

Operating manual

Pyrgeometer **LPPIRG01**



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1 INTRODUCTION

LPPIRG01 pyrgeometer measures the far infrared radiation (FIR). The measures are referred to radiations with wavelength greater than 4.5 μm .

The far infrared radiation derives from the measure of the thermopile output signal and from the knowledge of the instrument temperature. The temperature is measured with a 10 k Ω NTC inserted in the body of the pyrgeometer.

The pyrgeometer can be used also for energy balance studies. In this case, besides another pyrgeometer which measures infrared radiation upwards, it is necessary an albedometer (LPPYRA05, LPPYRA06 or LPPYRA11) for measuring the short wavelengths radiation ($<3 \mu\text{m}$).

The pyrgeometer is available in the following versions:

- **LPPIRG01:** Passive
- **LPPIRG01S:** With RS485 Modbus-RTU output.

The pyrgeometer is supplied factory calibrated and with a calibration report. The calibration is carried out outdoors, for comparison with a reference standard pyrgeometer calibrated at WRC (World Radiation Center). The two instruments are kept outdoors for at least one night in the presence of clear sky. The data acquired by a data logger are then processed to obtain the calibration factor.

2 WORKING PRINCIPLE

LPPIRG01 pyrgeometer is based on a thermopile sensor. The thermopile sensitive surface is coated with a black matt paint, which allows the pyrgeometer not to be selective at different wavelengths.

The sensor is covered by a silicon window that has two basic purposes:

1. protect the thermopile from bad weather;
2. determine the instrument spectral range: silicon is transparent to wavelengths longer than 1.1 μm , therefore on the inside of the window there is a filter to block radiation up to 4.5 - 5 μm . The silicon external surface, which is exposed to weather agents, has a scratch-resistant coating (DLC) to ensure strength and durability in all weather conditions. The scratch-resistant coating offers the advantage of cleaning the surface without the risk of scratching the window. The transmission of the silicon window as the wavelength varies is shown in figure 2.1.

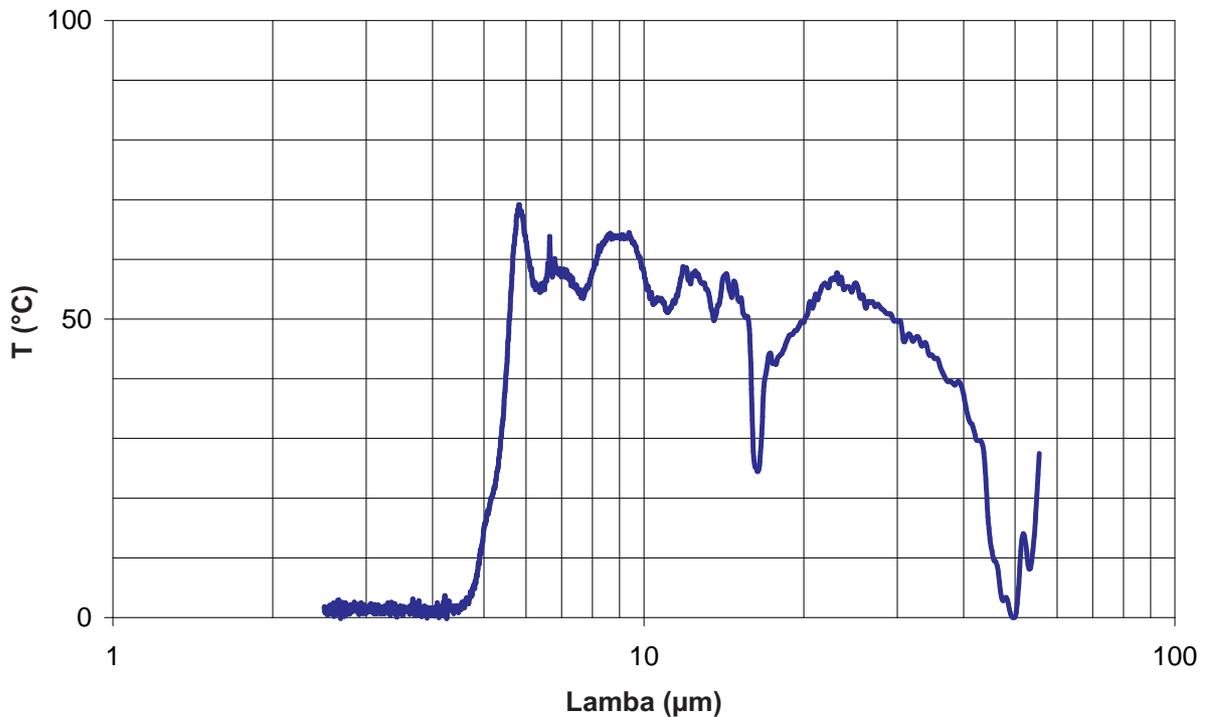


Fig. 2.1: Transmission of the silicon window

Radiant energy is absorbed/radiated by the thermopile black surface, thus creating a difference of temperature between the center of the thermopile (hot junction) and the pyrgeometer body (cold junction). Thanks to the Seebeck effect, the difference of temperature between hot and cold junction is converted into a Difference of Potential.

If the pyrgeometer temperature is higher than the radiant temperature of the portion of sky framed by the pyrgeometer, the thermopile will irradiate energy and the output signal will be negative (typical situation of clear sky); vice versa, if the pyrgeometer temperature is lower than that portion of sky framed, the signal will be positive (typical situation of cloudy sky).

Therefore, for the calculation of infrared radiation at ground level ($E_{\text{FIR}} \downarrow$), besides the thermopile output signal, it is necessary to know the temperature of the pyrgeometer, as shown in formula 1:

$$E_{\text{FIR} \downarrow} = E_{\text{term}} + \sigma T_{\text{B}}^4 \quad (1)$$

Where:

E_{term} = net radiation (positive or negative) measured by the thermopile (W m^{-2});

σ = Stefan-Boltzmann constant ($5.6704 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$);

T_{B} = pyrgeometer temperature (K), obtained by the reading of the NTC resistance (see table 5.1).

E_{term} is calculated from the sensitivity of the instrument C [$\mu\text{V}/(\text{W m}^{-2})$] and from the output signal U_{emf} according to formula 2:

$$E_{\text{term}} = U_{\text{emf}} / C \quad (2)$$

The first term of formula 1 represents the net radiation, that is to say the difference between ground infrared radiation and the pyrgeometer emission, while the second term is the radiation emitted by an object (assuming emissivity $\epsilon=1$) at temperature T_{B} .

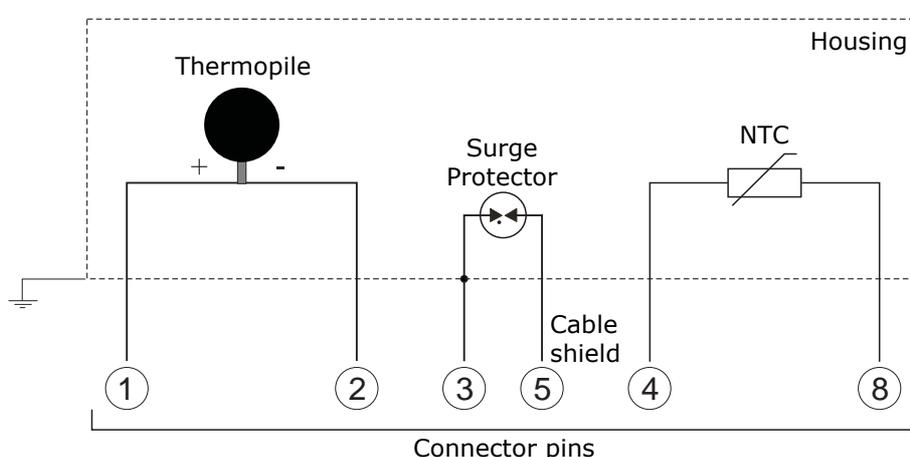


Fig. 2.2: scheme of principle LPPIRG01 (version with mV output)

To prevent internal condensation forming on the internal side of the window under certain climatic conditions, silica gel tablets are inserted inside the pyrgeometer to absorb humidity.

3 INSTALLATION

Before installing the pyrgeometer, refill the cartridge containing silica-gel crystals. Silica-gel absorbs humidity inside the instrument and prevents, in particular climatic conditions, condensation on the internal surface of the silicon window and measurement alteration.

Do not touch the silica gel crystals with your hands while refilling the cartridge. Carry out the following instructions in an environment as drier as possible:

1. Loosen the three screws that fix the white shade disk.
2. Unscrew the silica gel cartridge using a coin.
3. Remove the cartridge perforated cap.
4. Open the sachet containing silica gel (supplied with the pyrgeometer).
5. Fill the cartridge with the silica gel crystals.
6. Close the cartridge with its own cap, paying attention that the sealing O-ring be properly positioned.
7. Screw the cartridge to the pyrgeometer body using a coin.
8. Check that the cartridge is screwed tightly (if not, silica gel life will be reduced).
9. Position the shade disk and screw it with the screws.
10. The pyrgeometer is ready for use.

The figure below shows the operations necessary to fill the cartridge with the silica gel crystals.

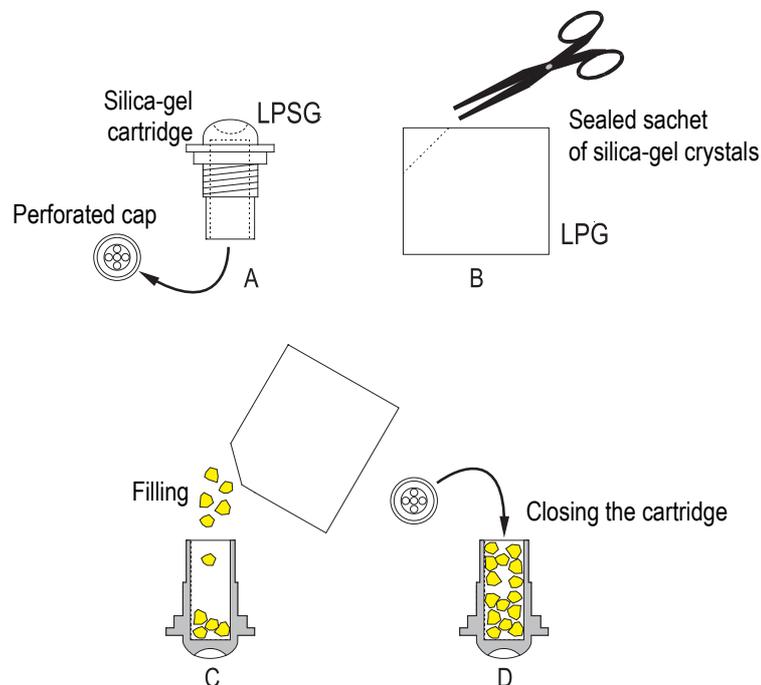


Fig. 3.1: filling the silica-gel cartridge

- The pyrgometer must be mounted in an easy-to-reach location in order to clean the silicon window regularly. At the same time, make sure that no buildings, constructions, trees or obstructions exceed the horizontal plane where the pyrgometer lies. If this is not possible, select a site where obstructions do not exceed 10°.
- In compliance with ISO TR9901 standard and WMO recommendations, when the pyrgometer is used without the white shade disk, it must be positioned so that its connector is pointed to the North Pole, if the instrument is used in the Northern Hemisphere, and to the South Pole, if used in the Southern Hemisphere. In any case, it is better to follow this suggestion even when the shade disk is applied.
- For fixing, use the holes on the pyrgometer body (remove the shade disk to access the holes and reposition it after mounting) or the suitable accessories (see the figures below). In order to allow an accurate horizontal positioning, the pyrgometer is equipped with a levelling device: the adjustment is made by means of the two levelling screws that allow adjusting the pyrgometer inclination.
- It is preferably to thermally insulate the pyrgometer from its mounting bracket ensuring, at the same time, a good electrical contact to ground.

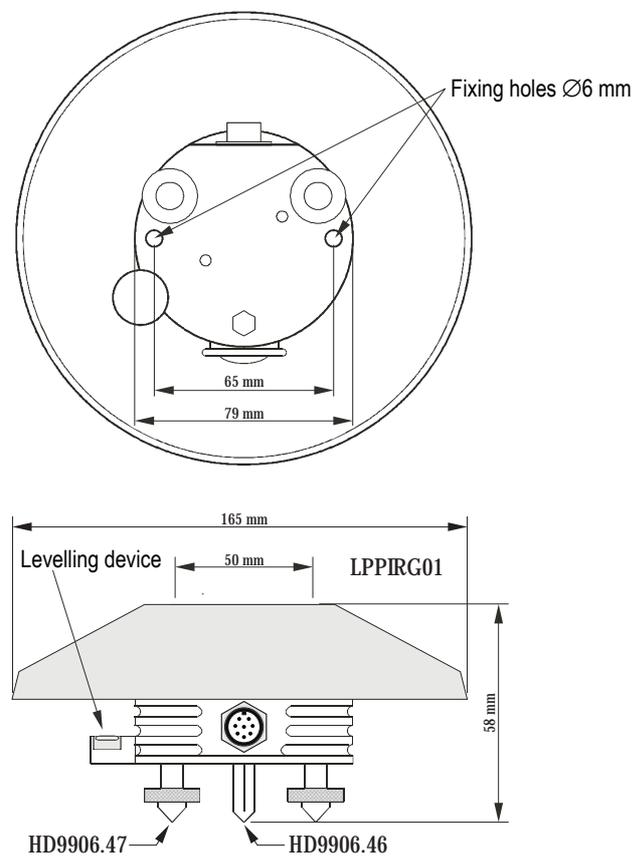


Fig. 3.2: fixing holes and levelling device

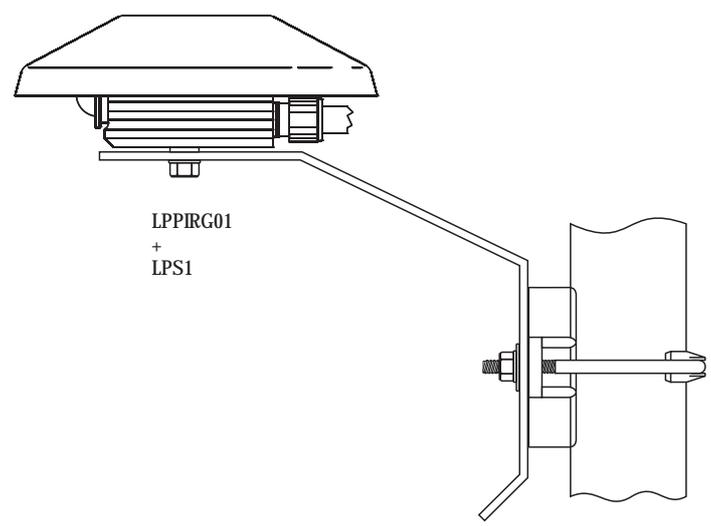
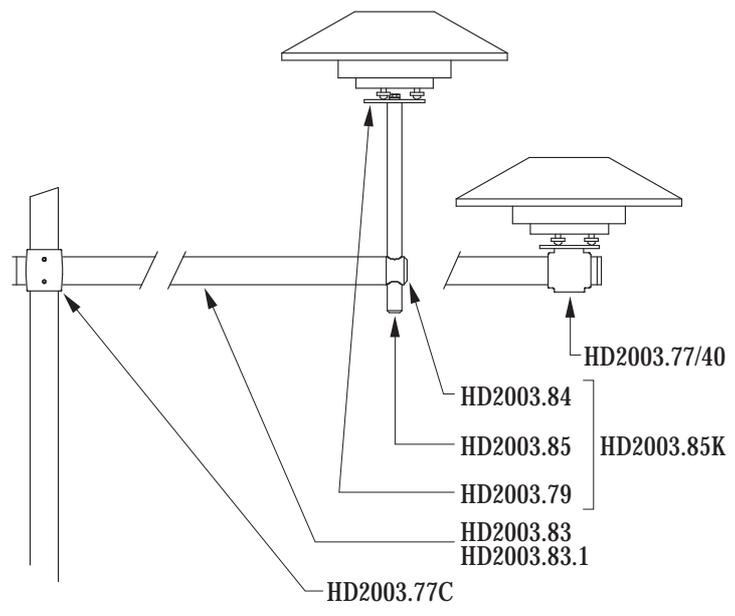


Fig. 3.3: fixing accessories

4 ELECTRICAL CONNECTIONS

The pyrgeometer has a 8-pole connector and uses the **CPM12AA8PG...** (LPPIRG01) or **CPM12-8D...** (LPPIRG01S) **optional** cables in UV resistant PTFE, with 8-pole connector on one side and open wires on the other side.



The metallic housing of the pyrgeometer should preferably be grounded (\pm) locally. In this case, do not connect the wire of the cable corresponding to the housing to prevent ground loops.

Only if it is not possible to ground locally the metallic case of the pyrgeometer, connect the wire of the cable corresponding to the housing to ground (\pm).

The wire of the cable corresponding to the housing depends on the model: white wire in LPPIRG01 and black wire (cable shield) in LPPIRG01S.

4.1 LPPIRG01 CONNECTIONS

The pyrgeometer LPPIRG01 is passive and does not require power supply. It is to be connected either to a millivoltmeter or to a data acquisition system. Typically, the pyrgeometer output signal absolute value does not exceed 4 mV. In order to better exploit the pyrgeometer features, the readout instrument should have 1 μ V resolution.

To determine the pyrgeometer temperature, the NTC resistance must be read.

Connector	Function	Color
1	Vout (+)	Red
2	Vout (-)	Blue
3	Housing	White
4	NTC	Green
5	Cable shield	Brown
6	Not connected	
7	Not connected	
8	NTC	Black

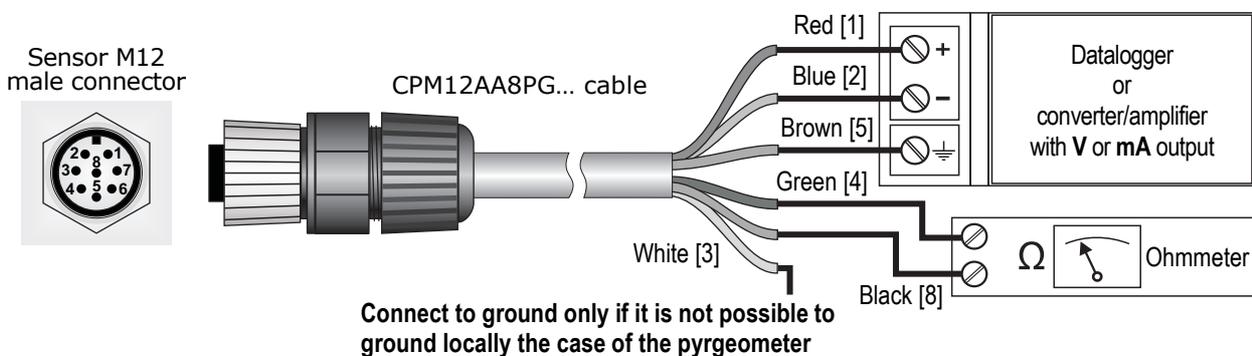


Fig. 4.1: LPPIRG01connections

4.2 LPPIRG01S CONNECTIONS

The pyrgometer LPPIRG01S has **RS485 Modbus-RTU** output and requires **5...30 Vdc** external power supply. It is to be connected to a power supply and to a PLC, a data logger or a RS485/USB or RS485/RS232 converter for PC as shown in fig. 4.2. The RS485 output is not isolated.

Connector	Function	Color
1	Power supply negative (GND)	Blue
2	Power supply positive (+Vdc)	Red
3	Not connected	
4	RS485 A/-	Brown
5	RS485 B/+	White
6	Housing	Shield (Black)
7	Not connected	
8	Not connected	

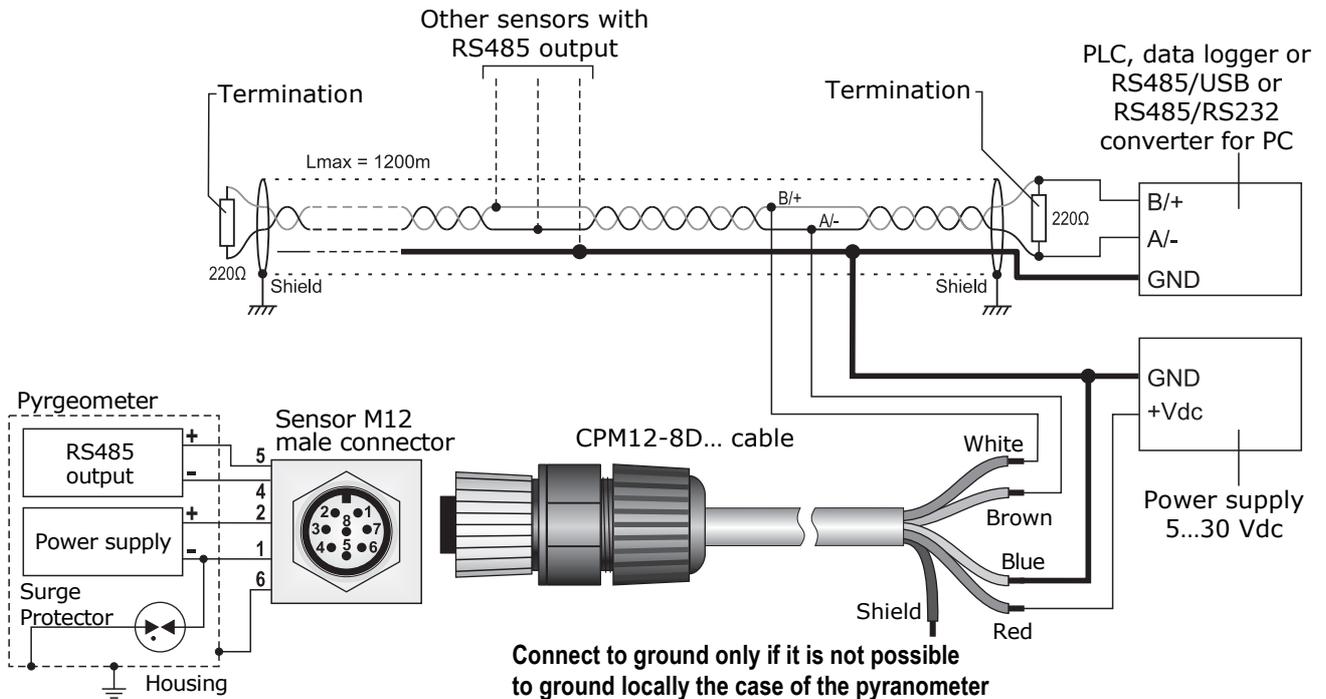


Fig. 4.2: LPPIRG01S connections

Before connecting the pyrgometer to the RS485 network, set the address and the communication parameters, if different from the factory preset (see chapter 6).

5 MEASUREMENT IN THE MODEL WITH ANALOG OUTPUT

Measure the NTC resistance R_{NTC} (Ω) and calculate the pyrometer temperature T_B (K) by using the formula 3:

$$\frac{1}{T_B} = a + b \log(R_{NTC}) + c \log(R_{NTC})^3 \quad (3)$$

Where:

$$a = 10297.2 \times 10^{-7}$$

$$b = 2390.6 \times 10^{-7}$$

$$c = 1.5677 \times 10^{-7}$$

The temperature is expressed in Kelvin.

Table 5.1 indicates the correspondence between T_B and R_{NTC} for temperature values between -25 °C and +58 °C. To obtain the temperature value in Kelvin, add 273.15 to the temperature value in degrees Celsius in the table.

TAB. Errore. L'origine riferimento non è stata trovata..1: **correspondence between pyrometer temperature and NTC resistance**

T_B (°C)	R_{NTC} (Ω)	T_B (°C)	R_{NTC} (Ω)	T_B (°C)	R_{NTC} (Ω)
-25	103700	3	25740	31	7880
-24	98240	4	24590	32	7579
-23	93110	5	23500	33	7291
-22	88280	6	22470	34	7016
-21	83730	7	21480	35	6752
-20	79440	8	20550	36	6499
-19	75390	9	19660	37	6258
-18	71580	10	18810	38	6026
-17	67970	11	18000	39	5804
-16	64570	12	17240	40	5592
-15	61360	13	16500	41	5388
-14	58320	14	15810	42	5193
-13	55450	15	15150	43	5006
-12	52740	16	14520	44	4827
-11	50180	17	13910	45	4655
-10	47750	18	13340	46	4489
-9	45460	19	12790	47	4331
-8	43290	20	12270	48	4179
-7	41230	21	11770	49	4033
-6	39290	22	11300	50	3893
-5	37440	23	10850	51	3758
-4	35690	24	10410	52	3629
-3	34040	25	10000	53	3505
-2	32470	26	9605	54	3386
-1	30980	27	9228	55	3386
0	29560	28	8868	56	3271
1	28220	29	8524	57	3161
2	26950	30	8195	58	3055

Once the pyrgeometer temperature T_B in Kelvin and the thermopile output signal U_{emf} in μV (measured with a multimeter) are known, irradiation $E_{FIR} \downarrow$ ($W m^{-2}$) is obtained from the formula 4:

$$E_{FIR} \downarrow = \frac{U_{emf}}{C} + \sigma T_B^4 \quad (4)$$

Where:

σ = Stefan-Boltzmann constant ($5.6704 \times 10^{-8} W m^{-2} K^{-4}$);

T_B = sensitivity of the instrument expressed in $\mu V/(Wm^{-2})$ and shown in the label on the pyrgeometer (and in the calibration report).

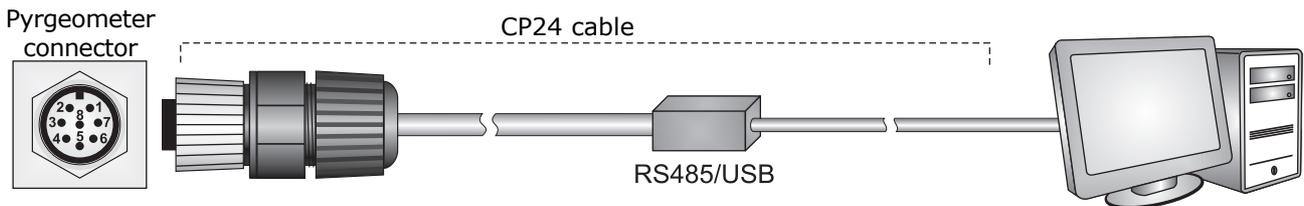
6 RS485 MODBUS-RTU OUTPUT

Before connecting the pyrgeometer to the RS485 network, an address must be assigned and the communication parameters must be set, if different from the factory preset.

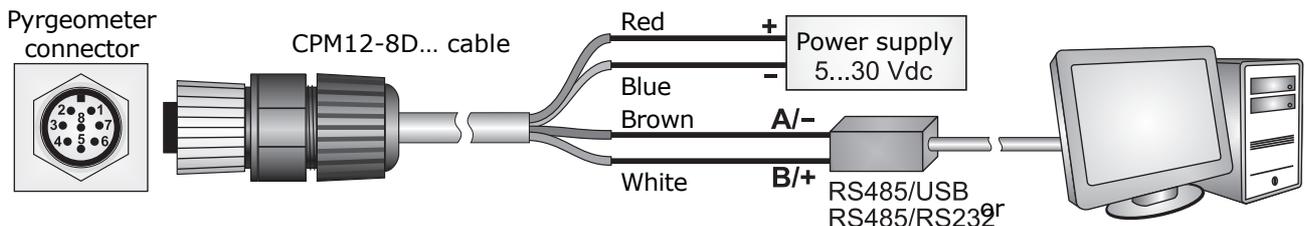
6.1 SETTING THE COMMUNICATION PARAMETERS

Connect the pyrgeometer to the PC in one of the following two ways:

- A.** By using the optional **CP24** cable, with built-in RS485/USB converter. In this connection mode, the sensor is powered by the PC USB port. To use the cable, it is necessary to install the related USB drivers in the PC.



- B.** By using the supplied 8-pole M12 female connector or the optional **CPM12-8D...** cable and a generic RS485/USB or RS485/RS232 converter. In this connection mode, it is necessary to power the pyrgeometer separately. If a RS485/USB converter is used, it is necessary to install the related USB drivers in the PC.



NOTES ON THE INSTALLATION OF UNSIGNED USB DRIVER: before installing unsigned USB driver into operating systems starting from Windows 7, it is necessary to restart the PC by disabling the driver signing request. If the operating system is 64-bit, even after installation the request of driver signing have to be disabled each time the PC is restarted.

Procedure:

1. Start with the pyrgeometer not powered (if the CP24 cable is used, disconnect one end of the cable).
2. In the PC, start a serial communication program. Set the Baud Rate to 57600 and set the communication parameters as follows (the pyrgeometer is connected to a COM type port):
 - Data Bits: 8
 - Parity: None
 - Stop Bits: 2

In the program, set the COM port number to which the pyrgeometer will be connected.

3. Switch the pyrgeometer on (if the CP24 cable is used, connect both ends of the cable).

4. Within 10 seconds from the pyrgeometer power on, send the @ command and press **Enter**.

Note: if the pyrgeometer does not receive the @ command within 10 seconds from power on, the RS485 MODBUS mode is automatically activated. In such a case, it is necessary to switch off and on again the pyrgeometer.

5. Send the command **CAL USER ON**.

Note: the command CAL USER ON is disabled after 5 minutes of inactivity.

6. Send the serial commands given in the following table to set the RS485 MODBUS parameters:

Command	Response	Description
CMA nnn	&	Set RS485 address to nnn Ranging from 1 to 247 Preset on 1
CMB n	&	Set RS485 Baud Rate $n=0 \Rightarrow 9600$ $n=1 \Rightarrow 19200$ $n=2 \Rightarrow 38400$ $n=3 \Rightarrow 57600$ $n=4 \Rightarrow 115200$ Preset on 1 $\Rightarrow 19200$
CMP n	&	Set RS485 transmission mode $n=0 \Rightarrow 8-N-1$ (8 data bits, no parity, 1 stop bit) $n=1 \Rightarrow 8-N-2$ (8 data bits, no parity, 2 stop bits) $n=2 \Rightarrow 8-E-1$ (8 data bits, even parity, 1 stop bit) $n=3 \Rightarrow 8-E-2$ (8 data bits, even parity, 2 stop bits) $n=4 \Rightarrow 8-O-1$ (8 data bits, odd parity, 1 stop bit) $n=5 \Rightarrow 8-O-2$ (8 data bits, odd parity, 2 stop bits) Preset on 2 $\Rightarrow 8-E-1$
CMW n	&	Set receiving mode after RS485 transmission $n=0 \Rightarrow$ Violate protocol and go in Rx mode right after Tx $n=1 \Rightarrow$ Respect protocol and wait 3.5 characters after Tx Preset on 1 \Rightarrow Respect the protocol

7. You can check the parameters setting by sending the following serial commands:

Command	Response	Description
RMA	<i>Address</i>	Read RS485 address
RMB	<i>Baud Rate</i> (0,1)	Read RS485 Baud Rate 0 \Rightarrow 9600 1 \Rightarrow 19200 2 \Rightarrow 38400 3 \Rightarrow 57600 4 \Rightarrow 115200
RMP	<i>Tx Mode</i> (0,1,2,3,4,5)	Read RS485 transmission mode 0 \Rightarrow 8-N-1 1 \Rightarrow 8-N-2 2 \Rightarrow 8-E-1 3 \Rightarrow 8-E-2 4 \Rightarrow 8-O-1 5 \Rightarrow 8-O-2
RMW	<i>Rx Mode</i> (0,1)	Read receiving mode after RS485 transmission 0 \Rightarrow Violate protocol and go in Rx mode right after Tx 1 \Rightarrow Respect protocol and wait 3.5 characters after Tx

Note: it is not required to send the CAL USER ON command to read the settings.

6.2 READING THE MEASURES WITH THE MODBUS-RTU PROTOCOL

In MODBUS mode, you can read the values measured by the pyrgeometer through the function code 04h (Read Input Registers). The following table lists the quantities available with the appropriate register address:

Number	Address	Quantity	Format
1	0	Temperature in °C (x10)	16-bit Integer
2	1	Temperature in °F (x10)	16-bit Integer
3	2	Solar radiation in W/m ²	16-bit Integer
4	3	Status register: bit0=1 ⇒ solar radiation measurement error bit2=1 ⇒ configuration data error bit3=1 ⇒ program memory error	16-bit Integer
5	4	Average values of the last 4 measurements	16-bit Integer
6	5	Signal generated by the sensor in µV/10 [e.g.: 816 means 8160 µV, the resolution is 10 µV]	16-bit Integer

Note: Register address = Register number - 1, as defined in the Modbus standard.

OPERATING MODE: the pyrgeometer enters RS485 MODBUS-RTU mode after 10 seconds from power on. In the first 10 seconds from power on the pyrgeometer does not reply to requests from the MODBUS master unit. After 10 seconds, it is possible to send MODBUS requests to the pyrgeometer.

7 MAINTENANCE

In order to grant measurements high accuracy, it is important to keep the silicon window clean. Consequently, the more the dome will be kept clean, the more measurements will be accurate.

You can wash it using water and standard papers for lens. If necessary, use pure ETHYL alcohol. After using alcohol, clean again the silicon window with water only.

Because of the high temperature changes between day and night, some condensation might appear inside the pyrgeometer (especially on the silicon window). In this case the performed reading is wrong. To minimize the condensation, the pyrgeometer is provided with a cartridge containing dessicant material (silica-gel). The efficiency of the silica-gel crystals decreases over time while absorbing humidity. Silica-gel crystals are efficient when their color is **yellow**, while they turn **white/translucent** as soon as they lose their efficiency. Read instructions at chapter 3 about how to replace the silica-gel crystals. Silica-gel typical lifetime goes from 2 to 6 months depending on the environment where the pyrgeometer works.

Hail of particular intensity/size may damage the silicon window; therefore, it is recommended to check the status of the window after an intense storm with hail.

To exploit all the pyrgeometer features, it is highly recommended that the calibration be checked annually.

8 TECHNICAL SPECIFICATIONS

Sensor	Thermopile
Typical sensitivity	5÷10 $\mu\text{V}/\text{Wm}^{-2}$
Impedance	33÷45 Ω
Measuring range	-300÷+300 W/m^2
Viewing angle	160°
Spectral range (50%) (transmission of the silicon window)	5.5÷45 μm
Operating temperature	-40÷80 °C
Output	Analog in $\mu\text{V}/\text{Wm}^{-2}$ (LPPIRG01) Digital RS485 Modbus-RTU (LPPIRG01S)
Power supply	5÷30 Vdc (LPPIRG01S)
Connection	8-pole M12 connector
Dimensions	Fig. 3.2
Weight	0.9 kg
Accuracy of levelling device	< 0.1°
Protection degree	IP 67
MTBF	> 10 years

Technical Specifications According to ISO 9060:2018

Response time (95%)	< 28 s
Zero offset (type B) a) response to a 5 K/h change in ambiente temperature	< $ \pm 4 \text{ W}/\text{m}^2$
Long-term instability (1 year)	< $ \pm 1.5 \%$
Non-linearity	< $ \pm 1 \%$
Spectral selectivity	< $ \pm 5 \%$
Temperature response	< 3 %
Tilt response	< $ \pm 2 \%$

9 SAFETY INSTRUCTIONS

General safety instructions

The instrument has been manufactured and tested in accordance with the safety standard EN61010-1:2010 "Safety requirements for electrical equipment for measurement, control and laboratory use" and has left the factory in perfect safety technical conditions.

The instrument proper operation and operating safety can be ensured only if all standard safety measures as well as the specific measures described in this manual are followed.

The instrument proper operation and operating safety can be ensured only in the climatic conditions specified in this manual.

Do not use the instruments in places where there are:

- Corrosive or flammable gases.
- Direct vibrations or shocks to the instrument.
- High-intensity electromagnetic fields, static electricity.

User obligations

The instrument operator shall follow the directives and regulations below that refer to the treatment of dangerous materials:

- EEC directives on workplace safety.
- National law regulations on workplace safety.
- Accident prevention regulations.

10 ORDERING CODES

LPPIRG01	Pyrgeometer. Complete with shade disk, cartridge for silica-gel crystals, 2 spare sachets, levelling device, M12 8-pole connector and Calibration Report. CPM12AA8PG... cable has to be ordered separately.
LPPIRG01S	Pyrgeometer. Complete with shade disk, cartridge for silica-gel crystals, 2 spare sachets, levelling device, M12 8-pole connector and Calibration Report. RS485 Modbus-RTU output. Power supply 5...30 Vdc. CPM12-8D... cable has to be ordered separately.
LPSP1	UV-resistant shade disk.
LPS1	Fixing bracket for the pyrgeometer, suitable for $\varnothing 40 \div 50$ mm mast. Installation on horizontal or vertical mast.
HD2003.79K	Kit to mount the pyrgeometer on $\varnothing 40$ mm clamping. To install the pyranometer on a transverse mast.
HD2003.85K	Kit with adjustable height to mount the pyrgeometer on a $\varnothing 40$ mm mast.
CPM12AA8PG.2	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 2 m.
CPM12AA8PG.5	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 5 m.
CPM12AA8PG.10	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 10 m.
CPM12-8D.2	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 2 m.
CPM12-8D.5	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 5 m.
CPM12-8D.10	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 10 m.
CP24	PC connecting cable for the RS485 MODBUS parameters configuration of the LPPIRG01S pyrgeometer. With built-in RS485/USB converter. 8-pole M12 connector on instrument side and A-type USB connector on PC side.
LPSG	Cartridge to contain desiccant silica-gel crystals, complete with O-ring and cap.
LPG	Pack of 5 sachets of silica-gel crystals.

DELTA OHM metrology laboratories LAT N° 124 are ISO/IEC 17025 accredited by ACCREDIA for Temperature, Humidity, Pressure, Photometry / Radiometry, Acoustics and Air Velocity. They can supply calibration certificates for the accredited quantities.

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WARRANTY

The manufacturer is required to respond to the "factory warranty" only in those cases provided by Legislative Decree 6 September 2005 - n. 206. Each instrument is sold after rigorous inspections; if any manufacturing defect is found, it is necessary to contact the distributor where the instrument was purchased from. During the warranty period (24 months from the date of invoice) any manufacturing defects found will be repaired free of charge. Misuse, wear, neglect, lack or inefficient maintenance as well as theft and damage during transport are excluded. Warranty does not apply if changes, tampering or unauthorized repairs are made on the product. Solutions, probes, electrodes and microphones are not guaranteed as the improper use, even for a few minutes, may cause irreparable damages.

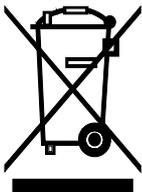
The manufacturer repairs the products that show defects of construction in accordance with the terms and conditions of warranty included in the manual of the product. For any dispute, the competent court is the Court of Padua. The Italian law and the "Convention on Contracts for the International Sales of Goods" apply.

TECHNICAL INFORMATION

The quality level of our instruments is the result of the continuous product development. This may lead to differences between the information reported in the manual and the instrument you have purchased.

We reserves the right to change technical specifications and dimensions to fit the product requirements without prior notice.

DISPOSAL INFORMATION



Electrical and electronic equipment marked with specific symbol in compliance with 2012/19/EU Directive must be disposed of separately from household waste. European users can hand them over to the dealer or to the manufacturer when purchasing a new electrical and electronic equipment, or to a WEEE collection point designated by local authorities. Illegal disposal is punished by law.

Disposing of electrical and electronic equipment separately from normal waste helps to preserve natural resources and allows materials to be recycled in an environmentally friendly way without risks to human health.

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