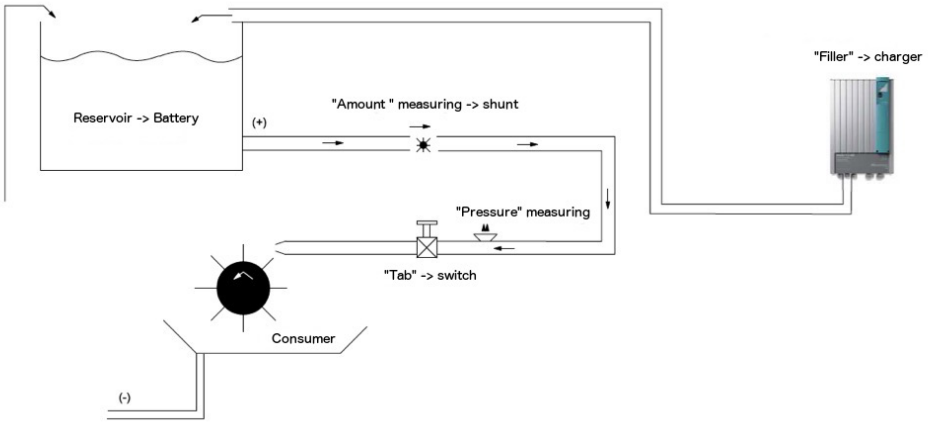
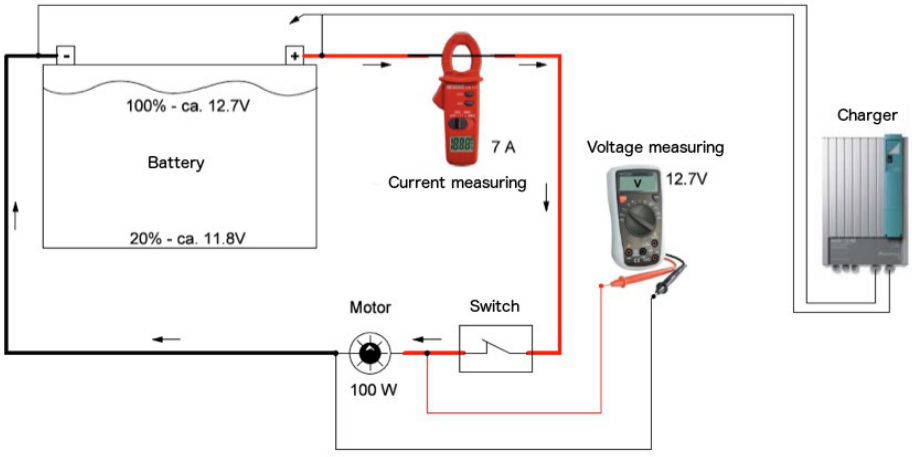
Electrical - Basics



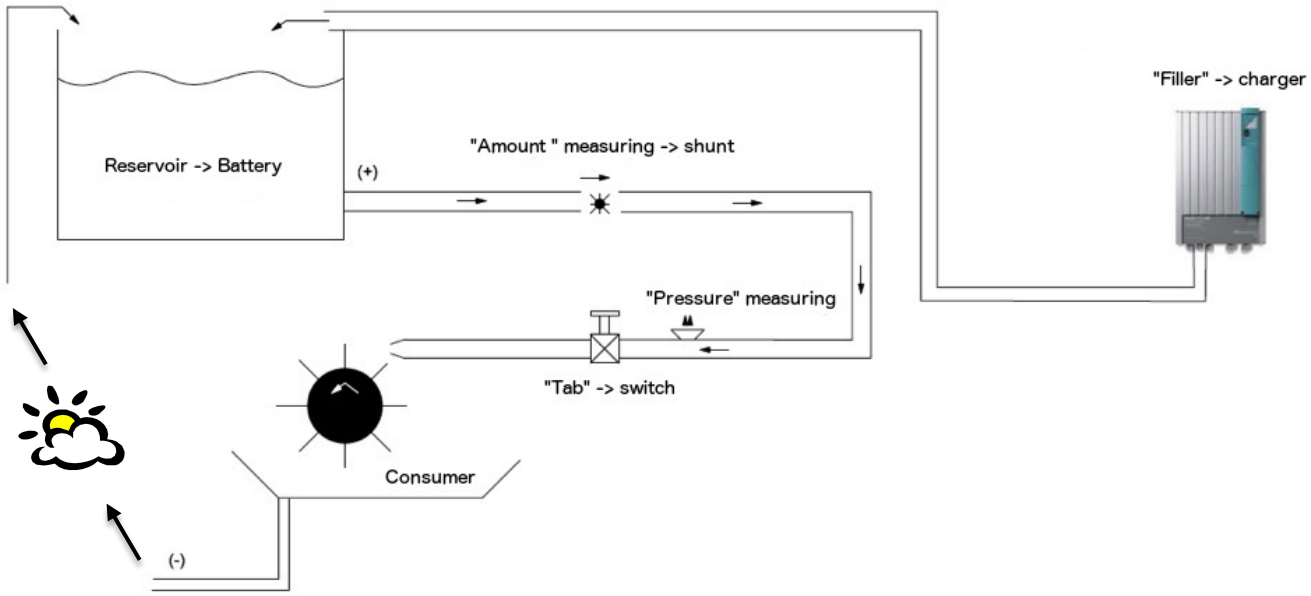


Electrical basics

To get a basic understanding of the function of the “Electric”, it needs no great expertise, some imagination, time and willingness to understand, is completely enough.
I like to use the comparison with water, because the process in a water circuit is well known.

It is best to print out these pages to look at them side by side, and if something seems unclear, you have the explanation by hand. Of course, this is for beginners and basic understanding. It is a very good basis and sufficient for the requirements to draw conclusions and to find faults.
If you want to know more, I suggest buying a professional book with further information.

The water cycle



In a reservoir, a certain amount of water can be stored (**capacity**). This is conducted through a pipe to a consumer (**water wheel**).
To control the rotation of the water wheel a tap is located in the line.

For turning the wheel, it needs **energy**. This consists of the **pressure** and the **amount** of water needed to turn. The water wheel is a **resistance** against the water.

If the reservoir is filled, there is a **pressure**. If the water wheel turns for an hour, it consumes an **amount** of **water** with adequate **pressure (energy / h)**.

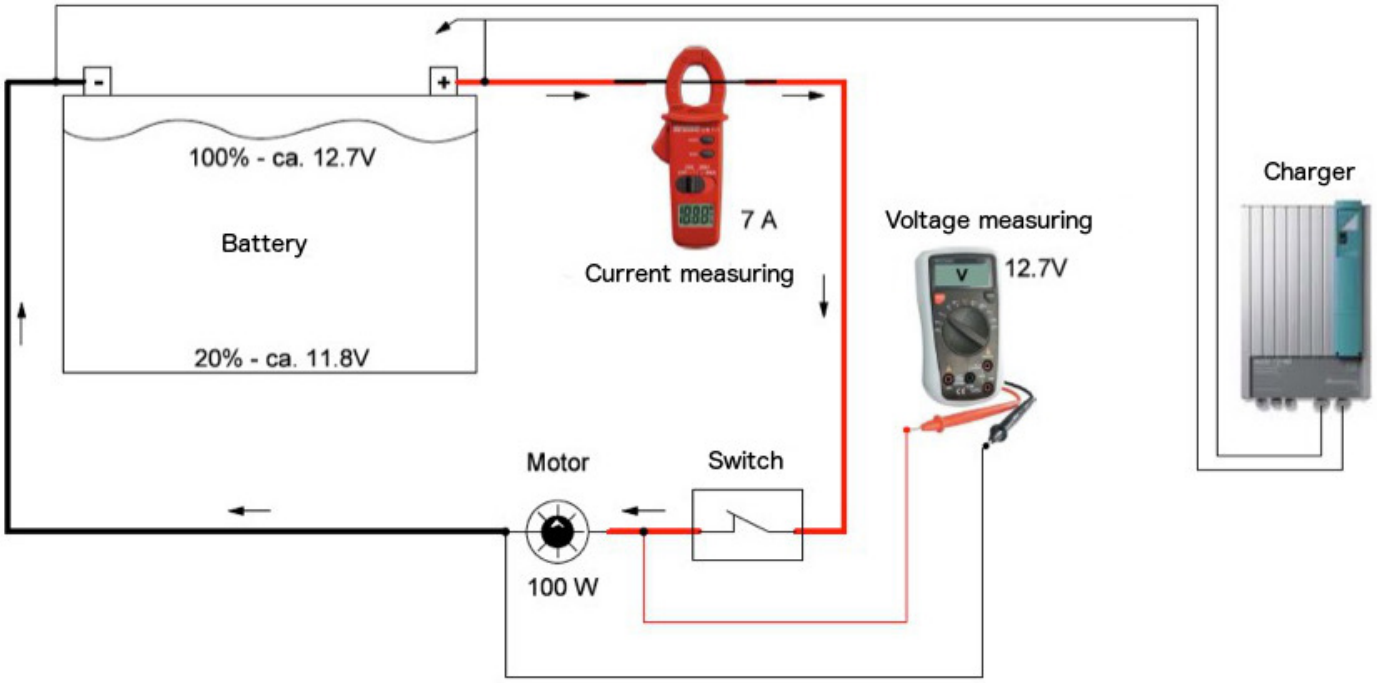
For monitoring, we measure two values:

- The **pressure**: it’s at any time at the tap, even if the tab is closed and the water wheel stoped.
- The **amount** of water: it flows only when the tab is opened and the wheel turns.

If we compare this with the electrical system it matched by the following:

Electrical circuit

Please note that we are talking only about a DC (direct current) circuits!



A battery stores a certain energy **"capacity"**, it is connected via two lines (positive and negative + -) to a load (motor) and back to the battery.
In order to control the activity of the motor, a switch is located in one line (normally in the positive), it disconnects the line to the consumer.

Thus, to rotate the motor, **energy** is needed. This is made out of the **voltage** (pressure) and a amount of **current**. The consumer put some **resistance** against the energy.

If the battery is full, there is a **voltage (12.7V / lead-acid battery)** (fully charged 12V battery).
If the motor runs for one hour, it consumes energy (**energy / h**)

For monitoring, we measure two values:

- The **voltage**: it stays on the switch all the time (battery side), even the circuit is open and the motor has stopped.
- The **current**: it flows only when the switch is closed (closed circuit).

The following is different to the water cycle:

- It always takes a line from the reservoir (battery) to the consumer and back.
- The battery is a small chemical plant, and is therefor more complex than a reservoir.
- The lower the resistance of the load, the greater the current which flows.
- The pressure decreases when a consumer is turned on.

This table shows the opposite terms in the water and electrical circuit.

liquid	electrical		shortcut	Formula symbol
pressure	voltage	volts	V	U
amount	current	ampere	A	I
energy	power	watts	W	P
resistance	resistance	Ohm	Ω	Ω
capacity	capacity	ampere / hour	Ah	Ah
time	time	hour	h	h

One of the most important calculations to determine the consumption on board will be:

- voltage x current = power — U x I = P — (volts x ampere = watts)
- power / voltage = current — P / U = I — (watt / volts = ampere)
- current x time = capacity — I x h = Ah — (ampere x hour = ampere / h)

Read and compare the two types, water / electrical to recognise the relationships and get familiar with the terms and shortcuts.

One of the main issues and problems of an electrical system on board are the cable diameters and contact resistance. They are in most cases responsible for not fully charged batteries that equipment is not running or a "wrong" voltage is measured, although the batteries are full. They are also often the cause of fires.
Cable diameters can be determined by your self. Contact resistance are caused by poor installation and / or moisture (salty air is very aggressive).

If a to big amount of energy have to flow through a cable per diameter and the cable is too long, the pressure degreases and the heat in the cable increases.
Are the cable connections not “tight”, you loose pressure.

Transferred into the electrical system means:

- To small cable diameter on long cables lead to voltage drops in the cables and heat them up.
- Are the cable connections bad, they create contact resistance, and the Voltage drops over it (voltage loss) and heat arise.

Other points in the electrical system:

- In every cable in which electric current flows, a magnetic field is produced, which is greater, as higher the current is that flows. -> Compass influence of magnetic fields / Autopilot probelms.
- We assume that the power flow from the positive “+” to the negative “-“ pol.
- Also 12V systems can be dangerous, as by short circuits very high currents can flow.

What does that mean in practice?

Charge:

As already mentioned, the battery is a small chemical plant. Therefore a correct and regular charge of the batteries, at the right time is essential for its optimal and long lifetime.

A battery must be charged with the appropriate voltage and the corresponding current (depending on battery type and capacity). If this is not the case, the battery loses its capacity and age more quickly.

Are the following points not met, the battery is not ideal / not fully charged:

- Correct charge voltage (depending on load level, battery type and temperature).
- Min / Max load current (depending on battery capacity).
- Proper cable diameter (depending on cable length and load current, otherwise (voltage drop and to small charging voltage).
- Regularly full charge, after discharge.
- Proper maintenance (depending on battery type).

If the battery is discharged too low (<10.5V), it will be damaged and loses its capacity. For optimum lifetime it is recommended to discharge a battery to only 50% of its rated capacity (normal batteries).
The exact determination of the state of charge (SOC) of a battery is almost not possible at short notice.
It is therefore crucial to know in what condition the battery is and how much energy is left.
For an accurate statement, a battery management system is essential. This monitors the voltage, the current flow and time. With this it calculates the state of charge, consumed capacity, time left. Some monitors also store historical data's about the usage of the batteries.

With the voltage measurement, just an estimated state of charge can be determined: (lead battery)

State of charge	Idle (min. 4hours. not in use)	light use (estimated)
100%	12.72 V	12.6 V
80%	12.51 V	12.4 V
50%	12.3 V	12.2 V
20%	11.88 V	11.7 V
0%	11.64 V	11.5 V

Consumers:

If you operate a refrigerator with a voltage of 12.7V and a current of 5A (power 60W) with a cable of 2.5mm2 diameter and 8m length (16m total, outward and return). The voltage drops while operating to 11.0V (on the refrigerator), so it creates a voltage drop of 1.7V. If the refrigerator is equipped with a low-battery switch-off (11.5V), it switches off shortly after it has been switched on. As voltage drops only during operation short after it has switched off, the voltage rises again, and the fridge try's to start again. This game goes on forever. What you definitely don't get is a cold beer.

The solution is: to increase the cable diameter. I recommend a cable from min.10mm2 or you reduce the cable length, which in practice is often difficult to achieve. This shows that it pays out to pay attention for short cables possible.

The reasons for similar voltage drops can also be bad / high contact resistance.
These are caused by corroded contacts, bad pressed connections or loose fittings.
Which can be counteracted by simple measures:

- Keep the cable connections dry, possibly treated with water protection spray (Wet-Protect).
- Use professional crimping tools or at least press them seriously and test for holding.
- Check connections and fittings. Especially in wirings where large currents flow, heat arise which results in a expansion of the material. (Charger, generator, inverter, shunt, main switch, main fuses).

This is an overview of the problems of cable lengths, wire sizes and voltage drops.
With this knowledge you are able to identify the causes of electrical problems.

After reading "Measurement Basics", you will be able to perform measurements.
Based on this, I can help you to optimize your system, to locate possible errors and problems, as well as resolve them.

Another important issue is the proper sizing of the batteries, its control, charging options, distribution, and the energy you are require.

I’m happy to assist you in all this questions.

Silvio Franceschini, y-tronics