Unique Features of SPD Lab PV Power Analyzers

The SPD Laboratory, Inc. has developed its first generation PV Power Analyzer VK-PA-25 (currently discontinued) with built-in Maximum Power Point Tracking (MPPT) function in 2015, and then delivered to Prof. Segawa Group at the RCAST, University of Tokyo. By utilizing this, Prof. Satoshi Uchida has patiently continued his research on perovskite solar cell (PSC) hysteresis and used MPPT technique to evaluate the PSC performance for the first time (PSCO-2015, Sep. 25, EPFL; Chem. Lett. ***2015****, 44, 1750-1752). The announcement was new to everyone's memory. In particular, it was significant to clarify that the hysteresis of a stacked PSC was caused by its capacitance component inside and to make the skeptical researchers mostly from Europe acknowledge its existence. Also, the MPPT has been gradually used in the real evaluation of solar cell performance, different from the conventional I-V curve method, where all of the SPD Lab's power analyzers have built-in advanced MPPT algorithms driven in firmware level by maintaining the cell at the maximum output conditions.*

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VK-PA-100

Home Page

Measure Range	:	Voltage: ±10 V to ±30 mV Current: ±1 A to ±6 µA
Maximum Measuring Resolution	:	Voltage: 2 µV (16-bit ADC) Current: 14 nA (16-bit ADC)
Communication	:	Bluetooth
Functions	:	I-V Tracer, MPPT, Potentiostat /Galvanostat, 4 Quadrant I-V, 4 Probe Ω Automatic Light intensity measurement
For More Details	:	http://www.spdlab.com/English/VK-PA-100.html

VK-MPA-100

Home Page

Measure Range	:	Voltage: ±10 V to ±100 mV (6 ranges) Current: ±1.2 A to ±20 µA (16 ranges)
Maximum Measuring Resolution	:	Voltage: 16 nV (24-bit ADC) Current: 3 pA (24-bit ADC)
Number of Channels	:	6 (PV), 4 (Light Intensity), 1 (Temperature)
Communication	:	Bluetooth
Functions	:	I-V Tracer with automatic curve fitting, MPPT, Programmable electronic load, Continuous plotting of light intensity and temperature graphs
For More Details	:	http://www.spdlab.com/English/VK-MPA-100.html

VK-PA-300

Home Page

Measure Range	:	Voltage: ±12 V to ±150 mV Current: ±4 A to ±6 µA
Maximum Measuring Resolution	:	Voltage: 9 nV (24-bit ADC) Current: 0.8 pA (24-bit ADC)
Communication	:	Bluetooth
Functions	:	I-V Tracer with automatic curve fitting, MPPT, Potentiostat/Galvanostat, Cyclic Voltammetry (CV) with automatic area calculation
For More Details	:	http://www.spdlab.com/English/VK-PA-300.html

VK-PA-1000

Home Page

Measure Range	:	Voltage: 100 V to 500 mV (8 ranges) Current: 1 A to 50 µA (15 ranges)
Maximum Measuring Resolution	:	Voltage: 62 nV (24-bit ADC) Current: 12 pA (24-bit ADC)
Communication	:	Bluetooth
Functions	:	I-V Tracer with automatic curve fitting, MPPT, Programmable electronic load.
For More Details	:	http://www.spdlab.com/English/VK-PA-1000.html

VK-PA-8000

Home Page

Measure Range	:	Voltage: ±20 V to ±250 mV Current: ±8 A to ±15 µA (±10 A Pulse)
Maximum Measuring Resolution	:	Voltage: 19 nV (24-bit ADC) Current: 2 pA (24-bit ADC)
Communication	:	Bluetooth
Functions	:	I-V Tracer with automatic curve fitting, MPPT, Potentiostat/Galvanostat, Cyclic Voltammetry (CV) with automatic area calculation
For More Details	:	http://www.spdlab.com/English/VMK-8000.html

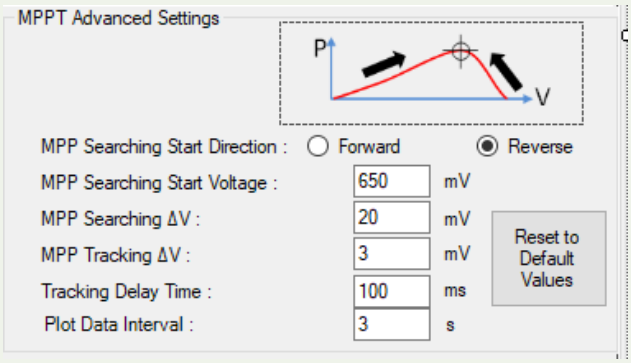
VK-PA-Pico

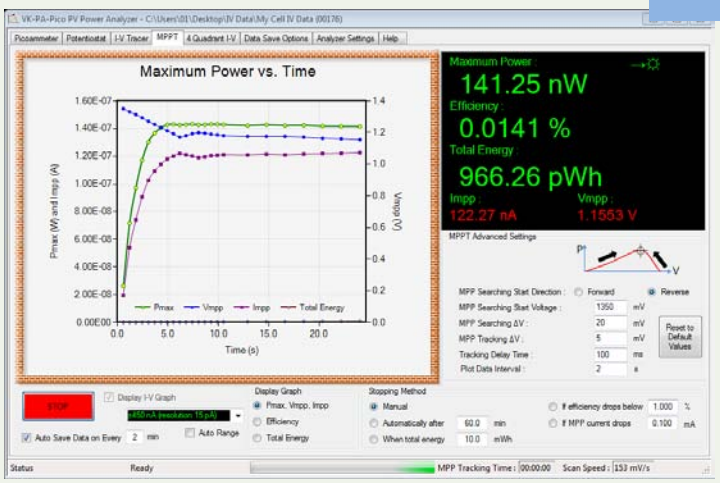
Home Page

Measure Range	:	Voltage: ±10 V to ±80 mV Current : ±5 mA to ±600 pA
Maximum Measuring Resolution	:	Voltage: 2 µV (16-bit ADC) Current: 17 fA (16-bit ADC)
Communication	:	Bluetooth
Functions	:	Pico Ammeter, Potentiostat, I-V Tracer, MPPT, 4 Quadrant I-V
For More Details	:	http://www.spdlab.com/English/VK-PA-Pico.html

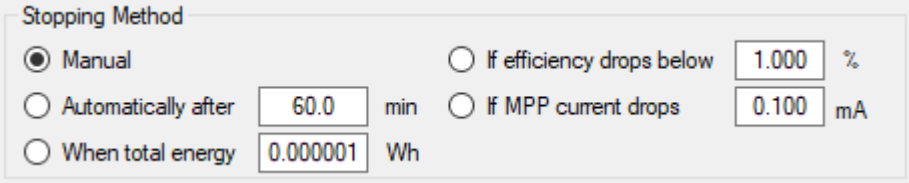
(1) True Maximum Power Point Tracking (MPPT) Function:

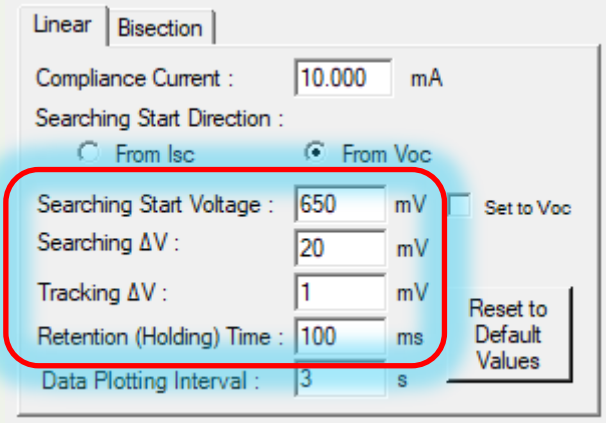
- Determination of true conversion efficiency of a solar cell is impossible with the I-V curve when it shows hysteresis effect.
- MPPT is the way to extract true maximum output power and efficiency of solar cell with time.
- Taking series of I-V curves with a given time interval and then plotting the calculated P_{max} against time will NOT solve the issue. Because of all I-V curves have two different P_{max} values for forward and reverse I-V.
- Our VK-PA series analyzers have built-in advanced MPPT algorithm driven in firmware level which can continuously maintain the cell at maximum output conditions.

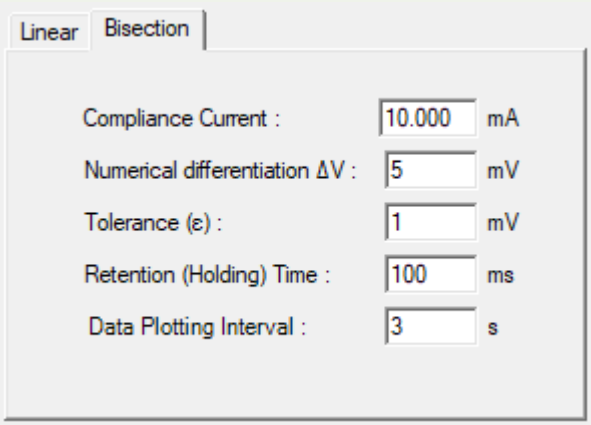




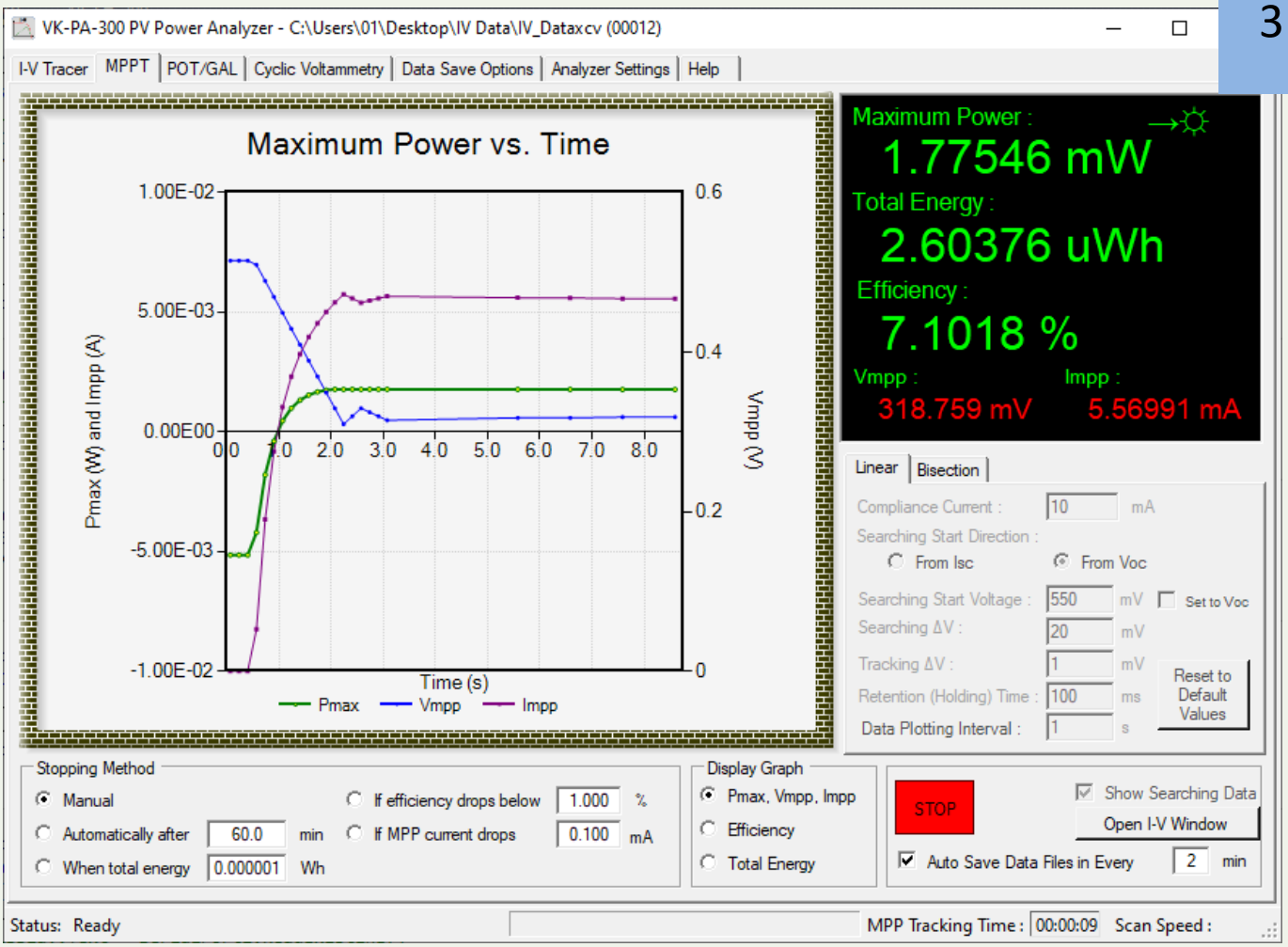
- Our user-friendly software interface offers maximum flexibility to set searching and tracking parameters.
- Measured power conversion efficiency, maximum output power, voltage, current, and total energy are plotted against time on an auto-scaling graph. Users can view I vs. V plot on a separate graph during MPPT.
- Optimized two step MPPT algorithm (initial searching and tracking) used in our analyzers capable of quickly reaching and keep tracking MPP without oscillatory behavior.
- Four different conditions can be conveniently used to automatically stop the tracking process when condition satisfied.



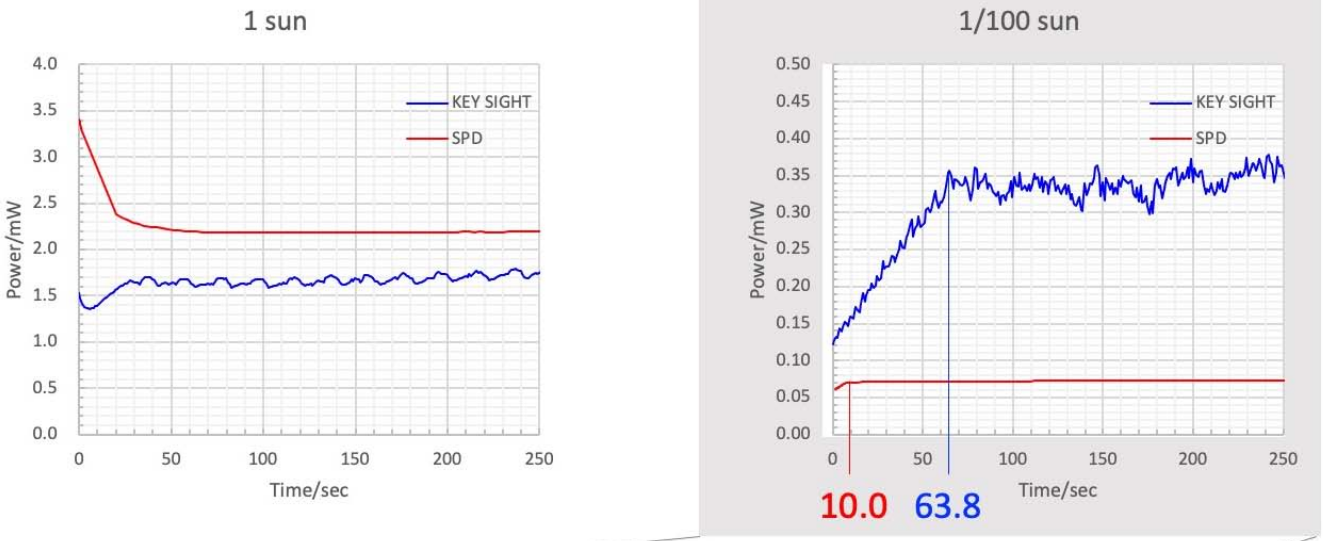




- Our VK-PA-300 and VK-PA-8000 analyzers offer two different maximum power point searching methods.
- "Linear" tab for "Hill climbing algorithm" to find the maximum power point.
- "Bisection" tab for "Bisection algorithm" to find the maximum power point.



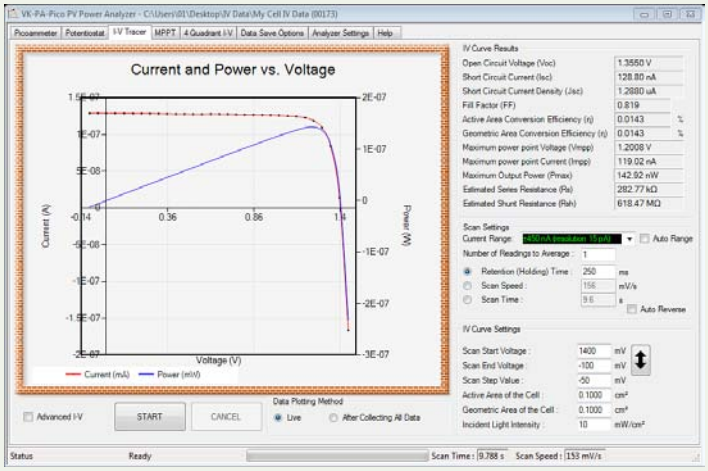
- Results of independent measurement on MPPT performed by Prof. Satoshi Uchida's group at RCAST, University of Tokyo shows the comparison between SPD Lab VK-PA-Pico and Keysight + add-in-software measuring systems.

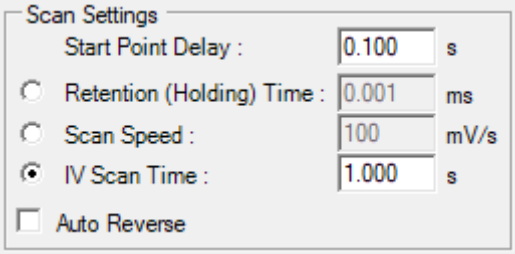


	Stabilization time /s	Drift Δ /%
Keysight	63.8	20.0 (for 198s)
SPD	10.0	1.4 (for 200s)

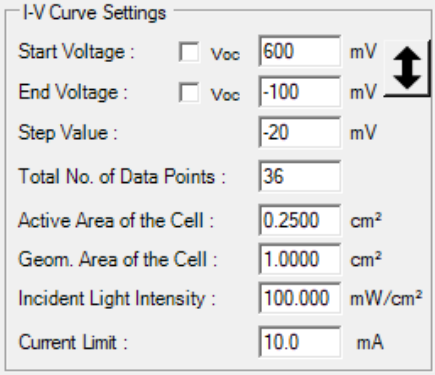
(2) I-V Tracing Function:

- All of our PV Analyzers offer conventional I-V tracing function with following capabilities.

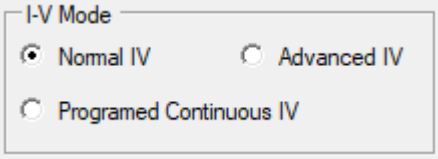




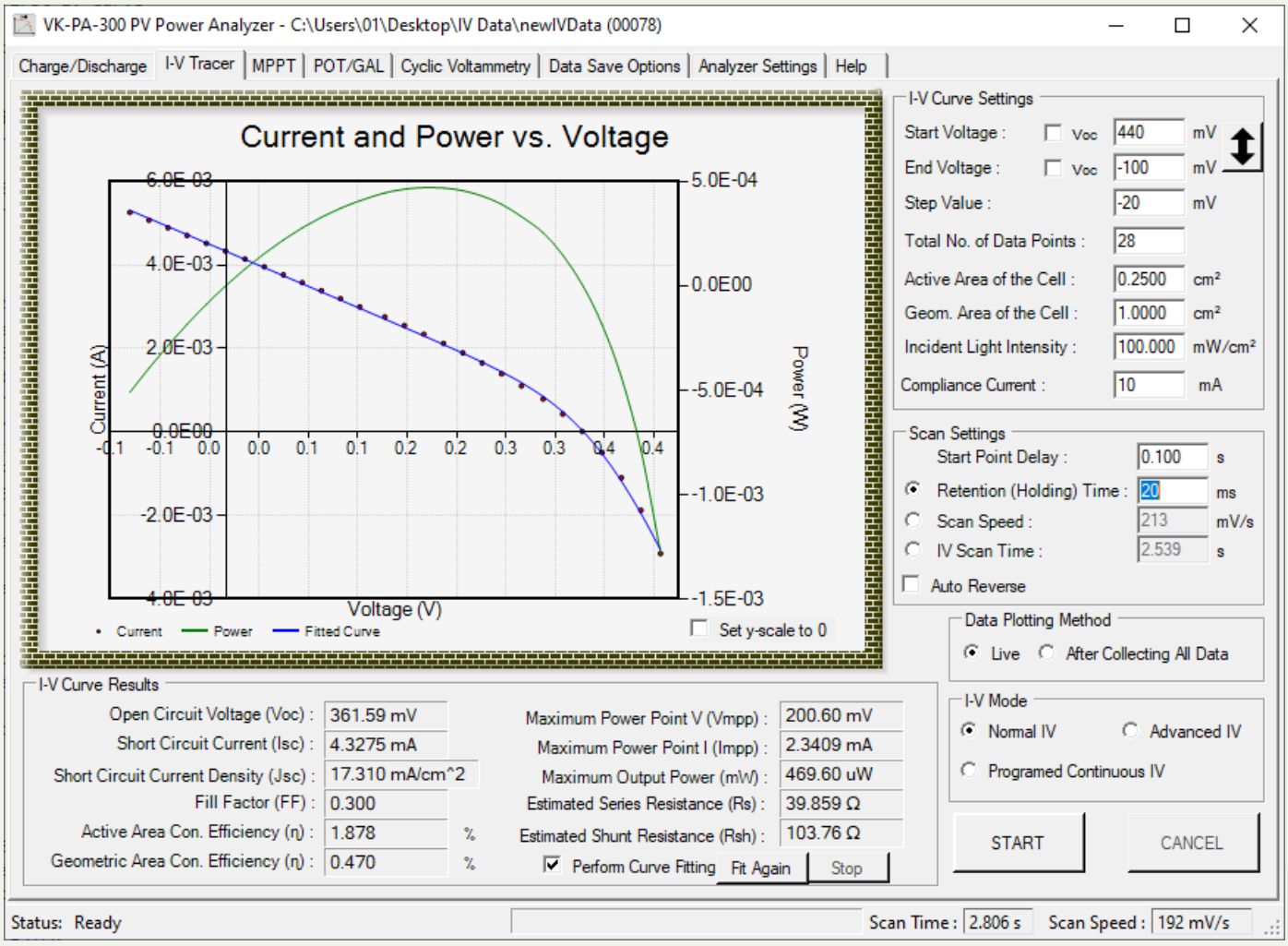
- "Auto Reverse" option allow user to plot forward and reverse I-V on same graph and analyze hysteresis effects



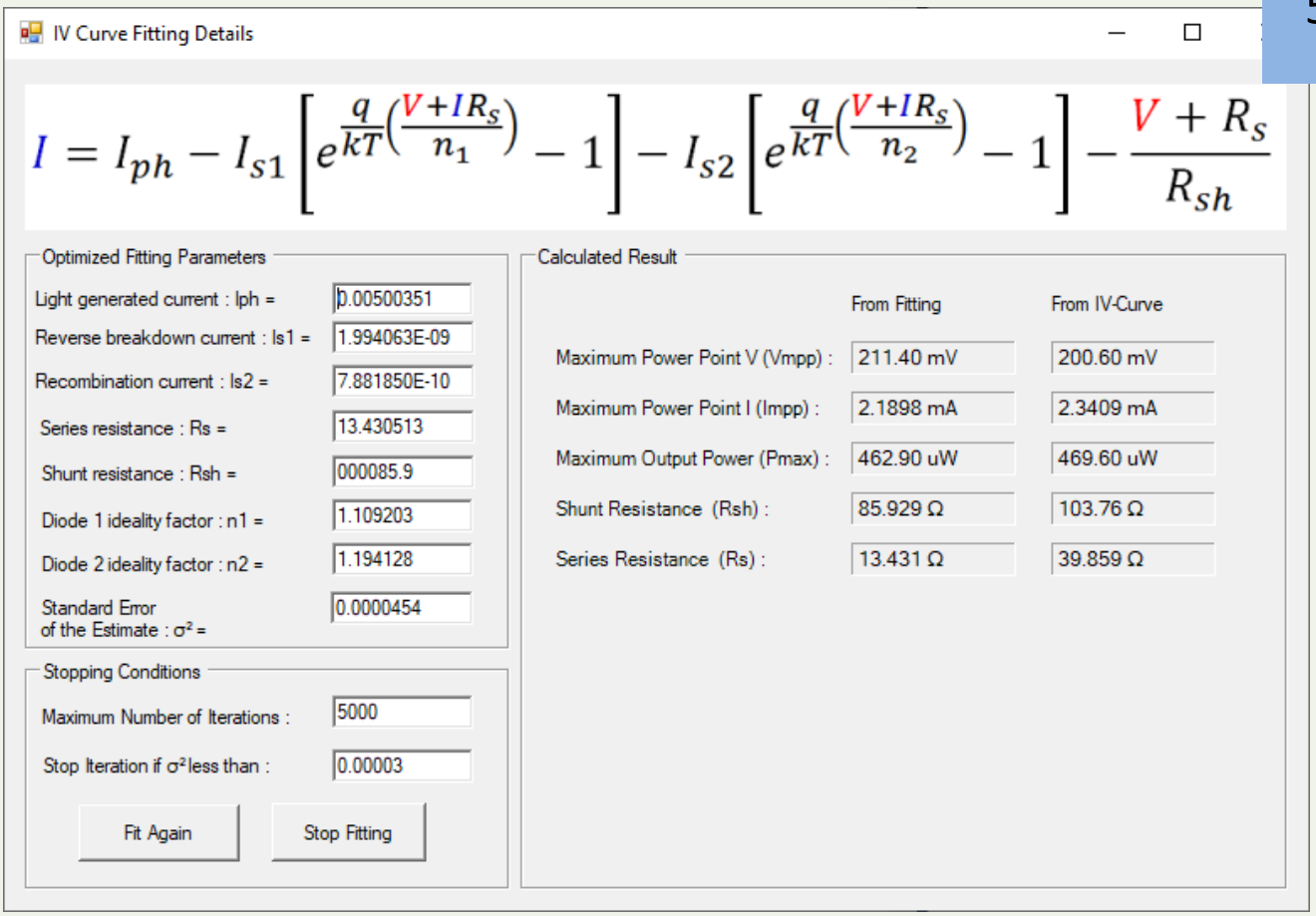
- User can set start, stop, step and select one of three different scan methods.



- Advanced I-V and "Programmed Continuous I-V" options are available.



Automatic curve fitting function is applicable to fit the I-V data with two diode model and calculate various parameters.



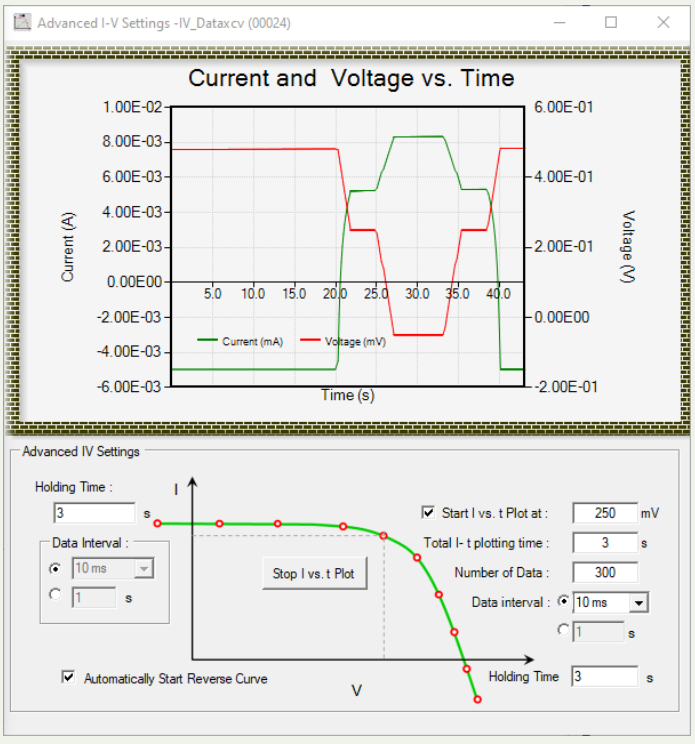
Calculated fitting parameters. This will show the difference of parameters calculated form the fitted curve and direct I-V data.

(This function is available on VK-PA-300 and VK-PA-8000)

(3) Advanced I-V Tracing Function:

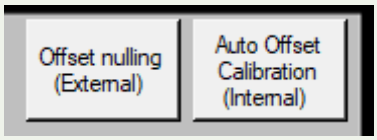
- This function allows user to change the following settings during I-V tracing and observe transient behavior of the cell.

1. Start point holding time
2. End point holding time
3. Current vs. time plot (I-t) for each data point
4. I-t plot for given fixed voltage in the middle of I-V curve.

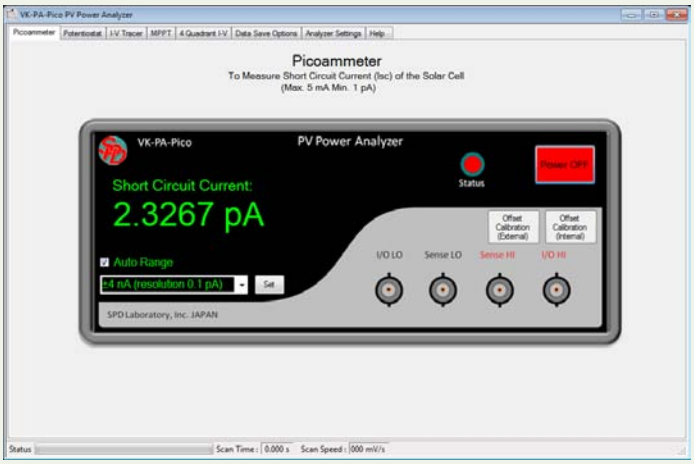


(4) Pico Ammeter Function:

- Pico ammeter function allow user to measure true short circuit current of PV device with 0 V voltage drop across the PV device.
- Analyzer uses trans-impedance amplifier with less than 4 µV offset and 0.015 µV/C˚ offset drift to perform this operation.
- VK-PA-Pico can reach the maximum measurement resolution of 17 fA.



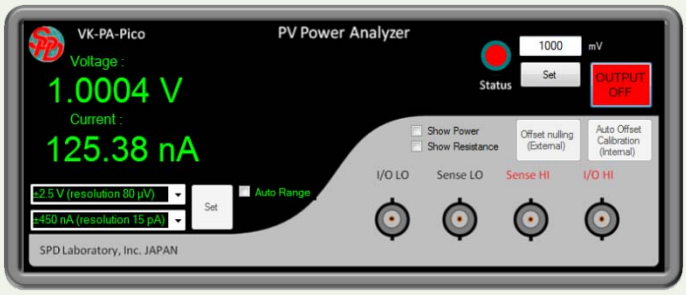
- Two automatic calibration functions allow user to null the thermoelectric current generated from dissimilar metal contacts in the circuit and measure only the photo current.



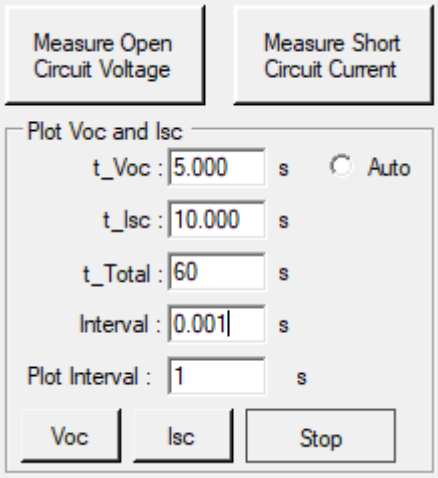
(This function is available on VK-PA-Pico only)

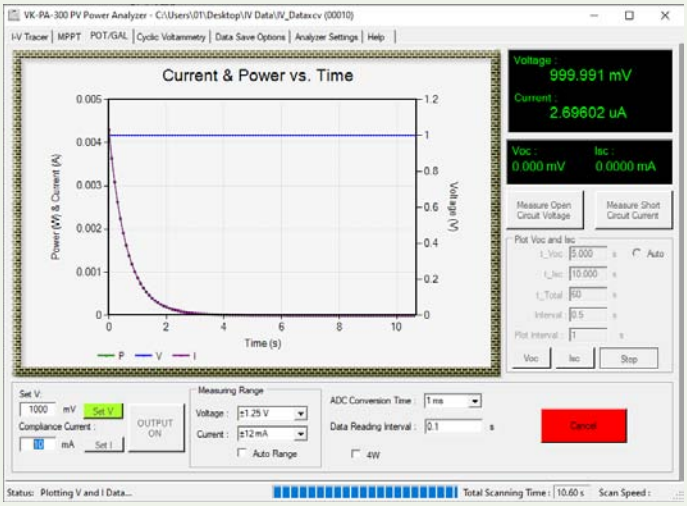
(5) Potentiostat /Galvanostat Function:

- Potentiostat function allow user to set the desired constant voltage across the sample and measure voltage current, resistance , and power.
- Galvanostat function (except VK-PA-Pico) allow user to set the desired constant current through the sample and measure voltage, current, resistance , and power.



- User can plot voltage , current, and power with the time under the given set voltage or current.

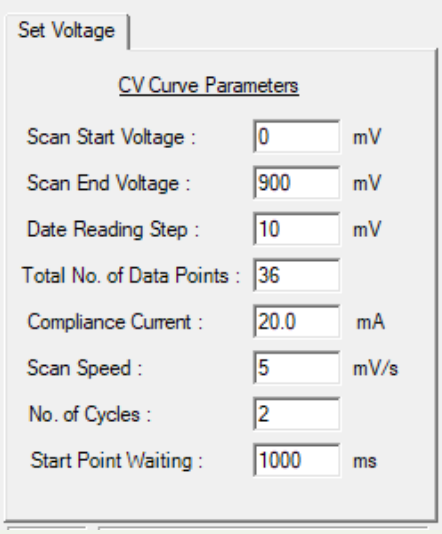


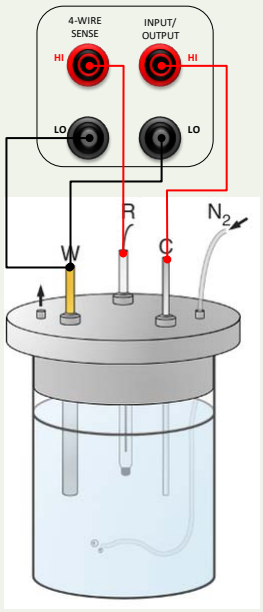


- "Plot Voc and Isc" special function allows user to plot the behavior of solar cell when it switched from open circuit to the short circuit condition and backward condition intermittently.

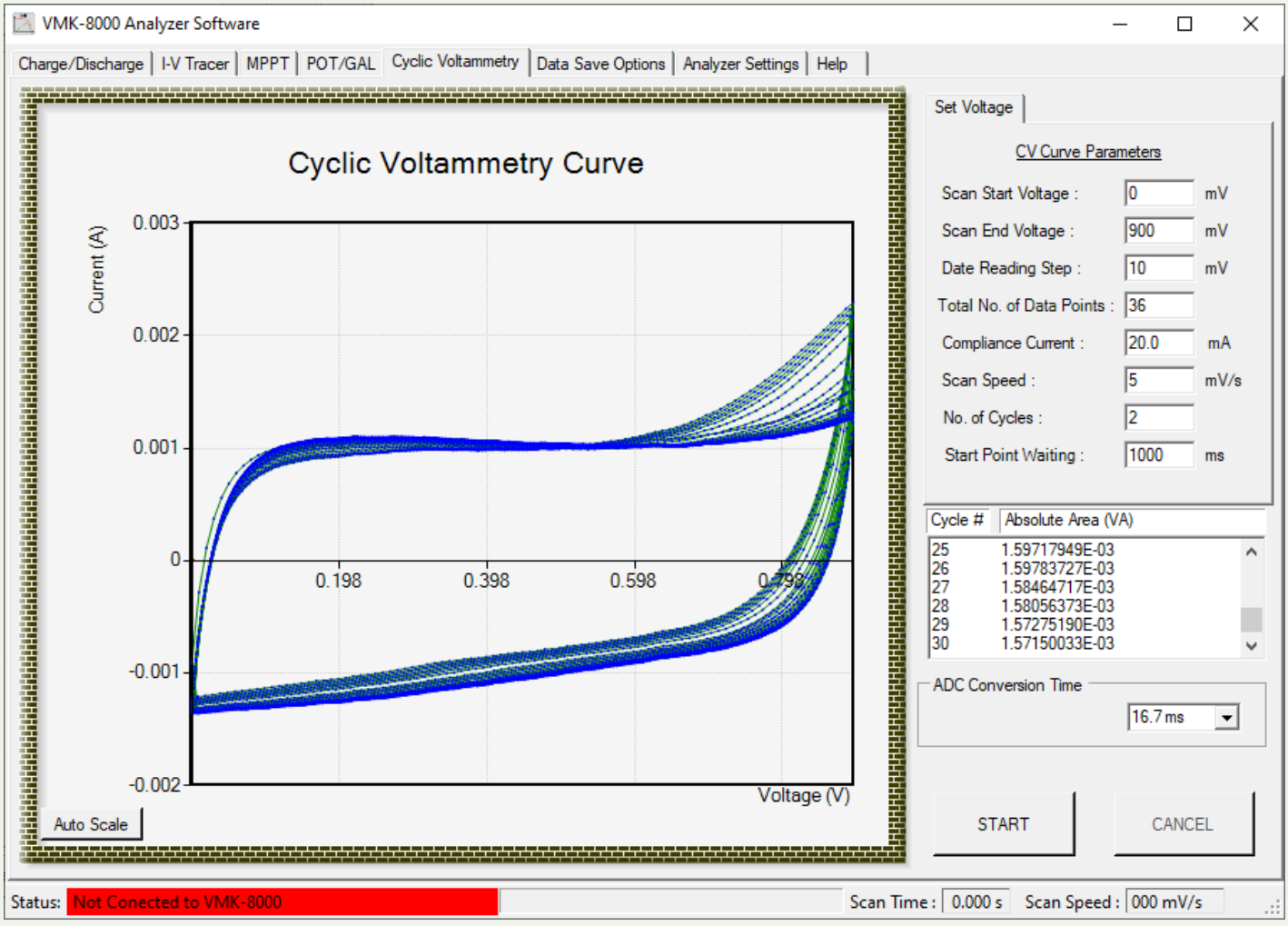
(6) Cyclic Voltammetry Function:

- This function allow user to plot CV curve of a sample.
- User can set the following parameters.





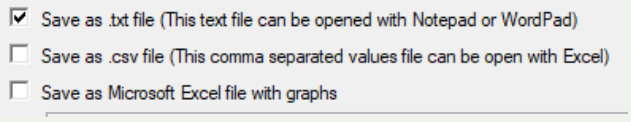
- User can use two or three electrode configuration to connect sample with the analyzer.
- The inside area of each curve is automatically calculated by the anlyzer software.



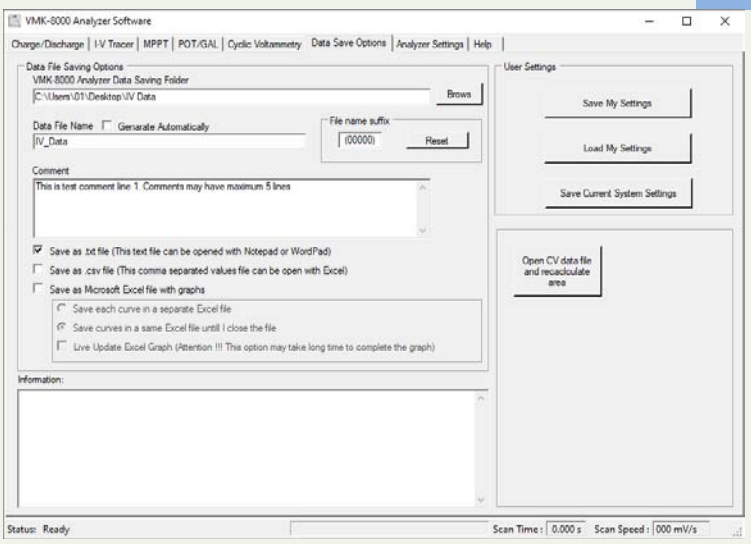
Screen shot of a Cyclic Voltammetry curve showing calculated absolute area inside each cycle

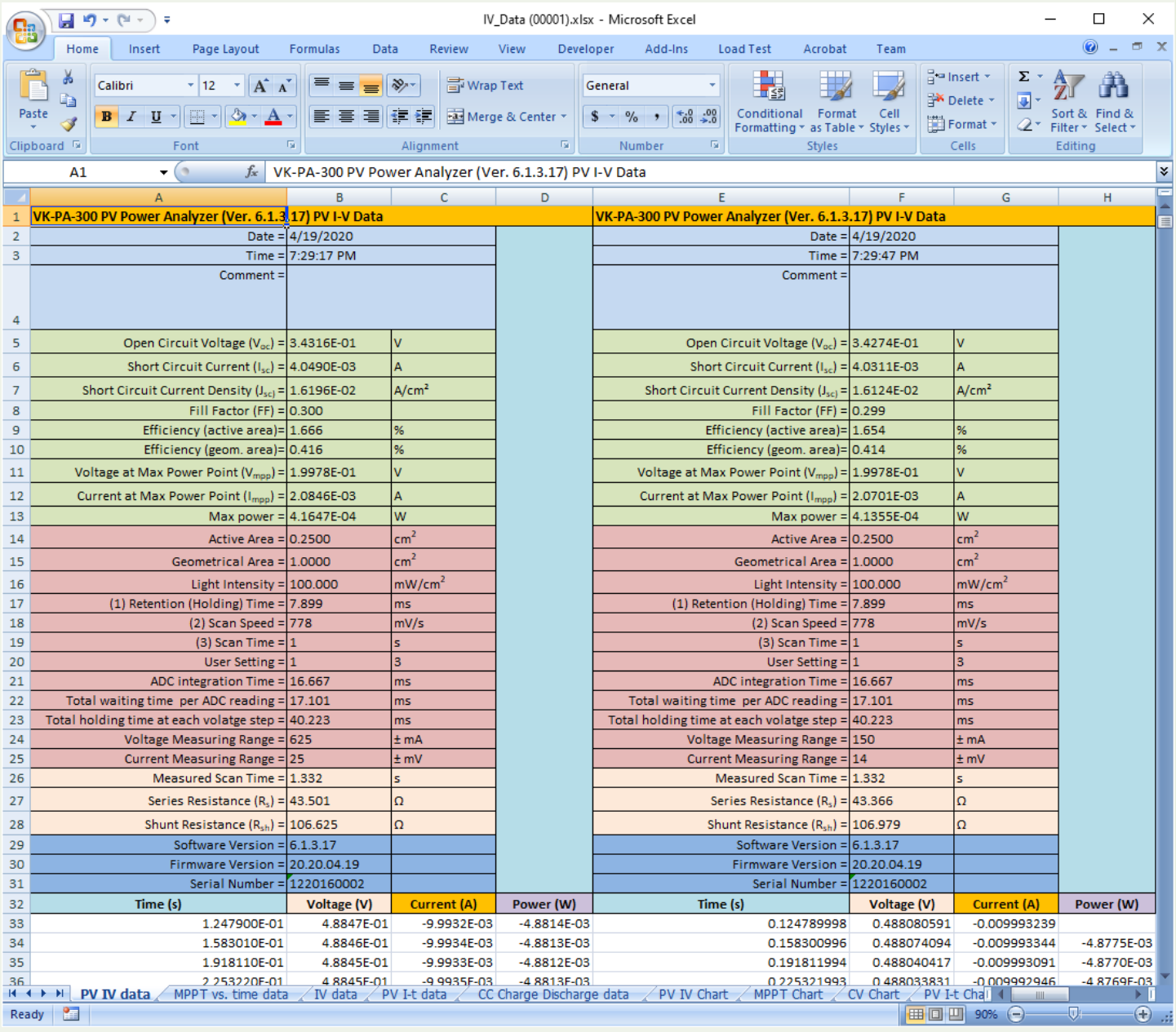
(7) Data Saving Options:

- The control software of our PV analyzer can automatically generate fully formatted Microsoft Excel workbook with data and graph.



- Text file (.txt) and comma separated text (.csv) format file saving is also possible.



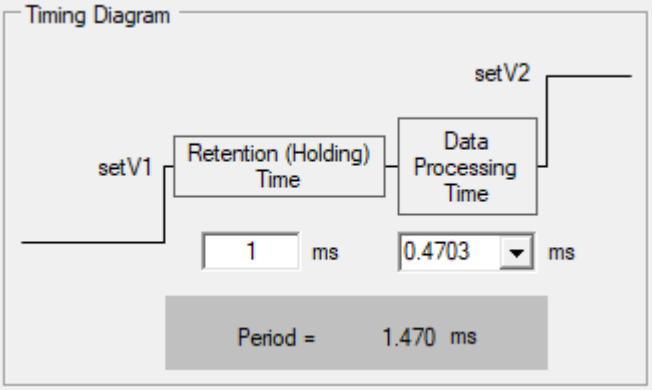


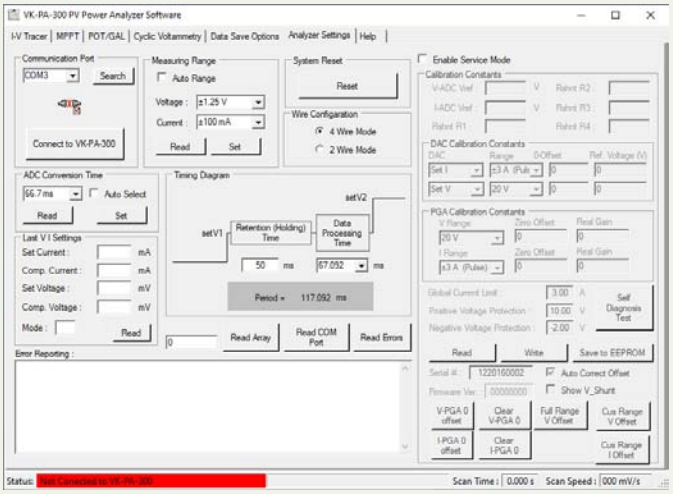
	A	B	C	D	E	F	G	H
1	VK-PA-300 PV Power Analyzer (Ver. 6.1.3.17) PV I-V Data				VK-PA-300 PV Power Analyzer (Ver. 6.1.3.17) PV I-V Data			
2	Date =	4/19/2020			Date =	4/19/2020		
3	Time =	7:29:17 PM			Time =	7:29:47 PM		
4	Comment =				Comment =			
5	Open Circuit Voltage (V_{oc}) =	3.4316E-01	V		Open Circuit Voltage (V_{oc}) =	3.4274E-01	V	
6	Short Circuit Current (I_{sc}) =	4.0490E-03	A		Short Circuit Current (I_{sc}) =	4.0311E-03	A	
7	Short Circuit Current Density (J_{sc}) =	1.6196E-02	A/cm²		Short Circuit Current Density (J_{sc}) =	1.6124E-02	A/cm²	
8	Fill Factor (FF) =	0.300			Fill Factor (FF) =	0.299		
9	Efficiency (active area)=	1.666	%		Efficiency (active area)=	1.654	%	
10	Efficiency (geom. area)=	0.416	%		Efficiency (geom. area)=	0.414	%	
11	Voltage at Max Power Point (V_{mpp}) =	1.9978E-01	V		Voltage at Max Power Point (V_{mpp}) =	1.9978E-01	V	
12	Current at Max Power Point (I_{mpp}) =	2.0846E-03	A		Current at Max Power Point (I_{mpp}) =	2.0701E-03	A	
13	Max power =	4.1647E-04	W		Max power =	4.1355E-04	W	
14	Active Area =	0.2500	cm²		Active Area =	0.2500	cm²	
15	Geometrical Area =	1.0000	cm²		Geometrical Area =	1.0000	cm²	
16	Light Intensity =	100.000	mW/cm²		Light Intensity =	100.000	mW/cm²	
17	(1) Retention (Holding) Time =	7.899	ms		(1) Retention (Holding) Time =	7.899	ms	
18	(2) Scan Speed =	778	mV/s		(2) Scan Speed =	778	mV/s	
19	(3) Scan Time =	1	s		(3) Scan Time =	1	s	
20	User Setting =	1	3		User Setting =	1	3	
21	ADC integration Time =	16.667	ms		ADC integration Time =	16.667	ms	
22	Total waiting time per ADC reading =	17.101	ms		Total waiting time per ADC reading =	17.101	ms	
23	Total holding time at each volatge step =	40.223	ms		Total holding time at each volatge step =	40.223	ms	
24	Voltage Measuring Range =	625	± mA		Voltage Measuring Range =	150	± mA	
25	Current Measuring Range =	25	± mV		Current Measuring Range =	14	± mV	
26	Measured Scan Time =	1.332	s		Measured Scan Time =	1.332	s	
27	Series Resistance (R_s) =	43.501	Ω		Series Resistance (R_s) =	43.366	Ω	
28	Shunt Resistance (R_{sh}) =	106.625	Ω		Shunt Resistance (R_{sh}) =	106.979	Ω	
29	Software Version =	6.1.3.17			Software Version =	6.1.3.17		
30	Firmware Version =	20.20.04.19			Firmware Version =	20.20.04.19		
31	Serial Number =	1220160002			Serial Number =	1220160002		
32	Time (s)	Voltage (V)	Current (A)	Power (W)	Time (s)	Voltage (V)	Current (A)	Power (W)
33	1.247900E-01	4.8847E-01	-9.9932E-03	-4.8814E-03	0.124789998	0.488080591	-0.009993239	
34	1.583010E-01	4.8846E-01	-9.9934E-03	-4.8813E-03	0.158300996	0.488074094	-0.009993344	-4.8775E-03
35	1.918110E-01	4.8845E-01	-9.9933E-03	-4.8812E-03	0.191811994	0.488040417	-0.009993091	-4.8770E-03
36	2.253220E-01	4.8845E-01	-9.9935E-03	-4.8813E-03	0.225321993	0.488033831	-0.009992946	-4.8769E-03

Example of Excel file for I-V data generated from VK-PA-300

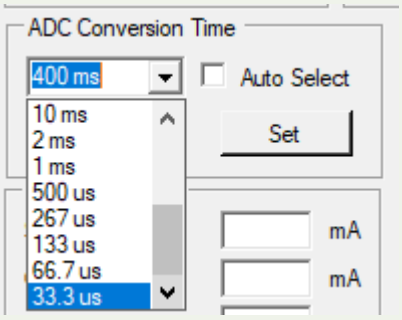
(8) Advanced User Settings:

- Our analyzers allow more flexibility to modify and monitor hardware .

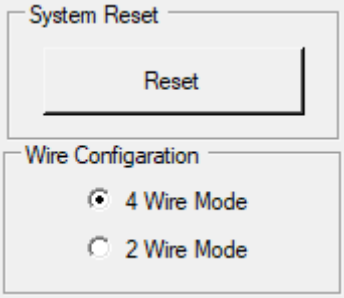




- Timing diagram will show you the details of real timing of voltage set point and data reading point.



- User has access to change the integration time of Analog to Digital Converter (ADC).



- Analyzer can be “Reset” using the software button remotely.
- Four or two wires configuration can be selected.

(9) Wireless Bluetooth Connection:

- Control command and data communication between PV analyzer and a computer is established by a Bluetooth communication.
- There is no wire connections between PV power analyzer and the computer where you installed the control software.
- User can conveniently place PV analyzer and computer in a two separate places in the laboratory.