# Construction manual USB solar suitcase

## Notice

These instructions show how to build a USB solar suitcase. At the end, there are also tips on how to use it.

## Safety note

**Building the suitcase is relatively complicated and requires knowledge of electronics and soldering.**
The suitcase contains rechargeable batteries and other parts that are live. Careless handling can cause sparks (fire hazard) or, in extreme cases, the lithium batteries could ignite. All work must be carried out by a person who has experience in the manufacture of electronic circuit boards and knows the precautionary measures for handling lithium-ion batteries.

## Material

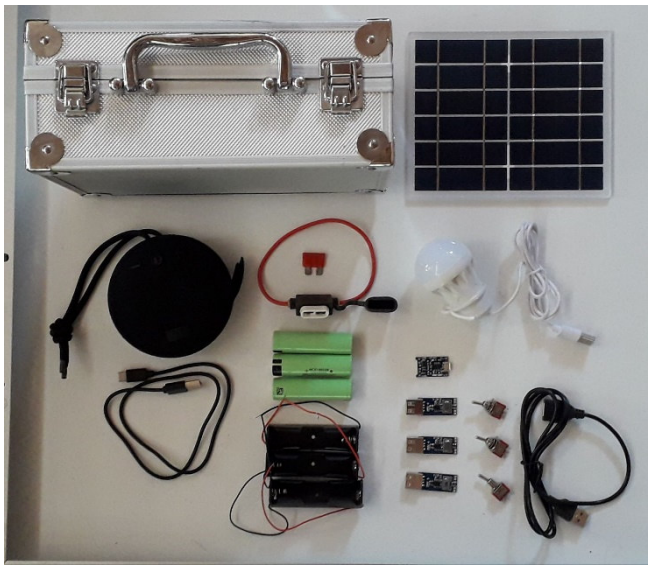
You will need the following materials for the construction:

- Empty suitcase or attaché case
- Solar panel 6V (12 cells in series)
- 1-3 lithium-ion batteries size 18650[1]
- 1-3 battery holders size 18650
- 1 fuse holder with fuse (5A or 10A)
- 1 charging module for lithium-ion batteries ("USB 5V 1A 18650 TP4056 Lithium Battery Charger Module")
- 2-3 switches
- 2-3 step-up USB modules ("DC-DC 2.5V-5.5V To 5V 2A Step Up Power Module")
- 1 LED lamp (5V) with cable and USB plug
- Red and black cable
- Soldering tin
- Insulating tape
- Material to attach the elements in the suitcase (cable ties, small screws, double-sided adhesive tape, etc.)
- Pieces of plywood, 9 mm thick

*Optional:*

- 1 Small digital voltmeter ("Digital LED Mini Display Module DC0-100V Voltmeter", select "3 line")
- 1 "normally off" push-button switch
- 1 Bluetooth speaker with charging cable
- USB extension cable
- Screw terminals

1 18650 is a typical size of batteries that are used in laptops or e-bikes, for example. Diameter: 18 mm, length: 650 mm



The suitcase and all components.

## Tools

For the construction, you will need the following tools:

- Soldering iron
- Pliers
- Wire strippers
- Knive
- Multimeter
- Saw or jigsaw
- Drill with drill bits
- Screwdriver
- Sandpaper

*Optional:*

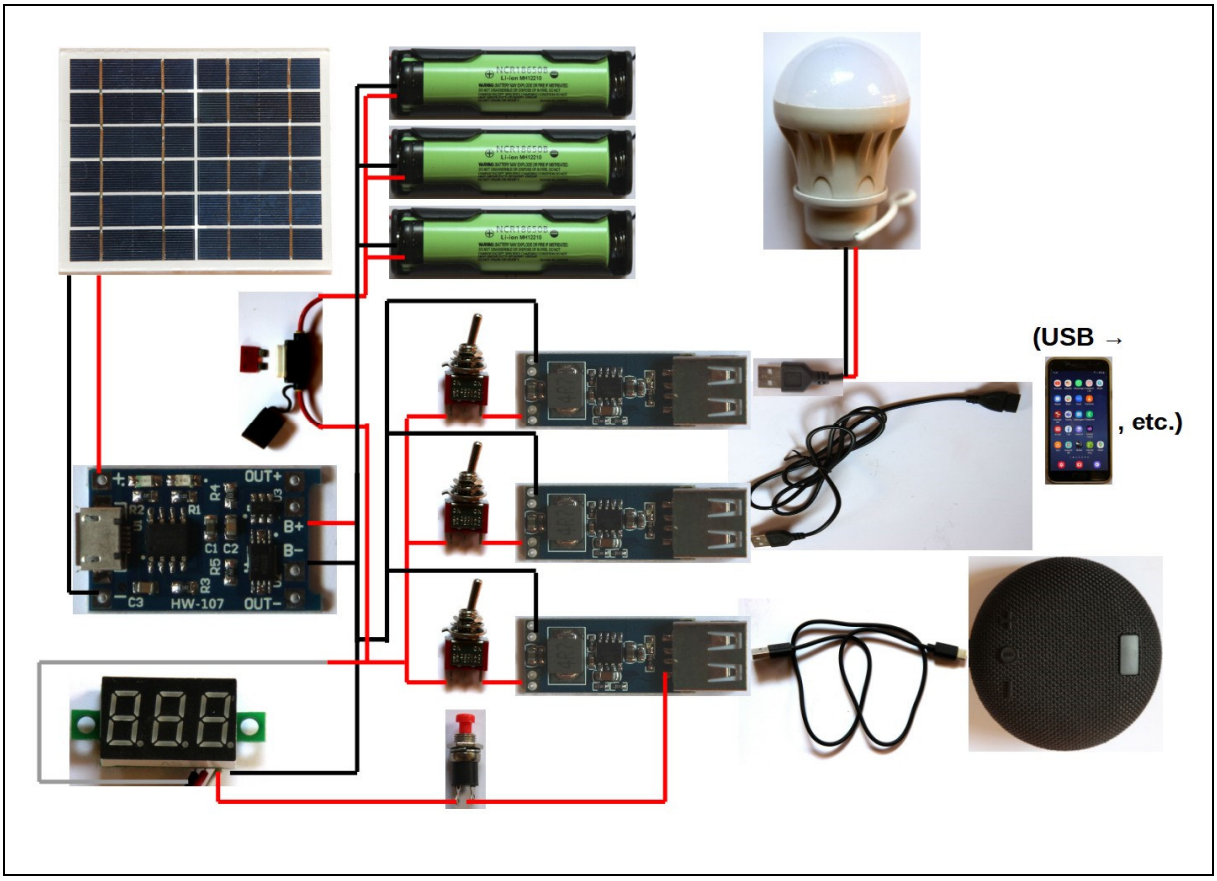
- Acrylic paint
- Brushes
- Silicone
- Heat-shrink tubing

## Step by step instruction

### Step 1: Prepare components and draw electrical diagram

First, we gather all the components. Then we draw the diagram for *our* solar suitcase with exactly the components that we will use.

The following graphic shows a possible scheme for a very complete version of the suitcase, which has three USB modules (one each for the LED lamp, for a Bluetooth speaker and for a USB socket where mobile phones etc. can be charged). It also displays the voltage of the batteries at the touch of a button.




Explanations to the graphic:

The **charging module** prevents dangerous overcharging of the batteries. It is connected to the solar panel and the batteries.

The **rechargeable batteries** are connected in parallel[2]. This means that the nominal voltage remains 3.6V, regardless of whether 1, 2 or 3 batteries are installed.

The **USB modules** receive their power directly from the rechargeable batteries. There is a switch in each positive line that can turn the respective module on or off.

The optional **voltage module** (small digital voltmeter) requires 5V for its own electronics. It is therefore powered by one of the USB modules (the red, positive cable of the module is soldered to a positive output of the module). At the same time, it must measure the voltage of the battery (the usually white "measuring cable" of the module is connected to the positive battery voltage). The black, negative cable is connected to the negative battery voltage. The push-button switch interrupts the positive 5V supply line.

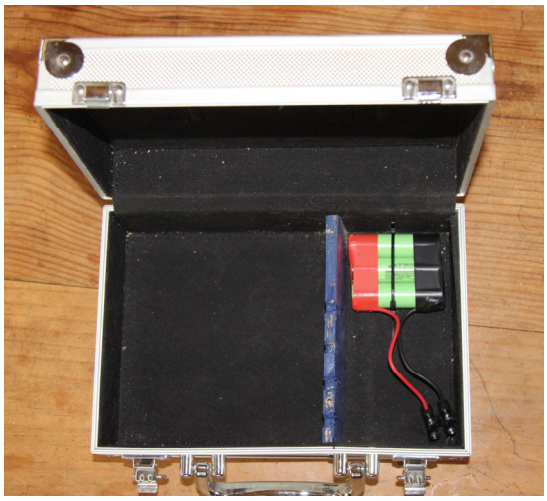
The **USB extension cable** allows the USB module to be concealed and the socket to be more easily accessible.

## Step 2: Prepare suitcase and base plate

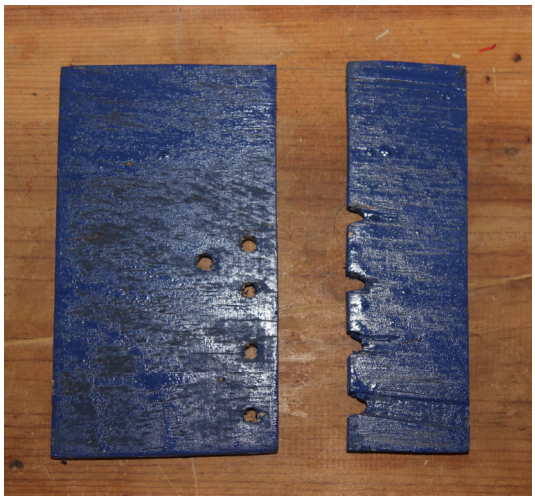
We need to decide where and how we want to install the individual elements in the suitcase. At the same time, we want to leave some space for accessories, cables, etc. We usually build a base plate from pieces of plywood, which is installed slightly elevated. This leaves space underneath for the

2 Warning: If Li-ion batteries are connected in series to achieve a higher voltage, a so-called BMS (battery management system) must also be installed. This is not necessary for parallel connection.

electronics and batteries. We drill and saw the necessary holes and openings for the switches, cables, etc. Then, we can paint the plywood parts.



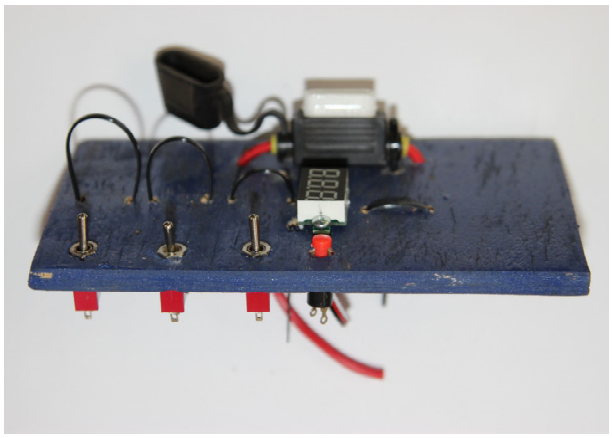
The right-hand part of the suitcase (width of the battery pack) will carry the base plate.



Base plate and dividing wall.

## Step 3: Fix the elements in their position

We mount all the elements in place and test, whether the suitcase can still be closed.

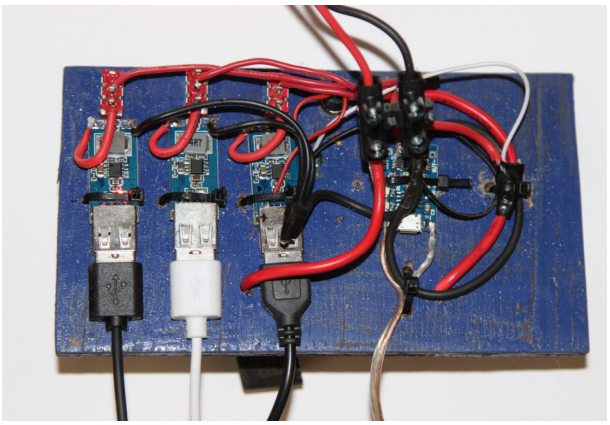


Top side with switches, fuse, voltage module, cable ties.

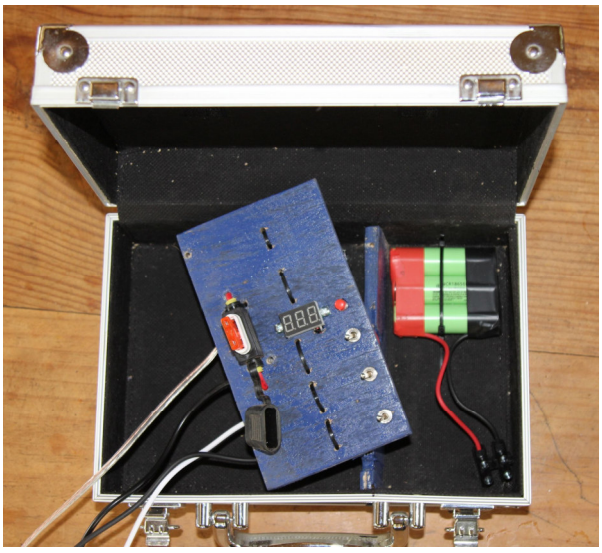
## Step 4: Soldering the cables

**Caution:** While building the electronics, we leave the batteries aside and do not insert the fuse yet. We solder all the cables according to our diagram. Wherever possible, we use red / black cables for the positive / negative connections. All "bare" metal parts (solder joints etc.) must be insulated with heat-shrink tubing or insulating tape. Finally, we compare all connections with our diagram.

If the solar panel does not have a cable yet, we now solder a cable to the solder lugs or solder joints on the back of the panel. Then, we cover the soldering points with silicone, to protect them against water and short circuits.



Bottom side with 3 USB modules and the charging module; the cables are soldered on.



Top side and view of the battery pack underneath.

## Step 5: Testing

We set all switches to OFF and place the batteries in their holders. Then, we insert the fuse. One by one, we test all USB outputs by activating one switch at a time and testing the function (light on? mobile phone charging? etc.). Normally, a small LED lights up on the selected USB module. If in doubt, use a multimeter (in the DC voltage position) to test how far the battery voltage gets and where a connection might be interrupted.

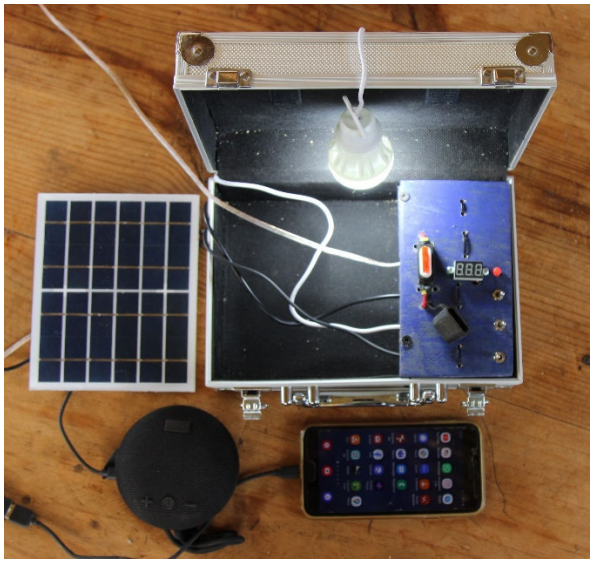
Finally, we place the panel in the sun. Normally, a small LED on the charging module lights up. We can measure the battery voltage now and an hour later once again. Is the voltage rising? If yes, everything is fine. If not, we need to check again the connections between the panel and the suitcase and possibly re-solder them.

## Step 6: User manual

It makes sense to write a short user manual for exactly *our* new solar suitcase. The practical tips below can form part of this document. We place the instructions in the suitcase for other users (or for ourselves).

These instructions should also include the list of installed parts and a sketch of the electrical diagram.

The USB solar suitcase with stowed panel, speaker and cables.



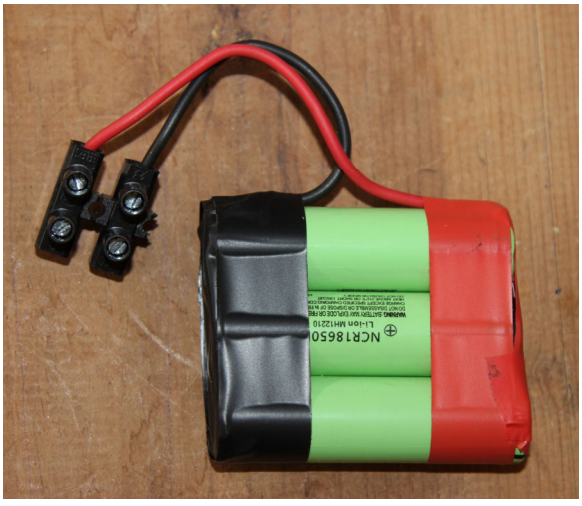
The suitcase simultaneously charges a mobile phone and the speaker, while the LED light is working.

**Option for experts: Spot welding rechargeable lithium-ion batteries**

If you have experience with spot welding metal strips to lithium-ion batteries and have the necessary equipment and nickel strips, you can interconnect two or three rechargeable batteries with metal strips and build a battery pack instead of using battery holders. Finally, you solder a cable to each end of the metal strips in the "classic" way. The corresponding soldering point must be beside the battery itself.

***Caution***: Soldering lithium-ion batteries is dangerous, because the rechargeable batteries may ignite[3]. Even without an accident, heating the solder joint during soldering can destroy a battery. Only the technique of spot welding avoids overheating the solder joint.


A "spot welder" can solder nickel strips to rechargeable batteries without overheating them.



The finished and secured battery pack.

3 Lithium-ion batteries on fire cannot be extinguished with water! Only a special fire extinguisher or dry sand may be used.

## Practical advice for the use of the solar suitcase

- The batteries in the suitcase are charged whenever there is sunlight falling on the solar panel.
- The solar panel must be in full sunlight to charge. Otherwise, charging will take much longer. Charging with artificial light or when there are dark clouds is almost useless.
- The suitcase itself should always be in the shade. Batteries and electronics do not appreciate the heat.
- With a panel that has a rated current of 500mA, it should be possible to fully charge a battery during one sunny day. A battery pack of 2 or 3 batteries requires 2 or 3 days of sunshine.
- There is no risk of overcharging the rechargeable batteries. The electronics takes care of switching off the panels as soon as the rechargeable batteries are full.
- If necessary, the suitcase can be charged from the power grid, using a mobile phone charger and cable plugged into the charging module.
- Unlike a power bank, our solar suitcase can be charged and discharged (used) at the same time.
- To save power, we only switch on the respective USB outputs as long as we are using them; each output has a small "stand-by" loss if it is not switched off.
- Roughly speaking, a full battery can fully charge a smartphone or a small speaker once without the sun. Or it can keep the lamp burning for two hours. (2 or 3 batteries provide 2 or 3 times more power).
- In order to measure the voltage of the batteries, we must switch on the one USB output that supplies the voltmeter itself with power. The voltage is then displayed at the touch of the button.
  The battery voltage indicates the charge status: 4.1V = rechargeable batteries completely full; 3.6V = rechargeable batteries half full; 3V = rechargeable batteries need to be recharged.
- At 2.5V, the electronics in the USB module automatically switches off the power. At 4.1V, the electronics in the charging module automatically switches off the solar panel.
- What to do if the suitcase is not in use for a long time? It is best to fully charge the batteries first (≥ 4.0V). Then stow the panel in the suitcase so that as little light as possible falls on it. Then remove the fuse. When putting the suitcase back into operation, *first* insert the fuse and *then* place the panel in the light.