SciPV: IV

User Manual

V2.4.2

Updated for SciPV: IV v1.0.1.2

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2. Overview

Sciencetech SciPV desktop application consists of two main tabs; IV and QE. The IV tab allows for the sequencing of generic source-meters to run current voltage scans. The QE tab allows for performing several measurands such as spectral response, external quantum efficiency, and internal quantum efficiency. Depending on the hardware to be controlled by the SciPV these tabs are enabled or disabled in the installer that is provided to you. For Sciencetech SSIVT series products only the IV tab is needed and thus enabled.

SciPV: IV is configured for four-wire (probe) measurement. The software also gives the user the ability to configure measurement parameters like samples per point, IV points per measurement, sweep direction, etc. Files can also be loaded back into SciPV: IV for review.

3. Software Installation

Please follow the instructions related to your Keithley. Before starting any installation steps, verify the Keithley version (2400, 2401, 2420, or 2450 that is supplied with your system).

3.1 Keithley 2400 Series (including 2401) Setup

This step should already be completed at Sciencetech, but it is good to verify that the Keithley (and any other accessories to be used with SciPV such as TEC Cell Chuck) is in the correct configuration. If the Keithley being used has not been supplied by Sciencetech, please follow these steps.

Power up the Keithley and go into the menu setup

1. Click the MENU button

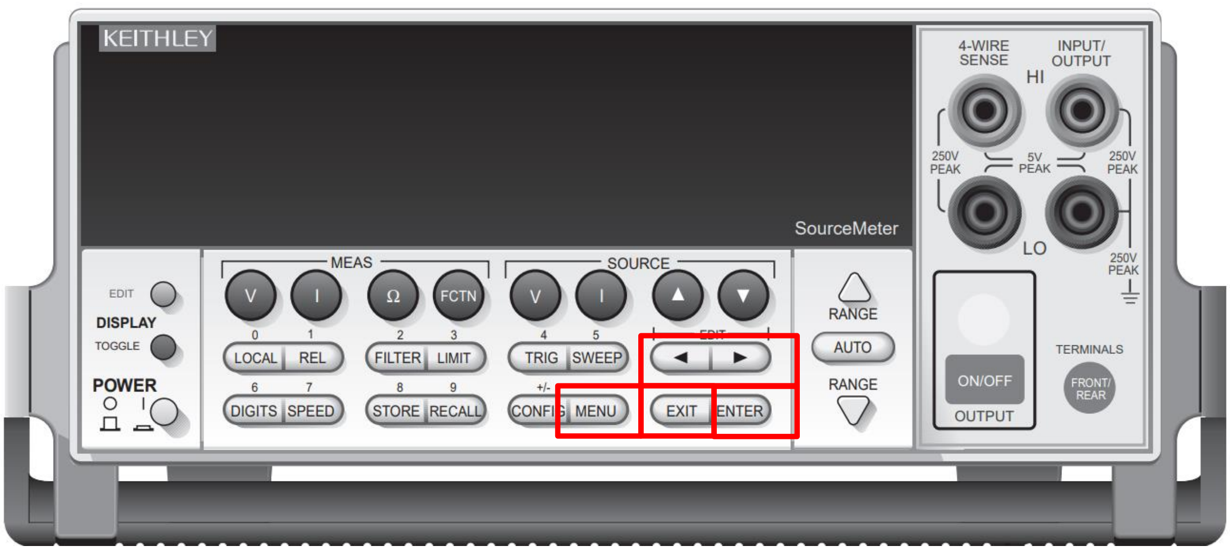


Figure 1. Keithley 24XX series front panel.

2. Navigate to COMMUNICATION using the side arrows and press ENTER
3. Set the communication to RS232, press ENTER
4. Set the baud rate to 19200, press ENTER
5. Set the Terminator to <CR+LF>, press ENTER
6. Make sure under the FLOW CONTROL, the XON/XOFF is selected.
7. Press the EXIT button.
8. Connect the Keithley to the computer with the provided USB to RS232 cable. Connect the RS-232 (DB9) connection on the rear of the Keithley to the computer to be used (any available USB port).

9. Go into Windows Device Manager and determine the serial Comm port for the Keithley device (and any other accessories used by SciPV, e.g. TEC cell chuck).

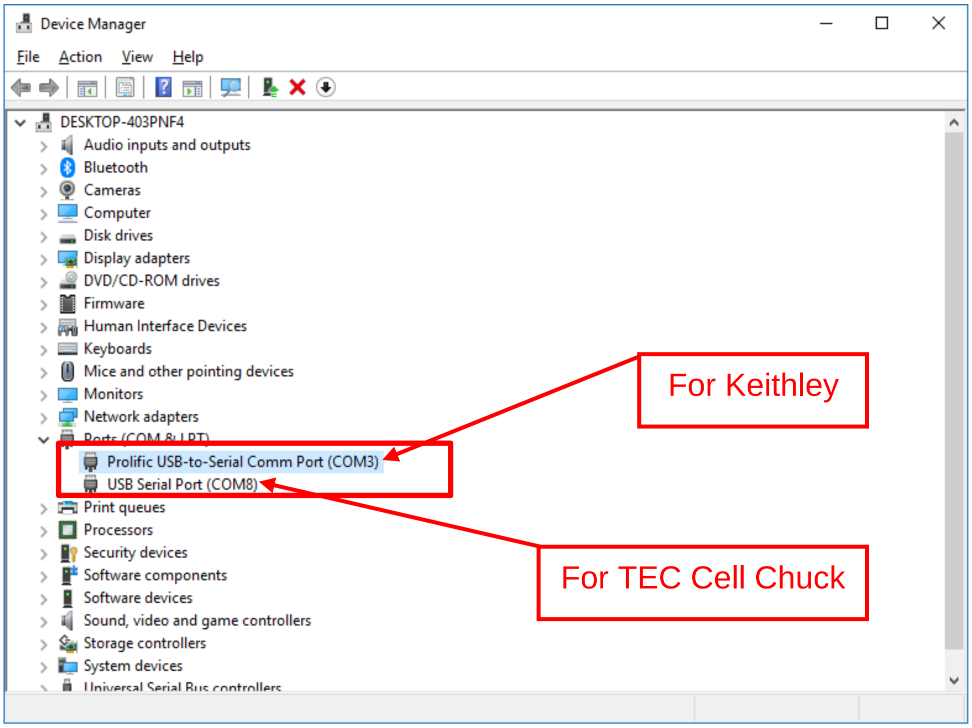


Figure 2. Device manager window with Keithley and cell chuck shown in Ports.

10. Edit the configuration file *KE2400Settings.config* (or KE2400DEMUXSettings.config file depending on the system configuration) and enter the determined serial port as the CommPort value. (In this example, 3). <CommPort>3</CommPort>. Configuration file location: Here is the configuration file location:
    C:\Users\Public\Documents\Sciencetech\Modules\Config
    If you are receiving a TEC Cell Chuck to be controlled by SciPV make sure set the CommPort value in the *TECSettings.config* file as well (In this example, COM8). Thus, set the following in the *TECSettings.config:*
    <PortNumber>8</PortNumber>
11. Ensure the Keithley configuration file also has the correct baud rate of 19200.
    <BaudRate>19200</BaudRate>

3.2 Keithley 2450 Drivers Setup

Keithley 2450's requires the following drivers (these drivers will be located on the supplied USB with your system):

1. Install the drivers supplied with your system in the following order:
   A. Install "..\VisaRunTime53\setup.exe"
   B. Install "..\IviSharedComponents64_260.exe"
   C. Install "..\Keithley2450-x64.msi"
2. Connection the Keithley to the computer to be used with the supplied USB cable.

Figure 3. Keithley 2450 back panel.

3.3 SciPV Installation

1. Move the installation folder to the local computer.
2. Install the Drivers (if necessary).
    a. If your system uses a Keithley 2450, ensure the Keithley 2450 drivers are installed (See section 2.2).
    b. If your system uses a Keithley 2400, 2401, or 2420, install the RS232 to USB cable drivers (Prolific_PL2303 – this will be in a separate folder inside the SciPV install master folder).
3. Run setup.exe inside SciPV v1.X.X.X folder (labelled according to the version of SciPV that is supplied).

4. Software Operation

Upon launching SciPV the user is greeted with the below screen (the window may not be exactly as pictured below depending on your system configuration):

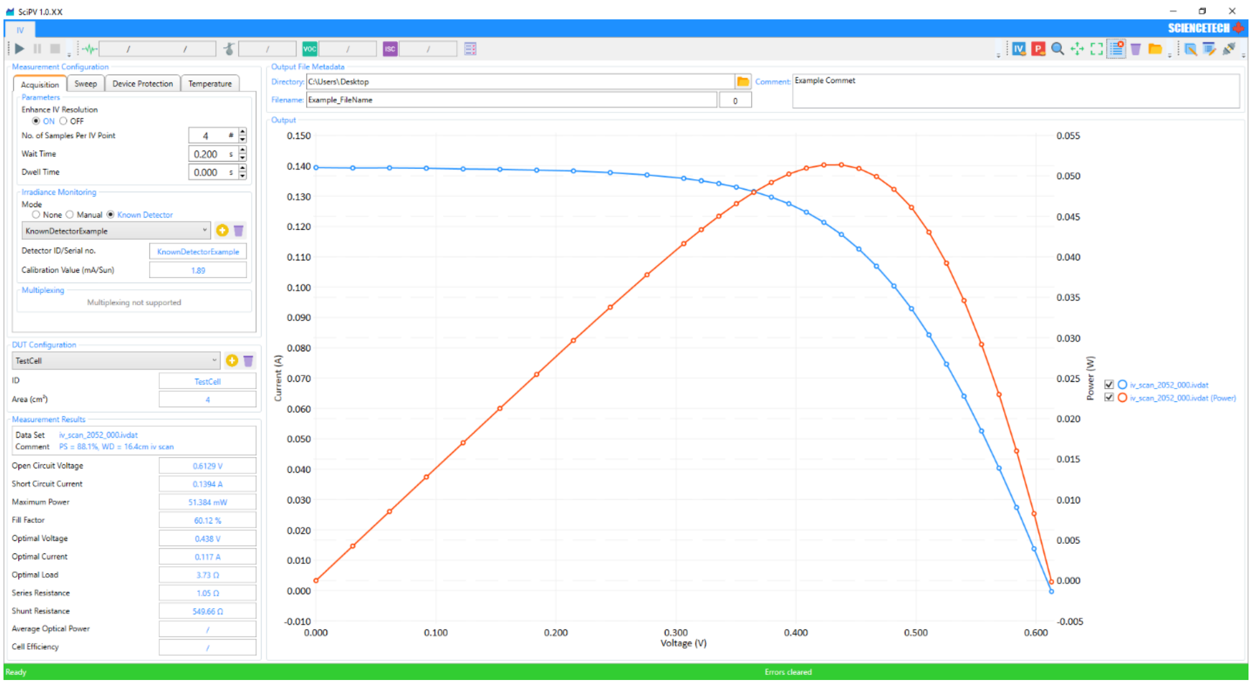


Figure 4. IV tab screenshot.

The controls of the main divisions of the software are described in their respective sections below.

4.1 Status Bar

The status bar is the strip at the bottom of the SciPV application that provides feedback on the current status of the system and any errors that occur.

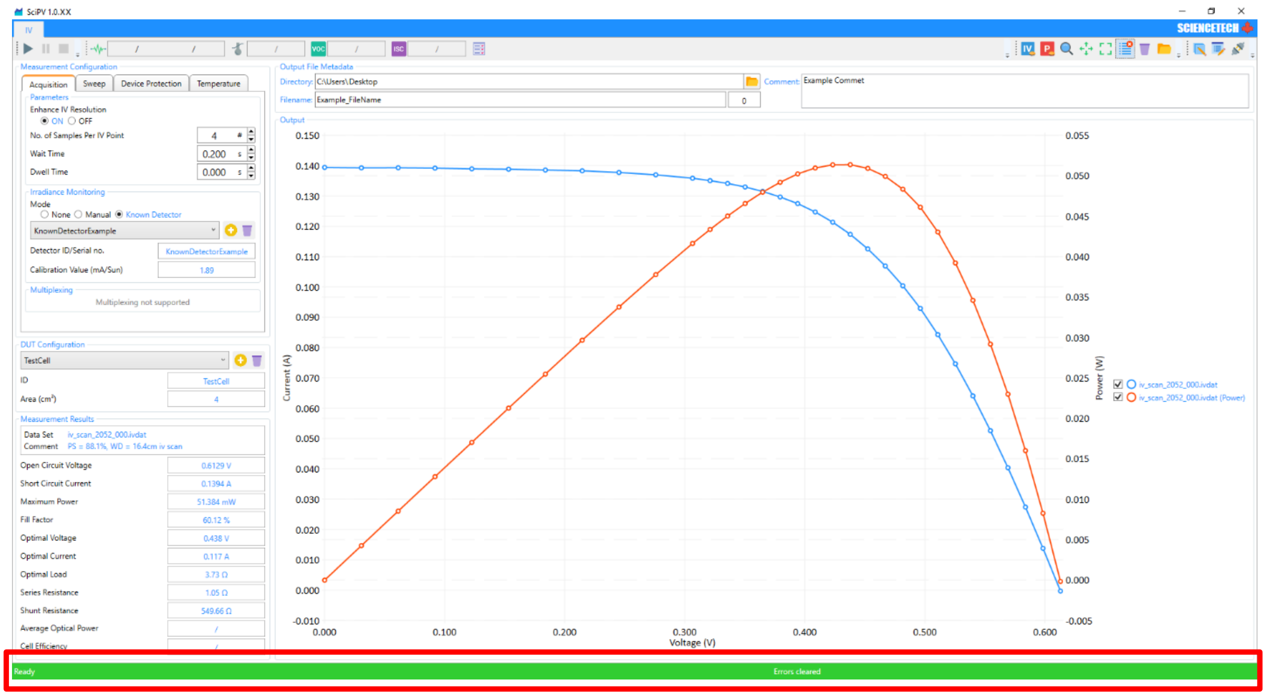


Figure 5. Status bar callout on IV tab.

The status bar will be one of three colours, GREEN, BLUE, or ORANGE.

4.1.1 Green Status Bar

If the status bar is green, the system is ready to be used and has completed any actions successfully. The status bar will display “Ready” on the left.

4.1.2 Blue Status Bar

If the status bar is blue, the system is currently performing an action, such as a scan. The status bar will display a string of the action that is currently being completed near the middle. The status bar will display “Working” on the left.

4.1.3 Orange Status Bar

If the status bar is orange, an error has occurred. The orange bar precedes all other colours. If the system is ready (green), or working (blue), the status bar will remain orange if an error has occurred. To view the error(s) that have occurred, click the error log button.

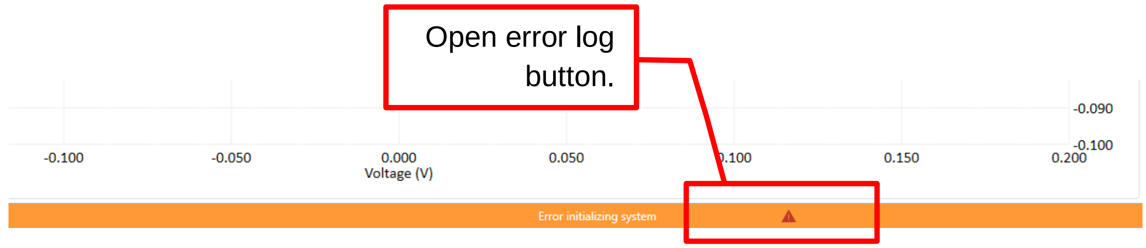


Figure 6. Error log callout.

Once the error log is open, the errors can be viewed. Please see the troubleshooting section of this user manual for various errors explanations and solutions. To clear an error, press click the trash can. To clear all errors, click the broom. The status bar will not change from orange until all errors are cleared manually.

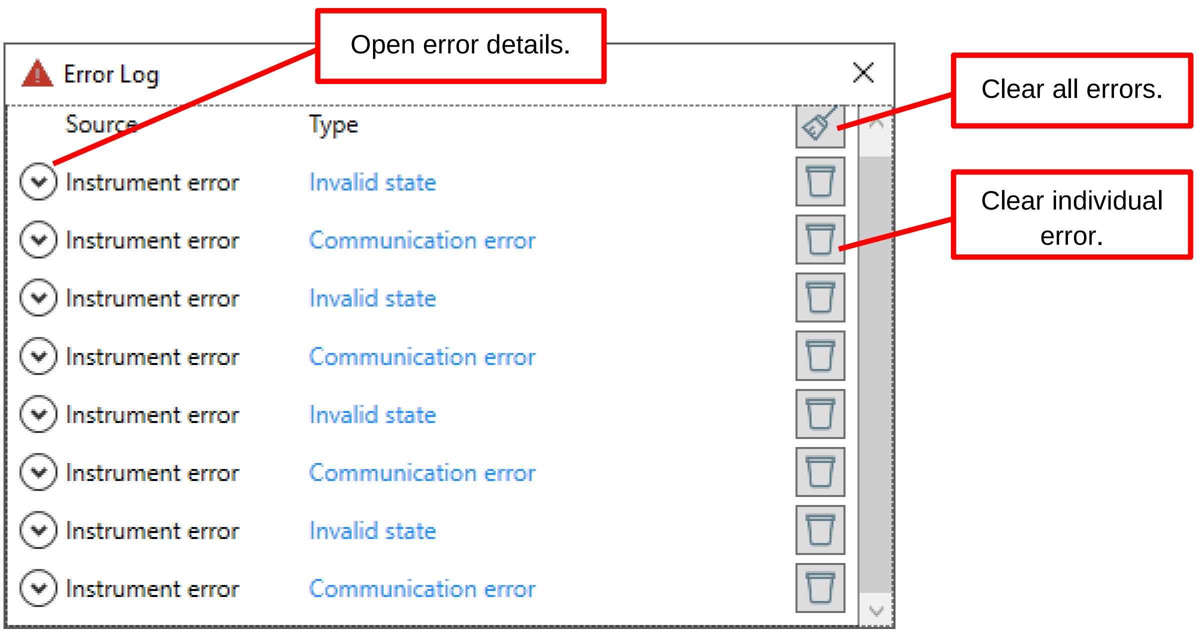


Figure 7. Error log example.

4.2 Toolbar Buttons

The buttons in the toolbar are each briefly described below:

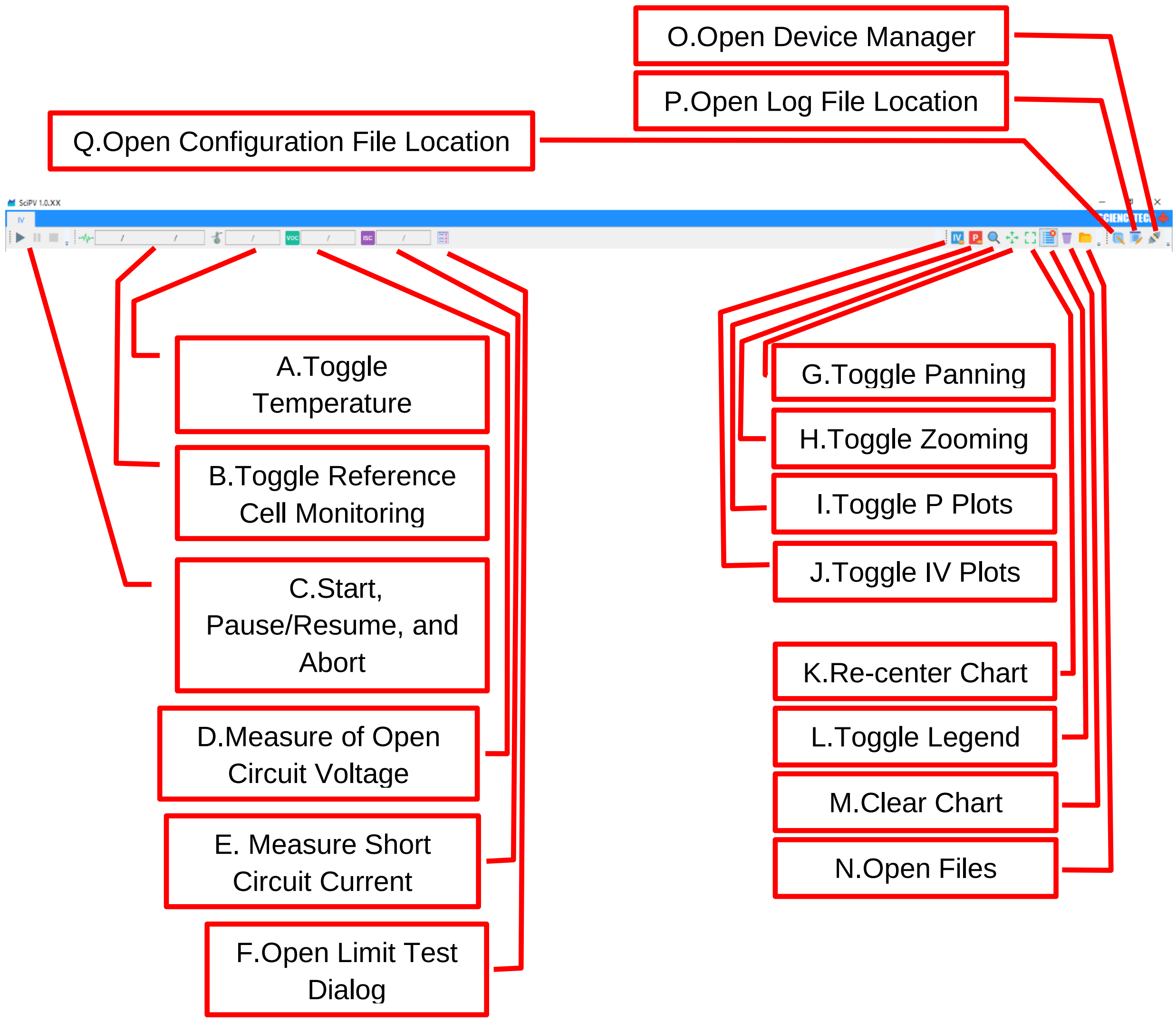


Figure 8. Toolbar Buttons Descriptions.

4.2.1 A. Temperature Monitoring

If the source meter being used by the application supports temperature measurements, you can monitor this temperature using the '*Toggle Temperature Monitoring*' tool bar button. Clicking once will begin monitoring the temperature sensor, and will report its value periodically in the toggle button in the tool bar. Clicking the button again cancels temperature monitoring.

4.2.2 B. Reference Cell Monitoring

If the source meter being used by the application supports reference measurements, you can monitor the reference cell by using the '*Toggle Reference Cell Monitoring*' tool bar button. Clicking once will begin monitoring the reference cell, and will report its value periodically in the toggle button in the tool bar. Clicking the button again cancels reference cell monitoring.

4.2.3 C. Start Pause/Resume. And Abort

To initiate the measurement, click on '*Start*' button. To Pause an undergoing measurement, click on the '*Pause'* button. To resume this measurement, press again on '*Pause'* button. Press the '*Abort'* button if you wish to cancel an undergoing measurement.

4.2.4 D. Measure of Open Circuit Voltage

This button only measures the V_{oc} of the device under test (DUT). Please note by pressing this button the V_{oc} is only shown on the tool bar, but no data is saved on your computer directory. If you wish to save this V_{oc}, please run a complete IV sweep.

4.2.5 E. Measure of Short Circuit Current

This button only measures the I_{sc} of the DUT. Using this button is useful for quickly checking the irradiance level of an illumination source when using a Reference Cell with a known I_{sc} (for example I_{sc} at 1 Sun irradiance level). Please note by pressing this button the I_{sc} is only shown on the tool bar, but no data is saved on your computer directory. If you wish to save this I_{sc}, please run a complete IV sweep.

4.2.6 F. Open Limit Test Dialog

User can enter limit test parameters such as V_{oc}, I_{sc}, etc. in this dialog box. After an IV sweep is performed, the software displays whether or not each of the calculated parameters of the DUT fall within the set limits.

4.2.7 G. Toggle Panning

Used for panning around a displayed curve. Simply press this button and left click on the display area and pan around. To disable this feature, press again on this button.

4.2.8 H. Toggle Zooming

Used for zooming in/out on a displayed curve. Simply press on this button and use the scroll wheel of the computer mouse. To disable this feature, press again on this button.

4.2.9 Toggle P Plots

To hide/show the power plot(s) from the display area.

4.2.10 Toggle IV Plots

To hide/show the IV plot(s) from the display area.

4.2.11 K. Center Chart

To set the setting of the display area after using either *'Toggle Panning'* or '*Toggle Zooming'*.

4.2.12 L. Toggle Legend

To hide/show of the legend beside the displayed curves.

4.2.13 M. Clear Chart

To remove any of displayed curves from the display area. Pressing this button does not delete any of the measured data from your computer directory, but only clean the display area.

4.2.14 N. Open Files

To open previous measured file for redisplaying.

4.2.15 O. Open Device Manger

To open the device manger of the software. Parameters such as Model and Serial Number of the connected Keithley and COM Port No. are displayed here.

4.2.16 P. Open Log File Location

It will open the directory where the Log File is saved. This file is mainly useful for debugging and troubleshooting of the software.

4.2.17 Q. Open Configuration File location

It will open the directory where the Configuration File is saved.

4.2.18 R. Open Application Help File

It will open the SciPV help file.

4.3 File Metadata

This section allows the user to specify where output data files are saved, as well as the name they are saved with, and may choose to insert a comment. Output files automatically index themselves, which means that if a target directory already contains a file with the target file name then the output will be saved with an indexed suffix which is specified by the number to the right of the file name. For example, the first file in a given directory will be saved as *file_000,* and the next will be saved with the name *file_001*. When the application detects that an invalid target file name or directory has been specified the field will become colored red.

4.3.1 Output File Format

When an IV measurement is run it generates an output data file(s), with the extension "**.ivdat"* (IV data). These files are split into three parts, from top to bottom, which are describe below:

1. Header – The header contains metadata about the measurement configuration, this includes things like sweep type, number of IV points, etc.
2. Data – The data section contains two large tab separated value (*.tsv) tables, the first is the IV data for the sweep, the second is associated PV data.
3. Footer – The footer contains the results of the IV measurement which are calculated after the last data file has been acquired. If a measurement is cancelled, or fails to run to completion this section of the file will contain no values.

4.4 Measurement Configuration

WARNING: Commas should not be used to separate numbers. For decimals only a period should be used.

This groupbox contains controls for parametrizing the IV measurements performed by the application. These controls are divided into three tabs: Acquisition, Sweep Configuration, and Device Protection.

4.4.1 Acquisition

A view of this tab can be seen below:

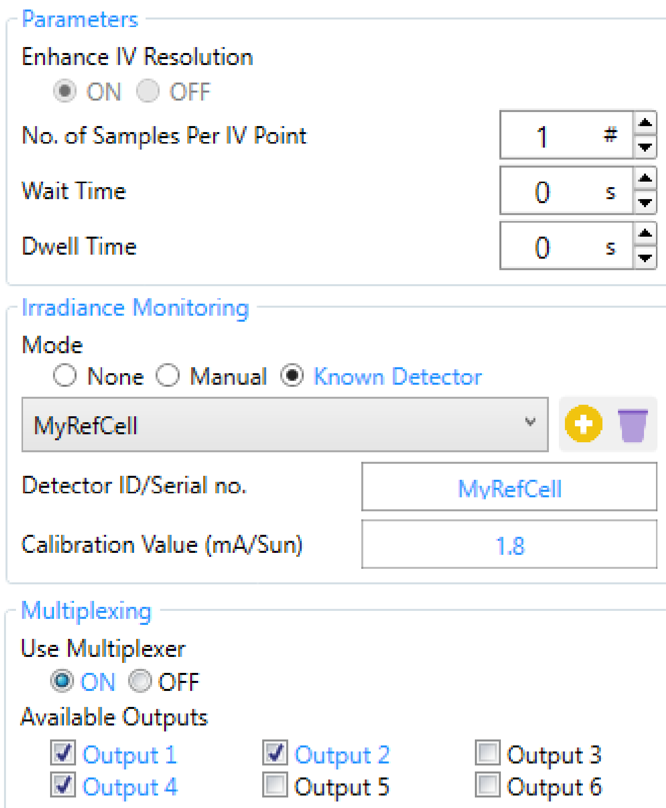


Figure 9. Measurement acquisition menu.

4.4.1.1 Parameters

The parameters group box controls how data points are measured.

'*Enhance IV Resolution*' increases the IV sweep resolution on the open circuit end of the measurement. Normally, the IV points are linearly spaced along the curve, when this feature is used half of the IV points are linearly spaced into the first two thirds of the sweep nearest the short circuit current, and the second half are linearly spaced into the last third, nearest the open circuit voltage. This feature is useful when the user wishes to achieve higher detail of the open circuit side of the measurement.

'No. of Samples Per IV Point' sets the number of measurements performed by the Keithley at each point on the IV curve. For example, if you set the No. of Samples Per IV Point to 5, the Keithley will make 5 measurements at each point on the curve and average those measurements to produce 1 data point.

'Wait Time' sets the time period before a new bias voltage is applied after a previous IV point.

'Dwell Time' sets the time period that a new bias voltage is applied before an IV point(s) measurement is performed.

Please note that both Wait Time and Dwell Time do not apply to the time between measurement of several measurement per each IV point (In case the *"No. of Samples Per IV Point"* in the Acquisition menu is set to value greater than 1).

Please also note the software can only accept '*Dwell Time'* and '*Wait Time'* values equal to 0, and 1 millisecond or more. This means the software can not support dwell Times and wait Times between 0 and 1 ms.

4.4.1.2 Irradiance Monitoring

Irradiance monitoring allows the use of a reference cell or detector to monitor the irradiance level at the test location with the use of a secondary device. There are three modes: None, Manual, and Known Detector. None disables irradiance monitoring. Manual allows the user to manually input a measured irradiance level. Known detector allows the user to create a known detector with an ID and calibration value. In known detector mode, the Keithley will read a device connected to the rear 4-wire connection at each IV point. These values are recorded and saved in SciPV data files and are used for some results calculations. To add a known detector, click the yellow plus button. The Detector ID/Serial no. and Calibration Value (mA/Sun) boxes will become bordered in blue (shown below). Enter in the desired known detector identifier and calibration value and click the red save button. The known detector will be stored, and can be selected from the drop-down menu for future use. To remove a known detector, select the detector you wish to delete, and click the trash can next to the add detector icon.

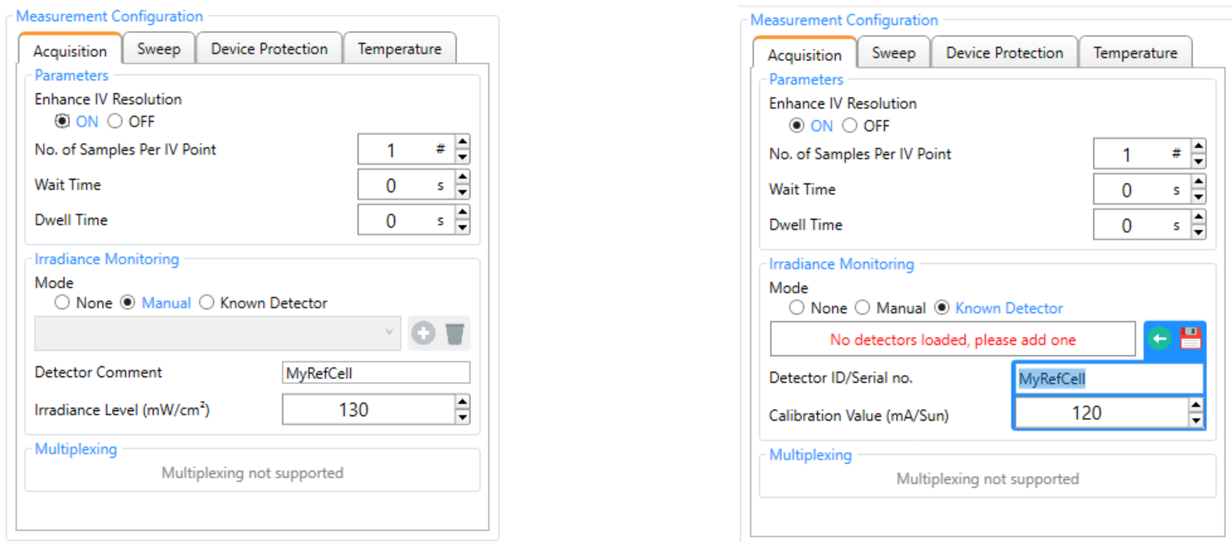


Figure 10. Irradiance monitoring dialogue box.

When irradiance monitoring is set to Known Detector, press the Green waveform button to read live values from a connected known detector. The are displayed as shown below.

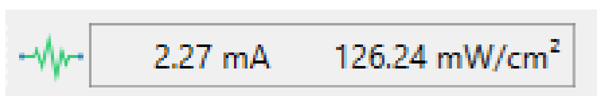


Figure 11. Reference cell irradiance monitoring display.

If the user has selected the *Known Detector* under the *Irradiance Monitoring* section and has entered the Irradiance Level of this reference detector under the *Irradiance Level (mW/cm^2)*, the result from the irradiance monitoring will be saved along the IV data of the DUT in the IVDAT file and can be used for future references.

4.4.1.3 Multiplexing

When running the application with a source meter that is equipped with a multiplexer it is possible to multiplex your measurements to multiple cells. The '*Use Multiplexer*' setting should be turned *ON* and then the target outputs should be checked. When the measurement is initiated, it will perform the same IV sweep on all targeted outputs. It should be noted that multiplexed measurements will produce multiple data file outputs. The naming schema for multiplexed outputs inserts a multiplexer index string to the data file name. For example, the above pictured output selection would generate the following files: *basefile_M1_000*, *basefile_M2_000*, and *basefile_M4_000*.

4.4.2 Sweep Configuration

A view of this tab can be seen below:

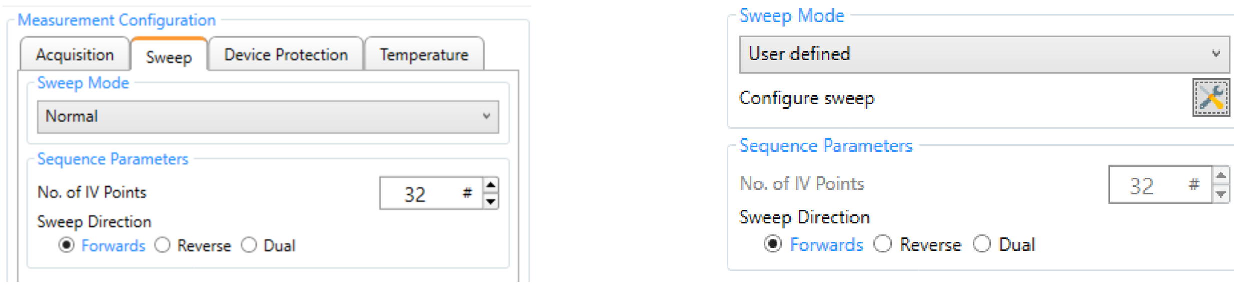


Figure 12. Sweep Mode and Sequence Parameters menu.

4.4.2.1 Sweep Mode

This setting selects whether a *Normal*, or *User Defined* sweep is run. A *Normal* sweep runs from the short circuit current, to the open circuit voltage, and a *User Defined* sweep runs from any bounds the user wishes to impose.

4.4.2.1.1 User Defined Sweep Builder

The *User Defined* sweep allows the user to scan from any starting voltage to any ending voltage they wish. The user can also select whether to include open circuit voltage and short circuit current measurements (V_{oc} and I_{sc} are measured whether or not the '*User Defined'* sweep crosses the V_{oc} and I_{sc} points). The user may also specify the number of points within these voltage bounds, and the user may divide the total measurement into as many of these user defined voltage bounds as they wish. When User Defined Sweep is selected from the drop-down menu, an edit button appears which allows the user to configure the sweep, it is pictured below:

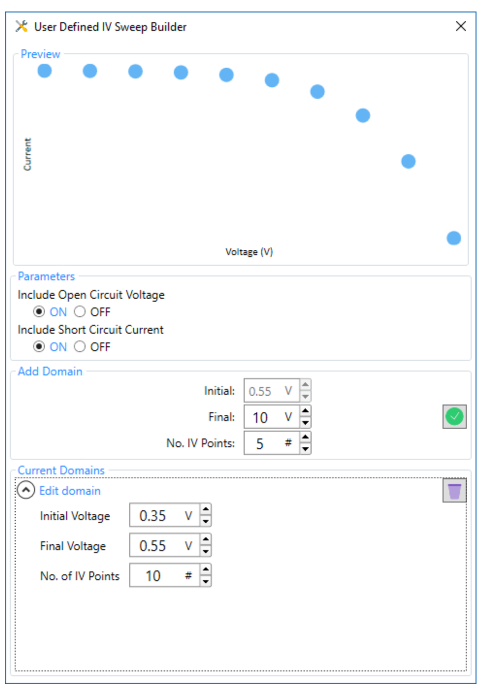


Figure 13. User Defined Sweep Builder menu.

Note that the dialog provides a rough estimate of the shape of the IV curve that can be expected based on the domain configuration.

To add more domains, edit the Initial Voltage, Final Voltage, and No. of IV Point values, and click the green check mark to add another domain. To remove a domain, click the purple trash can next to that domain. With a domain added, you can also edit the bounds by opening the drop-down section of that domain and editing any of the values. Once the user defined sweep is configured, click the X button on the software to close the window.

4.4.2.2 Sequence Parameters

The *Number of IV points* parameter allows the user to specify how many points are used when performing a normal sweep measurement.

The *Sweep Direction* allows the user to specify the direction the IV data points are acquired in. Normal runs from short circuit current to open circuit voltage, reverse runs from open circuit voltage to short circuit current, and dual scans from short circuit current, to open circuit voltage, and back again to short circuit current.

4.4.3 Device Protection

A view of this tab can be seen below:

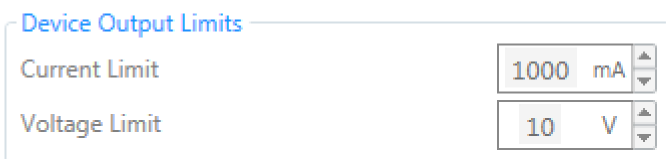


Figure 14 Device Protection menu.

4.4.3.1 Device Output Limits

This constrains the upper limit of voltage and current output of the source meter when running an IV sweep which may attempt to source currents and voltages that pose risk of damage to the target cell. This output limits can be used to protect your device under test.

4.4.4 Temperature

This section only applies to your SciPV software if you are using one of Sciencetech TEC cell chucks. First, make sure that your TEC cell chuck is Configured in your SciPV software. If you have not set the right COM port associated with the USB port connected to your TEC cell chuck or if you need to change it, click on the *IV Device Manager* icon on top right corner of SciPV user interface.

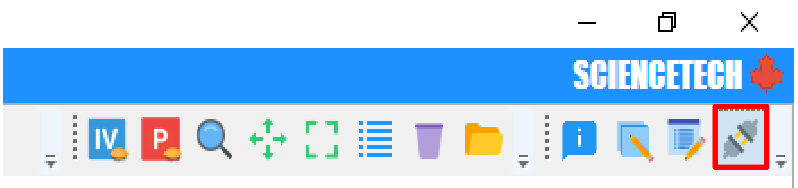


Figure 15. Device Manager window.

Here you can check, change or update the COM port related to your Keithley and/or the TEC cell chuck. After performing the update, close the window.

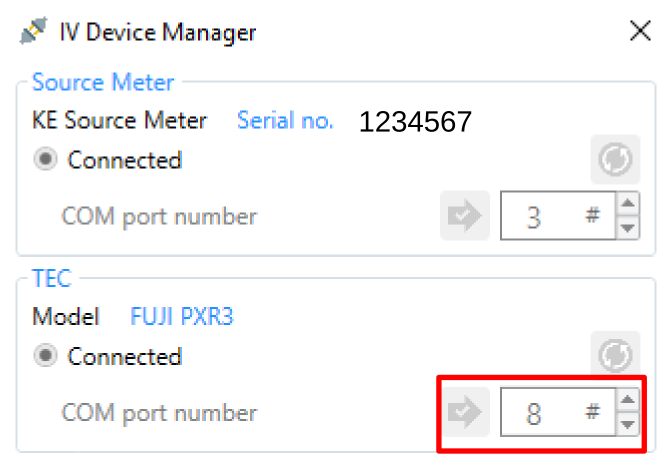


Figure 16. How to change the COM port for Keithley and TEC cell chuck.

Please note that if you do not turn on the TEC cell chuck while initiating the SciPV: IV software you will receive an error message both on the status bar (turns orange) and on the *Device Manger* icon.

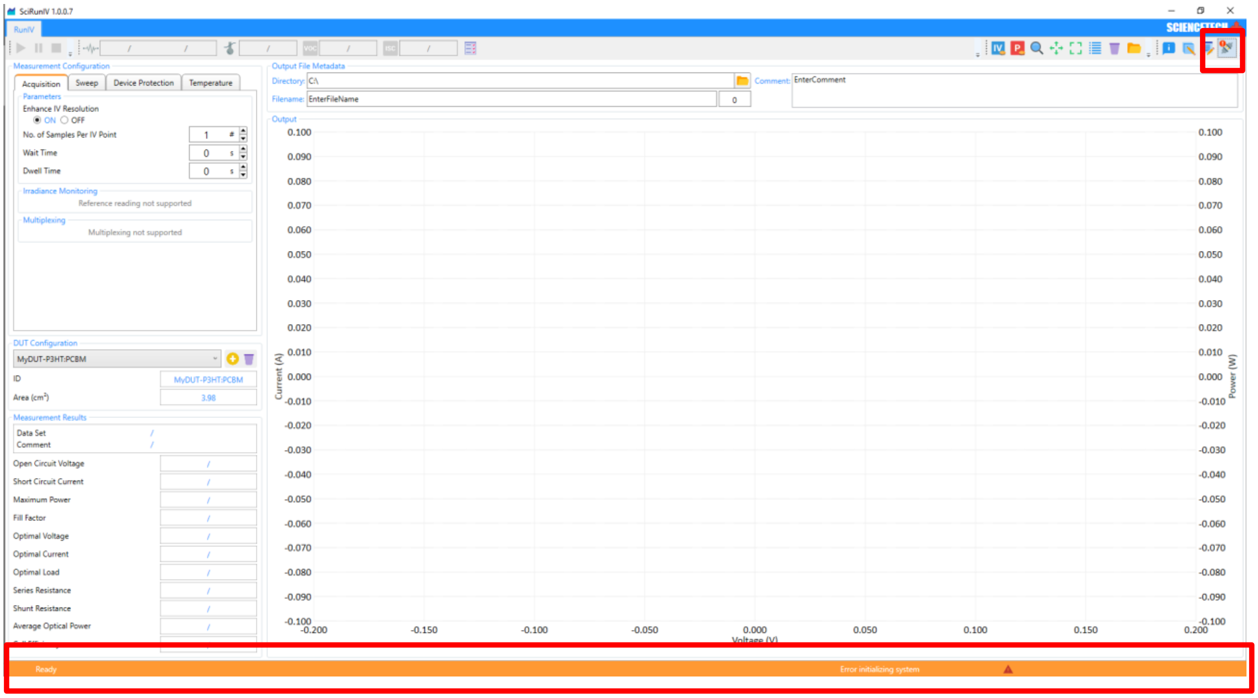


Figure 17. TEC cell chuck communication Error

To continue using the software without TEC cell chuck, left click on the orange ribbon at the bottom of the screen and open the *Error Log*. Next, press on the *clear all errors* item. Now, you can use the software without running the TEC cell chuck. However, you might still see an error icon on the device manager icon on top right corner of the screen. You can either ignore it or you can turn the TEC cell chuck momentarily, update the COM port number, and connect to the TEC cell chuck. Now, even if you turn off the TEC cell chuck, no error icon will appear on the device manger icon.

There are two ways to set the temperature of the TEC cell chuck; through *Set Point* section or through the *Sequencing* section. The Set Point section is useful if the user wants to set the temperature of the TEC cell chuck to a single stable temperature. The Sequencing section is useful if the user wants to preform a series of IV measurement at certain predefined TEC cell chuck automatically. Below each method is explained in detail:

4.4.4.1 Set Point

Through this setting user can set the temperature of the Sciencetech TEC cell chuck to a single set point temperature. This set point temperature should be within the temperature range that is set in the Configuration File of your SciPV installer.

After entering the *Set Point* temperature in the Set Point box, press the green arrow to enforce this setting. The status bar of the SciPV will turn blue. When the temperature of the cell chuck reached the setpoint, the status bar turns green and a "*Ready*" message appears at the left corner of the status bar. The current temperature that is measured by the RTD located beneath the cell chuck sample holder will be updated every few seconds and can be seen in the *Current Temperature* box. If you would need to work in other tabs of SciPV-IV other than Temperature tab, you can monitor the temperature through *Toggle Temperature Monitoring* box on top tool bar of SciPV.

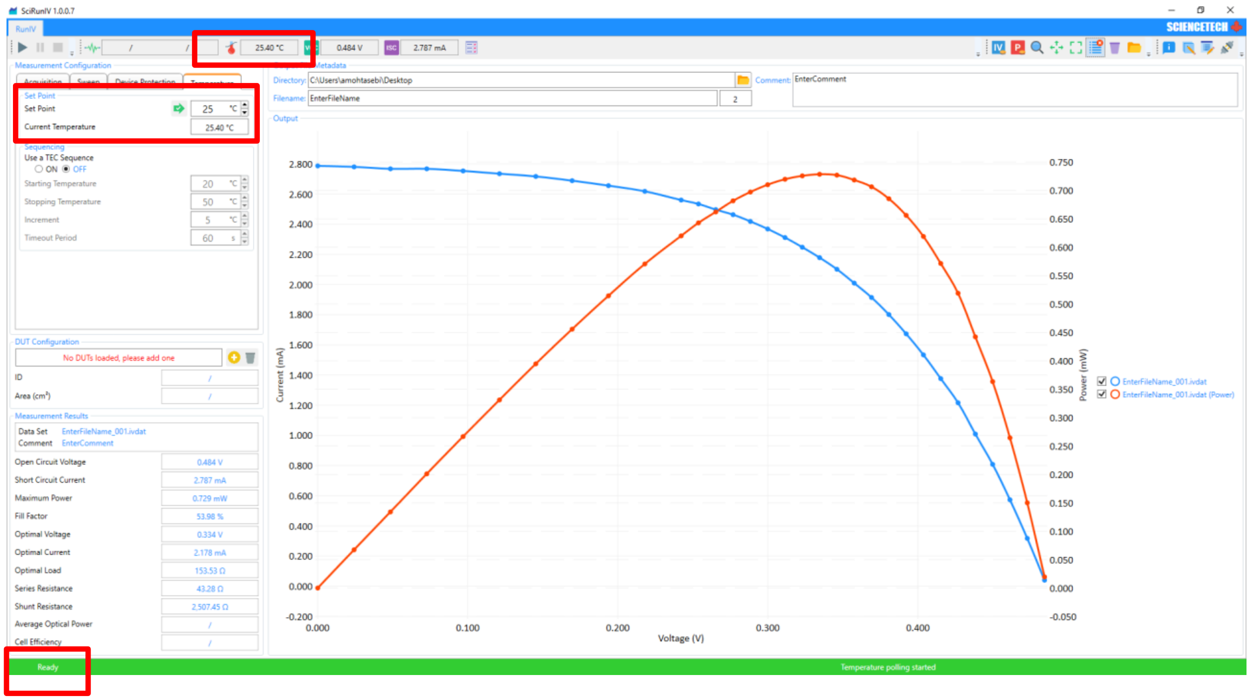


Figure 18. Temperature Set point setting and monitoring.

4.4.4.2 Sequencing

This setting can be used to sequence the temperature of a TEC cell chuck to different temperatures and automatically perform IV measurement at each step.

To use this feature, set it on *ON*. Next, enter the *Starting* and *Stopping* temperatures in their associated boxes. Please note that these temperatures should be within the acceptable temperature range that is already set in the configuration file of your SciPV installer. Next, set the *Increment*. Finally, enter the *Timeout Period* time. This is the maximum duration that SciPV waits at each increment to check if the cell chuck reached the stable temperature (~+/- 0.3 of the setpoint). To enforce your setting parameters and start your IV measurement, press the *Start* button on top left corner of the screen. The status bar at the bottom of the screen turns blue with the message related to the state of the experiment. System starts from the set *Starting Temperature* and waits for the *Timeout Period* to check if the temperature of the cell chuck is reached to a stable proximity of the set temperature to preform the first I-V measurement. Whether the system is able to reach the stable temperature (and performs the I-V measurement) or not (software will skip IV measurement at this temperature), the system moves to the next set temperature and tries the same loop.

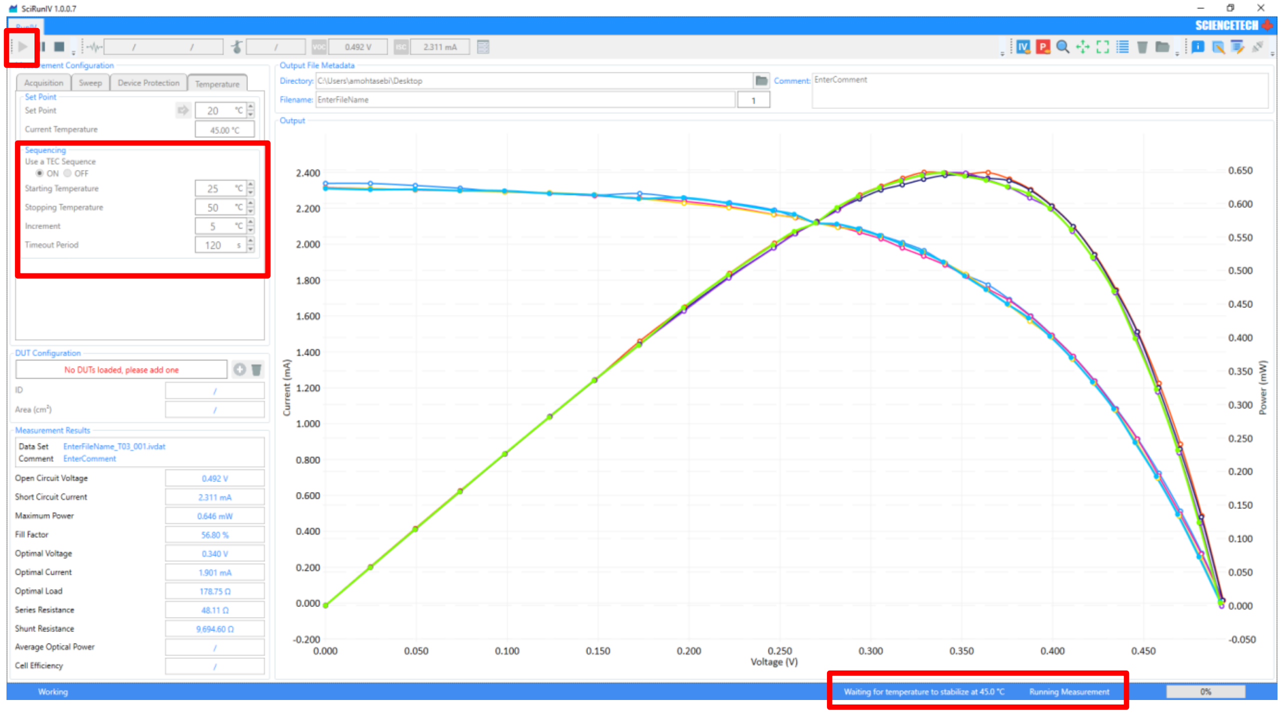


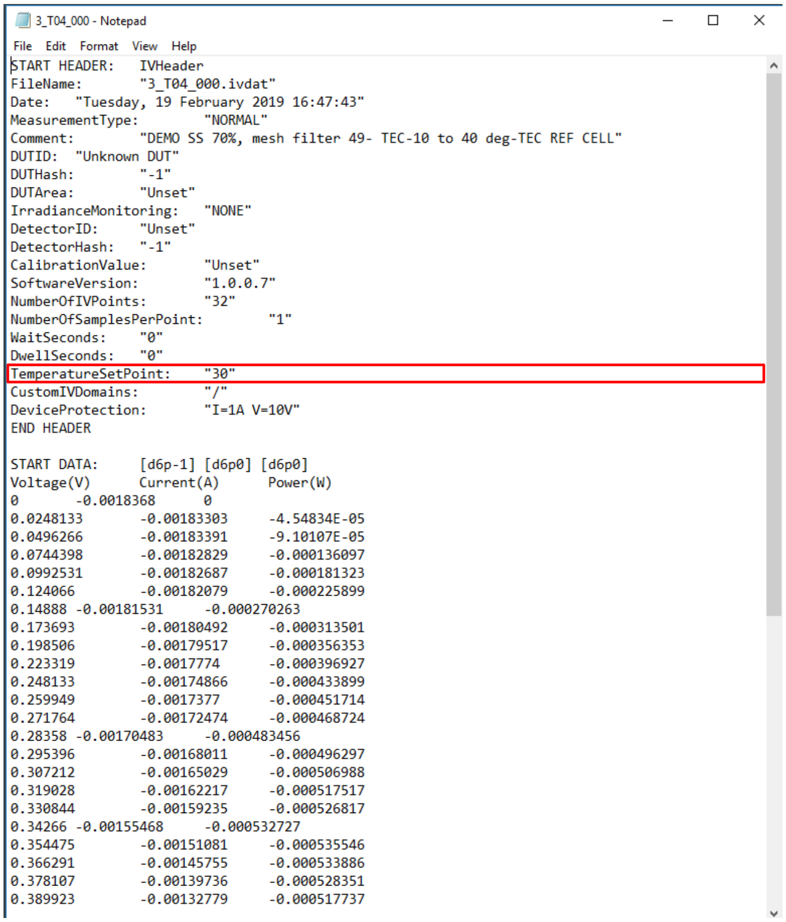
Figure 19. Temperature Sequencing and IV data acquisition.

The results of IV measurements using the *Sequencing* functionality will be output (saved) as multiple IVDAT files. Each IVDAT file is related to one of the predefined temperature steps:

3_T00_000	2019-02-19 4:45 PM	IVDAT File	3 KB
3_T01_000	2019-02-19 4:46 PM	IVDAT File	3 KB
3_T02_000	2019-02-19 4:47 PM	IVDAT File	3 KB
3_T03_000	2019-02-19 4:47 PM	IVDAT File	3 KB
3_T04_000	2019-02-19 4:48 PM	IVDAT File	3 KB
3_T05_000	2019-02-19 4:49 PM	IVDAT File	3 KB
3_T06_000	2019-02-19 4:49 PM	IVDAT File	3 KB

Figure 20. An example of IVDAT files from one temperature sequencing measurement.

The temperature at which the IV measurement has been performed can be found inside each IVDAT file and can be used for future reference:



```
3_T04_000 - Notepad
File  Edit  Format  View  Help
START HEADER:	IVHeader
FileName:	"3_T04_000.ivdat"
Date:	"Tuesday, 19 February 2019 16:47:43"
MeasurementType:	"NORMAL"
Comment:	"DEMO SS 70%, mesh filter 49- TEC-10 to 40 deg-TEC REF CELL"
DUTID:	"Unknown DUT"
DUTHash:	"-1"
DUTArea:	"Unset"
IrradianceMonitoring:	"NONE"
DetectorID:	"Unset"
DetectorHash:	"-1"
CalibrationValue:	"Unset"
SoftwareVersion:	"1.0.0.7"
NumberOfIVPoints:	"32"
NumberOfSamplesPerPoint:	"1"
WaitSeconds:	"0"
DwellSeconds:	"0"
TemperatureSetPoint:	"30"
CustomIVDomains:	"/"
DeviceProtection:	"I=1A V=10V"
END HEADER

START DATA:	[d6p-1] [d6p0] [d6p0]
Voltage(V)	Current(A)	Power(W)
0	-0.0018368	0
0.0248133	-0.00183303	-4.54834E-05
0.0496266	-0.00183391	-9.10107E-05
0.0744398	-0.00182829	-0.000136097
0.0992531	-0.00182687	-0.000181323
0.124066	-0.00182079	-0.000225899
0.14888	-0.00181531	-0.000270263
0.173693	-0.00180492	-0.000313501
0.198506	-0.00179517	-0.000356353
0.223319	-0.0017774	-0.000396927
0.248133	-0.00174866	-0.000433899
0.259949	-0.0017377	-0.000451714
0.271764	-0.00172474	-0.000468724
0.28358	-0.00170483	-0.000483456
0.295396	-0.00168011	-0.000496297
0.307212	-0.00165029	-0.000506988
0.319028	-0.00162217	-0.000517517
0.330844	-0.00159235	-0.000526817
0.34266	-0.00155468	-0.000532727
0.354475	-0.00151081	-0.000535546
0.366291	-0.00145755	-0.000533886
0.378107	-0.00139736	-0.000528351
0.389923	-0.00132779	-0.000517737
```

Figure 21. IVDAT file content.

4.4.5 Automatic Polarity Detection

SciPV-IV version 1.0.0.7 and its higher versions can detect the polarity of the DUT or if the negative and positive wires in the four wire measurements are plugged into their opposite polarity connections on the Keithley front or rear (e.g. the two red wires from the DUT into the two black connections on the front of the Keithley, and the two black wires into the red connections). Please note that SciPV is only configured for four-wire measurement and does not support two-wire measurements. By default, the software will preform IV measurement on the DUT connected to the Keithley if the positive wires from the DUT are plugged into the positive connections on the rear or front of the Keithley (red connections) and the negative wires form the DUT are plugged into the negative connections on the Keithley (black connections). However, if the wires are plugged into their opposite polarity connections on the Keithley (black to red, and red to black) the user will be notified that the software has detected reverse polarity in the DUT and several options will be presented. In this case, upon pressing on the Start button, the user will see the following pop-up message:

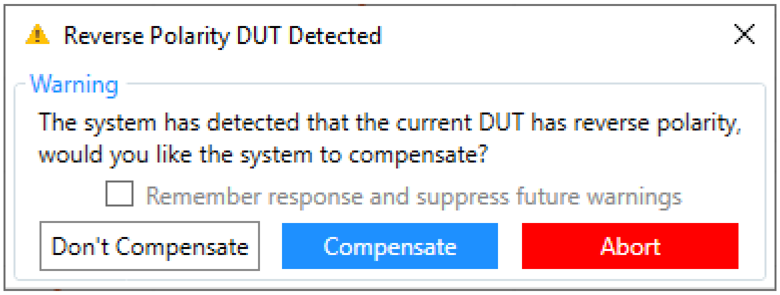


Figure 22. Reverse polarity detection alert.

In this situation, the user can let the software switch the polarity of the measured I_{SC} by selecting the *Compensate* button. Otherwise, the user can select the *Don't Compensate* button which means the software will not apply the polarity switching of the measured I_{SC}, or *Abort* which means the software will abort the measurement. In case the user wants any of these selections to be applied to the rest of the measurement in this IV measurement session (until the software is closed), the user should check the *Remember response and suppress future warnings* checkbox. To reset this selection at any time, the user should reboot the software. Please note that the polarity switching by SciPV software only applies to the results reported in the IVDAT file and the result which are shown on the *Measurement Results* section of the software on the left side of the screen.

To demonstrate how the polarity switching will work and affect the displayed results, we will use an example of plugging negative and positive wires in to their reverse polarity connections on the front panel of the Keithley 2400:

Negative wires (black and green wires in this example) to negative connections (black) and positive wires (red and white wires) into positive connections (red):

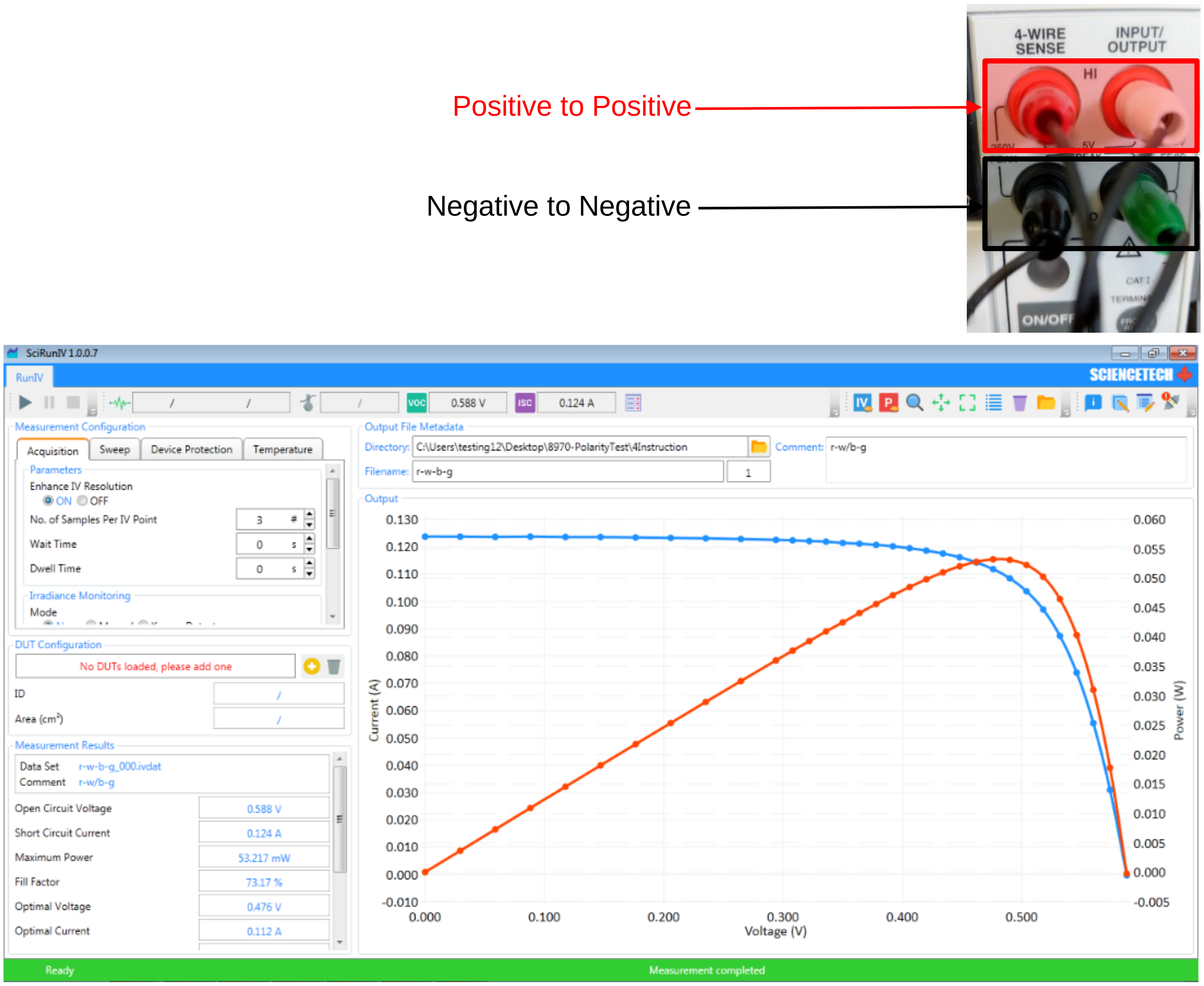


Figure 23. Example of an IV measurement with correct polarity connections.

Negative wires (black and green in this example) to the positive connections (red) and positive wires (red and white wires in this example) into the negative connections (black):

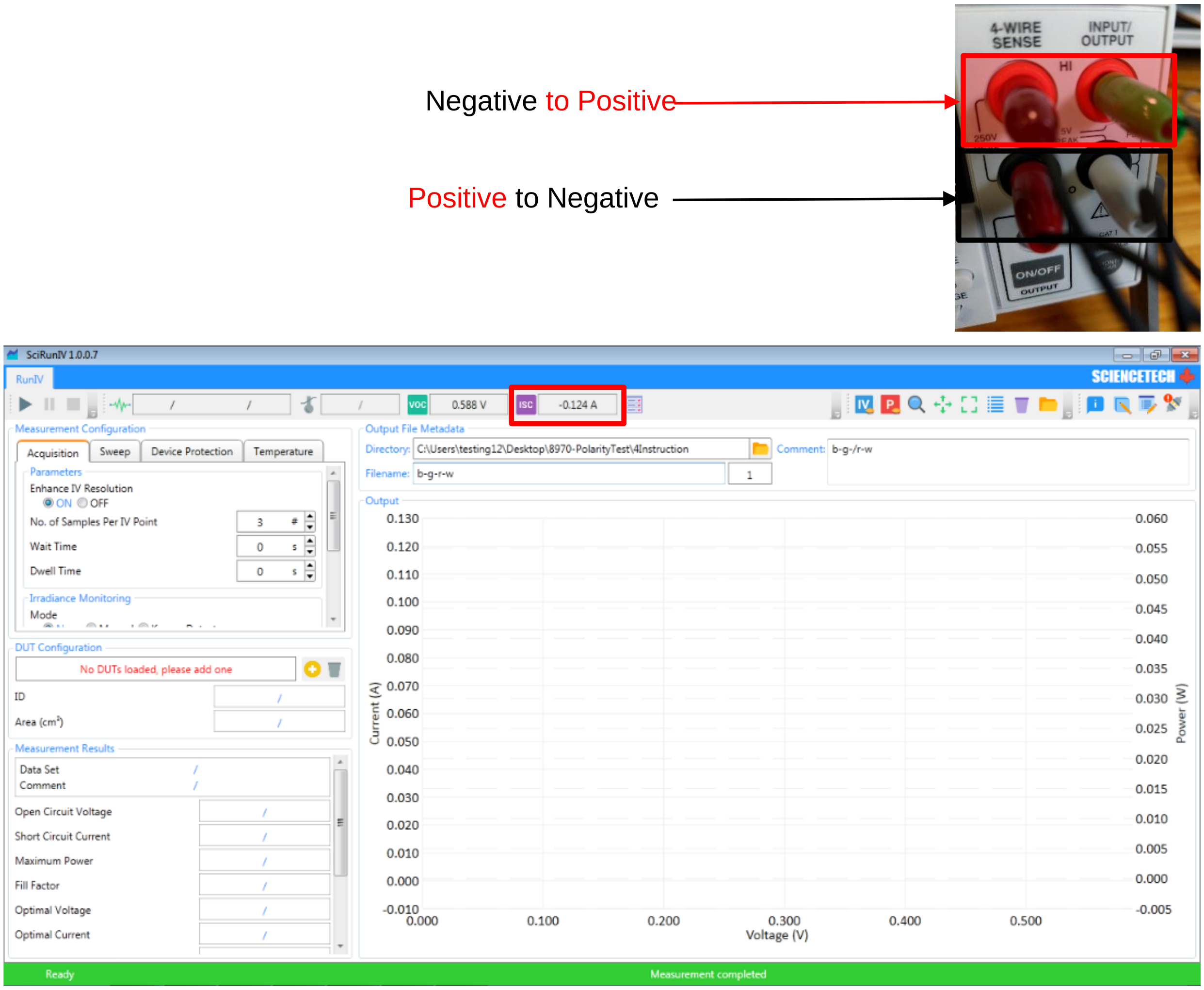


Figure 24. Plugging cables to the opposite polarity plugs on Keithley and detection of Isc with an opposite sign.

Pressing the quick I_{SC} button on top tool bar shows a negative I_{SC}. Thus, upon pressing the Start button we receive the *Reverse Polarity DUT Detected* message. In this example, we press *Don't Compensate* to perform the measurement without applying the polarity witching:

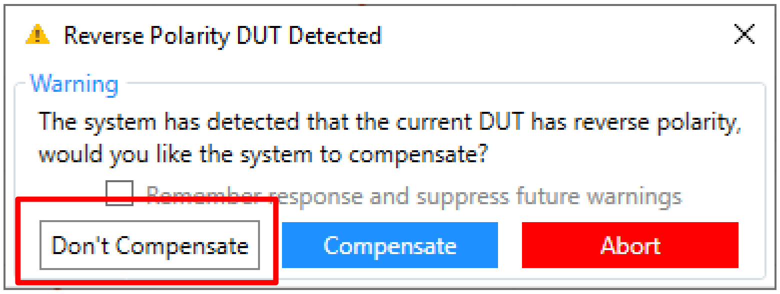


Figure 25. Canceling the command for automatic polarity switching.

Note the negative I_{SC} values on the Y-axis:

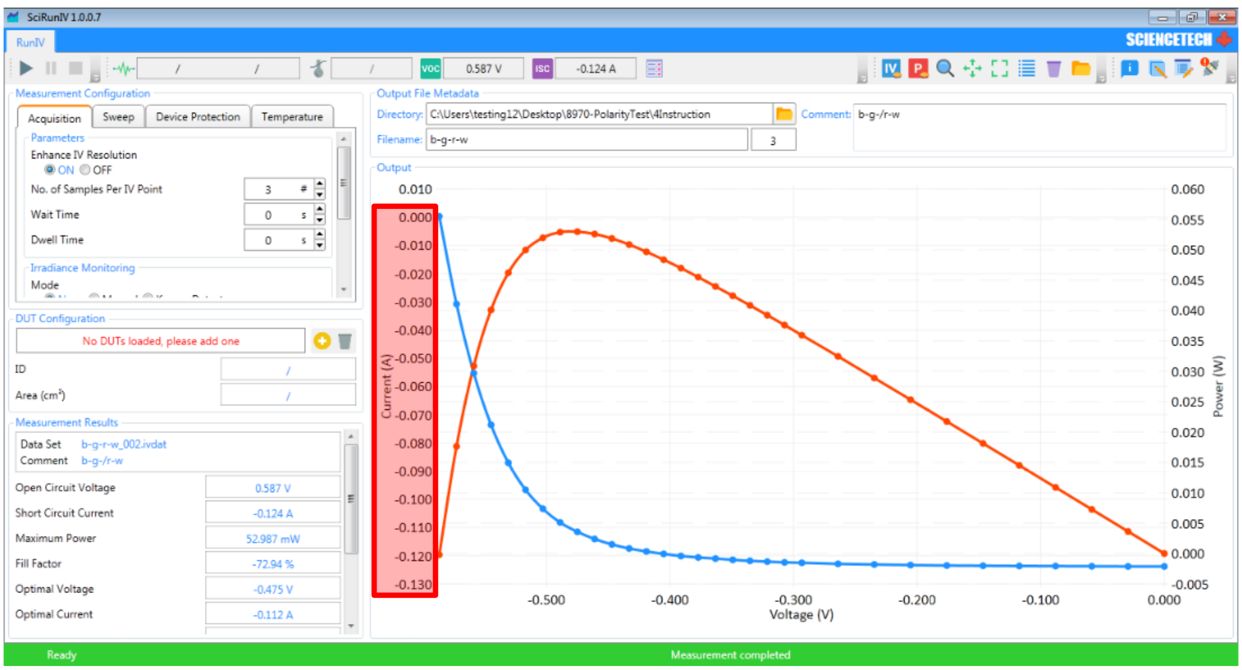


Figure 26. Result of an IV and Power measurement with reverse polarity.

Since we have not checked the *Remember response and suppress future warnings* in the pop-up message, if we try to perform another measurement, we will get the pop-up alert again asking the same question.

This time we check this box, and press the *Compensate* button to enforce the polarity switching for the rest of the measurements:

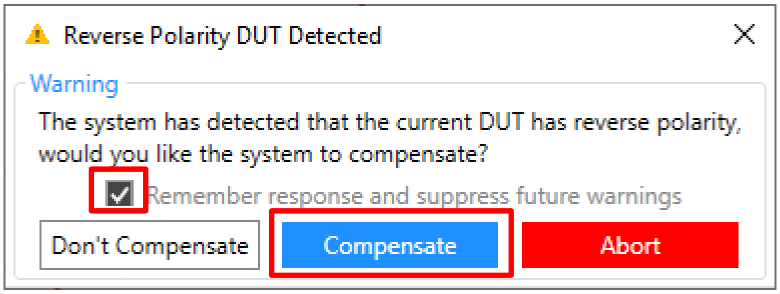


Figure 27. Accepting the command for automatic polarity switching.

Note the change in the polarity of the displayed ISC values.:

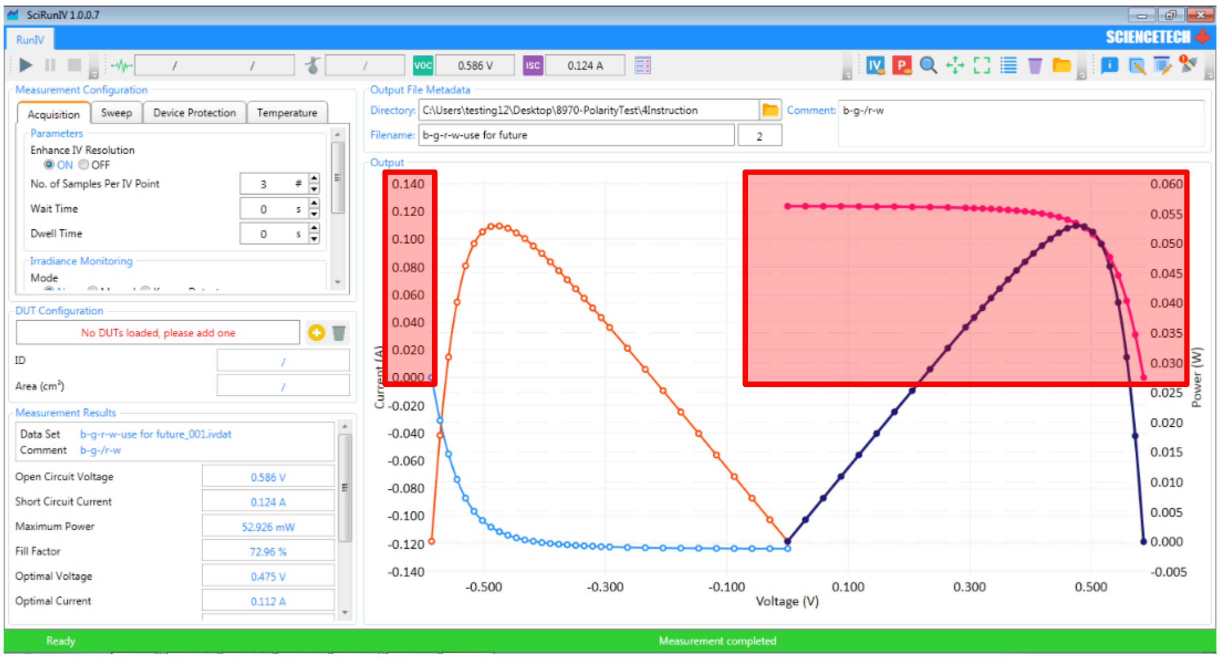


Figure 28. Result of IV and Power measurement after compensating for reverse polarity (red box) and by not accepting this command (curves outside of the red box).

If we try to perform another measurement by pressing the *Start* button again, the software will start the IV measurement as we have previously selected the *Use response and suppress future warnings* box.

4.5 SciPV: IV Results Calculations

This section briefly describes the calculations used in the *'Measurement Results'* section of the software.

Important Note: For dual sweeps any calculated field is evaluated for both Forward and Reverse part of the sweep, and the displayed value is the average of the two. The only parameter that this does not apply to is V_{oc}, because it is extracted from performing a single I-source/V-measure measurement.

4.5.1 Open Circuit Voltage (V_{oc})

Software will record a value acquired when sourcing 0 A to the DUT.

4.5.2 Short Circuit Current (I_{sc})

Software will find an IV point where voltage is exactly 0.0 and will use the ordinate of this point (current) as I_{sc}.

4.5.3 Maximum Power (P_{max})

Software will iterate over all IV points, compute the product of the ordinate and abscissa (current and voltage), and Select the maximum value as Maximum Power.

4.5.4 Fill Factor

It is calculated by dividing P_{max} by the products of the V_{oc} and I_{sc}. The result will be converted to percentage. This value is only calculated for sweeps that contain V_{oc} and I_{sc}.

4.5.5 Optimal Voltage

Software takes the abscissa (voltage) of the IV point that P_{max} occurs and display it as Optimal Voltage.

4.5.6 Optimal Current

Software takes the ordinate (current) of the IV point that P_{max} occurs and display it as Optimal Current.

4.5.7 Optimal Load

Software calculates the ratio of voltage over current of IV points associated with P_{max}, compute the average of these products and display it as Optimum Load Resistance.

4.5.8 Series Resistance

Software constructs a tangent to IV curve at V_{oc}, and take the slope of this tangent as the Series Resistance.

Please note, if the curve does not contain a V_{oc}, this value can not be calculated. Also, the points used to construct this tangent may be different than the nominal set of IV points.

4.5.9 Shunt Resistance

Software constructs a tangent to IV curve at I_{sc}, and take the slope of this tangent as the Shunt Resistance.

Please note, if the curve does not contain an I_{sc}, this value can not be calculated. Also, the points used to construct this tangent may be different than the nominal set of IV points.

4.5.10 Average Optical Power

This value is the average of the all irradiance values. Please note, if the irradiance values are not present, this cannot be calculated.

4.5.11 Cell Efficiency

Software divides the calculated P_{max} by the average optical power.

4.6 DUT Configuration

The DUT configuration allows the user to add device under tests (DUT) to the software. When a data file is created, metadata from the DUT that is selected is stored in the added to the file. The DUT area that is inputted is also used for various measurement calculations.

To add a DUT, click the yellow plus button. The ID and Area boxes will become bordered in blue (shown below). Enter in the desired DUT identifier and cell area and click the red save button. The DUT is stored, and can be selected from the drop down menu for future use. To remove a DUT, select the DUT you wish to delete, and click the trash can next to the add DUT button.

A DUT must be selected to perform a scan. A dummy DUT can be created if you do not wish to use a specific DUT.

Figure 29. DUT configuration menu.

4.7 Running a Measurement/Sweep

The top-left most tool bar contains start, pause/resume, and stop buttons for controlling scans. Once the user is satisfied the measurement configuration they have setup, they can initiate the scan with the above described controls. Note that data is saved as it comes in, stopping a scan early will not delete the associated data file that was created to save the IV measurement data.

Figure 30. Measurement Start, Pause, and Stop button.

4.8 Results and Limit Testing

After a measurement is run to completion results are calculated. They are displayed in the *Measurement Results* groupbox in the lower left-hand corner of the application. If the *Irradiance Level* and DUT area are entered into the software, the *Average Optical Power* and the *Cell Efficiency* are calculated in the *Measurement Results*. SciPV-IV provides a mechanism for determining if cell results fall into a predefined set of limits. Clicking on the '*Open limit test dialog*' button in the tool bar the user is greeted with the following window:

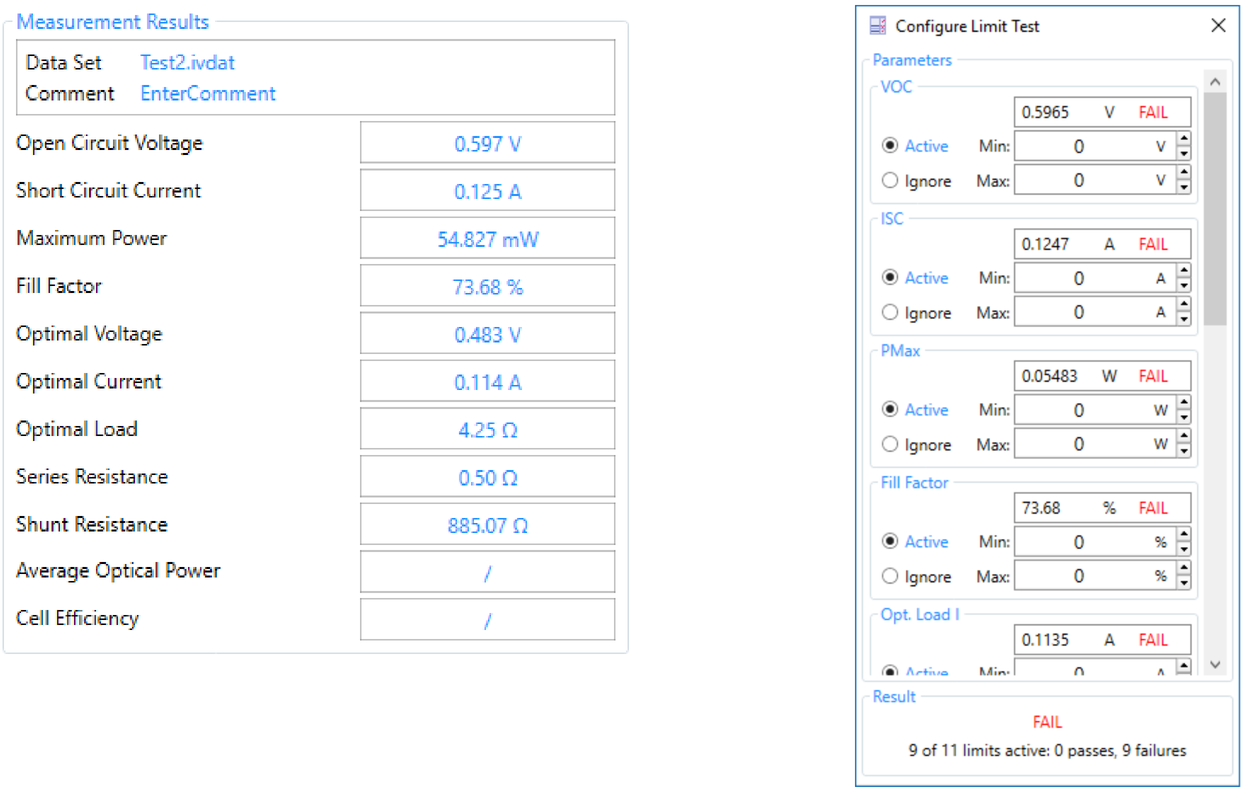


Figure 31. Final results windows (left) and Limit Test results (right).

The user may adjust the limit bounds for each parameter, and enable/disable each individual parameter limit test. The bottom of the dialog displays a summary of the compliance of the cell with regards to the specified limits.

4.9 Quick Start Measurements

It is suggested to read the entire user manual before starting an IV measurement. Below is a basic quick start guide to perform an IV measurement. Full descriptions of each feature are listed previously in their respective sections.

1. Select Irradiance monitoring type, None, Manual, or Known Detector (Acquisition Tab).
    a. If Manual, enter the manually measured irradiance value at the target plane
    b. If Known Detector, ensure the correct detector is loaded with correct calibration value.
2. Select DUT configuration.
    a. If you DUT does not exist, create the new DUT.
3. Select No. of Sample Per IV Point (Acquisition Tab).
4. Enable User Reference Cell, Enhance IV Resolution, and Multiplexing as desired (if applicable – Acquisition Tab).
5. Set Cell Area (if applicable – Main Window).
6. Set Sweep Mode and configure User Defined sweep if selected (Sweep Configuration Tab).
7. Set No. of IV Points (Sweep Configuration Tab).
8. Set Sweep Direction (Sweep Configuration Tab).
9. Select output folder, enter Filename, and Comment.

4.10 Displaying Previous Dataset Information

Previous measurement results can be loaded into SciPV-IV software for viewing the measurement results and their associated IV and Power curves. One or multiple previous IVDAT files can be selected through the '*Open Data File'* button on the software toolbar. Next, using the '*Show Legend'* button on the toolbar the associated legends can be shown next to the curves. In order to update the '*Measurement Results'* side box to display the results associated with your desired curve, simply click on any data points of that curve.

Using the '*Enable Panning'* button located on the tool bar, one can pan around the displayed curves. To reset this setting, simply click the 'C*enter Chart'* button. User can zoom in/out on any areas of the displayed curves by clicking on the '*Enable Zooming'* button followed by turning the scroll wheel of the computer mouse. To disable the zooming option, simply click again on the '*Enable Zooming*' button.

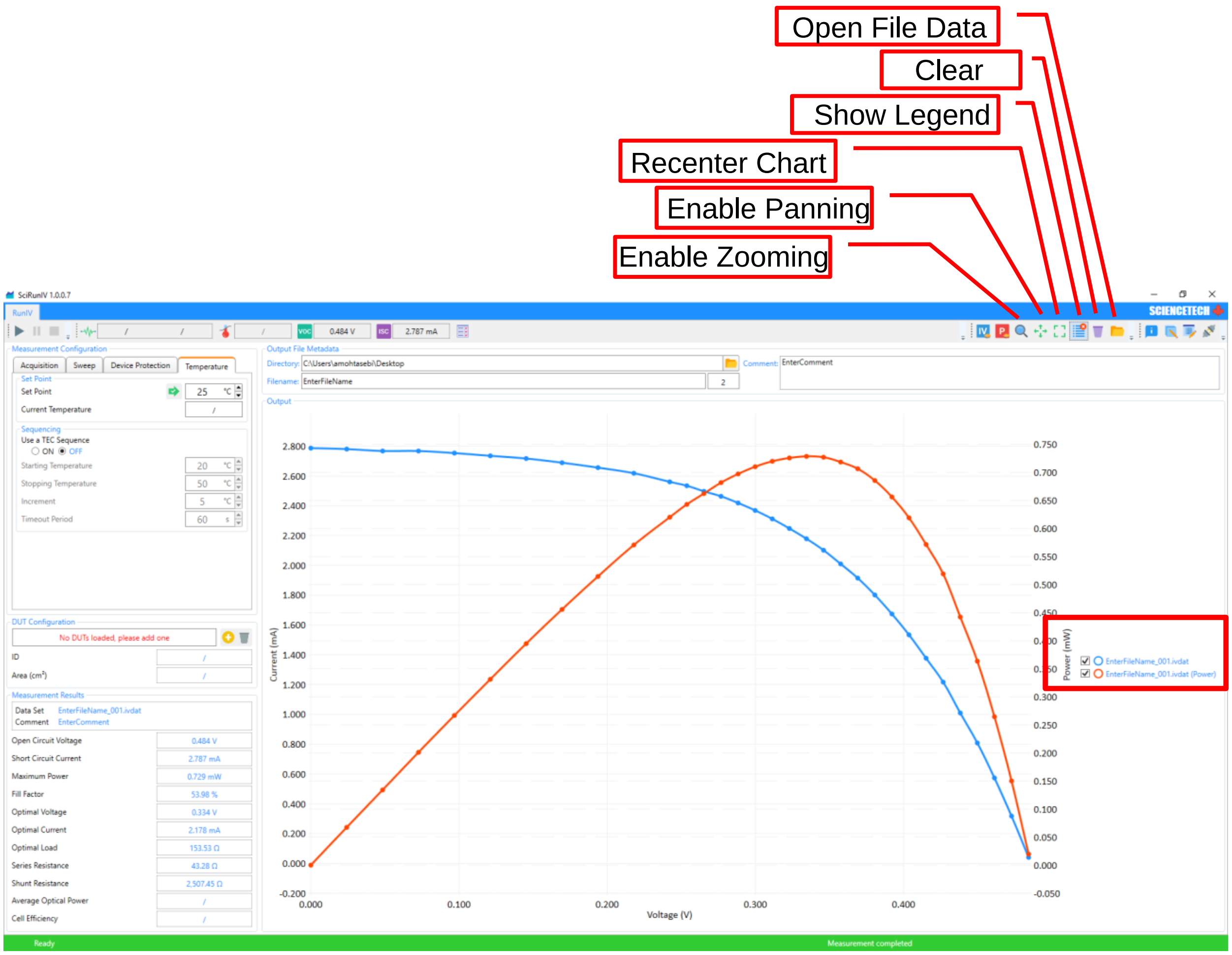


Figure 32. Previous data display options and tools callout.

5. Example IV Hookup Diagram

5.1 No DEMUX

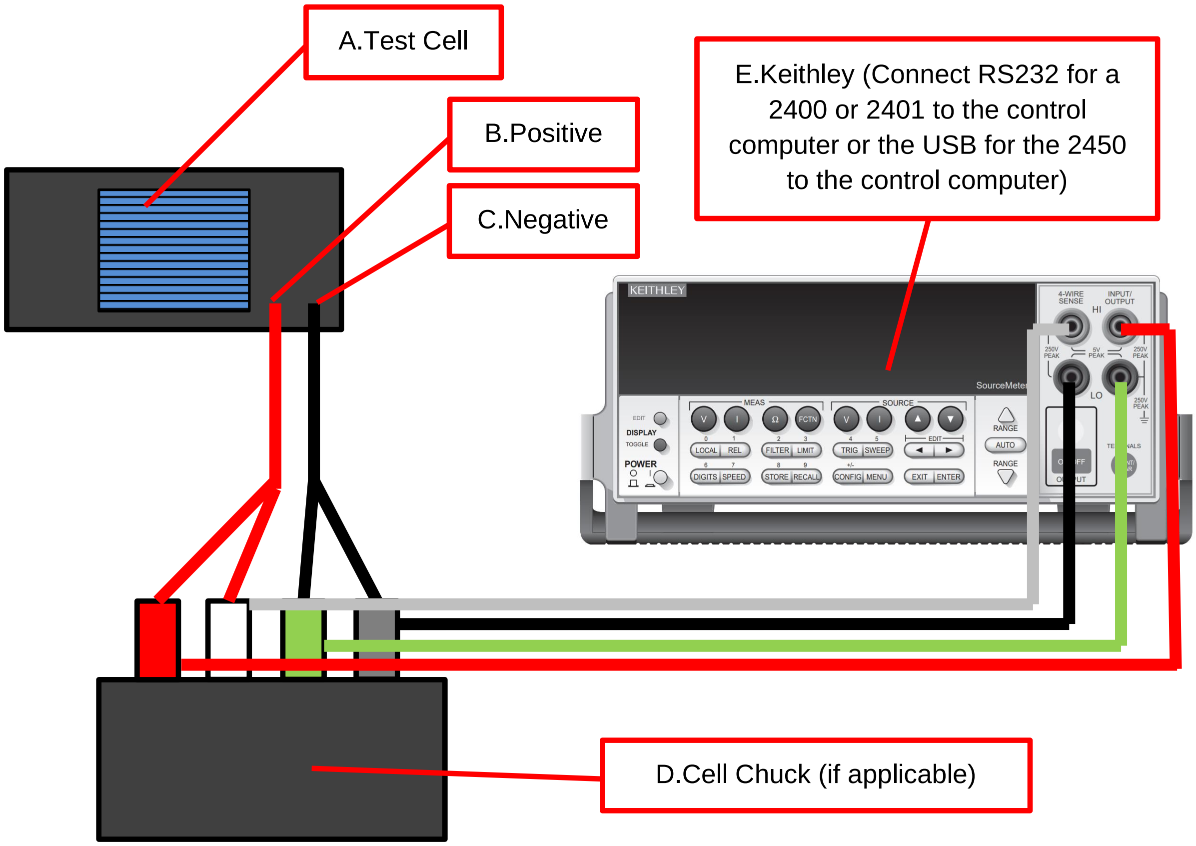


Figure 33. Wire routing for IV measurement without DEMUX callout.

1. Connect the test cell (A) to a cell chuck (D) if applicable.
    a. Connect the cell chuck (if applicable) to the front Inputs on the Keithley (use a 4-wire connection).
    b. If there is no cell chuck, connect the test cell (A) to the front Inputs on the Keithley (E) (use a 4-wire connection).
2. Connect the Keithley (E) to the control computer.
    a. For a 2400 or 2401, connect the RS232 connection on the rear to the control computer with the supplied RS232 to USB cable.
    b. For the 2450, connect the USB connection on the rear to the control computer with the supplied USB A-B cable.
3. Do not forget to illuminate the test cell and power on the Keithley (E) with the appropriate line voltage.

5.2 With DEMUX

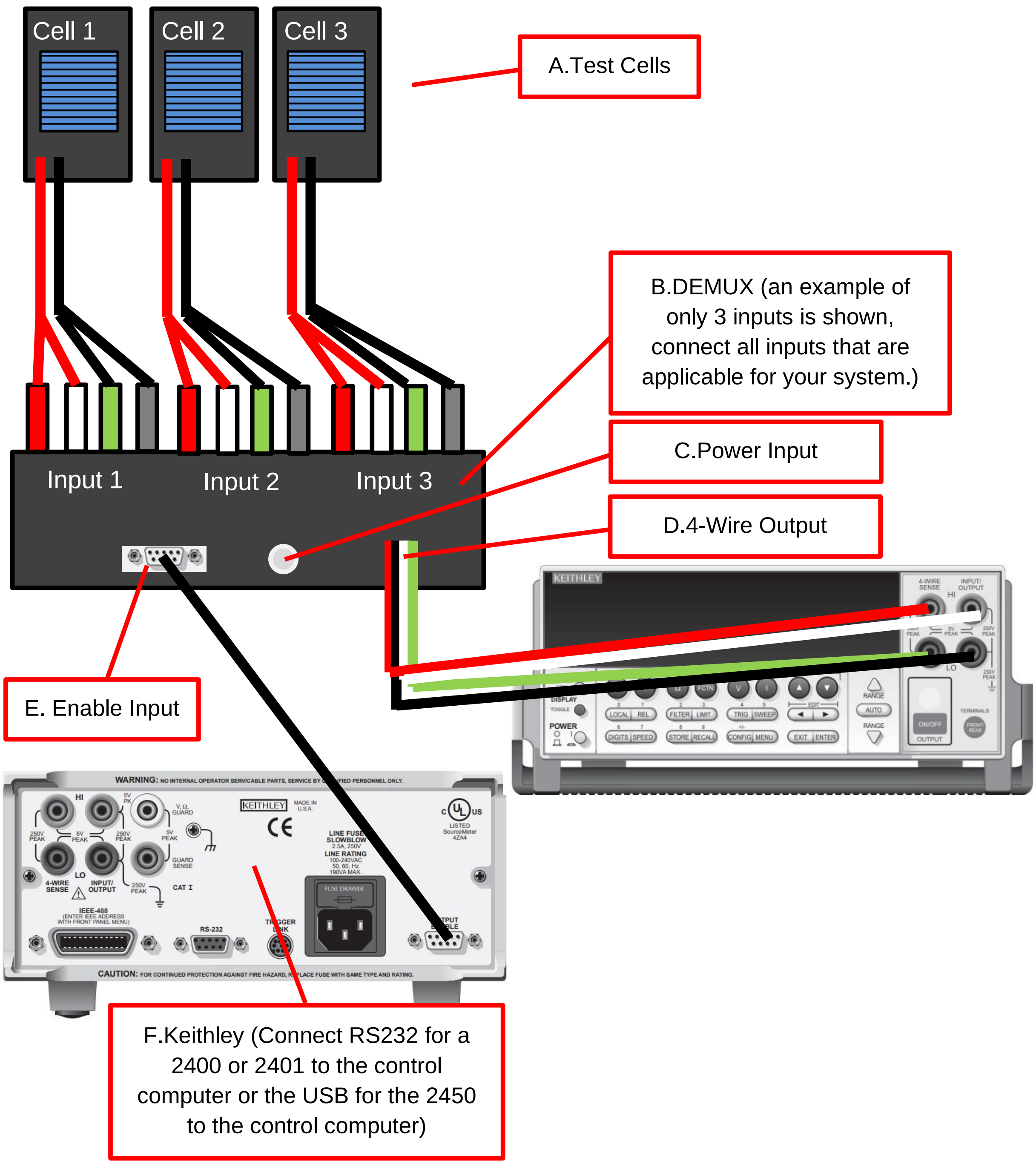


Figure 34. Wire routing for an IV measurement for with DEMUX.

1. Connect all test cells (A) to the inputs on the DEMUX box.

2. Connect Enable Output (E) on the rear of the Keithley to the Enable Input on the DEMUX box.
3. Connect the 4-wire output (D) output on the DEMUX to the front Keithley inputs (positive to positive and negative to negative).
4. Connect the Keithley (F) to the control computer.
    a. For a 2400 or 2401, connect the RS232 connection on the rear to the control computer with the supplied RS232 to USB cable.
    b. For the 2450, connect the USB connection on the rear to the control computer with the supplied USB A-B cable.
5. Connect the DEMUX power input (C) to the provided power brick.
6. Do not forget to illuminate the test cell and power on the Keithley with the appropriate line voltage.

5.3 Reference Cell Hookup

This diagram only shows the necessary connections for the reference detector/cell.

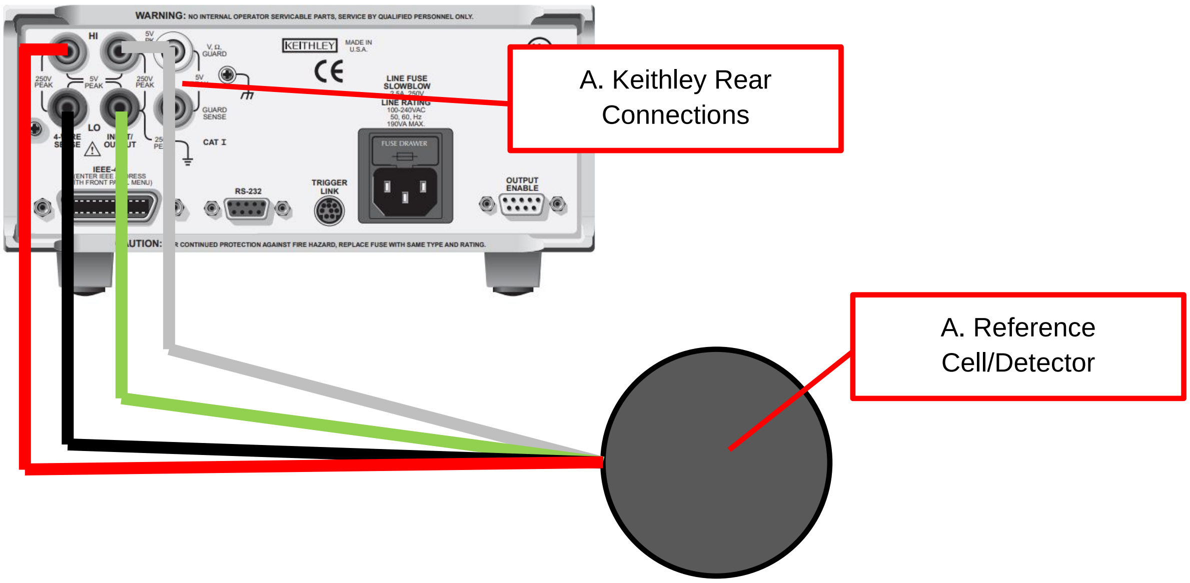


Figure 35. Reference cell hookup to Keithley 2400 series.

1. Connect the reference detector (or cell) (A) to the rear input connections on the Keithley (A).

5.4 Example Connections with Sample Chamber (with pictures)

The following instructions outline basic cable hookup and operation of a cell chuck and light tight sample chamber with a test cell for verification of your solar simulator and SSIVT-20C system.

1. With the cell chuck outside of the sample chamber, connect the RED-WHITE-BLACK-GREEN banana jack wires (circled in blue box) that are attached to the inside of the light tight sample chamber feedthroughs to the RED and BLACK banana jacks on the cell chuck as shown below. Your cell chuck will need to be close to the opening of the light tight sample chamber for the cables to reach.

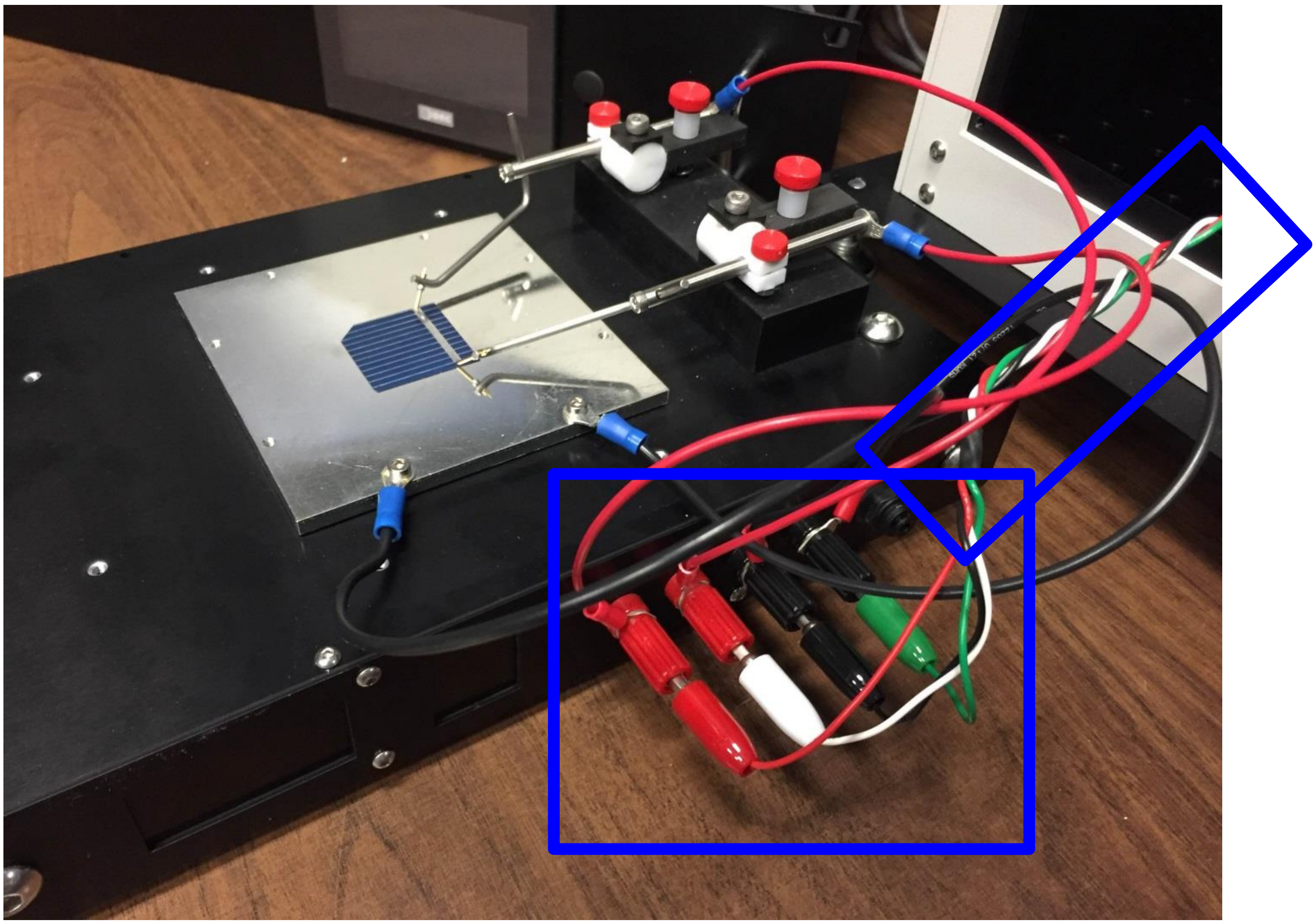


Figure 36. Example of wiring between cell chuck and probe station, step 1.

2. With the cell chuck still outside the sample chamber, connect the black wires to the cell chuck plate and connect the red wires to the two (or more) probe arms shown below.

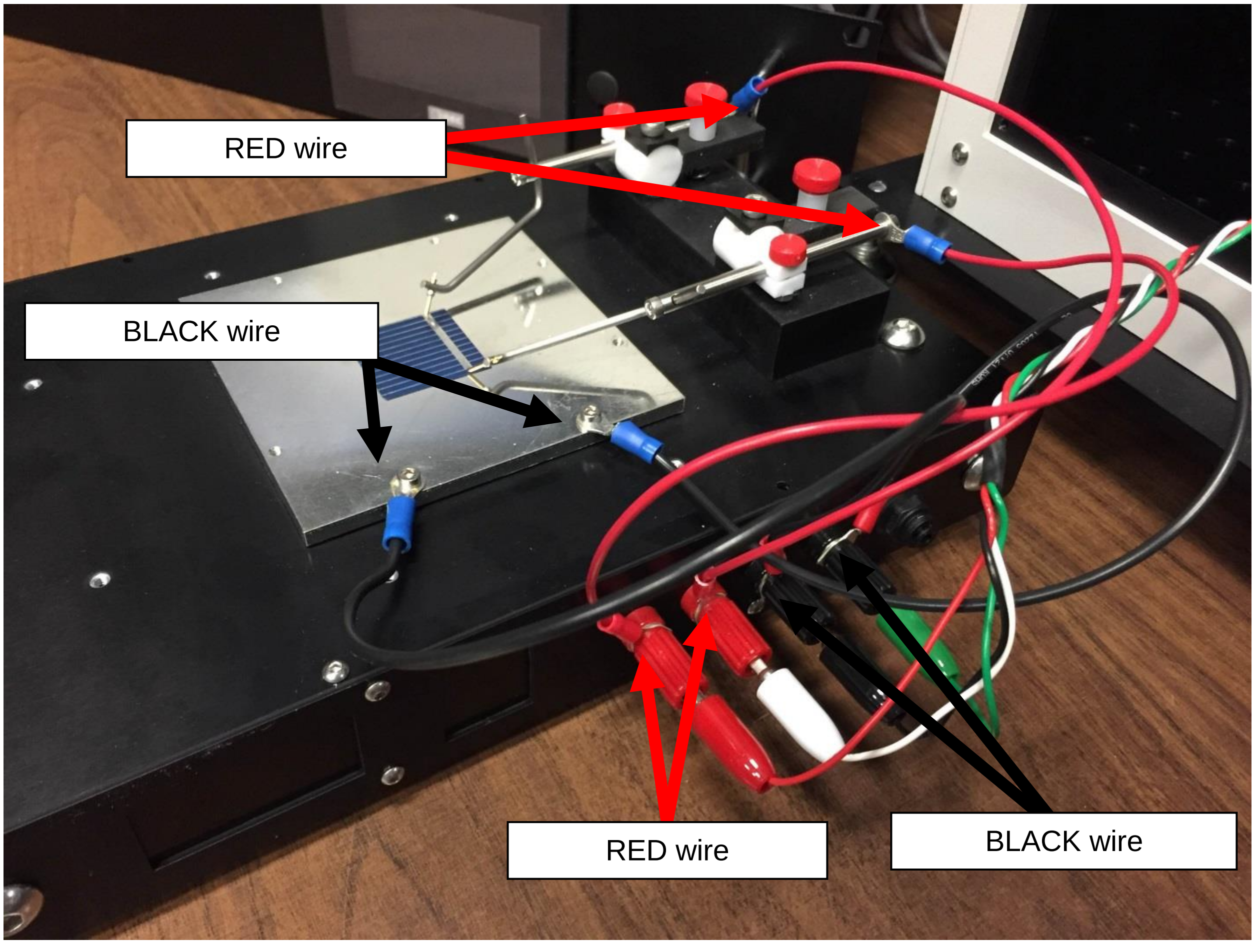


Figure 37. Example of wiring between cell chuck and probe station, step 2.

3. With the probe arms, make connections to the bus bar on the provided test cell shown below.

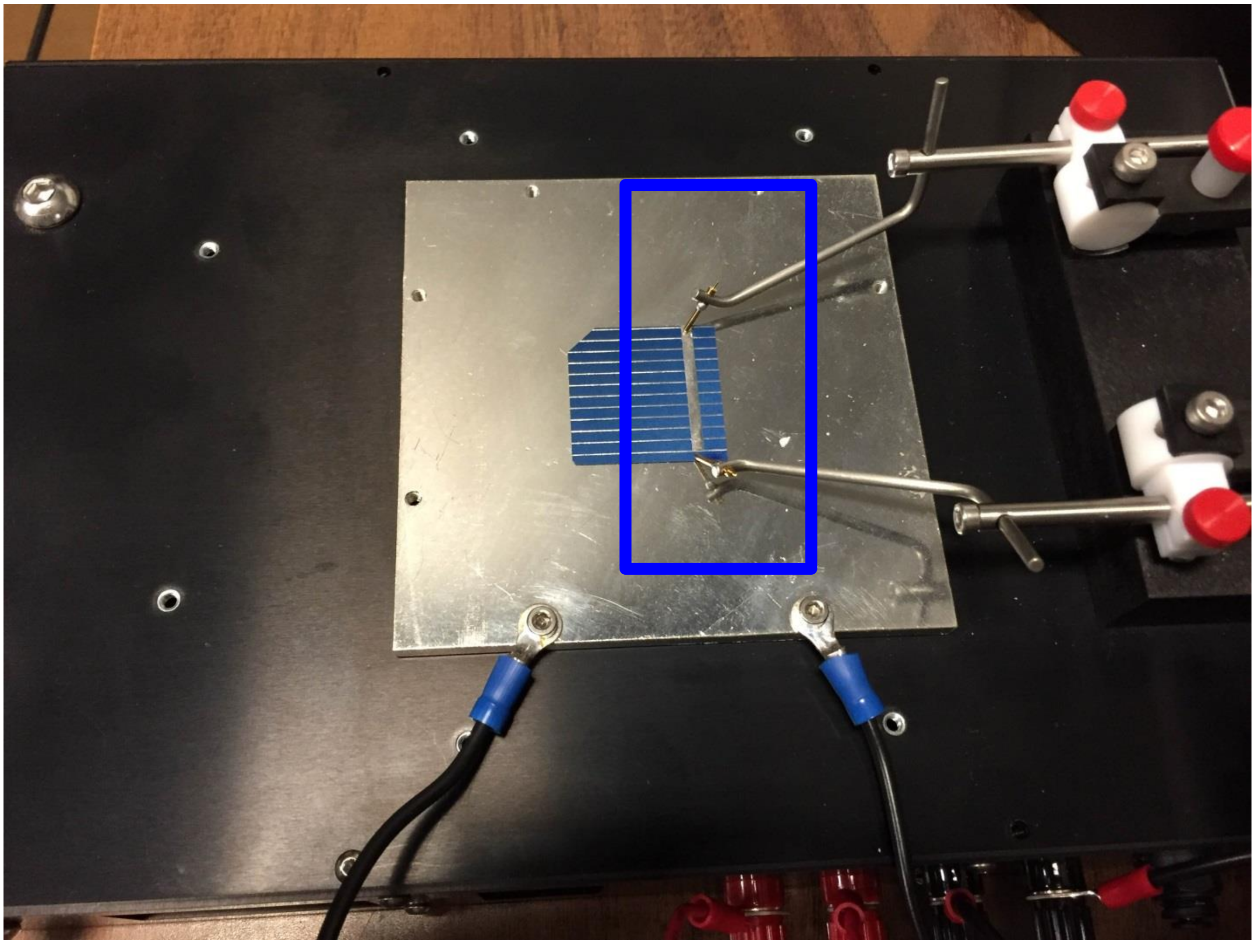


Figure 38. Example of wiring between cell chuck and probe station, step3 - probe tip contact with the DUT's BUS bars.

4. With all of these connections made, insert the cell chuck into the sample chamber.

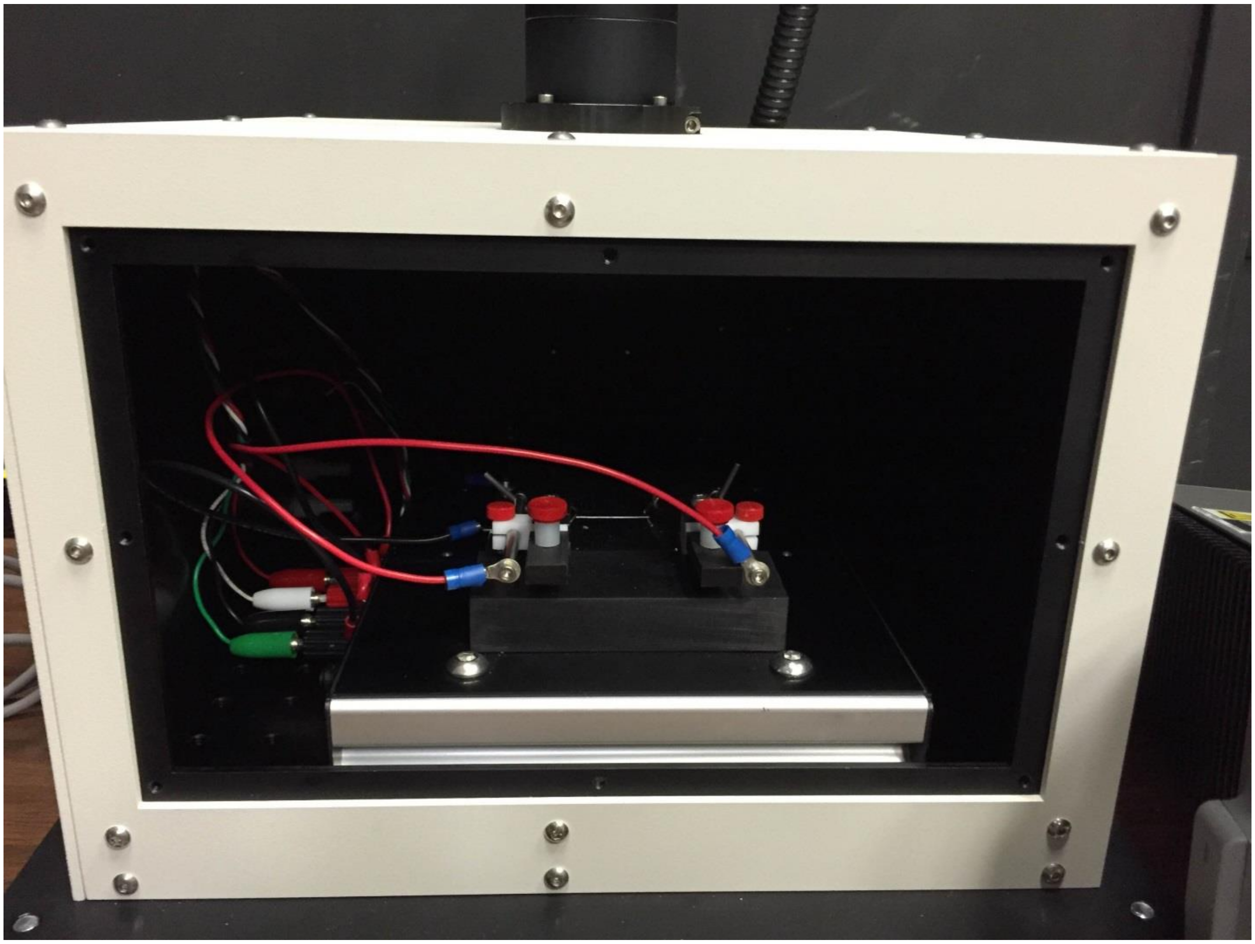


Figure 39. Example of wiring between cell chuck and probe station, step 4 - How to insert the cell chuck into the SC-12 sample chamber.

5. With the cell chuck in the sample chamber, connect the provided RED-WHITE-GREEN-BLACK wire to the outside of the sample chamber feedthrough and to your Keithley.

Figure 40. Example of wiring to cell chuck and probe station, step 5 - Wiring between Keithley and SC-12 sample chamber.

5.5 Example Connections with TEC Cell Chuck (with pictures)

The following instructions outline basic cable hookup for the TEC cell Chuck controlled by SciPV-IV:

1- The cable hookup between Keithley and your DUT is similar to section 4.1.
2- The cable hookup between the computer and the TEC cell chuck, vacuum line, and powering of the cell chuck is described in the following figure.
3- First connect the Power Adaptor to the TEC cell chuck.
4- Next, turn on the cell chuck.
5- Connect the USB cable to one of the USB ports on your computer. Make sure to use the USB cable that is supplied with the system.
6- Since an RTD sensor is installed under the cell chuck sample tray and has been already configured to the electronic board inside the cell chuck, no further connection other than the USB communication between the TEC chuck to computer is necessary.
7- Turn the Keithley on.
8- Run SciPV software. No error message should be displayed on the SciPV interface if the COM ports are configured correctly.

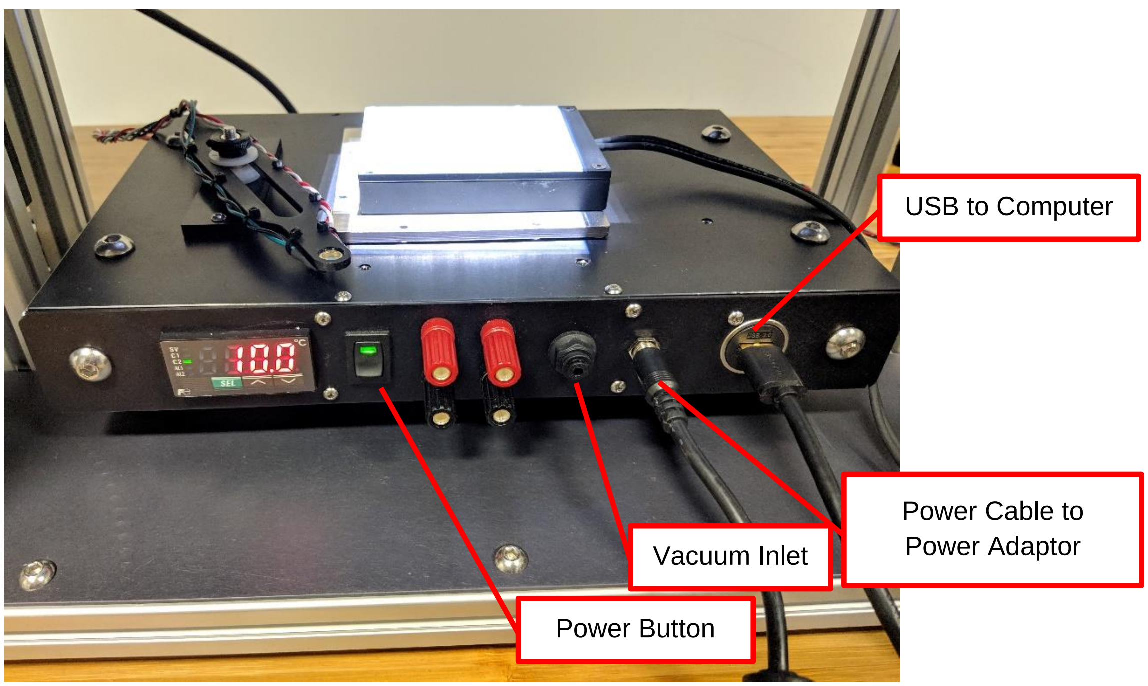


Figure 41. TEC cell chuck connection to computer.

6. Configuration and Assembly Files

SciPV-IV is written to be compatible with any generic source meter, as such it uses some configuration (*.config and *.asmy) and assembly (*.dll) files that need to be setup before running the software, this process is done by the application installer, but it is important to understand the file architecture in case the user experiences any issues at run time.

6.1 Configuration Files

There are a number of configuration files that the application uses. The type/purpose, location, and content of each is outlined in the below sections.

6.1.1 Device Configuration Files (*.config)

The purpose of this file(s) is to configure the source meter that is being sequenced by the application. This configuration file is generally named after the type of source meter being controlled; for example, if a Keithley 2450 is being used the configuration file would likely be named "*KE2450.config*" or some similarly descriptive name. It contains fields like COM port number (when applicable), device specific configuration parameters, etc.

This type of configuration file is found in the following directory:
C:\Users\Public\Documents\Sciencetech\Modules\Config

6.1.2 Module Configuration Files (*.asmy)

The purpose of this file is to associate a device configuration file(s) with an assembly file, in other words it links what code to use to control a source meter, and what configuration file to use to setup the source meter. These files contain fields that point to a specific assembly file (*.dll) and to specific (sets of) configuration files (*.config).

This type of configuration file is found in the following directory:
C:\ProgramData\Sciencetech\Modules

6.1.3 Application Configuration Files (*.config)

The purpose of these files is to configure the application to behave in a certain way, and to remember settings from previous application instances. There are three main configuration files that application uses to accomplish this task.

1. Module specification file – This file tells SciPV which module configuration file (*.asmy) to use to load the desired source meter. This file is located in the following location: *"C:\ProgramData\Sciencetech\SciPV \SciPVModules.config"*
2. License File – This file contains an encrypted hash the locks the software to a given source meter. This file is located in the following location:
"C:\ProgramData\Sciencetech\SciPV\License.config"

3. Application settings file – These files remember settings, for example, output folder, that the user has selected in previous application sessions. These files are located in the following directory:
C:\Users\[USER]\AppData\Roaming\Sciencetech\SciPV\Application Settings

6.2 Assembly Files

These files are compiled code binaries (*.dll) and are used to control specific source meters. They are device dependent, and SciPV loads the appropriate file based on what is specified in the module configuration file. These files are located in the following directory: *C:\Program Files (x86)\Sciencetech\Modules*

7. Troubleshooting

7.1 SciPV Errors

7.1.1 An unexpected error occurred when attempting to Initiate the Keithley(ModelNumber), see the error log for further details

Most likely the hardware is not powered on, it is not connected to the computer, or necessary drivers for the hardware are not installed.

Ensure all hardware is powered on and connected to the computer. Review section 2 to ensure all drivers are installed for your systems hardware.

7.1.2 Could not initialize Source meter

Most likely the hardware is not powered on, it is not connected to the computer, or necessary drivers for the hardware are not installed.

Ensure all hardware is powered on and connected to the computer. Review section 2 to ensure all drivers are installed for your systems hardware.

7.1.3 The measurement could not be started, the detected source meter serial number is not valid for the active software license

Please contact Sciencetech immediately to obtain the proper licence file.

7.2 Keithley Settings (2400 and 2401)

Ensure the correct communication settings are selected on the 2400 and 2401 Keithley, see Section 3.1.1. Ensure the correct COM port is set, see section 2.1. Ensure the correct baud rate is set on the Keithley and in software, see section 2.1.

7.3 4-Wire Connection for Measurements

Ensure that a 4-wire connection is made for IV measurements. SciPV operates in 4-wire measurement mode.

7.4 Determine Parameters for Your Device

7.4.1 Open Circuit Voltage and Polarity

You can determine the open circuit voltage under test conditions by following these steps

1. Connect the leads of your cell to a multimeter and set the multimeter to read DC voltage.
2. Illuminate your device to be tested with the desired illumination level (example 1 sun AM1.5G light).
3. The open circuit voltage (Voc) is the DC voltage you see on the multimeter.

4. With the leads still attached note the polarity of the voltage. If the voltage is positive, then you have the +'ve probe connected to the +ve lead and vice versa. Make sure you connect your cell for IV testing in this orientation.

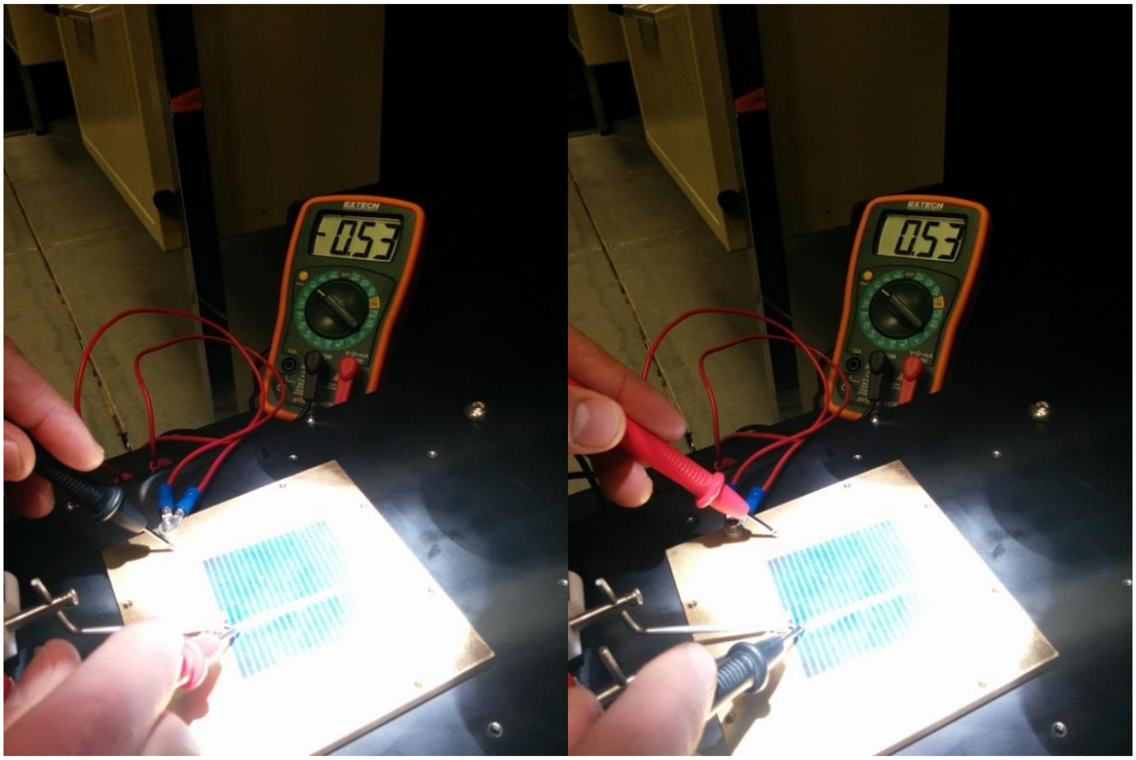


Figure 42. DUT polarity determination procedure.

7.4.1 Short Circuit Current

Short circuit current can be measured by placing a small resistor (1-20 ohm) in parallel with the cell to be tested. Illuminate the cell and measure the voltage across the resistor.

The short circuit current will be equal to the measured voltage / resistor used.

7.5 Setting the parameters for an IV scan

Generally, you only need to measure IV curves between 0 volts and the cell's open circuit voltage. Be careful about reverse biasing the cell during measurements. If you set a voltage range that goes from –ve to +ve then you will be reverse biasing the cell during testing. Some types of cells can be easily damaged when reverse biased. It is a good idea to limit the current to a value just above the short circuit current. Limiting the current can help to protect cells that are susceptible to damage if too much current passes through them.

7.6 Cell Connections

It is important to make sure that all electrical connections to the cell are made well. If you obtain IV curves that seem strange it is a good idea to check all the electrical connections. If poor electrical connections exist, you can usually troubleshoot this by checking for connectivity with a multimeter. If there is a large resistance (>1ohm) between two points in a circuit that are electrically connected, then there is likely a bad contact between those points.

Observe the following points as well to help fix bad connections.

7.6.1 Tighten Connections

Where connections are made with screws be sure to tighten the screws fully.

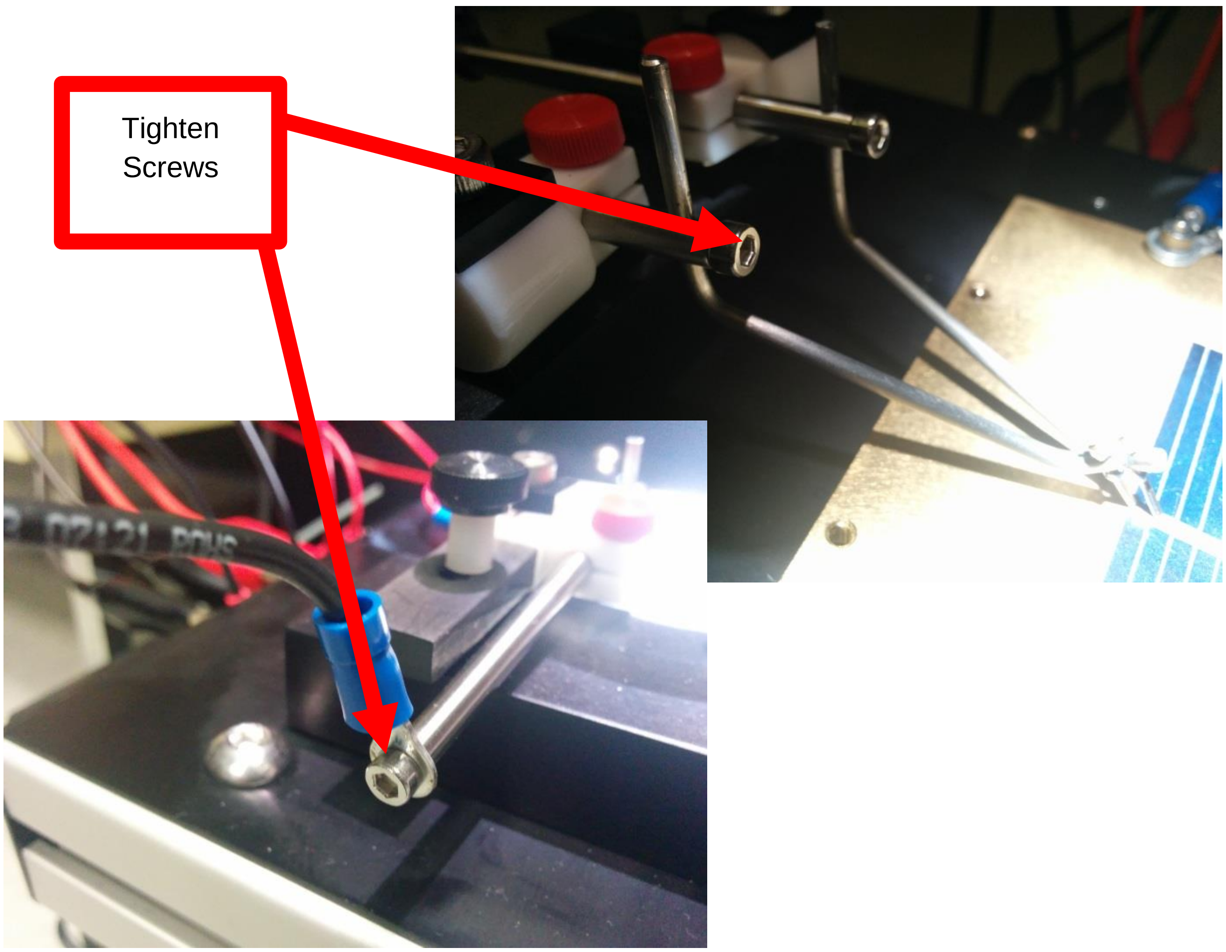


Figure 43. Probe station setup procedure.

7.6.2 Probe Tip Placement

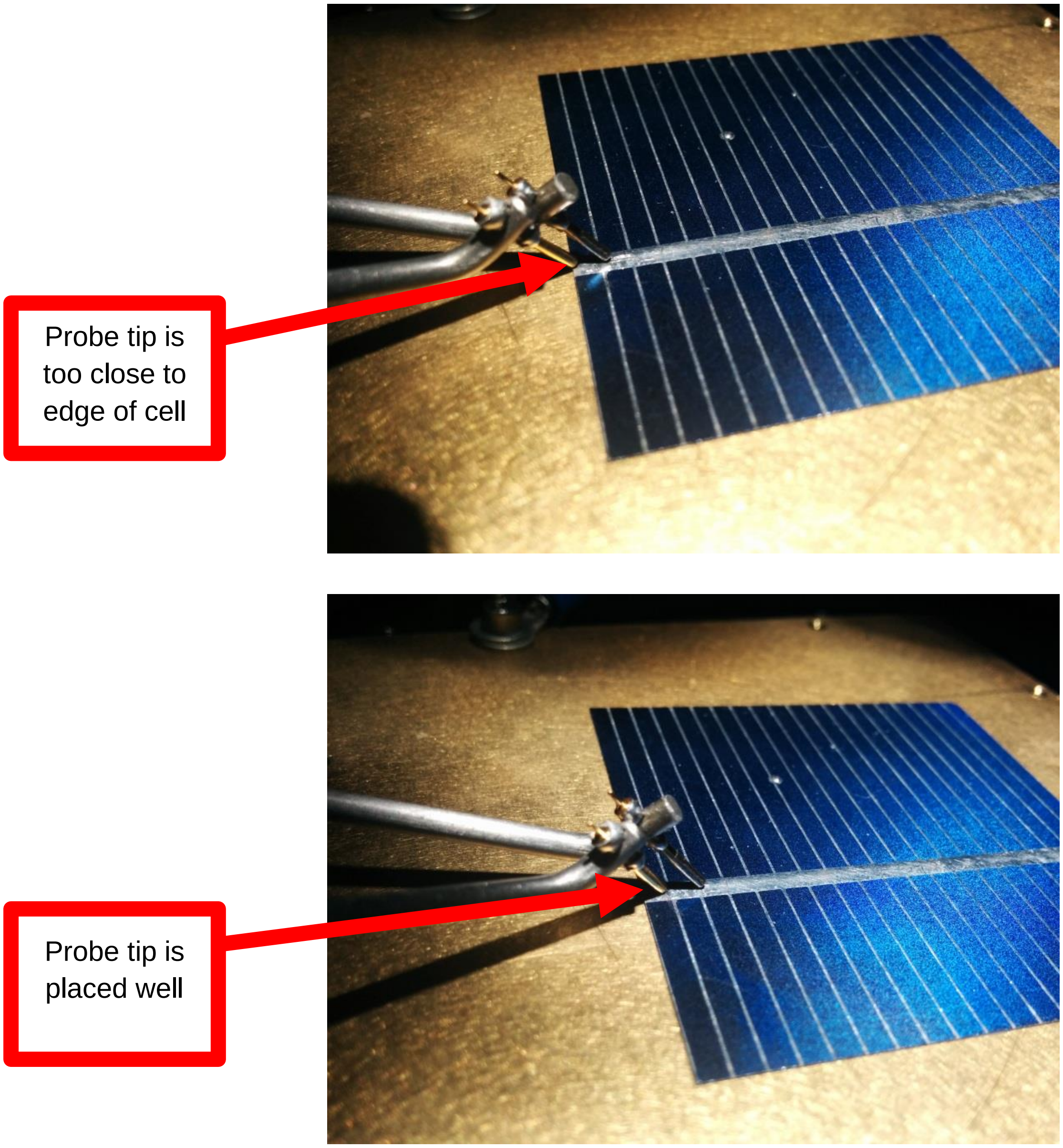


Figure 44. Probe tip placement.

7.6.3 Clean and Re-Seat Contacts

For contacts at binding posts it is possible that something can get stuck in the binding post and create a bad contact. It is a good idea to re-seat the contacts. For forked cables it is a good idea to clean the forks with alcohol on occasion.

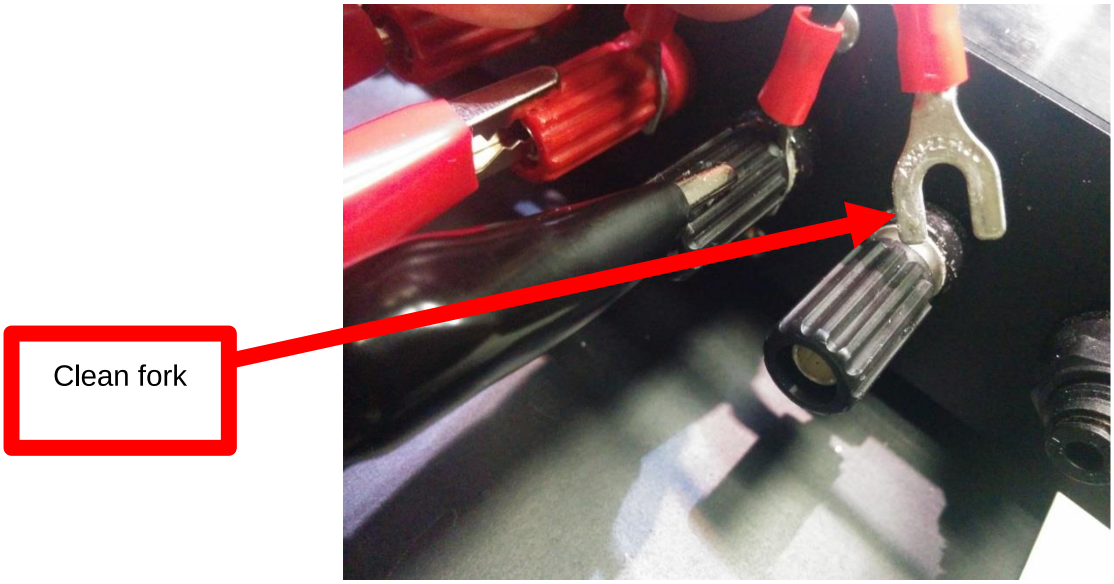


Figure 45. Electrical connection of probe station to cell chuck.

7.7 Redisplaying Multiple IVDAT Files

Opening numerous IVDAT files (e.g. 10 files or more) might take some time. Please wait and let the software load all the selected files. In addition, as the display area is not equipped with a scroll bar, software can not display the legend of all files if there are numerous files are selected. These features will improve in the next iteration of the software.

7.8 Decimals numbers

When entering decimals into the SciPV software, these values should be only entered using a period. The software will not function properly if a comma included in a number value entered by the user.

8. Important Notice

All electrical instruments may be dangerous if not handled in accordance with proper instructions and common precautions. Sciencetech Inc. will not be responsible for any damage caused by such units if instructions herein are not followed and repairs are not attended to or performed by company-trained or licensed personnel. All instruments should be operated with proper grounds on power line and should not be opened or handled as to electrical or electrically operated components without being switched off and disconnected from power receptacle.

Sciencetech Inc. reserves the right to make adjustments or improvements in its product without notice and without obligation to subsequent purchasers and without being required to make corresponding changes or improvements in products theretofore manufactured and sold.

We have done our very best in the manufacture and packing of this material. The transportation carrier is now responsible for delivering it to you in its original good condition, since all purchases are FOB London.

If the shipment is NOT delivered in good order and in accordance with quantity shown on Bill of Lading or Packing Slip, have the shortage or damage noted by the Carrier on both the delivery receipt and the freight bill, or by special form provided by United Parcel or the Post Office.

The Interstate Commerce Commission has ruled that Transportation Companies will not honor any losses or shortage claims unless exceptions are noted on the freight bill at the time of delivery. It is the buyer's responsibility to make a complete inspection immediately upon receipt of purchased goods.

If you accept shipment from the Transportation Carrier short of what is enumerated on the Bill of Lading – or in damaged condition – without having proper notation made by the Carrier, you do so at your own risk.

If bundles or crates are in apparent good order, but on opening contents are found to be damaged, call Carrier for adjuster to view same and have the Transportation Company/United Parcel/Post Office mark the freight bill or packing slip relative to such concealed damage. Make your claim at once for the Transportation Company/United Parcel/Post Office has a limited time for presentation of claims.

We are willing to assist you in every possible manner in collecting claims for loss or damage on this shipment, but this willingness on our part does not make us responsible for filing or collecting claims or replacing materials. Claims for Loss or Damage on shipment may not be deducted from out invoice, nor pay of the invoice withheld awaiting adjustment of such claims, as we cannot guarantee safe delivery.

Important: Do not return goods without written authority.

Contact factory for return material authorization.

Returned goods will not be accepted by us from the Transportation Company/United Parcel/Post Office unless written authorization has been issued by Sciencetech Inc.

Return of special or non-stock items cannot be authorized. Credit for goods returned - under authorization - will depend on the value to us based on our selling price, less a fair charge to cover the expense of shipping - re-handling - transportation - refinishing, etc, providing material is received in good condition - transportation charges prepaid - credit rendered to be used against future purchases.

All equipment manufactured by Sciencetech Inc. has been subjected to extensive performance and quality control testing. In order to constantly improve our product, we ask your assistance. Upon installation of our equipment, please fill out the attached card and return to us.

By completing the card and returning it to Sciencetech, you will register your instrument in warranty and enable us to provide you with the best possible service.

9. Warranty and Assistance

All Sciencetech products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. Products sold or resold, but not manufactured by Sciencetech, carry the warranty, if any of the original manufacturer. We will repair or replace products that prove to be defective during the warranty period or employ our best efforts to effect repair or replacement of equipment sold, but not manufactured, by Sciencetech. No other warranty is expressed or implied.

We are not liable for consequential damages.

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