SOLARTRAINER *junior*

Experiments with Solar Cells

Solutions

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IKS Photovoltaik

Lehrsysteme
Messtechnik
Sonderentwicklungen

Supported by the

ISET Institut für Solare Energieversorgungstechnik
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Contents

Intended Use

Notes on Safety

- The assemblies may only be operated when connected to the voltage intended for them.
- If the power cord is damaged, it may only be replaced by an expert.
- When pulling out the power cord, always pull the plug never the cord. Never put heavy objects on the cord and do not bend it in a narrow circle or around sharp edges.
- The permitted ambient temperature (room temperature) during operation may not fall below or exceed 10 °C and 40 ° C, respectively.
- The system is intended for use in dry and clean rooms.
- In case of condensed water a time for acclimatization of up to 5 hours must be adhered to.
- Operation of the system in the open or in moist rooms is not permitted.
- Protect the system from humidity, splash water and heat.
- The system may not be used in connection with easily inflammable and combustible liquids, gases or dusts.
- The modules may only be operated under the supervision and guidance of a competent teacher. In schools and other educational facilities, the operation of the system is to be supervised carefully by trained and qualified personnel.
- In case of industrial associations, the accident prevention regulations of the industrial trade cooperative association concerning electric plants and appliances are to be adhered to.
- If a module needs repair, use only original replacement parts! The use of deviating replacement parts can lead to considerable material and personal damage!
- A repair may only be carried out by a qualified expert!
- Always disconnect the system from the supply voltage after use.
- If liquid leaks into a module, this could lead to damages. If any liquid has been spilled over the assembly, the device must be disconnected from the power supply and tested by a qualified expert.
- When working with products in connection with electric voltage, adhere to the valid VDE (German Electrotechnicians' Association) regulations, especially VDE 0100, VDE 0550 / 0551, VDE 0700, VDE 0711 and VDE 0860.
- Before opening the module, always pull out the power plug and make sure the device is dead.
- Connection to the power supply network should only be made via a fault-current circuit breaker and a circuit with emergency switch.
- Cabling may only be made using the enclosed measuring cables.
- During operation of the modules, strictly adhere to the characteristic values for electric units mentioned in the respective description.
- Experimental assemblies always need to be checked with regard to their correct cabling / connection by qualified teaching or supervising personnel before commissioning.
- If the modules are used for experimental assemblies that are not described in these instructions, always check if the respective modules are fit for such use. If in doubt, always check with the manufacturer.
- Cleaning of the components may not be done using solvents. Clean with soft, dry or only slightly moist cloth.
- The factory-mounted signs and labels may not be modified, removed or made indecipherable.

Non-liability

The consulting engineers Kunsch (IKS) cannot control the adherance to these instructions nor the conditions and methods in terms of connection, operation, use and maintenance of the system.

Please note that operating and connection errors are beyond our control.
A faulty connection or operation can lead to material damages and in consequence, to health hazards.
Therefore, we do not assume responsibility and liability for losses, damages or costs resulting from faulty connection, improper operation or improper use and maintenance or being in any way connected with it.

We reserve the right to modify the product, its technical data or operating / experimenting instructions without prior notification.

Intended Use

The Intended Use of the individual modules is described in the previous pages and the instructions. Any use deviating from this is not permitted and done at the user's own risk.

Warranty

1. The delivered goods are to be inspected for transport damages by the customer immediately after arrival at their destination. Complaints concerning incomplete or wrong deliveries are to be notified to us no later than 8 working days after arrival of the good at their destination with sufficient justification. When this period has passed, the delivery shall be considered completed as per agreement.

2. We shall be liable for any hidden defects that could not be detected in immediate inspection, for a period of six months after the day of delivery, repair or replacement of the defective material at our discretion. If such a repair or replacement is impossible, failed or unacceptable, the customer can only demand a reduction of the purchase price or a cancellation of the defective part of the purchase agreement. In any case, the defective part is to be sent to our address for the purpose of repair or delivery of a replacement part and also in case of a cancellation of the agreement by the customer. For essential foreign products, the liability of the supplier shall be limited to the transfer of the liabilities he has towards the supplier of the foreign products.

3. The customer's right to assert claims from defects, shall expire in any case after six months from the time of due notification, but no sooner than with the expiry of the warranty.

4. Natural wear, improper use, negligence, damaging influence of unauthorized persons, use without supervision, as well as modifications of the delivered goods by the customer or third parties without our written consent, shall exclude our liability for defect and warranty obligation without exception.

5. The customer has to give us sufficient time and opportunity to rectify defects. If the customer is not willing to do this, or willing only under unacceptable conditions, any warranty obligation from our side shall expire. This also applies to notifications of defects according to point 1.

6. The warranty period for the replacement part and the repair shall be three months, but expiring no sooner than the original warranty period for the delivered object. The period for the liability of defects at the delivered object shall be extended by the duration of the downtime caused by the repair works.
   Further warranty and damage claims of the customer in any form are excluded, in particular any claim to damages that did not occur at the delivered object itself as well as claims of the customer from unpermitted actions of the supplier, if such an exclusion is permitted by law.
   In as far as the above-mentioned nonliability is not permitted by law, our liability shall be limited to 5 % of the purchase price of the material having caused the damage or being subject of the claim or in any way connected therewith, notwithstanding the legal argument.

Information

The values contained in the solutions can deviate from the actual measured values on account of tolerances of the parts and different operating conditions.

Some influences may be for instance thermal fluctuations, ambient light when irradiating the solar cells, changes in the brightness of the halogen lamp due to variations of the supply voltage etc.

When measuring the current values, pay attention to the stated measuring ranges for the multimeters.

The range “10 A” has a smaller internal resistance than the range “DCA 2000 mA”.
Refrain from switching between ranges during measurement, as this might tamper the series of measurements.

Information

The purpose of the measurements is to enable a classification of the dimension of irradiances.

The irradiation of the sun reaches a very high value on the earth despite the distance of about 150 million kilometres.

This value depends on the climatic conditions.

The irradiation depends on the distance of the measuring point from the light source.

The experiment with the artificial light source can show that the irradiation does not decrease linearly with the distance.

The fact that the value does not decrease exactly with the squared distance is due to the light source, which is not an ideal point, as well as to reflections and inaccuracies of the measuring devices.

Since the energy supply of the device is ensured by a solar cell, the measuring range starts at approx. 15 W/m^2.

Below an irradiation of 15 W/m^2, the values can be false.

*1 When measuring from a higher towards a lower irradiation, lower values can also be measured, since the internal storage capacitator is then charged, stabilising the supply of the measuring devices.
In practice, the room lighting is measured in Lux (brightness) For a better comparability, however, W/m^2 (irradiance) is used here, with 1 mW/cm^2 corresponding roughly to 1,250 Lux.

*2 Representative maximum value / width

Light source	Irradiation [W/m^2] / with distance	Irradiation [W/m^2] / with distance	Irradiation [W/m^2] / with distance
Halogen lamp (level 10)	*1,400 / 10 cm*	*400 / 20 cm*	*200 / 29 cm*
Flashlight	*125 / 10 cm*	*40 / 20 cm*	*21 / 30 cm*
Room lighting *1	*5 / 10 cm*	*3 / 60 cm*	*3 / 120 cm*
Sun * 2	*1,100 / 0° (Equator)*	*1,000 / 36.5° NB*	*920 / 51° NB*
Overcast sky	*65 / 0° (Equator)*	*50 / 36.5° NB*	*28 / 51° NB*
	The representation of the energy yields makes it possible to take time and local weather conditions into account:		
	1,100 / 0° (Equator)	*1,000 / 36,5° NB*	*920 51° NB*
	2,200 kWh / m^2 / a	*1,500 kWh / m^2 / a*	*860 kWh / m^2 / a*

With a distance of approx. 10 cm from the halogen lamp, one yields the same value as for a measurement of the irradiation from the sun on a clear day.

In comparison, room lighting is considerably weaker.

The distance from the light source has an influence on the value measured. Power does not decrease linearly with the distance, but stronger.

Despite the large distance of the sun to the earth, the irradiation power is comparatively great.

Information

Since the direction of rotation of the motor keeps changing, the solar cell depends on the polarity, just like a battery as a direct current source.

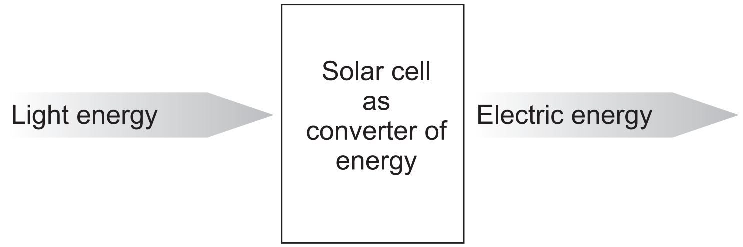
The motor will start only if sufficient light energy hits the solar cell.

The solar cell converts light energy directly into electric energy. There is only one conversion step:

Light energy
→ electric energy

In existing thermal power plants, four conversions take place:

Primary energy (fossil energy)
→ Thermal energy
→ potential energy (steam pressure)
→ Kinetic energy
→ electric energy



The direction of rotation of the motor keeps changing (as it is a direct current load).

The stronger the irradiation, the faster the motor turns.

In solar cell, light energy is converted to electric energy.

The stronger the irradiation, the more electric energy is converted.

In an electric motor, electric energy is converted in kinetic energy.

Information

Please note that the accumulator is charged at the start of the experiment.
Charging current 6.5 mA / 10 hours. Maximum voltage 1,4 V.

If the individual tasks do not take up too much time, a GoldCap capacitator can also be used as an alternative. Charge with maximum voltage of 2.3 V for approx. 7 minutes.

Can be connected with experiment 13 “Charging a GoldCap Capacitator / Accumulator”, page 23.

Results without shading plate:
Setup A

The solar cell as diode is in the circuit in the direction of the flow, but becomes an active voltage source when irradiated and delivers a voltage in opposition to the voltage of the accumulator.

Results without shading plate:
Setup B

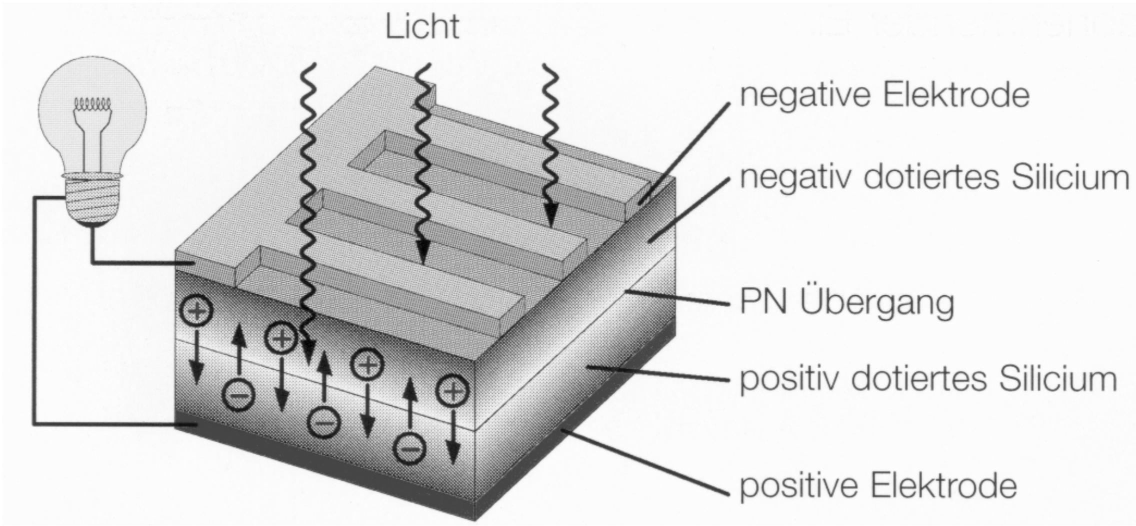
The solar cell is in the circuit in blocking direction, but becomes an active voltage source when irradiated and delivers a voltage in line with the voltage of the accumulator.

Results with shading plate:
Setup A

The solar cell as diode is in the circuit in the direction of the flow. There is voltage drop of approx. 0.4 - 0.5 V at the solar cell.

Results with shading plate:
Setup B

The solar cell as diode is in the circuit in blocking direction. There is a low leakage current flowing through the solar cell.



Results without shading plate:
Setup A

The motor is turning right. There is a current of 23 mA in the circuit

Results without shading plate:
Setup B

The motor is turning right, faster. There is a current of 29 mA in the circuit

Results with shading plate:
Setup A

The motor is turning right, somewhat faster than without shading. There is a current of 23 mA in the circuit

Results with shading plate:
Setup B

The motor stands still, there is a current of 0.3 mA in the circuit

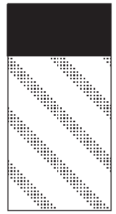
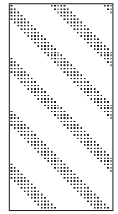
Information

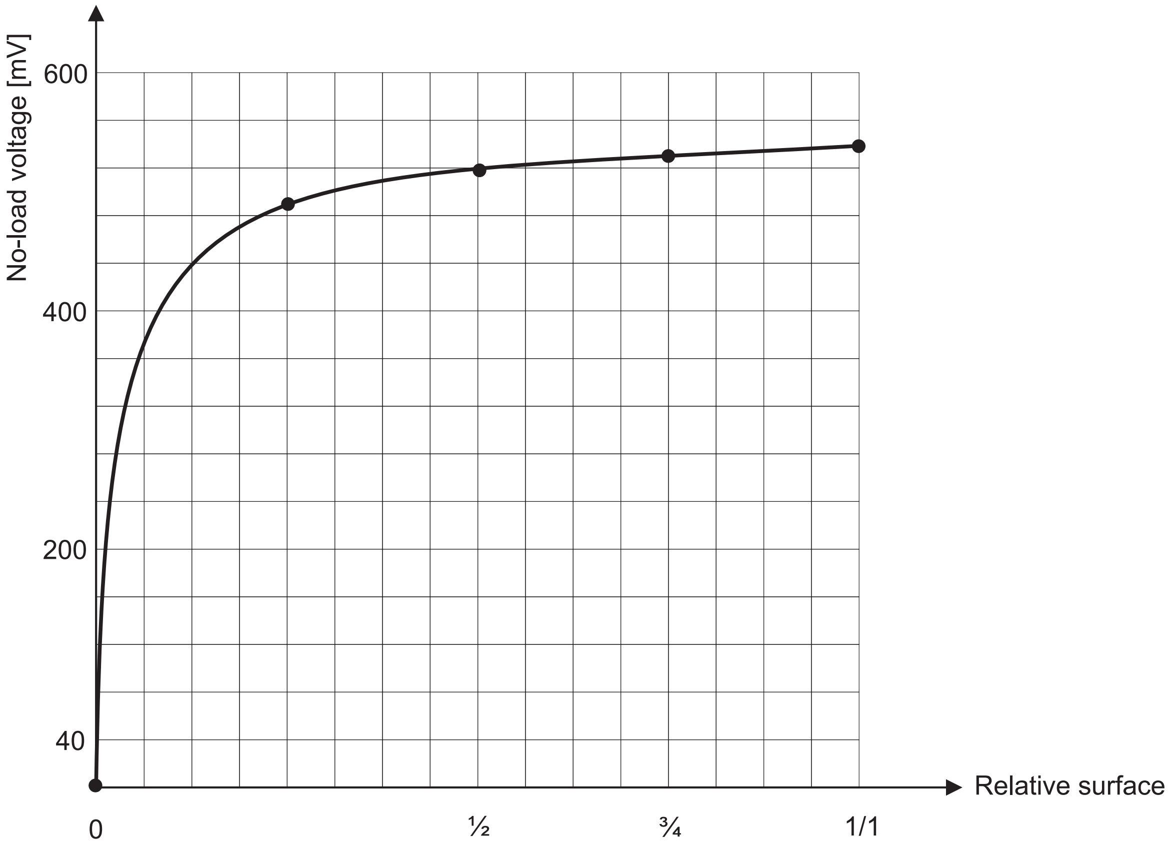
The no-load voltage U_L of a solar cell from silicon is U = 0.56 V with an irradiation of the sun of 1,000 W/m^2 and + 25 °C solar cell temperature.
Due to its dependency on temperature, the no-load voltage decreases with a decreasing temperature by approx. 2.3 mV/K.

A larger solar cell surface is therefore practically equivalent to a parallel connection of voltage sources. This means almost the no-load voltage of the unshaded cell already for smaller surfaces.

Possibly record intermediate values for surfaces of ½ to 0 by partial shading with a full plate.

A voltage greater zero can be measured mostly with complete shading due to ambient light. In order to improve the result, the halogen lamp should therefore be switched off.

Irradiated surface of the solar cell	0 	½ 	¾ 	1/1 
No-load voltage [mV]	*150*	*501*	*513*	*521*



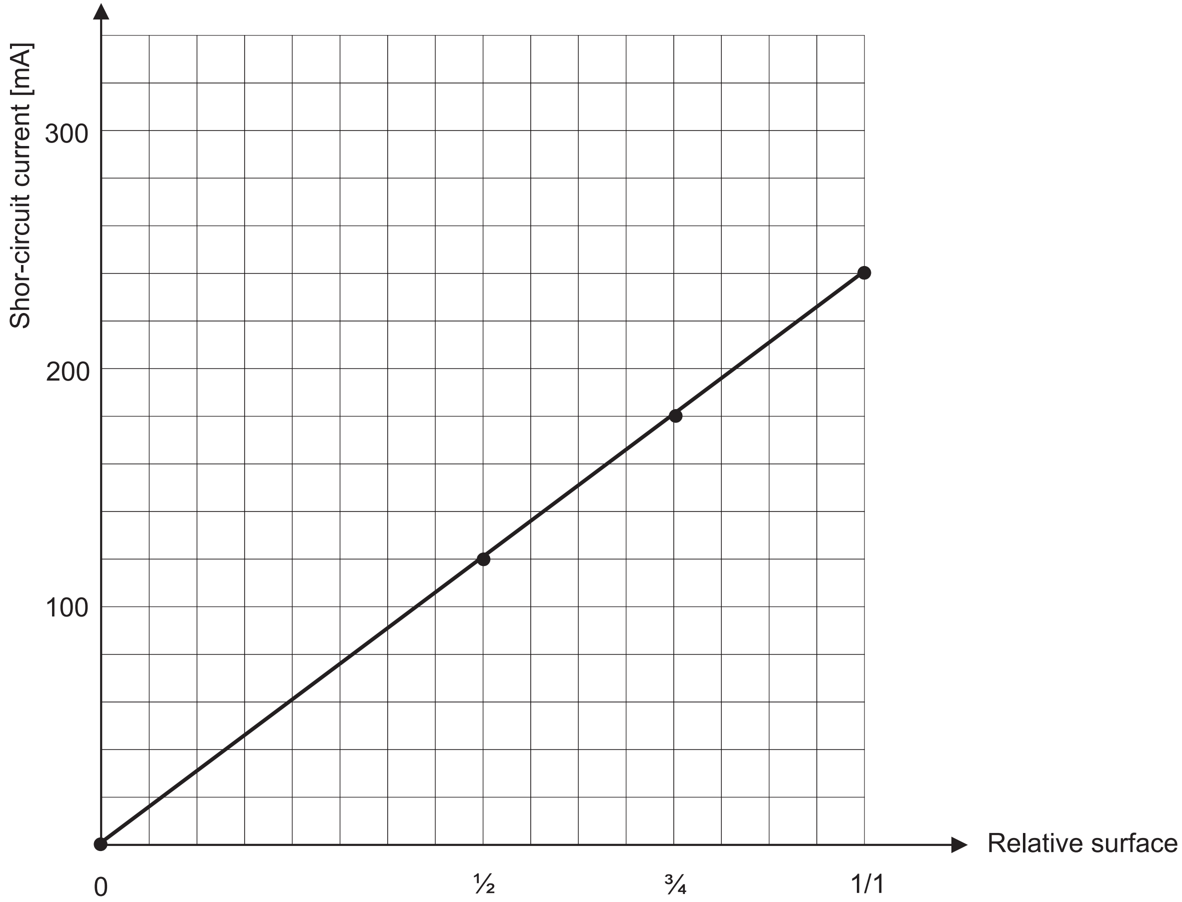
Even when irradiating a small surface, the voltage lies within the range of the no-load voltage of the whole solar cell

Information

The short-circuit current depends on the irradiated solar cell surface, the irradiation, the spectrum of the light and the temperature.
The short-circuit current increases slightly with an increasing temperature by approx. 0.01 %/K.

An enlargement of the solar cell surface is practically equivalent to a parallel connection of the current sources, this means that the short-circuit current increases linearly with an increasing surface.

Irradiated surface of the solar cell	0	½	¾	1/1
Short-circuit current [mA]	*0*	*80*	*120*	*160*



The short-circuit current increases linearly with the irradiated surface of the solar cell.

Information

For a better resolution of the values for the short-circuit current, the parallel connection of 2 solar cells has been chosen in this experiment.
The progression of the curve should be the same.

Even with a low irradiation, the no-load voltage reaches almost the same value as for a full irradiation.
The value for the irradiation “0” can only be measured with accurately shaded solar cells.

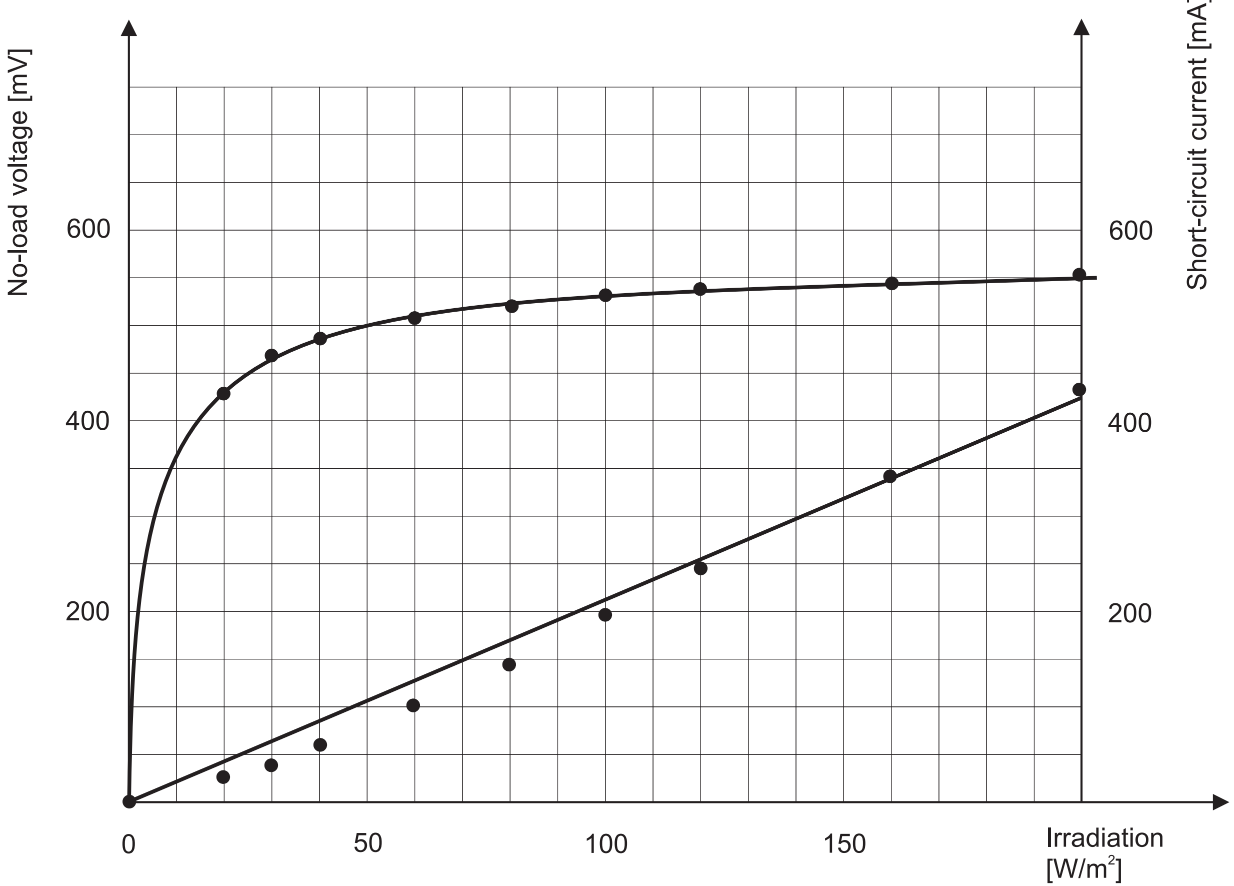
The short-circuit current depends on the irradiated solar cell surface, the irradiation, the spectrum of the light hitting the solar cells and the temperature.
The short-circuit current increases slightly along with an increasing temperature by approx. 0.01 %/K.

Under ideal conditions and with an irradiation with sunlight, the short-circuit increases linearly with the irradiation in the range of 0 to 1,000 W/m^2.

The deviations of the measuring points from the straight line have the following reasons:

- Resolution 10 mA of the multimeter in the range of “10 A” (In measuring range “DCA 200mA” the internal resistance is greater, tampering the measurement)
- Measurement only in the range of 0 - 150 W/m^2
- Light spectrum different to sunlight, spectrum of the halogen lamp changes with irradiation

Irradiation [W/m^2]	*0*	*20*	*30*	*40*	*60*	*80*	*100*	*120*	*160*	*200*
No-load voltage [mV]	*0*	*437*	*468*	*488*	*508*	*521*	*530*	*537*	*547*	*554*
Short-circuit current [mA]	*0*	*23*	*41*	*62*	*105*	*149*	*195*	*243*	*344*	*440*



Even with a low irradition, the no-load voltage reaches almost the same value as with full irradiation.

The short-circuit current increases almost linearly along with the irradiation.

Information

The irradiation E gives the radiant flux Φ arriving at the cell per surface A.
The radiant flux is the radiant power absorbed, measured in the unit Watt.

$E = \frac{d\Phi}{dA}$ and $[E] = \frac{W}{m^2}$

If the angle α with which the light beams hit the solar cell surface is to be taken into account as well, one obtains

$$E = \frac{d\Phi}{dA} \sin\alpha$$

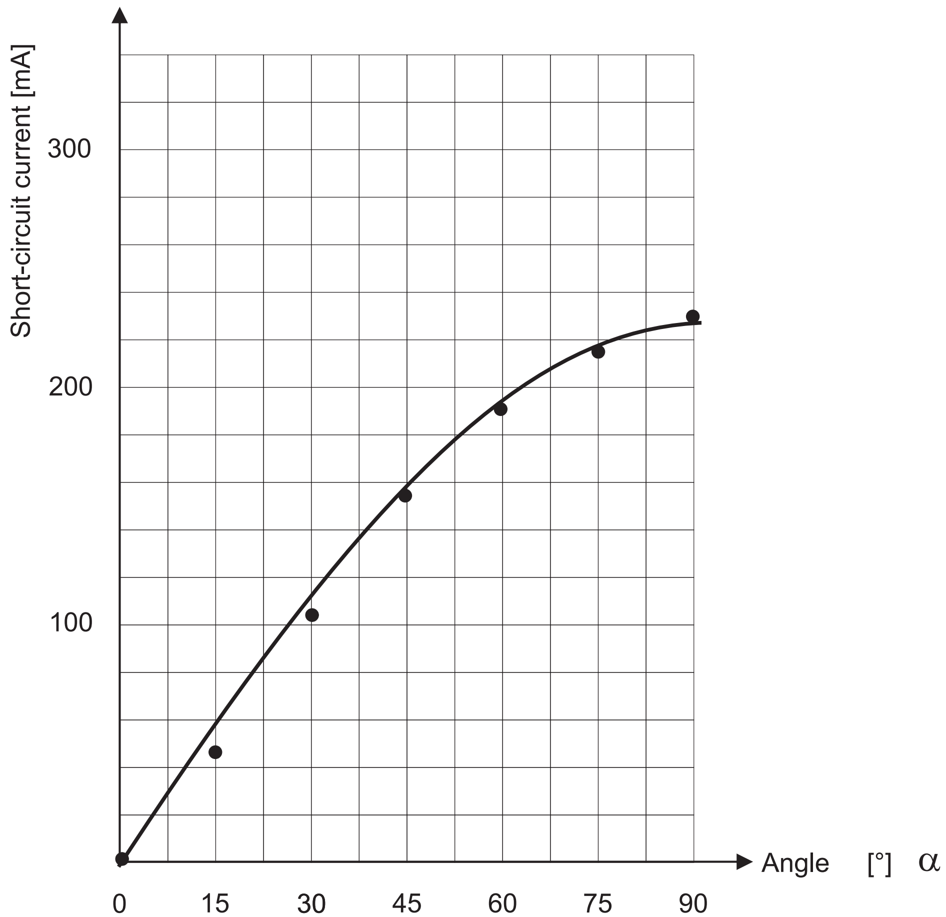
The short-circuit current depends on the irradiation and therefore also on the sinus of the angle α.

The maximum short-circuit current of a solar cell is yielded when the light beams hit the surface of the solar cell in a vertical angle.
If the angle is reduced to e.g. 60°, this has the same effect as a reduction of the surface to the 0,866-th part:

(α = 60° , $\sin\alpha$ = 0.866).

In practice, however, the reduction is not as important on account of the concurrent influence of diffuse irradiation.

Angle α [°]	90	75	60	45	30	15	0
Short-circuit current [mA]	*229*	*217*	*191*	*157*	*103*	*45*	*0*



If the light beams hit the solar cell surface in an angle of 90°, the short-circuit current is greatest. With a decreasing angle, the short-circuit current also decreases more and more rapidly.

Information

The individual solar cells differ slightly in terms of the no-load voltage and the short-circuit current.
The deviations increase with a decreasing irradiation.

The two outer solar cells have somewhat weaker values due to the weaker irradiation.
According to the characteristics, the deviations between the no-load voltage values are smaller than the deviations of the short-circuit current values.

With a series connection of solar cells, the no-load voltages add up.
The short-circuit current is determined by the solar cells with the lowest short-circuit current.

If a solar cell in a series connection is shaded step by step, the overall no-load voltage changes only slightly. Only with a complete shading does the influence become discernible.
The shaded solar cell with its short-circuit current determines the overall current flowing through the assembly.
The effect is strongest when the solar cell with the lowest short-circuit value is completely shaded.

The unshaded solar cells drive their current through the shaded solar cell, which can lead to undesirable local hot spots.

In practice the current flow through a shaded solar cell in a series connection is prevented by the parallel connection of a bypass diode through which the current can then flow.

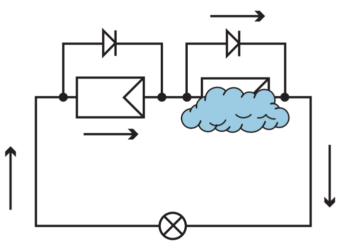


Table 1

	Solar cell 1	Solar cell 2	Solar cell 3	Solar cell 4
No-load voltage [mV]	*533*	*553*	*553*	*543*
Short-circuit current [mA]	*153*	*224*	*223*	*153*

The no-load voltage of the individual solar cells varies only slightly.

The short-circuit current of the outer cells is lower than of the central cells.

Table 2

	Solar cell 1	Series connection Solar cells 1+2	Series connection Solar cells 1+2+3	Series connection Solar cells 1+2+3+4
No-load voltage [mV]	*533*	*1,085*	*1,631*	*2,150*
Short-circuit current [mA]	*153*	*155*	*162*	*153*

The voltages of the individual cells add up.

The short-circuit current takes the value of the cell with the lowest value.

Table 3

	No shading	¼ Shading	½ Shading	Complete Shading
No-load voltage [mV]	*2,150*	*2,130*	*2,120*	*1,800*
Short-circuit current [mA]	*153*	*126*	*92*	*6*

The no-load voltage value changes only slightly.

With increasing shading, the short-circuit current is reduced to the value "0"

Information

The individual solar cells differ slightly in terms of the no-load voltage and the short-circuit current.
The deviations increase with a decreasing irradiation.

The two outer solar cells have somewhat weaker values due to the weaker irradiation.
According to the characteristics, the deviations between the no-load voltage values are smaller than the deviations of the short-circuit current value.

In a parallel connection of solar cells, the no-load voltage is constant.
The short-circuit currents of the individual solar cells add up.

If a cell in a parallel connection is shaded step by step, the change in no-load voltage is so small it can hardly be measured.
The short-circuit current is reduced by the reduction of the shaded solar cell.

The effect is strongest when the solar cell with the highest short-circuit current is shaded.

In a parallel connection, the shading of a solar cell can lead to an undesirable operating condition, as the current of the irradiated cells is driven to the shaded cell.

In practice, the current entry into a shaded cell in a parallel connection is prevented by the series connection of a string diode blocking the current flow.

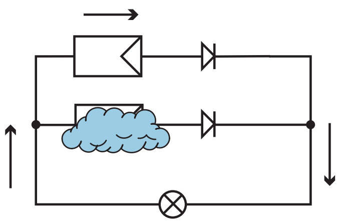


Table 1

	Solar cell 1	Solar cell 2	Solar cell 3	Solar cell 4
No-load voltage [mV]	*533*	*553*	*553*	*543*
Short-circuit current [mA]	*153*	*224*	*223*	*153*

The no-load voltage of the individual solar cells varies only slightly.

The short-circuit current of the outer solar cells is lower than of the central cells.

Table 2

	Solar cell 1	Parallell connection Solar cells 1+2	Parallell connection Solar cells 1+2+3	Parallell connection Solar cells 1+2+3+4
No-load voltage [mV]	*533*	*539*	*542*	*540*
Short-circuit current [mA]	*153*	*377*	*596*	*744*

The voltages remain the same.

The short-circuit currents of the individual solar cells add up.

Table 3

	No shading	¼ Shading	½ Shading	Complete Shading
No-load voltage [mV]	*540*	*540*	*536*	*531*
Short-circuit current [mA]	*744*	*696*	*638*	*523*

The no-load voltage value changes only slightly. The short-circuit current is reduced by the reduction of the shaded solar cell.

Information

The pre-determined values enable a simple recording of the measuring values for representation in characteristic curves. In the absence of a set point, one has to make sure that there is a sufficient number of measuring points recorded in the area of the knee of the characteristic curve.

The resistance is calculated from the voltage and current values: R = U / I.

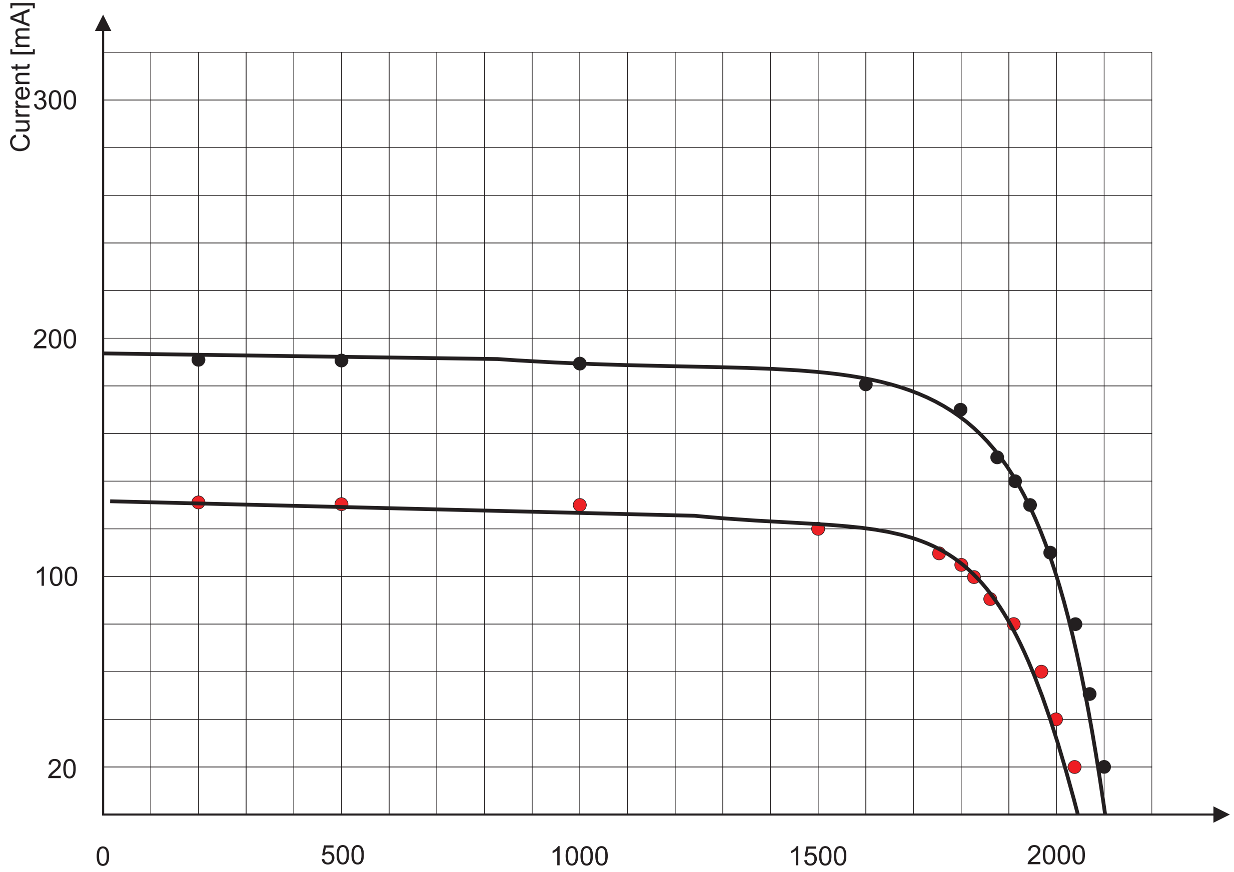
The current is overall constant in the load resistance range of 0 to approx. 12 Ohm
From 12 Ohm onwards, the current decreases considerably.

Table 1 Full irradiation (Intensity controller level 10)

Voltage [mV]	*2100*	*2080*	*2030*	*1990*	*1940*	*1910*	*1880*	*1800*	1600	1000	500	200
Current [mA]	20	50	80	110	130	140	150	170	*180*	*189*	*191*	*192*

Table 2 Lower irradiation (Intensity controller level 8)

Voltage [mV]	*2030*	*2000*	*1960*	*1910*	*1870*	*1830*	*1800*	*1760*	1500	1000	500	200
Current [mA]	20	40	60	80	90	100	105	110	*125*	*130*	*131*	*131*



Different irradiations lead to different characteristic curves.

From 0 to 1,600 mV, the current is overall constant, but decreases above that value.

Information

The maximum power of a solar cell here is 183.7 mW.

In the voltage / power diagram, the MPP is located on the vortex of the curve.
The intersection point of the vertical line of this with the characteristic curve of the voltage / current diagram gives the MPP of this characteristic curve.
From this point, one obtains a rectangle with the greatest area below the characteristic curve.

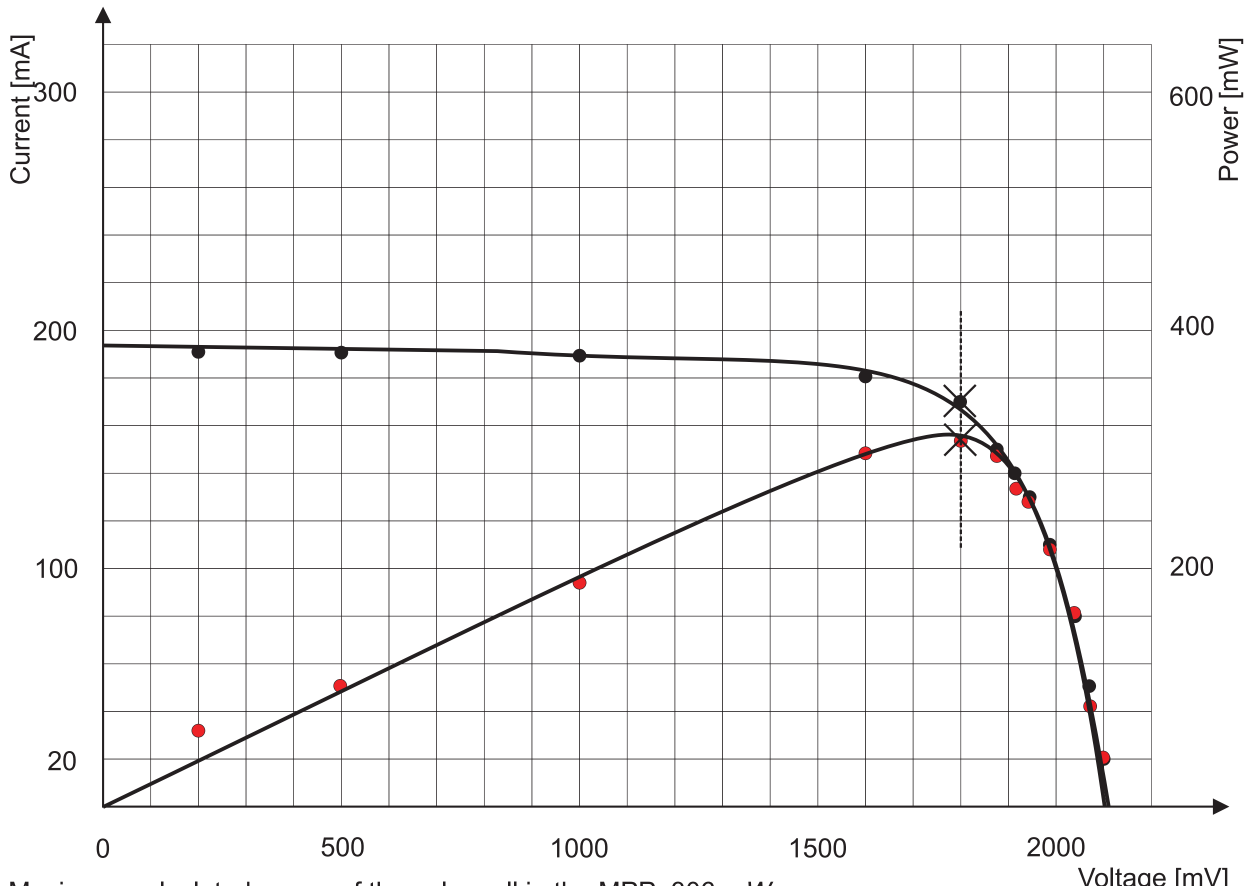
The resistance R is calculated from the voltage and current values: R = U / I.
In the MPP, the internal resistance of the solar cell has the same value as the load resistance.

The internal resistance of a solar cell depends on the irradiation.
The higher the irradiation, the lower the internal resistance.
Since, in practical operation, the irradiation keeps changing throughout the day, this changes the internal resistance and therefore also the MPP.
An adjustment of the load resistance through a regulator secures the maximum energy yield.

The efficiency factor of poly-cristalline solar cells with an irradiation of 1,000 W/m^2 with sunlight is in the range of 12 - 16 % (standard test conditions +25° C / AM 1.5)

The deviation of the effiency factor obtained is due to the deviation from the test conditions and also to the possible inaccuracy of the irradiation value.

Voltage [mV]	*2100*	*2080*	*2030*	*1990*	*1940*	*1910*	*1880*	*1800*	1600	1000	500	200
Current [mA]	20	50	80	110	130	140	150	170	*180*	*189*	*191*	*192*
Calculated power [mW]	*42.0*	*104*	*162.4*	*218.9*	*252.2*	*267.4*	*282*	*306*	*288*	*189*	*155.7*	*65.6*



Maximum calculated power of the solar cell in the MPP: 306 *mW*

Irradiation measured: 202 *W/m*^{2}

Total surface of the 4 solar cells: *5 cm x 10 cm x 4 = 200 cm*^{2} *= 0.02 m*^{2}

Irradiation power hitting the total solar cell surface: 202 *W/m*^{2} *x 0.02 m*^{2} *= 4.04 W*

Efficiency factor $\eta = \frac{0.306\ W}{4.04\ W} = 0.076 \times 100 = 7.6\ \%$

Information

A fixed solar cell with a tilt angle of approx. 30° and the orientation “Southwards” yields the maximum amount of energy for a location in Germany.

In order to increase the yield, a smaller tilt angle could be chosen for the summer months and a larger tilt angle for the winter months.

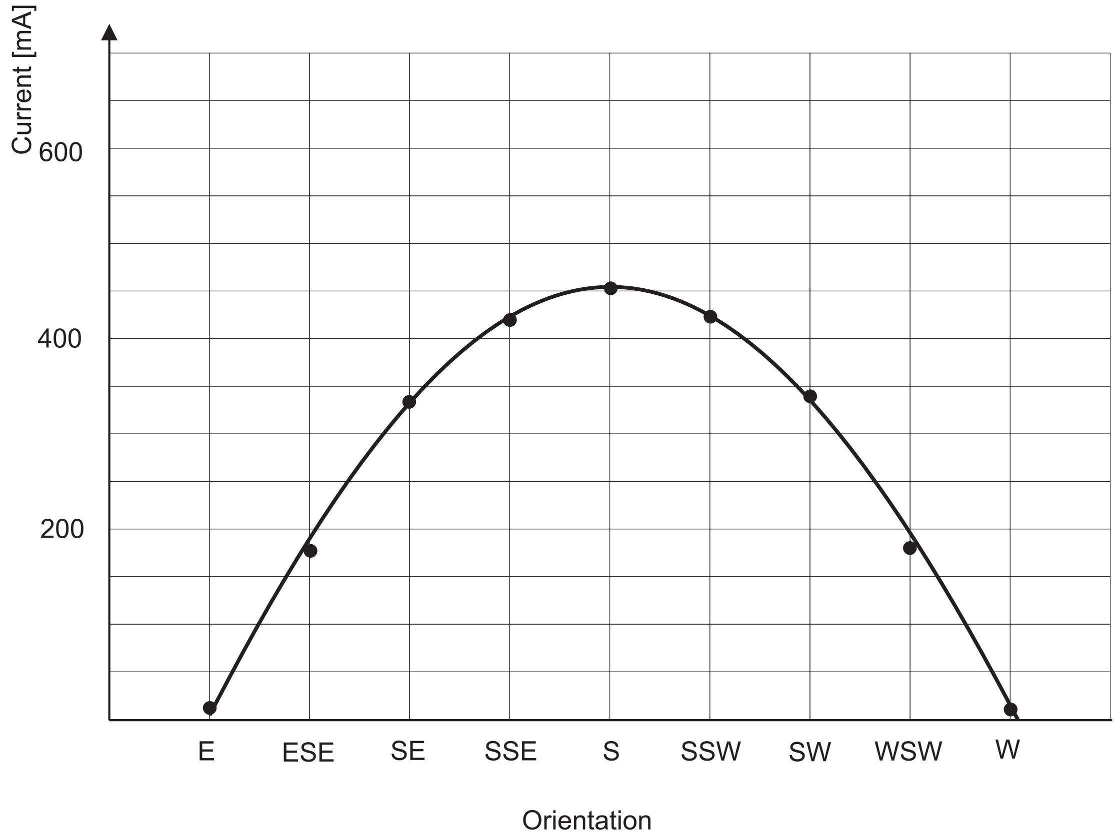
Plants for automatic adjustment of the solar cells according to the apparent movement of the sun are also possible in order to increase the yield.

In relation to the additional yield, effort and required energy amount would be disproportionately high in this regard.

On account of the influence of diffuse irradiation next to direct irradiation, a deviation from the optimum orientation does not lead to such a great reduction in yield as originally calculated.

The experimenting setup is actually correct only for a location at the equator, serving here for a basic representation of the interdependence between the power of a solar cell and the daily course of the sun.

	E	ESE	SE	SSE	S	SSW	SW	WSW	W
No-load voltage [mA]	*11*	*180*	*333*	*420*	*453*	*425*	*340*	*184*	*13*



In the position “Southwards”, the short circuit current is at a maximum value, with “Eastwards” and “Westwards”, the value decreases more and more until it is almost zero,

e.g. location equator, tilt angle 0°.

Choose tilt angle in such a way that the sun beams hit the solar cells vertically on average.

Take orientation “Southwards” into account.

Information

A “GoldCap” capacitator is a double layer capacitator with a large capacity.

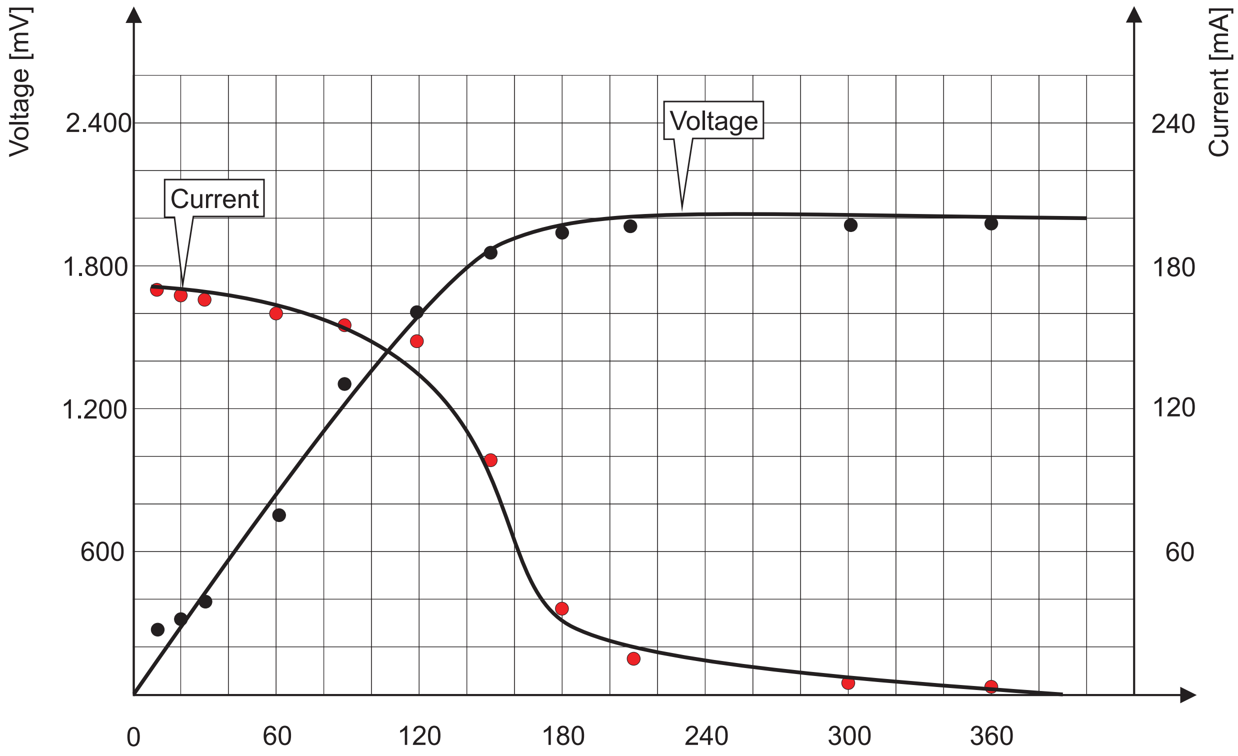
If the storage is discharged via a shaded solar cell, there is a lower current flowing than during the charging process. The current is limited by the relatively high internal resistance of the shaded cell.

Now, charging the storage via a blocking diode will lead to a voltage drop of about 0.6 V (for usual silicon diodes). The charging end voltage is reduced by this amount.

In the setup the voltage drop is measured at the amperemeter. The setup has been arranged like this since the same experiment can be carried out with PC measuring data logging and must therefore be arranged like this due to the data logger.

As an alternative, the accumulator can be charged also. This will take up more time, however. Depending on the charge state, a partial discharge should be carried out, until a voltage of around 1 V and with the bulb as load. The charging process will then require about xx minutes until the charging current has reached a value of xx mA.

Time [Sec]	10	20	30	60	90	120	150	180	210	240	300	360
Voltage [mV]	*280*	*300*	*390*	*760*	*1,270*	*1,600*	*1,840*	*1,930*	*1,950*	*1,950*	*1,950*	*1,950*
Current [mA]	*169*	*166*	*164*	*161*	*157*	*149*	*97*	*37*	*16*	*11*	*6*	*4*



A ....

B ....

C ....

D ....

Information

The “GoldCap” capacitator is suitable for loads with a low energy demand.

When using a motor as load, the voltage decreases less steeply, the current remains almost constant.
The motor can be operated during the whole of the measuring period.

When using the bulb as load, the voltage decreases faster, the current decreases to the value 0.
Operating the bulb is possible only during the first 1/6 of the measuring period.

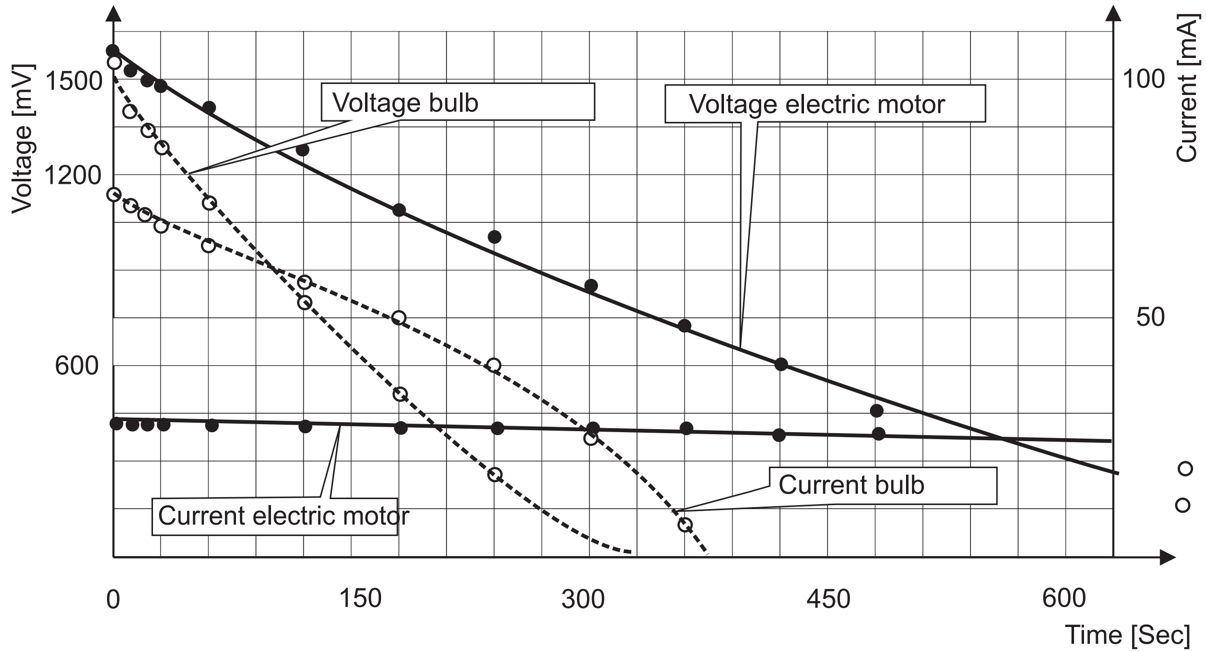
As an alternative, the accumulator can be discharged also. This will take up more time, however.
Depending on the charge state, the accumulator should be charged according to experiment 13 to a voltage of approx. 1.35 to 1.4 V and a current of not more than xx mA before the experiment starts.
The discharging process will then require around xx minutes with the bulb as load, until the voltage has decreased to approx. 1 V.

Table 1: Electric motor as load ———

Time [Sec]	0	10	20	30	60	120	180	240	300	360	420	480
Voltage [mV]	*1,580*	*1,520*	*1,480*	*1,460*	*1,390*	*1,270*	*1,130*	*1,000*	*860*	*720*	*600*	*460*
Current [mA]	*28*	*27*	*27*	*27*	*27*	*26*	*26*	*26*	*25*	*25*	*24*	*24*

Table 2: Bulb as load --------

Time [Sec]	0	10	20	30	60	120	180	240	300	360	420	480
Voltage [mV]	*1,590*	*1,420*	*1,360*	*1,300*	*1,130*	*810*	*520*	*250*	*7*	*0*	*0*	*0*
Current [mA]	*75*	*72*	*71*	*69*	*65*	*77*	*51*	*40*	*24*	*8*	*0*	*0*



When the motor is connected, the voltage decreases slowly, the current remains constant.

When the bulb is connected, the voltage decreases fast, the current decreases to 0.

Information

With these experiments, one can demonstrate the influence of the individual components and different operating conditions on the functionality of an isolated system.

Which components must be adjusted how under certain operating conditions to achieve the optimum functionality of the isolated system?

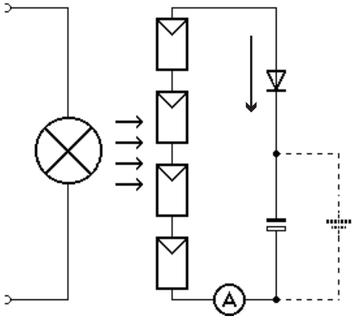
Operating conditions:

Switch-on period / Switch-on frequency of the load
Switch-on time
Irradiation potential

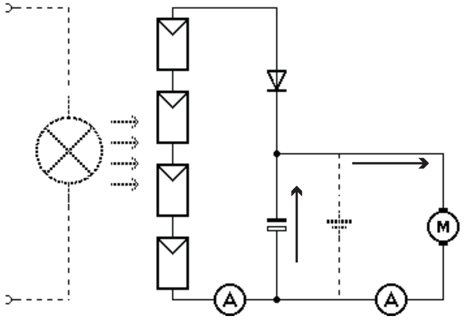
Components:

Energy content of the storage
Power of the solar cell
Power consumption of the load

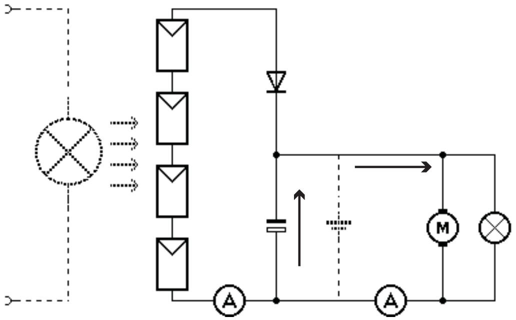
A



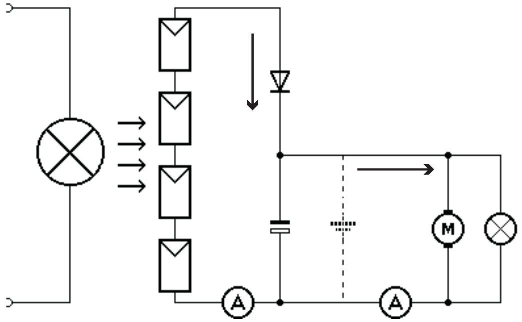
B



C



D



B *The load current remains constant. The operating behaviour of the motor does not change.*

The charging current is 0.

C *The discharging current increases strongly, then decreasing rapidly. The bulb goes out after*

a short time, the motor slows down until it finally stands still.

D *The charging current first takes on the maximum value. The load current value increases slowly,*

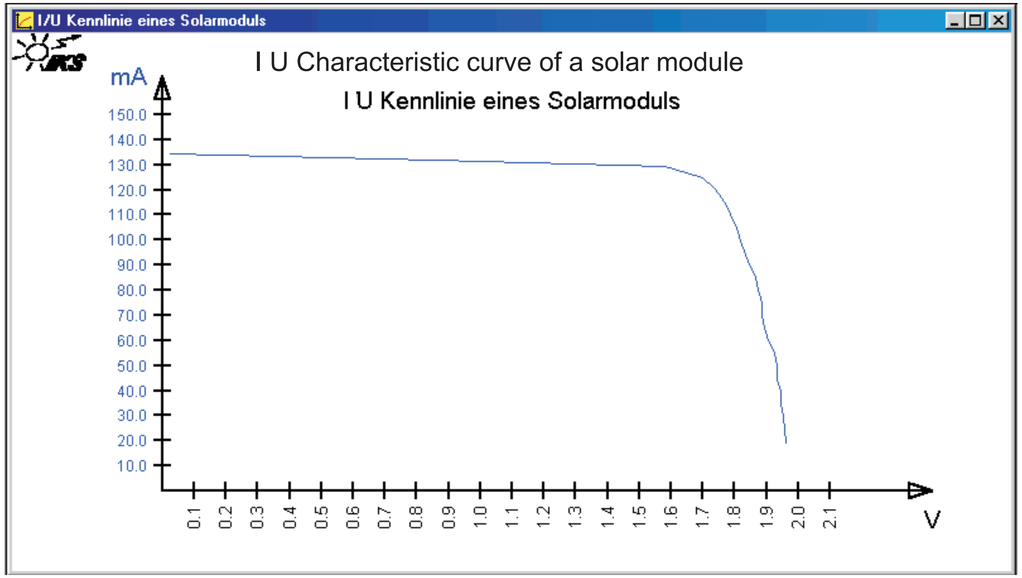
The motor accelerates and the bulb goes on. Charging current and

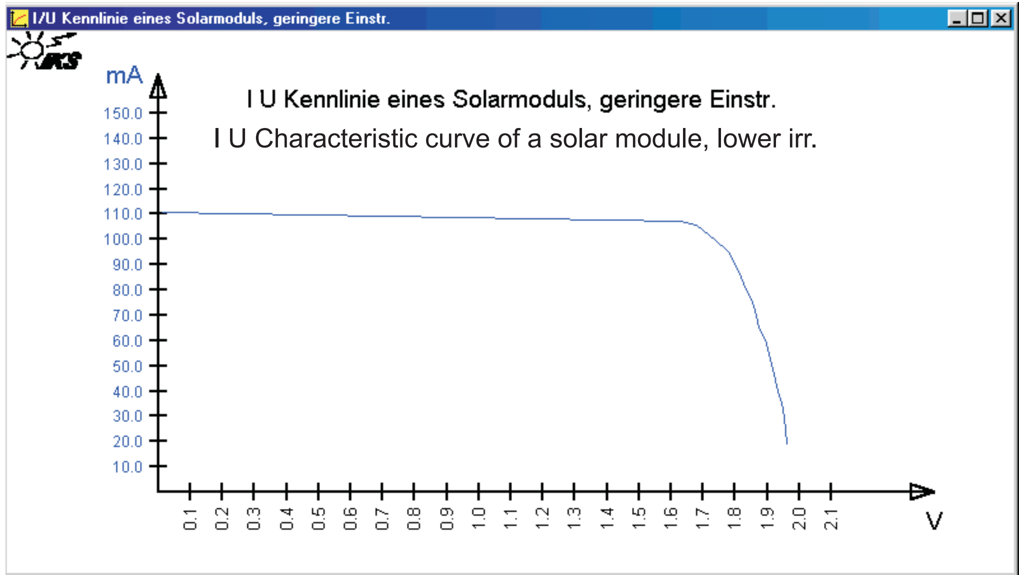
and load current take on the same values after a few minutes.

E *Discussion, notes see left-hand text*

Information

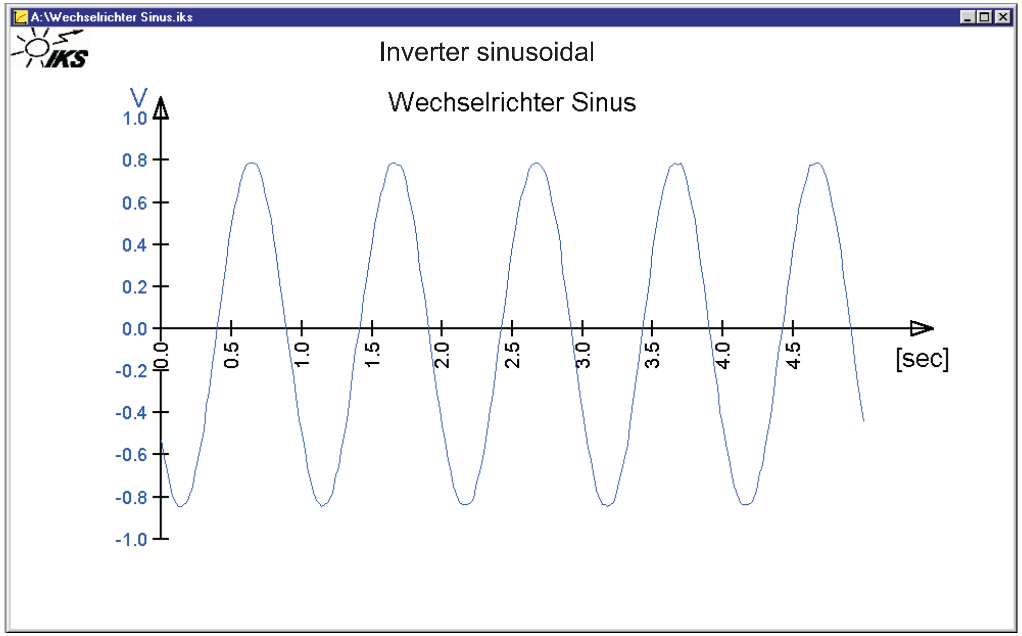
Taking up additional measuring values in the area of the knee of the characteristic curve will provide for a more regular progression of the curve.
(small current changes with large voltage changes).

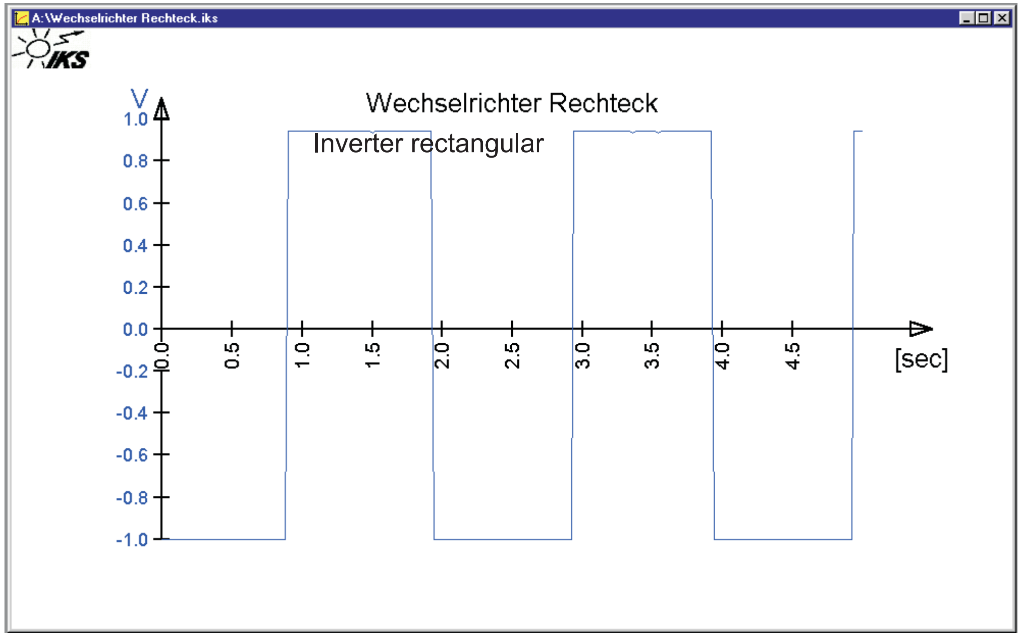




Information

This is only a basic representation of the alternating current. The frequency of 50 Hz cannot be transferred due to the “slow” interface, it is approx. 1 Hz for sinusoidal alternating current and 0.5 Hz for rectangular alternating current.





Information

See also experiments 13 and 14.

Charging GoldCap
The dispersion of measured values at the start of the current curve is due to changes in brightness of the halogen lamp, caused by voltage deviations of the supply transformer.

Discharging GoldCap bulb
Due to temperature changes of the filament during the discharging process, the resistance is not linear. That is why the current curve showes a knee.

Discharging GoldCap motor
The dispersion of measured values at the current curve is due to current peaks during commutation.