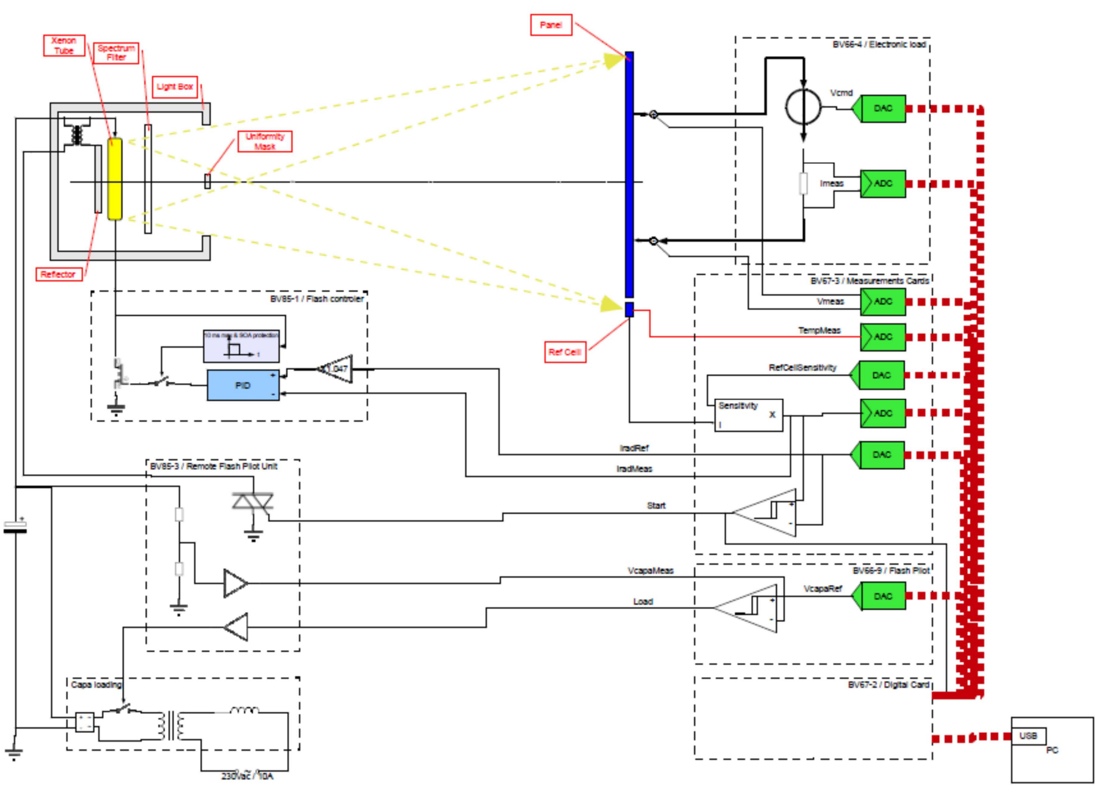
Training Manual

Module: Measurement Principles



SunSim 3b/3c

Part-No.: Osc_010103
Version (Date): beta_16.12.2011

A member of Meyer Burger Group

PASAN S.A.
Rue Jaquet-Droz 8 / CH-2000 Neuchâtel
Phone +41 (0) 32 391 16 16
service@pasan.ch / www.pasan.ch

Table of Contents

1 Learning Objectives

The trainee will understand the measurement principles of the SunSim 3c/3b and can explain the whole measurement loop. He will have the knowledge to perform a quality measurement and knows how to interpret typical errors.

1.1 Requirements

The trainee needs to know the basics of the general operation of the SPROD/SLAB software. He is familiar with the names of the measurement cards and can name the different parts of the SunSim. He knows how to initialise a measurement. The trainee will broaden his knowledge by studying the software user manual.

Further the trainee will take over the responsibility for the correct machine and module settings and will do the set up of the module recipes.

2 Security

Never open the lamp housing while the power cable is still connected to the lamp. Risk of sever eye injury and electrocution. High voltage inside.

Never open the flash generator cabinet. Risk of electrocution. High voltage inside.

Never touch the contactors for the module while a measurement is taking place. Risk of electrocution . High voltage can be applied during the measurement.

Never look towards the flash lamp while a flash can occur. Risk of eye injury.

Always switch off the flash generator cabinet when approaching the lightning side of the flash lamp closer than the distance that you have between the module and the flash lamp (SunSim 3c →5.5m, SunSim 3b →8m). Risk of severe eye injury.

3 Flow of measurement

To obtain a quality measurement, all the parts of the SunSim play their role. They stand in relation to each other.

During the measurement cycle, the software SPROD in not interfering into the capturing of the data. There are three basic phases to a measurement:

- SPROD sends the machine settings to the electronic load (E-load)
- E-Load controls the measurement loop and captures/stores the data
- SPROD fetches the recorded data and post processes it

3.1 Flow diagram

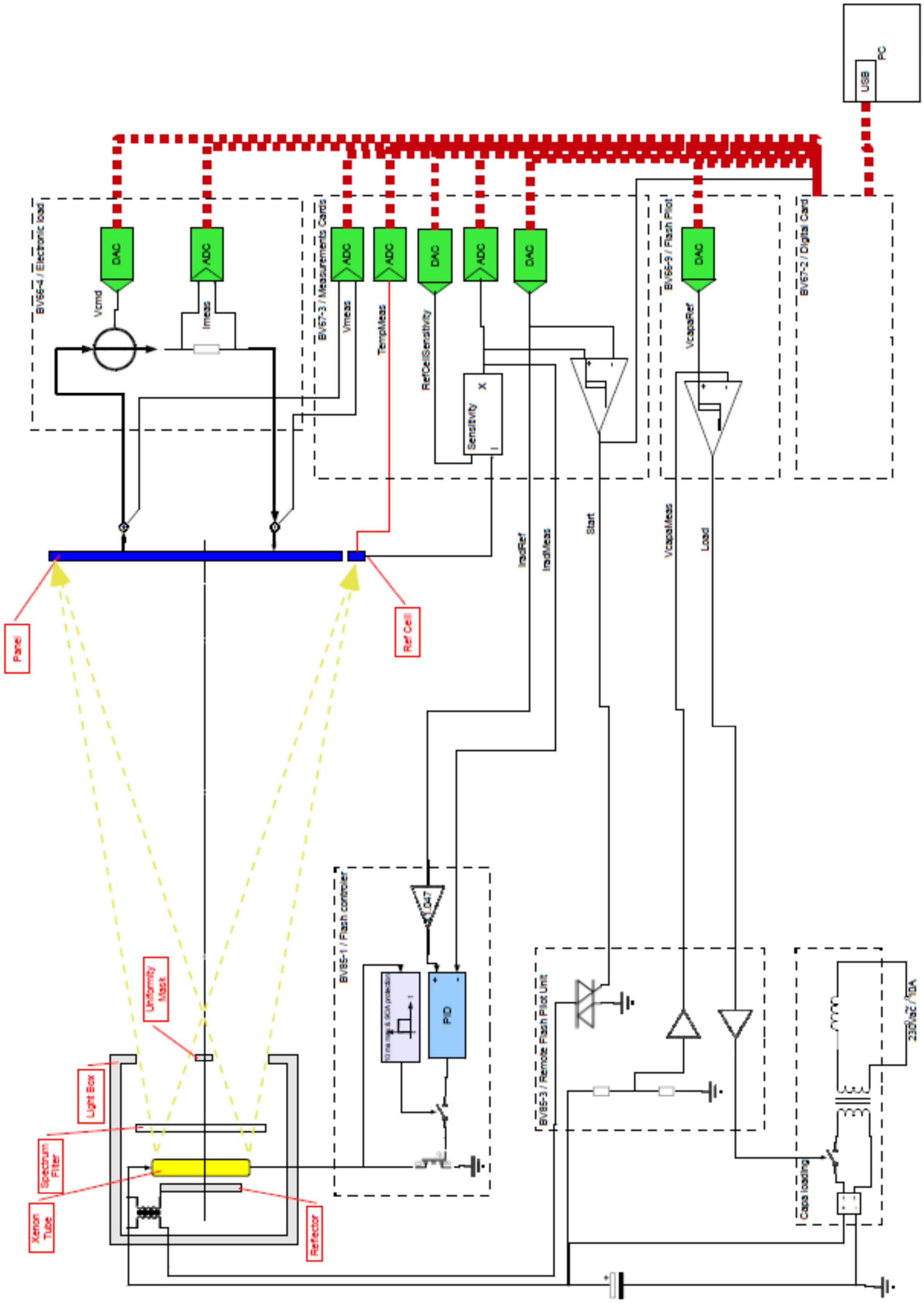


Fig 1: Electronic flow diagram for the SunSim

PC

Via the software SPROD the machine settings are loaded to the E-load prior to the measurement. These are

- The flash capacitance load
- The irradiance adjust factor
- The sampling rate
- The number of samples
- The voltage ramp
- The scales to use for the measurement of the current and voltage
- The set value of the monitor cell

Charging of the capacitors

The flash capacitance load which can be accessed via SPROD→config→setup determines to which final voltage the capacitors inside the flash generator cabinet will be loaded. A value of 800V corresponds to 100% flash capacitance load.

In the E-load, the flash pilot card BV 66-9 constantly monitors the charge of the capacitors and compares it with the set value. In case the charge is too low the charging will be started until the set value is reached.

Starting the flash

The signal to start a measurement can be either triggered by SPROD or by the flash pedal. The start signal will be send from the voltage measurement card BV 67-3 via the flash pilot unit to the BV 83-3 card on the flash generator. The command to ignition the flash tubes is send and the discharge of the capacitors is taking place.

Control loop

The monitor cell receives the flash light and is generating a current. The voltage drop over a build in 1 ohm resistor is proportional to the amount of received light and is constantly being measured. It is the input for a PID control loop which is located on the BV 85-3 card. This measured value is being subtracted from the previously programmed set value and the discharge of the capacitors is then driven by the so called ballast (a set of Mosfet inside the flash generator cabinet). After 10.5ms this control loop gets shut down and no more current can flow to the flash tubes.

Measurement

The irradiance (a voltage) gets constantly recorded by the USB card (BV67-2). When a threshold is reached, the measurement will start. At each sample point, a voltage gets injected to the module by the current card (BV 66-4) and depending on the module settings a certain measurement scale is used to read the current (Iread). At the same time the irradiance (Irrad) and the read back voltage (Vread) is recorded by the voltage card (BV 67-3). The sample rate and the number of sample points were previously defined by the mode settings. When the voltage ramp is applied, the sampling of the corresponding values is always happening at the very end of the duration of the applied voltage. If the module that is being tested has a high capacity, this circumstance can help to achieve more exact data (extra time to stabilize), when the sampling time gets increased.

Vread can - and under no circumstance – never be the same as the imposed voltage. When a voltage gets applied, there are series resistances that add up. There will be a voltage drop on the measurement chuck, on the measurement cable, on the connector and finally on the module itself. When the voltage gets read back, although a Kelvin probe is used (measurement of voltage and current over two different cables), at some point these will meet in one wire and at that end a bigger voltage drop on Vread will happen.

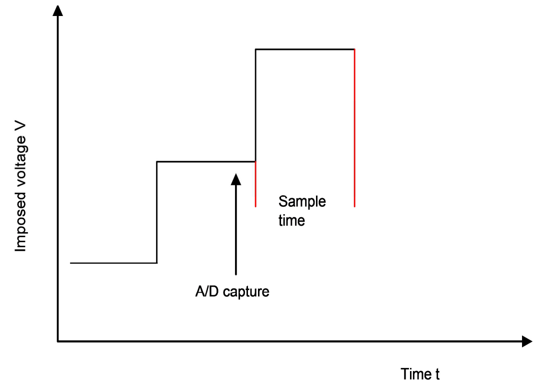


Fig 2: A/D sampling before next voltage step

Cycle

During the flash time of about 10ms the capacitors loose about roughly one third of their initial charge voltage. The flash pilot card will now detect the voltage difference and will start the charging of the capacitors again. If the charging takes longer than 30sec the flash generator will fall into alarm mode. Although the capacitors will charge up in less time, there is a delay of 30 seconds before a new flash can happen.

Processing of the data

At the end of the measurement, data is available and Sprod will fetch the stored data. Correction to the raw data will be applied. The data will be first temperature compensated, then computed to the reference irradiance and finally the calibration factors will be applied. If this compensated data is now valid to calculate the IV curve, this will be done and graphically displayed. Otherwise an error is shown.

An IV-curve can only be drawn, if

- The compensated voltage will at some point cross the 0 Volt with a ramp like look. This must happen during the measurement time of 10 ms
- The current that is generated by the module also needs to fall below 0 Amps after the applied compensation

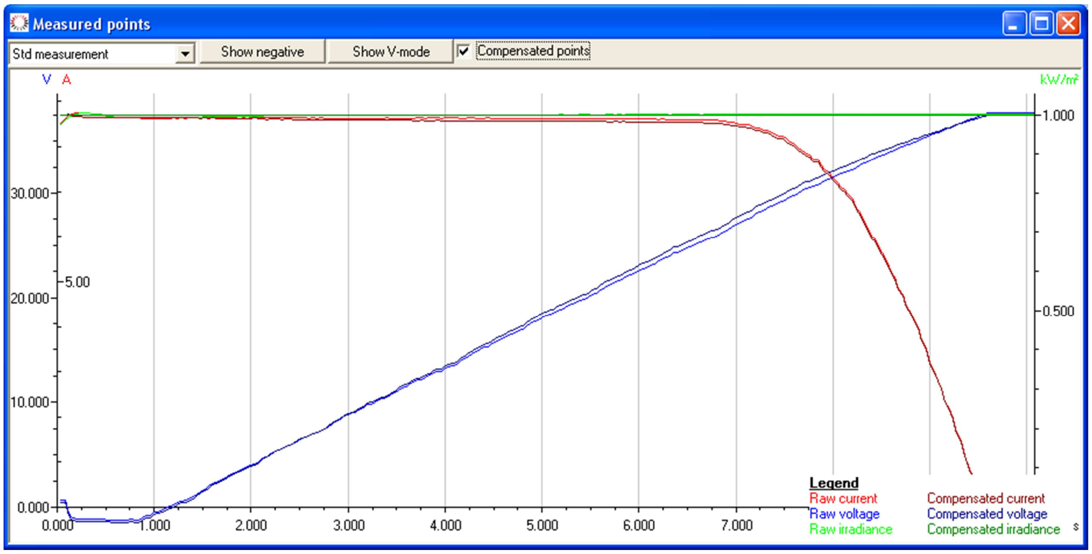


Fig 3: blue line is the voltage ramp, notice how it crosses smoothly the 0 axis, the first flat part is due to a trigger delay of about 0.8ms. When the compensated voltage gets positive, the irradiance (green line) shows stable values around 1000 W/m2. The red curve shows the generated current of the module and also crosses zero (hidden).

3.2 Settings for a quality measurement

Before setting the parameters for your module recipe you need to know some characteristics of your module.

You must know about the temperature coefficients unless you measure at 25°C. This information you should obtain from an official institute. If not available get this information from your cell supplier. Remember when you enter the values, that for silicon type modules these values lie in the range of alpha =10-25 uA/cm2/°C and for beta = -2.3 to – 1.8 mV/°C. If you calculate other values you are wrong!

3.2.1 Settings for the irradiance:

You want to be sure, that the irradiance is stable until the end of the measurement.

You get the most reliable information on this, if you don't just have a look at the graph and the green curve, but if you also have a look in the list of the measured points. There you scroll to the last measured points and confirm, that the values for Irrad are only maximum three points away from the average irradiance that is shown in the measurement result window.

If this is not the case, you need to increase the flash capacitance load. Choose a setting that will just allow you not to drop with the irradiance towards the end of the measurement.

List of measured points

Std measurement

Point []	Vimp [V]	Vread [V]	Iread [A]	Irrad [kW/m²]	Ucomp [V]	Icomp [A]	Pcomp [W]
212	32.861	33.545	5.71	1.001	33.994	5.67	192.750
213	33.008	33.643	5.62	1.001	34.082	5.57	189.941
214	33.203	33.789	5.45	1.001	34.211	5.41	185.187
215	33.398	33.984	5.21	1.001	34.380	5.18	177.934
216	33.594	34.131	5.09	1.001	34.514	5.05	174.446
217	33.740	34.326	4.85	1.001	34.683	4.82	167.060
218	33.936	34.473	4.71	1.001	34.815	4.68	162.800
219	34.131	34.619	4.46	1.001	34.933	4.43	154.711
220	34.326	34.717	4.35	1.001	35.018	4.32	151.184
221	34.473	34.912	4.12	1.001	35.188	4.08	143.727
222	34.668	35.010	3.99	1.001	35.271	3.96	139.622
223	34.863	35.205	3.71	1.001	35.435	3.68	130.477
224	35.059	35.352	3.53	1.001	35.562	3.50	124.563
225	35.205	35.547	3.22	1.001	35.721	3.19	114.036
226	35.400	35.645	3.06	1.001	35.800	3.03	108.560
227	35.596	35.791	2.81	1.001	35.917	2.79	100.034
228	35.791	35.938	2.65	1.001	36.047	2.63	94.627
229	35.938	36.133	2.34	1.001	36.207	2.32	83.986
230	36.133	36.230	2.17	1.001	36.284	2.15	78.009
231	36.328	36.377	1.97	1.001	36.408	1.95	71.038
232	36.523	36.572	1.66	1.001	36.567	1.64	60.001
233	36.719	36.670	1.47	1.001	36.644	1.46	53.552
234	36.865	36.865	1.15	1.001	36.801	1.14	41.827
235	37.061	36.963	0.92	1.001	36.871	0.91	33.683
236	37.256	37.109	0.64	1.001	36.984	0.63	23.385
237	37.451	37.256	0.47	1.001	37.112	0.46	17.168
238	37.598	37.451	0.11	1.001	37.265	0.11	4.049
239	37.793	37.549	-0.12	1.001	37.334	-0.12	-4.633
240	37.988	37.695	-0.39	1.001	37.450	-0.39	-14.452
241	38.184	37.695	-0.39	1.001	37.449	-0.39	-14.634
242	38.330	37.695	-0.40	1.001	37.448	-0.40	-14.996
243	38.525	37.695	-0.41	1.001	37.447	-0.41	-15.178
244	38.721	37.695	-0.41	1.001	37.447	-0.41	-15.178
245	38.916	37.695	-0.41	1.001	37.447	-0.41	-15.359
246	39.063	37.695	-0.42	1.001	37.446	-0.42	-15.540
247	39.258	37.695	-0.42	1.001	37.446	-0.42	-15.540
248	39.453	37.695	-0.42	1.001	37.445	-0.42	-15.721
249	39.648	37.695	-0.42	1.001	37.445	-0.42	-15.903
250	39.795	37.695	-0.42	1.001	37.445	-0.42	-15.903
251	39.990	37.695	-0.43	1.001	37.444	-0.43	-16.084
252	0.000	37.695	-0.43	1.001	37.444	-0.43	-16.084

Print ... Exit Copy

Fig 4: The measurement points can be displayed by hitting the Val button. In this window you can see, that the last measurement points still receive a constant irradiance.

This setting can be accessed via: Menu→Config→Setup and determines to which final voltage the capacitor banks in the flash generator will be loaded. 100% corresponds to 800V. Typical values range between 80% and 94%. This value needs to be increased, if the irradiance starts dropping towards the end of the measurement time of 10ms (behaviour when the tubes get older). This you can check by having a look at the graph (Fig 3) and the value (Fig 4) window.

After an exchange of flash tubes the flash capacitance load is decreased again.

It is advised to monitor the irradiance and if necessary to perform an adjustment of this parameter

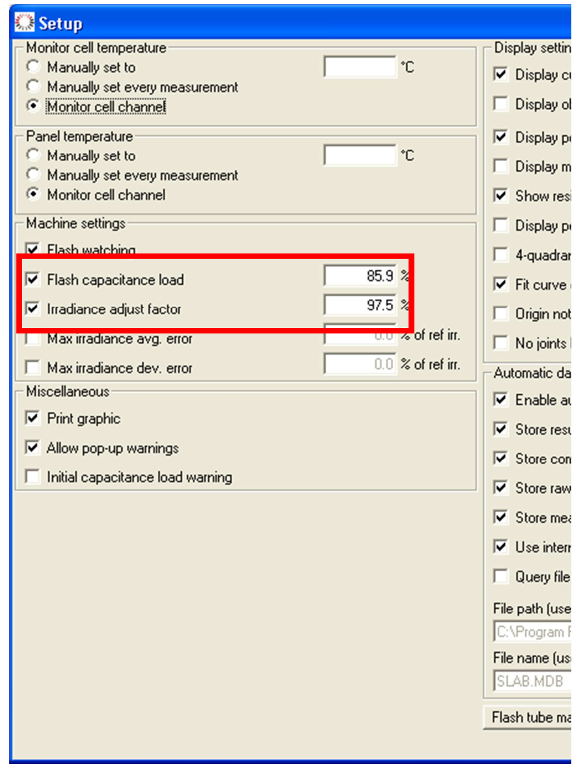


Fig 5: Machine settings

You also want to be close to your desired irradiance. This will be 1000 W/m2 STC.

You can influence the avg. irradiance by trimming the irradiance adjust factor.

This setting can be accessed via: Menu→Config→Setup and holds the value for the gain of the irradiance regulation loop. In the control theory this is the multiplier, the I element of the control loop. The value that is set for the irradiance adjust factor (Fig 2) is proportional to the avg. irradiance which is displayed in the values box on the main window (Fig 5).

By doing a cross multiplication (rule of three) you set this value so you get an avg. irradiance of 1000W/m2.

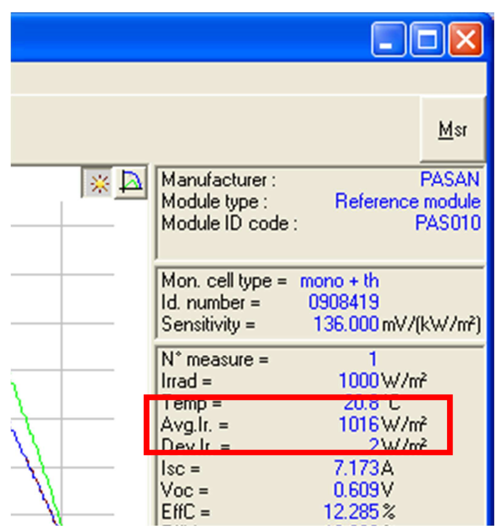


Fig 6: The avg. irradiance measured

3.2.2 Module parameter settings

By defining the module settings you control how your module will be measured.

During the measurement information is recorded, so that an IV curve can be calculated. To draw an IV curve you need some valid measurement points. You want to have this IV curve sharp enough to fulfil your requirements. This depends on the number of data points. If you sample your measurement with the maximum rate you will have more points than you need and you need to save a lot of data which will quickly fill your hard drive. As a rule of thumb, 200 data points for your IV curve are enough. (You can modify the number of sample points in the measurement mode menu.) You want to distribute them over a valid measurement time. Fig 7. shows you a very nice measurement. The voltage ramp crosses zero at about 1.2 ms and the current drops below zero right near the end of 10 ms. This is the time frame that is used for calculating the IV curve.

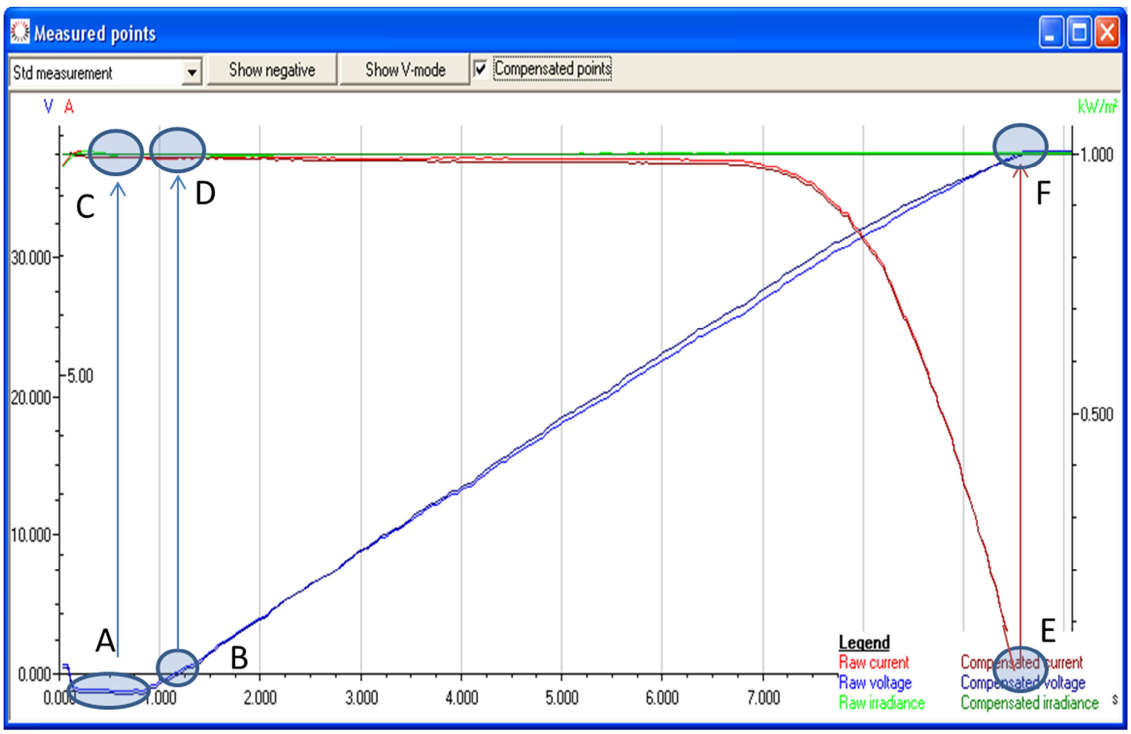


Fig 7: Points that qualify a good setup of the module parameters

In above measurement some points are marked with circles and a letter. The compensated data is also displayed. This is why you notice a close by second line. The marked parts give some extra information about the quality of the measurement.

- **A**: here you see a plateau before the beginning of the voltage ramp. The electronic load injects the start scanning voltage to the DUT. Then during the trigger delay (setting in the module parameters) this negative voltage is held. It is what this plateau shows. After the trigger delay the voltage ramp starts.
- **B**: from negative voltage points we cross to positive voltage. This point we call Vread=0.
- **C**: At this point the current is observed, while the electronic load is injecting negative voltage to the DUT. You don't want to see a big current spike here. If a current spike is shown (saturating the measurement scale), it means, that your bypass diodes are conducting. Our load in this case will provide up to 30A, if on the module side such little resistance is given to it. There is the risk, that bad quality diodes can be harmed. If you observe

this behaviour your start scanning voltage is too low. Decrease (less negative) the start scanning voltage to a value, where you just don't notice a rising current (or it only rises a tiny bit).

- **D**: This is the Isc point. You retrieve this point from the position of Vread=0. At this position you want to observe the green irradiance graph. The irradiance is controlled by a control loop and like every control system it needs some time to stabilize. Check that the irradiance is already stable at this point, because the Isc point will be the first valid point in your IV-curve. If this is not the case, increase the trigger delay

- **E**: At this point the red current line will go from positive to negative. This point is called Iread=0. You should not cross too close to the 10ms mark. Leave about 0.5 ms as a buffer. To cross earlier you need to increase the absolute maximum voltage in the module parameters.

- **F**: This is called the Voc point and is found where no current will flow. At this point you also want to observe the irradiance. You want to notice, that it is still stable. If not so, increase the flash capacitance load under config→setup. The age of the flash tubes will have an effect on the irradiance and regular adaption of the flash capacitance load is necessary.

Remarks: