

DS-100C I-V CURVE TRACER User Manual



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WARNINGS

THE IMPROPER USE OF THIS INSTRUMENT CAN PRESENT AN ELECTRICAL SHOCK HAZARD THAT CAN CAUSE DEATH OR SERIOUS INJURY.

THIS INSTRUMENT SHOULD ONLY BE USED AS DESCRIBED IN THIS OPERATIONS MANUAL.



WARNING THIS INSTRUMENT MAY PRESENT AN ELECTRICAL SHOCK HAZARD WHICH CAN RESULT IN DEATH OR SERIOUS INJURY IF THE FOLLOWING PRECAUTIONS ARE NOT FOLLOWED:

- THIS INSTRUMENT MUST ONLY BE USED FOR TAKING ELECTRICAL CURRENT AND VOLTAGE (I-V) CURVES OF PHOTOVOLTAIC (PV) SOLAR MODULES.
- THIS INSTRUMENT MUST NOT BE USED BEYOND ITS OPERATING RANGE.
- THIS INSTRUMENT MUST NOT BE USED BY PERSONNEL WHO DO NOT HAVE EXPERIENCE HANDLING HIGH VOLTAGE DC AND PHOTOVOLTAIC MODULES.
- THIS INSTRUMENT MUST NOT BE USED DURING RAIN, SNOW, SLEET, OR IN ANY AREA OF HIGH MOISTURE SUCH AS AREAS WITH STANDING WATER OR MUD.
- THIS INSTRUMENT MUST NOT BE USED IF IT IS NOT FUNCTIONING AS DESCRIBED IN THIS USER MANUAL .

NOMENCLATURE

A	Amperes or Amp
Hz	Hertz
I	Current
I_{pk}	Current at peak power
I_{sc}	Short-Circuit Current: The maximum current a photovoltaic cell can generate with the output terminals shorted
I-V	Current-Voltage
PV	Photovoltaic
V	Voltage
V_{HIGH}	High voltage range < 600 Volts
V_{LOW}	Low voltage range < 150 Volts
V_{oc}	Open-Circuit Voltage: The maximum voltage a photovoltaic cell can generate with the output terminals open circuited
V_{pk}	Voltage at peak power

1.0 Installation & Taking IV Curves

Basic Description

The standard DS-100C Tracer has two user selectable current ranges (10 and 100 Amperes), three automatically selected voltage ranges (600 V, 60 V, and 6 Volts), two irradiance and two temperature measurement inputs. Unless otherwise noted, this manual refers to standard DS-100C models.

Note: The three measurement voltage ranges listed here should not be confused with the load ranges (V_{HIGH} and V_{LOW}) selected with the range switch.

A computer running the IVPC for Windows program controls the DS-Tracer. (See the IVPC Reference Manual). The computer running the IVPC application may be connected to the DS-Tracer by RS-232 serial or USB.

Most DS-Tracer operations are performed with the IVPC program. Refer to the IVPC manual for details on operating the DS100C IV Tracer. However, the basic steps for using the DS-Tracer are:

- Connect the DS-Tracer to the computer (either RS-232 or USB).
- Turn on the tracer power and connect DS-Tracer test leads to PV array.
- Connect pyranometers and thermocouples to DS-Tracer.
- Install and run IVPC for Windows (see the IVPC manual for details).
- From File menu select New I-V Curve.
- Enter curve information and take curve.
- Save curve data.

To proceed with the Installation & Quick-Start, you will need the following:

- DS-Tracer I-V curve tracer and test leads.
 - IVPC CD-ROM.
 - PC computer running the Microsoft Windows® operating system.
-

- Serial or USB cable to connect your computer to the DS-Tracer.

IVPC Installation

IVPC is written for use with Windows® 98/2000/XP which must be running to operate IVPC. To install IVPC, insert the IVPC CD-ROM in your computer. Open the IVPC CD-ROM and run the “setup.exe” program by double click with the mouse.

The setup program will prompt you for information on where you want to install IVPC. If you are unsure, use the defaults which create an IVPC sub-directory off of the root directory on drive C:. IVPC Setup automatically installs the necessary files in the IVPC directory and makes additions to your Windows system directory.

Precautions

There are several precautions to observe before using the DS-Tracer and IVPC to take I-V curves.

- The DS-Tracer battery should be fully charged. The DS-100C has a universal power supply that works with AC line voltages from 85 V_{ac} to 264 V_{ac} 50/60 Hz.
- The DS-Tracer DISCONNECT switch should be in the OFF position and the DS-Tracer power should be turned on when making or breaking connections to a PV system or when changing the voltage range switch.
- The DS-Tracer should be connected to the PV array through a PV system disconnect switch capable of interrupting the short-circuit current of the array at peak-power voltage. This ensures that you can disconnect the DS-Tracer if a problem occurs. Refer to the DISCONNECT switch discussion in section 2.0 Panel Layout for details.



NOTE: The DS-Tracer DISCONNECT switch is not rated to interrupt high voltage systems producing more than five amps.

- Do not connect the DS-Tracer to anything other than an open-circuited PV system. Be sure the PV array is electrically isolated from power conditioning equipment such as charge controllers or inverters.

- Do not connect the DS-Tracer to a PV system with an open-circuit voltage greater than 600 Volts.
- Do not connect the DS-Tracer to any PV system with a short-circuit current greater than maximum for your unit (100 Amperes for a standard DS-100C).



The DS-Tracer RS-232 and USB ports, irradiance inputs, temperature inputs, auxiliary analog inputs, and auxiliary charge inputs are all referenced to the same electrical common inside the tracer. Therefore these devices must be either electrically floating or referenced to the same electrical common.

However, all of these connections are electrically isolated from the PV inputs.

Connecting Your Computer to the DS-Tracer

The DS-100C IV Tracer provides two interfaces; an RS-232 and USB port. The RS-232 interface uses a standard female, 9 pin connector as shown in Figure 8. The standard USB connection is labeled “Main USB.” Either of these connections may be used depending on the configuration of the computer running the IVPC program. Though, only one of these ports should be connected at a time.

Note: Special USB drivers must be installed on the computer in order to use the USB port. See the section Appendix C DS-100 USB Drivers for details on installing these drivers.

Connecting a PV Module to the DS-Tracer

The DS-Tracer is connected to the PV array or module with the test leads provided. Before connecting a PV module, be sure the DS-Tracer power switch is ON and the DISCONNECT switch is in the OFF position. Plug the test lead into the DS-Tracer being sure to match the red and black connectors. The Voltage Sense connector is keyed and can only be inserted in one way.



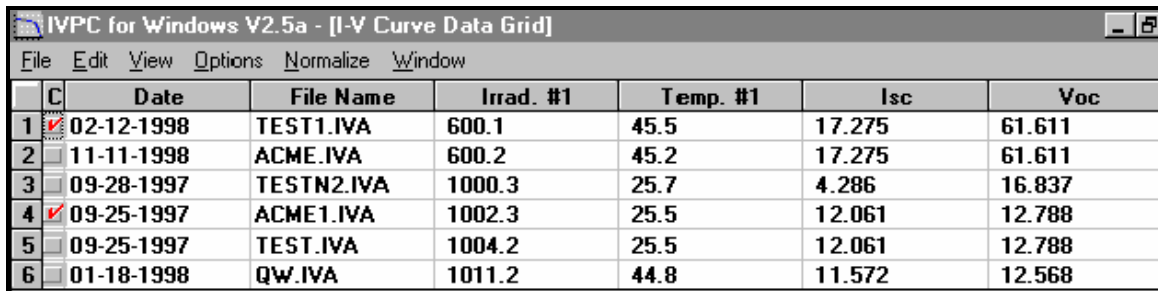
For safety, it is recommended that connections be made to a circuit that can be isolated from the PV array with a system switch rated at full PV power. Refer to section 2.0 Panel Layout for details.

With the DS-Tracer DISCONNECT switch still OFF, attach the test leads to your PV module. By making connections with the PV system disconnect switch off,

the chance of electric shock is avoided. After connecting the test leads, close the PV system switch. At this point, PV voltage should be present at the DS-Tracer. Turn the DS-Tracer DISCONNECT switch to ON. Note: For normal operation, the DS-Tracer DISCONNECT switch should always be the last switch closed and the first switch opened.

Starting IVPC

The following description assumes the use of IVPC 2.X. IVPC opens to the Data Grid window shown in Figure 1. IVPC Data Grid window.. The Data Grid is a spread sheet that lists all of the I-V curve data files stored in the current directory. When starting IVPC for the first time the Data Grid may be empty if no I-V curves have been taken.



C	Date	File Name	Irrad. #1	Temp. #1	Isc	Voc
1	02-12-1998	TEST1.IVA	600.1	45.5	17.275	61.611
2	11-11-1998	ACME.IVA	600.2	45.2	17.275	61.611
3	09-28-1997	TESTN2.IVA	1000.3	25.7	4.286	16.837
4	09-25-1997	ACME1.IVA	1002.3	25.5	12.061	12.788
5	09-25-1997	TEST.IVA	1004.2	25.5	12.061	12.788
6	01-18-1998	QW.IVA	1011.2	44.8	11.572	12.568

Figure 1. IVPC Data Grid window.

The Data Grid can be thought of as a detailed directory of the I-V curves. However, in addition to file names, you can display other curve data such as peak-power or module ID. Refer to the IVPC Reference Manual for directions for changing the data displayed. Use the Data Grid to locate and display I-V curves that were taken previously and stored.

Taking an I-V Curve

Before taking a curve, the DS-Tracer should be turned on and connected to the PV system. Your computer should be connected to the DS-Tracer and running IVPC. From the File menu, shown in Figure 2, select New I-V Curve or press Ctrl-N (control and N keys at the same time).

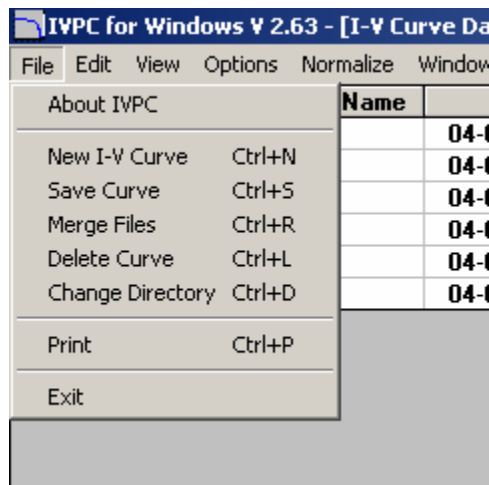


Figure 2. Select New Curve in the File menu to take an I-V curve.



Note: Some figures shown in this manual may be different than your version of IVPC. Please refer to the IVPC manual for the most up-to-date information on using IVPC..

IVPC will open a new curve window as shown in Figure 3. This window provides areas to enter curve information identifying the I-V curve. The DS-Tracer takes up to 12 seconds to initialize the tracer hardware. Typically you will enter curve data during this delay. For example, if not using the Auto feature to read an irradiance or temperature channel, you could enter a value manually at this time. A status message indicating that the DS-Tracer is pre-charging is displayed in the area normally used to plot the curve.

IVPC for Windows V 2.63 - [New Curve 2]

File Edit View Options Normalize Window

Peak Power (W) 0.00 Fill Factor (%) 0.0

Vpk (V) 0.000 Voc (V) 0.000

IpK (A) 0.000 Isc (A) 0.000

Name Test1

Site Daystar

Sub-System String 1

Module N/A

Irrad. #1 (W/m²) 903.0

Irrad. #2 (W/m²) 0.0

Temp. #1 (°C) 46.0

Temp. #2 (°C) 0.0

Misc.

Date 10-18-2002

Time 09:12:49

Pre-Charging DS-Tracer

Firmware Version # VERS 5.21-100C

V HIGH=600 V I HIGH=100 A

V LOW=150 V I LOW=10 A

Take Curve

Comments:

Figure 3. New Curve screen while DS-Tracer is pre-charging.

After initialization, the status message changes and the Take Curve button is enabled as shown in Figure 4. The status message indicates that a curve can be taken by using the mouse to press the Take Curve button or by pressing Alt-T.

The screenshot shows the 'IVPC for Windows V 2.63 - [New Curve 1]' window. The interface includes a menu bar (File, Edit, View, Options, Normalize, Window) and a main area with several input fields and a large central display.

Input Fields:

- Peak Power (W): 0.00
- Fill Factor (%): 0.0
- Vpk (V): 0.000
- Voc (V): 0.000
- Ipk (A): 0.000
- Isc (A): 0.000
- Name: Test1
- Site: Daystar
- Sub-System: String 1
- Module: N/A
- Irrad. #1 (W/m²): 903
- Irrad. #2 (W/m²): 0
- Temp. #1 (°C): 46
- Temp. #2 (°C): 0
- Misc.:
- Date: 10-18-2002
- Time: 09:12:03

Central Display:

Press Take Curve (Alt-T) when ready.

Bottom Section:

- Firmware Version #: VERS 5.21-100C
- V HIGH=600 V
- I HIGH=100 A
- V LOW=150 V
- I LOW=10 A
- ☒ (selected)
- ☐
- Take Curve** button

Comments: Curve Taken by John Doe

Figure 4. DS-Tracer is pre-charged and ready to immediately take the curve.

After pressing Take Curve, the DS-Tracer takes approximately 6 seconds to take the curve and plot the data as shown in Figure 5. You may save this data by selecting Save I-V Curve from the File menu. The curve is stored in the current directory and the Data Grid is updated.

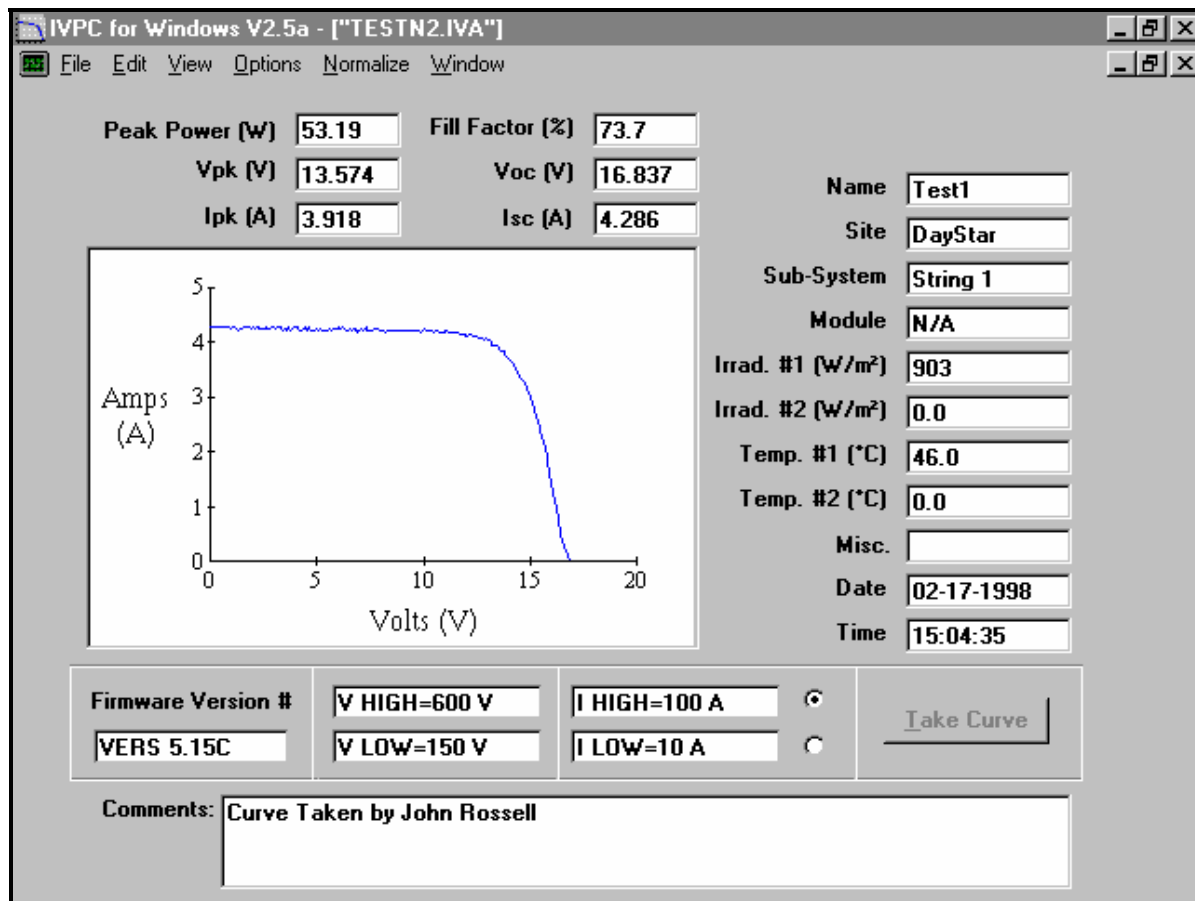


Figure 5. Example of I-V curve.

You can return to the Data Grid without closing the curve window by using the Window menu shown in Figure 6. Closing the I-V curve window will also return you to the Data Grid window.

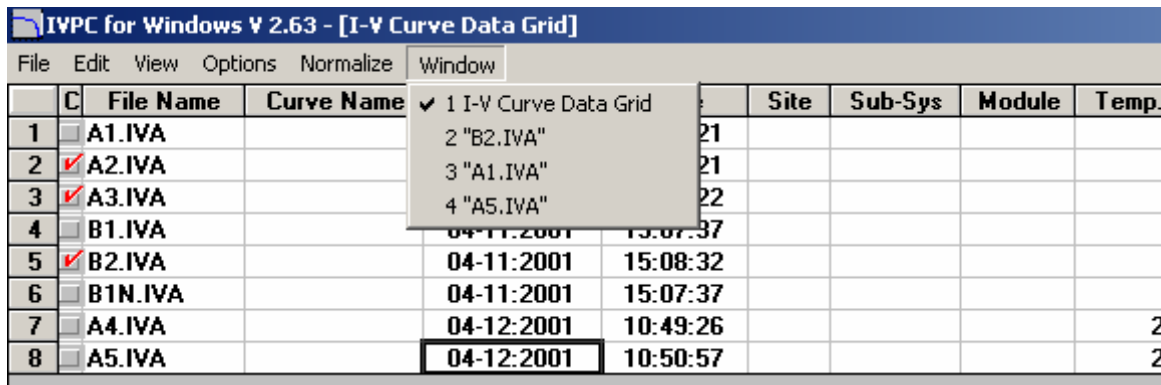


Figure 6. Moving to the Data Grid with the Window menu.

If You Get an Error

There are several error messages you may see when taking a curve. The DS-Tracer automatically turns itself off when it does not receive a command for 15 minutes. This feature helps to protect the DS-Tracer battery. If the DS-Tracer has been on for more than 15 minutes without taking a curve it will power down and you will receive an error indicating that the DS-Tracer does not respond. Simply turn the DS-Tracer switch off, wait several seconds, and turn it back on. Allow the tracer approximately 10 seconds to initialize. Then press Yes to retry as indicated on the error dialog box.

Other errors occur if the PV array voltage is too high or if it is zero or negative. Simply follow the IVPC directions given when the error occurs. Most errors happen as soon as you chose New I-V Curve from the File menu. Most often you can correct the problem and continue without having to restart.

The most common problem results from a communication error. This is usually due to not setting the correct COM port in IVPC. The COM port settings must match the actual COM port on your computer. Note: If the COM port is a "virtual"

COM port, such as those created by USB to serial adapters or by the DS-100C USB drivers used for IVPC version 2.X and older, it is possible that this COM port number has been inadvertently changed.

Use the Windows device manager to confirm the current COM port setting of the virtual COM port. The COM port number set for this virtual port must match the COM port number set in IVPC.

Displaying Saved Curves

Stored I-V curves are selected from the Data Grid. The Data Grid displays the curve files in the current directory. Be sure to set the current working directory to the sub-directory where the curves are stored. Use the Change Directory command in the File menu to select a new directory as shown in Figure 7.

To display a curve shown on the Data Grid, double click anywhere on the row for that curve. A window very similar to the one used to take a curve is displayed. More than one curve window may be open at the same time. Use the Window menu to return to the Data Grid and select another curve. The Window menu is also used to switch between curve windows.

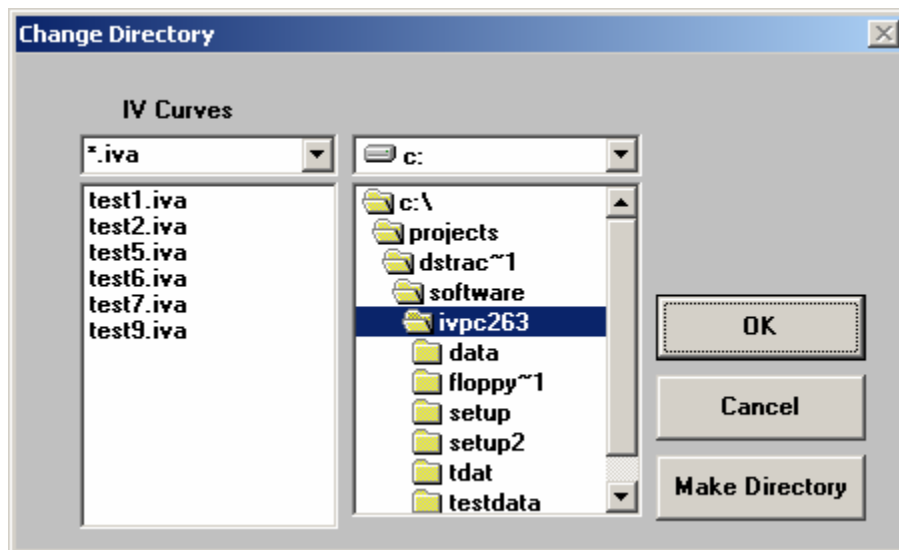


Figure 7. Change Directory dialog box.

Summary of Steps for Taking IV Curves

1. Connect your computer to the DS-Tracer and start IVPC for. Turn the power switch of the DS-Tracer ON.
2. You can connect one or two pyranometers directly to the DS-100C. If pyranometers are connected you must enter correct pyranometer constants in IVPC. Refer to the IVPC manual for details.
3. You may connect one or two thermocouples directly to the DS-100C Refer to the IVPC manual for details.
4. Open the PV array system switch to isolate the PV array under test. NEVER try to take a curve of a PV array connected to a battery or inverter.
5. With the DS-Tracer DISCONNECT switch in the OFF position, connect the PV system to the DS-Tracer front panel using the leads provided. (Red is positive, black is negative.) Plug the red and black leads and the voltage sense plug into the mating connectors on the DS-Tracer; then connect the negative lead to the PV array followed by the positive red lead. Be sure to connect the tracer to the PV system through a system disconnect switch rated for I_{sc} and V_{oc} . Refer to the discussion of the DISCONNECT switch in the section 2.0 Panel Layout.
6. Set the voltage-range switch to the desired setting, V_{LOW} or V_{HIGH} . Leave the voltage-range switch in the V_{HIGH} position unless taking a curve of a high current (> 50 Amperes), low voltage (< 24 Volts) PV array.
7. Turn the DS-Tracer DISCONNECT switch to the ON position. The DS-Tracer is now ready to take I-V curves.
8. From the File menu in IVPC select "New I-V Curve".
9. To take another I-V curve of the same PV system, repeat step 9.

To test another PV subsystem, turn the DS-Tracer DISCONNECT switch to OFF and open the PV system disconnect switch. Remove the cables and repeat steps 5 through 9.

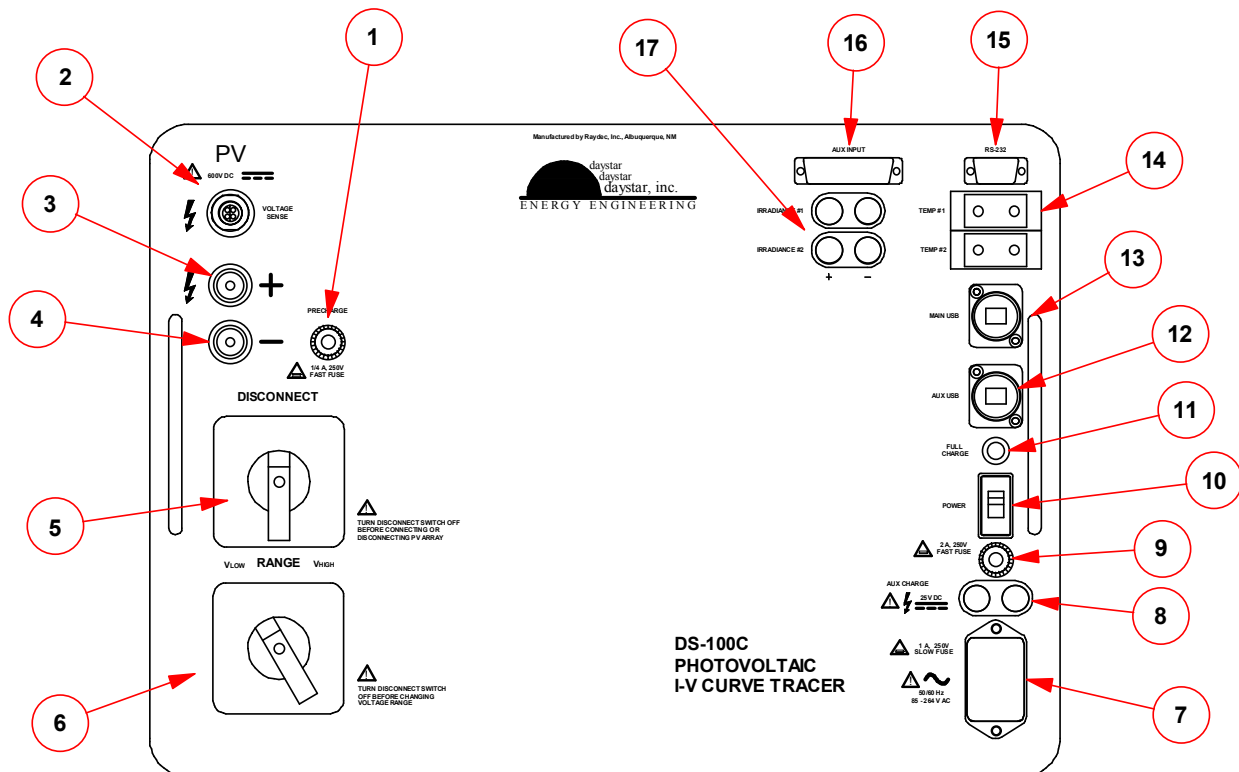


WARNING: Disconnecting cables when the array disconnect switch is ON may result in electrical arcing and may damage the DS-Tracer and/or injure the operator.

10. When finished taking curves, turn the DS-Tracer DISCONNECT switch to the OFF position and open the PV system disconnect switch. Disconnect the DS-Tracer from the PV system. Remove the positive, red lead first followed by the negative lead.
 11. Switch off the power to the DS-Tracer.
-

2.0 Panel Layout

This section describes the DS-100C photovoltaic I-V curve tracer in more detail. The DS-Tracer generates a complete current-voltage (I-V) curve that characterizes the photovoltaic system under test. Figure 8 shows the front panel layout of the DS-100C. Each of the key components is described in detail in the following section.



- | | |
|---------------------------------|----------------------------------|
| 1. Pre-Charge Fuse | 10. On-Off Switch |
| 2. Voltage Sense Connector | 11. Full-Charge Indicator |
| 3. Positive PV System Connector | 12. AUX USB Port |
| 4. Negative PV System Connector | 13. Main USB Port |
| 5. Disconnect Switch | 14. Thermocouple Inputs |
| 6. Voltage Range Switch | 15. RS-232 Serial Port Connector |
| 7. AC Supply Input & Fuse | 16. AUX Analog Inputs |
| 8. DC Supply Input | 17. Irradiance Inputs |
| 9. DC Supply Input Fuse | |

Figure 8. Face plate of the DS-Tracer .

Pre-Charge Fuse

The DS-Tracer uses a pre-charge circuit to apply a negative voltage to the DS-Tracer load capacitors before taking a curve. The pre-charge fuse protects the pre-charge circuit if it is inadvertently active while the DS-Tracer load capacitors are sweeping an I-V curve. Typically this fuse blows if the DS-Tracer DISCONNECT switch is turned on or off during the pre-charge cycle. Replace the fuse with only a **1/4 A Fast 3AG** fuse. Refer to the section 5.0 Pre-Charge Precautions for more details and information on the potential damage the pre-charge can do to thin-film PV modules.



Note: Only replace this or any other fuse with the DS-Tracer completely disconnected from the PV array.

PV & Voltage Sense Connectors

When an I-V curve is taken, the load current flows through the test lead into the large red and black PV connectors. The red and black connectors go to PV array positive and negative terminals respectively. The PV array voltage is measured separately to avoid measurement errors caused by voltage drops in the test leads. The test leads incorporate voltage sense wires that run between the Voltage Sense connector and the ends of the test leads.

DISCONNECT Switch

The DISCONNECT switch is used to isolate the DS-Tracer from the PV array when connecting or disconnecting the test leads between the tracer and PV system. Having this switch in the OFF position ensures that no significant current can flow into the DS-Tracer while making or breaking connections. This feature prevents the possibility of an electrical arc and protects the user from possible injury. Although the DISCONNECT switch should always be OFF when connecting or disconnecting the test leads, it becomes more important at higher PV voltages.



Note: the DS-Tracer DISCONNECT switch is not rated to break the electrical current at the full voltage and current rating of the DS-Tracer.

The DS-Tracer should always be connected through a PV system disconnect rated at the PV system V_{oc} and I_{sc} values as shown in Figure 9. A system switch provides a way to break a circuit should the DS-Tracer have a major internal failure.

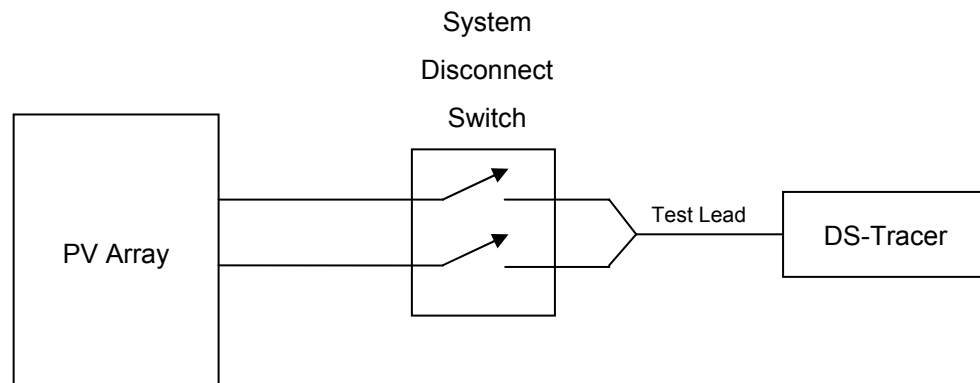


Figure 9. Use of PV system disconnect switch.

Voltage Range Switch

The voltage-range switch changes the electrical configuration of the capacitors that form the load for the PV array. It will not affect the measurement range of the I-V curve but it does affect how quickly an I-V curve is taken. In the low voltage setting, the DS-Tracer has more load capacitance and therefore a curve is swept slower. Note: This affects how quickly the PV array sweeps from I_{sc} to V_{oc} . It does not affect how long it takes a curve to plot in IVPC.

The higher I_{sc} and the lower V_{oc} the more quickly a curve is taken. If curves are swept too fast, the dynamic characteristics of the PV array can become significant and affect the accuracy of an I-V curve. Under most circumstances, the DS-Tracer can be left in the V_{HIGH} range. However, the low voltage range will give a better curve of low voltage, high current PV systems (for example 60

Amps, 12 Volts). Refer to section 3.0 Theory for more details on DS-Tracer capacitance.



NOTE: Leave the voltage range switch on the DS-Tracer in the HIGH position unless taking a high current, low voltage I-V curve.

AC Power Entry & Fuse

The DS-Tracer battery is recharged by connecting the DS-Tracer to an AC power source with the cord provided. It is not necessary for the tracer to be ON. Refer to section 4.0 for details of battery charging.

ON-Off Switch

This switch turns on the DS-Tracer power. This switch should be on before connections are made to a PV array. The curve tracer takes approximately 10 seconds to initialize after it is turned on. Be sure to allow for this before attempting to use IVPC to operate the tracer. If you attempt to communicate with the tracer before it completes initialization, you will receive an error in IVPC.

It makes no difference if it is on or off while connecting to the control computer. Of course, it must be on to take an I-V curve. The DS-Tracer automatically turns itself off if a curve has not been taken for 15 minutes. This feature protects the DS-Tracer battery. If you suspect that the DS-Tracer has turned itself off, simply switch the power switch off, wait several seconds, and turn the switch back on.

Full Charge Indicator

When this LED lights it indicates that the DS-Tracer battery is fully charged. Sometimes this LED will turn on for several seconds if the AC power cord is unplugged before the battery is fully charged. This occurrence does not indicate a fully charged battery.

Aux Charge Power & Fuse

The Aux Charge connector is a standard banana jack connector used to recharge the battery from a DC power source such as a PV module. Do not exceed the input voltage. A fuse protects the tracer from excess current.

RS-232 Serial Port

All DS-Tracer operations are controlled with commands sent to the DS-Tracer through this serial port or the USB port. This port is a standard 9 pin RS-232 port. This port is configured as a DCE device. Normally the DS-Tracer functions are controlled with the IVPC software, but you can create your own software using the DS-Tracer command codes described in section 6.0 DS-100C Additional Capabilities.

The DS-Tracer uses the following RS-232 format:

9600 Baud
No parity
8 data bits
1 stop bit

Main USB Port

All DS-Tracer operations are controlled with commands sent to the DS-Tracer through this USB port or the RS-232 port. This port is a standard USB Type-B port. Normally the DS-Tracer functions are controlled with the IVPC software, but you can create your own software using the DS-Tracer command codes described in section 6.0 DS-100C Additional Capabilities.

Aux USB Port

This port supports auxiliary DS-100C operations. This port is a standard USB Type-A port. This port is NOT used to control the DS-100C IV tracer. It is meant to be used to update the IV curve tracer internal firmware and to load updated calibration constants. In the event that an update is needed, the proper use of

this port will be described at that time. This port may also be used for advanced features in future releases of DS-100C firmware or IVPC.

Irradiance Inputs

The model DS-100C has two irradiance inputs for measuring pyranometers. These inputs measure DC voltages only. In order to use a reference cell, the cell must have a shunt resistor attached to convert the cell current to a voltage. Refer to the IVPC Manual and Appendix C “DS-Tracer Technical Specifications” for details on the voltage range of the irradiance inputs.

These inputs are differential, but there is a 10 K resistor from the negative (black) input and the internal circuit common. Therefore the pyranometer can be either electrically referenced to the same common as the other inputs such as the computer, or it can be electrically floating.

Thermocouple Inputs

The standard model DS-100C is configured with two Type “T” thermocouple inputs for measuring PV array module temperatures. Refer to the IVPC manual for details on making temperature measurements and Appendix C DS-100 USB Drivers for details.

Aux Analog Inputs

This auxiliary analog input connection is currently disabled. However, implementation is expected in future releases of IVPC and DS-100C firmware.

3.0 Theory of Operation

The DS-Tracer obtains an I-V curve by varying the electrical impedance connected across the PV array output terminals. Varying the impedance from zero to infinity causes the array operating point to change from I_{sc} to V_{oc} . The DS-Tracer accomplishes this impedance change by connecting the array to a capacitive load. As the capacitor charges, the array moves through its operating range and presents a set of current and voltage values that form the I-V curve. When the capacitor load reaches V_{oc} data sampling stops.

The DS-Tracer employs two high-speed, analog-to-digital converters to sample the current and voltage. One converter digitizes the array voltage while the other digitizes the array current. The DS-Tracer analyzes the digitized values, saves those that show significant change, and transfers the data set to the control computer. The data set includes the I-V curve data plus values of open-circuit voltage, V_{oc} , and short-circuit current, I_{sc} . Peak-power, voltage at peak-power V_{pk} , current at peak-power I_{pk} , and fill factor are calculated and displayed with the curve.

Irradiance and temperature data, and array identification may be added to each data set. The irradiance and temperature data are either entered by the operator using IVPC or sampled by the DS-100C.

The DS-Tracer sweeps an I-V curve by switching the PV system to a bank of capacitors. As these capacitors charge, the PV system voltage increases until open circuit voltage is reached. While the voltage is increasing, and the current to the capacitors is decreasing from its maximum, short-circuit value, the voltage and current are sampled by high-speed analog-to-digital converters. These data points define the I-V curve.

Before acquiring data, the DS-Tracer reverse charges its capacitive load to approximately -25 V. This negative pre-charge is used to offset any voltage drops created by the test leads and to allow any switching transients to settle before I_{sc}

is reached. This method allows a true short circuit current reading to be made. The DS-Tracer allows 5 seconds for a curve to reach open circuit voltage. At this point the circuitry discharges the capacitors through a resistive load.

The complete cycle actually begins with a discharge of any residual voltage on the capacitors. This discharge is followed by 7 seconds of pre-charge, 5 seconds to take the curve, and finally another 5 seconds for discharge. The initial discharge cycle is not normally needed. However, it ensures that the load capacitors are ready to accept a pre-charge. The initial discharge, if needed, may take up to 5 seconds.

The DS-Tracer uses an SCR to close the circuit between the PV system and the load capacitors. SCRs are susceptible to false triggering (turn on) if the voltage across them is increased too rapidly. The DS-Tracer DISCONNECT switch uses two 1M Ω resistors (one each for the positive and negative leads) across the disconnect switch contacts. These resistors allow the SCR to “see” the PV system voltage before the DISCONNECT switch is closed; thereby preventing the SCR from false triggering when the disconnect switch is closed. Under normal operating conditions, this switch should always be the last switch closed and the first switch opened when making PV system connections.



Note: In an emergency situation, it is recommended that the PV system switch be opened first. The DS-100C disconnect switch is not rated to break significant current at high voltage.

Some PV systems are sensitive to how quickly an I-V curve is taken. The speed of a curve is most easily expressed in volts per second by taking the PV short circuit current in Amps (I_{sc}) and dividing it by the DS-Tracer load capacitance in Farads. Refer to Appendix D - DS-100C Technical Specifications for the values of load capacitance for each position of the voltage-range switch. For example, if using a load capacitance value of 0.005 F (low range), and a PV system with an I_{sc} of 20A the rate would be:

$$\text{Rate} = 20\text{A}/0.005 \text{ F} = 4000 \text{ V/S.}$$

When comparing this value to the PV system, it is best to normalize this rate to an individual PV cell. This can be done by dividing the rate by the number of PV cells in series. If the previous example had fifty cells in series the rate of each cell would be $4000 \text{ V/S} \div 50 = 80 \text{ V/S}$. Different PV technologies vary in their sensitivity to the charge rate. It is left to the user to determine if there is reason for concern. Often the PV module manufacturer can provide information concerning how quickly an I-V curve can be swept on their modules. Daystar, Inc. will also provide any assistance possible.

4.0 Maintenance

Battery Charging and Care

The DS-Tracer contains a 12-Volt sealed, maintenance-free, lead-acid battery. (A 5 AH Cyclon brand, #0809-0012 manufactured by Hawker Energy.) The battery is designed for 400 cycles of a 50 percent discharge. Using the DS-Tracer for 6 hours continuously discharges the battery 50 percent. If the DS-Tracer were used for 6 hours every day, the battery should have a minimum life of 13 months (one discharge/charge cycle a day). Fully charging the DS-Tracer after every use increases battery life. The DS-Tracer is programmed to turn itself off after 15 minutes without a command. This eliminates the possibility of completely discharging the battery if the DS-Tracer power is accidentally left on.

The DS-Tracer battery may be charged in two ways—AC line power or a DC source such as a PV module. The DS-100C has a universal AC power supply and therefore will work with single phase, AC line voltages from 85 V_{ac} to 264 V_{ac} 50/60Hz. To charge the battery from AC line power, simply connect the tracer to the AC source (with the AC power cord provided). The tracer will immediately start charging the battery

Battery charging is independent of using the DS-100C tracer. Therefore the tracer may be used to take curves using AC power. The battery will continue to charge while the tracer is used.



NOTE: In order to minimize potential ground loops and maximize safety, it is recommend that the DS-100C NOT be connected to AC power when taking curves. However, this is only to eliminate.

In addition to using AC power, you can connect a DC supply such as a PV module to the DC input connector. This feature is useful when working in remote locations without AC power. Connect a DC Voltage source within the range specified on the DS-Tracer front panel to the DC Power connector. This is a

standard banana jack connector. Connect the DC positive and negative to the red and black jacks respectively.

The charge circuit uses a maximum of 1 A and requires a minimum of 16 V. If using a PV module for recharging, the open circuit voltage of this module should not exceed the maximum rating shown on the DS-Tracer front panel. If you connect a supply that produces less than 1A, the DS-Tracer simply takes longer to recharge. The internal charging circuitry limits the DC charging current. Therefore power sources with current capabilities greater than 2 A can be used. For example, a 5 A PV module could be used. The DS-Tracer will only draw the current it needs for charging.

The automatic charging system maintains the battery at its peak charge level and will not overcharge the battery. When the battery is fully charged, the full-charge indicator comes on. You do not need to turn the DS-Tracer on to recharge the battery. Operating the tracer will not affect the time it takes to recharge.

It will not harm the battery to leave the DS-Tracer connected to the power source after the battery is fully charged. Note: The full charge indicator may come on for a short time if the charging power is removed before the DS-Tracer is fully charged. This occurrence does not indicate that the battery is fully charged.

During charging, the front panel of the DS-100C near the irradiance connectors may get slightly warm.

Exterior Cleaning

The exterior surface of the DS-Tracer may be cleaned with a soft cloth dampened with water or a mild soap only. Do not use detergents, abrasive cleansers, or other solvents.

Transportation

Treat the DS-Tracer as you would a notebook computer. The DS-Tracer is mounted in a heavy-duty case but this is **NOT** adequate to ship the unit as freight without using a shipping container. Because of its weight, it will likely be

damaged if it is dropped or tossed. Due to airline security, Daystar does not recommend attempting to carry the tracer on board a commercial airplane as carry-on baggage. A shipping container with foam packing is supplied as standard equipment with all DS-100C curve tracers. Daystar strongly recommends using this case anytime the DS-100C is shipped.

DS-Tracer Fuses

The DS-Tracer has three externally accessible fuses. The first of the external fuses is located in the AC input power receptacle. Power line surges or internal faults can cause this fuse to fail. Return the DS-Tracer for repairs if this fuse blows repeatedly. Replace this fuse with the type indicated on the DS-Tracer panel.

A user accessible fuse is located on the front panel and is labeled “PRE-CHARGE” fuse. This **1/4 Amp, fast-blow fuse** protects the DS-Tracer pre-charge circuitry. See section 5.0 Pre-Charge Precautions for more details. This fuse may blow if the DS-Tracer connection and disconnection sequences are not followed exactly. Replace only with a **1/4 Amp, fast-blow fuse**.

A third user replaceable fuse is the **2 Amp, fast-blow DC charging fuse**. This fuse should only blow if a DC source voltage exceeds the rating on the DS-Tracer panel. Replace only with a **2 Amp, fast-blow DC charging fuse**.

There is an internal fuse on the power supply board battery circuit. This fuse is installed as protection when the DS-Tracer is removed from its case during repairs. Contact Daystar, Inc. if you suspect that this fuse has blown.

5.0 Pre-Charge Precautions

In order to compensate for voltage drops across the test leads, the DS-Tracer pre-charges the capacitive load to -25 V. When an I-V curve is taken, the PV module voltage will start at -25 V and increase to 0 V (I_{sc}) and continue to V_{oc} . Most PV modules (single crystal silicon for example) can easily withstand this negative pre-charge voltage. However, this pre-charge voltage can damage some thin-film modules—particularly those with very low V_{oc} values. Higher voltage modules have more cells in series and therefore the pre-charge voltage is spread across more cells. Only individual low-voltage, thin-film modules are affected. It is not a concern for systems with many modules in series.

You can avoid damage to a thin-film module by inserting a by-pass diode across the module terminals as shown in Figure 10. This diode limits the reverse voltage to approximately -1 V maximum. Locating the diode at the PV module terminals allows the pre-charge to still offset voltage drops across the test leads.

The by-pass diode should be rated to handle the instantaneous peak current created by shorting the pre-charge capacitor through the by-pass diode. Due to circuit resistances, this current will not exceed 250 A and can last less than 2 ms. The diode reverse voltage rating must be greater than module V_{oc} . A Motorola MR750 series rectifier is recommended. This rectifier has a reverse voltage rating of 50 V and can handle peak currents over 300 A.

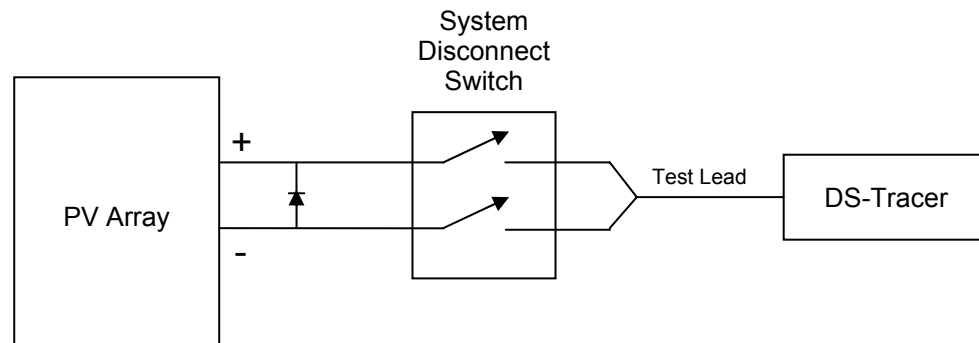


Figure 10. Use of by-pass diode to protect thin-film PV modules.

6.0 DS-100C Additional Capabilities

The DS-100C tracer has auxiliary capabilities. These include analog circuits for reading external temperatures and irradiances.

Temperature & Irradiance Inputs

The DS-100C has two thermocouple temperature inputs and two dual, 5-way binding posts for connecting pyranometers. You do not need to use these inputs to take I-V curves. The temperature and irradiance inputs are enabled using the AUTO feature of IVPC. When a curve is taken, the temperature and irradiance inputs are sampled immediately before the DS-100C takes a curve. Refer to the IVPC operating manual for details on using these inputs when taking I-V curves.

Temperature Connections

Two standard thermocouple connectors are available on the front of the DS-100C. A standard DS-100C comes with Type- "T" thermocouple connectors. In order to accurately acquire temperature data, only matching thermocouple types can be used. The thermocouple inputs are electrically isolated from the PV system, but not isolated from other analog circuits or the computer connections. Therefore, it is necessary that the thermocouple be electrically insulated when bonded to a surface.

Irradiance Connections

There are two dual, 5-way binding posts for pyranometer inputs located on the front panel of the DS-100C. These programmable inputs can accommodate ± 5 V signals and accurately measure millivolt signals. These inputs can be used for any analog voltage measurement within the range of the DS-100C. Refer to the Appendix D - DS-100C Technical Specifications for details on measurement ranges.

Multiple Current Ranges

The standard DS-100C includes two current ranges, 10 Amperes and 100 Amperes. Before a I-V curve is taken, you may select one of these two ranges using IVPC. You will not damage the DS-100 by inadvertently selecting the low range when the high range is required. However, the displayed I-V curve will not include current values higher than 10 Amperes.

External Command Set

Typically the IVPC program controls the DS-100C, however you can write your own program if necessary. Some users may want to write software to perform custom tracer operations. This is possible using the following commands sent to the DS-100C through its RS-232 serial or USB control ports.

The DS-100C sends a prompt character ">" when it is ready to receive a command line. Commands should only be sent to the DS-Tracer after receiving this prompt. Each command has a unique one character start code, indicating the type of command, followed by comma-delineated parameters as required.

After receiving a command line, the DS-Tracer attempts to perform the requested operation. If the command and its parameters can be decoded properly, the DS-Tracer sends a "*" followed by a carriage return (ASCII 0DH) to indicate that the command was accepted. If the command was not accepted, the DS-Tracer will return an error line in place of the "*" line . It is this return line that should be checked following all commands. Refer to Appendix B DS-Tracer ERROR CODES for a list of error messages. Each command of the DS-Tracer is described below with an example of a proper command line and responses from the DS-Tracer.

Note: Optional parameters are shown with brackets [].

Read I & V "B"

This command reads the DS-100C current and voltage analog-to-digital converters (ADCs), and repeatedly outputs their 16 bit integer values until

another command is received. Note: Any command sent to it to stop this command is ignored. Typically this command is used to calibrate the DS-Tracer.

Note: These values may or may not have had offset correction applied depending on the whether the "Z" parameter is passed (see below).

Format

"B,n1,n2,[Z]" n1 = Voltage gain code 0,1,2, or 3.
 n2 = Current gain code 0,1,2, or 3.
 Z = Use current offset values (see auto
 zero)

Gain Codes

0 = 1X	used for 600 V, not used for current
1 = 10X	used for 60 V, 100 A
2 = 100X	used for 6 V, 10 A
3 = 1000X	not used for any measurements

Example

```
command  "B,0,1"      or "B,0,1,Z"
response "*"
response "3045"       Voltage A/D Output.
response "2839"       Current A/D Output.
delay
response "3046"
response "2838"
```

Continues until any other command is received..

Auto Zero I & V "Z"

This sets the current circuit offset to the current reads from the PV voltage and current channels. Therefore this command should only be used when the current and voltage values are known to be true zeros. This command is typically used for calibration purposes.

Format

"Z,n1,n2" n1 = Voltage gain code 0,1,2, or 3.
 n2 = Current gain code 0,1,2, or 3.

Gain Codes

0 = 1X	used for 600 V, not used for current
1 = 10X	used for 60 V, 100 A
2 = 100X	used for 6 V, 10 A
3 = 1000X	not used for any measurements

Example

command "Z,0,1"
response "*"
response ">"

Pre-Curve "E"

This command initiates the pre-curve sequence. The sequence has up to a 5 second discharge of the tracer load capacitors followed by a 7 second pre-charge.

Format

"E" Start pre-curve sequence.

Example

command "E"
response "*"
7 to 12 second delay
response ">"

Read Analog Input "R"

The read-analog command has a form for reading a specified analog input channel, a form for auto-calibrating the gain of the analog circuits, and a form for defining the averaging period for analog readings.

The analog channels are not related to the circuits used for the current and voltage readings. The analog channels refer to the irradiance (pyranometer), and

temperature readings as well as auxiliary analog port, and internal readings such as battery voltage.

Format

Option 1

"R,n1,n2" Read input n1 (0-13).
 n2 = Pyranometer constant in W/m^2 / volt.
 Only needed if n1 = 2 or 3.

Option 2

"R,C" Calibrate analog board circuits.

Option 3

"R,P,t" Set analog averaging period 't' in
 microseconds.

Option 1 reads one of 14 possible analog inputs. It returns a numeric value for the channel.

"n"	Description
0	Temperature #1
1	Temperature #2
2	Irradiance #1
3	Irradiance #2
4	Battery Voltage
5	4 V Reference
6	0V Reference for 5.0 V scale
7	0.4 V Reference
8	0V Reference for 0.50 V scale
9	40 mV Reference
0	0V Reference for 50 mV scale
11	4 mV Reference
12	0V Reference for 5 mV scale
13	Thermocouple Reference Junction Temp.
20	PV Voltage

Option 2 is used to calibrate the gain of the analog circuit based on the 4 V internal reference. The option 2 format does not return any values.

Option 3 sets the averaging period for all analog readings. The default value is 16,667 microseconds. This is equal to 1 60 Hz ac power cycle. Averaging over one AC cycle helps to reduce AC noise picked up the thermocouples and pyranometers. This value is limited to a maximum of 65,535. A value of 0, disables all averaging.

The most common reason to use this command would be to set the tracer to cancel power line noise that is not 60Hz. For example, 50 Hz. In that case, the averaging constant should be set to 20000.

Example 1

```
command  "R,5"  Read 2.5 V reference.
response "*"
response "2.499"
response ">"
```

Example 2

```
command  "R,C"  Calibrate.
response "*"
response ">"
```

Example 3

```
command  "R,Z,16667" Set averaging period to 1 60 Hz
                        period.
response "*"
response ">"
```

PV V & I Scales Factors "S"

This command returns the floating-point conversion constant for the PV voltage and current inputs for the specified gain codes. There is a different conversion constant for each gain code. The integer values returned by the DS-Tracer for the PV voltage and current values are multiplied by these constants to convert these values to engineering units. The constants are returned in IEEE single precision (32 bit) binary format.

Format

"S,n1,n2" n1 = Voltage gain code 0,1,2, or 3.
 n2 = Current gain code 0,1,2, or 3.

Gain Codes

0 = 1
1 = 10
2 = 100
3 = 1000

IEEE 32 bit floating point format:

1 sign bit, 8 bit signed exponent, 23(+1) bit mantissa.
Refer to IEEE documentation for more details.

Example

command "S,0,1"
response "*"
4 byte (32 bit) voltage constant
4 byte (32 bit) current constant
response ">"

Take I-V Curve "T"

This command causes the DS-Tracer to take an I-V curve using the specified current range. The I-V curve data is accessed with the "Transfer" command "X".

Format

"T,L" Use low current range.
"T,H" Use high current range.

Example 1

```
command  "T,L"  
response "*"   
response ">"
```

Take low current curve.

Example 2

```
command  "T,H"  
response "*"   
response ">"
```

Take a high current range curve.

Read DS-Tracer Version "V"

This command reads the software version number, current and voltage ranges.

Format

"V"

Example

```
command  "V"  
response "*"   
response "VERS 6.0C"  
response "V LOW=150V"  
response "V HI=600V"  
response "I LOW=10A"  
response "I HI=100A"  
response ">"
```


Get Information "G"

This command gets various DS-Tracer information depending on the parameters used. Currently two version are define:

Get Configuration

"G,C"

Example

```
command  "G,C"
response "*"
response "123456"      tracer serial number
response "8-13-06"     date of manufacture
response "9600"        RS-232 port baud rate
response "9600"        secondary port baud rate
response "600"         nominal high-voltage range
response "150"         nominal low-voltage range
response "100"         nominal high-current range
response "10"          nominal low-current range
response "T"           thermocouple #1 type
response "T"           thermocouple #2 type
response ">"
```

Get Calibration Constants

"G,B"

Example

```
command  "G,B"
response "*"
response "123456"      tracer serial number
response "8-13-06"     calibration date
response "0.6"         0.6V voltage constant (NA)
response "6.1056"      6V range voltage constant
response "60.1439"     60V range voltage constant
response "600.0123"    600V range voltage constant
response "1.0"         1.0A current constant (NA)
response "10.0839"     10A range current constant
response "100.0529"    100A range current constant
```

response "1000.0"	1000A current constant (NA)
response "4.00183E-3"	5 mV analog constant
response "4.00381E-2"	50 mV analog constant
response "3.999921-1"	500 mV analog constant
response "4.00094E-0"	5 V analog constant
response "-0.35"	CJC offset
response ">"	

Disable Power Down “W”

Normally the DS-Tracer turns itself off after 15 minutes without any activity. This command disables this feature until the DS-Tracer is reset by turning power off.

Format

“W”

Example

```
command  "W"
response "*"
response ">"
```

Enable Power Down “P”

Normally the DS-Tracer turns itself off after 15 minutes without any activity. This command enables this feature. By default this feature is enable. This command is only necessary if the power-down feature has been disabled using the “W” command.

Format

“P”

Example

```
command  "P"
response "*"
response ">"
```

Transfer Curve Data “X”

This command is used to transfer curve data from the DS-Tracer. The command transfers the I-V curve data in binary format. If there are no errors, this command returns “*” followed by a 1056 byte binary data record.

Format

“X” Transfer last data record.

Binary format.

```
int    Voc;                /* Curve Voc    */
int    Isc;                /* Curve Isc    */
int    Num_Points;         /* Number of data points
                           */
char   V_Gain;             /* V gain code used */
char   I_Gain;             /* I gain code used */
int    Volts[256];         /* Array of voltage data
                           */
int    Amps[256];          /* Array of current data
                           */
float   Vscale;            /* Voltage constant */
float   Iscale;            /* Current constant */
float   Temp1;             /* Temperature #1 */
float   Temp2;             /* Temperature #2 */
float   Irrad1;            /* Irradiance #1 */
float   Irrad2;            /* Irradiance #2 */
```

int Format: 8 bit MSB|8 bit LSB

IEEE 32 bit floating point format:

1 sign bit, 8 bit signed exponent, 23(+1) bit mantissa.

Refer to IEEE documentation for more details.

Example

```
command  "X"
response ""
response 1056 binary bytes
response ">"
```

7.0 Troubleshooting

- **Data is not plotted after taking an I-V curve.**
 - Proper connection has not been made to PV system (check DISCONNECT switch).
 - **I-V curve is flat.**
 - PV short circuit current exceeds current range (check current range setting). Check for bad connections to PV module or array.
 - **I-V curve does not start at 0 V (does not reach I_{sc}).**
 - Pre-charge fuse has blown (check and replace).
 - **DS-Tracer Stops Working (Locks Up)**
 - Battery out of power (charge battery).
 - Unknown Reasons (reset DS-Tracer by recycling power).
 - **Cannot establish connection of external computer to DS-Tracer.**
 - DS-Tracer is not turned on or has turned itself off.
 - DS-Tracer RS-232 or USB port is not connected to computer.
 - IVPC is set to wrong COM port.
 - **DS-Tracer will not accept external command.**
 - Parameters are not properly formatted.
 - **Irradiance readings are incorrect.**
 - Pyranometer coefficients are incorrect.
 - Analog circuit requires factory calibration
-

Appendix A IV Curve ASCII File Format

Note: Each line of the ".IVA" format starts with a unique ID letter followed by a space. The ID letter and space should be used to decode this file. Line arrangements are subject to change as additional information is added to this file format.

```
"F" curve name
"D" date
"T" time
"S" site
"B" sub-system
"M" module
"P" temperature #1
"Q" temperature #2
"R" irradiance #1
"U" irradiance #2
"X" miscellaneous
"H" short circuit current
"O" open circuit voltage
"C" current at peak power
"K" voltage at peak power
"W" peak power
"L" fill factor
```

THERE CAN BE 0 TO 257 I-V DATA PAIRS

```
"I" current value voltage value
"I" current value voltage value
"I" current value voltage value
.
.
.
"I" current value voltage value
"I" current value voltage value
"E"
```

Appendix B DS-Tracer ERROR CODES

ERROR 10 “I/O ERROR”

RS-232 serial communications error. Baud rate, parity, number of data bits, or number of stop bits is incorrect. DS-Tracer uses 9600 baud, no parity, 8 data bits, and 1 stop bit.

ERROR 13 “UNKNOWN COMMAND”

Command is not recognized by the DS-Tracer . This may be due to a syntax error.

ERROR 14 “BUFFER OVERFLOW”

Internal command line buffer overflow. Total number of characters in command line cannot exceed 255.

ERROR 15 “COMMAND LINE OVERFLOW”

A command has been sent to the DS-Tracer before the previous command has finished. Wait for return prompt.

ERROR 16 “PARAMETER TOO LONG”

The maximum length of any command line parameter is 15 characters.

ERROR 17 “TOO MANY PARAMETERS”

A maximum of 16 parameters (including command code) are allowed.

ERROR 30 “OVER MAXIMUM VOLTAGE”

The take I-V curve command cannot continue because the PV system voltage exceeds the maximum voltage range (this PV system cannot be tested with the DS-Tracer).

ERROR 31 “OVER LOW VOLTAGE RANGE”

The take I-V curve command cannot continue because the PV system voltage exceeds the low voltage range (switch to high voltage range).

ERROR 32 "INPUT LESS THAN OR EQUAL ZERO VOLTS"

The take I-V curve command cannot continue because the PV system voltage is less than or equal to 0 V. Check PV system and DS-Tracer disconnect switches. This error can also be caused by a reverse polarity on the DS-Tracer to PV system connection.

ERROR 40 "DISCONNECT SWITCH IS OFF"

The DS-Tracer is trying to take an I-V curve, but the DS-Tracer DISCONNECT switch is off.

ERROR 50 "INVALID NUMERIC PARAMETER"

Parameter must represent valid numeric value.

ERROR 60 "INVALID ANALOG I/O CHANNEL #"

The DS-Tracer accepts channel numbers 0 through 13.

ERROR 63 "DSP ERROR"

DS-Tracer DSP board has an error. Usually an A/D has failed or the connect to the DSP board has failed.

ERROR "UNKNOWN ERROR"

Some type of unknown error has occurred. Check parameters for proper syntax.

Appendix C DS-100 USB Drivers

In order to use the DS-100C USB port for tracer control, the DS-100 USB drivers must be installed on the computer running IVPC. Two drivers will be installed. The primary driver will be a USB device driver labeled “DS-100 IV Tracer”. The second driver will be a virtual COM port also labeled “DS-100 Tracer”. This virtual COM port will function as a conventional COM port.

IVPC version 2.X and lower only work with COM ports and therefore require the virtual COM port. New versions of IVPC will not need this virtual COM port, but still require the USB driver installation.

IVPC 2.X and lower only support COM ports 1 through 4. Therefore after being created, the virtual COM port must be assigned a COM port number in this range. It is common for the operating system to assign a COM port number outside this range, even if a COM port number from 1 to 4 is not in use.

Use the Windows OS device manager to change the COM port number assigned to this virtual COM port. Often Windows will warn that this COM port is in use. But if you know that it is not in use, you can reassign it to the necessary value from 1 to 4. After changing the COM port assignment, it is best to restart the computer to ensure proper operation.

Consult the Microsoft documentation and help system for details on using the device manager.

Note: If you have a conventional RS-232 COM port available, there is no advantage to using the DS-100C USB port and it is not necessary to install these USB drivers. However, many modern notebook computers do not have COM ports, and therefore it is necessary to install these DS-100 USB drivers.

The DS-100 USB drivers are located on the IVPC CD-ROM supplied with the tracer in the DS-100 USB Drivers folder. This folder contains detailed instructions on how to install the drivers for your version of the operating system.

Note: These instructions are not specific to the DS-100C and where provided by the USB hardware manufacturer. Therefore these instructions will not refer to the DS-100 IV Tracer driver by name.

When you first connect the DS-100C to your computer using the USB connection, Windows will recognize that new hardware has been connected and begin the process of installing the driver. The instructions on the CD-ROM provide much more detail, but in general, you will want to have Windows use the drivers in the driver folder on the IVPC CD-ROM using the “Have Disk” option.

Follow the steps as outlined in the driver installation instructions. After installation confirm that the assigned COM port number is appropriate and if necessary change it to a number from 1 to 4 as described above. Also, be sure to set the COM port number in IVPC to match this setting.

Appendix D - DS-100C Technical Specifications

PV Voltage Measurements

Gain Code = 0

Range	600 V dc.
Accuracy	Larger of +/- 0.5% of reading or +/- 0.28 V.
Resolution	18 mV.

Gain Code = 1

Range	60 V dc.
Accuracy	Larger of +/- 0.5% of reading or +/- 28 mV.
Resolution	1.8 mV.

Gain Code = 2

Range	6 V dc.
Accuracy	Larger of +/- 0.5% of reading or +/- 280 mV.
Resolution	0.18 mV.

PV Current Measurements

Gain Code = 1

Range	100 A dc
Accuracy	Larger of +/- 0.5% of reading or +/- 0.45 A.
Resolution	3 mA.

Gain Code = 2

Range	10 A dc
Accuracy	Larger of +/- 0.5% of reading or +/- 45 mA.
Resolution	0.3 mA.

RANGE switch settings

V_{HIGH} 600 V dc (max.)

V_{LOW} 150 V dc (max.)

Temperature

Range	-30°C to 120°C.
Accuracy	+/- 1°C.
Resolution	0.1°C.

Irradiance

Ranges	+/-5 V, +/- 500 mV, +/- 50 mV, +/- 5 mV,
Accuracy	+/- 0.1% of Range.
Resolution	1/65,536 of Range.

Power Supply

Power 85 Vac to 264 Vac V 50/60 Hz ac.
Battery 5 A-Hr sealed lead acid. (Hawker Energy Products #0809-0020)
Hours of Use Up to 13 Hours on a full charge.
Charge Time Less than 8 hrs.

Load Capacitors

Low Voltage Range
Capacitance 5,000 uf.
Voltage Limit 350 V dc.

High Voltage Range
Capacitance 1,600 uf.
Voltage Limit 700 V dc.

Approximate Size & Weight

18" x 14" x 8" (46 cm X 36 cm X 20 cm)
28 lbs. (13 kg)