



# IV Curve Measurement System

## User Manual

Manual version 1.0.D

Product code: T2002/T2003

Product Version 1.0.0

Software version: 1.0.0

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# 1. Safety

## 1.1 Warning

To avoid safety hazards, obey the following:

- Do not leave devices with applied bias or current unattended as a power failure may result in board damage or device damage - and potentially hazardous situations.
- The maximum allowed driving voltage is  $\pm 10$  V and the maximum current is  $\pm 100$  mA. Operating the system outside the operational range can cause damage to the device and greatly increase the risk of electrical shock.
- Do not operate the switches or touch the system when voltage and/or current are applied.

## 1.2 Caution

To avoid damaging devices or equipment obey the following:

- Do not connect a voltage source to either of the SMUs on the X100 Source Measure Unit, as this will damage the system.
- Avoid electrostatic discharge (ESD) as this may damage the device. To avoid damage, use static discharge and prevention equipment where necessary.
- Only use the device for the purposes intended (described in this document)
- Do not expose the device to any inappropriate cleaning fluids or solvents.
- Follow good practice when setting up the test system.
- Avoid placing near sources of electromagnetic interference.

## 2. Introduction

The Ossila IV Curve Measurement System is designed as a low-cost solution for reliable current-voltage measurements. The system can also perform characterisation and lifetime measurements of solar cells, enabling rapid testing of photovoltaic devices. Operation of the system is controlled by specifically designed software which can perform multiple IV measurements, determine key metrics of solar cells, and measure these metrics over long periods of time.

### 2.1 Component List

- X100 Source Measure Unit
- Push-Fit Test Board (T2002)
- Multiplexer Test Board (T2003)
- Baseplates
- 18 V DC Power Supply
- Micro USB to USB A Cable
- BNC Cable
- Spacers and Fittings

## 2.2 Specifications

<b>Voltage range</b>	±333 $\mu$ V to 10 V
<b>Current range</b>	±10 nA to 100 mA
<b>Substrate Size</b>	20 mm x 15 mm
<b>Substrate Compatibility (T2002A/T2003A)</b>	S101 (OLED substrates)
<b>Substrate Compatibility (T2002B/T2003B)</b>	S211 (PV substrates)
<b>Substrate Compatibility (T2002C/T2003C)</b>	S171 (Pixelated cathode substrates)
<b>Overall Dimensions (T2002)</b>	Source Measure Unit: Width: 123 mm Height: 40 mm Depth: 165 mm Test Board: Width: 105 mm Height: 40 mm Depth: 125 mm
<b>Overall Dimensions (T2003)</b>	Width: 140 mm Height: 80 mm Depth: 265 mm

## 2.3 Requirements

The system requires a computer running Windows (Vista or newer) with an available USB (recommended) or network port. Further details are given below:

<b>Monitor Resolution</b>	<ul style="list-style-type: none"> <li>• The software requires a monitor resolution of at least 1680 x 1050. <ul style="list-style-type: none"> <li>○ The optimum resolution is 1920 x 1080.</li> </ul> </li> </ul>
<b>Power</b>	<ul style="list-style-type: none"> <li>• The system requires an 18 V DC power supply.</li> <li>• A power supply fitting this description is provided along with the system.</li> </ul>
<b>USB</b>	<ul style="list-style-type: none"> <li>• To use the USB, your controlling device should support USB communication. A USB-B cable is supplied with system.</li> </ul> <p><i>NOTE: The USB connection does not supply power to the system.</i></p>
<b>Network</b>	<ul style="list-style-type: none"> <li>• The system should be connected to a network supporting 10/100Mbps transmission.</li> <li>• DHCP must also be running on the network, and available to the system for the device to operate properly. <ul style="list-style-type: none"> <li>○ To check if DHCP is running on your network you should attempt to connect another device to the network as you would the system. <ul style="list-style-type: none"> <li>▪ If the device automatically obtains an IP address, then DHCP is working correctly.</li> </ul> </li> </ul> </li> </ul>

## 3. Getting Started

Connect the system to your computer using either the USB cable provided, or an Ethernet cable if preferred. Next, plug in the power supply for the system and check that the X100 Source Measure Unit 'ON' LED turns on. Allow the system to warm up for 30 minutes before taking a measurement to ensure the most accurate results.

For the T2003, the power supply must also be plugged into the multiplexer. Check that the power light starts flashing.

For the T2002C, connect the BNC cable to your desired measurement system. Please note, that the system is not compatible with E541 (Smart PV and OLED Multiplexor Test Board with JV Sweep Software).

### 3.1 Software Installation

- Run the file 'Ossila IV Installer.exe' on the USB drive provided and follow the on-screen instructions.
  - I. This will install the IV Curve Measurement System software.
- Open the 'x100-driver' folder and run the file 'Windows 32-bit Xtralien Driver' for 32-bit operating systems or 'Windows 64-bit Xtralien Driver' for 64-bit operating systems.
  - I. This will install the drivers for the IV Curve Measurement System.
  - II. Alternatively, the drivers may be downloaded from:  
<https://www.ossila.com/pages/downloads>
  - III. Note, on Windows 10 computers the drivers will install automatically when the system is plugged in.

### 3.2 Taking a Measurement

1. Place your device in the test board.
  - I. If performing a solar cell measurement: place the test board under your solar simulator.
2. Start the program 'Ossila IV' and the window shown in Figure 3.1 will open.
3. Select the experiment you wish to perform by clicking the corresponding button or selecting the tab in the top-left of the screen.

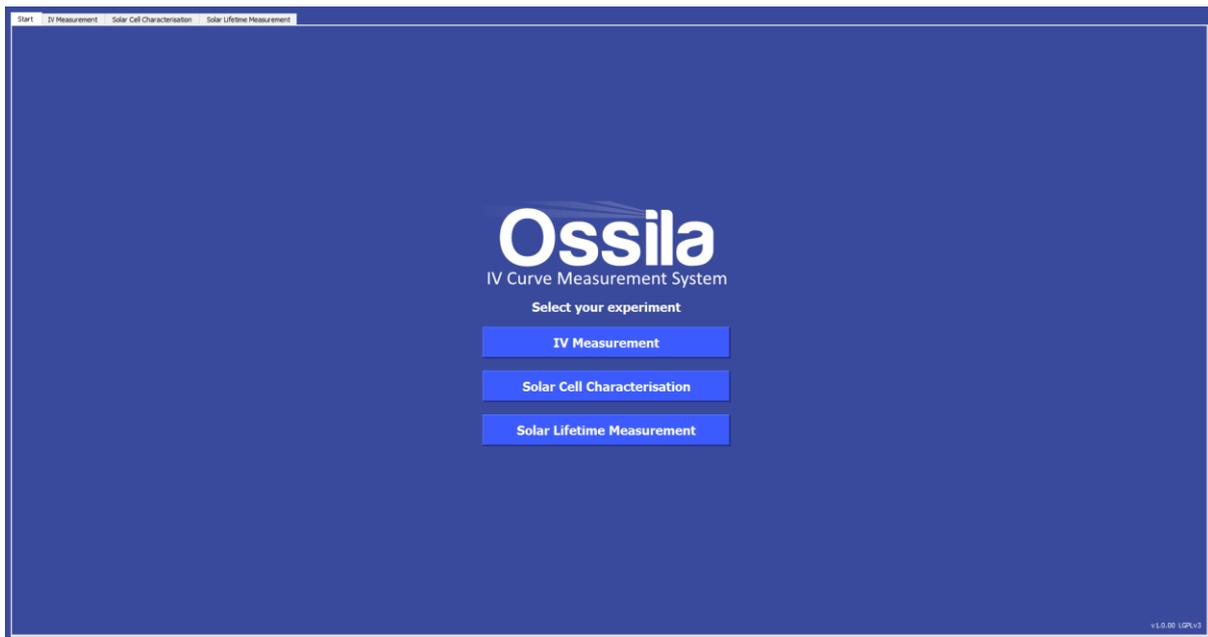


Figure 3.1. Ossila IV Software start screen.

There are 3 measurements that can be performed by the system: IV measurement, solar cell characterisation, and solar cell lifetime. The interfaces for these measurements are shown below, with the important areas highlighted.

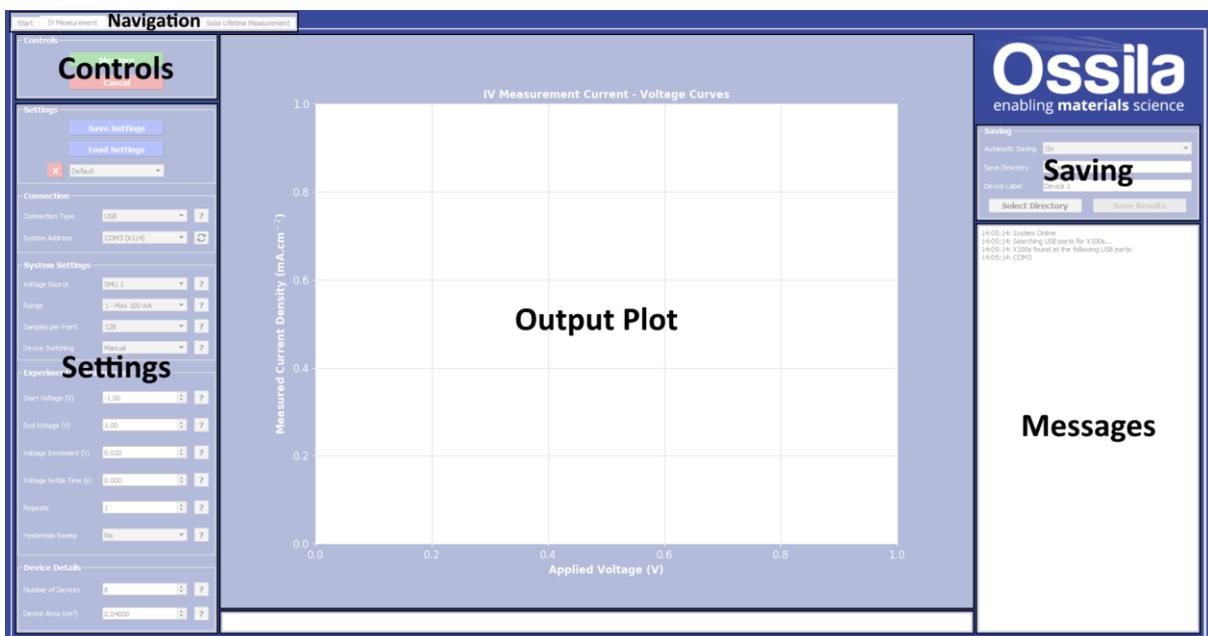


Figure 3.2. IV measurement window.

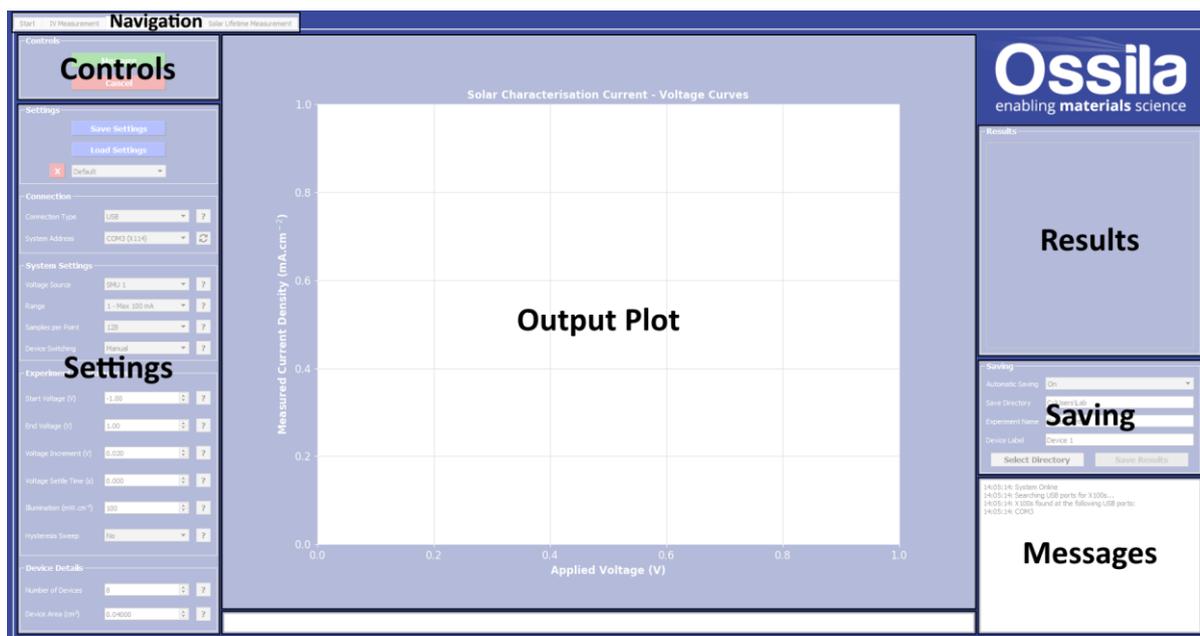


Figure 3.3. Solar cell characterisation window.

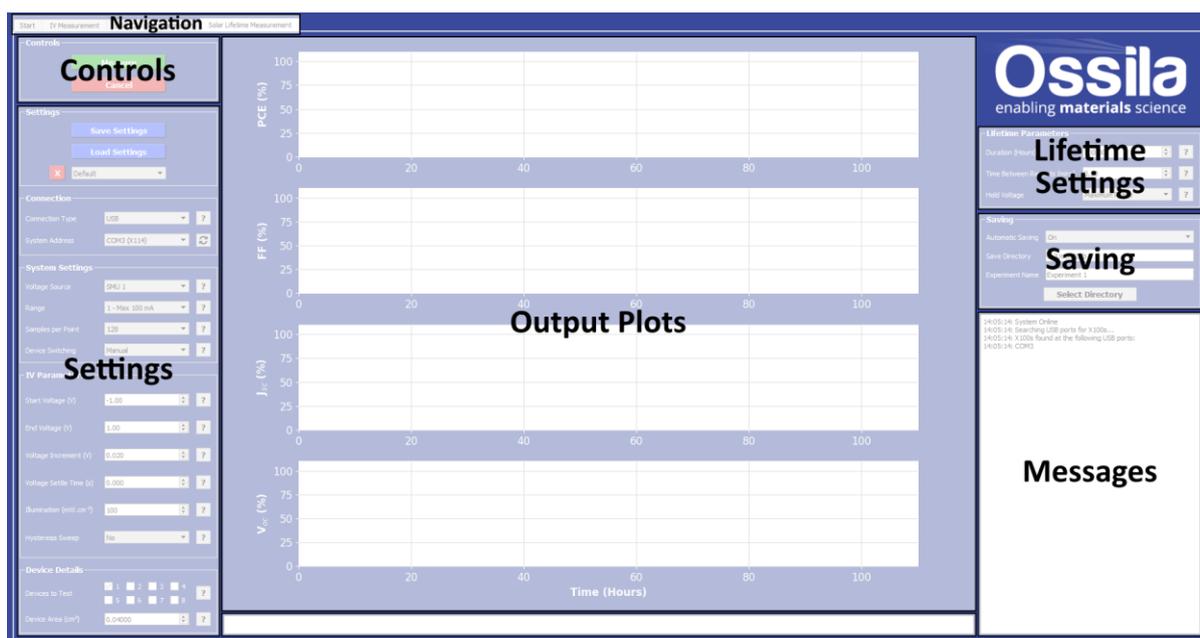


Figure 3.4. Solar cell lifetime window.

There are several settings in the program which must be filled in before taking a measurement, which are detailed below. Most of these settings are used in all the measurements, some are specific to particular measurements and are labelled with the measurement they are used in. Additionally, this information can be found by clicking the help buttons next to each field (labelled '?').

### 3.2.1 Connection

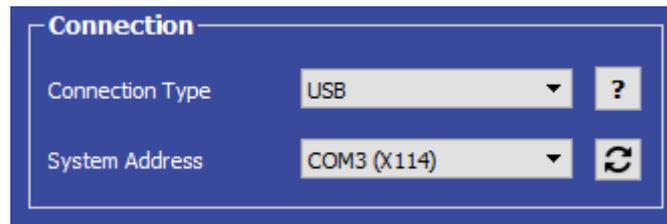


Figure 3.5. Connection settings.

#### (I) Connection type

- Select the type of connection being used, either USB or Ethernet.
  - I. The program will automatically search for any available X100s connected to the computer and will populate the 'System Address' box.
  - II. To rescan for connected X100s (in case the connection is changed) just select the type of connection being used or press the refresh button next to the System Address box.

#### (II) System Address

- Select the COM port or IP address of the connected X100 (USB and Ethernet connection respectively).
  - I. This box will be populated automatically with the address and board number of any X100s connected to the computer via the method selected in the Connection Type box.
  - II. If unsure which X100 to connect to, the board number is displayed on the screen, and written on the underside of the board and in the documentation supplied with the system.
  - III. To rescan for connected X100s, press the refresh button next to the System Address box.

### 3.2.2 System Settings

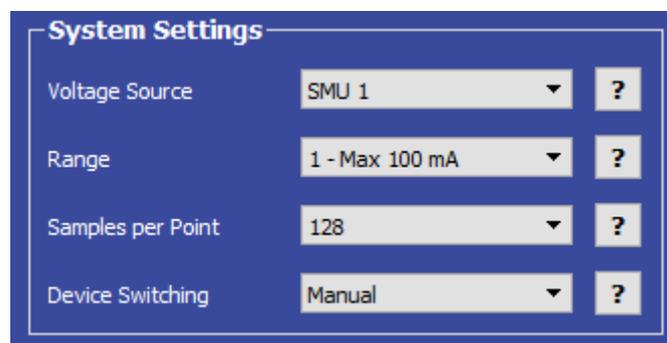


Figure 3.6. System settings.

## (I) Voltage Source

- Select which number SMU on the X100 is connected to the test board.
  - I. The SMU numbers are labelled on the board and highlighted in Figure 3.7.

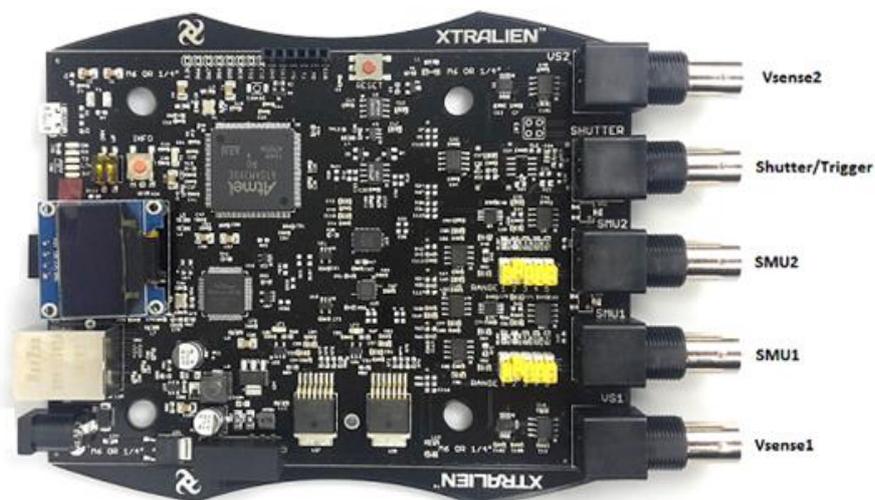


Figure 3.7. X100 Source Measure Unit, Vsense and shutter output connection ports.

## (II) Range

- Select the range of the SMU to be used for the measurement.
  - I. This defines the upper limit and sensitivity of current measurements that can be performed by the SMU. These values for each range are given in Table 3.1 below.
  - II. The maximum current values for each range are also shown in the range selection box.

Table 3.1. Maximum current and resolution for the different range settings for the X100 SMUs.

Range	Maximum Current	Resolution
1	100 mA	100 $\mu$ A
2	10 mA	10 $\mu$ A
3	1000 $\mu$ A	1000 nA
4	100 $\mu$ A	100 nA
5	10 $\mu$ A	10 nA

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**Warning:** The range **must be set physically on the X100** using the 5 yellow switches next to the SMU being used (Figure 3.8), as well as being set in the program.

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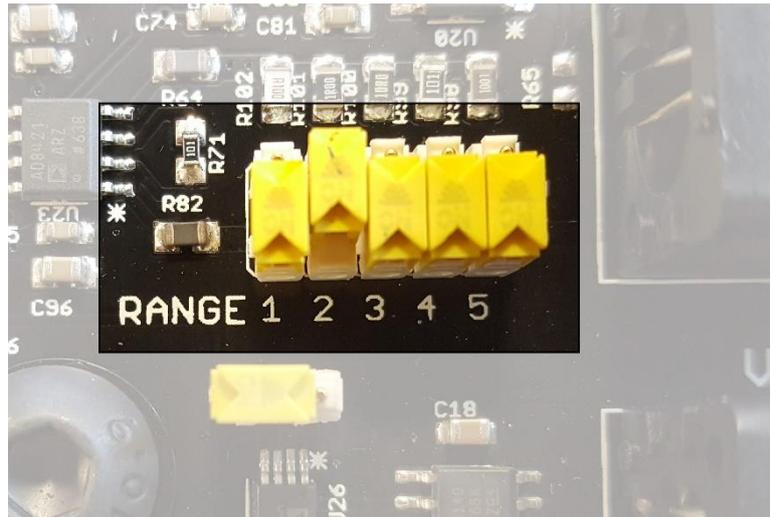


Figure 3.8. Manual range switches on the X100.

**(III) Samples per Point**

- Select the number of samples to be taken for each measurement.
  - I. A higher number of samples per point will improve the accuracy of the measurement, but will increase the time taken for it to be performed.

**(IV) Device Switching**

- Select whether changing the connected device will be performed manually by the user or automatically by the system.
  - I. Automatic switching can only be performed by T2003A and T2003B.

**3.2.3 Experiment Parameters**

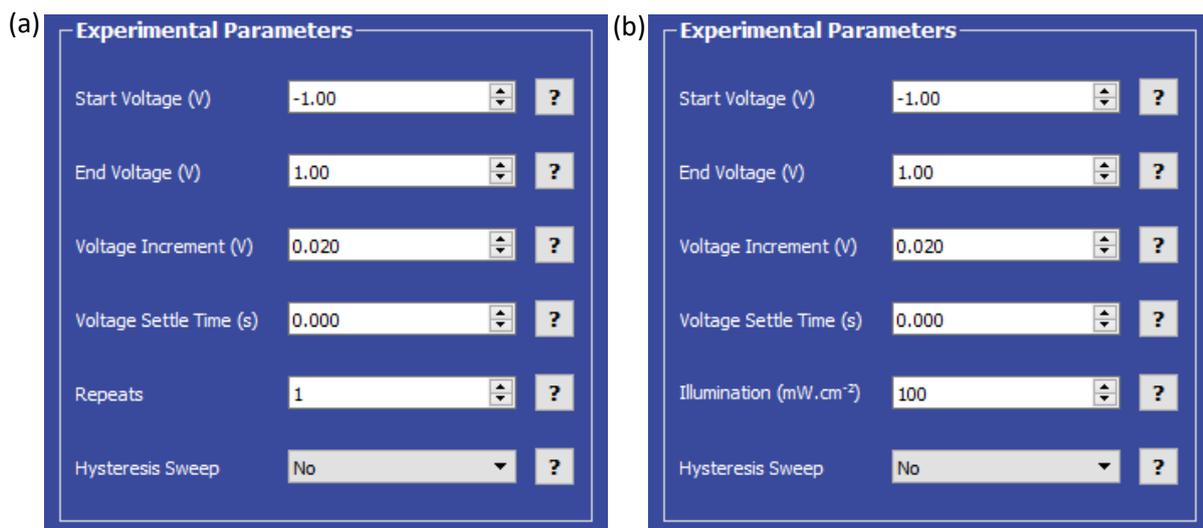


Figure 3.9. Experimental Parameters settings for the (a) IV measurement, and (b) solar characterisation and lifetime.

**(I) Start Voltage**

- Sets the start voltage in volts for the current-voltage sweep.
  - This can be set between -10 V and +10 V.

**(II) End Voltage**

- Sets the start voltage in volts for the current-voltage sweep.
  - This can be set between -10 V and +10 V.

**(III) Voltage Increment**

- Sets the step size in volts for changing the voltage during the current-voltage sweep.

**(IV) Voltage Settle Time**

- Sets the time in seconds between applying a voltage and measuring the current.
  - This has a maximum of 1 second.

**(V) (a) IV Measurement: Repeats**

- Sets the number of times the measurement will be performed.

**(IV) (b) Solar Characterisation and Lifetime: Illumination**

- Sets the illumination intensity in mA.cm<sup>-2</sup> being used during the measurement.

**(V) Hysteresis Sweep**

- Sets whether or not to perform a reverse current-voltage sweep after the forward current-voltage sweep has completed.
  - This reverses the set start and end voltages, and uses the same voltage increment and settle time as for the forward sweep.

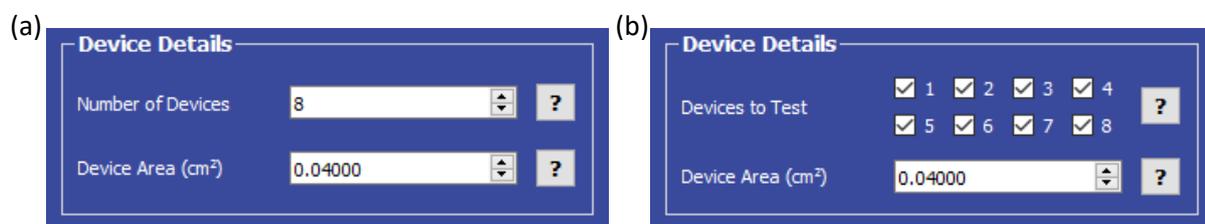
**3.2.4 Device Details**

Figure 3.10. Device Details settings for (a) manual device switching, and (b) automatic device switching using the Ossila Multiplexer.

**(I) (a) Manual Device Switching: Number of Devices**

- Sets the number of individual devices on the substrate being tested.
  - If using manual switching for the lifetime measurement, layout (b) will be shown, but locked to a single device.

**(I) (b) Multiplexer Device Switching: Devices to Test**

- Sets which devices will be tested when using the Ossila Multiplexer (T2003).

**(II) Device Area**

- Sets the area in  $\text{cm}^2$  of each device on the substrate in.

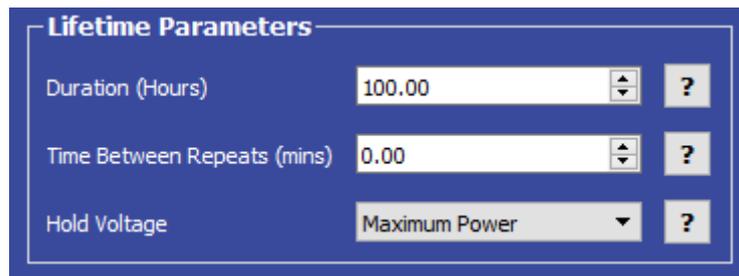
**3.2.5 Lifetime Parameters (Solar Lifetime)**

Figure 3.11. Lifetime Parameters settings.

**(I) Duration**

- Sets the total duration in hours of lifetime measurement.

**(II) Time Between Repeats**

- Sets the time interval in minutes between performing current-voltage sweeps of the devices.

**(III) Hold Voltage**

- Sets the voltage that all devices will be held at between measurements. This can be set as:
  - Short-Circuit – hold at 0 V.
  - Maximum Power – hold at the average maximum power point determined from the latest IV sweep.
  - Open-Circuit – hold at the average open-circuit voltage determined from the latest IV sweep.

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*Note: As the voltage source is only a single channel the hold voltage will be same for all of the devices being tested.*

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### 3.2.6 Saving and Loading Settings

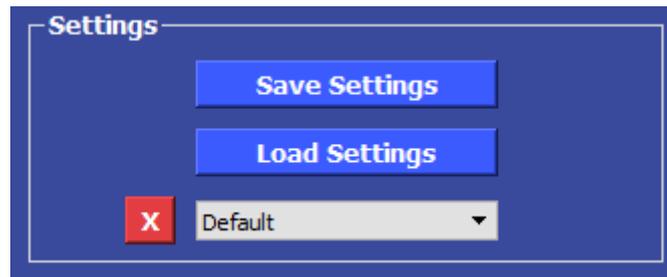


Figure 3.12. Controls for saving and loading settings.

#### (I) Saving Settings

- To save the current settings for use at another time, click the 'Save Settings' button.
  - I. The user will be prompted to name the settings configuration.
    - If the name is already in use, the user will be asked if they wish to overwrite the previous configuration.
    - The name cannot contain the characters: \ / : \* ? " < > |
    - To change the default settings choose the name 'Default'.
  - II. The settings will be added to the drop-down box using the given name.

#### (II) Loading Settings

- There are 2 ways to load settings:
  - I. Select a settings configuration from the drop-down box.
    - This will load settings that have been saved using the 'Save Settings' button.
  - II. Click the 'Load Settings' button.
    - In the dialog box that opens, select the desired file and click 'Open'.
    - The program will populate the settings fields with the values in the settings file.

#### (III) Deleting Saved Settings Configurations

1. Select the settings configuration to be deleted from the drop-down box.
2. Press the red 'X' button.
3. Confirm that this is the configuration to be deleted.

### 3.2.7 Saving Results

- The program allows for data to be saved automatically, as well as manually once the measurement is complete.
  - I. To enable or disable automatic saving, choose the appropriate option from the drop-down box.
  - II. For automatic saving, the 'Saving' fields must be filled in before the measurement can start, these are detailed below.
  - III. The 'Save Results' button is enabled once a measurement has been completed.

- For all measurements, a save directory must be specified. This can be done either by:
  - I. Manually typing the directory into the 'Save Directory' field,
  - II. Copy and pasting from your file explorer,
  - III. Clicking the 'Select Directory' button, which will open a dialog box to allow the selection of a folder to save to.
- All output files are comma separated variable (.csv) files.

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**Warning:** Automatic saving can be turned off for lifetime measurements. However, **manual saving is unavailable for lifetime measurements**, so you will not be able to save your data if it is turned off.

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### (I) IV Measurement

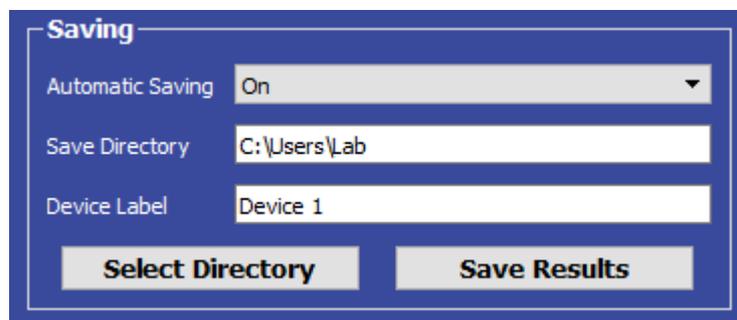


Figure 3.13. IV measurement saving.

- For IV measurements, a device label is required.
  - I. The device label cannot contain the characters: \ / : \* ? " < > |
- When saving, the specified directory will be populated with two files:
  - I. The data for the current-voltage sweep of all tested devices.
  - II. The settings of the experiment (this file can be loaded by the program if you wish to use the same settings again).
- The file names will contain the time the file is saved and the specified device label.

### (II) Solar Cell Characterisation

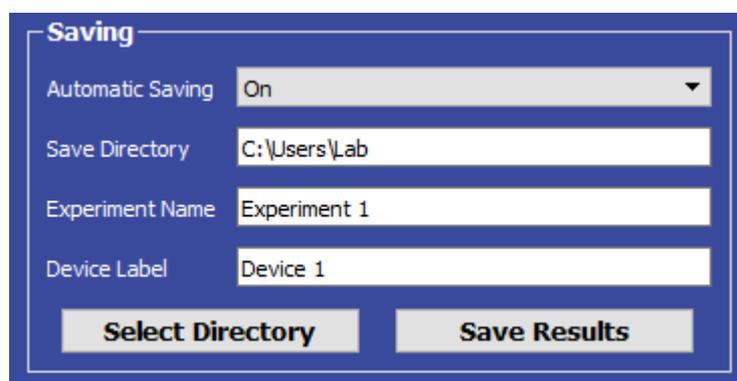


Figure 3.14. Solar cell characterisation saving.

- For solar cell characterisation, an experiment name and device label is required.
  - I. The device label and experiment name cannot contain the characters: \ / : \* ? " < > |
- When saving, the specified directory will be populated with three files:
  - I. The key metrics for all tested devices.
  - II. The data for the current-voltage sweep of all tested devices.
  - III. The settings of the experiment (this file can be loaded by the program if you wish to use the same settings again).
- The IV data and settings will be located in the folders 'IV Curves' and 'Settings' respectively, and labelled with the time of saving and device label.
- The device metrics will be labelled with the experiment name.
  - I. Results from further measurements using the same experiment name will be appended onto the end of the existing file.

### (III) Solar Lifetime

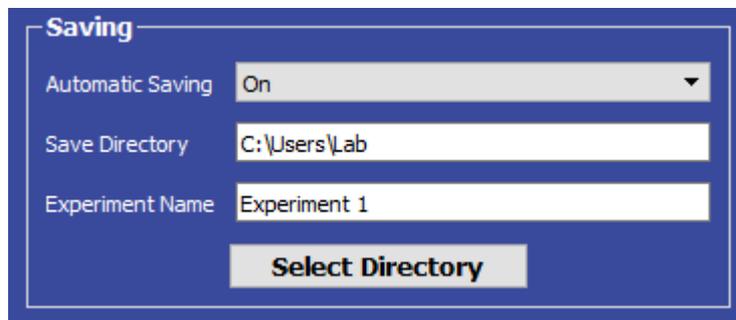


Figure 3.15. Solar lifetime saving.

- For solar lifetime measurements, an experiment name is required.
  - I. The experiment name cannot contain the characters: \ / : \* ? " < > |
- When the measurement starts, the save directory will be populated with a settings file, and metrics file and IV Curve folder for each device being tested.

### 3.2.8 Controls



Figure 3.16. Controls of the Ossila IV Curve Software.

- Once the settings have been set, click the 'Measure' button and the measurement will begin.
  - I. For all experiments, the X100 will perform a current-voltage sweep on the first connected device.

- II. If hysteresis sweep is turned on, a reverse sweep will be performed once the forward sweep is completed.
  - III. This will be repeated for all connected devices.
- How the measurement proceeds is described below for each of the available measurements.

### (I) IV Measurement

- The current-voltage sweep (and hysteresis if selected) will be repeated for the number of times specified in the settings.

### (II) Solar Characterisation

- The following metrics of the tested devices will be displayed in the program after each current-voltage sweep has been completed:
  - I. Power conversion efficiency (PCE)
  - II. Fill factor (FF)
  - III. Short-circuit current density ( $J_{sc}$ )
  - IV. Open-circuit voltage ( $V_{oc}$ )
  - V. Shunt resistance ( $R_{sh}$ )
  - VI. Series resistance ( $R_s$ )

### (III) Solar Lifetime

- The metrics of the tested devices will be displayed in the program after each current-voltage sweep has been completed.
- These values are plotted as relative to the initial measurement in the program.
- If there is a delay between current-voltage sweeps, the devices are held at the selected voltage until the next measurement.

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*Note: The current-voltage data and absolute device metrics taken during the lifetime test are displayed in the Solar Characterisation tab.*

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### (IV) Stopping a Measurement

- The measurement can be stopped by the user by clicking the 'Cancel' button.
  - I. Note that if the measurement is stopped before it completes, the user will be unable to save the experimental data.

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*Note: if any errors occur during operation, a message describing the error will appear at the bottom of the screen.*

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## 4. Troubleshooting

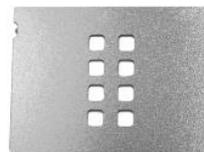
Before we send you your system we run extensive tests to verify that it is stable and working. However, sometimes you may have issues connecting to and using the system. Most of the issues that may arise will be detailed here. However, if you encounter an issue that is not stated here, please do not hesitate to contact us by email ([info@ossila.com](mailto:info@ossila.com)) and we will respond as soon as possible.

Problem	Possible Cause	Action
No power/display	The power supply may not be connected properly.	Ensure the system is firmly plugged into the power supply, and that the plug is connected to both the adaptor and a working power socket.
	The power supply adaptor has a fault.	Contact Ossila for a replacement power supply adaptor.
Software does not start	The wrong version of Windows is installed on the computer.	Install the software on a computer with Windows Vista or newer.
	The software has not installed properly.	Try reinstalling the software.
Cannot connect to the system via USB	The USB cable may not be connected properly.	Ensure the USB cable is firmly plugged in at both ends.
	The USB cable may not be connected to a working USB port.	Try connecting the system to a different USB port on the computer.
	The drivers may not be installed or may not have installed properly.	Try installing or reinstalling the drivers. They can be downloaded from the address given in the Software Installation section.
	The USB cable is defective.	Try using a different micro-USB cable (any should work), and contact Ossila if necessary.
Cannot connect to the system via Network	The MAC address of the system is not registered with the internal network.	Register the system on the network using the MAC address obtained via a USB connection (see Source Measure Unit manual).
	The Ethernet cable may not be connected properly.	Ensure the Ethernet cable is firmly plugged in at both ends.
	The Ethernet cable is defective.	Try using a different Ethernet cable.

## 5. List of Related Products



ITO Glass - Photovoltaic Substrates (8 Pixel) – S211



Measurement Aperture Mask for Photovoltaic Substrates (8 Pixel) – E521



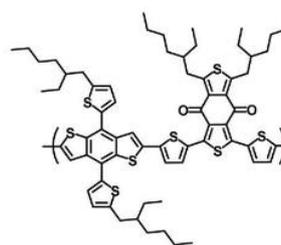
ITO Substrates for OLEDs (Pixelated Anode) – S101



Spin Coater – E441



Perovskite Precursor Ink (for Air Processing) – I101



PCE12 (PBDB-T) – M1001

## 6. Revision History

Rev	Date	Description
A	Sept 2017	Initial version
B	Feb 2018	Change company's address
C	July 2018	<ul style="list-style-type: none"><li>• Updated instructions for switching the system on.</li><li>• Updated network troubleshooting section.</li></ul>
D	Aug 2018	Warranty section removed – now a separate document