

**TS-Space Systems IJ Measurement Software Manual**

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## **1. Overview**

The software is designed to run on a Windows PC and be used with a Agilent B2900 series source meter to provide a varying load to a solar cell under test.

The software offers standard facilities to:

- Sweep volts and measure current
- Sweep current and measure volts
- Select either auto to manual sweep
- Vary the number of sweep steps
- Configure the measurement settings available on the SMU (integration, averaging etc.)
- Calculate cell characteristics from measured parameters
- Save sweep data to tab-delimited measurement file
- Load IV curves from measurement files

The software also provides more advanced features to:

- Measure the temporal stability of a light source via a connected monitor cell (not included)
- Conduct Dark IV analysis by exporting IV data to an analytical spreadsheet (included)
- Specify VL and VFwd measurements to be included
- Group cells by measured IL values using user-defined grouping tables

## **2. Installation**

a) Install the TSIV software by running the 'TSIV Measurement Installer' program supplied. This will install the measurement software as well as the NI Labview™ Runtime engine and NI-VISA Runtime software.

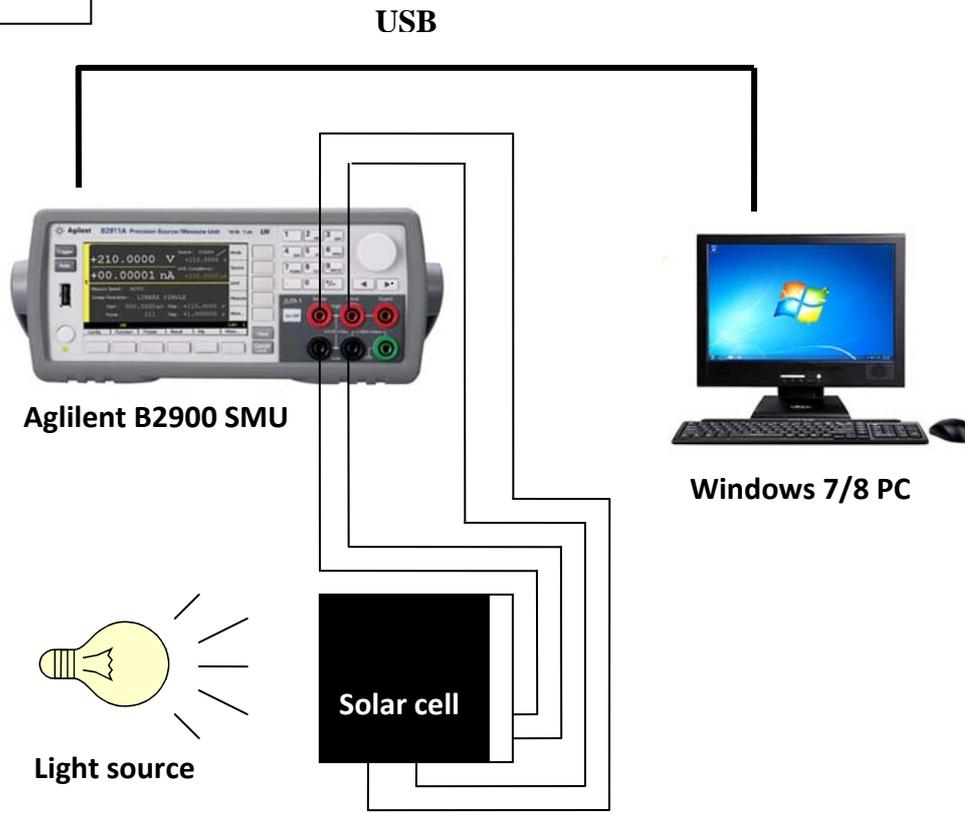
b) Install the Agilent software drivers if not already installed if you wish to use other software with your SMU such as the Agilent 'Quick IV' or the VISA configuration tool. These can be found on the 'Agilent IO Libraries Suite' CD that is included with your source meter. The latest version can be downloaded from the [Keysight website](#).

Ensure that the Agilent VISA is set as the secondary VISA driver using the Keysight I/O library software.

c) Ensure the software is set to run as administrator. If not, right click the 'TSIV Software.exe' located in the installation directory and select 'run as administrator'.

d) Connect the B2900 to the control computer and test sample as shown in Figure 1.

Figure 1.

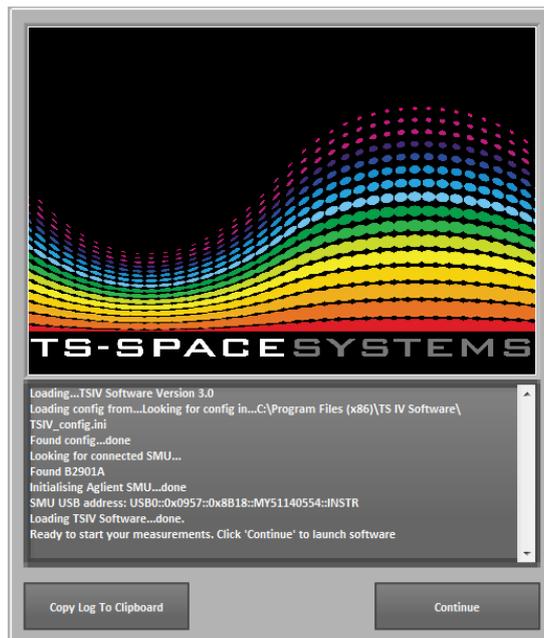


**N.B.** For test purposes, it is possible to dispense with the 4 wire connection. Simply connect to the pair of sockets labelled “force” and loop link the 4 wire sockets

**N.B.** Take care to read and understand the safety implications of using the Agilent electronic load. Incorrect use and or wiring can be extremely dangerous to the operator and can damage the source meter

### 3. Getting started

After launching the TSIV software a loading screen, as shown below, will be visible. The software will load a configuration file if one is available and then check the communication link with the B2900 source meter. Once the source meter is located the software can be started by clicking the “continue” button. If the connection fails the user is notified and the software will quit once the “continue” button is pressed.



#### 3 a) Main screen

The software is divided between a main screen and a run-time menu list in the top left of the window. The main screen provides access to all of the settings and parameters required in order to define and execute an IV sweep. The run-time menu provides access to the additional features of the software (stability monitor, Dark IV etc).

When the software starts the user is presented with a prompt to input the test information. It is not mandatory to complete all/any fields if they are not required. Test information can be added/changed at any point.

The main screen controls are divided into several categories. From left to right these are:

- **Start IV Sweep button:** Starts an automatic or manual sweep. On dual channel instruments the channel to be used is also selectable. OV/OC LEDs are also shown.
- **Measurement settings:** Change the sweep/measure mode and type, set the number of steps and how the SMU will range the output and measurements.
- **SMU Settings:** Select output protection, settle time, 4-wire mode and NPLC (integration) for the sweep. For specific details of these parameters, please refer to your B2900 series manual. One can be downloaded from the [Keysight website](http://www.keysight.com).

- **Manual Sweep and IL/IFwd:** A manual sweep mode can be selected and defined using the tick-box and start/stop value controls respectively. If IL and IFwd values are desired then these can be engaged using the “Measure IL/IFwd” tick box. The current will be measured for these values at the specified VL and VFwd voltages. These measurements are conducted as single-point measurements before the sweep begins i.e. they are not conducted during the sweep.
- **Test Constants:** Set the solar constant and cell area of the device under test. These values are used to calculate the Jsc and Eff% values.
- **SMU Ranges:** Select to use the auto-range feature of the SMU i.e. let the SMU define and control the range using the ‘Auto Range Mode’ rule selected under the ‘Measurement Settings’ category. If auto-range is deselected the volt (V) and amp (I) ranges set using numerical controls are used, as are the compliance settings. If a measurement results in the compliance being broken, the OV/OC LED will be lit and the user notified.

In addition to the main screen controls there are also passive displays for graphical and numerical data as well as system information. These are:

- **IV graph:** Located on the left hand side of the graph area, a plot of the voltage vs current data for each sweep in the current measurement session is shown. Hovering the mouse over a specific IV curve will show a pop-up text box containing the voltage and current values at that specific point as well as other salient data values for the curve as a whole. The Power graph will also switch to show the power vs voltage plot for the currently selected IV curve.
- **Power graph:** Shows a plot of power vs voltage for the currently selected (mouse-over) IV curve. Both this and the IV graph can be manipulated using the toolboxes located in the top left and right corners respectively.
- **Cell Characteristics:** Shows the measured and calculated values for the most recent IV sweep (N.B. This is **not contextual** and will not update when an IV curve is selected via mouse-over). If automatic IL grouping is not selected, the group will be set to 0 by default.
- **Measured Data:** Displays the numerical data for the most recent IV sweep. (N.B. This is **not contextual** and will not update when an IV curve is selected via mouse-over).
- **System log:** Shows a real-time, date and time-stamped log of actions performed within the software.

The plot legend is located between the IV graph and Power graph spaces and is updated automatically after a successful sweep. The IV curve name can be changed either:

- after it is completed by double clicking the name in the legend and typing in a new name. The test information for that IV sweep will then be updated.
- before it is completed via the run-time menu ‘**settings**’->‘**edit test info**’.

### **3 b) Run-time menu**

The run-time menu can be accessed in the top left of the window and provides the following functions from left to right:

- **File**
  - **Save data file:** Saves the measurement session (all IV, measured and calculated values) to a tab delimited text file which can be imported into Excel.
  - **Load data file:** Load a saved measurement session.
  - **Quick export to excel:** Dumps all IV data to an Excel session and starts Excel for quick analysis.
  - **Dark IV analysis:** Exports a selected IV curve into a Dark IV analysis spreadsheet and starts Excel (see section 5 for more details).
  - **Save config to ini:** Save the measurement setup (main screen settings) as default to be loaded when the software next starts.
  - **Close:** Close the TSIV Measurement software. Can also be done using the red cross in the top right of the window.
- **Settings**
  - **Stability Monitor App:** Launches the stability monitor app (see section 4 for more details).
  - **Check connection polarity:** Conducts a Voc measurement (sinks current to 0A and measures the voltage). If the voltage is negative then an incorrect polarity is reported.
  - **Check SMU comms:** Checks the address and communication status of the SMU.
  - **Edit test info:** Opens a window for the user to enter new test data. Fields left blank will remain unchanged. Only fields that are given an input will be updated.
  - **Show test info:** Prints the current test information to the System Log window.
- **Graph**
  - **Auto-scale graph:** Will re-scale the graph using the auto-setting which will fully display all IV curves in the measurement session.
  - **Clear graph:** Clears all IV curves and data from the measurement session and clears the graph. **Cannot be undone.**
  - **Y-Axis log scale:** Toggles the Y-axis to be shown in Log format or linear (linear is the default).
- **Help**
  - **TSIV Software Manual:** Opens this document.
  - **About TSIV Software:** Shows the software version of TSIV Measurement Software installed.

### **3 c) Auto-sweep mode**

The easiest way in which to operate the software is to use the default auto-sweep mode. When this is engaged, clicking the 'Start IV Sweep' button will trigger the following measurement procedure:

- The source meter comms will be checked
- The Voc will be measured and the polarity checked
- The Isc will be measured
- If IL/IFwd measurements are selected these will be measured. If automatic IL grouping is selected the group will also be set.
- The sweep will be conducted between from 0V -> Voc if in voltage sweep mode, or 0A-Isc if in current sweep mode. The respective value will be measured depending on the sweep mode.
- Measured and calculated parameters are displayed via the numerical indicators on the front panel. The IV graph space is updated.

If problems with the SMU comms or connection polarity are detected the sweep is aborted before the Isc is measured. All steps and any errors in the procedure are printed to the System Log window to assist with trouble shooting.

### **3 d) Manual-sweep mode**

The manual sweep mode can be engaged from the main screen (see section 3a) and allows the user to specify their own sweep range. The numerical controls for the sweep start and stop values are contextual to the sweep mode selected i.e. if a voltage sweep is selected, 'sweep start' refers to the start voltage and 'sweep stop' refers to the stop voltage in V.

It is possible to damage a device if a too large a voltage is driven across it. As such a warning is posted to the screen whenever the manual mode is engaged to notify the user that manual mode is active. It is recommended that manual mode is **only engaged if you are confident if the electrical limits of your device under test.**

### **3 e) Group Tables using IL measurement**

The measured device can be automatically grouped using the measured IL value and a user defined group table. The automatic grouping is engaged from the 'Group Tables' tab in the main screen. From here group tables can also be created and loaded. Only one group table can be loaded at any one time.

To create a group table:

- In the 'CREATE NEW GROUP TABLE' boxout (see figure 3 below), use the 'Group name' and 'IL(mA)' numerical controls to configure a group. For example a group name of '0' and an IL(mA) value of '0.1'.
- Click the 'Add' button to add the values to the next row in the table. You will see them appear in the table to the right.
- To remove the last row click the 'Remove' button.
- Once you have added as many groups (rows) as required, click the 'Add Group Table' button. You will be prompted to give the table a name.
- The group table will now be saved and is available to be loaded.

To load a group table:

- In the 'LOAD A GROUP TABLE' boxout (see figure 3 below), click on the name of the table you wish to load in the 'IL Tables' list. The group names and IL(mA) values are shown on the right so that you can check it is correct.
- When you have selected the group table you require, click the 'Load Group Table' button. You will be notified that the table has been loaded via a pop-up and the System Log on the main screen.

To engage automatic grouping:

- The group table currently loaded will be shown in the 'CURRENT GROUP TABLE' boxout.
- To turn on automatic grouping via IL measurement, tick the 'Auto-group' tickbox (see figure 3).
- On the main screen (click on the 'Main' tab to get back), tick the 'IL/IFwd' tickbox to turn on the IL and IFwd point measurements (see Figure 2). This will also enable the VL and VFwd numerical controls.
- Set the VL and VFwd voltages as desired.

Figure 2.

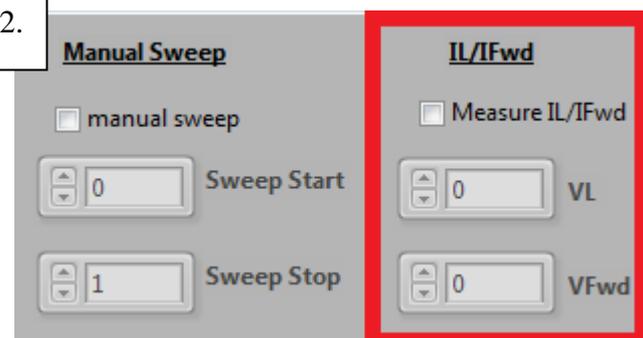
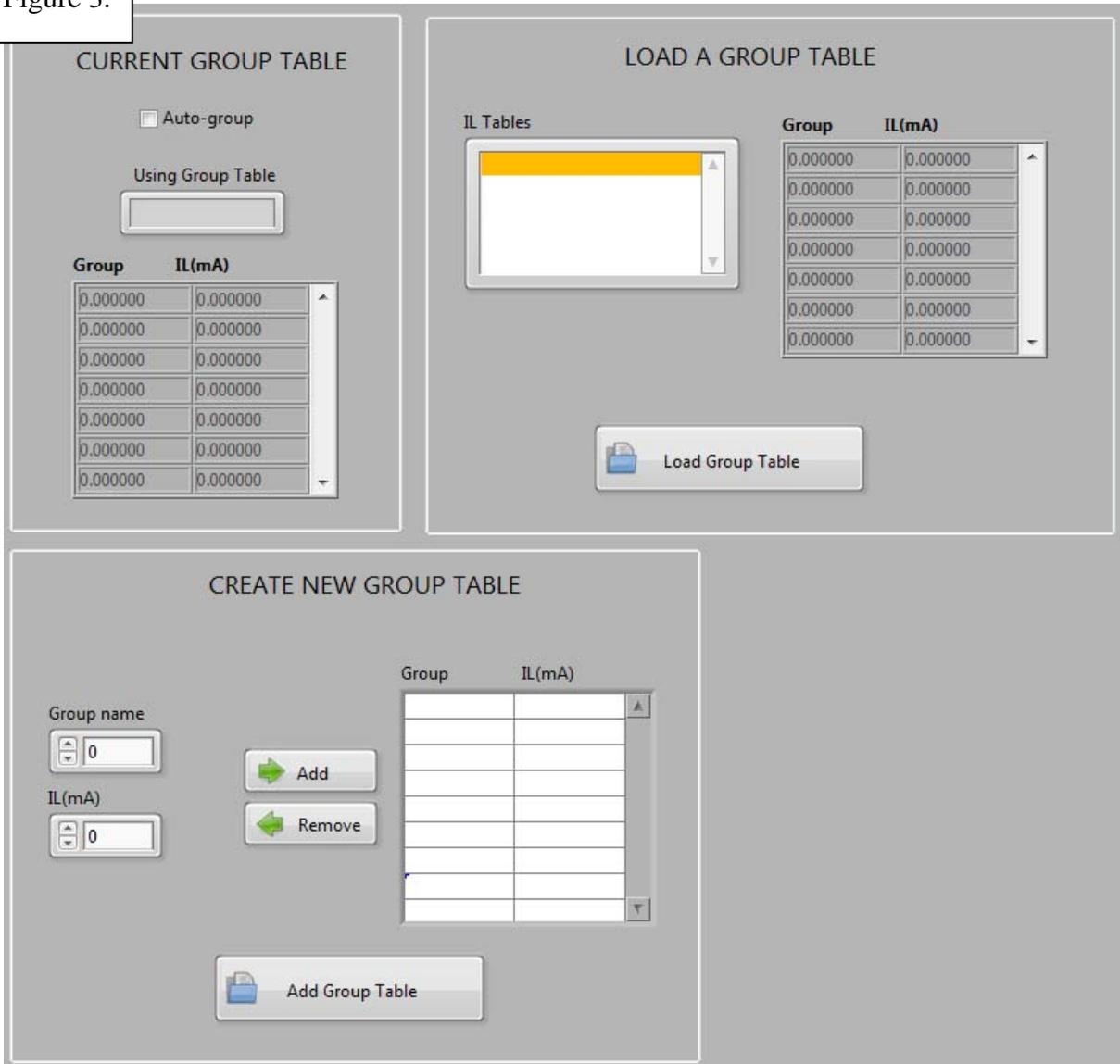


Figure 3.



#### 4. Stability Monitor App

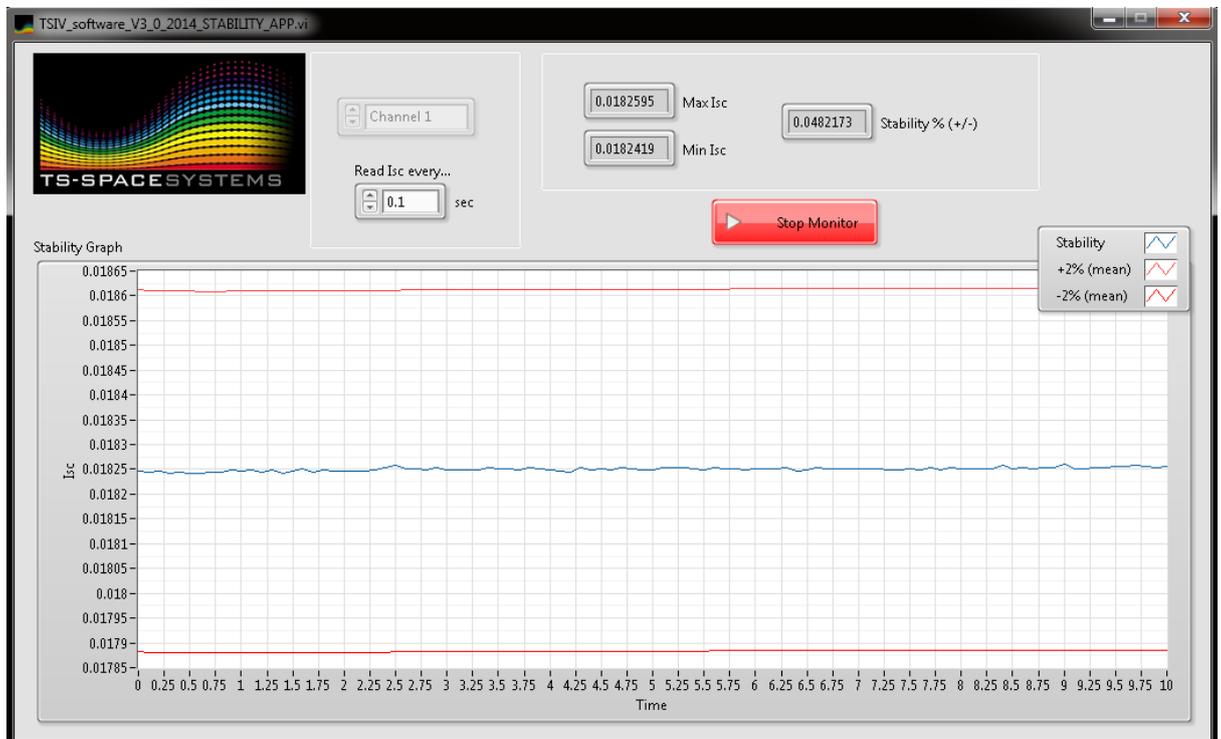
The 'Stability Monitor App' allows a user to monitor and measure the temporal stability of a light source using a monitor cell (not provided).

Once started, the Isc of the monitor cell is measured i.e. the voltage across the device is driven to 0V and the current is measured. The user can select the time between these measurements depending on which timescale the temporal stability is to be measured across. The software will continue to take measurements until the 'Stop Monitor' button is clicked.

During the measurement the graph is updated in real-time every time a new Isc measurement is taken and plotted in blue. There are also two plots in red which show a value of +/-2% from the mean of all the Isc measurements in the current stability measurement session.

The maximum and minimum Isc readings as well as the total temporal stability (+/- %) are shown in the numerical indicators and are also updated in real-time.

Once the user is finished with the Stability Monitor App it can be closed and the user is returned to the main software screen.



## 5. Dark IV Analysis

A dark IV curve can be measured and analysed using the following procedure:

- Setup your device for a dark IV test as desired. If you are using a TS-Space Systems™ ‘Unisim’ solar simulator, please refer to your manual for how to operate the pneumatic shutters (the switches will usually be located on the front control panel in manually operated systems).
- The y-axis of the IV graph can be changed to a log form using the run-time menu (see section 3b).
- **It is recommended that you measure at least 140 steps in the IV sweep for dark IV analysis.**
- Engage manual mode and set your sweep range values (see section 3a).
- Start your sweep by clicking the ‘Start IV Sweep’ button.
- Once the sweep is complete, from the run-time menu select **File -> Dark IV Analysis**. If there is more than one IV curve in the measurement session you will be prompted to select the number of the curve you wish to export for dark IV analysis.
- The software will launch Excel and export the selected plot into the dark IV analysis worksheet
- The fitting parameters are shown on the left hand side of the worksheet (see Figure 4). The imported IV values are shown to the right of these and the measured, estimated and fitted plots are shown to the right.
- The variables can now be adjusted in order to minimise the calculated error (see Figure 4) and derive the values of RSH and RSER

Figure 4.

Dark IV Analysis Spreadsheet	
<b>Constants</b>	
T	298
k (Boltzmann's constant eV/K)	8.617E-05
kT	2.568E-02
<b>Variables</b>	
Io1	2.10E-25
Io2	5.10E-15
RSH	9.33E+06
RSER	2.14E+00
<b>Error Optimisation</b>	
Calculated error	1.100908

## 6. Troubleshooting

Problem	Suggestions
"The software cannot find the source meter"	<ul style="list-style-type: none"> <li>- Check the USB connection between the PC and the source meter.</li> <li>- Plug the USB cable into a different port on the PC (if possible).</li> <li>- Power cycle the SMU.</li> <li>- Use the NI MAX application to detect the attached instrument. Check comms by sending a *IDN?\n command.</li> <li>- Use the Agilent IO Control application to check that the NI VISA is the primary VISA for the SMU.</li> <li>- Uninstall all drivers (Agilent and NI) and software. Reboot and reinstall following instructions in section 2.</li> </ul>
"The sweep fails due to incorrect polarity"	<ul style="list-style-type: none"> <li>- Check the connections to the device are in the correct polarity.</li> <li>- Check the connections to the device are well made (poor connections can cause negative voltages which will be reported as problems with the polarity).</li> </ul>
"Dark IV analysis worksheet isn't importing data correctly"	<ul style="list-style-type: none"> <li>- Make sure you have closed Excel from the previous session.</li> <li>- It is recommended to use &gt;140 steps in a dark IV sweep. If you use fewer this may cause problems with the data export to Excel.</li> </ul>
"I can't take any more IV sweeps"	<ul style="list-style-type: none"> <li>- You will need to save the measurement session and clear the graph via</li> </ul>

the run-time menu.