Grüezi YouTubers. Here is the guy with the Swiss accent. With a new episode around sensors and microcontrollers.

In video #142 we started a journey to power or small devices with solar power. We quickly discovered that the problem to power small devices is different to the normally covered problem to produce “big” energy using solar panels. Especially important is the winter with only little sun. There, we need to convert all available energy into electricity.

Today, we continue this journey. We will

* Have a look at the available boards and chips to connect solar panels to batteries
* We will try to classify them according to the technology used
* We will have a look at the theory behind the different technologies
* We will build a setup to compare two devices under very similar conditions
* We will do first measurements in full sun and in cloudy sky condition
* We will see if the chargers will not discharge the battery if no sun is shining

In this video, we will concentrate on 6-volt panels and one 3.7 v Lipo battery. This is the most obvious solution to power 3.3 or 5-volt devices. LiFePo batteries would fit even a bit better, but most of the chargers do not support the maximum 3.6-volt necessary for this battery type.

So, our overall system will look like that:

We start with a solar panel which creates around 6 - 7 volts in full sun. It is connected to a specialized charger, which converts the fluctuating voltage and current into a steady voltage and current for the charging of the 3.7-volt Li-Po battery. The battery stores electricity, and because modern microcontrollers run on 3.3 volts, we need a regulator which stabilizes the voltage. If we want to use it for a 5V microcontroller, we have to replace this LDO with a small boost converter.

If no sun is there, the battery could be discharged by the charger itself. This is not ideal, of course.

In this video, we will build two times the same setup in parallel to measure the following data:

* The power flowing from the solar panel to the charger
* The power flowing from the charger to the battery

In this first phase, we will not look at the LDO nor at the microcontroller. And we will use only one model of solar panels. Like that, we really compare the different chargers and not something else.

And we start with nearly empty batteries.

I purchased a bunch of different battery chargers, most of them somehow marked as “Solar Chargers” or “MPPT” chargers.

To start a comparison, we need an overview. And to create such an overview, we have to look at the purpose of such a charger.

As we already saw in video #142, the characteristics of solar panels look like that: On the vertical axis, we see the current flowing out of the panel into a load. And on the horizontal axes the resulting voltage.

If we do not draw any current, we get the open-circuit voltage and, because power is the multiplication of voltage times current, the power obviously is zero. If we start to draw some current, the voltage is reduced, but the power increases up to a maximum. If we increase the current even more, the power curve decreases quite fast, because the voltage drops rapidly. So, if we want that the solar panel delivers maximum power, we have to draw a current close to the maximum power or stabilize the voltage close to the maximum power point, or MPP.

Unfortunately, this curve varies with the illumination. If we have a low illumination, the curve is rather low, and also the MPP changes a little. As we see here for a 12-volt panel, it does not vary a lot, maybe one volt, which is about 10%.

You can read a lot about MPP tracking devices. This becomes more important with high power panels. For our purpose, this seems to be not too important, because of three facts:

1. We have to optimize our charger for harvesting the maximum at low illuminations. During high illuminations, we anyway will have too much energy.
2. MPP trackers are quite complicated and also need some power. So, it is not clear, if we even lose efficiency using such a technology.
3. The power difference of a non-optimal selection of this point can easily be offset by a slightly bigger solar panel. These panels get also cheaper every year.

But it is still important to make sure, that our solar panel is used around this optimum, as we will see later on.

With this know-how in mind, let’s classify our chargers:

* We have switching chargers and non-switching chargers
* And we have chargers which are capable to deal with this optimal MPP situation and others, which do not care about that
* We have chargers, which are optimized to charge Li-Po batteries from a constant voltage
* Then, we have some combined devices, where a Solar charger and a regulator is on the same PCB.

We plan to test one device of each sort and, later on, use a knock-out tournament to choose a winner for high illumination situation.

Next, we will choose a winner for a low illumination situation. The measurement will be done on the battery side of the charger because like that, we take also the efficiency of the charger into account.

But first, let’s have a closer look at the competitors. Because we have to expect input voltages of about 4-6 volt, we use the newly built DPS5005 remotely controlled power supply. I program it to apply voltages between 4 and 6 volts. At the output of the charger, we connected a half-charged battery.

The first test is with a solar charger CN3791 chip manufactured by Consonance Electronics, a Chinese producer of many different solar charger chips. It is a switching charger which has the capability to keep the input voltage constant and adjust the input current accordingly. This makes sure we run the Solar panel at a good operating point. If no sun is available, the chip is shut down and should not discharge the battery. And it stops charging if the Li-Po battery reaches 4.2 volts. So, the battery is protected.

Here we see the result of the CN3791 chip. It only starts to charge at about 5.5 volts. You can change these resistors to influence that voltage level. We have to see in real life situations if this voltage level is a good choice. Maybe, I will replace these resistors with a potentiometer to optimize this voltage. But anyway, once selected, this voltage stays the same and can only be optimized for one particular illumination.

BTW: There are many videos about how switching and linear chargers work, and where the difference is. Usually, the “switchers” have advantages, if the voltage difference between input and output is big. The linear bunch is usually better if this difference is small.

The next is an ordinary switching buck converter using an LM2596 chip. We adjusted its output voltage to about 4.2 volts to protect the Li-Po battery from overcharging. This is not easy because of the wide range of operating voltages of the charger. But this is important, because, if this voltage is too high, we reduce the life time of our battery, and if it is too low, the battery will not be charged completely.

This general-purpose charger is neither optimized to charge Li-Po batteries nor to keep a solar panel at an optimal point. The test shows, that it starts to charge at about 4.7 volt (which is about 1 volt higher than the battery voltage). And it charges up to 0.6 A at 6 volts. We have to see how this characteristic will behave if connected to a solar panel.

A very similar concept is the AM1117 chip. It is a linear regulator. Because we use the adjustable version of the chip, we can set the output voltage to 4.2 volts. The curve matches the one of the LM2596 nearly 100%. The only thing we did not test is the efficiency, which could be different.

The next chip is also manufactured by Consonance. It is a CN3065 linear solar charger chip. The data sheet does not completely describe how the regulation at the input works. It already starts to charge at 4.4 volts and there is no possibility to adjust the behavior on the input side. Only the battery charging current can be adjusted with this resistor. We will see, how this chip behaves in real situations.

The next one uses an XL6009 chip is similar to the LM2596. It is also a switcher, but not only regulates the voltage down, it also can “boost” it to a higher voltage. The diagram shows, that it already delivers a high current at 4 volts. Regulators like that should not be very good for solar cells because they will use a lot of current at a low voltage. So, we can expect a very low output from the solar panels.

The next chip is optimized for Li-Po battery charging: The famous TP4056. It has a very elaborate battery charging behavior. But this behavior depends on a stable input voltage. We will see, how it behaves with a solar panel. As expected, it also starts very early with the charging and the current linearly goes up. Here, it is very similar to the CN3065. For sure, it will treat the battery very well, because this is, what it is built for.

The last chip in today’s selection is the MCP73871. It is also a linear Li-Po charger like the TP4065.

It seems to have an elaborated battery management system. I am not sure if this will help us a lot in our setup. This charger is the only one which has a separate connector for the battery and an output for the load. For this first test, nothing is connected to the load pins. It starts to charge at about 5 volts, which should be not too bad for a solar cell.

I have many other charger modules in my lab. Some are similar to the ones in this test, and some are made for higher voltages and currents. One, however, is a very special one: The Swithdoc SunControl. I recently got one from Kickstarter, but I will do a full review in a separate video.

Let’s do a first test with these modules. At the beginning of the week, we had lots of sun and we set-up our measuring system on a sheet of wood. We used two identical panels, two of our home-made volt-ampere, and watt meters, and two half charged batteries. Like that, we can take the whole setup and run, if it starts to rain…

The laundry rack is a perfect helper, not only for the solar panels…

Because of the heavy sun, it is not easy to film, but here are first results of our measurements in full sun:

The “winner” is the CN3791. It operated at 5.6 volts, which should be quite close to the MPP of this panel at full illumination. Second is the TP4056. It operated at a much higher voltage but still delivered nearly 2 watts. The XL6009 behaved as expected: It tried to get a lot of current and the solar panel’s voltage was dropped to 3.2 volts. The result is only about half the power of the best.

The surprise is the CN3065 which does not draw a lot of current. We have to investigate further if our setup was faulty, or what else is the reason for that bad result.

You see also, that we measured the power delivered by the solar panel to the chargers. Next time, we will measure the power delivered by the charger to the battery. Because this takes also the efficiency of the chargers into account.

We did the same measurements later in the day with cloudy skies. Here are the results. As expected, we get much less power, and here, the TP4056 is the winner. After that, we did not see the sun again and we had to concentrate on another, very important fact: How much current draws the charger if there is no sun available. This is particularly important if we have a low power device powered by the battery. Because the charger without sun behaves like an additional load which also discharges the battery. We simulate this by switching the power supply off and measure the current which flows back via the charger.

These values are very different: Three of them have nearly no back flowing current and tree have quite high currents. In our scenario, such currents cannot be tolerated. We can reduce it by adding a Schottky diode. But of course, these diodes add some waste and we have to take this into account for the overall ranking.

Summarized, we

* Built a setup for comparing chargers in real life situations
* Tried to get an overview of the different technologies which can be used to charge a 3.7-volt Li-Po battery with a 6 V solar panel
* We found linear and switching chargers
* We found chargers, which are advertised for solar panel usage and which have some means of MPP tracking, however none with variable MPPT
* We found chargers which are optimized for Li-Po battery charging
* And we also tried general purpose regulators
* We characterized the input stage because this part is more important for the overall performance than the optimal treatment of the Li-Po battery. We found completely different behaviors of the different technologies
* We did an initial test in full sun and under cloudy skies and found a first ranking. This ranking is only preliminary and it will be revised
* We measured the reverse current which discharges the battery when no sun is shining (in Switzerland perceived 95% of the time)

With this legwork, in a next video, we should be able to get good results. We also know, which chargers are promising and where we just want to confirm the bad performance.

We will also extend the participants of the shootout, and we will extend the system by including regulators and 3.3 or 5-volt microprocessors.

I hope, this video was useful or at least interesting for you. Bye