PVIV SERIES

IV STATION

User's Manual

ORIEL®
INSTRUMENTS
A Newport Corporation Brand

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LIST OF FIGURES

Please read these instructions completely before operating this equipment. The specification and operating instructions apply only to the model(s) covered by this manual. If there are any questions or problems regarding the use of this equipment, please contact Newport or the representative from whom this equipment was purchased.

1. INTRODUCTION

This Manual covers the setup and operation of all configurations of the Newport Oriel® I-V measurement systems. These products have been designed for operation with the Newport Oriel® Solar Simulator product line. However, the components are modular and not restricted to Newport Oriel® products. Often adjusting cell height with respect to another light source is all that is required.

The Solar simulator must be purchased separately.

The table below shows the following Models comprising a SourceMeter®, I-V software, associated cabling, and 1 Ohm (4.5 Amp continuous) Resistor Box (90026597).

Newport Oriel® I-V Station Model Num.	2400 SourceMeter® kit 1 Amp	2420 SourceMeter® kit 3 Amp	2440 SourceMeter® kit 5 Amp	PVIV-10A-I-AMP Current Amplifier 10 Amp	91540 PVIV 2.1 I-V software
PVIV-1A	✔				✔
PVIV-3A		✔			✔
PVIV-5A			✔		✔
PVIV-10A	✔			✔	✔

A certified Silicon Reference Cell with calibration-matched meter is sold separately (91150V). This includes an accessory cable (91150V-CBL) to adapt the Reference Cell amphenol connector to two double banana jacks to allow connection to a Source Measurement Unit (SMU) for I-V characterization.

The following is a list of PVIV-related accessories sold separately:

- PVIV-VAC-CHUCK   Basic vacuum chuck sample holder
- PVIV-TC-VAC   Temperature Controlled Vacuum Chuck Assembly
- PVIV-PROBE-KIT   PVIV Probe Kit (right angle bracket and magnetic base probe)
- PROBE-TIP-RPL   PVIV Tungsten Probe Tip Replacement (package of 5)
- PVIV-CHILLER   Chiller
- PVIV-VAC-PUMP   Vacuum Pump 110V
- PVIV-VAC-PUMP-220   Vacuum Pump 220V

  Individual probes (PVIV-PROBE-KIT) are generally recommended for the PVIV-TC-VAC and PVIV-VAC-CHUCK. It is an important distinction that the PVIV-VAC-CHUCK is fixed in place with vertical adjust, while the PVIV-TC-VAC is a sliding chuck allowing for placement of the 91150V and sample cell simultaneously.

Oriel® Instruments provides complete PVIV solutions, with high performance at a reasonable cost. Shown below is a typical 6x6 PVIV setup, with a 6x6 AAA Solar Simulator, sliding cooled vacuum chuck, reference cell, chiller, probe kit, and vacuum pump.
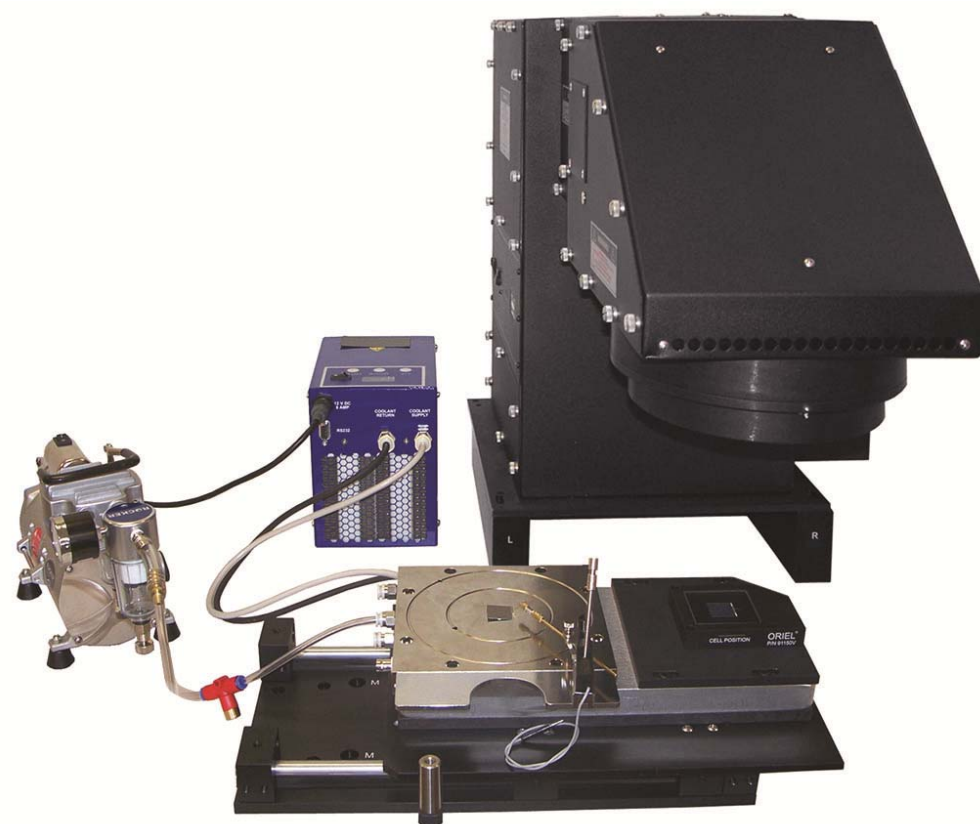

Figure 1: 6x6 PVIV Setup: PVIV-TC-VAC, PVIV-1A, 91150V, PVIV-PROBE-KIT, PVIV-CHILLER, PVIV-VAC-PUMP

2. SPECIFICATIONS

Below is the Oriel® I-V Test Station specification table.

	PVIV-1A	PVIV-3A	PVIV-5A	PVIV-10A
Voltage range (V)	± 200mV -200 V	± 200mV-60 V	± 200mV -40 V	± 2.5 V
Current range (A)	± 1uA -1.00A	±10uA - 3.00 A	±10uA - 5.00 A	-4 to +10 A
Output power (W)	20 W	60 W	50 W	25 W
Voltage Measurement Resolution	1uV – 1mV	1uV – 1mV	1uV – 1mV	1uV - 1mV
Current Measurement Resolution	10pA – 10uA	100pA – 10uA	100pA – 10uA	10pA – 10uA
Voltage Source Accuracy	± 0.02%	± 0.02%	± 0.02%	± 0.02%
Current Measurement Accuracy	< 0.23% across all ranges	< 0.053% across all ranges	< 0.11% across all ranges	<0.23% across all ranges
	All Models			
Electrical Interface	4-wire probing; 4 quadrant Sourcing and Sinking			
Duration of I-V measurement (sec)	0.6 – 58 with 0.5 sec pre-sweep delay			
Number of measurement points	2 – 1000			
Thermistor temperature accuracy (°C)	± 0.25°C @ 25°C			
Test device size (inch [cm])	0.4 (1cm) - 6.14 (15.6cm) for all vacuum chuck fixtures			
Software	LabVIEW 2009 SP1 GUI			
Measurements performed	Voc, Isc, Jsc, Vmax, Imax, Pmax, Efficiency, Fill Factor, R@Isc, R@Voc, Rshunt, Cell Temp (start), Cell Temp (end), Exposure Duration, Date &Time Stamp			

3. COMPUTER REQUIREMENTS

Minimum 2 GHz processor
Microsoft Windows XP™, Service Pack 2 or 3; Windows 7 or 10, 32-bit or 64-bit
512MB available RAM
CD-ROM Drive
Minimum Hard drive space available 600 MB

Note: SourceMeter® is a registered trademark of Keithley Instruments, Inc.

4. UNPACKING THE I-V STATION

The **PVIV-1A, PVIV-3A,** and **PVIV-5A** Newport Oriel® I-V Station comes with:

- PN 91540: I-V Software package on USB drive
    - software installation files
    - this manual

- Keithley SourceMeter® kit (1 Amp, 3 Amp and 5 Amp models)
    - SMU
    - PN 51-10-010: USB to GPIB controller
    - PN 100783: red and black test leads (2 sets)
    - PN 91530-1030: cable, SMU to shutter (9-pin DSUB to BNC)
    - PN 90009203: cable, SMU to thermistor (Dual Banana Plugs to BNC)
    -

The **PVIV-10A** 10 Amp Current Amplifier system comes with:

- PN 2400: 1 Amp SMU
- PN PVIV-10A-I-AMP: 10 Amp Current Amplifier
- PN 51-10-010: USB to GPIB controller
- PN 91540: software installation CD
- PN 68700-1030: interlock plug
- PN 91530-1030: cable, SMU to shutter (9-pin DSUB to BNC)
- PN 90009203: cable, SMU to thermistor (Dual Banana Plugs to BNC)
- PN 70016: cable, Amplifier shutter out to Solar Simulator shutter in (2M BNC to BNC)
- PN 90026573: cable, SMU to Amplifier to fixture (Dual Banana Plugs both ends, QTY3)
- PN 100783: cable, Dual Banana Plug to Minigrabber, QTY2)
- PN 90034536: connector, SMU to Probe kit (Banana Jack to 2 Pin Jack, QTY2)

The following cell holding fixtures are available:

The **PVIV-VAC-CHUCK** Fixed Vacuum Chuck (single cell holder for either test or Reference Cell, fixed position) comes with:

- PN 90026536: Vacuum plate assembly
- PN 90009203: Cable, BNC made to double banana plug, 60" lg
- PN 90-11-052: Allen wrench, 2mm
- PN 90-11-047: Allen wrench, 9/64"
- PN 90-11-049: Allen wrench, 3/16"

- PN SPV-3: 3" Post qty 4
- PN VPH-3-P: 3" Post Holder qty 4
- PN PS-F: Clamping Fork qty 4

- PN 84-20-006: Tubing, 1/8" ID x ¼" OD PVC, 10 feet

- PN A1JD0824QAZB: #8-32 x 3/4" lg socket head cap screw, qty 4
- PN A1JD1420QAZB: #1/4-20 x 5/8" lg socket head cap screw, qty 4

The **PVIV-TC-VAC** Dual cell chuck (separate holders for test and Reference Cells, cell holders are rail mounted) comes with:

- Temperature controlled vacuum chuck on a manual slide
- PN 90009203: Cable, BNC male to double banana plug, 60" lg
- PN 90-11-046: Allen wrench, 1/8"
- PN 90-11-065: Hex Balldriver, 7/64"

- PN 90-11-069: Hex Balldriver, 3/16"
- PN SP-2: 2" Post qty 4
- PN SP-4: 4" Post qty 4
- PN BC-5: Base Clamp qty 4
- PN TA-8Q20-10: Thread adaptor (English), 1 pkg
- PN TA-8M6-10: Thread adaptor (Metric), 1 pkg
- PN 84-20-006: Tubing, 1/8" ID x ¼" OD PVC, 10 feet
- PN A1JD1416QAZB: #1/4-20 x 1/2" lg socket head cap screw, qty 4
- PN A1JD1412QAZB: #1/4-20 x 3/8" lg socket head cap screw, qty 6
- PN A1JD0624QAZB: #6-32 x 3/4" lg socket head cap screw, qty 4

The **91150V** Reference cell system comes with:
- PN 91150V-CELL: PV Reference Cell
- PN 91150-2000: PV Reference Cell meter
- PN 90021927: Cable, Reference Cell to Meter (Amphenol to Lemo connector)
- PN 90021928: Cable, Type K thermocouple
- PN 91150V-CBL: Cable, Reference Cell to Keithley
- PN M91150V: Manual for Reference Cell system

5. INSTALLATION OF THE TEMPERATURE CONTROLLED VACUUM CHUCK

To mechanically install the Temperature Controlled Vacuum Chuck Assembly refer to the PVIV-TC-VAC user manual (some extra hardware may remain). For a picture of **PVIV-PROBE-KIT** electrical connections to the chuck, refer to Figure 7 and Figure 8.

The following diagram is an illustration of connecting the Temperature Controlled Vacuum Chuck system based on a typical setup with the following parts:

- **PVIV-TC-VAC**   Temperature Controlled Vacuum Chuck   Qty 1
- **PVIV-PROBE-KIT**   PVIV Probe Kit   Qty 2
- **PVIV-CHILLER**   Chiller (and heating capable)   Qty 1
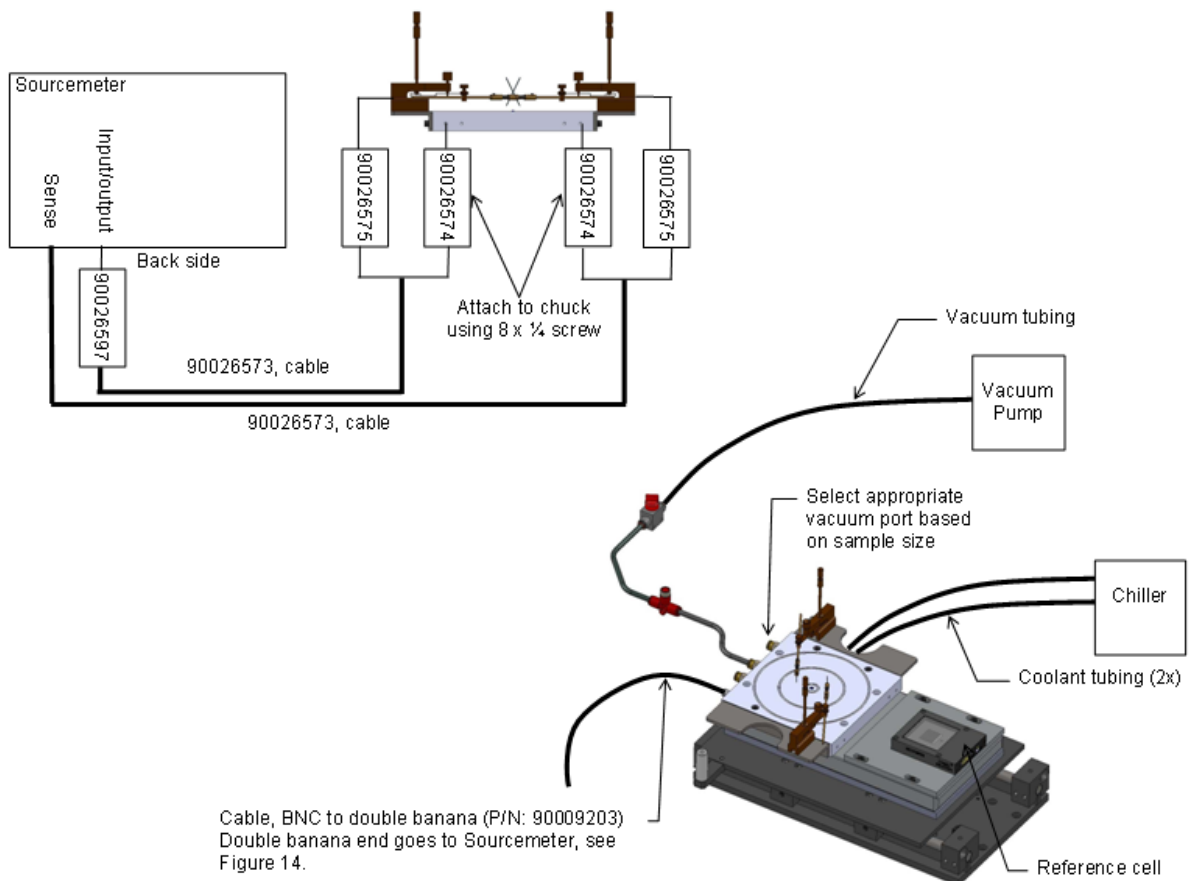- **PVIV-VAC-PUMP**   Vacuum Pump   Qty 1

Figure 2: Temperature Controlled Vacuum Chuck system connections
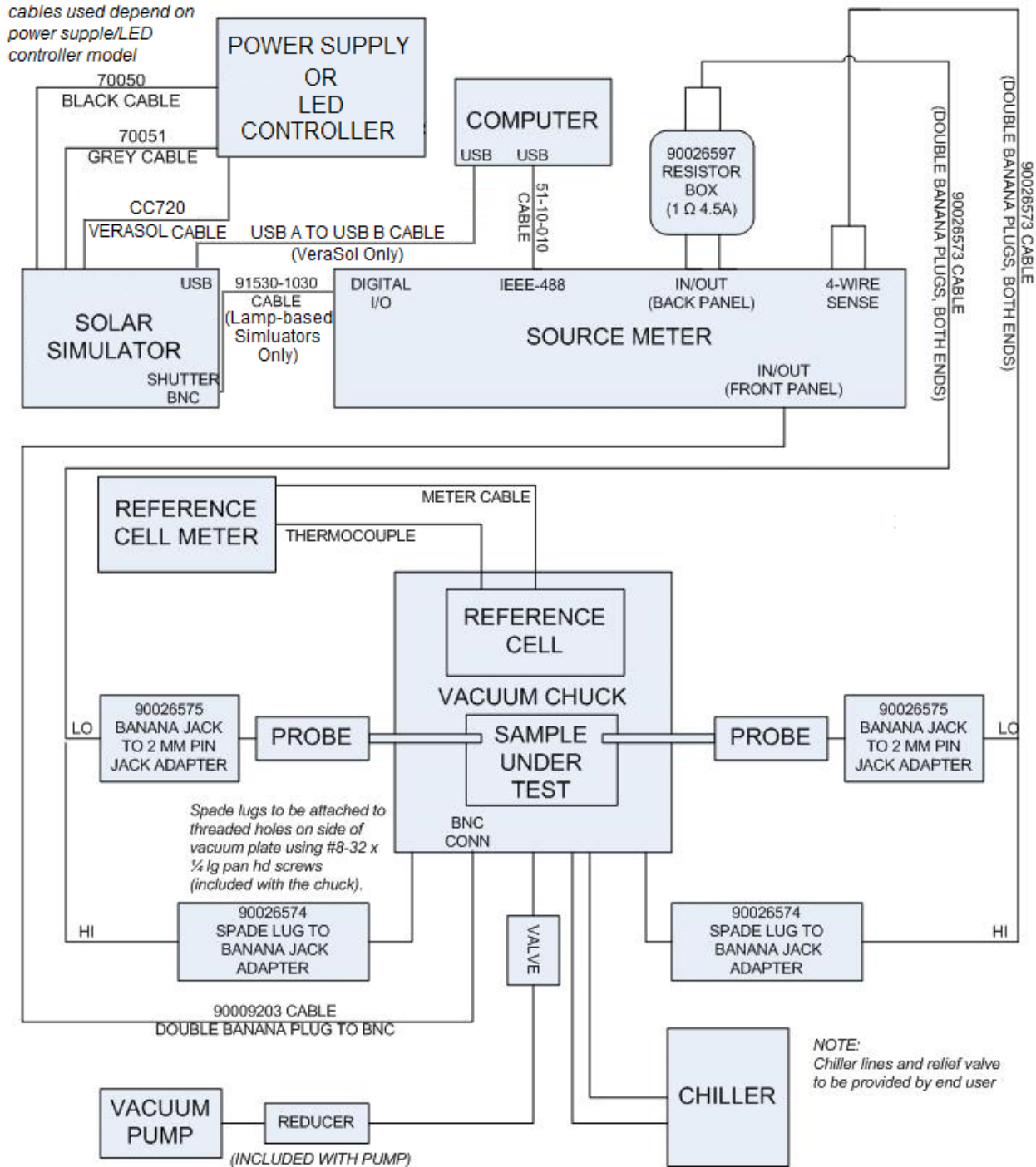
6. WIRING THE I-V TEST STATION

Figure 3: Diagram of system connections for PVIV-TC-VAC and PVIV-VAC-CHUCK.
Certain optional components may not be available depending on the order configuration.

Notes on the electrical connections:

1. If you are using a lamp-based simulator, be sure that the connectors on the power cables between the arc lamp power supply and the solar simulator housing are seated well and the jacks screws are tight. Refer to Figures 4 and 5**,** which show a 4" x 4" Solar Simulator system. Note that 2" x 2" systems may use a single cable between the housing and power supply.

2. If you are using a LED-based solar simulator, be sure that the connectors on the power cables are seated well, and for the VeraSol-2 system that the cable between the LSH-7520 source head and LSS-7120 controller is seated well and the jack screws are tight. Refer to their respective user manuals for further set up detail.

3. A 4-wire connection is used between the cell under test and the SMU. Make these connections to the rear terminals of the SMU. A source (Input/Output) wire pair, one connected to the top of the cell and one to the bottom, and a similar pair of meter wires (4-wire sense) are used. Typically the bottom of the cell is connected to the HI terminal of the SMU, and the cell top to the LO terminal.

4. For small cells with Isc below 10mA, probing can be difficult. Two electrical connections can be made to the cell. These connections are then split to become the 4-wire Current Source and Voltage Sense connections. Voltage drop error from contact resistance is smaller with lower current.

5. The Cell temperature is sensed by the spring-loaded thermistor built into the center of the Cell Holder. It is in close thermal contact with the bottom of the PV Cell. If the User has not purchased an Oriel® fixture, the thermistor function may be incorporated into the User-supplied apparatus. The thermistor is Vishay (BC Components) P/N NTCLE203E3103FBO, Digikey P/N BC2299-ND. It has a NTC resistance (10KΩ @ 25°C, -4390ppm / °C, Vishay Curve 01) read by the Keithley$^{®}$ every second in standby mode, which is converted by the software to a temperature in degrees C.

6. The thermistor has a 2-wire connection to the SMU front panel (Input/Output) jacks. The SMU makes temperature measurements in standby mode, but not during the actual I-V scan. These are isolated non-polar connections, so they may be interchanged with no ill effect. Use the BNC to Dual Banana plug cable (90009203).

Refer to the photos below for the details of the electrical connections.

Shutter
Connection
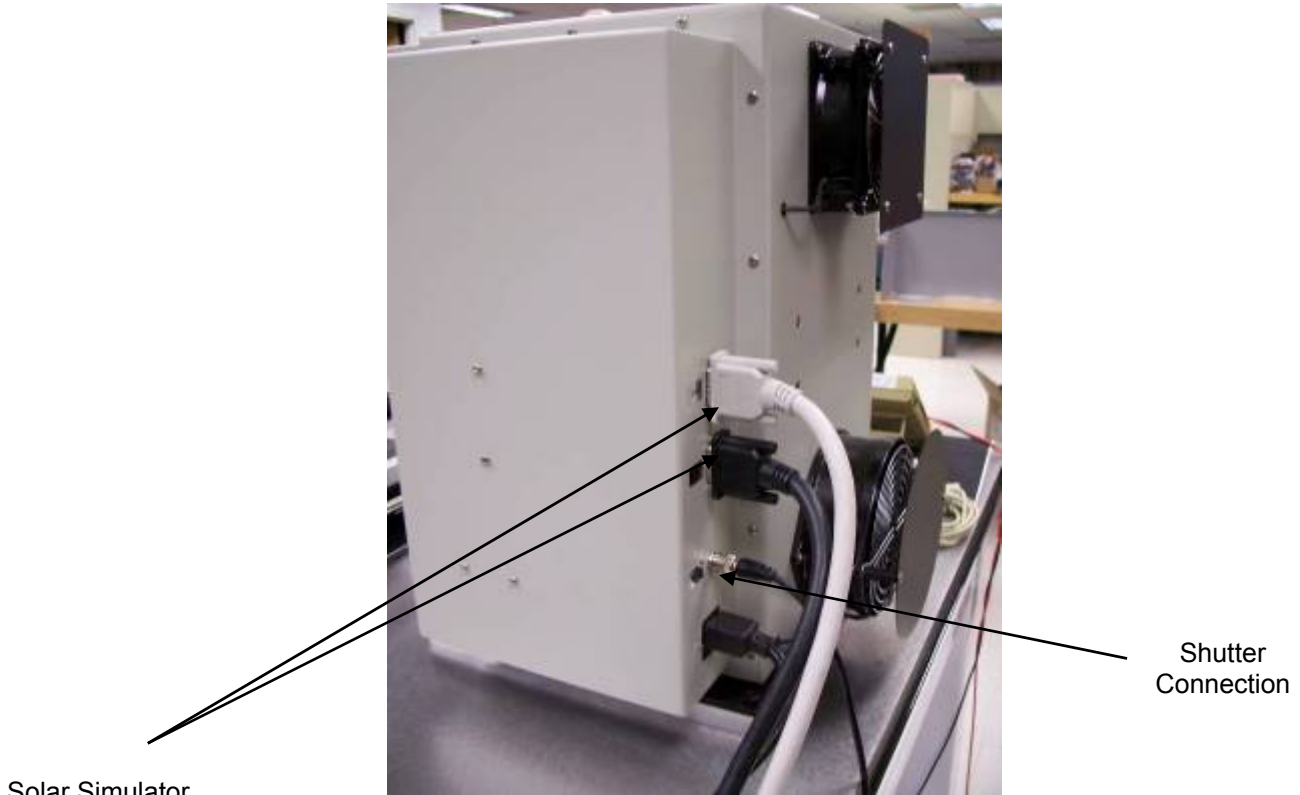
Solar Simulator
Power Supply
Connections

Figure 4: Rear view of a 4 x 4" solar simulator cable connection.

Figure 5: Rear view of a 4 x 4" solar simulator power supply.

PV Reference
Cell Meter

Test leads
from test cell
(Red on top)

GPIB
Connection

Shutter Cable
from Solar
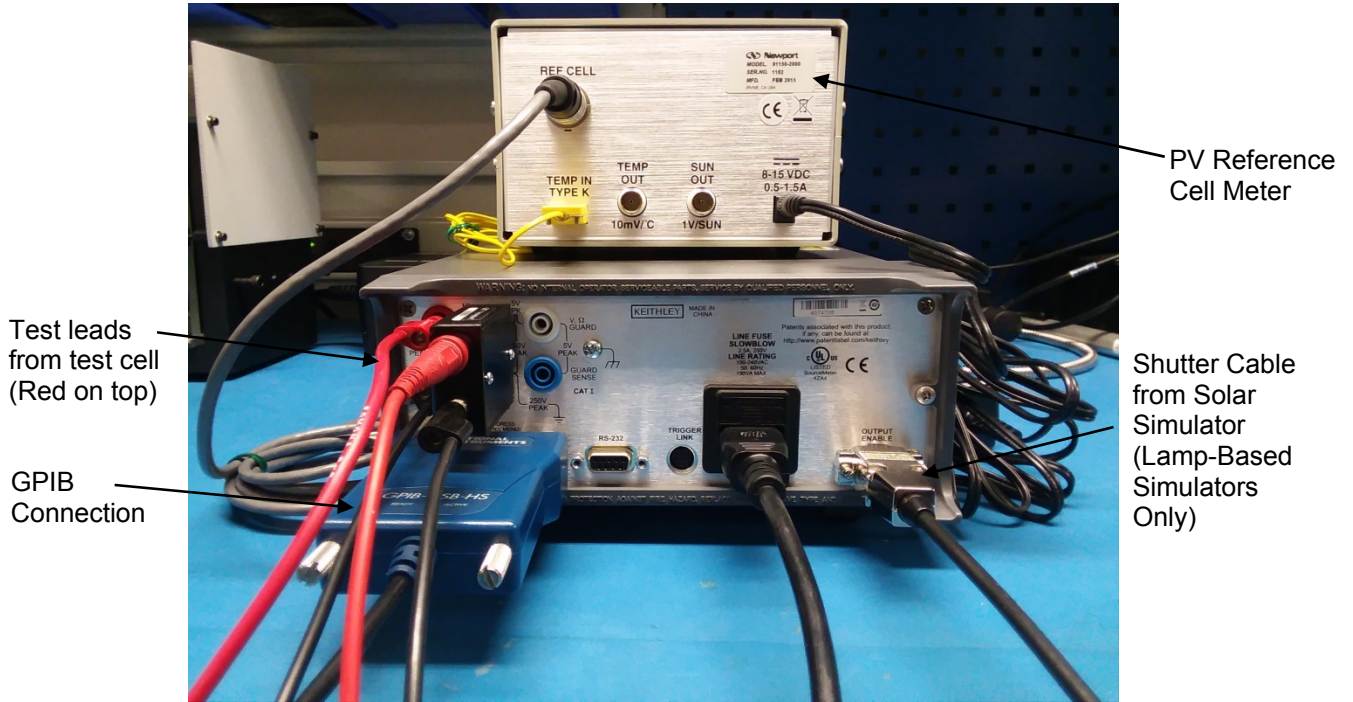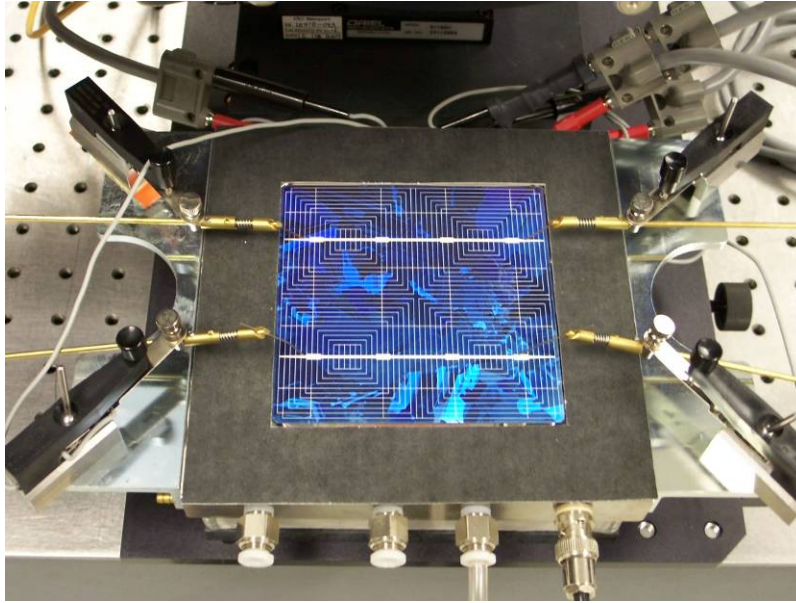Simulator
(Lamp-Based
Simulators
Only)

Figure 6: Rear view of the wires connected to the SMU.

**Figure 7: Using 90026574 and 90026575 adaptors to connect to the vacuum chuck**

Figure 8: PVIV-TC-VAC cooled sliding vacuum chuck with (4) PVIV-PROBE-KIT probing: (3) for Current Sourcing, (1) for Voltage Sensing.

7. ORIEL® I-V TEST STATION SOFTWARE

I-V TEST STATION Software – Installation

1. Before installing the Oriel® IV Test Station software, the GPIB communication must be set up and ran properly either by using the supplied USB/GPIB converter with its associated National Instruments installation CD, or by using an existing installed GPIB card. National Instruments drivers are required for the NI USB-GPIB hardware to communicate with the Keithley® meter. The required installer is included with the NI USB-GPIB hardware.

2. Insert the Oriel® I-V Test Station installation USB drive. Double click on 'Setup'. Actual installation procedure may be different than described below depending on the Operating System version of the computer.

3. Click 'Next' if you want to install the software to the default directory. The installer will install the program files to "C:\Oriel Instruments" by default. Otherwise, click 'Browse' and select the desired path. Then click 'Next'. The window below will appear. Click 'Next'.
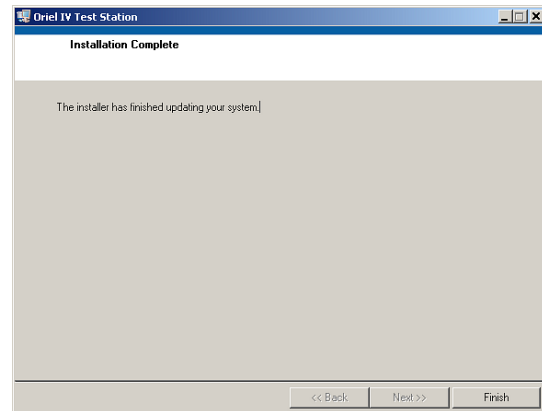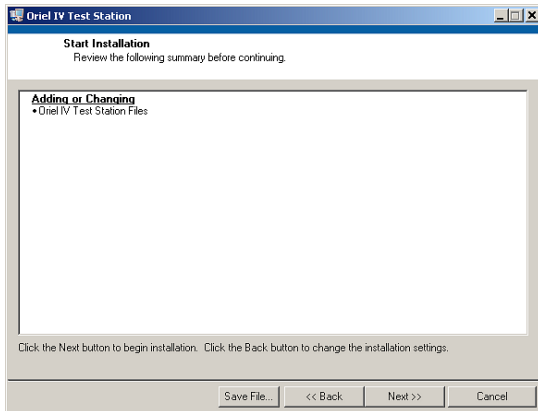
4. Once the installation is complete, click 'Finish' in the window shown above.

5. By default, he installer will create a shortcut "Oriel IV Test Station" in the Start Menu under "Programs\Oriel Instruments" as well as on the desktop.

6. The default locations for Recipes and Results are subfolders in C:\PVIV. These can be changed by editing the "Oriel IV Test Station.ini" file which can be found in the application folder.

7. The application requires LabVIEW 2012SP1 Runtime Engine from National Instruments. This should be installed as part of the package automatically.

8. The PVIV software may be used on a Windows 7 operating system. In order to run, do the following:

   a. Right click the short cut icon on the desktop for the Oriel® IV Test Station application

   b. Select properties

   c. Set privileges for administrator, which will allow creation and modification of the Recipe and Result files.

I-V Test Station Software – INTRODUCTION SUMMARY

Oriel® IV Test Station Version 2.1.1 is a minor update that provides the following added functionality:

- Compatibility with Windows 10 operating system

To ensure proper communication with the Keithley®, set "Regional and Language Options" – "Regional Options" tab to "English (United States) – US".   Also set "Regional and Language Options" – "Languages" tab, "Details" button to "English (United States) – US" to change the Keyboard setting. This will avoid the issue of an ASCII comma being sent in place of a decimal point, causing an "error code 822 current too small to sense" message.

Start the 'Oriel IV Test Station' program. A window similar to the one shown below will appear.
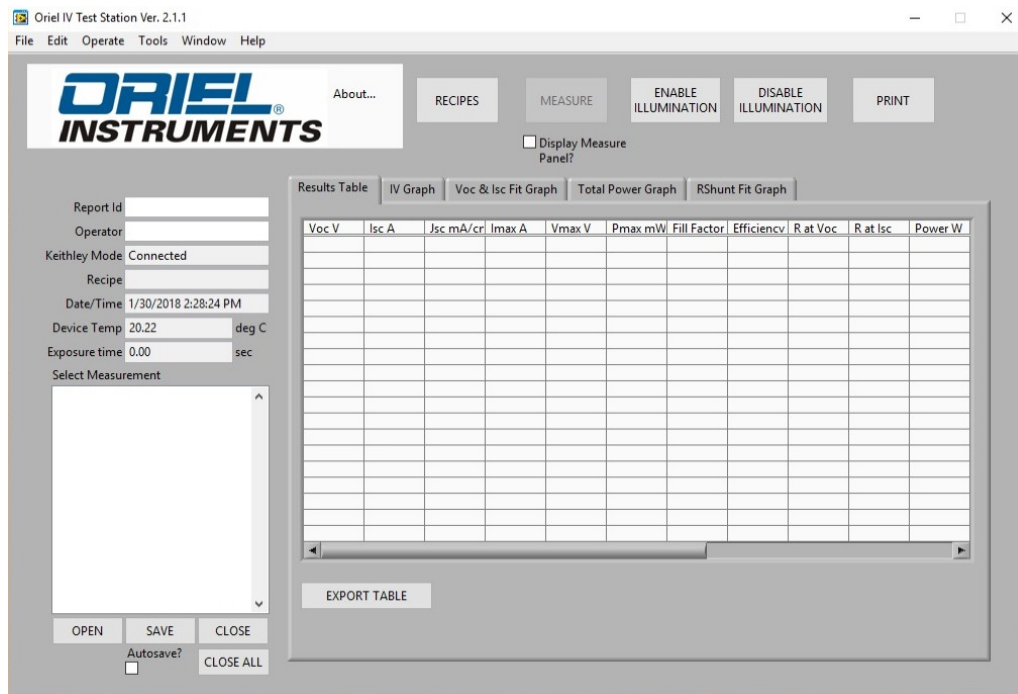
The following fields appear toward the left of the window:

'Report ID' and 'Operator' are text fields into which the user can enter appropriate information. It is a requirement to enter a description into the 'Report ID' field in order for a measurement to be taken, which will facilitate file management.

'Keithley Mode' indicates 'Connected' when the software has established USB - GPIB communication with the SMU. It will display 'Emulation' if the communication link has not been established.

'Recipe' indicates the filename of the test method that is currently in use.

'Date/Time' is the current Date and Time, which corresponds to a Date and Time stamp for a measurement run.

'Device Temp' is the cell temperature of the test device updated every second when not running a scan. If the measured temperature is out of the range of -15°C - 70°C, then "NaN" will be displayed, indicating "Not a Number".

'Exposure time' is a display of the amount of time in seconds that the shutter is (or was last) open.

'Select Measurement' shows the names of the displayed measurement scans, which are presently loaded. Each one is identified by its Report ID followed by the Date/Time Stamp. Left clicking on one will highlight it in this window as well as the display tab windows. The checkbox to the left of each of these is checked when the measurement has been saved as a file. A maximum of 15 measurements can be stored in memory at any time. The oldest measurements will be discarded if necessary to store new measurements or to load measurements from disk. The user will NOT be warned in this case if unsaved data will be discarded.

Four buttons are associated with the 'Select Measurement' field, which are underneath it:

'OPEN' is used to open a previously saved file for further analysis, or for comparison to other measurements.

'SAVE' is used to save a measurement scan to a file. A window will come up to provide a path and filename to the measurement. Note that if the 'Autosave' checkbox is selected, the measurements will be automatically saved into the last folder used for saving results. The default folder is C:\PVIV\Results.

'CLOSE' is used to close the highlighted measurement scan. If it has not been saved, the Operator will be prompted to optionally save it.

'CLOSE ALL' is used to close all of the measurement scans in the 'Select Measurement' field. If any measurements have not been saved, the Operator will be prompted to optionally save them.

The following five buttons appear at the top of the window:

'RECIPES' opens the measurement method settings window.

'MEASURE' performs a measurement according to the recipe selected. It is disabled until a recipe is selected.

'ENABLE ILLUMINATION' manually turns on the light source, either by th mechanical shutter in the lamp-based simulators or by turning on the LEDs of the VeraSol-2 or LSH-7320. The exposure time is displayed in the "Exposure Time" field.

'DISABLE ILLUMINATION' manually turns off the light source either by the mechanical shutter in the lamp-based simulators or by turning off the LEDs of the VeraSol-2 or LSH-7320. The exposure time that has elapsed is displayed in the 'Exposure Time' field.

'PRINT' sends a screenshot to the printer chosen.

The following result Tabs appear in the middle of the window:

'**Results Table**' (shown below) provides the following measurement and calculated data:
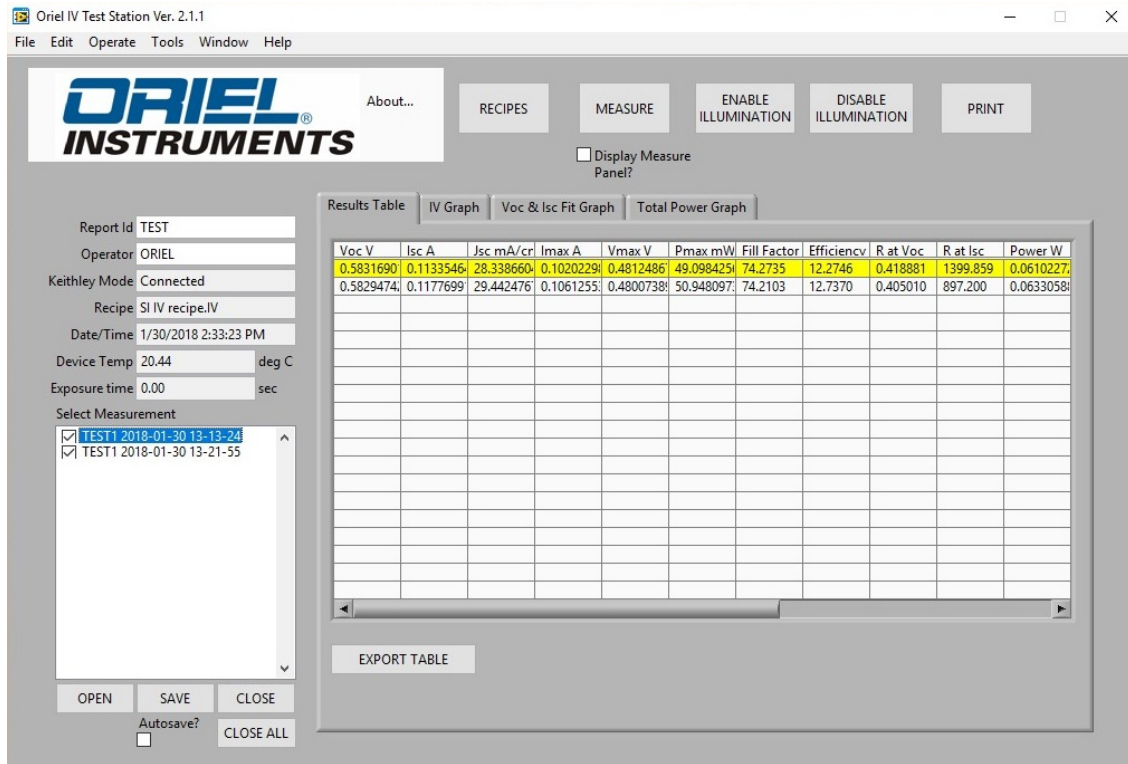
V_{oc} (V): open circuit voltage in volts- the voltage at which there is zero current through the cell

I_{sc} (A): short circuit current in amps- the current at zero volts

J_{sc} (mA/cm^2): short circuit current density in mA/cm^2- I_{sc} in mA divided by the sample area

I_{max} (A): current at which the maximum power is achieved

V_{max} (V): voltage at which the maximum power is achieved

P_{max} (mW): the maximum power point, in mW, as calculated by $I_{max} \times V_{max}$. The software calculates two P_{max} values, one from the raw data and the other from data fitting. Once the raw data measurement is completed, the software fits the data to a fourth order polynomial and calculates P_{max}. If the difference between the two values is greater than 2%, the software will return the value calculated from the raw data. If the two values are within 2%, the software will return the value from the fit data. It is strongly recommended that the minimum number of data points be at least 50 points to ensure an accurate measurement.

Fill factor (%): = $100 \times \dfrac{P_{\max}}{I_{sc} \times V_{oc}}$

Efficiency (%): = $100 \times \dfrac{P_{\max}}{\text{Irradiance (mW/cm}^2) \times \text{Total area (cm}^2)}$

R at V_{oc} (Ohm):
Series resistance in Ohms derived from an illuminated IV measurement scan for the points near Voc

R at I_{sc} (Ohm):
Shunt resistance in Ohms derived from an illuminated IV measurement scan for the points near Isc

Power (W): integral of the power in the first quadrant of the IV curve

Rshunt (Ohm):
Shunt resistance in Ohms derived only from a Dark IV measurement scanbased on the best fit straight line for the points between Rshunt V-Lo and Rshunt V-Hi in the Recipe

Cell Temp start (°C): device Temperature at the start of the measurement scan

Cell Temp end (°C): device Temperature at the end of the measurement scan

Exposure (sec): duration of the shutter opening during a measurement scan

Time (24h:mm:ss): time stamp taken at the beginning of the measurement scan

Date (mm/dd/yyyy): date stamp taken at the beginning of the measurement scan

The 'EXPORT TABLE' button below the table provides a means to merge and export all the data shown in the table (up to 15 scans) to a Tab delimited ASCII text file. The data can then be inserted into a spreadsheet for further analysis, if desired.   The default folder is C:\PVIV\RESULTS, though you may want to create a subfolder for these merged results to avoid confusion.   Note that the raw data must be saved independently, if desired, and it is recommended to do so with a similar filename to keep archived data organized.

'IV Graph' (shown below) provides graphs of all the measurement scans that are in the 'Select Measurement' window to the left. The selected measurement scan is highlighted in blue in the 'Select Measurement' window, and colored red in the graph.
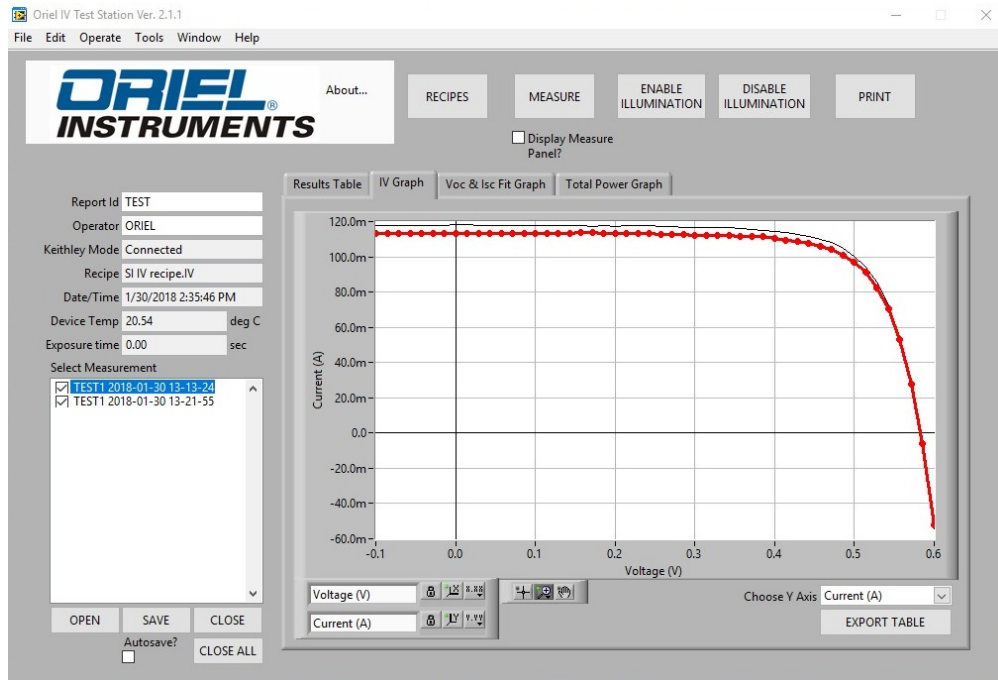
Below the graph is the X-axis and Y-axis unit display and other graphical controls. When the 'Padlock' (autoscale lock) is locked, the corresponding axis will auto-scale to fit the data whenever the chart is updated. This is indicated by the closed 'Padlock' icon, and also a green dot in the adjacent X-axis or Y-axis icon. When the 'Padlock' is unlocked, the axis scaling will not change when new data is displayed. Autoscaling enabled is one of the default settings. When autoscaling is disabled, the operator may change the endpoints of the axes either with the zoom

functions, or manually by highlighting the value with a left click-mouse drag, and typing in the new value. The 'X.XX' and 'Y.YY' buttons provide adjustment to the scaling of the axes, including number format and number of decimal points displayed.
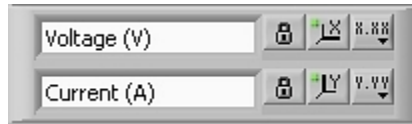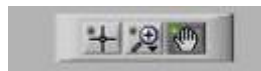
Graph controls are below the graph, near the center. They are used to enable moving the cursor, as well as zooming or panning the display. Each button displays a green dot when it is enabled.

CURSOR : Moves the cursor on the graph, displaying individual data point values.
ZOOM: Zooms in and out of the graph.
PANNING: Picks up the graph and moves it around on the display.

The ZOOM button has the following options, clockwise from the top left:
ZOOM TO RECTANGLE: With this option, left-click a point on the display you want to be the corner of the zoom area and drag the mouse until the rectangle covers the desired zoom area.
X-ZOOM: Use this option to zoom in on an area of the graph along the x-axis.
Y-ZOOM: Use this option to zoom in on an area of the graph along the y-axis.
ZOOM IN ABOUT POINT: With this option, click a point you want to zoom in on.
Press and hold the <Shift> key to switch between ZOOM IN ABOUT POINT and ZOOM OUT ABOUT POINT.
ZOOM OUT ABOUT POINT: With this option, click a point you want to zoom out from
ZOOM TO FIT: Use this option to autoscale the X- and Y-scales on the graph.
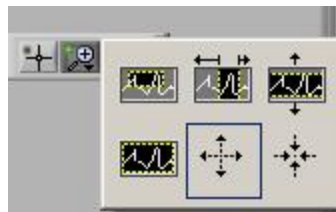
The 'Choose Y Axis' selector box is below the graph and to the right. It can display Current (A), Power (W), or Resistance (Ohms) in the Y-axis, vs. Voltage (V) in the X-axis.

The EXPORT TABLE button below the table provides a means to merge and export all the data shown in the table to a Tab delimited ASCII text file. The data can then be inserted into a spreadsheet for further analysis, if desired. The default folder is C:\PVIV\RESULTS, though you may want to create a subfolder for these merged results to avoid confusion. Note that the Results Table data must be saved independently, if desired, and it is recommended to do so with a similar filename to keep archived data organized.

'Voc & Isc Fit Graph' (shown below) provides graphs of the currently selected measurement scan, along with the best fit lines used to derive Voc, Isc, R@Voc, and R@Isc in the Results Table.
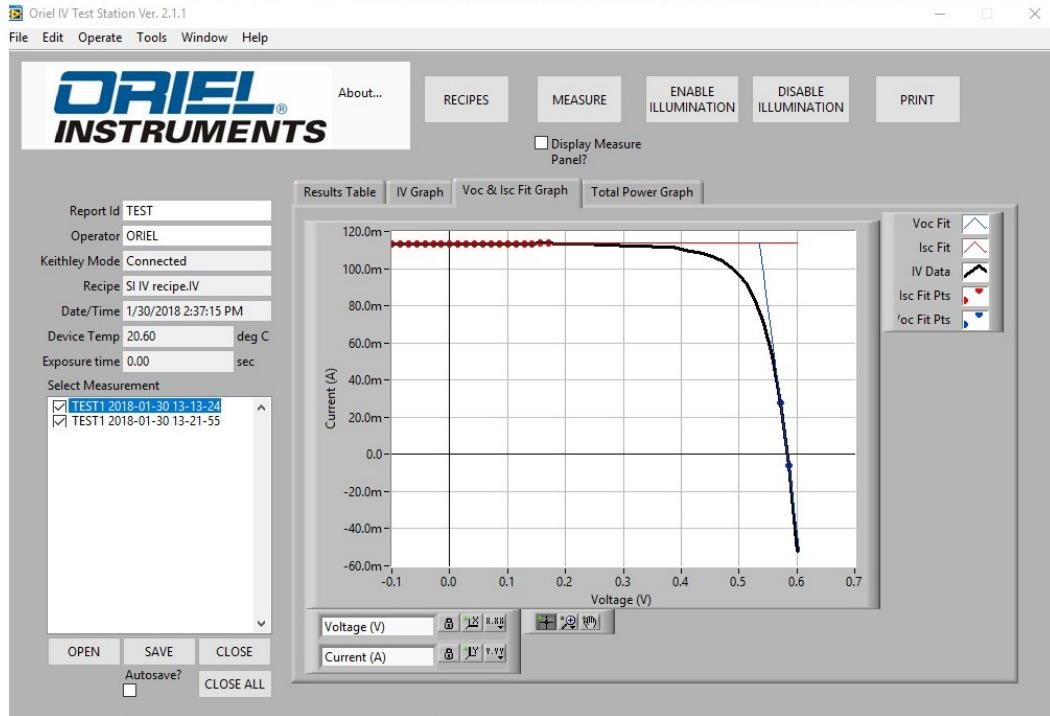
Additional plotting controls are located to the right of the graph.

'Total Power Graph' (shown below) provides a graph and the integrated value of the area under the IV curve in the first quadrant. This result is below the graph on the right, and is also displayed in the Results Table Tab in the column marked "Power W".
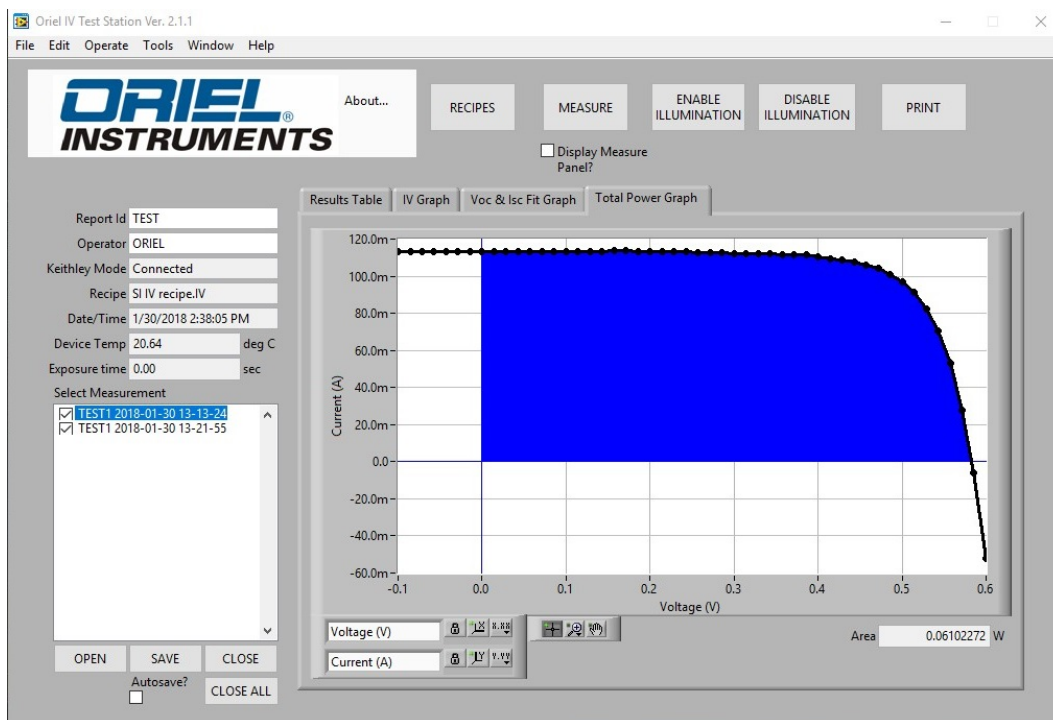
'PVIV Recipe Editor' window (shown below)

<<< Warning >>>
Do not press 'Measure' button until the Voltage settings , Current limit, and other configurations have been properly set up using the 'Recipe Editor'.
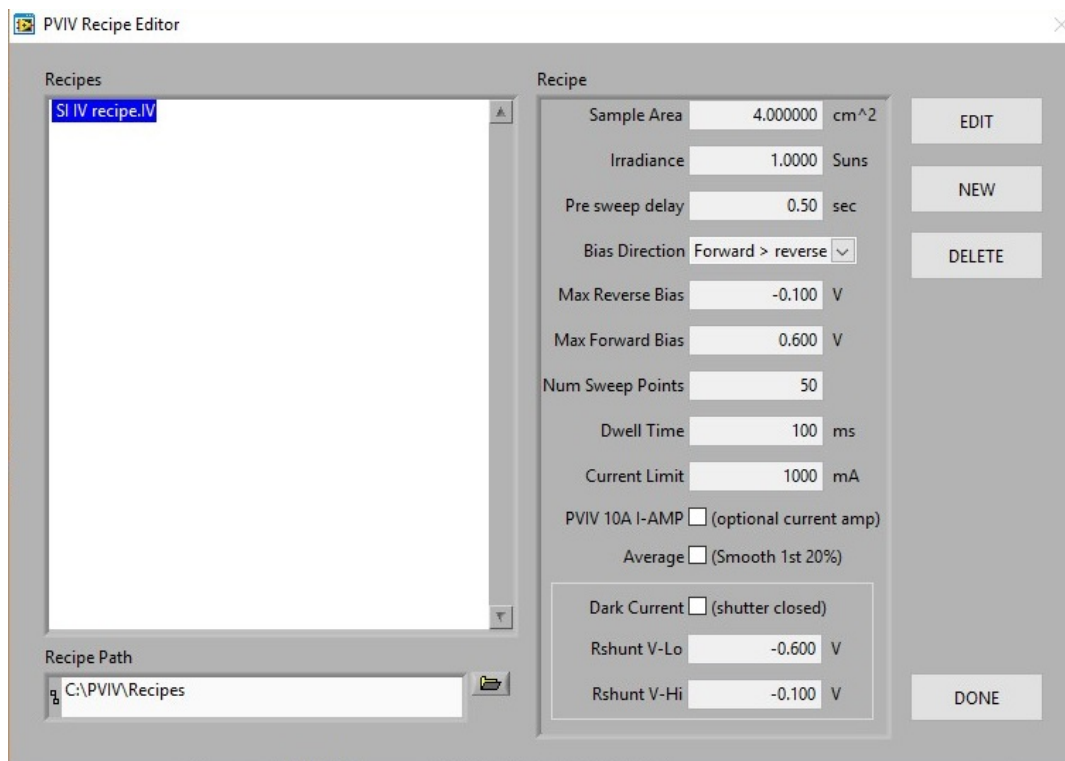
Note that this recipe contains Oriel recommended settings for use with a 91150V Si reference cell.

Pressing the 'RECIPES' button will open the 'PVIV Recipe Editor' window.

'Recipes' on the left lists saved Recipes.

'Recipe Path' shows the filename path for the Recipes shown above.

'Recipe' lists the measurement configuration. The 'EDIT' or 'NEW' button must be pressed to change these values. A Recipe can be deleted by highlighting it in the 'Recipes' window, then pressing 'DELETE'. When edits are complete, the Recipe can be saved with the same name by pressing 'SAVE', or may be renamed by pressing 'SAVE AS'.

The following parameters are provided in a recipe:

Sample Area (cm^2): product of the dimensions of the cell under test in cm^2, entered manually. Acceptance range is from 0.000001 cm^2 to 1000 cm^2.

Irradiance (# suns): The 'number of suns' value taken from the Reference Cell measurement, entered manually.

Pre Sweep Delay (sec): The time between the actual shutter open/LED enable and the start of the test cycle in seconds. This allows a variable amount of "light soakage" and preheating. Note that there is a minimum of approximately 300 msec of delay no matter what the delay setting is.

Bias Direction: Chooses the direction of the Voltage scan. Forward > Reverse is generally preferred, since a device has a higher temperature coefficient near Voc.

Max Reverse Bias (V): Maximum reverse-bias value; when slightly negative, allows for accurate calculation of I_{sc} and *R at* I_{sc}.

Max Forward Bias (V): Defines maximum forward bias voltage of the scan.

Number of Sweep Pts.: The number of data points for the I-V curve measurement. The valid range is from 2 to 1000 data points.

Dwell time (msec): The amount of extra time spent at each voltage step to allow for proper settling. A default value of 30ms is provided. If too short, there may be a drop in the curve during range switching, and is dependent on the cell capacitance.

Current Limit (mA): The maximum current that the system will drive into the cell during a scan. In case the current limit is reached during measurement, the measurement will be clipped. Note that this should be set to approximately 20% above the expected Isc, to limit the energy in the event of mis-wiring or a short.

PVIV 10A I-AMP in use: Selected when using the PVIV 10Amp system apparatus. The software will then be properly set up to have the correct Current Limit scaling, properly scaled Current Axis on the graph, as well as Isc, Jsc, Imax, Pmax, Efficiency, R at Voc, and R at Isc.

Average (Smooth First 20)%: A checkbox for selecting a smoothing filter for the first 20% of the I-V curve near I_{sc}.

Dark Current: A checkbox for selecting when a Dark IV measurement scan is run. This will disable the shutter opening or LED enabling during a scan, and enable the "Rshunt Fit Graph" tab in place of the "Voc & Isc Fit Graph" and "Total Power Graph" Tabs.

Rshunt V-Lo: The lower Voltage endpoint for the data used to calculate Rshunt.

*Rshunt V-Hi*: The upper Voltage endpoint for the data used to calculate Rshunt.

To configure any of these parameters, select the 'EDIT' button on the right side of the window. After all the entry boxes are properly filled, select 'SAVE' or 'SAVE AS' to keep these changes.

Press 'DONE' to select this recipe.

I-V Test Station Software – USE SUMMARY

The following instructions refer to taking an Illuminated IV scan. To take a Dark IV scan,
proceed to step 9.

1. Turn on the instruments including the solar simulator and warm up the system for a minimum of 30 minutes for improved accuracy. Make sure that all the instruments are operating normally. Also make sure that the GPIB communication is active. For assistance on the operation of the Newport Oriel® solar simulator, the Newport Oriel® Reference Cell Meter, the National Instruments GPIB controller and the Keithley SourceMeter®, please refer to their respective manuals or instruction sheets.

2. Start the PVIV software.

3. Place a Newport Oriel® Reference Cell onto the chuck holder, if you are using one. While the Reference Cell is placed under the solar simulator, expose the cell to the output of the Oriel® solar simulator manually by clicking the 'ENABLE ILLUMINATION' button. Measure and record the temperature and the solar simulator irradiance from the LCD panel of the Reference Cell Meter. Block the light from the solar simulator manually by clicking the 'DISABLE ILLUMINATION' button. For operation at Standard Measurement Conditions, the solar simulator power should be adjusted to attain as close to 1.000 SUN. Consult the Reference Cell Meter System manual for additional notes on its operation.

4. Place the Photovoltaic Cell to be tested onto the vacuum chuck. Turn on the vacuum, making sure the vacuum line is connected to the preferred port according to its size, as shown in the vacuum chuck manuals. This can help enable the temperature sensing thermistor to maintain contact with the center of the Photovoltaic Cell to be tested. If wires are not attached, engage the test probes or Busbar probing as required.

5. Press the 'RECIPES' button to enter the measurement scan parameters. It is recommended to start with a low current limit, a maximum Voltage just above Voc, and a low number of scan points in case of mis-wiring.

6. Press the 'MEASURE' button. The 'Exposure Time' will start after the shutter opens, and the SMU will beep. You may watch the SMU display to monitor the scan progress.

7. Make sure that the current sourcing loop does not become unstable and cause the SMU to oscillate. This would be evident from an unusual dip in the curve as it transitions toward its flat high current portion. The Keithley meter will also flash "Cmpl" on its display when this happens, even though the measured current may be in compliance. Remedies include: Reducing the loop inductance by twisting together the wire pair connected to the Input/Output terminals or adding resistance in series with the Input/Output current sourcing loop. The appropriate series resistance can be calculated with the equation: $R_{series} = 0.5V / I_{sc}$. Be mindful not to exceed the power rating of the Resistor used.

8. After the Voltage sweep is complete, the result will be displayed in the 'IV Graph' Tab, and results in the 'Results Table'. Examine the results to see if the recipe needs adjustment.

9. To take a Dark IV scan, the solar simulator does not need to be turned on. Select the *Dark Current* checkbox in the 'PVIV Recipe Editor', and enter the negative Voltage endpoints to be used for a best fit straight line, from which Rshunt is derived (equal to the inverse slope). Cover the Photovoltaic Cell to be tested such that no light whatsoever is allowed to illuminate it. Press the 'MEASURE' button to take the measurement.
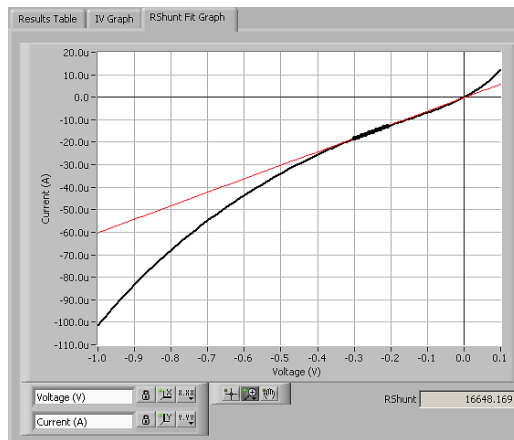
Example of RShunt calculation from a dark current scan

8. TROUBLESHOOTING

PROBLEM	POSSIBLE CAUSE	ACTION
"FAULT" LED turns on during test and/or "Cmpl" is flashing on the Keithley® and/or glitch is occurring in the IV curve	Oscillation is occurring in the current sourcing loop due to too much phase shift	Reduce INPUT and OUTPUT inductance by reducing cable lengths, twisting wire pairs, or paralleling cables
		Increase INPUT resistance by inserting 1 Ohm resistance Box (90026597) or other suitable resistance in series between Keithley® "INPUT/OUTPUT" and "CURRENT INPUT" of Current Amp
	Incorrect or missing connections	Inspect for proper wiring according to diagram in Figure3, or excessive contact resistance at Solar Cell
Shutter does not operate during test	Shutter circuit open	Check the 9-pin DSUB cable connection from the rear panel of the Keithley® "OUTPUT ENABLE"
		On the lamp-based simulator housing, check the BNC cable connection from "SHUTTER REMOTE"
		On the Verasol-2 simulator, check the USB cable connection from the LSS-7120 controller to the computer
		On the LSH-7320 simulator, check the BNC cable connection

9. WARRANTY & SERVICE

CONTACTING ORIEL® INSTRUMENTS

Oriel® Instruments belongs to Newport Corporation's family of brands. Thanks to a steadfast commitment to quality, innovation, hard work and customer care, Newport is trusted the world over as the complete source for all photonics and laser technology and equipment.

Founded in 1969, Newport is a pioneering single-source solutions provider of laser and photonics components to the leaders in scientific research, life and health sciences, photovoltaics, microelectronics, industrial manufacturing and homeland security markets.

Newport Corporation proudly serves customers across Canada, Europe, Asia and the United States through 9 international subsidiaries and 24 sales offices worldwide. Every year, the Newport Resource catalog is hailed as the premier sourcebook for those in need of advanced technology products and services. It is available by mail request or through Newport's website. The website is where one will find product updates, interactive demonstrations, specification charts and more.

To obtain information regarding sales, technical support or factory service, United States and Canadian customers should contact Oriel® Instruments directly.

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Customers outside of the United States must contact their regional representative for all sales, technical support and service inquiries. A list of worldwide representatives can be found on Oriel's website: http://www.newport.com/oriel.

REQUEST FOR ASSISTANCE / SERVICE

Please have the following information available when requesting assistance or service:

Contact information for the owner of the product.
Instrument model number (located on the product label).
Product serial number and date of manufacture (located on the product label).
Description of the problem.

To help Oriel's Technical Support Representatives diagnose the problem, please note the following:
Is the system used for manufacturing or research and development?
What was the state of the system right before the problem?
Had this problem occurred before? If so, when and how frequently?
Can the system continue to operate with this problem, or is it non-operational?
Were there any differences in the application or environment before the problem occurred?

REPAIR SERVICE

This section contains information regarding factory service for this product. The user should not attempt any maintenance or service of the system beyond the procedures outlined in this manual. This product contains no user serviceable parts other than what is noted in this manual. Any problem that cannot be resolved should be referred to Oriel® Instruments.

If the instrument needs to be returned for service, a Return Merchandise Authorization (RMA) number must be obtained prior to shipment to Oriel® Instruments. This RMA number must appear on both the shipping container and the package documents.

Return the product to Oriel® Instruments, freight pre-paid, clearly marked with the RMA number and it will either be repaired or replaced at Oriel®'s discretion.

Oriel® is not responsible for damage occurring in transit. The Owner of the product bears all risk of loss or damage to the returned Products until delivery at Oriel®'s facility. Oriel® is not responsible for product damage once it has left the facility after repair or replacement has been completed.

Oriel® is not obligated to accept products returned without an RMA number. Any return shipment received by Oriel® without an RMA number may be reshipped by Newport, freight collect, to the Owner of the product.

NON-WARRANTY REPAIR

For Products returned for repair that are not covered under warranty, Newport's standard repair charges shall be applicable in addition to all shipping expenses. Unless otherwise stated in Newport's repair quote, any such out-of-warranty repairs are warranted for ninety (90) days from date of shipment of the repaired Product.

Oriel® will charge an evaluation fee to examine the product and determine the most appropriate course of action. Payment information must be obtained prior to having an RMA number assigned. Customers may use a valid credit card, and those who have an existing account with Newport Corporation may use a purchase order.

When the evaluation had been completed, the owner of the product will be contacted and notified of the final cost to repair or replace the item. If the decision is made to not proceed with the repair, only the evaluation fee will be billed. If authorization to perform the repair or provide a replacement is obtained, the evaluation fee will be applied to the final cost. A revised purchase order must be submitted for the final cost. If paying by credit card, written authorization must be provided that will allow the full repair cost to be charged to the card.

WARRANTY REPAIR

If there are any defects in material or workmanship or a failure to meet specifications, notify Oriel® Instruments promptly, prior to the expiration of the warranty.

Except as otherwise expressly stated in Oriel®'s quote or in the current operating manual or other written guarantee for any of the Products, Oriel® warrants that, for the period of time set forth below with respect to each Product or component type (the "Warranty Period"), the Products sold hereunder will be free from defects in material and workmanship, and will conform to the applicable specifications, under normal use and service when correctly installed and maintained. Oriel® shall repair or replace, at Oriel®'s sole option, any defective or nonconforming Product or part thereof which is returned at Buyer's expense to Oriel® facility, provided, that Buyer notifies Oriel® in writing promptly after discovery of the defect or nonconformity and within the Warranty

Period. Products may only be returned by Buyer when accompanied by a return material authorization number ("RMA number") issued by Oriel®, with freight prepaid by Buyer. Oriel® shall not be responsible for any damage occurring in transit or obligated to accept Products returned for warranty repair without an RMA number. Buyer bears all risk of loss or damage to the Products until delivery at Oriel®'s facility. Oriel® shall pay for shipment back to Buyer for Products repaired under warranty.

WARRANTY PERIOD
All Products (except consumables such as lamps, filters, etc) described here are warranted for a period of twelve (12) months from the date of shipment or 3000 hours of operation, whichever comes first.

Lamps, gratings, optical filters and other consumables / spare parts (whether sold as separate Products or constituting components of other Products) are warranted for a period of ninety (90) days from the date of shipment.

WARRANTY EXCLUSIONS
The above warranty does not apply to Products which are (a) repaired, modified or altered by any party other than Oriel®; (b) used in conjunction with equipment not provided or authorized by Oriel®; (c) subjected to unusual physical, thermal, or electrical stress, improper installation, misuse, abuse, accident or negligence in use, storage, transportation or handling, alteration, or tampering, or (d) considered a consumable item or an item requiring repair or replacement due to normal wear and tear.

DISCLAIMER OF WARRANTIES; EXCLUSIVE REMEDY
THE FOREGOING WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES. EXCEPT AS EXPRESSLY PROVIDED HEREIN, ORIEL® MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, EITHER IN FACT OR BY OPERATION OF LAW, STATUTORY OR OTHERWISE, REGARDING THE PRODUCTS, SOFTWARE OR SERVICES. NEWPORT EXPRESSLY DISCLAIMS ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE FOR THE PRODUCTS, SOFTWARE OR SERVICES. THE OBLIGATIONS OF ORIEL® SET FORTH IN THIS SECTION SHALL BE ORIEL'S SOLE LIABILITY, AND BUYER'S SOLE REMEDY, FOR BREACH OF THE FOREGOING WARRANTY. Representations and warranties made by any person including distributors, dealers and representatives of Oriel® / Newport Corporation which are inconsistent or in conflict with the terms of this warranty shall not be binding on Oriel® unless reduced to writing and approved by an expressly an authorized officer of Newport.

LOANER / DEMO MATERIAL

Persons receiving goods for demonstrations or temporary use or in any manner in which title is not transferred from Newport shall assume full responsibility for any and all damage while in their care, custody and control. If damage occurs, unrelated to the proper and warranted use and performance of the goods, recipient of the goods accepts full responsibility for restoring the goods to their original condition upon delivery, and for assuming all costs and charges.