The RO3 is an advanced I-V curve tracer and a dynamic load tracker capable of maximum power-point tracking operation for Thermoelectric Generators and PV panels from milliWatts up to 250W (in I-V trace mode)

**Features**

- Instantaneous Electrical Performance Analyser displaying the power & voltage vs current curves
- Dynamic Load Tracking (MPPT) to evaluate ‘in-system’ TEG/PV performance
- Constant current or constant voltage load modes
- No other loads required. Powered by mains
- Touch screen and/or PC software control interface
- Four automatically-selected ranges of voltage and current to suit different TEG characteristics
- Optional expansion boards to measure temperatures or other values.

**Quick Description**

The RO3 I-V Tracer and at-load Tester device is an independent electronic load specifically designed for TEG(s) and solar PV cell(s). It is a flexible solution to test TEGs and PV cells and to operate them at load. The RO3 can instantaneously inspect the electrical performance of the device connected to its input terminals or continuously operate it at-load. The power obtained by the TEG/PV is dissipated internally to the RO3; hence this is a test solution that allows evaluating the performance of TEG/PV when operating in the user’s system. No other load or battery store is required. The RO3 can also emulate a MPPT converter thus allowing you to test your TEG system at load to verify overall thermal and electrical performance. It can also be used as a constant current or constant voltage electronic load.

The RO3 device is rated for 150W continuous power dissipation and 250W during I-V trace measurements. The RO3 is designed to encompass a wide voltage (from 0V to 65V) and current (from
RO3-series: I-V curve tracer and dynamic electrical load

0A to 25A) range while obtaining high levels of precision thanks to auto-selected measurement channels. The resolution of voltage and current measurement/adjustment depends on actual voltage/current channels enabled (see the Specifications Table). A 4-wire voltage sensing method is used to remove the influence of voltage drops on power cables.

The RO3 features a sleek touchscreen interface giving you complete control to generate an IV trace, operate as a DC load, or emulate the operation of a MPPT converter. A software program is also provided to control the operation of the RO3 from a Windows PC and to save measured data. The USB cable provided with the RO3 can be used to connect to the PC. The RO3 is provided in a metal enclosure and powered by mains electricity. The front panel hosts the colour touchscreen display and all connections are located at the rear.

The RO3 does not come with thermal-mechanical parts; check TEconversion.com for thermoelectric devices and the variety of mechanical assemblies to clamp thermoelectric devices that Thermoelectric Conversion Systems Ltd offer.

**Modes of Operation**

*** DO NOT BLOCK THE REAR VENTS. THIS WILL CAUSE OVERHEATING ***

** THE AMBIENT OPERATING TEMPERATURE SHOULD NOT EXCEED 35°C **

1. **Dynamic tracking at-load:**
   a. **Fractional Open-Circuit:** the RO3 device operates continuously at a fixed percentage (selected by the user) of the instantaneous open-circuit voltage (Voc). The Voc and the short-circuit current (Isc) are measured (in 5 msec) every second and the load is dynamically adjusted to the selected percentage of Voc, which can be modified live. Selecting 50% of Voc, the RO3 works at the Maximum Power Point (MPP) of the “common” constant-temperature power curve. The device continuously operates at-load without the need for any electrical load or storage device.
   b. **Perturb and Observe (P&O):** the RO3 device emulates the operation of a MPPT converter controlled by the P&O algorithm. The RO3 continuously modifies the operating point to obtain the MPP.

2. **I-V curve scanning:** when triggered the RO3 device obtains a range of IV points (selected by the user from 5 to 65 points) on the actual electrical characteristic of the TEG(s) or solar cell(s) connected to the input (at the current temperature difference or irradiance level). The scan is performed in approximately 2 msec per point and the settling time can be adjusted by the user. In thermoelectric applications a scan lasting less than 50 msec leaves the thermal operating point unaffected.

3. **Electronic load:** the user selects a constant current or constant voltage operating point. The open-circuit voltage and the short-circuit current are measured (in 5 msec) every one second and all relevant electrical data are provided.
Specifications Table

$T_a = 23 \, ^\circ C$; specifications subject to change without notice.

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<tr>
<th>Specification</th>
<th>Value</th>
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<td>Max Power Dissipation in I-V Trace</td>
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<td>Input Voltage Range</td>
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<td>Voltage Reading Accuracy</td>
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**Electronic Load Function:**

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<td>Resolution of Current Setting</td>
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</table>

Diagram of Connections

Connect the TEG/PV source to “+” and “−” (respectively, positive and negative power connections) with suitable sized cables (26-14 AWG) depending on the expected current output from the TEG/PV source. Each screw terminal is rated at 14A, hence both positive and both negative screw terminals should be used when the expected maximum electrical current exceeds 14A.

Connect “s+” and “s−” (sense terminals, 36-16 AWG) to the terminals of the device to compensate for voltage drops across the power cables (remote sensing), or connect “s+” to “+” and “s−” to “−” (local sensing). The sense connections must be used to ensure correct operation of the RO3 device.
Description of Operation from Touch-screen Display

In this guide, the numbering of buttons goes from top-left to bottom-right. 1, 2, 3 and 4 are on the left side; 5, 6 and 7 are on the right side.

0. Home page: This screen appears after the splash screen. The following functions are selected touching the corresponding button:
   1. I-V Trace to obtain the Power vs Current and Voltage vs Current curves and select related options.
   2. Constant Voltage (CV) and Constant Current (CC) electronic load modes
   3. Dynamic Tracking for Fractional Open Circuit (FOC) and Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) modes

1. 0. A) If the RO3 device has not obtained any I-V characteristic since its start, the new screen updates the open-circuit voltage (Voc) reading and provides three choices:
   1. Perform a new I-V scan
   4. Go to the Settings page for the I-V mode
   7. Go back to the Home page (0.)

1. 0. B) If the RO3 device has already obtained at least one I-V characteristic since its start, Voc is updated on the screen and three choices are provided:
   1. Perform a new I-V scan
   2. View the last I-P and I-V curves
   3. View the last R-P curve
   4. Go to the Settings page for the I-V mode
   7. Go back to the Home page (0.)

1.1. After a short delay necessary for the analogue measurements and the digital update of points on the screen, the newly obtained Voltage vs Current (I-V) and Power vs Current (I-P) curves are plotted.
   The buttons on the bottom right allow to:
   5. Go Back to (1.0.B.)
   6. View the corresponding R-P curve
   7. Go back to the Home page (0.)

1.2. Same as 1.1. but the measurements are not updated.

Same screen as 1.1.
1.3. After a short delay necessary to update the points on the screen, the Power vs Resistance (R-P) curve is plotted. The buttons on the bottom right allow to:

5. Go Back to (1.0.8.)
6. View the corresponding I-V characteristic (1.2.)
7. Go back to the Home page (0.)

1.4. The available settings are:

1. Adjust the settling time for each I-V point. This delay is added to the time required by the RO3 device to set the new point, which is approximately 2 msec.
2. Select if a TEG or a PV panel is connected to the RO3 device. This influences how the I-V characteristic scan is performed.
3. Go back to the (1.0.)

1.4.1. Enter the number of msec of additional delay. Click on Enter to confirm and go back to (1.4.) or Cancel to go back to (1.4.) and discard any change.

1.4.2. Select if a thermoelectric generator (TEG) or a solar PV panel (PV) is connected to the RO3 device. After the selection the screen goes back to (1.4.). Clicking on Settings goes back to (1.4.).

1.4.3. Select the number of I-V points to measure on the electrical characteristic. After the selection the screen goes back to (1.4.). Clicking on Settings goes back to (1.4.).
2.0. The Electronic Load home page continuously updates the Voc reading and lets the user select between:

2. Constant Voltage mode (CV)
3. Constant Current mode (CC)
7. Go back to the Home page (0.)

2.2.1. Voc is continuously updated while the user can select the value in volts (V) to operate at.

- If the load is OFF: Click on Enter to confirm and go to (2.2.2) or Cancel to go back to (2.0.) and discard any change.
- If the load is ON: Click on Enter to confirm the new value or Cancel to discard it. Both options bring back to (2.2.3.)

2.2.2. Electronic Load in CV mode OFF: the RO3 device continuously updates the Voc reading and allows to:

1. Set a different value (go back to 2.2.1.)
4. Turn the load ON and go to (2.2.3.)
7. Stop and go back to (2.0.)

2.2.3. Electronic Load in CV mode ON: the RO3 device updates the measured readings every second. Voc and the short-circuit current Isc are measured in 5 msec every second. Vmp is the actual load voltage, Imp the load current and Pmp the power generated from the source.

1. Set a different value (go back to 2.2.1.). The load remains ON and, when selecting a new value, this is instantaneously updated.
4. Turn the load OFF and go to (2.2.2.)
7. Stop and go back to (2.0.)

2.3.1. Voc is continuously updated while the user can select the value in amperes (A) to operate at.

- If the load is OFF: Click on Enter to confirm and go to (2.3.2) or Cancel to go back to (2.0.) and discard any change.
- If the load is ON: Click on Enter to confirm the new value or Cancel to discard it. Both options bring back to (2.3.3.)
2.3.2 Electronic Load in CC mode OFF: the RO3 device continuously updates the Voc reading and allows to:

1. Set a different value (go back to 2.3.1.)
4. Turn the load ON and go to (2.3.3.)
7. Stop and go back to (2.0.)

2.3.3. Electronic Load in CC mode ON: the RO3 device updates measured readings every second. Voc and Isc are measured in 5 msec every second. Vmp is the actual load voltage, Imp the load current and Pmp the power generated from the source.

1. Set a different value (go back to 2.3.1). The load remains ON and, when selecting a new value, this is instantaneously updated.
4. Turn the load OFF and go to (2.3.2.)
7. Stop and go back to (2.0.)

3.0. The MPPT dynamic tracking home page continuously updates the Voc reading and lets the user select between:

1. Select the set-point for the fractional Voc (FOC) method. By default it is set to 50%. The screen goes to (3.1.)
3. Turn the FOC MPPT load ON (3.3.)
4. Turn the P&O MPPT load ON (3.4.)
7. Go back to the Home page (0.)

3.1. Voc is continuously updated while the user can select the percentage (5) of Voc to operate at.

- If the FOC load is OFF: Click on Enter to confirm the new value or Cancel to discard it. Both options go back to (3.0.)
- If the FOC load is ON: Click on Enter to confirm the new value or Cancel to discard it. Both options bring back to (3.3.)

3.3. The RO3 device operates in FOC MPPT mode and it updates the measured readings every second. Voc and Isc are measured in 5 msec every second. Vmp is the actual load voltage, Imp the load current and Pmp the power generated from the source.

The user can select between:

1. Select the set-point for the fractional Voc (FOC) method. By default it is set to 50%. The screen goes to 3.1.
3. Turn the FOC MPPT load OFF (3.0.)
4. Turn the P&O MPPT load ON (3.4.)
7. Go back to the Home page (0.)
3.4. The RO3 device operates in P&O MPPT mode and it updates the measured readings every second. Voc and Isc are measured in 5 msec every second. Vmp is the actual load voltage, Imp the load current and Pmp the power generated from the source. The user can select between:

1. Select the set-point for the fractional Voc (FOC) method. The screen goes to 3.1.
2. Turn the FOC MPPT load ON (3.3.)
3. Turn the P&O MPPT load OFF (3.0.)
4. Go back to the Home page (0.)

**Description of Operation from the PC**

**When connecting for the first time to a Windows 10 PC:**

1. Connect the USB cable from the RO3 device to one of the available USB ports on the PC.
2. Turn the RO3 device on and Windows should automatically detect a new hardware and proceed to the automatic installation of the necessary driver.
3. Windows assigns a COM port number to the RO3. This can be seen under Device Manager; to access it either:
   a. type “Device Manager” in the Windows Search Bar, or
   b. right-click on “This PC”, select “Manage” and double-click on “Device Manager” on the left menu bar.
4. Expand the “Ports (COM & LPT)” section where the RO3 is listed as “RO3” or “USB Serial Device”.

**When connecting for the first time to a Windows 7 (or earlier) PC:**

1. Connect the USB cable from the RO3 device to one of the available USB ports on the PC.
2. Turn the RO3 device on. Windows should automatically detect a new hardware and try to automatically install the necessary driver. Wait for it to finish or “Close”.
3. Open Device Manager: right-click on “Computer”, select “Manage” and double-click on “Device Manager” on the left menu bar.
4. The “RO3” device should appear under “Other Devices”.

5. Right-click on “RO3” and select “Update Driver Software”, next choose “Browse my computer for driver software”.

6. If not already done, extract the .zip file with the TCS RO3 driver.

7. In the next screen click on “Browse” and select the location of the folder to which the driver was unzipped to, then click “Next”.

8. A Windows Security window might appear. Choose “Install this driver software anyway” and the driver will be installed.
Using the PC Software:

1. Double-click on the TCS RO3 .exe software.

2. Click on “Re-scan Ports”
3. Select the COM port discovered in 4.
4. Click on the “Connect” button
5. The default window is the I-V Tracer and the following image shows the location of data, options and commands.
6. After selecting the required options, click on “Capture new IV Trace”. The RO3 device performs an I-V scan and measurement data is populated to the software window and to the RO3 screen.
7. Clicking on the top left tab “DC Load” loads the DC load page.

8. On the top-right select the measurement data to display and select the load operating mode between constant voltage, constant current, fractional Voc and P&O. Click “On” to activate the load and “Off” to turn-off. “Pause Logging” stops updating values on the PC window but the load continues to operate and to display data on its screen.

9. In both software windows clicking on “Export Data” prompts the user to save a .csv file that can be opened in Excel for post-analysis, e.g.:

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<th>Variables</th>
<th>Load Type</th>
</tr>
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<tbody>
<tr>
<td>Load Type</td>
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</table>
What is included in the box

- RO3 device
- Mains power cable (EU or UK)
- USB cable
- Stylus pen for touch-screen display

Thermoelectric Conversion Systems Limited (TCS) does not assume any responsibility for use of any circuit described, no circuit patent licenses are implied and TCS reserves the right at any time without notice to change said circuitry and specifications.

This TCS product is not authorised for use as critical component in life support devices.

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