ENTEC SOLAR

E-1500 | E-1000

Smart I-Vcurve tracer
Entec Solar

User manual
E-1500 / E-1000
E-Sens y E-Temp

V1.2

E-1500

Smart I-V Curve Tracer

E-1000

Smart I-V Curve Tracer

E-Sens

VOC: 0.00 V
ISC: 43.08 mV
PT1: 13.56 °C
PT2: 14.15 °C
PT3: 14.24 °C
VBAT 3.77 V

Índice

Índice

Thank you for purchasing
the Entec Solar I-V Curve Tracer.

With the goal of creating hardware tools to facilitate the work of individuals, Entec Solar has developed the E-1000 and E-1500 I-V Curve Tracers. Both have been developed in collaboration with the company QPV **(www.qpv.es)**. This company specializes in audits and quality control of large photovoltaic power plants and has highlighted the current needs in the field of I-V curve measurement. The combination of Entec Solar's hardware development expertise and QPV's experience in I-V curve measurement has resulted in the fastest and most innovative I-V curve tracers on the market, all with unparalleled measurement precision.

This high-precision instrument allows for the measurement of several hundred I-V curves per working hour, whether from photovoltaic modules or strings up to 1500V and 35A. In addition, it incorporates several new features, including a barcode reader for automatic identification of the module under test and its position in the installation; an automated report generation tool to reduce processing time; an automatic measurement option to free up the operator's hands during panel connection and disconnection; a wireless sensor (E-Sens) with a communication range of several hundred meters to measure irradiance and temperature conditions; a mobile phone application for remote device control; and many more options that will revolutionize your I-V curve measurement campaigns.

Furthermore, through a WiFi connection, the I-V curve tracer synchronizes with PVET® servers (**www.pvet.es**), facilitating storage, comparison, and post-processing of measurement campaigns for fault diagnosis in your plants.

1. Warnings

The E-1000 is an I-V curve tracer designed to work with voltages of up to 1,000 VDC, which can be hazardous to humans. That is why the E-1000 and its accessories should only be used with the components supplied by Entec Solar. Before using the E-1000, read this manual in its entirety and pay special attention to the points related to electrical safety and the points highlighted by the warning and risk of electric shock symbols (see section 1.2).

The use of unapproved accessories can affect the safety of this device and can cause considerable damage to equipment or people. The E-1000 should be used only by personnel trained in low voltage electrical installations and preferably with specific training in photovoltaic solar energy installations. Entec Solar will not assume any responsibility for damages caused due to misuse of the device or its associated components. The E-1000 and its components must not be manipulated, modified, opened, or repaired by any personnel other than those of Entec Solar. Any tempering of the device by third-party personnel may result in loss of equipment warranty. In case the E-1000 or any of its associated accessories or components need repair or re-calibration, please contact Entec Solar or any of its distributors.
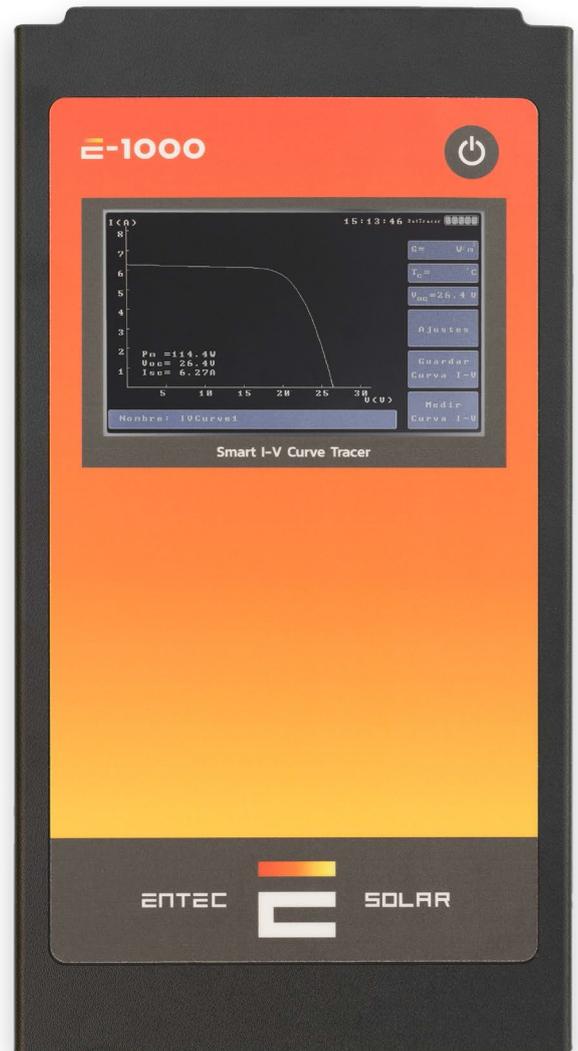
1.1. Used Symbols

• **Double or reinforced continuous insulation** (protection class II)**.**
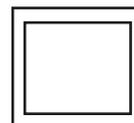
• **Caution danger!** Pay attention to the documentation! This symbol is placed in front of instructions that must be followed to prevent material damage and harm to individuals.

• **Take into account all the documentation provided with the measuring instrument.**

• **Caution high voltage, danger of death.**

• **Measurement instruments should not be disposed of with household waste.**

1.2. Safety Measures During Use

The I-V Curve Tracer has been designed and manufactured in accordance with the standard EN61010-1:2011 "Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use" and has been certified by an independent laboratory under the criteria of this standard as equipment with reinforced insulation CAT II 1000V DC.

To ensure that all safety measures designed into the equipment are met, the following rules must be strictly adhered to:

- Before using the equipment, carefully read the entire manual and pay special attention to points related to electrical safety.

- Use the equipment only for measurements in photovoltaic installations. Other current or voltage sources that are not of photovoltaic origin can damage the measuring instrument.

- Disconnect the photovoltaic circuit under test from any other connected circuit (e.g., inverter, charge controller, battery, etc.) before connecting the I-V Curve Tracer.

- Before taking measurements, ensure that they do not exceed the operating limits of the equipment: for the E-1000, these are 1,000V and 20A; for the E-1500, they are 1500V and 35A. A measurement that exceeds these limits could cause irreparable damage to the equipment.

- The equipment should only be used by personnel trained in low voltage electrical installations who have been specifically trained in the use of this equipment.

- During measurements, use recommended personal protective equipment (PPE) for electrical measurements: insulated gloves, safety boots, face shield, etc.

- Never disconnect measurement cables while a measurement is being performed. This could cause an electric arc and damage to the equipment and individuals.

- Avoid contact with the photovoltaic circuit under test and with any other metallic part in the vicinity.

- Avoid exposing the equipment to direct sunlight.

- Do not perform measurements in humid environments or in rainy conditions, and ensure that no liquids enter the equipment.

- Do not perform measurements in environments with gas, explosive materials, flammable substances, or dusty environments.

- Use only genuine Entec Solar original accessories.

- For the E-1500, a 1500V fuse holder is provided that connects to the four-point cables via an MC4 connector. Entec Solar always recommends its use during measurements as an additional protective measure.

2. General Description

The Entec Solar I-V Curve Tracer consists of a main unit, either the E-1500 or E-1000, which is complemented by several devices (E-Sens, E-Temp, barcode reader), each with its specific functionality.

The I-V Curve Tracer, either the E-1500 or E-1000, is the device responsible for the physical measurement of photovoltaic panels. It connects using four-point cables and is in charge of measuring voltage and current, receiving information from other devices, processing the data, displaying it on the screen, and storing it.

The E-Sens is an independent device that complements the I-V Curve Tracer. Its purpose is to measure irradiance and temperature values of the provided calibrated cell, as well as the temperature of up to three optional PT-1000 sensors. It needs to be physically connected to the calibrated cell for measurements. Communication with the I-V Curve Tracer is automatically done through radio waves, eliminating the need for a physical connection. This feature allows for more flexible positioning.

The E-Temp is an optional device designed for measuring the temperature of photovoltaic panels. While there are various ways to measure panel temperature, Entec Solar has developed this quick and convenient solution. It operates independently and communicates through radio waves, offering flexibility and making temperature measurements in less accessible locations easier.

The barcode reader is an optional device designed to read identification labels found on photovoltaic modules. The reader must be physically connected to the I-V Curve Tracer via USB and activated by the operator. It is particularly useful for measuring I-V curves of modules, as it enables unique identification of each measurement using the module's barcode.

2.1. Equipment Functionality

El E-1500 / E-1000 puede ser utilizado de manera autónoma o de manera conjunta con otros accesorios, como el E-Sens, el E-Temp o el lector de código de barras.

El uso del E-1500 / E-1000 junto con todos sus accesorios proporciona la mayor comodidad y precisión en la medida de curvas I-V.
A continuación, se listan todas las funcionalidades que proporcionan el E-1500 / E-1000 y todos sus accesorios.

-Medida de la tensión de circuito abierto, VOC. (E-1500 / E-1000)

-Medida de la corriente de cortocircuito, ISC. (E-1500 / E-1000)

-Medida de la curva I-V a 4 puntas hasta 1500V y 35A. (E-1500 / E-1000)

-Medida de la irradiancia a través de una célula calibrada o módulo de referencia (E-SENS)

-Medida de hasta tres puntos de temperatura mediante PT-1000 (E-SENS)

-Medida de temperatura de un módulo de referencia (E-SENS)

-Medida de temperatura mediante sensor de infrarrojo (E-Temp)

-Transmisión inalámbrica de los datos de irradiancia y temperatura (E-1500 / E-1000, E-Temp)

-Extrapolación de las curvas I-V medidas a STC mediante IEC-60891 (E-1500 / E-1000)

-Selección del sensor de temperatura para la extrapolación (E-1500 / E-1000)

-Lectura del código de barras del módulo bajo ensayo (E-1500 / E-1000)

-Generación automática de informes diarios (E-1500 / E-1000)

-Modo automático de medida (E-1500 / E-1000)

-Modo automático de guardado de la medida (E-1500 / E-1000)

-Modo de medida continua mediante periodo seleccionable (E-1500 / E-1000)

-Almacenamiento de datos en tarjeta SD extraíble (E-1500 / E-1000)

-Almacenamiento de datos en tarjeta MicroSD extraíble (E-Sens)

-Lectura de datos mediante conexión inalámbrica WiFi (E-1500 / E-1000)

-Visualización y control de medidas a través de App móvil (E-1500 / E-1000)

2.2. External Connectors and Parts Description

2.2.1. E-1500

1. SD Card Slot

3. Positive Terminal Inputs for I-V Curve Measurement

2. Negative Terminal Inputs for I-V Curve Measurement

Figure 2.1 shows the upper connectors and their description.

1. Power Button

E-1500

Smart I-V Curve Tracer

2. Touchscreen Display

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1. USB Connector for Barcode Reader Connection

2. Battery Charger Jack Connector
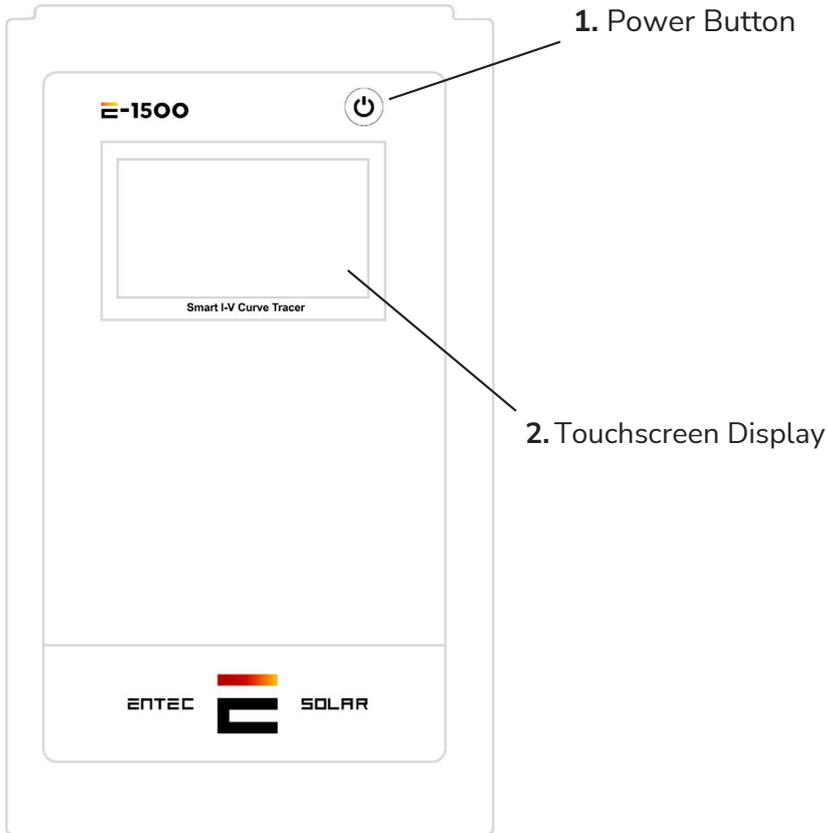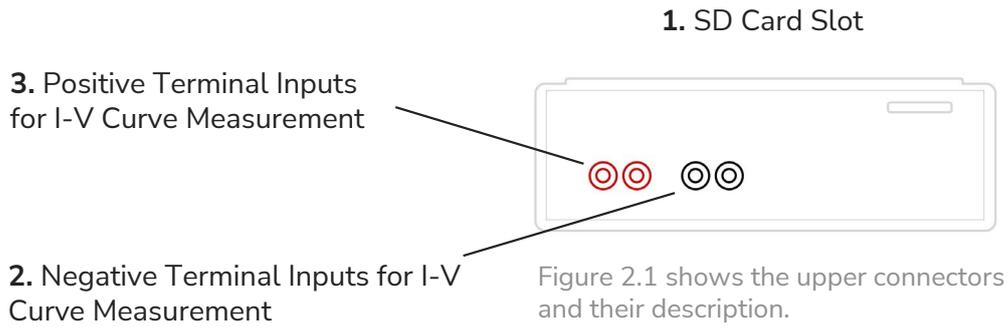
Figure 2.2 displays the front connectors and their description.
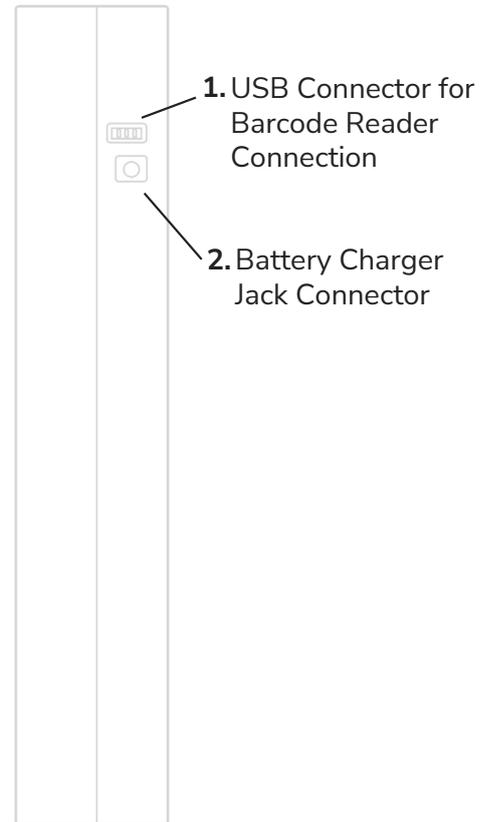
Figure 2.3 displays the side connectors and their description.

⚠️ **ATTENTION:** Avoid prolonged exposure to direct sunlight.

2.2.2. E-1000

1. SMA connector for external antenna

2. SD card slot

3. Negative pole inputs for I-V curve measurement

4. Positive pole inputs for I-V curve measurement

Figure 2.4. Shows the top connectors and their description.
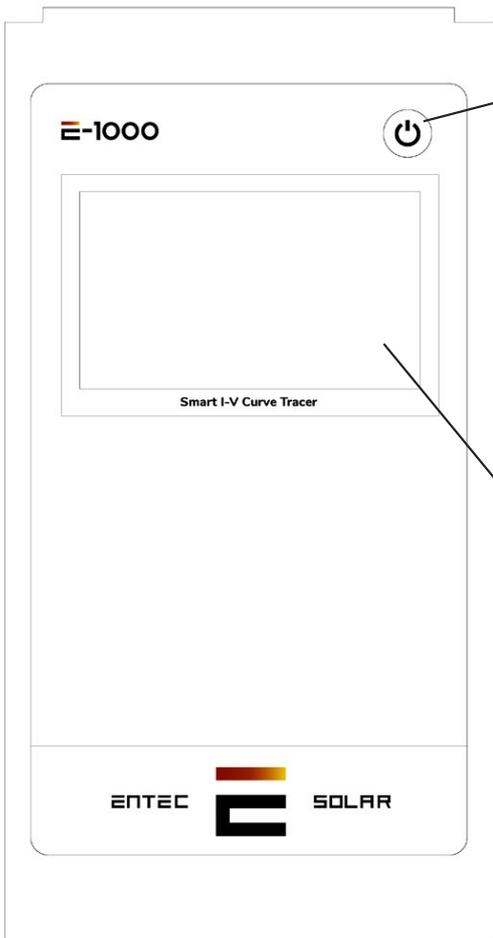
1. Power button

2. 5-inch color touchscreen. Resolution 800x480

E-1000

Smart I-V Curve Tracer

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1. Battery charger Jack connector

2. USB connector for barcode reader connection

3. micro USB connector for SD card access

Figure 2.5. Shows the front connectors and their description.

Figure 2.6. Shows the side connectors and their description.

⚠️ **ATTENTION:** Avoid prolonged exposure to direct sunlight.

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2.2.3. E-Sens

1. SMA connector for external antenna

2. microSD card slot

Pt1000-1   Pt1000-3
Pt1000-2
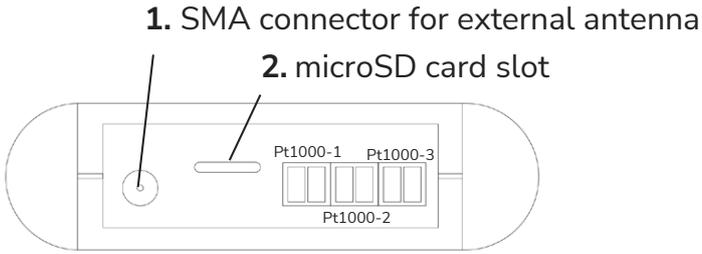
Figure 2.7. Shows top connectors and its description.

1. Reference cell PT1000
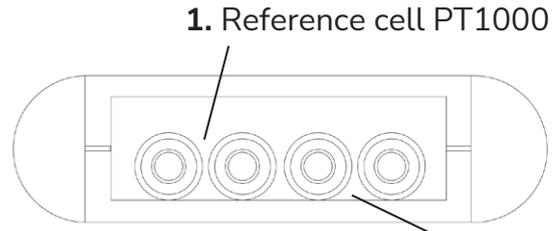
Figure 2.8. Shows the connectors below and their description.

2. Reference cell

1. Power button

2. Color display

2. Battery charging LED indicator

1. USB connector for battery charging
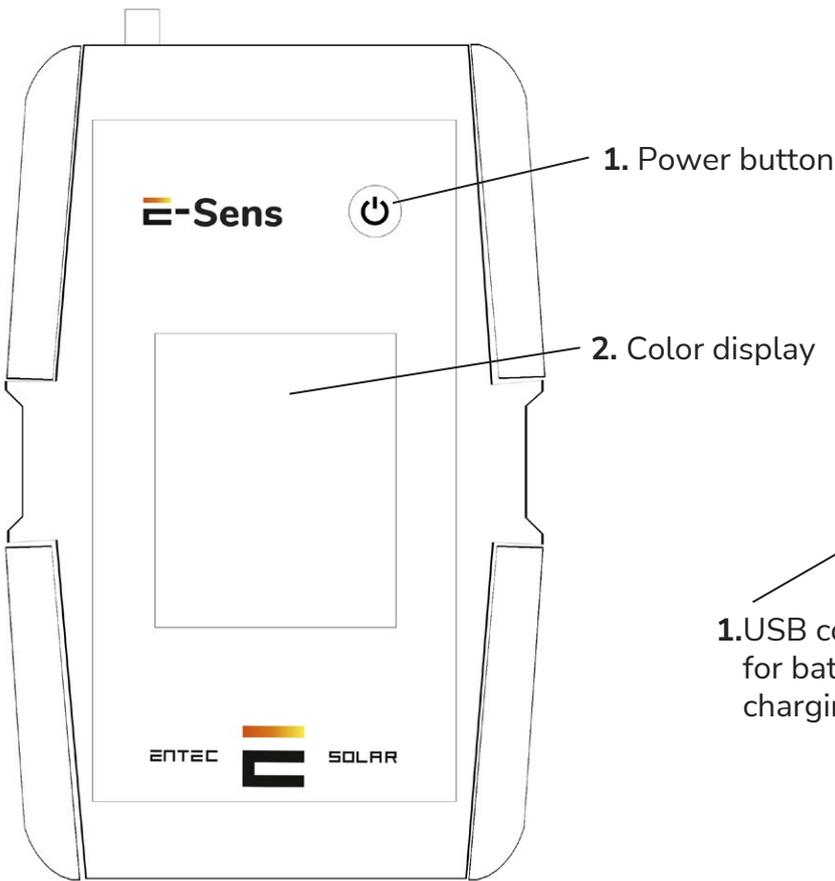
Figure 2.9. Illustrates the front connectors and their description.
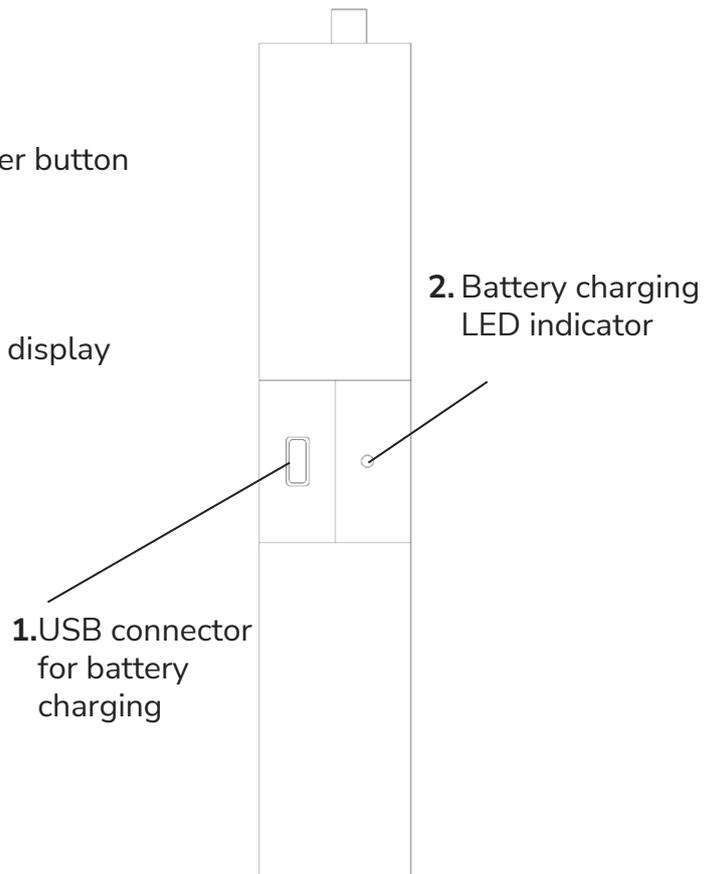
Figure 2.10. Illustrates the side connectors and their description.

⚠️ **ATTENTION:** Avoid prolonged exposure to direct sunlight.

2.2.4. Optional: E-Temp (IR Sens)
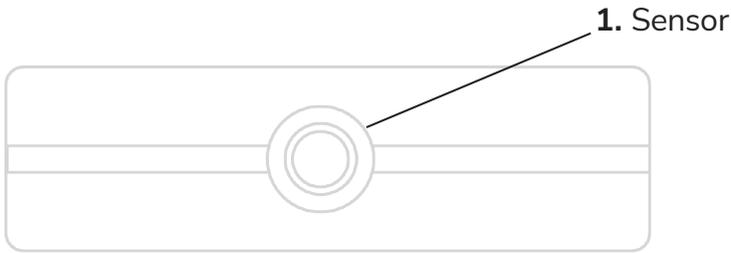
1. Sensor

Figure 2.11. Illustrates the infrared sensor on the top.

1. Color display.

2. Power button.

3. LED.

1. Micro USB port.

4. Grip tape.
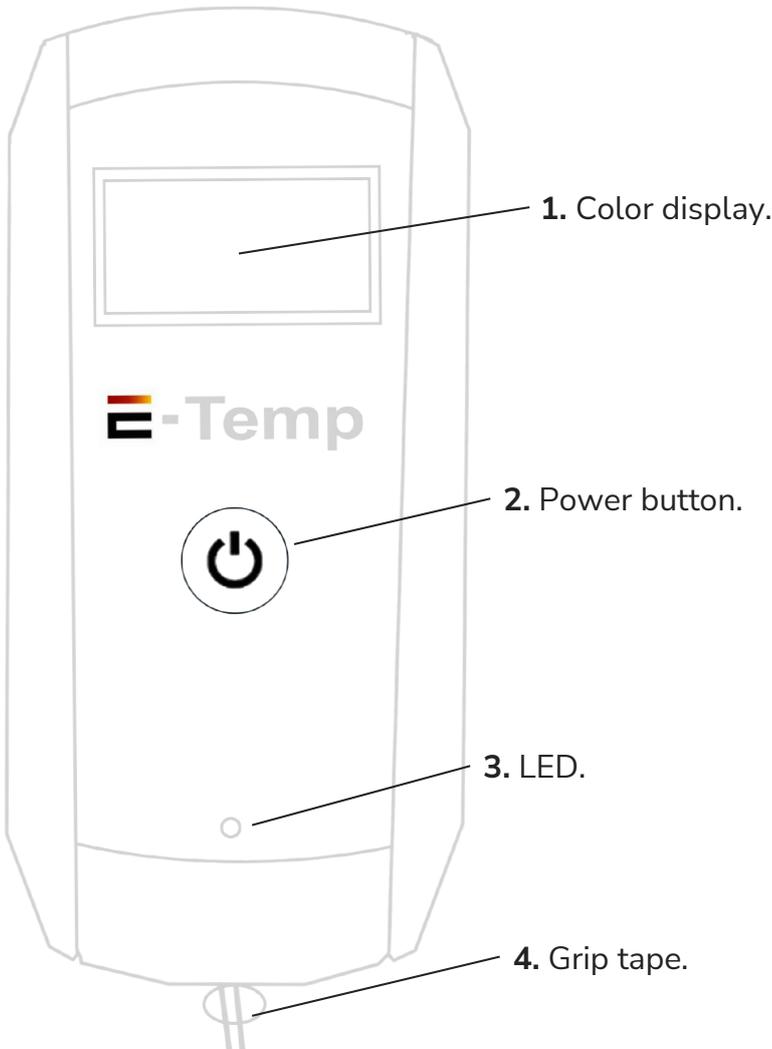
Figure 2.12. Illustrates the front display and button.
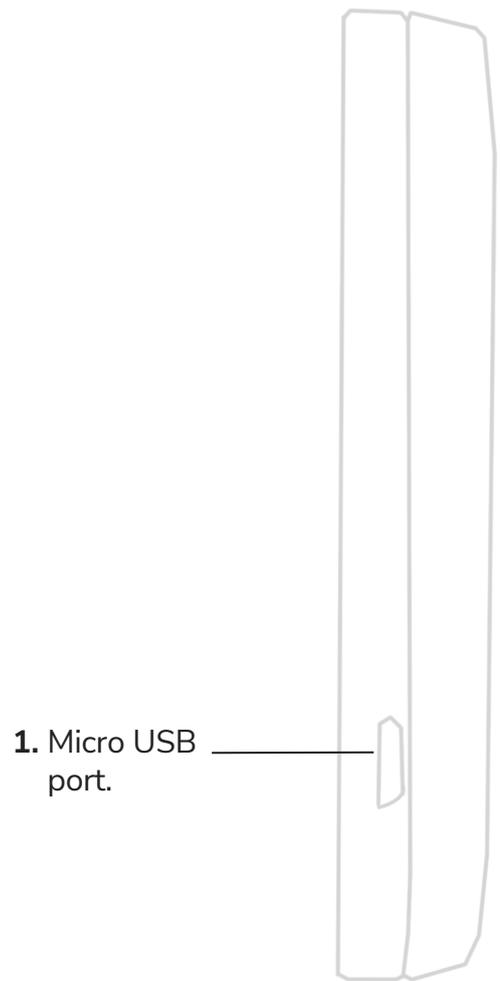
Figure 2.13. Illustrates the micro USB charging port on the side.

⚠️ **ATTENTION:** Avoid prolonged exposure to direct sunlight.

2.3. . Description of Elements on the Initial Screen

In this section, we will focus on the E-Sens and E-Temp devices, as the elements on the curve tracer screen are available in Section 5 of this manual.

2.3.1. E-Sens

To power on and off the E-Sens, press the black button on the top right of the screen. While the device is booting up, the loading screen will be displayed for a few seconds.

On this screen, the message "Initializing..." is shown, along with two important pieces of information. The first is "SN," which corresponds to the Serial Number of the device. The second is "Fw V," which corresponds to the Firmware version of the device.

Once the device has finished initializing, the main E-Sens screen will be displayed. This is the screen where all the device information is shown.

In the upper bar, from left to right, you will find the following elements:
- Device logo
- MicroSD detected and initialized icon
- Battery status icon
- Date and time

The following data is displayed in a vertical order:
- ISC: Measurement of the voltage of the calibrated reference cell in millivolts to obtain irradiance.
- Tc Isc: Temperature measurement of the PT1000 of the calibrated reference cell.
- PT1: Temperature measurement of channel 1.
- PT2: Temperature measurement of channel 2.
- PT3: Temperature measurement of channel 3.
- VBAT: Measurement of the battery voltage.
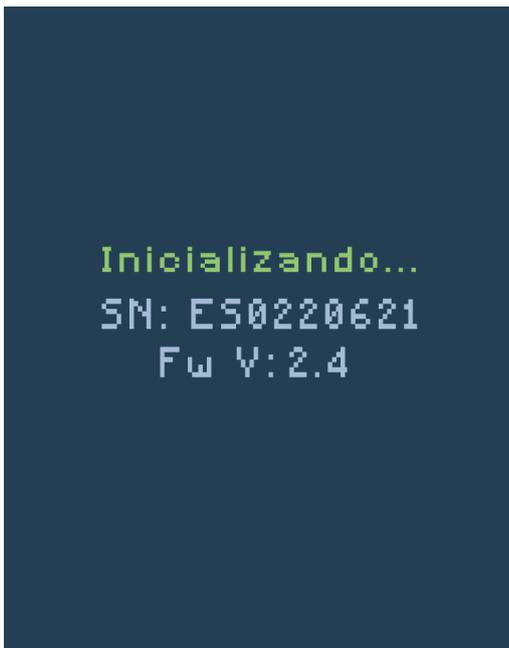
Figure 2.14. E-Sens screen during device startup.

Figure 2.15. E-Sens screen during device startup.

2.3.2. E-Temp

To power on the E-Temp, briefly and gently press the power button once, and wait for a couple of seconds until the startup screen is displayed. Similarly, to turn off the device, press and hold the same button for 5 seconds.

⚠️ **IMPORTANT:** During startup, it is important not to press the button multiple times in succession or press it for an extended period, as this may turn off the device.

The initial data displayed includes the device name, the device's serial number, and the firmware version.
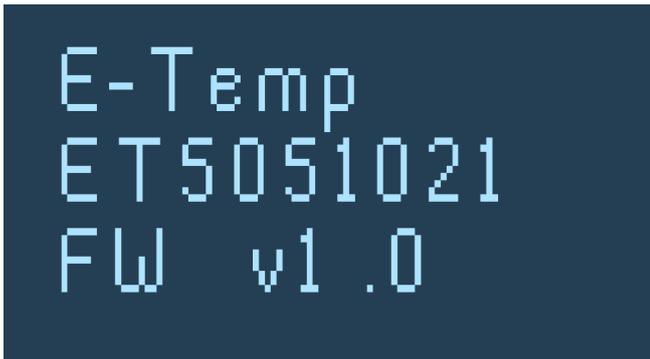
Figure 2.16. E-Temp screen during device startup.

Once the device initialization is complete, the standby screen will be shown. In this mode, the device is ready to take measurements but displays minimal information to save battery power by reducing screen energy consumption.

Figure 2.17. E-Temp standby screen.

Once the device initialization is complete, the standby screen will be shown. In this mode, the device is ready to take measurements but displays minimal information to save battery power by reducing screen energy consumption.

Subsequently, three temperatures will be displayed on the screen:
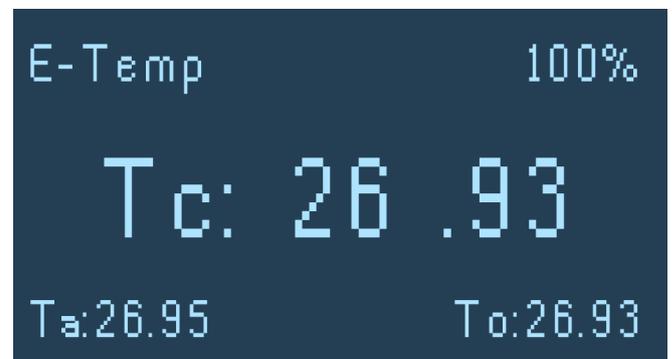
Figure 2.18. E-Temp measurement screen.

- Tc: This corresponds to the temperature of the measured point and is located in the center, displayed larger. This is the temperature stored in the curve tracer's SD card data.
- Ta: This corresponds to the ambient temperature, located at the bottom left.
- To: This corresponds to the temperature of the temperature sensor packaging. Excessive temperature can affect the accuracy of the device. It is located at the bottom right.

When performing the measurement, the data will be displayed on the screen for approximately five seconds. At the end of this period, the device returns to the standby state.

Please note that the same button is used to power on the device, take measurements, and power off the device, so you should be cautious when pressing it. It is important not to press the button multiple times in succession or press it for an extended period.

2.4. Supply Package

The E-1000 can be purchased in its basic version or with various options. Below is a list of accessories included in the basic version and optional accessories.

Included in the Basic Version:

- 1 x E-1500 / E-1000.

- 1 x E-Sens.

- 1 x Padded transport case with wheels.

- 1 x Set of four-point measurement cables with MC4 terminals.

- 1 x SD card for E-1000.

- 1 x MicroSD card for E-Sens.

- 1 x Charger for E-1000.

- 1 x Set of crocodile clips.

- 1 x USB cable for charging E-Sens.

- 1 x Calibrated reference cell.

- 1 x PT-1000.

- 1 x Wireless communication antenna.

- 1 x 1500V fuse in cable (for E-1500).

Optional Accessories:

- Barcode reader.

- Infrared temperature sensor (E-Temp).

- Access to PVET for data storage and advanced analysis.

- Additional PT-1000 sensors.

Figure 2.19. Devices and accessories included.

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3. Measurement Quantities and Operating Conditions

3.1. Measured Quantities

Unlike measuring I-V curves under controlled conditions, such as with a flash tester, measuring I-V curves in the field under variable operating conditions requires extrapolation of the measured curves to standard test conditions (STC).

The E-1500 performs this extrapolation automatically according to the procedure described in IEC 61829 and based on measurements of irradiance, module temperature, and the I-V curve. To facilitate the measurement of these quantities, Entec Solar has devised a solution that involves using the E-1500 I-V curve tracer along with the E-Sens and E-Temp devices. Figure 3.1 illustrates the measured quantities and the processes carried out to obtain the I-V curve under STC conditions.

To obtain irradiance **(G)**, the E-Sens measures the short-circuit current **(ISC cell)** and temperature **(Tc cell)** of the calibrated cell and sends these values to the E-1500 / E-1000. The E-1500 processes these quantities and converts them to irradiance using the calibration values of the calibrated cell (see section 5.5.6.B).

To obtain the module temperature[1] **(TM)**, there are two options:

- **- E-Temp:** An infrared thermometer designed by Entec Solar, which allows practical and non-contact temperature measurement of various points on the tested element.

- **- E-Sens:** It has up to three channels for the use of Pt1000 sensors.
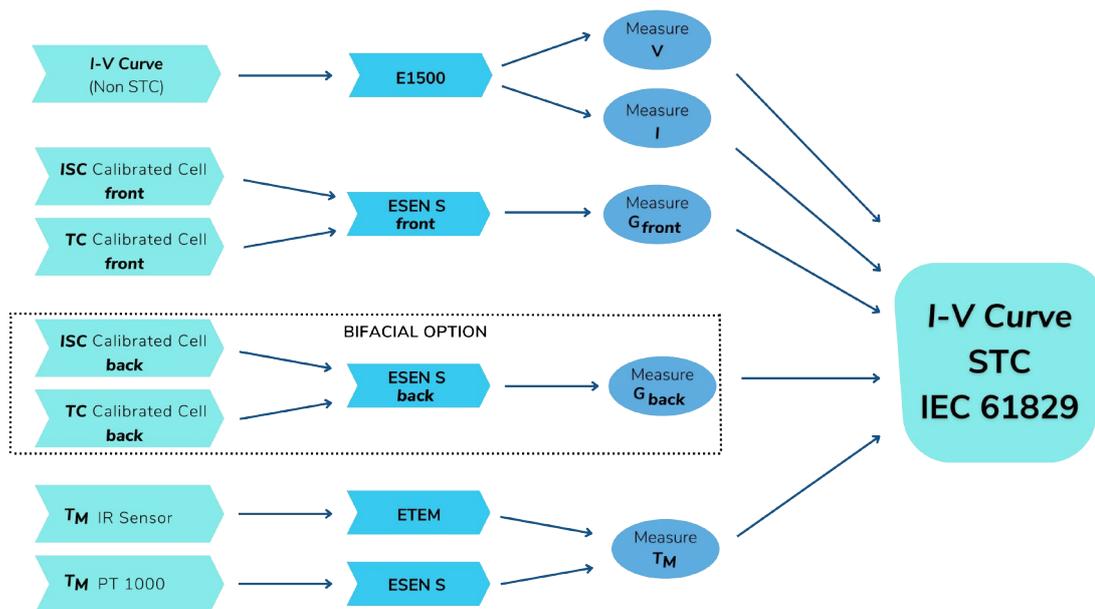
Figure 3.1: Illustration showing the measured quantities, the equipment used, and the procedures carried out to obtain the curve measured under STC conditions.

[1] It's important not to confuse this temperature with the temperature of the cell. They are different temperatures and are obtained and used differently.

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3.2. Operating Conditions

Measuring I-V curves under actual sunlight requires special care regarding the weather conditions during the test. Irradiance and module temperature are the variables that most significantly affect the final result. Therefore, special attention must be given to measuring these variables to obtain accurate and consistent results. To achieve this, the following precautions should be taken:

Regarding Irradiance Measurement:

- Conduct measurements during periods of clear sky throughout the day. If the reference cell and the tested circuit are exposed to different levels of irradiance due to factors like passing clouds, the extrapolation to standard test conditions (STC) results may not be consistent.

- Ensure coplanarity and proximity between the reference cell and the tested circuit. Differences in orientation, tilt, or measured irradiance between the reference cell and the tested circuit can lead to inconsistent extrapolations to STC.

- IEC 61829 recommends a minimum irradiance of 700 W/m2 during measurements. However, more accurate results are achieved with irradiance closer to 1000 W/m2.

- Avoid having the angle of solar incidence on the tested circuit exceed 40°.

Regarding Temperature Measurement:

- Avoid measurements on very windy days. Wind can cause significant variations between the actual cell temperature and the measured temperature, as well as temperature differences within the tested circuit. In the case of module chains, wind can cause substantial differences

between end modules and those in the center of the structure, or between modules in lower and upper rows. Large temperature differences between the tested circuit and those measured by the E-Sens can lead to inconsistent extrapolations to STC.

- To minimize errors due to temperature differences within the tested circuit (e.g., temperature differences between cells within a module or between modules in module chains), it is recommended to measure temperatures at various points within the tested circuit.

- IEC 61853-1 recommends measuring the temperature of a module at the three positions shown in Figure 3.1 and using the average of the three temperatures for extrapolation to STC. The E-1000 has been programmed to average up to three PT-1000 measurements taken with the E-Sens or to use the average with a user-selected number of points measured with the E-Temp.

- For temperature measurement in module chains, it is recommended to measure the temperature of at least three modules in the chain, using the three points indicated in Figure 3.2 within each module. It is advisable to measure a module near the end of the chain and two modules from the center of the chain. The use of the E-Temp, which enables wireless measurements, is highly recommended for this purpose.
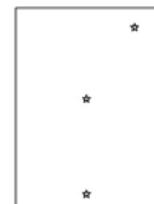
Figure 3.2. Positions for placing temperature sensors on a photovoltaic module based on IEC 61853-1.

4. Preparation Prior to Measurements

4.1. First Use of the Device

The E-1500 / E-1000, before being shipped, has undergone rigorous quality controls during its production and has been electrically and mechanically inspected after manufacturing. All functionalities of the device have been tested, and every possible precaution has been taken to ensure the device is delivered without any damage or operational defects. However, it is advised to thoroughly examine the device and test its operation upon receipt and before beginning a measurement campaign. If any defects or anomalies in operation are detected, contact Entec Solar or your nearest distributor immediately.

4.2. Battery Charging

Both the E-1500 / E-1000 and the E-Sens have a rechargeable lithium-ion battery inside. The complete device package includes a specific charger for the E-1000 / E-1500 battery and another specific charger for the E-Sens. Each charger has a different type of connector: the E-1000 uses a Jack connector, and the E-Sens uses a micro-USB connector. The charging connector for each device can be seen in Figures 2.3 and 2.6 in sections 2.2.2 and 2.2.3.

By default, both devices are distributed with a battery charge level of 60%. Before the first use of the devices, make sure to charge both batteries to 100% to maximize their usage time. With a fully charged battery, the E-1500 / E-1000 can operate for more than 8 hours, while the E-Sens can operate for more than 10 hours.

The E-1500 / E-1000 charger includes an LED that indicates the charging status. During battery charging, this LED will be red, and once the device is fully charged, it will turn green. The E-Sens is charged using a standard micro-USB cable from any 5V source, such as a computer USB port or a mobile phone charger. While the E-Sens is charging, an LED inside it lights up, located just above the micro-USB connector and visible from the outside (See Figure 2.10).

During charging, this LED emits a red light, and when charging is complete, it emits a green light.

The battery charge status of both devices (E-1500 / E-1000 and E-Sens) can also be seen in the top-right corner of their respective screens (Figure 5.3). The indicator displays the charge status in levels, where each level indicates a specific charge status (Figure 5.3).

  - One red square: charge between 0-10%.

  - One white square: charge between 10-25%.

  - Two white squares: charge between 25-50%.

  - Three white squares: charge between 50-75%.

  - Four white squares: charge between 75-100%.

On the E-Sens screen, the actual battery voltage can also be seen. This value provides a more accurate representation of the battery's charge level, where below 3.5V, immediate charging of the device is recommended.

The E-1500 / E-1000, before being shipped, has undergone rigorous quality controls during its production and has been electrically and mechanically inspected after manufacturing. All functionalities of the device have been tested, and every possible precaution has been taken to ensure the device is delivered without any damage or operational defects. However, it is advised to thoroughly examine the device and test its operation upon receipt and before beginning a measurement campaign. If any defects or anomalies in operation are detected, contact Entec Solar or your nearest distributor immediately.

Insert the cards into the slots located at the top of each of the devices (Figures 2.1 and 2.4).

⚠ **IMPORTANT:** The battery charge level is indicative and depends on various variables, such as ambient temperature, the rate of device usage, battery lifespan, manufacturing differences between batteries, etc. The displayed levels are approximate and based on a standard battery. These levels can change over time, causing the battery to discharge earlier than expected or even jump between levels more quickly than the percentages described in this section. As the device is used, these levels may change, and the user should be aware of this to avoid running out of battery during a measurement campaign.

4.3. Memory Card Insertion

The E-1500 and E-1000 store all measured data on SD cards, while the E-Sens uses a MicroSD card. Both cards are supplied with the device shipment. Both devices can function without these cards, but it will not be possible to store data without them. In the event of loss or replacement of the supplied cards, the use of reputable brand SD cards is recommended to avoid potential data loss or memory corruption.

Before each use of the device, ensure that the SD cards are inserted and functioning properly to be able to store all measurements

Insert the cards into the slots located at the top of each of the devices (Figures 2.1 and 2.4).

⚠ I**MPORTANT:** Insertion and removal of the cards should be done with the devices turned off to avoid damage to the cards and the possibility of losing stored data.

⚠ I**MPORTANT:** The format of the cards should be FAT32.

4.4. Initial Configuration

The E-1500 / E-1000 has been designed to offer very simple operation. However, minimal configuration is required before each measurement campaign. The following are the main steps to follow in configuring the E-1500 / E-1000 before starting a measurement campaign:

1. Set the local time and synchronize it with the E-Sens (See section 5.5.11.A.).

2. Configure the module and tested generator characteristics: The E-1500 / E-1000 uses key electrical characteristics of the tested module (VOC, ISC, VM, IM, α, β, and NS, provided by the manufacturer) as well as the generator configuration (number of modules in series and parallel) as input parameters to calculate series resistance and the parameter k, both necessary for extrapolation to STC according to IEC-61829 (See section 5.5.4).

3. Configure the irradiance and temperature sensors[2]: Set the calibration values of the reference cell (irradiance sensor) and select the temperature measurement method (e.g., PT-1000, reference module, E-Temp) as detailed in section 5.2.2.A.

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2 Para la obtención de los valores de calibración de la célula de referencia consulte el certificado de calibración entregado con su equipo.

6. Measurement and Saving Options Selection (e.g., autosave, auto-measure, continuous measurement, barcode reading, etc.) as detailed in section 5.4. For a more detailed description of how to carry out the above steps, refer to the corresponding sections. All these configurations, except the measurement option, are saved in the device even when powered off. Therefore, this configuration will only need to be performed at the beginning of a new measurement campaign, when switching to a different module type or tested generator, or if you want to modify the file name. The E-Sens requires no further configuration beyond time synchronization with the E-1500 / E-1000, which is done from the E-1500 / E-1000 (see section 5.5.11.A.).

⚠️ **IMPORTANT:** Points 2 and 3 of the above list are essential to obtain accurate results.

When connecting to the RTD connections of the E-Sens, which will automatically correct the current measurement. The calibration parameters provided in the calibration certificate supplied with your equipment must be included in the settings as detailed in section 5.5.6.A.

4.5. Mounting of Irradiance and Temperature Sensors and Their Connection to the E-Sens

The process of mounting and connecting the irradiance and temperature sensors is detailed below. The necessary adjustments for these sensors to function correctly are defined in section 5.5.6.B.

4.5.1. Irradiance Sensor

The irradiance sensor provided with the equipment is a calibrated silicon solar cell. This cell should be mounted coplanar to the module or tested generator (Figure 4.1).

Figure 4.1. Reference Mounting.

The irradiance sensor provided with the equipment is a calibrated silicon solar cell. This cell should be mounted coplanar to the module or tested generator (Figure 4.1).

Once secured with the proper inclination and as close as possible to the modules under test, connect it to the E-Sens through the banana-type connection for ISC measurement on the 2V connector at the bottom of the E-Sens (see Figure 2.8). Additionally, the reference cell incorporates a PT-1000 for correcting irradiance measurement with temperature. This PT-1000 will be connected to the RTD connections of the E-Sens, which will automatically correct the current measurement.

4.5.2. Temperature Sensor

There are three types of sensors that can be used to record temperature with the E-Sens:

1. PT-1000

Using PT-1000 sensors, you can measure the temperature of the module under test (Tm) and the cell temperature on the backsheet. When measuring Tm, the PT-1000 sensors should be attached to the backside of the module, preferably following the guidelines depicted in Figure 4.1.

The PT-1000 sensors should be connected to the E-Sens, which has three inputs on its top labeled as Pt1000-1, Pt1000-2, and Pt1000-3 (see Figure 2.7.) for temperature readings. If you want to measure the temperature of the reference cell, it is measured through a built-in PT-1000 as detailed earlier. For more information on configuring the PT-1000 sensors on the E-Sens, refer to section 5.5.6.B.

2. Calibrated Module

The calibrated module should be mounted in a representative position of the module to be characterized. If the test is on arrays, then it should be a central module so that its conditions represent the majority of modules in the array. The output of the module should be connected to the 60 V channel of the E-Sens with the correct polarity. To obtain an accurate temperature value, you must configure the calibration values of the reference module in the E-1500 / E-1000 (section 5.5.6.B).

3. Infrared Temperature Sensor E-Temp

The E-Temp is wirelessly connected to the E-1500 / E-1000 and automatically registers temperatures. Therefore, no prior configuration is required. Just ensure that the E-Temp and the E-1500 / E-1000 are sufficiently close for a wireless connection. For more information on how to measure with the E-Temp, refer to section 5.3.6.

4.6. Connection of the Module or Array under Test

Before connecting the circuit under test, whether it's a single photovoltaic module or an array with multiple modules in series and parallel, the user must disconnect this circuit from any other connected elements, such as inverters, charge controllers, batteries, or other circuits in series or parallel with the sample under test. Once the circuit is completely isolated from other elements, it can be connected to the E-1500 / E-1000.

Use the set of cables supplied with your equipment to connect the circuit under test to the E-1500 / E-1000. This cable set consists of two pairs of measurement cables, one red and one black, allowing for a four-point measurement setup. This setup is used for high-precision measurements, as it avoids voltage drop caused by wiring during measurement. This ensures that the real I-V curve at the photovoltaic module output is measured without interference or distortion.

In the case of the E-1500, Entec Solar provides a fuse holder with MC4 connectors (Figure 4.2a). This additional safety element should be connected between the array and one of the four-point cables. It doesn't vmatter if it's the positive or negative pole. The fuse holder incorporates a 1500V insulation fuse and 6A overcurrent protection. If the fuse acts and blows, the circuit will be open, and therefore, the curve tracer will stop measuring voltage. If this happens, you should review what might have caused this situation before continuing with the measurements. The fuse can be easily replaced with a new one by opening the fuse holder in half and replacing the blown cartridge with a new one.

Under no circumstances should you replace the fuse with a non-fusible metallic element.

Entec Solar recommends the use of this safety element, as well as all other safety elements.

Figure 4.2a. 1500V in cable fuse-holder.

First, connect the four banana plugs (two red and two black) to the E-1500 / E-1000. Connect the red banana plugs to the red inputs of the E-1500 / E-1000 and the black banana plugs to the black inputs. The red color represents the positive pole of the test circuit, and the black color represents the negative pole (see Figures 4.2b and 4.2c).

Figure 4.2b. Correct Connection E-1000.
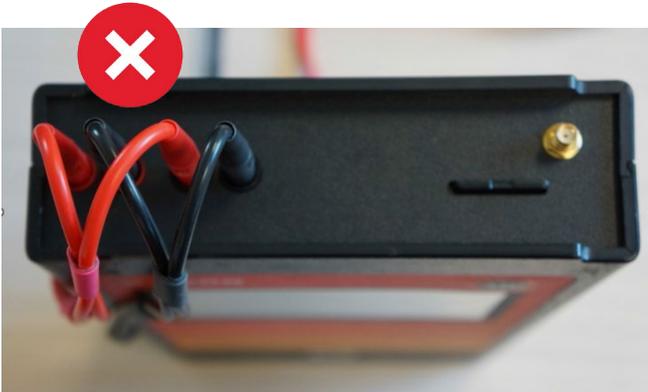
Figure 4.2a. Incorrect connection E-1000.

Once the wiring is connected to the E-1500 / E-1000, connect the other end of the wiring to the test circuit. The supplied cables have an MC4 termination for direct connection to photovoltaic modules. The cables supplied with the E-1500 / E-1000 have been manufactured with the appropriate type to enable direct connection. Therefore, the positive pole (red cable) has a female MC4 terminal, and the negative pole (black cable) has a male MC4 terminal. Avoid using cables from other manufacturers or self-made cables to minimize risks and prevent potential polarity issues.

For connecting the E-1500 / E-1000 to other components, such as a parallel bar, Entec Solar can provide a special cable with four crocodile clips instead of an MC4 terminal.

⚠️ **IMPORTANT:** Incorrect connection of the positive and negative poles of the test circuit to the E-1500 / E-1000 can cause irreparable damage to the equipment. The red color represents the positive pole, and the black color represents the negative pole.

⚠️ **WARNING:** During these operations, there is a risk of electric shock. Necessary personal protective equipment (PPE) should be used to minimize this risk, and the established sequence for disconnecting the test circuit from other components, such as the inverter or other parallel circuits, should be followed. Entec Solar is not responsible for any damage to equipment or individuals due to improper use of the E-1500 / E-1000.

⚠️ **IMPORTANT:** Before connecting the test circuit to the E-1000, the user must ensure that their current and voltage values are within the measurement range of the equipment: 1,000 V and 20 A.
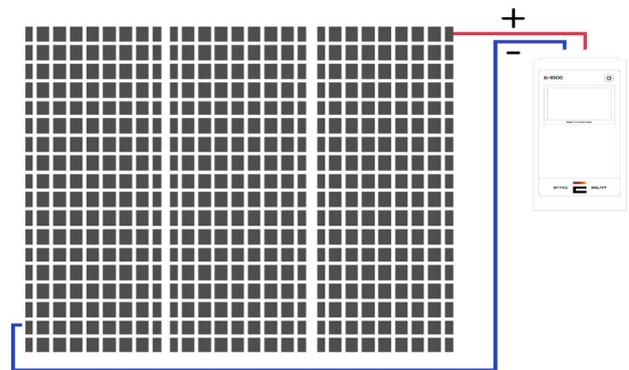
Figure 4.3. Test Circuit Connection to E-1500 / E-1000.

1. Configuration and operation

The control and configuration of the E-1500 / E-1000 are carried out through the touchscreen incorporated into the equipment. The following sections describe each screen of the device along with the available settings and controls.

5.1. Startup

During startup, the E-1500 / E-1000 performs equipment configuration and checks that the main peripherals are functioning correctly. While this initial configuration is taking place, the E-1500 / E-1000 displays the startup screen (Figure 5.1.) with the following information:

- Equipment serial number: Identifies each unit and will be necessary for any communication with technical support. The last four digits indicate the month and year of manufacture.

- Firmware version: Indicates the installed firmware version on the equipment and allows you to verify if you have the latest available version. The firmware version will also be necessary for any communication with technical support.

- Calibration date: Indicates the equipment's calibration date.
- Valid until: Indicates the date until which the equipment's calibration is valid. Once this date is reached, the equipment should be sent back to the factory for re-calibration.

After a few seconds, two messages related to the initialization of the SD card and the LoRa communication module (the wireless communication module built into the E-1500 / E-1000, the E-Sens, and the E-Temp) will appear on the main screen.

Bienvenido al Smart I-V Tracer

Inicializando...

- Nº Serie: E10030519
- Version Firmware: 05/03/2020
- Fecha calibracion: 21/10/2019
- Valida hasta: 21/10/2021

Figure 5.1. E-1500 / E-1000 Startup Screen..

In case of an initialization error, a red error message will be displayed. If the initialization has been successful, a white "configuration successful" message will be shown (Figure 5.2.).

Bienvenido al Smart I-V Tracer

Inicializando...

- Nº Serie: E10030519
- Version Firmware: 05/03/2020
- Fecha calibracion: 21/10/2019
- Valida hasta: 21/10/2021

- Error en tarjeta SD !!!!
- LoRa inicializada correctamente

Figure 5.2. Startup Screen with SD Card Error.

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5.2. Main Screen

Once the equipment is initialized, the main screen (Figure 5.3.) will be accessed automatically. This screen provides all the information and controls necessary to perform I-V curve measurements.
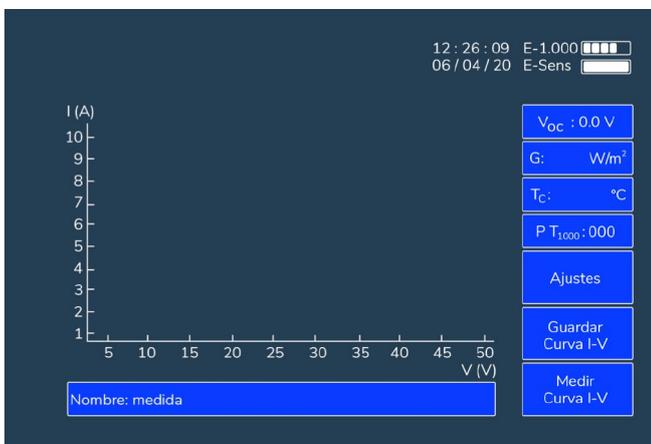
Figure 5.3. Main Screen.

5.2.1. Main Screen Information

On the main screen (Figure 5.3.), the following information is displayed:

- Date and time: Date and time configured in the E-1500 / E-1000. These values are stored and updated automatically even if the equipment runs out of battery. However, over time, a small time deviation may occur in the internal clock, so it should be periodically updated as indicated in section 5.5.11.A. It will also be necessary to adjust the date and time when changing time zones or with daylight saving time changes.

- Battery levels: In the upper right corner, the battery levels of the E-1500 / E-1000 and E-Sens are displayed as described in section 4.2.

- VOC rectangle: Displays the open-circuit voltage of the circuit under test, between 0 and 1,000V. When no circuit is connected to the E-1500 / E-1000, the displayed voltage is 0.0V.

- Solar irradiance (G) rectangle: Displays the incident irradiance on the reference cell measured with the E-Sens. To obtain a coherent irradiance value, the cell must have been installed in the same plane as the circuit under test (see section 4.4.1), and the E-1500 / E-1000 must have been configured with the reference cell calibration values (see section 5.5.6.).

This rectangle is also displayed with a color code representing the suitability of the incident irradiance for performing measurements:

- Green: Irradiance between 800 and 1,200 W/m². Indicates an optimal moment for performing an I-V curve measurement.

- Yellow: Irradiance between 600-800 W/m². Indicates a suitable moment for performing an I-V curve measurement, though not optimal. The error may be slightly higher than at higher irradiances but still within acceptable margins.

- Red: Irradiance below 600 W/m². I-V curve measurements can be performed, but results should not be considered conclusive. The error in extrapolation to STC conditions is significant and may lead to inconsistent results.

- Cell Temperature (TC) rectangle: Displays the temperature of the circuit under test in degrees Celsius. Similar to the irradiance rectangle, different situations can occur:

- If communication with the E-Sens is established when turning on the equipment, the measurement will be displayed in °C in the rectangle.

- If communication with the E-Sens is not established when turning on the equipment, nothing will be displayed in the rectangle.

- If the values received from the E-Sens are out of range, the symbol N/A will be displayed with a one-second blinking.

- If communication with the E-Sens is lost, the N/A symbol will be displayed continuously.

5.2.2. Main Screen Controls

5.2.2.A. TC Sensor Selection

This rectangle displays the temperature sensor in use and allows you to select one of the three available options (reference module, PT-1000, or E-Temp) that you want to use. The installation of these sensors or the adjustment of their parameters is explained in detail in their respective sections 4.5.2 and 5.5.6.B.
Additionally, this rectangle displays a three-digit code indicating the configuration of the three PT-1000 sensors (in case this method is selected as the temperature sensor), where:

  - 0: Off
  - 1: Tm (Module temperature)
  - 2: Tsen (Cell temperature)
  - 3: Ta (Ambient temperature)

For example, the PT-1000 code: 123 indicates that PT-1000-1 is configured to measure the temperature of the circuit under test, PT-1000-2 is configured to measure the temperature of the reference cell, and PT-1000-3 is configured to measure the ambient temperature.

5.2.2.B. Access to Settings Menu
Pressing the "Settings" button provides access to the settings menu where the configuration of the E-1500 / E-1000 is carried out. For more details on the available settings, refer to section 5.5.

5.2.2.C. Save I-V Curve
This button allows you to save the last measured I-V curve. To do this, simply press the "Save Curve" button. For a more detailed explanation of the saving process and how the name influences this process, please refer to section 5.12.

5.2.2.D. Measure I-V Curve

This button serves as a trigger to perform the measurement of an I-V curve. For more details on the measurement process, refer to section 5.3.

5.2.2.E. Name

Clicking on this box opens a keyboard that allows you to enter the filename under which the measurements will be saved. For a more detailed explanation of the saving process and how the name affects it, please see section 5.4.

IMPORTANT: Since the equipment adds the measurement number to the selected name **(see section 5.4.)**, it is recommended not to use names ending in a hyphen followed by a number from 000 to 999. For more information, refer to section 5.4.

5.3. I-V Curve Measurement

The E-1500 / E-1000 has been designed to simplify the I-V curve measurement of photovoltaic systems as much as possible. However, the process of measuring I-V curves under actual sunlight is complex, and certain instrument configurations are required to obtain accurate and consistent results. This section describes all the necessary details for the correct setup and operation of the instrument.

5.3.1. General Considerations

Once the irradiance and temperature sensors are installed, and the E-1500 / E-1000 is configured with module, generator, and sensor values, you are ready to carry out I-V curve measurements.

The measurement of an I-V curve is performed in three phases: pre-measurement preparation, I-V curve measurement, and preparation for the next measurement.

The actual measurement of the I-V curve typically takes between 30 and 300 milliseconds, although it will depend on the circuit under test and the irradiance and temperature conditions. The first measurement may take longer than usual during which the equipment is automatically optimizing the measurement time and points. In this case, a message will appear at the top of the screen indicating:

"Adjusting measurement time"

Once the equipment has adjusted the measurement time, it will not be necessary to readjust the measurement time as long as the measurement conditions remain stable (i.e., irradiance, temperature, or type of circuit under test such as module model or module string length).

However, it should be noted that the complete measurement cycle takes about 3-4 seconds as the equipment needs to prepare for the next measurement.

At the beginning of the measurement, the "Measure I-V Curve" button will turn red, indicating that the measurement has started. First, the equipment will check whether the voltage of the module under test is within the measurement limits. If it is not, a warning will be displayed on the screen, and the I-V curve measurement will not be performed. If the voltage is within the permissible range, the measurement of the I-V curve will launch automatically.

After completing the I-V curve measurement, it will be displayed on the screen. However, the equipment will remain locked for an additional 3 seconds to prepare for the next measurement. When the equipment finishes the complete measurement cycle, the measurement button will return to blue, indicating that the next measurement can be performed.

At this point, the measurement must be saved manually if automatic saving has not been activated (see section 5.4). Once the file has been saved successfully, the name of the file and the message "-saved" will appear in the name rectangle.

NOTE: On days with variable cloudiness, the measurement time may be longer than indicated above as the equipment needs to continuously adjust the measurement time to adapt to changing conditions. In the case of measuring modules with defects, the measurement time may also increase or the measurement may not be possible at all. In these cases, a message will appear at the top of the screen indicating "Adjusting Measurement Time" to alert the user to the situation.

⚠️ **IMPORTANT:** Do not disconnect the measurement cables until the I-V curve is displayed on the screen. Once the I-V curve is displayed, you can disconnect the circuit under test and connect the next circuit, even if the complete cycle has not finished. This helps reduce the duration of measurement campaigns.

To measure an I-V curve, the E-1500 / E-1000 offers several options:

- Manual measurement

- Auto-measurement

- Continuous measurement

⚠️ **IMPORTANT:** If you want to obtain measurement results extrapolated to STC conditions, the first step must be the installation of irradiance and temperature sensors and connecting them to the E-Sens (see section 4.4). Additionally, ensure that the measurement conditions are appropriate (see section 3).

⚠️ **IMPORTANT:** Make sure you have correctly configured the characteristic values of the module and the generator under test, as well as the sensor settings (see sections 5.5.4-5).

⚠️ **IMPORTANT:** Before connecting the E-1500 / E-1000 to the circuit under test, ensure that it is within the voltage and current limits accepted by the equipment. Connecting the E-1500 / E-1000 to a circuit with voltages higher than 1,000 V and currents higher than 20 A can cause irreparable damage to the equipment.

5.3.2. Manual Measurement

To carry out a manual measurement, follow these steps:

1. Connect the E-1500 / E-1000 to the circuit under test (section 4.5).

2. Verify that the open-circuit voltage displayed on the E-1500 / E-1000 is correct and within the equipment's limits. You can see this voltage in the VOC rectangle on the main screen (section 5.2).

3. Press the "Measure Curve" button on the main screen.

Upon completing the above steps, and if the circuit's voltage is within the measurement range, the "Measure Curve" button will turn red, and the equipment will initiate the measurement process (section 5.3.1). Additionally, before saving the measurement (or having it saved automatically if this option is enabled, section 5.4.2), the steps for recording the barcode (section 5.3.5) or measuring the temperature using the E-Temp (section 5.3.6) must be performed if these options are activated.

5.3.3. Auto-Measurement

The E-1500 / E-1000 features a very practical "Auto Measurement" function that allows the user to free their hands during the measurement process to connect and disconnect the circuits under test or take notes of the measurements.

This option is intended to be used in conjunction with the "Auto Save" option (section 6.2.2) to enable the entire process of measuring and saving the I-V curve without the need to operate the equipment. Furthermore, if used in combination with the Android App, it allows the equipment to be carried in a backpack, completely freeing the operator's hands.

This function is also compatible with the "Barcode" (section 5.3.5) and "E-Temp" (section 5.3.6) options.

⚠️ **IMPORTANT:** This function is not compatible with "Continuous Measurement" (section 5.3.4). If both options are activated simultaneously, an error message will be displayed when attempting to measure the I-V curve, and both options will be deactivated, requiring one of the two to be reactivated.

The auto-measurement process varies based on the chosen options. The common sequence for all options is as follows:

1. Enter the settings menu and press the "Auto Measurement" button.

2. The button will turn red, indicating that the option is active.

3. Also select the "Auto Save" option if you want to use this option in conjunction.

4. Return to the main screen.

5. Connect the E-1500 / E-1000 to the circuit under test.

6. If the circuit's voltage is within the equipment's range, the automatic measurement process will initiate at this point (section 6.1.4).

7. Once the I-V curve measurement is complete, a first beep will be emitted.

8. After the beep, the user can disconnect the circuit under test.

After completing the above sequence, several paths can be taken based on the selected options.

A. If no additional options are selected:

9A. The I-V curve will be displayed on the screen, and the characteristic values of the curve will be shown.

10A. The equipment will remain idle for about three seconds while it prepares for the next measurement.

11A. Upon completing the setup for the next measurement, the equipment emits a double beep indicating that it is ready for the next measurement. However, the equipment will not initiate another measurement until it detects a disconnection and reconnection or until a manual measurement is initiated.

12A. If the user is satisfied with the obtained result, they can save the curve manually. Once the curve is saved, the user can connect the equipment to the next circuit under test.

13A. If the desire is to repeat the measurement of the same circuit under test, it can be done manually or by disconnecting and reconnecting the circuit.

⚠️ **IMPORTANT:** The E-1500 / E-1000 automatically detects if the equipment has been disconnected and reconnected to a new circuit. For this to happen, there must be a time gap of more than one second between disconnection and reconnection. Additionally, the E-1500 / E-1000 must detect a voltage lower than 5 V during disconnection and higher than 5 V during reconnection. If these criteria are met, the equipment will initiate a new measurement process automatically.

⚠️ **IMPORTANT:** In some cases, especially when measuring module strings, it's possible that due to capacitive effects of the photovoltaic field, the measured voltage may exceed 5V when disconnecting only one of the terminals. In such cases, it will be necessary to disconnect both terminals to use the auto-measurement function, or alternatively, opt for manual measurement.

B. If only the "Auto Save" option is selected:

9B. The I-V curve will be displayed on the screen, and the characteristic values of the curve will be shown.

10B. The equipment will proceed with the automatic saving of the I-V curve (section 5.4.2.) and the preparation for the next measurement.

11B. The equipment will remain idle for about three seconds while it prepares for the next measurement.

12B. After the three seconds have passed, a double beep will be emitted, and the equipment will be ready for the next measurement. However, the equipment will not initiate another measurement until it detects a disconnection and reconnection or until a manual measurement is initiated.

C. If the "Barcode" option is selected:

9C. The I-V curve will be displayed on the screen, and the characteristic values of the curve will be shown.

10C. The following message will appear on the screen: "Waiting for Barcode."

11C. The E-1500 / E-1000 will remain idle until a barcode is read using the associated reader.

12C. Once the barcode is read, a second beep will be emitted.

13C. If the "Auto Save" option is active, the I-V curve will be saved automatically, and a double beep will be emitted. If this option is not activated, the user will need to save the I-V curve manually.

14C. The equipment is ready for the next measurement. However, the equipment will not initiate another measurement until it detects a disconnection and reconnection or until a manual measurement is initiated.

D. If the "E-Temp" option is selected:

9D. The I-V curve will be displayed on the screen, and the characteristic values of the curve will be shown.

10D. The following message will appear on the screen: "Waiting for E-Temp Measurement."

11D. The equipment waits for the user to measure the number of temperature points selected. The user must wait a minimum of

300 milliseconds between consecutive temperature measurements.

12D. Once the three temperature measurements are obtained, the E-1500 / E-1000 will emit a second beep.

13D. If the "Auto Save" option is active, the I-V curve will be saved automatically, and a double beep will be emitted. If this option is not activated, the user will need to save the I-V curve manually.

14D. The equipment is ready for the next measurement. However, the equipment will not initiate another measurement until a disconnection and reconnection is detected, or until a manual measurement is initiated.

5.3.4. Continuous Measurement

This function is intended to keep the E-1500 / E-1000 fixed on the same circuit under test for an extended period of time, with the equipment periodically and automatically measuring the I-V curve. To use this function, the "Auto Save" feature must be used to save the results of each measurement automatically. In this mode, the "Barcode" and "E-Temp" functions cannot be used.

To configure this option, the user should:

1. Enter the settings menu.

2. Press the "Continuous Measurement" button.

3. A sub-menu will appear to configure the measurement period.

4. Select the measurement period, which should be between 15 and 600 seconds.

5. Exit the sub-menu.

6. Upon exiting the sub-menu, the "Auto Save" function will be automatically activated. If you do not wish to use the "Auto Save" function, it can be deactivated.

7. Press the "Exit" button to return to the main screen.

8. At the top of the main screen, a message will appear indicating that continuous measurement is active and the selected period.

9. Connect the circuit under test.

10. Press the "Measure Curve" button to start continuous measurement.

11. A new red button labeled "Stop Measurement" will appear on the main screen. To stop the continuous measurement process, it will be necessary to press this button twice while the "Measure Curve" button is blue.

12. The E-1500 / E-1000 will perform the I-V curve measurement and save it automatically if the "Auto Save" option is selected.

⚠️ **IMPORTANT:** In continuous measurement mode, it will not be possible to save the measured curves if the "Auto Save" option is not selected. After 15 seconds of starting the continuous measurement process, the device's screen will turn off to conserve battery. If you occasionally want to monitor the continuous measurement process, you can turn the screen back on by pressing any part of it. The screen will turn off again after 15 seconds.

⚠️ **IMPORTANT:** If touching the screen doesn't turn it on, wait for about three seconds and try again. It is possible that touching the screen during an I-V curve measurement may cause the equipment not to respond.

⚠️ **IMPORTANT:** The start of each measurement always begins precisely at the selected period's exact moment. However, if the measurement time needs to be adjusted in any measurement (especially due to varying irradiance conditions), it may result in the measured curves not being taken at exact intervals.

⚠️ **IMPORTANT:** This function is not compatible with "Auto-measure" (section 5.3.3). If both options are activated simultaneously, an error message will be displayed when attempting to measure the I-V curve, and both options will be deactivated, requiring one of the two to be reactivated.

5.3.5. Barcode Registration

This option facilitates the identification and data analysis when measuring modules, associating the measurement data with the corresponding barcode.

To enable this option, it is necessary to request it at the time of purchasing the equipment. This way, the I-V curve tracer will be supplied with a barcode reader and the option pre-activated.

When performing a measurement, make sure to activate this option (section 5.5.10.), which will be highlighted in red. Connect the barcode reader, and it will emit a beep to confirm that it is powered on.

Perform the I-V curve measurement as usual, and afterward, you will see the message: "Waiting for Barcode." The equipment will remain in standby mode until you perform the reading. This is when you should use the barcode reader to scan the module's barcode. If the reading is successful, the code will appear at the top of the screen, and a beep will sound.

It's important to scan the barcode only when prompted by a message on the E-1500 / E-1000 screen. Otherwise, the scanned code may not be correctly associated with the measured I-V curve

5.3.6. Temperature Measurement Using E-Temp

If the option for temperature measurement using E-Temp is selected (section 5.5.6.B), it allows registering the temperature with E-Temp after each I-V curve measurement.

This enables a faster and simpler temperature recording without the need for making relevant connections on each module (Figure 5.5).

If this option is activated, you will be prompted to record one or several temperature points (it is recommended to use the points defined in Figure 3.1. as detailed in the IEC 61853-1 standard). The user should wait a minimum of 300 milliseconds between consecutive temperature measurements.

While temperatures are being recorded, the following message will appear on the screen: "Waiting for E-Temp Measurement." The E-1500 / E-1000 will remain inactive until the three temperatures are read. Once read, the E-1500 / E-1000 will emit a beep, and the regular measurement process will continue. To record a temperature, simply aim at the desired area and press the E-Temp button.

Figure 5.4. Barcode registration.

Figure 5.5. Temperature measurement via E-Temp.

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⚠ **IMPORTANT:** To obtain the most reliable temperature measurements, position the E-Temp at a distance between 3 and 5 centimeters from the module and at a 90-degree angle to it.

5.3.7. Measurement Process Results

Once the I-V curve measurement is complete, the results will appear immediately on the screen (Figure 5.6.). Only when using the "E-Temp" option will it be necessary to measure the three temperature points before the results are displayed on the screen.

If you are correctly receiving irradiance and temperature data from the E-Sens, two curves will appear on the screen: one in white and the other in green. The white curve represents the actual measurement, while the green curve represents the extrapolated result under STC conditions. If you do not wish to view the green curve (STC conditions), you can deactivate this option as detailed in section 5.5.1. The results for PM, VOC, and ISC displayed correspond to the results of the curve extrapolated to STC (if calculated). These results can be used to compare the obtained performance with the manufacturer's catalog values.

If irradiance and temperature conditions are not received from the E-Sens, extrapolation to STC conditions will not be possible. Therefore, only the white curve (actual measurement) will be displayed, and the results for PM, VOC, and ISC displayed will correspond to the measured curve. In this case, the results cannot be compared with the manufacturer's catalog values.

Once the curve is measured, the process will continue based on the selected measurement options (see sections 5.3.2-5.3.4). Additionally, the file name will change, incrementing by one and displaying the actual name under which the curve will be saved if the user chooses to save it. For more information about the format and content of the saved I-V curve measurement file, refer to section 5.4.3.
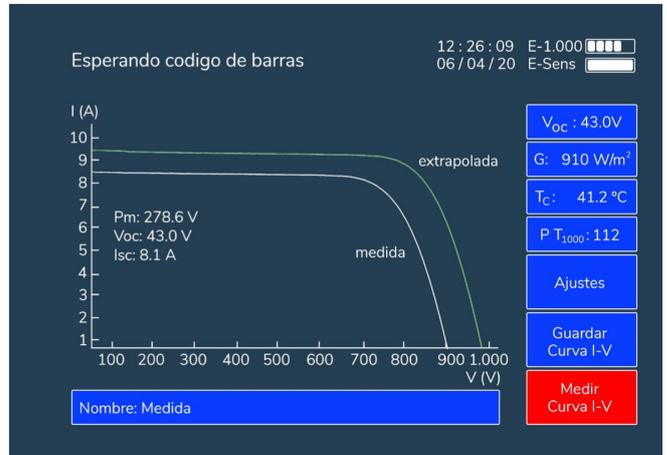
Figure 5.6. Measurement of the I-V curve.

5.4. Saving I-V Curve

The file will be saved with the name displayed in the "Name" box. This name is automatically modified by the device by adding, at the end of it, the measurement number (the quantity of measurements performed with the same name).

As a result, the final name is composed of the user-configured base name (section 5.2.2.E.) followed by a hyphen, the curve number (which is updated automatically), and the ".csv" extension at the end. An example of the saved name is shown below: · Measure-009.csv

Before saving a curve with the assigned name, the device checks the SD card to ensure that no file with that name already exists. If a file with the same name is found, the device will automatically increase the measurement number, modify the name with this new number, and save the curve under the new name. The device starts from number 1 and has a limitation of up to 999 curves with the same name. Once this number of curves is reached, a warning will be displayed indicating that the limit has been reached:

"LIMIT OF CURVES WITH THE SAME NAME."

IMPORTANT: To avoid issues with tracking measured curves after measurements are completed, it's advisable not to have curves stored in the SD card with the same base name as the new curves to be measured. If curves with the same base name exist, the E-1500 / E-1000 could assign non-consecutive numbers to the new measurements.

IMPORTANT: The device sequentially adds numbers, starting from number 1. This could result in overwriting a curve if the same base name as in previous measurements is used. It's recommended to change the base name for each new sequence of measurements to avoid overwriting files. Two options are available to save the last measured I-V curve:

- Manual saving

- Automatic saving

In either case, the device automatically assigns a name to the measurement to streamline the saving process, especially when measuring a large number of curves, reducing the total time spent. If the curve is successfully saved, the message "-Saved" will appear to the right of the file name within the file name rectangle.

5.4.1. Manual Saving

Allows you to save the last measured curve. Upon pressing the button, the following cases may occur:

- If there is a measured curve pending to be saved, the button will change to red, indicating that the curve is being saved. Once the curve is saved, the button will return to blue, and the message "-Saved" will appear to the right of the file name within the file name rectangle.

- If no new curves have been measured, or if the last curve is already saved, a message will appear in the center of the screen indicating

"NO CURVE MEASURED."

5.4.2 Automatic Saving

When the automatic saving option is activated, a saving process occurs after each measurement, whether performed manually, automatically, or continuously (see sections 5.3.2-4).

To activate this option, enter "SETTINGS" and select the automatic saving option. The blue box will change to red, indicating that the option is activated.

NOTE: Remember that if certain options, such as barcode registration or temperature measurement using E-Temp, are activated, certain steps need to be taken after measuring the I-V curve before the data is saved (see section 5.3).

5.4.3. Saved File Format

The I-V measurement data is saved in a ".csv" file format without any encoding, making the data directly accessible from spreadsheet programs like Excel, LibreOffice, or any text editor.

Figure 5.7 shows the content of an I-V curve file generated by the E-1500 / E-1000. The first columns correspond to the measured I-V curve (V, I, and P), followed by the extrapolated I-V curve at STC (V*, I*, and P*). On the right side (columns 8-13), the parameters of the extrapolated I-V curve (PM*, VOC*, ISC*, VM*, IM*, and FF*) are shown in the second row, and the parameters of the measured I-V curve (PM, VOC, ISC, VM, IM, and FF) are shown in the fourth row.

Additionally, the nominal module parameters at STC (provided by the manufacturer) are displayed if they were added to the E-1500 / E-1000 prior to the measurement (PM_Mod, VOC_Mod, ISC_Mod, VM_Mod, IM_Mod, FF_Mod), as well as the measurement conditions (irradiance and temperature), variation parameters with irradiance and temperature (Beta_Mod (%) and Alfa_Mod (%)), and an estimation of the series resistance (RS). Additionally, the barcode is displayed if it was measured.

V(V)	I(A)	P(W)	V*(V)	I*(A)	P*(W)
0.00000	1.954.337	0.00000	0.00000	1.974.333	0.00000
4.877.671	1.952.251	95.224.384	16.099.258	1.964.796	316.317.529
5.837.055	1.950.687	113.862.695	17.058.644	1.963.222	334.899.072
6.802.567	1.949.817	132.637.585	18.024.156	1.962.346	353.696.265
7.768.761	1.949.218	151.430.115	18.990.350	1.961.744	372.542.017
8.739.314	1.948.653	170.298.926	19.960.904	1.961.175	391.468.286
9.702.918	1.948.125	189.024.988	20.924.509	1.960.643	410.254.980
10.656.038	1.947.625	207.539.697	21.877.629	1.960.140	428.832.227
11.606.977	1.947.137	226.003.809	22.828.569	1.959.649	447.359.912
12.555.873	1.946.631	244.416.479	23.777.466	1.959.139	465.833.691
13.505.859	1.946.124	262.840.747	24.727.452	1.958.629	484.319.141
14.454.482	1.945.883	281.267.334	25.676.074	1.958.387	502.836.963
15.406.239	1.945.384	299.710.522	26.627.832	1.957.885	521.342.285
16.353.773	1.945.165	318.107.886	27.575.366	1.957.664	539.833.154
17.298.991	1.944.801	336.430.908	28.520.584	1.957.298	558.232.715
18.243.259	1.944.509	354.741.870	29.464.853	1.957.004	576.628.467
19.187.250	1.944.148	373.028.613	30.408.844	1.956.641	594.991.992
20.129.881	1.943.634	391.251.294	31.351.477	1.956.124	613.273.730
21.072.784	1.943.380	409.524.194	32.294.379	1.955.867	631.635.205
22.019.640	1.942.763	427.789.453	33.241.235	1.955.247	649.948.291
22.959.546	1.942.384	445.962.646	34.181.143	1.954.866	668.195.508
23.899.043	1.942.005	464.120.703	35.120.639	1.954.484	686.427.393
24.837.726	1.941.593	482.247.656	36.059.323	1.954.070	704.624.316
25.775.052	1.941.211	500.348.145	36.996.649	1.953.685	722.797.900
26.709.232	1.940.777	518.366.699	37.930.829	1.953.248	740.883.301
27.648.459	1.940.299	536.462.891	38.870.056	1.952.768	759.041.846
28.586.731	1.939.658	554.484.814	39.808.328	1.952.122	777.107.080
29.519.965	1.939.213	572.455.078	40.741.565	1.951.674	795.142.725
30.452.792	1.938.594	590.355.908	41.674.393	1.951.051	813.088.574
31.382.755	1.937.949	608.181.641	42.604.355	1.950.401	830.955.957
32.313.538	1.937.176	625.970.020	43.535.138	1.949.624	848.771.484
33.242.413	1.936.582	643.766.504	44.464.017	1.949.026	866.615.234
34.173.468	1.935.820	661.536.816	45.395.071	1.948.259	884.413.672

Pm*(W)	Voc*(V)	Isc*(A)	Vm*(V)	Im*(A)	FF*	Fecha medida	Hora medida
20332.40	1400.68	19.743	1108.86	18.336	0.735	26/05/2022	10:30:07
Pm(W)	Voc(V)	Isc(A)	Vm(V)	Im(A)	FF	Num Serie Tracer	Num Serie E-Sens
18170.91	1288.44	19.543	1004.70	18.086	0.722	E15130222	ES0321121
Pm_mod(W)	Voc_mod(V)	Isc_mod(A)	Vm_mod(V)	Im_mod(A)	FF_mod	Mod_ser	Mod_par
370.00	48.40	9.930	39.70	9.320	0.770	28	2
G(W/m2)	Tc(°C)	Beta Mod(%)	Alfa Mod(%)	Rs	Codigo de Barras		
978.19	52.67	0.286	0.057	5.314			
Tc_Cel(°C)	PT1-Tmod(°C)	PT2-Tmod(°C)	PT3-Tmod(°C)	Tc_IR_1(°C)	Tc_IR_2(°C)	Tc_IR_3(°C)	Tc_IR_4(°C)
46.40	-99.00	-99.00	-99.00	52.67	0.00	0.00	0.00

Figure 5.7 shows the content of an I-V curve file generated by the E-1500 / E-1000.

The last row displays temperature measurements corresponding to: Calibration cell temperature, the three temperatures from PT-1000 channels, and the four temperature measurements obtained with E-Temp.

In columns 14 and 15, certain paired data are displayed, such as: the date and time of the measurement, the serial number of the curve tracer and the used E-Sens, or the series and parallel module configuration of the generator.

5.5. Settings

An image of the settings menu is shown in Figure 5.8. All necessary equipment configurations can be carried out from this menu.

Three types of functions or configurations can be performed from the settings menu: operating options, parameter configuration, and additional functions.

Operating options can be directly activated or deactivated from the main screen of the settings menu by touching the corresponding button. When the button is blue, it indicates that the option is deactivated, and when the button is red, it indicates that the function is activated. The operating options include: Show STC curve, APK Connect, Auto-measure, Auto-save, Continuous Measurement, and Barcode. Among these options, only Continuous Measurement requires additional configuration.

Parameter configuration options are those that modify certain equipment parameters, whether general parameters like date and time or parameters related to the measurement process. Pressing these functions opens a second screen where the selected adjustment can be configured. These options are: Module Settings, Generator Settings, Sensor Settings, and Others (where options such as Set Date and Time and Set Language are located).

The additional functions are those that perform an extra function beyond the I-V curve measurement, such as generating a report or updating the firmware.

All of these functions are described in detail in the following sections.

Figure 5.8.A: E-1500 Settings Menu.

5.5.1. Bifacial Measurement

The I-V curve tracer E-1500 / E-1000 has the capability to measure I-V curves for bifacial modules. To activate the bifacial operation mode of the equipment, press the "Bifacial Measurement" button. When the button is highlighted in red, the option will be activated. To deactivate it, press the button again. The background color will return to blue.

5.5.2. Load Module

The E-1500 / E-1000 allows you to load parameters for different modules in a simple and quick manner. This provides significant flexibility when working with multiple photovoltaic plants or plants using different types of modules.

To access the module loading screen, navigate to the "Settings" menu and select the second button labeled "Load Module." Inside this menu, you will find 10 configurable slots where module data is stored (refer to Figure 5.9). To choose a specific slot, just tap on the desired slot, and the corresponding parameters will be loaded.

Figure 5.8.B: E-1000 settings menu.
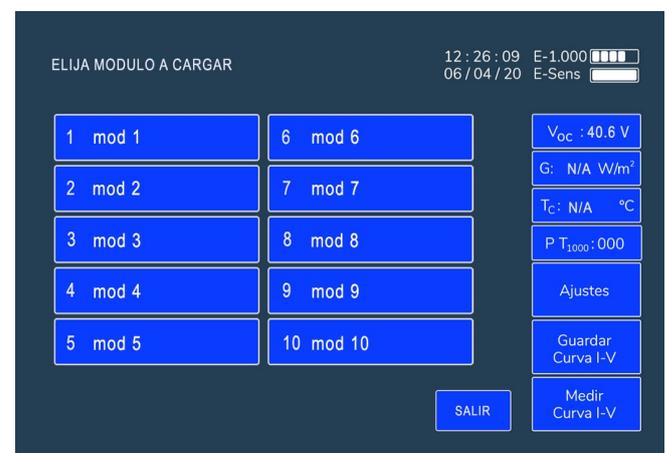
Figure 5.9: Module Loading Screen.

When you tap on the desired slot, the screen will switch to the module settings screen (refer to Figure 5.10). On this screen, you can verify that you are indeed loading the desired parameters and also modify them if needed, then save the changes (Section 5.5.4.B).

Keep in mind that to modify the parameters, you should tap on the corresponding value field and enter the digits using the number buttons on the left, even if they are leading zeros.

Remember, you can save the settings from this window by tapping on the "Save" button, selecting the desired slot, and choosing a name for the settings that will be displayed, with a maximum of 6 characters.

Figure 5.10: Module Settings Screen.

5.5.3. Measurement Settings

Press the "Measurement Settings" button to access the submenu.

Figure 5.11: Measurement settings screen.

5.5.3.A. G Limit

The E-1500 / E-1000 allows you to set a lower limit for the irradiance value when performing I-V curve measurements. This is useful to ensure measurement reliability. The IEC-XXX standard stipulates that measurements should be taken with an irradiance greater than 800 W/m2. However, this value may vary based on project criteria.

Press the blue "G Limit" button to access the submenu where you can set the solar radiation value to be used as the lower limit. Once activated, the button will turn red, and the equipment will not allow measurements if the radiation is below the specified value. To deactivate it, press the button again, and it will return to blue.

It is not recommended to perform measurements below an irradiance of 600 W/m2.

5.5.3.B. V Range

The "V Range" button is used to manually select the voltage range for operation. To do this, press the button until the desired voltage range is displayed.

There are four measurement ranges in the E1500:

- 5 – 160 V

- 160 – 450 V

- 450 – 900 V

- 900 – 1500 V

The E-1500 / E-1000 automatically measures within a wide voltage range. For safety reasons, it is necessary to select the voltage range in which you will be working. If you select a range higher than what you will actually work with, measurement inaccuracies may occur. If you are working at the boundary between two ranges, select the higher range.

5.5.3.C. Measurement Tolerance

The E-1500 / E-1000 calculates the percentage errors of the measurements relative to acceptable results, based on a configurable tolerance value (Figure 5.12). To do this, you must enter the accepted percentage error for each of the three parameters:

- Short-circuit current (Isc)

- Open-circuit voltage (Voc)

- Maximum power (Pm)

To input the values, first press the box of the parameter you want to fill. Then, press the buttons with the numbers on the left. Remember that you should fill in all the dashes, even if they are leading zeros. Finally, press the variable button to save the result.
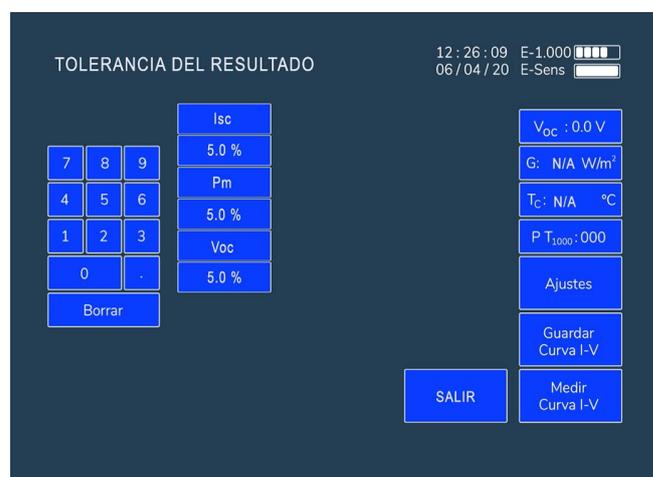
Figure 5.12: Measurement Tolerance.

Once configured, when you take a measurement, the obtained results will be displayed on the measurement screen. On this screen, the results of the measured curve are shown in three lines at the bottom left of the graph, and to the right of these values, the percentage differences with respect to the values entered in the module settings are indicated within parentheses (Figure 5.13.). Similarly, color codes are used to indicate whether the values are within the configured acceptable tolerance range, with values within the range shown in green and values outside the range shown in red.
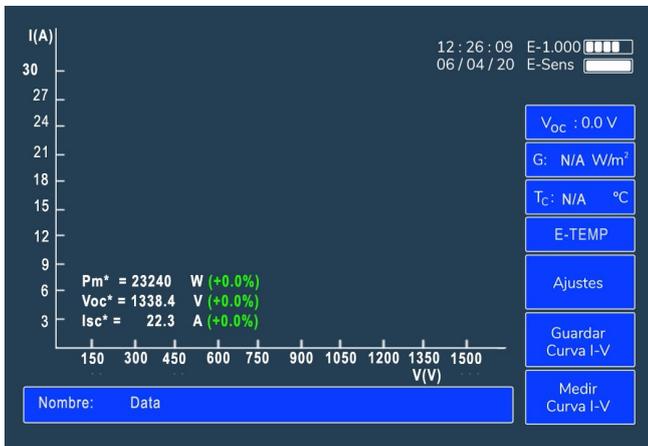
Figure 5.13: Results on the measurement screen of the team.

5.5.3.D. Tc Comp

This option automatically performs the temperature compensation between the cell and the backsheet as described in the IEC-60891 standard.

Press this button to activate the temperature compensation. Once the button is activated, it will be displayed with a red background. Similarly, you can deactivate the option in the same way by pressing the button, and it will be displayed with a blue background.

5.5.4. Module Settings

⚠ **IMPORTANT:** Before starting a new measurement campaign, make sure that the configured values in this section match those of the module under test.

For proper extrapolation of the measured I-V curves, it is necessary to input the characteristic parameters of the module under test, which are typically provided by the manufacturer. The E-1500 / E-1000 estimates the values of the series resistance (RS) and the temperature coefficient of variation of RS (k) based on these parameters, using an internal algorithm. Additionally, these values are required for accurate extrapolation of the I-V curve, so any errors or variations in these values will lead to errors in the curve extrapolation.

To configure the module parameters, access the menu:

· Settings -> Module Settings

Upon entering this submenu, the screen shown in Figure 5.12 will appear, indicating that you are in the "Module Settings" menu through a message at the upper left. The user must configure all the parameters of the module under test according to the catalog values and under standard test conditions (STC). These values can be found in the module model's datasheet or on the sticker attached to the back of the modules, which includes key information.

The values that need to be configured include:

· VOC: Open-circuit voltage under STC (V)

· ISC: Short-circuit current under STC (A)

· VM: Voltage at the maximum power point under STC (V)

· IM: Current at the maximum power point under STC (A)

· Alfa (α): Coefficient of variation of current with temperature

· Beta (ß): Coefficient of variation of voltage with temperature

· Ns: Number of cells in series

Figure 5.14: Module settings image

Vt, Rs, and k are calculated by the equipment based on the values provided earlier.

To configure each of these values, you should select them individually by clicking on the box with the parameter's name that you want to modify. At that moment, the box with the name of the selected parameter will change to red, and the configuration of that parameter will be enabled, displaying dashes instead of numbers (see Figure 5.14). As you input the desired value, the numbers will automatically fill in the corresponding positions.

⚠️ **IMPORTANT:** It is necessary to input values in all the spaces, even if they are zeros to the left or right of the decimal point.

⚠️ **IMPORTANT:** The values configured in this menu are saved in memory and remain configured even if the equipment is turned off. If you switch to a different module model under test, you must reconfigure these values.**

⚠️ **IMPORTANT:** All modules must be of the same type and category, with the same nominal value for the mentioned parameters. Otherwise, the adjustment could yield inconsistent results.**

Once you have entered the parameters, press the button for the variable's name to set the new value in memory. The name will change back to blue, and the newly configured value will appear in the immediately lower box. If the value displayed is not the one you configured, enter it again and ensure that you input numerical values in all spaces with dashes.

5.5.4.B. Save and Load Module Configurations

Once values have been entered in the module settings, click on "Save" and select one of the available slots to save the module configuration. To do this, you will need to enter a name of up to 6 characters.

From this point, you can quickly and easily load the module values by going to Settings -> Load Module and selecting the desired slot.

The equipment allows you to have up to 10 memory slots with different module configurations.

5.5.5. Generador Settings

⚠️ **IMPORTANT:** Before starting a new measurement campaign, make sure that the configured values in this section match those of the generator under test.

For proper extrapolation of the measured I-V curves, it is necessary to configure the "Generator Settings" (section 5.5.5 and Figure 5.13) with the number of modules in series and parallel. If measuring a single module, set the value of 1 for the number of modules in series and parallel.

To configure the parameters of the generator under test, go to:

- Settings -> Generator Settings

Upon entering this sub-menu, the screen displayed in Figure 5.15 will appear, indicating that you are in the "Generator Settings" menu, with a message at the top left.

To configure one of the variables (number of modules in series or parallel), press the name of the variable you want to configure. This box will change to red, and the numerical value of that variable will be replaced by dashes, indicating all the digits that need to be entered to configure the variable (see Figure 5.16). As you input the desired value, the numbers will automatically fill in the corresponding positions.

Figure 5.15. Generator settings.

Figure 5.16. Generator settings submenu.

⚠️ **IMPORTANT:** It is necessary to input values in all the spaces, even if they are zeros to the left or right of the decimal point.

⚠️ **IMPORTANT:** The values configured in this menu are stored in memory and remain configured even when the equipment is turned off. If you change the generator configuration or if you want to start measuring individual modules, you must reconfigure these values

Figure 5.17. Generator settings submenu.

Once the parameters are entered, press the button of the variable's name again to save the new value in memory. The name will return to blue, and the newly configured value will appear in the box below the name. If the displayed value is not what you configured, enter it again and ensure that values are entered in all spaces with dashes.

5.5.6. Sensor Settings

⚠️ **IMPORTANT:** Before starting a new measurement campaign, make sure that the configured values in this section match those of the used sensor.

For accurate extrapolation of I-V curves, it's necessary to input the characteristic parameters of the sensors used to characterize the measurement conditions. These parameters are crucial for identifying how far you are from the standard test conditions (STC) and thus enabling the extrapolation process to those conditions.

5.5.6.A. Irradiance Sensor

In the irradiance sensor, you need to set the ISC of the reference cell and the alpha coefficient of temperature variation. Both values will be provided in the calibration report along with the rest of the equipment. To set these values, go to Settings, Sensor Settings. In this section, you can adjust both variables. To do this, simply select the name of the variable to be configured. You'll notice that the name turns red, and the numeric value immediately below it is replaced by dashes. Enter the desired value, making sure to input as many digits as there are dashes, including any necessary leading or trailing zeros.

⚠️ **IMPORTANT:** You need to input values in all spaces, even if they are zeros to the left or right of the decimal point.

⚠️ **IMPORTANT:** The configured values in this menu are saved in memory and remain set even if the equipment is turned off. If you switch to a different model of module under test, you must change these values again.

5.5.6.B. Temperature Sensor

In the sensor settings, you need to choose which sensor is in use (PT-1000, reference module, or E-Temp) and configure the corresponding parameters. To do this, go to:

· Settings -> Sensor Settings

Press the central box under the current sensor configurations until the desired selection appears:

· **PT-1000:** In the case of measuring with PT-1000, you need to configure what is being measured with each PT-1000: module under test (Tm), reference cell temperature (Tsen), ambient temperature (Ta), or, if no selection is made, OFF. To do this, press the name of the corresponding PT-1000 (PT_1, PT_2, or PT_3) until the type of measurement corresponding to that PT-1000 appears below it. The selected PT-1000 code will be displayed on the main screen as indicated in section 5.2.1.

· **MOD REF:** If using a reference module, you need to set both its VOC and the beta coefficient of temperature variation. To do this, simply select the name of the variable to be configured. You'll notice that the name turns red, and the numeric value immediately below it is replaced by dashes. Enter the desired value, making sure to input as many digits as there are dashes, including any necessary leading or trailing zeros.

· **E-Temp (IR SENS):** If using the temperature sensor, you can configure the number of measurement points. To do this, press the box labeled "N° Points:1" to increase the number of points by one. When it reaches the maximum, if you press again, the counter will reset to a single measurement point.

Figure 5.18. "Sensor Settings" submenu, configured for IR Sens.

When you measure a curve with this option activated, you will see the message: "WAITING FOR IR MEASUREMENT". In case you have configured multiple E-Temp points, you should press the E-Temp button as many times as indicated on the screen.

5.5.7. Continuous Measurement

This function sets up the E-1500 / E-1000 to measure a curve periodically (Figure 5.19.). By pressing the button, you enter a sub-menu where you can configure the period for continuous measurement. For more information on how to use this mode, refer to section 5.3.4.

Figure 5.19. "Continuous Measurement" submenu.

5.5.8. Auto Save

This function activates the automatic saving feature described in section 5.4.2. To select this option, simply press the auto-save button (Figure 5.17.). It will change to red color indicating that the option is activated.

Figure 5.20. Curve saving message.

5.5.9. Auto Measure

The auto-measure function activates automatic measurement of the E-1500 / E-1000 whenever a new connection is detected. For more information about this option, refer to section 5.3.3. To select this option, simply press the "Auto Measure" button. It will change to red color indicating that the option is activated.

5.5.10. Barcode (Optional)

This option enables barcode reading as detailed in section 5.3.5. To select this option, simply press the "Barcode" button. It will change to red color indicating that the option is activated.

5.5.11. Other

Press the "Other" button to access the submenu.

Figure 5.21. Others menu.

5.5.11.A. Adjust Time/Day

The time adjustment is done in the submenu. To set a new time, follow these steps:

A. Press "Set Time"
B. The button will turn red, and the time will change to hh/mm/ss
C. Enter the desired time using the number keypad on the left. As you type the numbers, they will appear in the corresponding position in the order of entry.

⚠️ **IMPORTANT:** All numbers must be entered, even if they are zeros.

NOTE: If the device detects an impossible time (e.g., hour 30 or minute 75), the device will clear the incorrect selection, and the time must be re-entered from the beginning.

5.5.11.B. Update Firmware

The E-1500 / E-1000 allows updating the firmware of the device to the latest available version using an update file provided by Entec Solar. This file is named "E-1000_update.bin." If the update file does not have this name, the name should be modified for the file to be detected.

IMPORTANT: Ensure that the device has a good battery charge before performing the update. If the device powers off during the update, it may become unusable and require service. Additionally, the device may restart repeatedly during the update due to low battery charge.

To update the firmware, follow these steps:

- Insert the attached file on an SD card.

- Insert the SD card into the device.

- Go to Settings -> Other -> Update Firmware

- The device will indicate that a firmware update has been detected. Press Yes twice, and the device will update.

IMPORTANT: Do not power off the device or remove the SD card during the update process.

5.5.11.C. Generate Report

This option allows generating a summary report of all measurements taken in a single day (Figure 5.10.). This facilitates result analysis and the preparation of the final measurement report.

The report is generated in a '.csv' file format and includes characteristic values of the measured curves.

· G: Irradiance at the time of measurement (W/m2)

· Tc*: Average cell temperature at the time of measurement (°C)

· PM and PM*: Measured power at the maximum power point, PM, and extrapolated to STC, PM* (W)

· VOC and VOC*: Measured open-circuit voltage, VOC, and extrapolated to STC, VOC* (V)

· ISC and ISC*: Measured short-circuit current, ISC, and extrapolated to STC, ISC* (A)

· VM and VM*: Measured voltage at the maximum power point, VM, and extrapolated to STC, VM* (V)

· IM and IM*: Measured current at the maximum power point, IM, and extrapolated to STC, IM* (A)

· FF and FF*: Fill Factor of the measured I-V curve, FF, and of the extrapolated to STC, FF* (Adim)

· Barcode: Barcode of the measured module. If not measured, "N/A" will be displayed.

The daily report does not include the complete I-V curve data. To access the complete data and to plot the measured I-V curve, it will be necessary to access the individual file of each I-V curve (see section 5.4.3.).

ha y hora	Nombre	G	Tc	Pm*	Voc*	Isc*	Vm*	Im*	FF*	Pm	Voc	Isc	Vm	Im	FF	Codig
11:32:35	Curva-001	844.46	44.7	9788.34	1402.9	9.292	1130.33	8.66	0.751	7708.74	1302.89	7.924	1041.9	7.399	0.777	N/A
11:32:47	Curva-002	845.09	44.85	9710.24	1397.13	9.298	1124.73	8.633	0.747	7647.92	1296.88	7.926	1035.96	7.382	0.777	N/A
11:32:59	Curva-003	845.37	44.9	9637.99	1392.35	9.251	1118.8	8.615	0.748	7594.73	1292.21	7.891	1037.66	7.319	0.777	N/A
11:33:05	Curva-004	846.34	45	9750.9	1402.9	9.232	1126.68	8.632	0.753	7686.5	1301.62	7.897	1039.78	7.392	0.777	N/A
11:33:13	Curva-005	846.29	45.1	9674.23	1394.98	9.241	1116.71	8.063	0.75	7622.48	1293.81	7.902	1035.19	7.363	0.777	N/A
11:33:19	Curva-006	844.18	45.2	9682.01	1393.27	9.255	1120.76	8.639	0.751	7607.11	1291.64	7.89	1030.68	7.381	0.777	N/A
11:33:24	Curva-007	843.44	45.25	9763.55	1404.19	9.185	1131.39	8.63	0.757	7667.48	1301.49	7.818	1056.55	7.257	0.777	N/A
11:33:36	Curva-008	841.97	45.5	9660.22	1397.19	9.272	1127.7	8.566	0.746	7562.9	1293.76	7.842	1035.89	7.301	0.777	N/A
11:33:43	Curva-009	841.23	45.6	9630.13	1397.95	9.182	1123.72	8.57	0.75	7534.83	1293.97	7.786	1047.5	7.193	0.777	N/A
11:33:56	Curva-010	842.2	45.7	9693.51	1403.04	9.213	1133.46	8.552	0.75	7585.25	1298.28	7.819	1040.27	7.292	0.777	N/A
11:34:02	Curva-011	842.88	45.8	9515.58	1393.36	9.161	1125.61	8.454	0.745	7449.65	1288.91	7.784	1040.52	7.16	0.777	N/A
11:34:06	Curva-012	842.88	45.85	9446.13	1401.37	9.145	1164.61	8.111	0.737	7407.89	1296.09	7.759	1070.23	6.922	0.777	N/A
11:34:17	Curva-013	841.12	46.05	9896.66	1410.11	9.347	1133.35	8.734	0.751	7726.78	1303.14	7.912	1054.63	7.327	0.777	N/A
11:34:22	Curva-014	839.36	46.1	9851.37	1405.42	9.286	1131.56	8.706	0.755	7672.97	1298.46	7.872	1044.79	7.344	0.777	N/A
11:34:27	Curva-015	839.36	46.1	9748.17	1403.39	9.255	1133.14	8.603	0.751	7592.21	1296.59	7.849	1046.3	7.256	0.777	N/A
11:34:32	Curva-016	839.98	46.15	9804.79	1405.26	9.301	1131.3	8.667	0.75	7641.25	1298.12	7.892	1052.34	7.261	0.777	N/A
11:34:37	Curva-017	839.02	46.15	9676.98	1393.02	9.267	1124.1	8.609	0.75	7531.41	1286.76	7.843	1029.71	7.314	0.777	N/A
11:34:42	Curva-018	837.99	46.15	9681.44	1393.53	9.221	1122.02	8.629	0.753	7524.5	1287.17	7.802	1027.65	7.322	0.777	N/A
11:34:48	Curva-019	839.3	46.2	9731.48	1397.75	9.276	1128.91	8.62	0.751	7578.9	1290.92	7.86	1042.1	7.273	0.777	N/A
11:34:51	Curva-020	840.72	46.2	9723.46	1395.28	9.299	1125.01	8.643	0.749	7580.89	1288.73	7.893	1030.24	7.358	0.777	N/A
11:34:56	Curva-021	840.67	46.3	9590.14	1388.96	9.179	1113.76	8.611	0.752	7472.73	1282.42	7.796	1035.2	7.219	0.777	N/A
11:35:01	Curva-022	841.01	46.3	9862.83	1407.99	9.335	1138.89	8.66	0.75	7690.78	1300.02	7.926	1042.69	7.376	0.777	N/A
11:35:06	Curva-023	841.98	46.3	9739.25	1397.85	9.325	1128.84	8.628	0.747	7602.16	1290.71	7.926	1033.36	7.357	0.777	N/A

Figure 5.22. Example of a daily report generated for the E-1500 / E-1000.

To generate a daily report, follow these steps:

1. Ensure that all the curves for which you want to generate the report are on the SD card and that it is properly inserted into the equipment.

2. Within the settings menu, access the "Generate Report" submenu (see figure 5.23).

3. Select the date for which you want to generate the report and press "Set Date."

4. The button will change to red, and the date will change to dd/mm/yy.

5. Enter the desired date using the number keypad on the left. As you type the numbers, they will appear in the corresponding positions in order of input.

⚠ IMPORTANT: Enter all the numbers, even if they are zeros.

NOTE: If the equipment detects an impossible date (e.g., day 36 or month 15), it will clear the incorrect selection, and you will need to enter the date again from the beginning.

7. Press the "Generate Report" button (see figure 5.23).

8. The screen will display the message "Generating Report."

9. When the report generation is complete, the message "Report Generated" will appear, and the report will be saved on the SD card.

10. Turn off the equipment and access the SD card to download the report to your PC.

Figure 5.23. Image of the sub-menu "Generate Report."

5.5.11.D. Language Selection

Language selection is done by pressing the corresponding blue button until the desired language appears in the text.

5.5.11.E. Sound On / Off

The I-V Curve Tracer E-1500 / E-1000 has a built-in speaker that produces beeps to notify the user when performing certain actions. It is possible to enable or disable the speaker by pressing the corresponding blue button. The option will be enabled when it says "Sound ON" and disabled when it says "Sound OFF".
There is a sound code that associates a meaning with the number of beeps the device produces when performing an action. The code is:

• 1 beep: Measured curve and its extrapolation are correct.

• 1 beep: E-Temp signal received.

• 2 beeps: Curve saved successfully.

• 3 beeps: Curve not measured due to low irradiance.

• 3 beeps: Measured curve and its extrapolation are NOT correct.

• 4 beeps: Curve could NOT be saved. Check if the SD card is inserted in the device.

• 5 beeps: Curve not measured due to variable irradiance.

5.5.11.F. Info

The "Info" button displays the most important parameters of the software and hardware of the device. This way, you can check, for example, the firmware version or the serial number of the device without having to turn it off and on. It has an informational and consultative function if needed.

Figure 5.24. Info Button. Displays information about software and hardware.

5.5.12. APK Connect

Both the I-V Curve Tracer E-1500 and E-1000 have a mobile or tablet app that allows remote control of the device. The app can be downloaded for free from the Google Play Store.

This app enables the device to be carried in a backpack or case, allowing the operator to have hands-free operation for connecting and disconnecting the circuit under test.

Figure 5.25. Use of the E-1500 App through the mobile.

For more information on how to use the app, please refer to section 8 of this manual.

5.5.13. Display STC Curve

This function allows you to select whether you want to display the curve extrapolated to STC conditions on the screen. To activate or deactivate this function, go to Settings -> Display STC Curve. This function is active by default when the device is turned on. If you want to deactivate the function, you need to press the button each time the device is turned on. This option only affects the display. The extrapolated curve continues to be calculated and saved.

6. Configuration and Measurement of Bifacial

6.1. Necessary Material

To measure bifacial I-V curves, you will need the following material, which is provided when you acquire the bifacial measurement option for the E-1500:

• An E-1500 with the I-V curve measurement option enabled. This option is an extra feature for the equipment, and it must be enabled to activate it in the menu.

• An E-Sens with bifacial measurement capability. The first models of E-Sens only allowed connecting one calibrated cell at a time. The latest models now allow connecting two calibrated cells simultaneously, measuring both ISC and both temperatures of their PT1000 sensors. As a general rule, bifacial E-Sens models have one yellow and one blue banana jack, where you can connect the bifacial calibrated cell instead of the two blue banana jacks used previously.

• A second calibrated cell prepared for albedo measurement. This cell has a higher calibration value that allows for more precise measurement of irradiance from the backside of the modules. It also has blue and yellow banana jacks instead of the two blue jacks to indicate where it should be connected to the E-Sens.

6.2 Assembly and Connections

If your E-1500 includes the bifacial measurement option, you can press the blue button "Bifacial Measurement" in the E-1500 menu to activate bifacial measurement. The button will turn red, indicating that bifacial measurement is active, and you can proceed to measure bifacial modules.

Figure 6.1. Similar to 5.8.A but with the "Bifacial Measurement" button in red.

To deactivate the option, simply press the button again. It will turn blue, and you can measure monofacial curves again.

Please note that to measure bifacial curves, you need to measure both the frontal solar irradiance with the monofacial calibrated cell and the albedo solar irradiance on the backside of the modules or strings. This is possible using the aforementioned material.

To achieve this, you must configure both calibrated cells, the monofacial and bifacial ones, in the sensor settings. Additionally, you need to position both cells coplanar to the surface of the photovoltaic modules. The monofacial calibrated cell should face the front, while the bifacial calibrated cell should point towards the backside of the module. You can distinguish both cells because the bifacial cell has a higher calibration value, which allows for better irradiance measurement. Connect both cells to the E-Sens and position them properly. For strings, it is recommended to measure the albedo irradiance at least three modules away from the string's end because the irradiance is higher as you get closer to the string's end due to the "edge effect" of albedo.

Figure 6.3. Bifacial assembly.

Once both cells are mounted, make the following connections to the E-Sens.

- Banana connectors according to their corresponding color code. These connections measure the short-circuit current (ISC) of each cell.
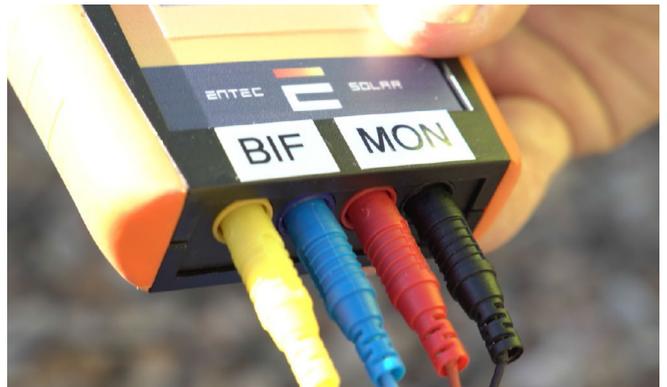
Figure 6.3. banana connectors.

Figure 6.2. Front mounting.

- Green connectors to measure the temperature of the calibrated cells. (Figure X)

 o From the frontal irradiance cell at the Pt1000-3 position.

 o From the albedo or backside irradiance cell at the Pt1000-1 position.

This leaves only one Pt1000 connector available to measure the module's temperature (Pt1000-2, the central connector). When measuring bifacial strings, it is not recommended to use a Pt1000 to measure the module's temperature, as it will cast a shadow on the strings. To address this issue, Entec Solar has devised a solution using the infrared thermometer E-Temp for this purpose.
.

1. Conector SMA para antena externa
2. Ranura para tarjeta uSD
Pt1000-1 Pt1000-3
Pt1000-2
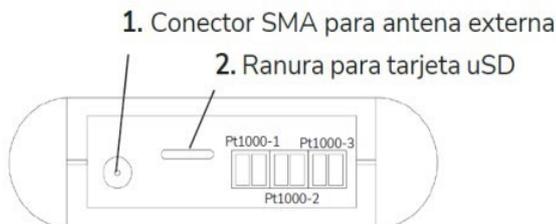
Figura 6.4. Connection of temperature sensors.

6.3 Bifacial Operation Procedure

The bifacial measurement option with the E-1500 has some particularities in its operation mode. These are:

• The irradiance displayed on the main screen will be the sum of the frontal and rear irradiance, considering the bifaciality factor (BF).

• The equation for calculating the total irradiance is:
Gtotal = Gfront + BF * Gback [Eq. X]

• The color code in the irradiance value box is as follows:

 - Red:

  * G total > 1400 W/m2 or G total < 600 W/m2
  * Rear G not received
  * Rear G > 250 W/m2 or Rear G < 5 W/m2

 - Yellow:

  * If G total < 800 W/m2 & G total > 600 W/m2

 - Green:

  * For all other situations

• The extrapolation to standard test conditions (STC) is done using G total.

• PT1000-1 and PT1000-3 are assigned to measure the temperatures of the reference cells. PT1000-1 should have the bifacial or albedo reference cell, while PT1000-3 should have the monofacial or frontal reference cell. PT1000-2 can be used to measure the temperature of the modules, but it is recommended to use the E-Temp for this purpose.

• The I-V curve file contains new information regarding the temperatures and solar irradiance recorded during measurements. Figure X shows these new values saved in the .csv file. These values are:

- G: Value of G total, calculated according to Equation X.

- Tc: Similar to the monofacial mode, this represents Tc. You can obtain it using the E-Temp or with a PT1000 connected only to PT1000-2 of the E-Sens. If the PT1000 option is used, the value should be the same as PT2 or a few degrees higher if the Tc compensation option is enabled (see section X).

- G_front: Irradiance measured by the frontal reference cell.

- G_back: Irradiance measured by the albedo or rear reference cell. This value should always be lower than the frontal irradiance and approximately 5-15% of the frontal irradiance (G_front).

- Tc_cell: In the bifacial mode with the new E-Sens, this value always displays 25 because it is not used.

- PT1 Tcel back: Temperature of the albedo reference cell. It should be lower than PT1_Tcel_front. This value is only shown as a reference and for error control.

- PT1 Tcel front: Temperature of the frontal calibrated cell. It should be higher than PT1_Tcel_back. This value is only shown as a reference and for error control.

- PT1: Measured temperature and measurement mode (TM, Iamb) of PT1000 channel 2.

Figure 6.5. Boxes to use in the bifacial measurement mode.

7. Data Download

7.1 Data Download to PC

The data measured by the E-1500 / E-1000 can be stored on SD cards installed in the equipment. In the case of the E-Sens, data is automatically stored on the microSD card of the equipment. All files are saved in CSV format and have no encoding. We recommend using Microsoft Excel to view or edit the files in their original format.

To transfer the measured data from the equipment to a PC, follow these steps:

• Ensure that the equipment is turned off.

⚠️ **IMPORTANT:** Removing the SD card with the equipment powered on can cause irreparable damage to the card and result in data loss.

• Gently press the SD card inward until you hear a click from the spring. For the E-Sens, you may need to use a thin object to push the microSD card inward.

• Release your finger and wait for the card to pop out of its slot.

• Fully remove the card from the equipment.

• Insert the card into the card reader on your PC, or alternatively, use a USB card reader.

• The PC will automatically detect the inserted SD card.

• Open a file explorer folder on your PC and navigate to the directory of the SD card.

• Copy the files from the SD card directory to the destination directory on your PC.

For extracting data measured by the E-Sens, it will only be possible to use the microSD card extraction method. This action is not strictly necessary since copying data to the microSD card of the E-Sens serves as a backup.

7.2. Opening Saved Files in a Data Sheet

To view the data from the measured I-V curves, you need to open the file of each curve in a tool like Excel. In this file, all the current, voltage, and power values of the measured curve are displayed, as well as the curve extrapolated to STC (indicated with an asterisk). Additionally, a summary of the main parameters of both curves (PM, VOC, etc.), irradiance and temperature values of the measurement, and measurement configuration parameters are shown.

With the data included in this file, you can also plot the measured and extrapolated I-V and P-V curves, as shown in Figure 7.1. To plot these curves, you should select the corresponding columns and follow the steps outlined in Figure 7.2.
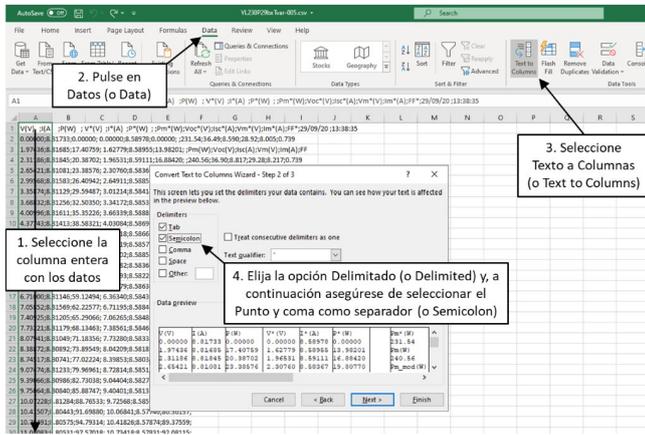
Figure 7.1. Follow the steps indicated to prepare the data in the necessary format.
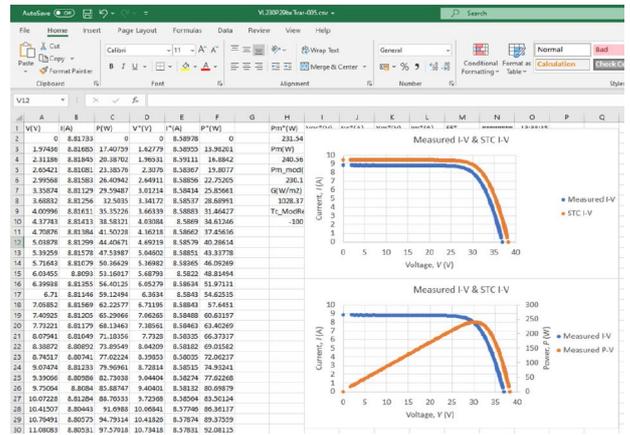
Figure 7.3. An example of the resulting graphs.
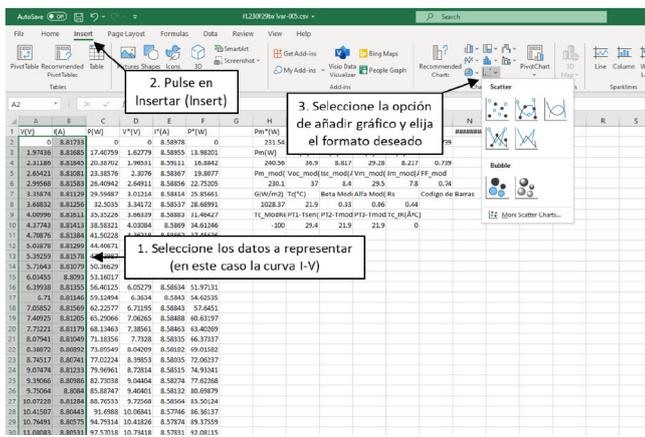
Figure 7.2. To view the data, you can choose certain columns and see the corresponding graph.
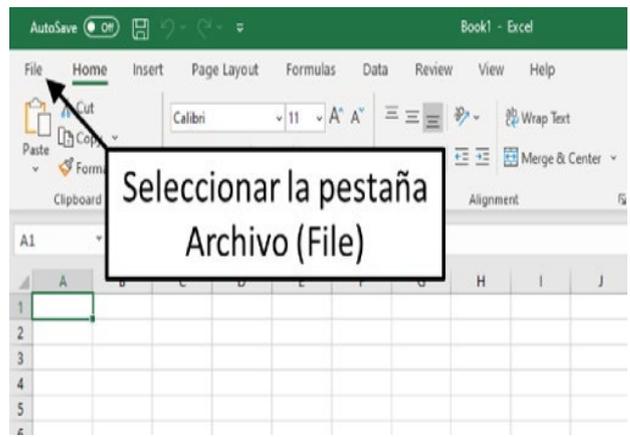
Figure 7.4. Go to the File tab.

If your system defaults to using a comma as the decimal separator, follow the procedure below before importing the data. Select the File tab -> Options (as shown in Figures 7.4 and 7.5). Once inside the options, choose the Advanced tab (see Figure 7.6.), and there, uncheck the option to use the system separators (defined by your system's language) and manually select the separators you want to use. In this particular case, choose a period as the decimal separator and a comma as the thousands separator.
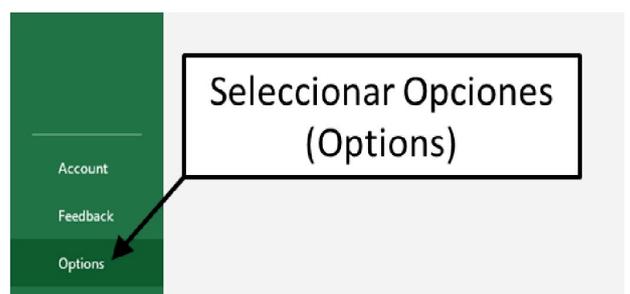
Figure 7.5. Select Options.
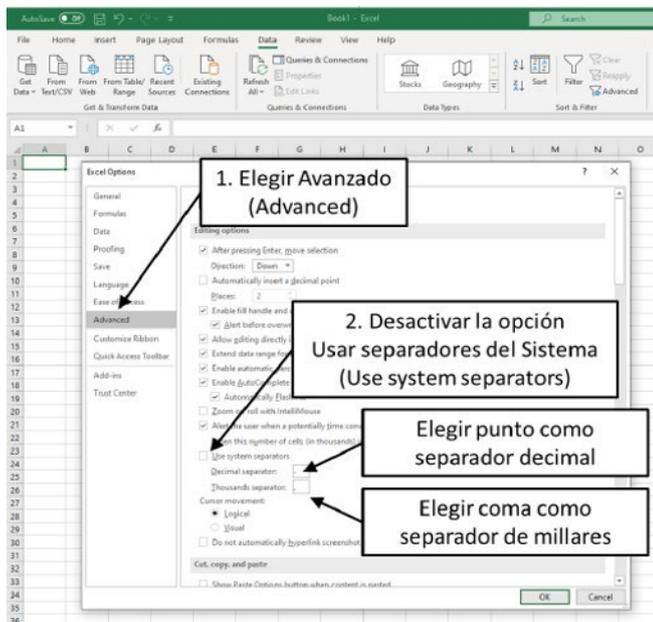
Figure 7.6. Choose Advanced, turn off option to use system tabs and choose the desired decimal and thousands separators, in this case comma as decimal separator and period as thousand separator.

8. User Manual - APK Connect

The I-V Curve Tracer E-1500, as well as the E-1000, have their respective mobile or tablet Apps that allow remote control of the equipment. This enables the operator to transport the equipment in a backpack or case and have hands-free operation for connecting and disconnecting the circuit under test. The connection between the E-1500 / E-1000 and the App is done through a WiFi-Direct connection, and it is necessary for the mobile phone or tablet to have a WiFi connection, although internet access is not required.

To use the E-1500 / E-1000 App, you need to first have the App installed on your mobile phone or tablet. You can download and install the App from the Google Play Store for Android. To do this, search for "E-1500" or "E-1000" (make sure to include the hyphen), depending on the equipment you are using. Once you find the App, click on "Install." The App will be automatically downloaded and installed on your device.
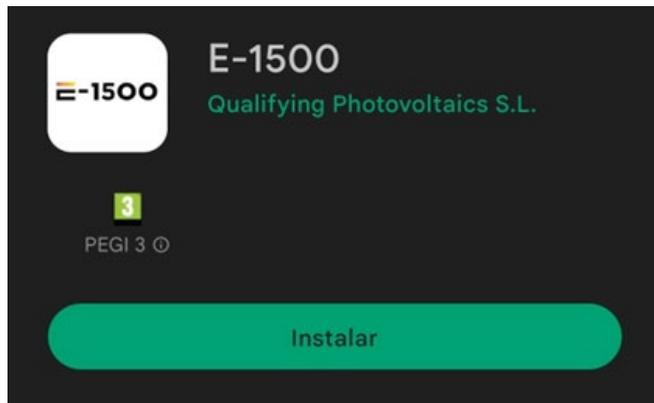
Figure 8.1: App in Play Store.

Once the App is installed on the remote device, follow these steps to remotely control the E-1500 / E-1000:

1. Turn on the WiFi adapter on your mobile phone.

2. For the E-1000, you need to activate the APK connect option. To do this, go to settings and select APK Connect. The button will turn red, and the E-1000 screen will lock. For the E-1500, this option is permanently activated, so you don't need to do anything.

3. Access the settings on your mobile device and search for the WiFi network of the I-V Curve Tracer. For the E-1000, the network name is "E-1000 XXX," where XXX represents the ID of your E-1000. For the E-1500, the network name is the serial number of the equipment (in the format E15XXXXXX).

4. Connect your remote device to the WiFi network of the I-V Curve Tracer. The network password is "carga1234," all in lowercase and without quotes.
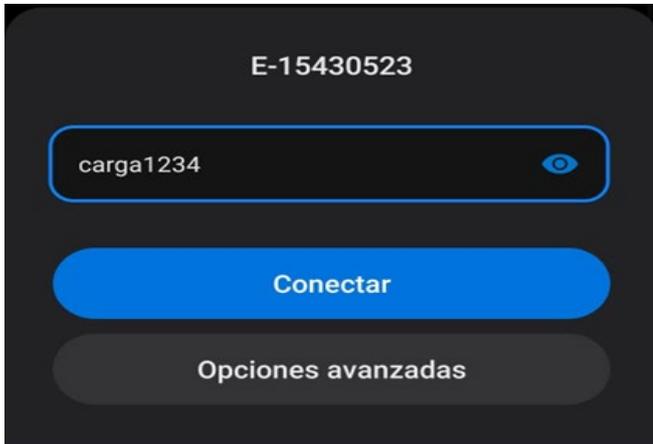
Figure 8.2: Password to connect to the WiFi network.

5. Once connected to the WiFi network, wait for a few seconds. An Android window will appear, informing you that the WiFi network you have connected to does not have internet access. It is important to click on "Keep" because otherwise, your mobile phone or tablet will disconnect from the curve tracer while searching for an internet connection.
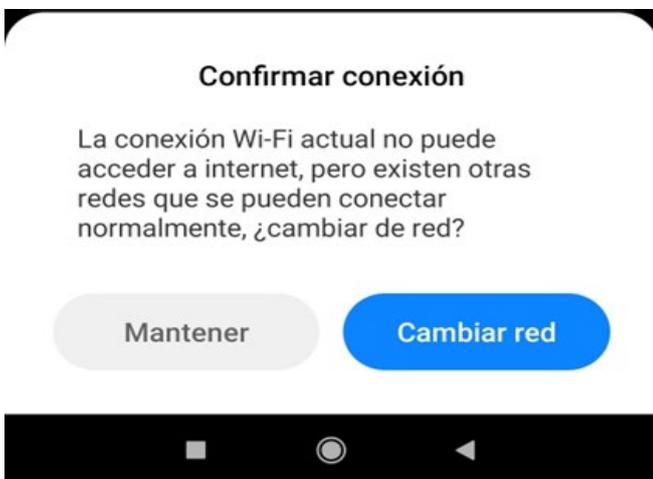
Figure 8.3: Connection message without internet.

6. Open the App on the remote device. The first time you start the App, a message about GPS permissions will appear. It is important to select "Allow while the app is in use." This way, the App will be able to use the GPS of your phone or tablet to save the location in the measurement files.
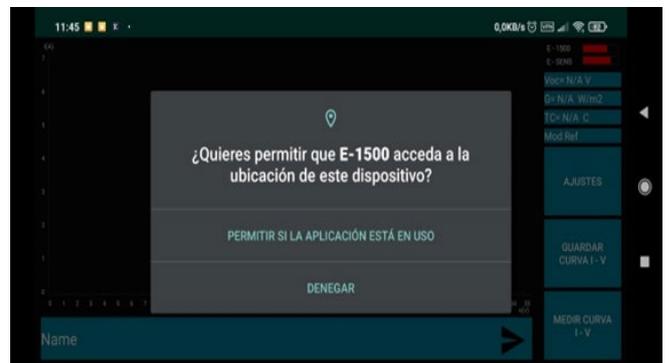
Figure 8.4: Message to grant GPS location permissions.

7. Whenever the App connects to the equipment, a "Successful Connection" message will appear. Click "Accept" to continue using the equipment. Pay attention to the fact that when the App is connected to the I-V Curve Tracer, the equipment's time will be displayed on the screen, and the second hand will be advancing. If the time does not change, it means the connection has been lost.
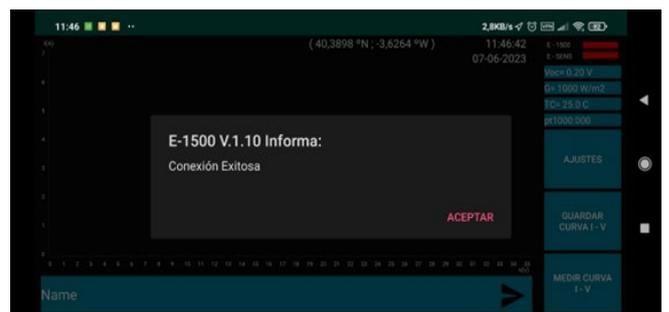
Figure 8.5: Successful connection message.

8. If at any point, the connection between the App and the I-V Curve Tracer is lost, you can reconnect by tapping on "Settings" in the App and then selecting "Connect." This will display a connection configuration window that will reestablish the connection with the equipment. You do not need to modify the IP and Port values shown, as they are correct. If the connection is successful, the "Successful Connection" message will appear again.

Figure 8.6: Settings window.

Finally, the main screen of the App will be displayed, which has a similar interface to the E-1500 / E-1000.
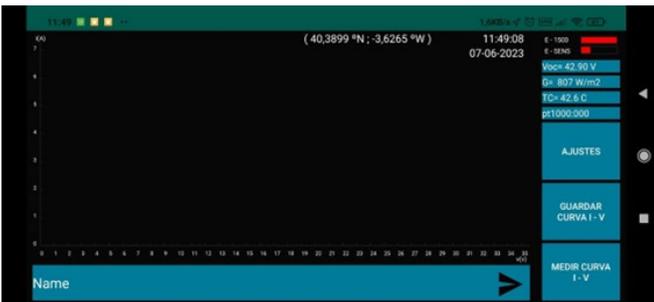
Figure 8.7: Main screen of the App.

At the top of the screen, GPS coordinates are shown in parentheses. These values are saved in the curve files when you perform measurements. On the right, you can see the date and time of the I-V Curve Tracer. You can easily check if the connection has been successful by monitoring the time on the App. If the time advances, it means that the curve tracer and the remote device are connected correctly.

In the right column, you can find:

- The battery indicator of the curve tracer.

- The battery indicator of the E-Sens.

- Measurement of Voc (Open Circuit Voltage) of the curve tracer.

- Irradiance measured in the E-Sens.

- Tc temperature measured in the E-Sens or E-Temp.

- Operating mode: It can be PT1000 or E-Temp.

- Settings button.

- Save I-V Curve button.

- Measure I-V Curve button.

Finally, at the bottom of the screen, you will find the bar displaying the names of the measured curves. You can tap on it to change the names of the measured curves. To do this, tap on the bar, a keyboard will appear on the screen, where you can type the desired name, type the name of the curve, tap on "Done," and finally, tap on the triangle located on the right side of the bar to send the curve name to the curve tracer. A message will appear on the screen indicating that the curve name has been successfully renamed. One advantage of using the App is that the number of characters that can be used to name the measurement is significantly larger than on the E-1500 / E-1000 device.

The Settings button does not allow you to configure the settings of the E-1500 / E-1000 but is used for App connection configuration, just like in the curve tracer. The App will display a message when it performs the first measurement after being turned on, indicating that the measurement time is being adjusted according to the irradiance of the day. Tap "Accept" to dismiss this message.
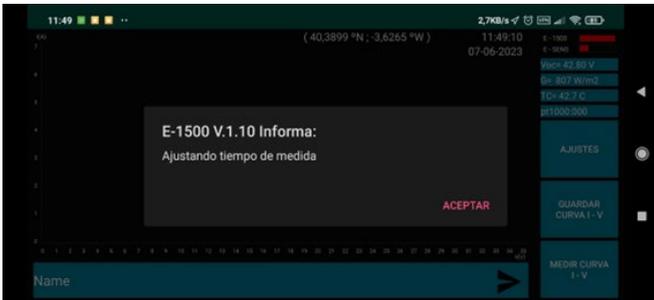
Figure 8.8: Adjustment of measurement time message.

Figure 8.10: Main screen with a curve measured without Android's dark mode.

Once the measurement is complete, the App will display the measured and extrapolated curves, as well as the name and notes, in the same way as the E-1500 / E-1000. The values of Pm*, Voc*, and Isc* will also be shown, along with the percentage differences from the nominal values configured in the equipment, just like on the device's screen.

⚠ **IMPORTANT:** From the remote device's App, only functions from the main screen can be carried out, and no menu configuration settings can be accessed. All necessary settings must be configured on the E-1500 / E-1000 before establishing a connection with the remote device.
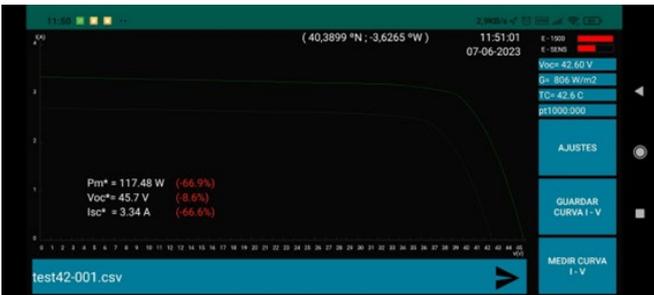
Figure 8.9: Main screen with a curve measured in Android's dark mode.

If the curve lines appear too thin, it is because the dark mode is enabled on your mobile phone or tablet. Disable the dark mode on your phone so that the lines appear normally.

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9. Manual de usuario – App Curvas *I-V*

9.1. Introduction

This user manual describes the operation of the application for automatic processing of I-V curves measured with the E-1000 or E-1500 curve tracers. The application is a cloud-based software tool running on the PVET platform, developed by QPV.

The application allows the following functionalities

- Storage of files in the cloud

- Automatic processing of I-V curves

- Elimination of errors

- Visualisation of I-V curves

- Statistical analysis of results

- Automatic report generation

- Automatic detection of faults in I-V curves

9.2. 2. Plant creation

On entering the application, the user will be directed to the platform dashboard, where all the plants where action has been taken can be viewed on a map (Figure 9.1).
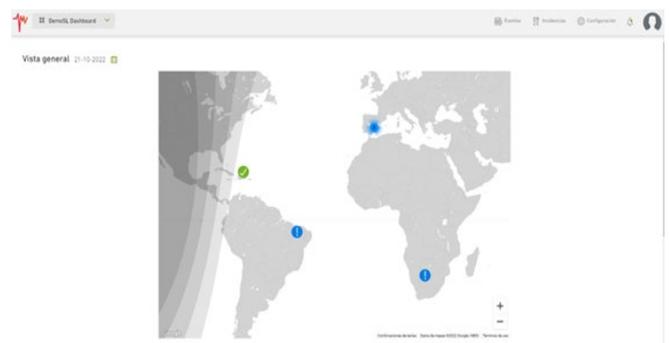
Figure 9.1: Example of the platform dashboard.

To create a new plant, the user must go to "Configuration" on the top right.
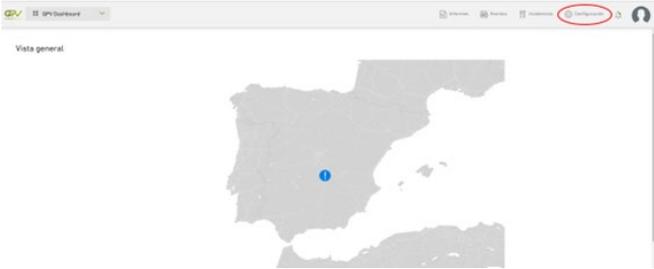
Figure 9.2: Location of the configuration button on the dashboard.

By clicking on "Configuration" the user will be redirected to a new screen where the list of plants created by the user and the option to "Create new plant" will appear.

Figura 9.3: Configuration window with the option to create a new plant.

By clicking on "Create New Plant," the user will be redirected to the new plant creation screen, where they will need to enter the following data to create the plant.

- Name: name of the plant.

- Location: For location and time zone, there are two options:

   - Manual entry of all parameters: time zone, location (city or nearby town), country, latitude, longitude, and altitude.

   - Automatic selection: By zooming in on the map and clicking on the plant's location, all the above parameters are automatically selected.

- Plant structure: The maximum values for each level must be entered.

   - CT: total number of CTs or Power Stations in the plant.

   - INV: maximum number of inverters per CT.

- SB: maximum number of sub-boxes per inverter.

- Plant modules: The module model must be entered through a search engine in our database. If it is not found, you can send an email to pvet@qpv.es with the manufacturer's module catalog, and it will be added to the database.

Once all the data is entered, click on "Create Plant," and the system will take you directly to the plant list, where the plant will be marked as "pending." The validation process for the plant may take between 1 and 5 minutes. Once the plant is validated, it will appear as "Ok" (Figure 4).

Once all the data is entered, click on "Create Plant," and the system will take you directly to the plant list, where the plant will be marked as "pending." The validation process for the plant may take between 1 and 5 minutes. Once the plant is validated, it will appear as "Ok" (Figure 4).

Figure 9.4: "Pending" plan and "Ok" plan.

9.3. File uploading and data processing

9.3.1. File upload

For the reports to be output correctly, the files must be uploaded sorted by CT, INV, and String Box. For this purpose, there are two possibilities for uploading the files:

9.3.1.1. Automatic upload of files via Rosetta

Figura 9.5: Bulk file upload

Uploading files via Rosetta is a way to upload a large number of files in a faster and easier way. In this case, you will need to upload two files:

• Rosetta, a .csv document that assigns the position of each curve within the plant structure.

• A compressed .zip folder with all the curves (IMPORTANT: IT IS MANDATORY THAT THE FORMAT BE .zip AND NOT OTHER TYPES OF COMPRESSED FILES SUCH AS .rar / .7z, etc.).

This process, especially if it is a large number of curves may take a few minutes. A notification will appear on the top right-hand side of the screen indicating that the files have been uploaded successfully once it has finished. In addition, to check that the files are uploaded, you can browse the plant structure and check that the name of your curves is displayed.

A	B	C	D	E	F	G
mbre curv	CT	INV	SB	N§ string	Modelo de módulo	
rva-001	1	1	1	1	19691	
rva-002	1	2	1	2	19691	
rva-003	1	3	1	3	19691	
rva-004	1	4	1	4	19691	
rva-005	1	5	1	5	19691	
rva-006	1	6	1	6	19691	
rva-007	1	7	1	7	19691	
rva-008	2	1	1	1	19691	
rva-009	2	2	1	2	19691	
rva-010	2	3	1	3	19691	
rva-011	2	4	1	4	19691	
rva-012	2	5	1	5	19691	
rva-013	2	6	1	6	19691	
rva-014	2	7	1	7	19691	
rva-015	3	1	1	1	19691	
rva-016	3	2	1	2	19691	
rva-017	3	3	1	3	19691	
rva-018	3	4	1	4	19691	
rva-019	3	5	1	5	19691	
rva-020	3	6	1	6	19691	

Figura 9.6: Rosetta example.

Instructions for creating the Rosetta:

1) It must be a ".csv" file.

2) It must have as many rows as the number of curves.

3) It must have six columns: Curve Name, CT, INV, SB, Curve Number, Module Model.

4) All cells must be filled.

5) The plant's structure must be followed.

6) The Rosetta's name should be the same as the file name without the ".csv" extension.

Recommendations for preparing the Rosetta:

1) As the main recommendation, use Excel's autocomplete feature whenever possible.

2) For example, if curve names are consecutive, write the first one and drag the cell in Excel to automatically fill the rest.

3) Another way to copy the curve names is to enter the folder where the curves are stored, select them, and choose the "copy file path" option.
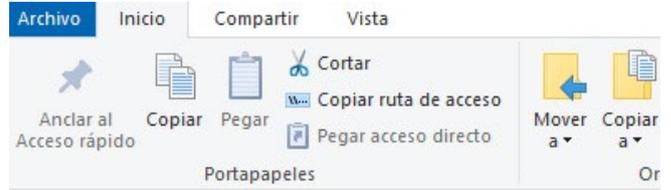
Figure 9.7: Copy path to file names.
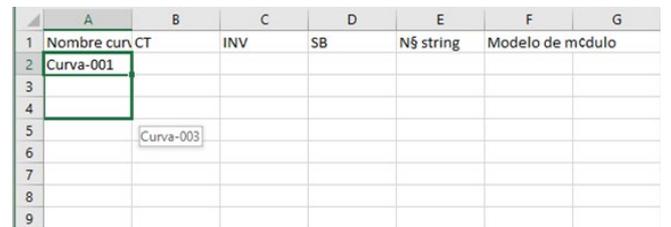
Figure 9.8: Example of how to drag cells in Excel.

4) Once this is done, it is recommended to start from right to left, assigning the module model and the number of strings first.

5) Next, you should add the number of SB (String Box), IN (Inverter), and CT (Transformer Center).

9.3.2. Data Processing

Once the files to be studied have been uploaded, to process the data, simply click on the process button. A message will appear indicating that the data is being processed. The data processing time depends on the number of curves, ranging from a few seconds to several minutes.

Once the data processing is finished, you can access the sections of numerical summary, statistical analysis, and curve visualization, while the reports will continue to run in the background.

Figure 9.9: Processing data message on the tab of the browser.

9.4. Visualization of Results

9.4.1. Statistical Analysis

The statistical analysis section displays a graph representing the frequency of maximum module power. Additionally, a table with minimum, maximum, average, and standard deviation data of short-circuit current, open-circuit voltage, Fill Factor, and maximum power under standard measurement conditions is also shown.

The statistical analysis of the modules is very helpful to understand if the tested elements, as a whole, are performing as expected concerning their nominal production. It also allows for the detection of any specific module failure.

9.4.2. Numerical Summary

The numerical summary section presents a table that includes data such as irradiance, cell temperature, short-circuit current, open-circuit voltage, Fill Factor, maximum power under standard measurement conditions, and the difference between maximum power and the module's nominal power.

9.4.3. Curve Visualization

In the curve visualization section, you can navigate through the plant's tree structure and select the curve of the chosen module. You can view the nominal curve, the curve extrapolated to standard measurement conditions (STC), and the measured curve.

This section allows you to quickly and individually visualize the curves, comparing each measured curve with its extrapolation and nominal curve.

9.4.4. Reports

Once the reports have been generated, a notification will appear informing you of this. To download the generated reports, simply go to the "Generate Report" tab and select the desired option, available in both Spanish and English.

Figure 9.10: Generate Report Screen.

10. Quick start guide

The following list summarizes the components of procedure required to perform a complete measurement cycle. It is strongly recommended to read the entire manual before proceeding and to consult the corresponding sections in case of any doubt.

1. Battery level check of all devices, as well as making sure that the SD cards are inserted.

2. Connection of E-Sens with the E-1000.

3. Connection of the barcode reader to the E-1000 (optional).

4. Connection the irradiance and temperature sensors to the E-Sens.

5. Setting the time of the E-1000 to local time and synchronization of the time with the E-Sens.

6. Configuration of module characteristics under test (VOC, ISC, VM, and IM, α, ß and NS)

7. Configuration of generator characteristics (number of modules in series and in parallel).

8. Irradiance sensor configuration (reference cell)

9. Selection and configuration of the temperature sensor (reference module, PT-1000, or E-Temp).

10. Selection of the file name under which the data will be saved.

11. Selection and configuration of the measurement process (manual measurement, auto-measurement, or continuous measurement).

12. Selection of the method for saving the data (manual save, or auto save).

13. Execution of the measurement process in line with the selected options.

In addition, it is recommended to carry out the measures considering the following:

- Carry out the measurements during periods of the day when the sky is clear and with little wind.

- Ensure coplanarity and closeness between reference module and the circuits under test. It is advisable to also measure the temperature at different points of the circuit.

- Perform measurements with an irradiance level of between 800 and 1200 W/m2, and never below 600 W/m2.

- Avoid angles of incidence of the sun greater than 40°.

11. Technical specifications

E-1500 Specifications

Input Voltage Range	0-1500 V
Input Current Range	0.1 - 20 A (optional up to 35A)
Accuracy	± 0.3 % ± 2 dígitos (Voltage and Current) ± 0.5 % ± 0,1 W (Power)
Resolution	22.5 mV 0.5 mA
Measurement Time	30-200 ms (typical)
Measurement Cycle Time	3 - 4 s (typical)
I-V Curve Points	200
Operating Temperature	-10 a +65 ºC
Battery Life	8 hours in continuous operation (over 2000 I-V curves)
Dimensions	310x180x55 mm
Weight	2.3 kg
Protections	Over-voltage, Over-current, and Reverse Polarity
Data Storage and Format	SD Card 12 KB per I-V curve in .csv format
Electrical Safety	CAT II- 1000 V, EN-61010-1
Standards	I-V Curve Measurement according to IEC-61829 Extrapolation to STC according to IEC-60891
Warranty	2 years for product defects

E-1000 Specifications

Input Voltage Range	0-1000 V
Input Current Range	0.1-20 A
Accuracy	± 0.3% ± 2 digits ± 0.5% ± 0.1 W (Power)
Resolution	15 mV 0.3 mA
Measurement Time	30-200 ms (typical)
Measurement Cycle Time	3 - 4 s (typical)
I-V Curve Points	200
Operating Temperature	-10 to +65 °C
Battery Life	8 hours in continuous operation (over 2000 I-V curves)
Dimensions	298x160x50 mm
Weight	1.3 kg
Protections	Over-voltage, Over-current, and Reverse Polarity
Data Storage and Format	SD Card 12 KB per I-V curve in .csv format
Electrical Safety	CAT II-1000 V, EN-61010-1
Standards	I-V Curve Measurement according to IEC-61829 Extrapolation to STC according to IEC-60891
Warranty	2 years for product defects

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E-Sens Specifications

Inputs	1 x Irradiance Measurement 1 x PT1000 for Irradiance Cell 3 x Additional PT1000 inputs
Voltage Measurement Accuracy	± 0.3%
Temperature Measurement Accuracy	± 0.3°C, Class B
Voltage Measurement Resolution Temperature Measurement Resolution	0.45 mV for the 60 V channel 0.015 mV for the 2 V channel
Measurement Interval	1 second for Irradiance channel 2 seconds for all other channels
Wireless Link Range	Several hundred meters to 2 km
Wireless Link Frequency	433 MHz (915 MHz for USA)
Operating Temperature	-10 to +65°C
Battery Life	10 hours of operation
Dimensions	195x95x29 mm
Weight	265 grams
Protections	Over-voltage and Reverse Polarity
Data Storage and Format	micro-SD Card
Electrical Safety	EN-61010-1
IWarranty	2 years for product defects

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E-Temp Specifications

Operating Temperature	10 to +65 ºC
Temperature Measurement Accuracy	± 1°C typical
Battery Life	3 hours of operation
Working Ambient Temperature Range	-40°C to +170°C
Object Temperature Range	-70°C to +380°C
Wireless Link Range	Up to several hundred meters
Wireless Link Frequency	433 MHz (915 MHz for USA)
Dimensions	90x44x16 mm
Weight	40 g
Warranty	2 years for product defects

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12. Warranty, Calibration, and Repair

Entec Solar guarantees that this product and its associated accessories will be free from defects during the legal warranty period of 24 months from the date of purchase, as indicated on the sales invoice. This warranty does not cover fuses or damage caused by accidents, negligence, modifications, abnormal operating conditions, or improper use or handling. Opening the equipment for inspection or manipulation in any way will immediately void the warranty. Distributors are not authorized to extend this warranty on behalf of Entec Solar.

During manufacturing, the E-1500 / E-1000, E-Sens, and the reference cell have undergone a calibration process for voltage and current measurements, and internal adjustments have been made to compensate for any variations in the measured parameters. Over time, degradation of electronic components can occur due to temperature changes, high operating currents, prolonged application of voltage, etc. This can lead to deviations in the calibration constants of the equipment, resulting in inaccurate measurement results. Entec guarantees the calibration of all its devices for a period of 24 months, after which the equipment should be returned to the factory for recalibration to ensure the highest accuracy in measurements.

All items sent for repair or calibration, whether within or outside the warranty period, must be accompanied by Entec's service form. This document can be obtained from the website **www.entecsolar.es** or directly from your nearest distributor.
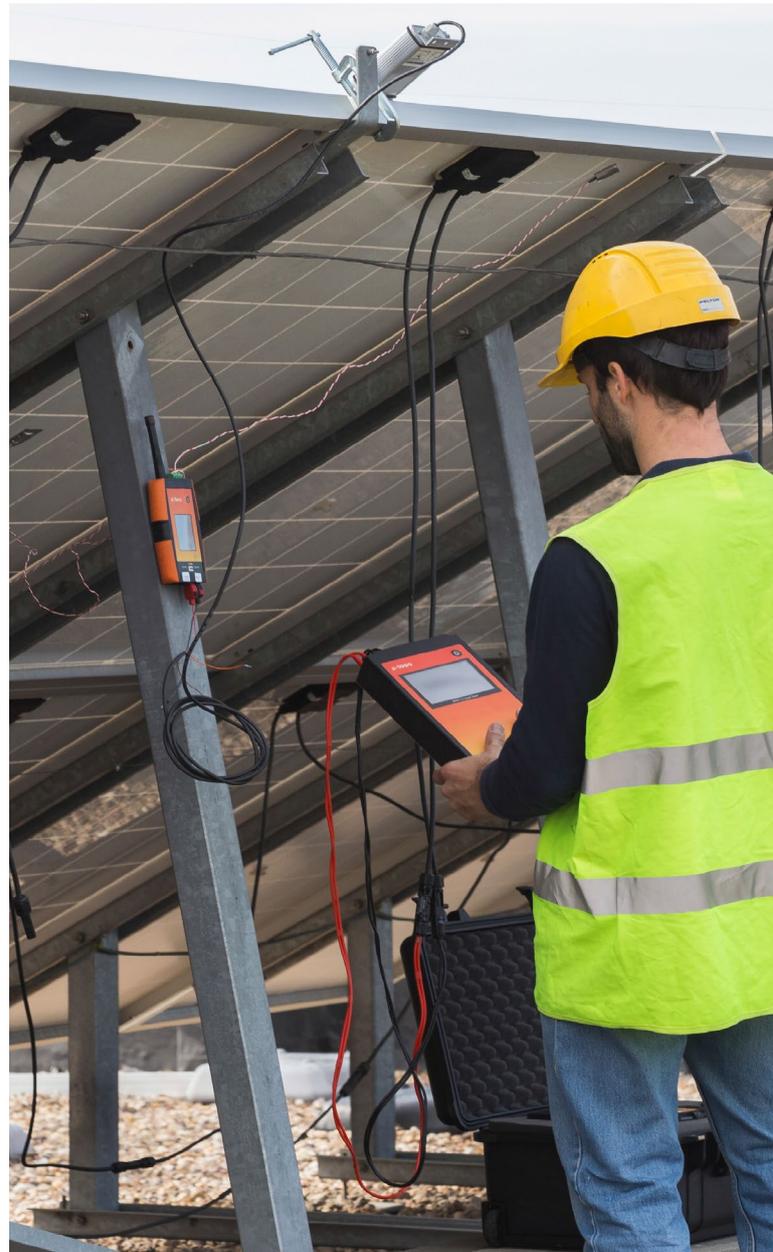
13. Common Errors and Solutions

1. When starting the equipment, the message "SD Card Error" is displayed:

a. Ensure that an SD card is inserted into the equipment.

b. If there is no SD card, turn off the equipment, insert an SD card, and restart the equipment.

c. If a card is inserted or if the message persists after inserting the card, try using another card.

d. If the message continues to appear, contact technical support.

2. The displayed irradiance value on the E-1500 / E-1000 is incorrect or not shown:

a. Ensure that there is communication between the E-Sens and the E-1500 / E-1000. To do this, the background of the G rectangle should be red.

b. Check that the sensor configuration is correct. Select Settings -> Sensor Settings and verify that the Isc and Alpha values are accurate. Modify them if necessary.

c. If there is no communication, turn off and then turn on the E-1000. It could also be a distance-related issue. Try again with the devices close to each other and with the antennas in place.

d. It's also possible that multiple E-Sens units and E-1500 / E-1000 devices are working in the same location. This can cause signal interference. Therefore, only work with one E-Sens, although you can use multiple I-V curve tracers simultaneously.

e. If the error persists, contact technical support.

3. The displayed temperature value is incorrect.

a. Ensure that there is communication between the E-Sens and the E-1500 / E-1000. To do this, the background of the G rectangle should be red.

b. Check that the sensor configuration is correct. Select Settings -> Sensor Settings and first verify that the sensor is in the desired mode (PT1000, IR Sens, Mod Ref); and with the appropriate values. Refer to section 5.5.6.B of the manual.

c. If there is no communication, turn off and then turn on the E1000 / E-1500. It could also be a distance issue. Try again with the devices close to each other and with antennas properly positioned.

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d. It's also possible that multiple E-Sens and E-1500 / E-1000 devices are operating in the same location. This can lead to signal interference. Therefore, it's recommended to work with only one E-Sens at a time, although you can use multiple I-V curve tracers simultaneously.

e. If the error persists, please contact technical support.

4. When pressing the measure button, the equipment beeps but doesn't display the curve or allow button presses.

a. If you carefully read the display, there should be a message at the top indicating that the equipment has performed the measurement and is awaiting temperature measurement values from the E-Temp. It also indicates the number of points it requires. Use the E-Temp to send the necessary data. If you don't have an E-Temp or don't need to use it, deactivate it in sensor settings before performing the measurement.

5. The device doesn't save the barcode in the CSV files, even though it displays it on the screen.

a. When you want to perform a measurement and save the barcode, you should use it only when prompted by the equipment through a message. If you scan the barcode too early, it will be displayed but not saved in the file as it won't be associated with any measurement.

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