04

b: coefficient = 2.6092929546095 E-04

c: coefficient = 1.3016564067 E-07

**Leaf-to-Air temperature difference:**

Leaf-to-Air temperature can be easily calculated via:

$\Delta T_{Leaf-Air}$ (°C) = $T_{Leaf}$ (°C) - $T_{Air}$ (°C)

Calculated as indicated, a negative $\Delta T_{Leaf-Air}$ signal indicates a lower, a positive signal a higher leaf surface temperature, as compared to air temperature.

## 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.

On deciduous species, the sensor should be deinstalled before leaf fall, to avoid damage of the sensor. The same applies in regions with a pronounced winter season, where the sensor should be deinstalled before snow fall.

## 8. Technical Specifications

| Name | LAT-B3 : Leaf-&-Air Temperature Sensor, broadleaf type |
|---|---|
| **Application positioning**<br><br>**Suitable leaf size and thickness** | Mounting position: Leaf surface<br>Dual-probe spacing: User-configurable distance between $T_{leaf}$ and $T_{air}$ probes max. 35 mm<br>Standard sensor size for leaves of:<br>Length > 1.4 cm<br>Width > 0.8 cm<br>Stable magnet-mounting possible for leaf thickness < 0.7 mm |
| **Measurement range** | -25 to + 70°C |
| **Accuracy** | Sensor dependent:<br>Tolerance of Absolute Tair & Tleaf:<br>± 0.4 °C in temperature range between +5°C to+40°C<br>± 0.8 °C in temperature range between -25°C to+70°C<br>Tolerance of leaf-to-air temperature difference (∆Tleaf-air):<br>± 0.2° in temperature range between -25°C to+70°C<br><br>Logger dependent, @ 25 °C:<br>e.g. CR300 series: ± 0.01 °C<br>e.g. DL18 Logger: ± 0.03 °C |
| **Resolution** | Logger dependent, @ 25 °C:<br>e.g. CR300 series: 0.25 * $10^{-4}$ °C<br>e.g. DL18 Logger: 0.35 * $10^{-3}$ °C |
| **Size and weight** | Diameter 12 mm, weight ca. 0.9 g |
| **Output signal type** | Supplied with 2500 mV, output signal is between 0 to 2500mV |
| **Power supply** | Excitation voltage Vex usually switched 2500 mV, power up 100ms max.<br>Power consumption negligible. |
| **Operating conditions** | Air temperature: -25 to 70 °C, air humidity: 0 to 100% |
| **Cable length** | 0.5m + 4.5m plug-in extension, plug-in extension up to max. 50 m possible |