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# **Selecting the correct cables, connectors and fuses**

They might seem cheap and insignificant, but cables connectors and fuses are critical to the safe and effective function of your solar system.

## **What cable to use**



A selection of tri-rated multi-strand cables

When installing wiring in boats and vehicles, it is important that a multi-stranded cable is used. Household wiring with a single or a few stiff strands is not suitable as it is liable to break when exposed to vibration.

It is also wise to stick to the standard colours of red (positive) and black (negative) when installing DC wiring, to avoid confusion with any AC wiring.

Standard or slimline automotive wiring can be used, but a tri-rated cable will tolerate higher temperatures without burning - a good idea if your cables are running through insulation or in tight bundles.

Cables installed outdoors should be resistant to ultraviolet light and abrasion; the excellent [FlexSolar](#) cable is perfect for the job.

## How thick?

To work out what thickness of cable you need for a particular job, first you need to know the maximum current it will need to carry in amps. Often, this will be written on the appliance somewhere. If you can only find a power rating in watts, simply divide it by 12 for 12V appliances or 24 for 24V devices.

Next, you need to measure the length of the cable. Longer cables need to be thicker to transmit the same power because longer cables tend to suffer voltage drop - where the cable itself uses up some of the power. You can measure the length of either the positive or negative cable, you don't need to add them together.

Now just check the chart below to select the appropriate cable thickness. This will tell you the lightest cable you can get away with, while losing no more than 5% of the voltage in the cable. There never any harm in using a heavier cable.

<i>Minimum cable size in mm<sup>2</sup> (for max 5% volt drop on 12V DC wiring)</i>								
<b>Amps</b>	<b>Cable length (one way, metres)</b>							
	<b>1</b>	<b>2</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>	<b>25</b>	<b>30</b>
<b>1</b>	0.75	0.75	0.75	1.5	1.5	1.5	1.5	2.5
<b>2</b>	0.75	0.75	0.75	1.5	2.5	2.5	4	4
<b>3</b>	0.75	0.75	1.5	2.5	2.5	4	6	6
<b>4</b>	0.75	0.75	1.5	2.5	4	6	6	10
<b>5</b>	0.75	0.75	1.5	4	6	6	10	10
<b>7.5</b>	1.5	2.5	2.5	6	10	10	16	16
<b>10</b>	1.5	1.5	4	6	10	16	16	16
<b>15</b>	2.5	2.5	4	10	16	25	25	25
<b>20</b>	2.5	2.5	6	16	25	25	35	35
<b>25</b>	4	4	10	16	25	35	35	50
<b>30</b>	4	4	10	25	25	35	50	50
<b>40</b>	6	6	16	25	35	50		
<b>60</b>	8	8	25	35	50			
<b>80</b>	16	16	25	50				

<b>100</b>	16	16	35					
<b>125</b>	25	25	35					

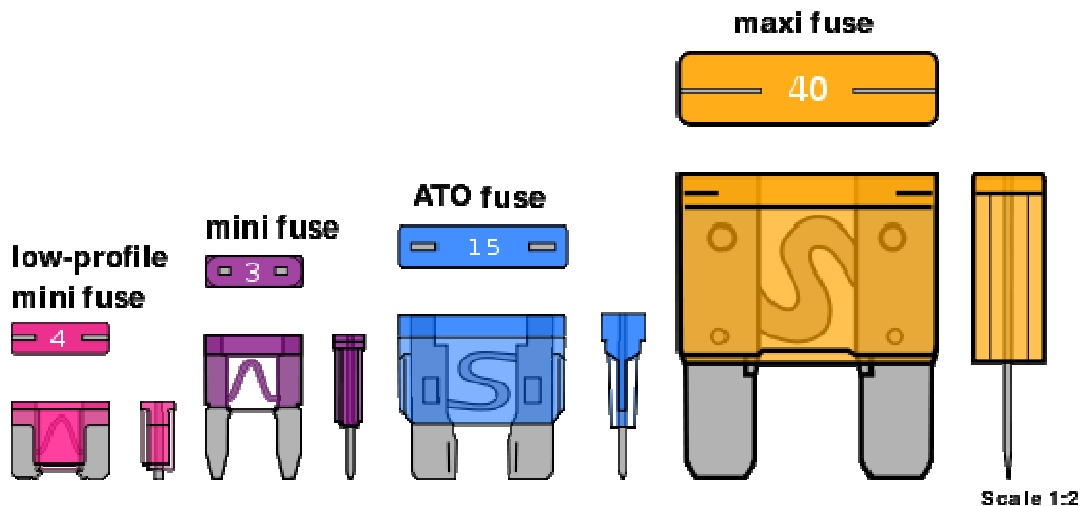
If you want to be a bit more accurate, or if you have cable sizes other than the standard tri-rated ones listed above, you can calculate the minimum cable size yourself.

To ensure a voltage drop of no more than 5% (0.6V), the formula is:

**Minimum cable area** (in mm<sup>2</sup>) = **0.0546 x current** (in A) x **length** (in m)

Again, the length here is the distance from the battery to the appliance only, and not all the way back again.

## Fuses



Various automotive fuses [CC Havarhen](#)

That's not the end of the story - fuses are an essential safety feature of all DC wiring (compulsory on boats). The fuse can be anywhere on the positive side of the circuit, but it makes sense to put them all in a convenient place by using some sort of switchboard. They can be fitted directly to cables using an appropriate in-line fuse holder.

Fuses protect your *cables* not your appliances. Cables get hot when carrying currents close to their design limits, and if a fault somewhere causes an even higher current they can start a fire! Fitting a correctly-rated fuse ensures the circuit is broken before the fault starts a fire.

Always fit a fuse with a equal or lower rating than the cable. These ratings are a little on the conservative side, to allow for cables that might get usually hot, for example when in contact with insulation:

<i>Maximum fuse ratings</i>	
<b>Cable thickness (mm<sup>2</sup>)</b>	<b>Fuse rating (amps)</b>
0.75	5
1.5	10
2.5	20
4	30
6	40
8	50
16	80
25	100
35	150
50	200

The one place where a fuse should *not* be installed is the engine starter cable. Starter motors can draw very high currents that will blow even the largest fuses, but since they are only switched on for a few seconds at a time the risk of overheating is minimal. This is why you should not crank your engine for more than about 20 seconds at a time, and allow a few minutes for everything to cool down between attempts.

**Circuit breakers** make a good alternative to fuses. Just ensure you use breakers that are rated for DC wiring not just AC, or they can be damaged each time they trip.

## Making good connections

Crimp-on terminals come in all shapes and sizes. There's little point in investing in good quality, thick cables unless you make a sound, strong, low-resistance connection at the ends!

Some devices, such as our [MorningStar 24-volt solar regulators](#), can connect directly to a bare wire but most of the time you need a suitable terminal.

Battery terminal clamps generally require a ring terminal with an 8mm hole. Regulators and solar panels often take a fork terminal, and switchboards, fuses and some appliances often require spade terminals.

Use the correct terminal for your cable gauge. Crimps with red sleeves fit 0.5 to 1.5mm<sup>2</sup> cables, blue terminals fit 1.5 to 2.5mm<sup>2</sup> and yellow 4 to 6mm<sup>2</sup>. Larger cables have specific terminals, generally uninsulated.

If possible use the proper tools to attach them, if not a vice will do a reasonable job. The larger uninsulated terminals can also be soldered on, but take care not to let the solder run down the cable as this can create an inflexible weak spot.

For that professional finish, cover the join with some heat-shrink insulation.

Below is a table showing approximate resistances per metre length for different sizes of copper wire. (Resistance is measured in ohms)

Cable Cross Sectional Area mm <sup>2</sup>	Approximate Equivalent American Gauge	Approx. Resistance per M Length ohms
1.5	16	0.012
2.5	14	0.007
6	10	0.003

So, how do we use this information?

Let's suppose the cables we connect to our solar panels are going to have a 1.5mm<sup>2</sup> cross sectional area and are going to be 20m in total length (10m each for positive and negative cables).

The total resistance of our cable will be  $20 \times 0.012 = 0.24$  ohms

Let's suppose that our solar panels are going to be pushing out 20 amps of current, then we can use ohms law to calculate the "voltage drop" along these cables.

ohms law can be stated as:  $V=IxR$

Or, Voltage Drop = Current in amps x resistance in ohms

In our case above, the voltage drop is going to be  $20 \times 0.24 = 4.8$  volts. This means that the voltage at the charge controller end of the cables will be 4.8 volts less than the voltage produced by the panels if a current of 20amps is flowing.

This voltage drop is irrespective of the voltage we are using, it is caused by the current and the resistance.

If our panels are wired for a 24 volt system we would be looking at a voltage drop of 20% which is clearly unacceptable. Various different figures may be quoted as a maximum acceptable voltage drop but 2% sounds like a good target.

In our example above, 6mm<sup>2</sup> cable would still have caused a 5% voltage drop, so it would be worth considering larger cable still, or separate cables for each panel (each cable then carries a smaller current so there is a lower voltage drop, or mount the panels closer to the charge controller and batteries to reduce the cable length.

If you are still in the design stage of your system, you may consider using a higher voltage system.

Panels producing the same wattage as those in our example above (20 amps x 24 volts = 480 watts) but wired to give 48 volts, will only be producing half the current (still the same power of 480 watts).

With only half the current flowing, the voltage drop will be half, and better still, with double the voltage, the percentage voltage drop is halved again, ie, the same cable will result in 1/4 of the % voltage drop that you would get with a 24 volt system of the same power.

### Earthing PV Panels

Depending on your location, it may be required that your panel frames are earthed, and it is certainly advisable.

Non earthed frames can acquire an induced electrical voltage (which may or may not be harmful) or could accidentally come into contact with a live conductor.

Making a good connection between a copper earthing wire and the aluminium frame of a pv panel is not straight forward due to natural oxidation of aluminium, and any manufacturers instructions should be followed.

In some cases, the DC circuit should also be earthed, as should the AC circuit, following manufacturers instructions.

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