

# DESIGNING MOTORHOMES WIRING HARNESS



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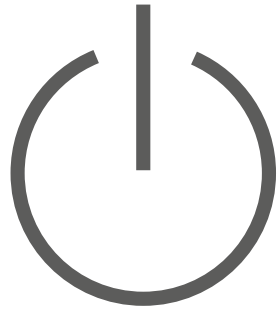
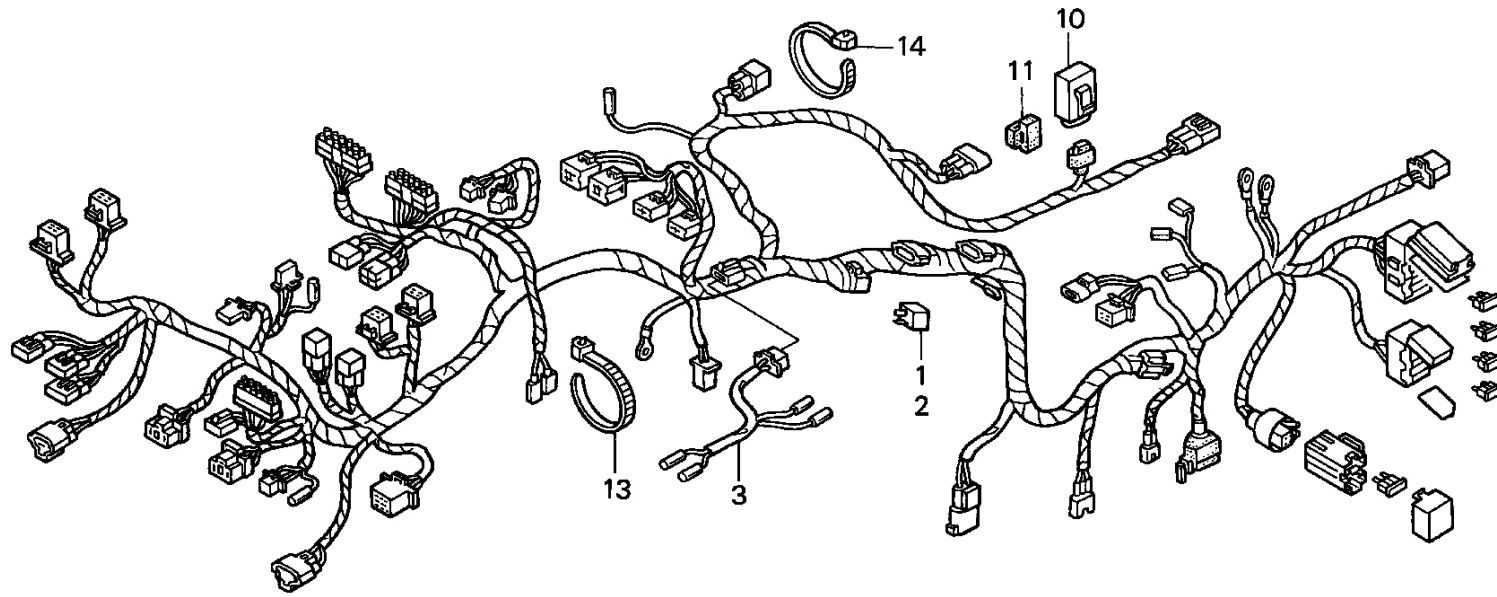
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DESIGNING MOTORHOMES WIRING HARNESS

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**BEFORE WE START**



This little booklet is meant as a very simple guide for motorhome maker to design the electrical and electronic wiring harness.

It is by no means exhaustive, but it deals with the most common problems when designing modern wiring solutions.

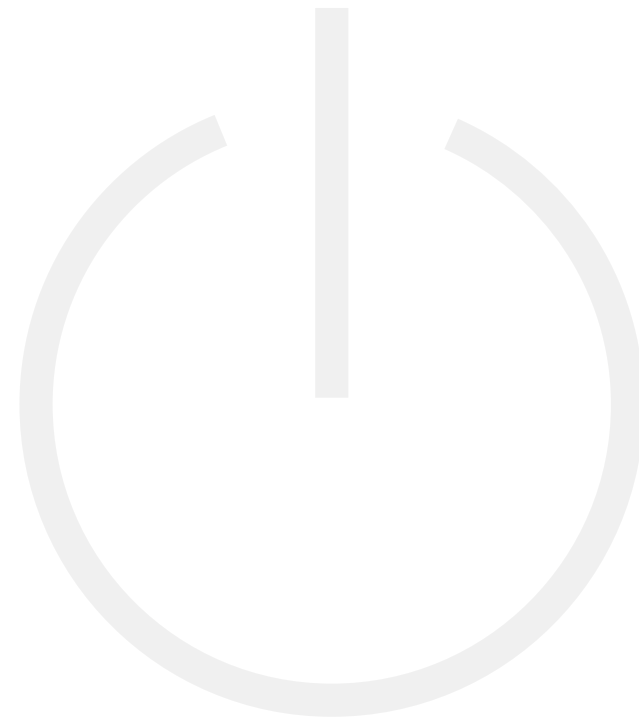
Following a path already set by the car industry, the Motorhome makers faced a new challenge: abandoning substantially simple electrical wiring and adopting bus solutions.

*Advantages of this novel approach are many, but three are the most important benefits:*

- **weight saving (less copper!)**
- **unprecedented flexibility (add new plug and play aftermarket components)**
- **increasing safety in electrical fire prevention (electronic protection)**

The drawback is that this solution requires new competences and a different approach to the design. This is why this paper was written!!

In the following we will try to express clear guidelines for designing motorhomes electrical systems using latest available technologies.





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# BASIC GLOSSARY



*Before we start we need to understand the basic building blocks you will most likely need, beside the wires.*

### **Power Supply / Battery Charger**

The Power Supply, as its name implies, delivers the power necessary to charge the battery/s and/or to all appliances installed in the motorhome. It basically transforms higher voltage AC voltage (110 or 220-230 V) down to 13V DC. According to the model specifications it might be of different power rating. Care should be taken in choosing the right amount of power needed, since extra power is often more expensive and, most important, weights more!

Nowadays more often new units incorporate in the same case a power supply and battery charger. What this means is that these units beside energizing the motorhome are also able to perform special charging cycles according to batteries types and charge status.

### **First Level Distribution Box: Power-Links**

Power-Links distribute energy from the PowerSupply/Charger to the batteries. This unit

incorporate a logic to connect the motor battery in parallel with the aux or leisure battery, only when the alternator is charging (engine running) or if the battery charger is connected to the main and delivering power. Quite often these units incorporate a logic for common devices too, like refrigerators and external car lights. Power Links outputs are connected to one or more secondary power distribution units.

Several levels of thermal and electrical protections are active to prevent all sorts of accidents. The Power-Links might also incorporate a secondary distribution section to power some local loads. They normally have some inputs lines too, to monitor different signals: alternator charging, main hookup etc.

### **Secondary distribution boxes: Power-Hubs**

They are attached to the PowerLink and distribute power in complete safety to all the appliances in the motorhome. Most often there is one or two power hub installed in the ceiling to power all the lighting elements, and one in the floor to energize all the devices placed nearby. Several sizes of power hubs are available on the



market, differentiating mainly in the number of independent outputs and max deliverable power per output.

## **Water Pump Node**

It is normally placed close to the tanks and to the water pump. It can safely drive a water pump and at the same time monitors the levels of several clear and waste water tanks.

## **Additional Nodes**

In a similar way, Solar panel Nodes, heating mats controllers, Sat Antenna suppliers and other specialties node can eventually be installed according to particular needs.

## **Control Panels**

The system is never complete without one or two control panels.

The control panel is the main user interface. It can be of several sizes and can provide different level of accuracy of introspection on the system. It might range from a simple panel with several warning lights and switches to a complete large size touch technology LCD monitor with several screens of data and possible actions. The basic actions common to most panels are: switching

on the main for the lights, for the floor loads power and the water pump. Most often it lets the user monitor the water tanks levels and battery charge status.

More sophisticated interfaces let you perform a complete check up of your motorhome and diagnose malfunctions.

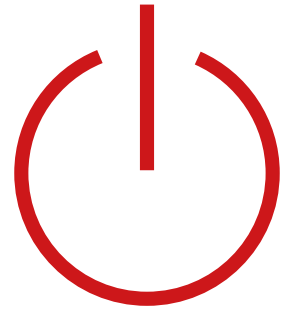
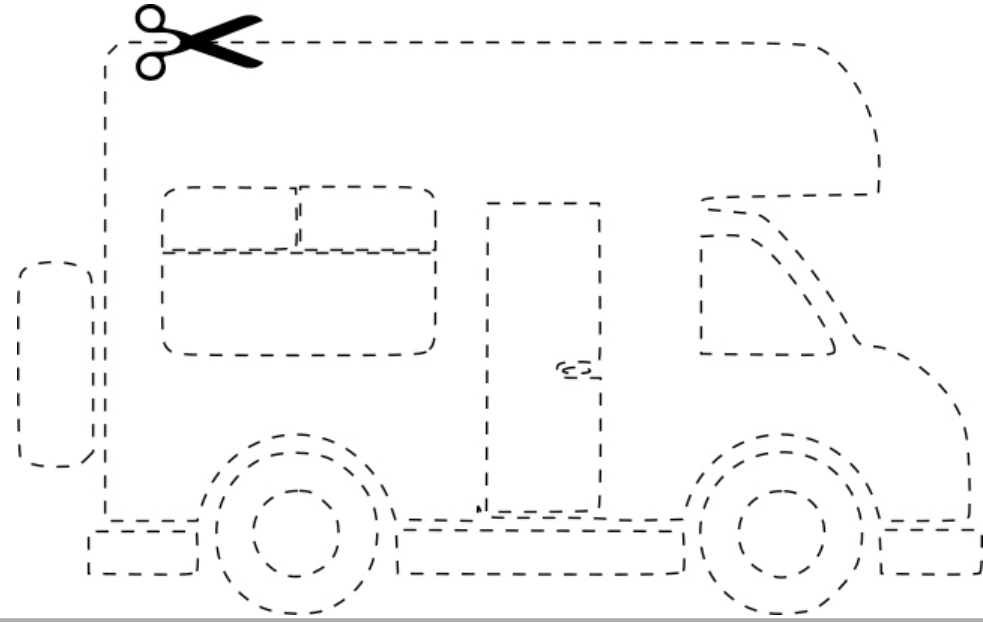
## **Putting it all together**

The logic diagram below shows a typical motorhome system, with 2 batteries (bottom) attached to one Power-Link, and two Power-Hub for the ceiling lights. A power supply, one water pump node and a control panel complete the picture. In red the energy distribution backbones, where most of the energy flows. In green the communication bus line. Two little 4 or 6 switches panels are used to remotely quickly access, most common functions (lights, external lights, water pump etc.)









# STARTING UP



## Counting the loads

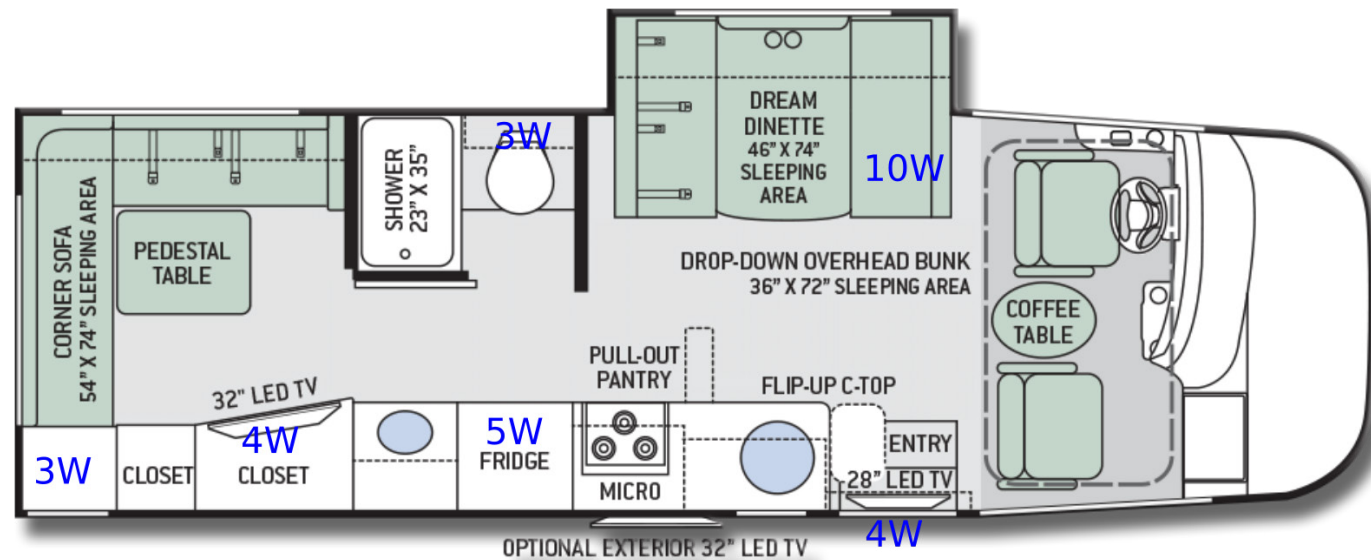
First step is to take the motorhome floor-plan and the roof-plan too. Over these two drawings we locate all the appliances that need energy to function. Close to each of the appliances, we should write down the max power (Watts) stated on the device label.

From power (Watts), if we divide divide this by average supply voltage (12.5V) we obtain the

max current.

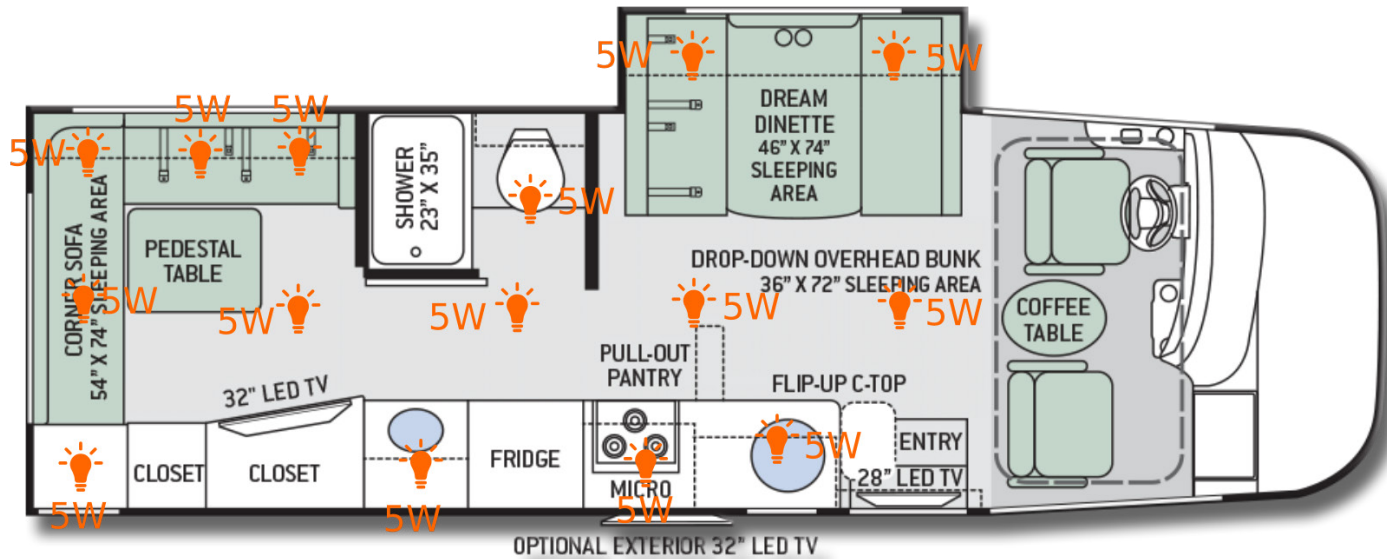
Adding up all the max power of the devices which can possibly function together, floor and roof, give us a quite important figure, max deliverable power. This figure will help us in the next chapters to choose the right size of the power supply, and also to dimension the main cables correctly in further chapters.

*Typical example of a floor-plan is depicted below:*



*Doing some maths:*

*Total Floor loads power consumption:  $3+4+5+3+10+4 = 29$  Watts max.*



*Total roof lights power =  $15 \times 5W = 75$  Watts total.*

*Adding up the total max power for floor loads and ceiling.*

*For a total of  $29.75 = 104$  Watts, it will require at minimum a  $10A \times 12V = 120W$*

*Power supply max output power.*



The AL-Bk20 is probably the right model for you. This unit is a basic model which can effectively charge lead acid batteries and provide plenty of power (240 Watts) for all the loads when vehicle is attached to the distribution line (220V or 110V).





**ENERGY**



# WHERE DOES THE ENERGY COME FROM?

## **Batteries Wiring**

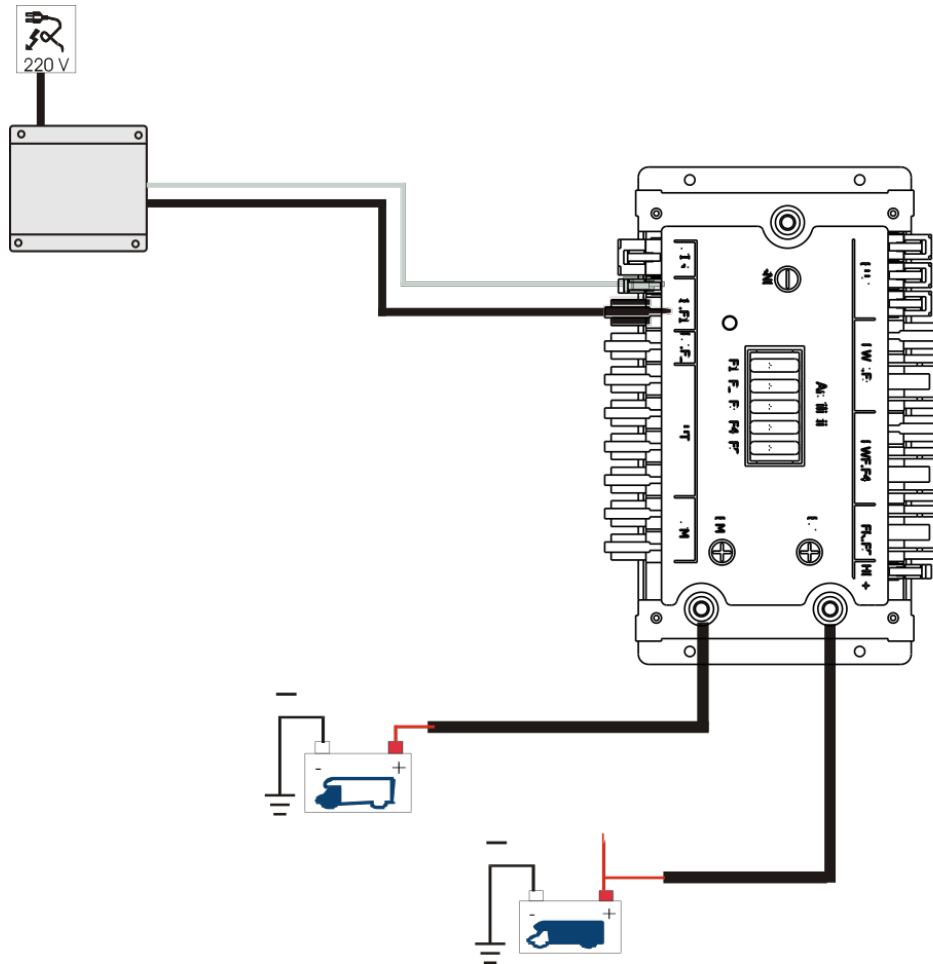
First step is to decide where the batteries are located. Normally the engine battery has its place pre assigned by the car maker, while we are free to choose where to place leisure batteries.

We need a place that should be vented and easily accessible. As a rule of thumb, the closer to the power link we can keep both the batteries, the more we will save in term of weight and cost of copper.



The wires that connect these batteries with the power-link are by far the thickest present in the motorhome in term of copper cross section, in order minimize losses during charging and avoid fire risks. Any effort to reduce the length of these wires is well worth!

The cabling looks something like this:



By ArSilicii

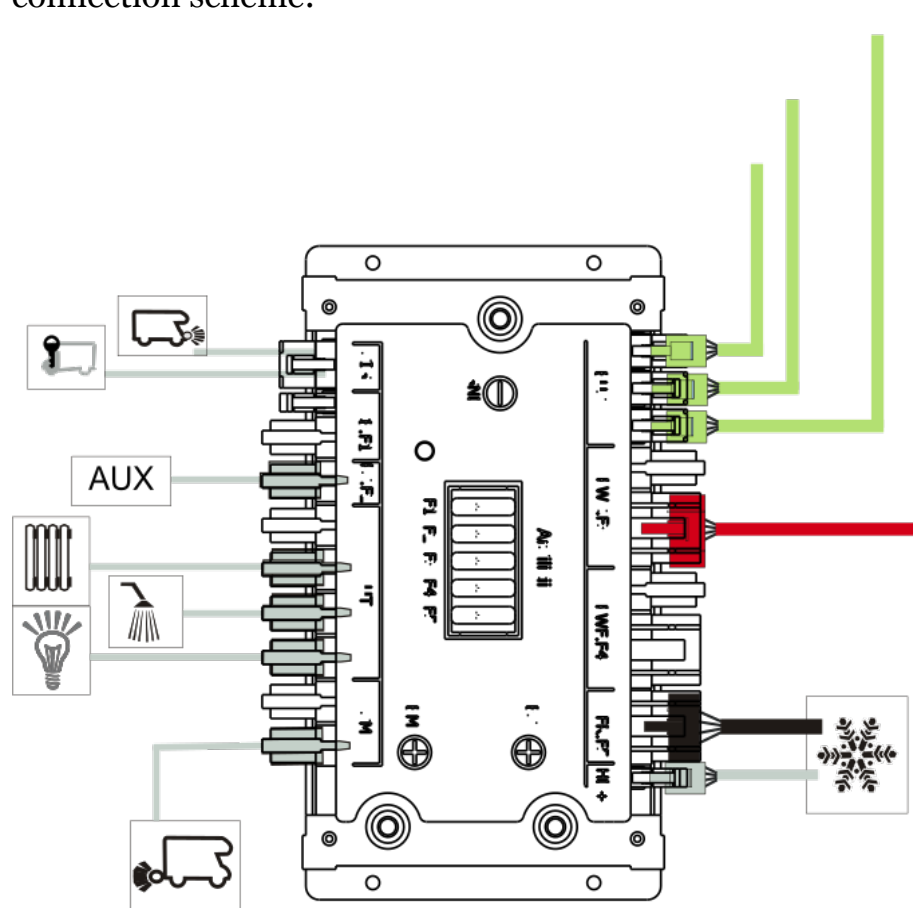
Please refer to the appendix A at the end for some advices for cable size selection.

Each cable must be protected by a fuse or some other kind of protection scheme, this topic is of extreme importance and is dealt with in the appendix B.



The power-link, as stated previously, is also attached to the power supply, normally via two wires (see the picture before), the power cable, providing the energy to recharge the batteries, and a signal cable to communicate the presence of an active external source.

The Power-Link serves also as a collector of many other signals. In the picture below a typical connection scheme:

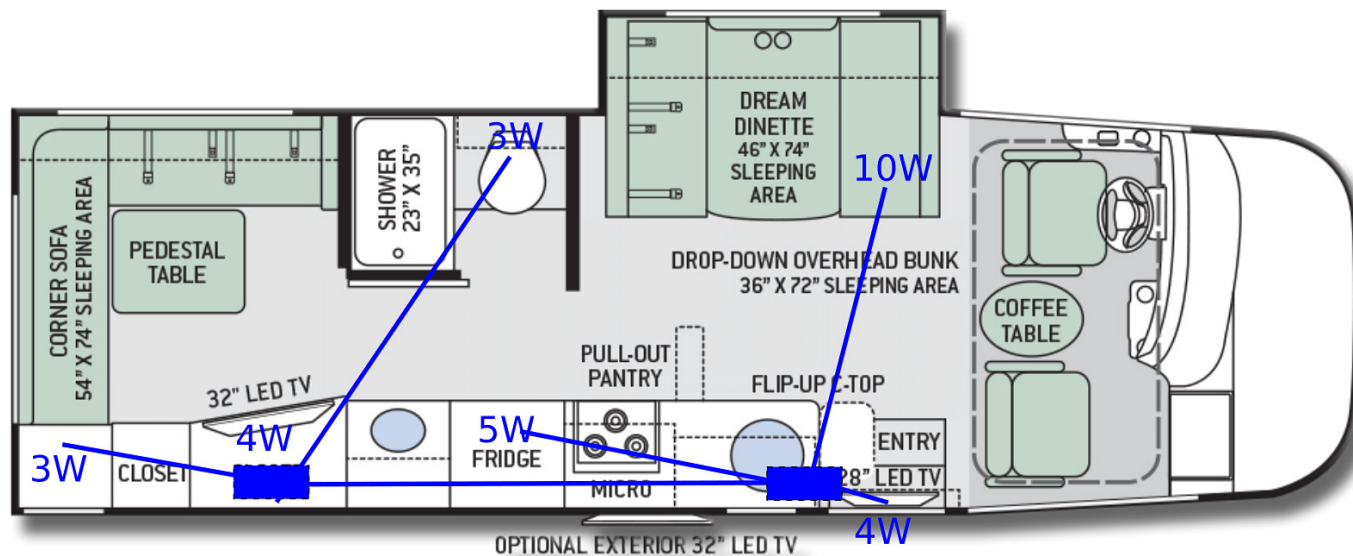


As you can see (Starting from the top right going clock wise), in green are the bus lines that connect to Power-Hubs and to other nodes, in red one (or more) power lines connecting typically to PowerHubs for energy distribution. There is a special refrigerator output, that can deliver in full protection, both the line for the internal light and the power line for the cooling process.



There is an output line driving auxiliary cruise lights when the car main front light are turned on. Many of our units, like the one depicted above incorporate in the same box also a small Power-Hub to energize and protect floor lights, water heater, central heating stove and other special loads. In the upper left corner the unit receives as inputs, the signals of the car engine running (to connect the batteries together in parallel when charging, and to run the fridge with 12V) and an input of signal of the car's front lights on.

*Looking back at the floor map that we drew in the previous chapter:*



We might decide to power some of the floor loads with some of the outputs of the power-Link, and add a powerHub for all the loads located near the back of the motorhome (blue boxes in the drawing above).

In the case above from ArSilicii catalog we might want to use are the following devices:

The PowerLink PL2 TTK

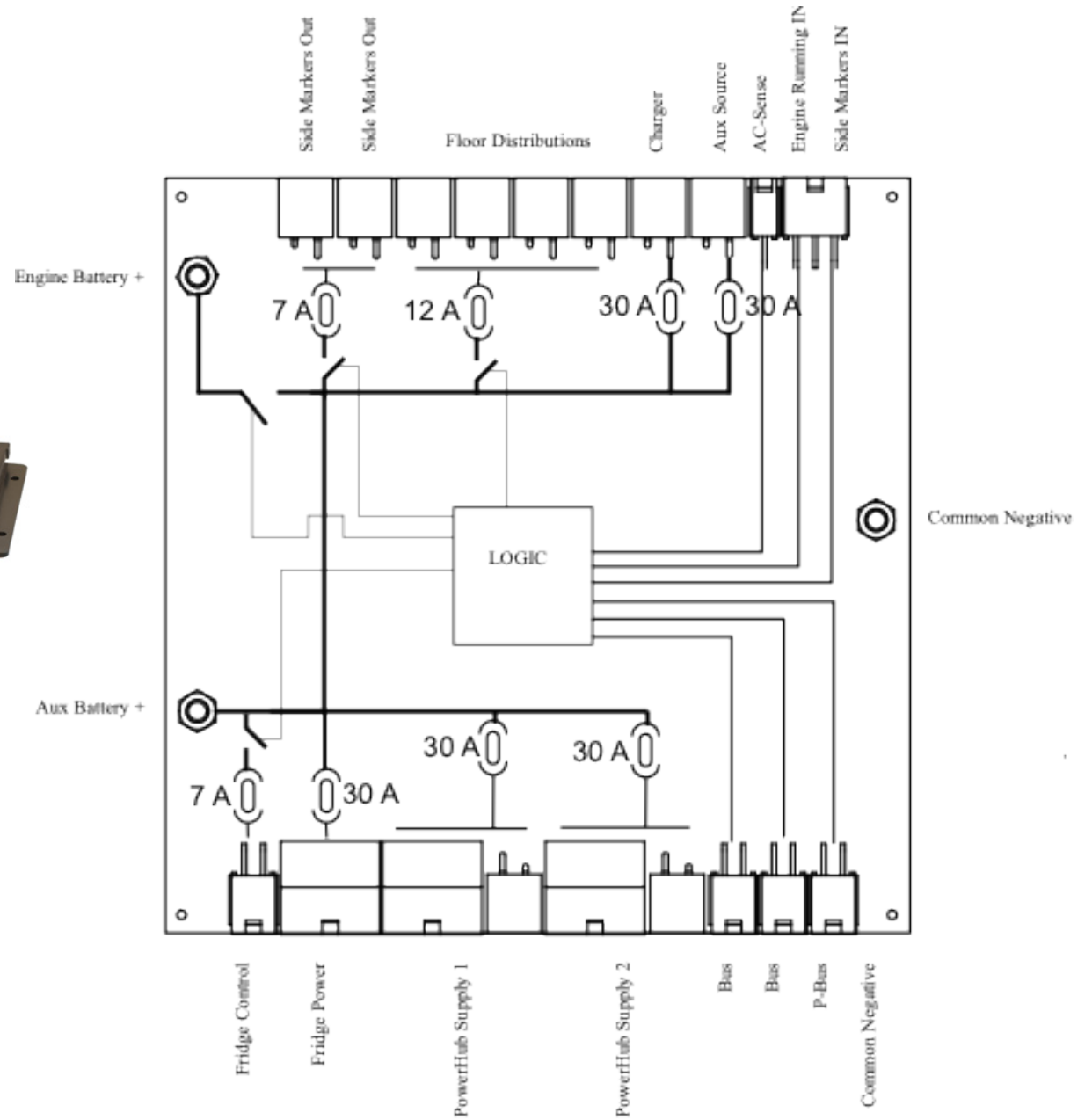
It can deliver up to 12A on each of the power output, and it has embedded Fridge logic and battery parallel logic. Furthermore it features a good amount of I/O ports.



Below is the logic diagram of the PowerLink.



PowerLink PL2 TTK

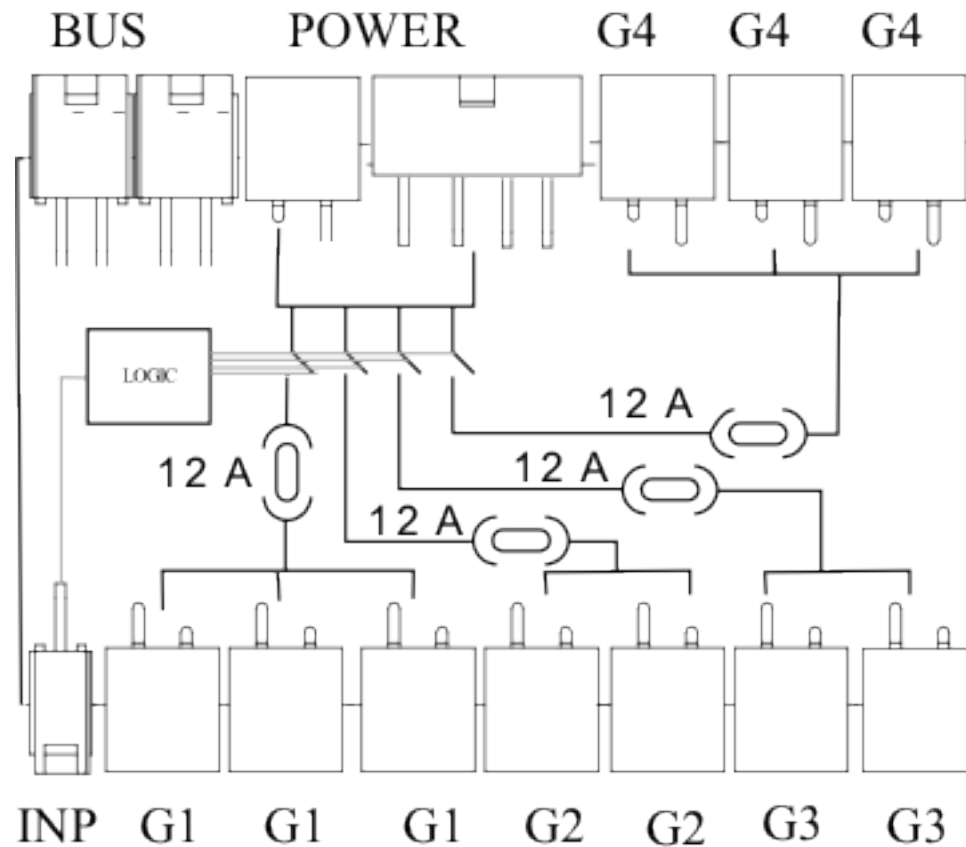


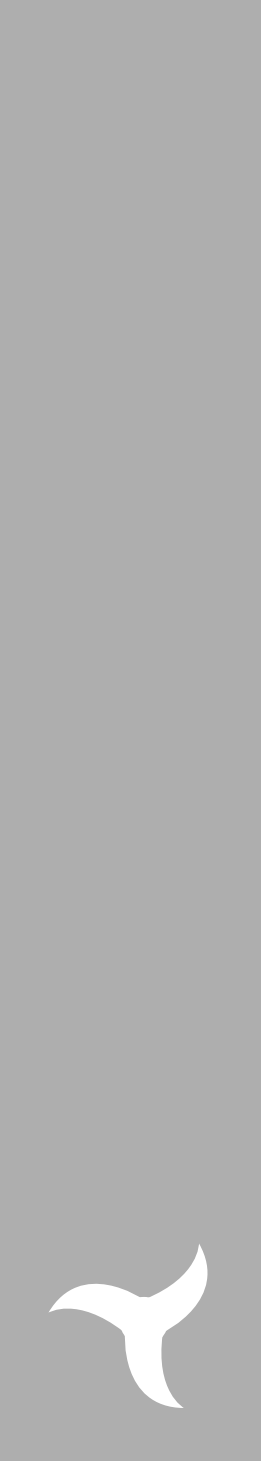
If we decide to split the loads adding a Power Hub attached to the output of the PowerLink we might opt for a simple PH4P, featuring 16 outputs connector divided in 4 groups each able to provide up to 12 Amps,.

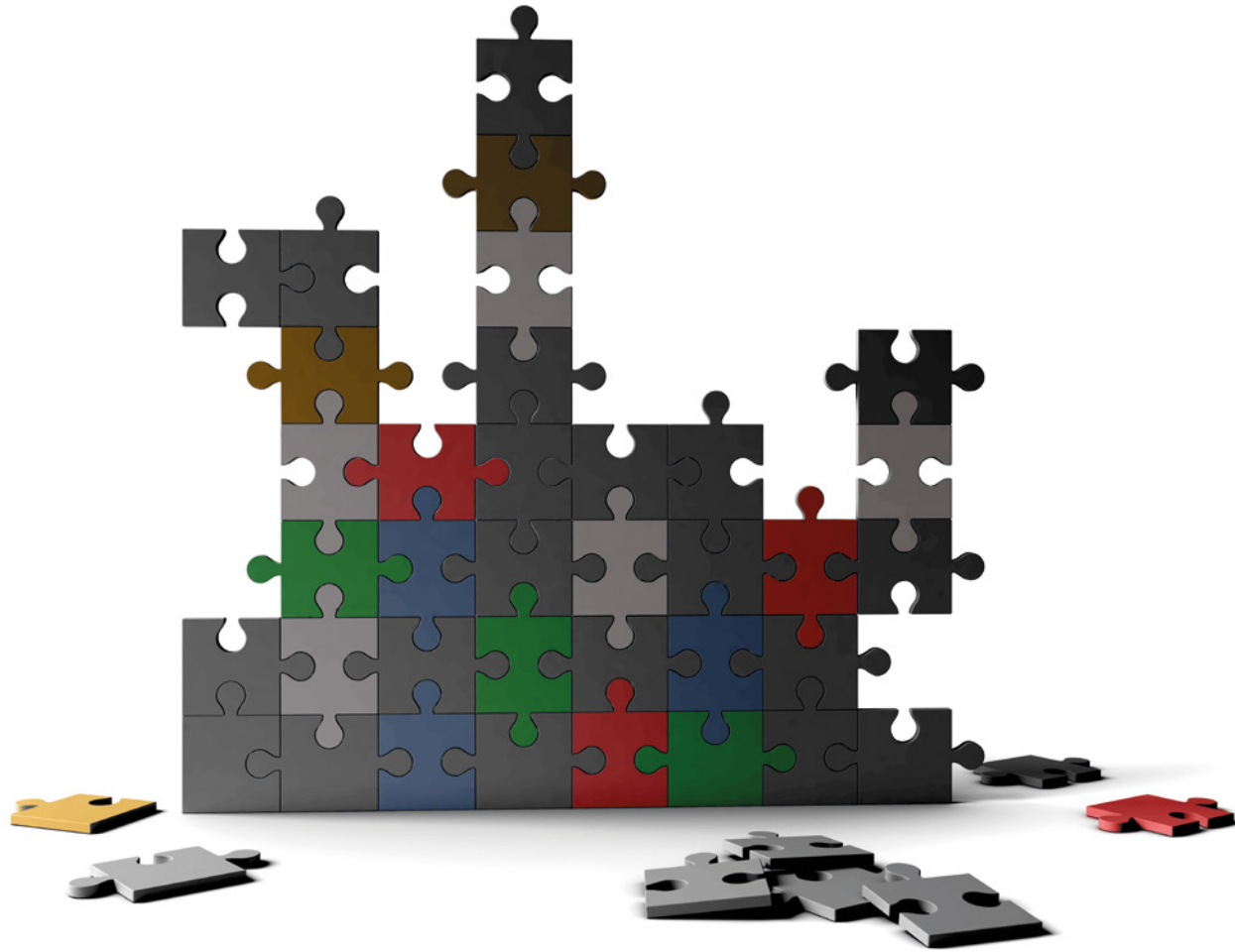
*Below a logic diagram of this unit too:*



PH4P







**FROM THE GROUND UP..**

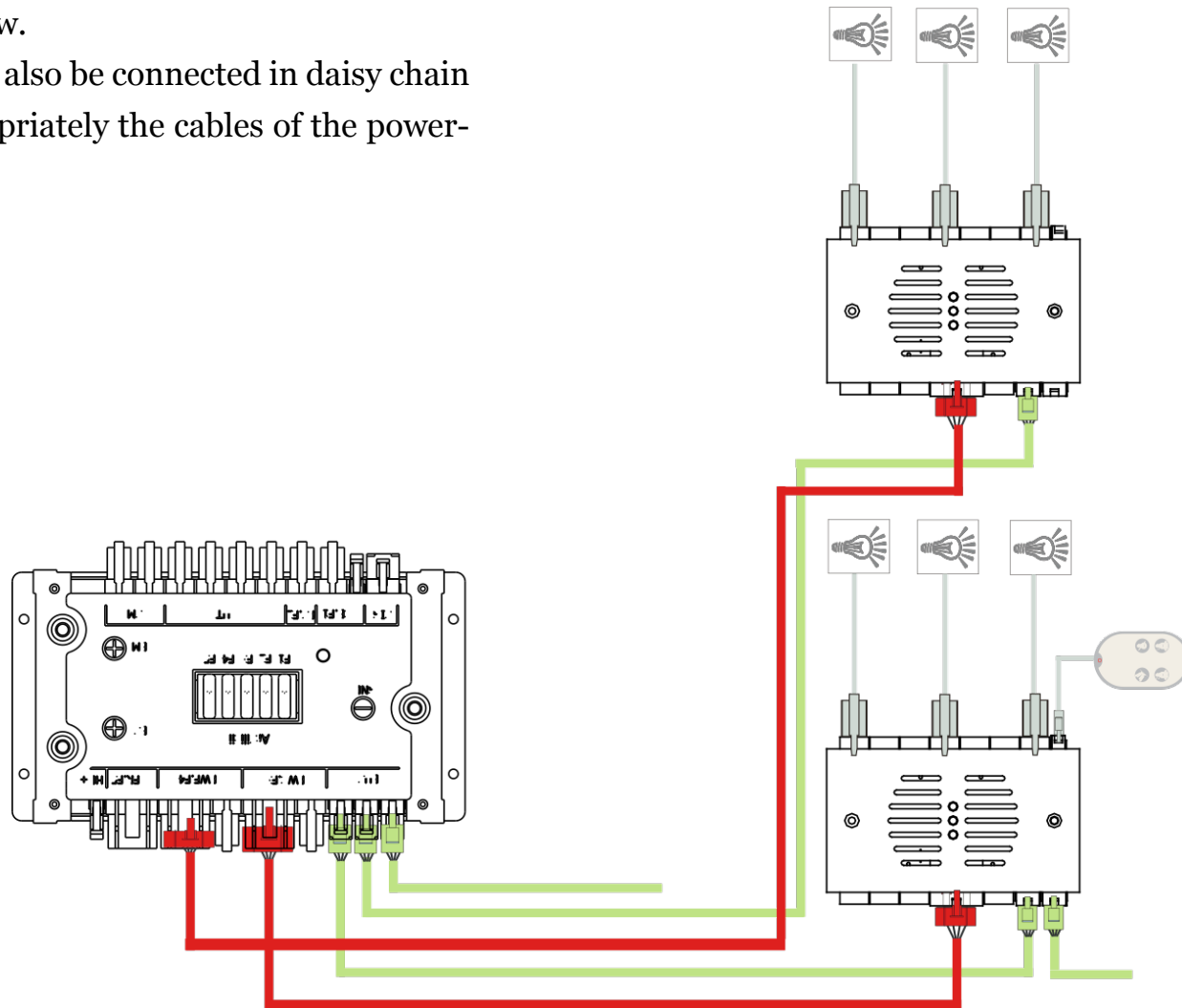


## Cabling up to the ceiling

From the power link unit we need to run the wire (or the wires) that connect to all the power hubs located in the floor and on the ceiling.

The wiring diagram for a two Power Hubs system is depicted below.

PowerHubs can also be connected in daisy chain up-sizing appropriately the cables of the power-line.



As usual in choosing the wire gauge and lengths we must follow the specs of the protection scheme and ratings of the power links outputs (see appendixes A & B). The same consideration for keeping the wires lengths down is true here. But the problem is a bit more difficult to solve and decide where to place the Power Hubs, in order to minimize the total length of the wiring harness.

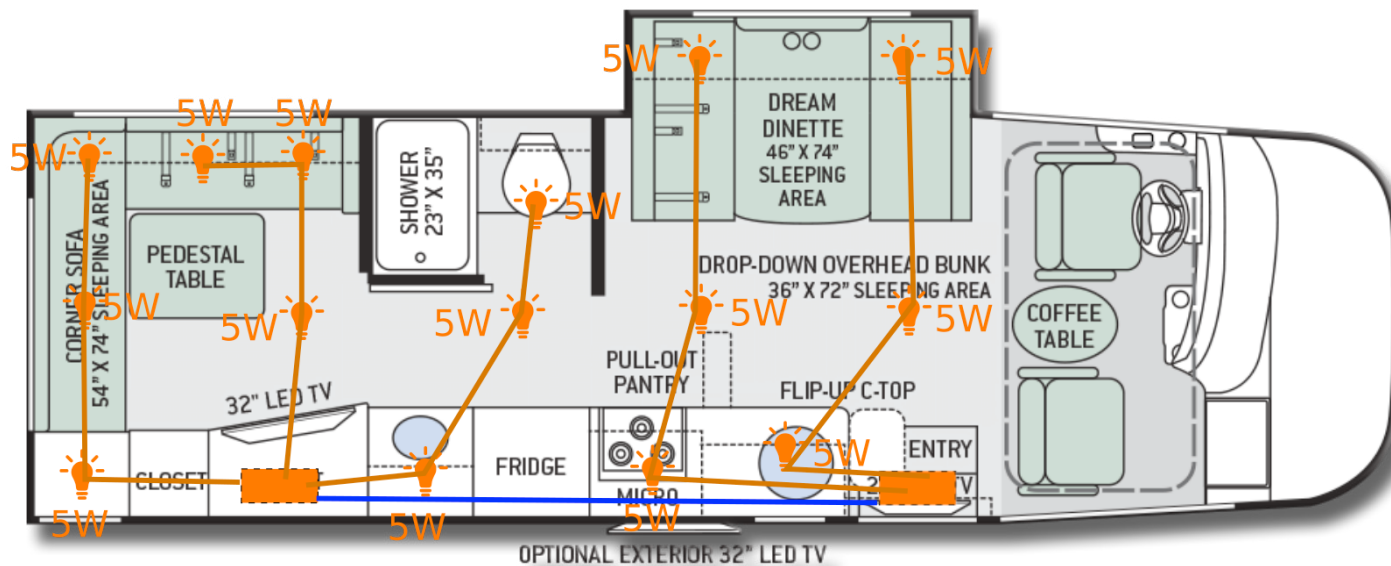
Using the floor plan with all the floor appliances marked down we try to place the power hubs in the center of the loads it needs to feed.

The same is done for the roof plan for the lights. Choosing the number and length of the power-lines backbones connecting the power link with all the power hubs it depends entirely on the current needed and total wire length of that branch.

*Here is sketch of a possible solution for a relatively simple floor plan.*

*In the drawing above, the lights' position is indicated by the lightbulb symbol.*

*The boxes indicate the Power-Hubs.*



Grouping together lights on the same line has the advantage of saving some cable length, even if the section of the wire increases. Obviously if a line fails, for example for a short circuit in any point of that line, the Power-hub selectively protect that line, and shuts it off: this mean that all 3 these lights will not work.

Normally it is a good idea to choose a trade off between running a separate line for each individual light, and grouping many lights under the same line.

Beside if we would like to operate a light or a group of lights remotely through one of the control panels, we need to assign to this group the same independent output.

If we suppose that all the lights are 5Watts lights, we might decide to group 3 lights together under the same line on a single output of a PowerHub.  $5 \text{ Watts} \times 3 \text{ light} = 25 \text{ Watts}$  per line this in turn means :  $25 \text{ Watts} / 12.5 \text{ Volts} = 2 \text{ Amps}$  per line. If we choose PH4 (see previous chapter for logic schematic), it can deliver at least 10 Amps per line to guarantee that protection won't trigger for peaks of extra current when turning on the lights.

Following the direction stated in Appendix A, we must select the cable section to have an acceptable voltage drop on the furthest light.

We also must keep in mind that our electronic protection won't fire till the current reaches 10 Amps. Let's Suppose the furthest light needs a 4 meter long cable, the minimum section given by the table in Appendix A is AWG 8!





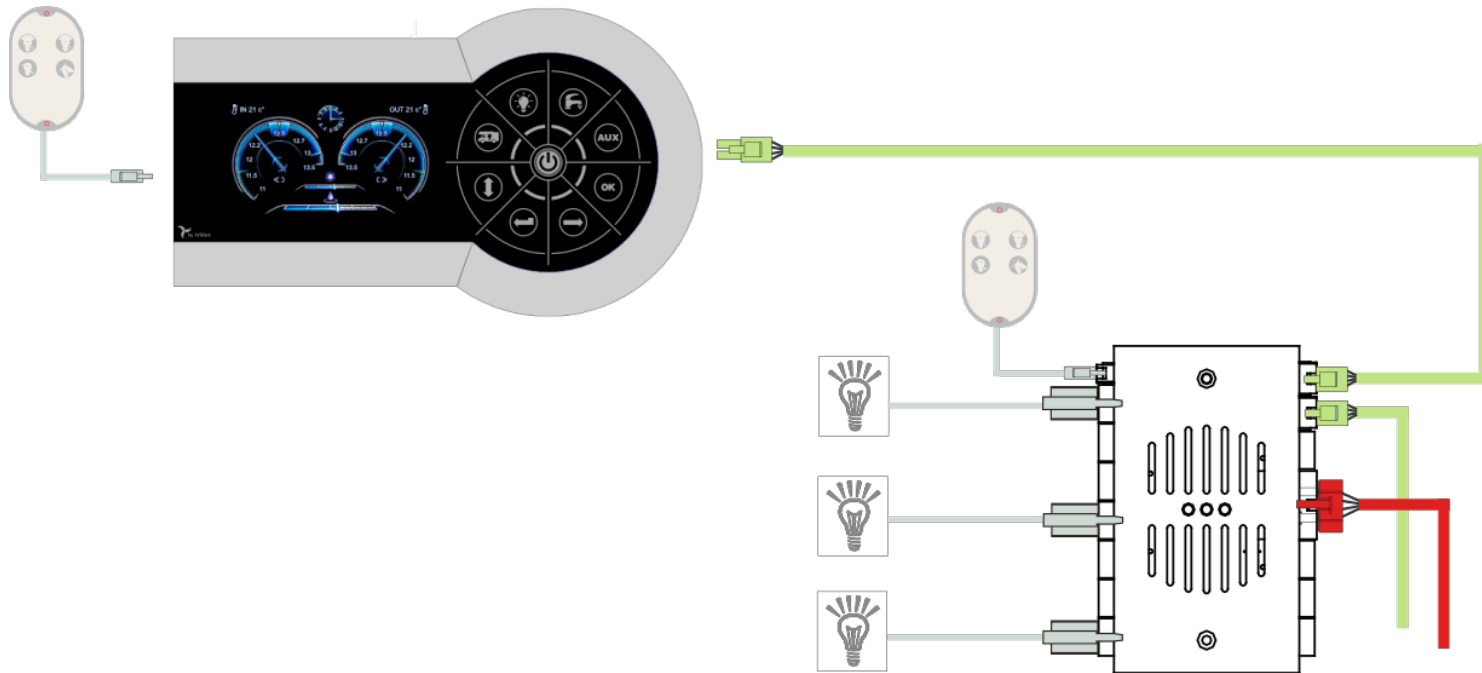


## CATCHING THE BUS!

*We voluntarily left off the details of data bus cabling. All the units exchange information between each other by means of a bus communication. The water pump node sends the levels to the control panel also the power link measures and send the status of charge of the batteries to the control panel, while the control panel sends command of switching on the pump to the water pump node. All these data runs on a pair of wires. These pair of wires connects all the units.*

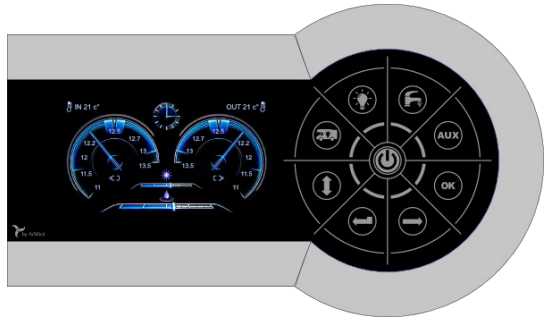
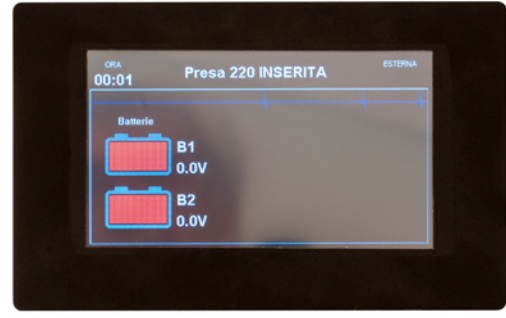


Below in green is represented the connection of the Control Panel. It is often convenient to connect it to one of the ceiling Power Hubs, bus line is green.



There can be more than one control panels, often another smaller control panel is located by the driver's seat. Here Some Example of our control panels





CATCHING THE BUS!



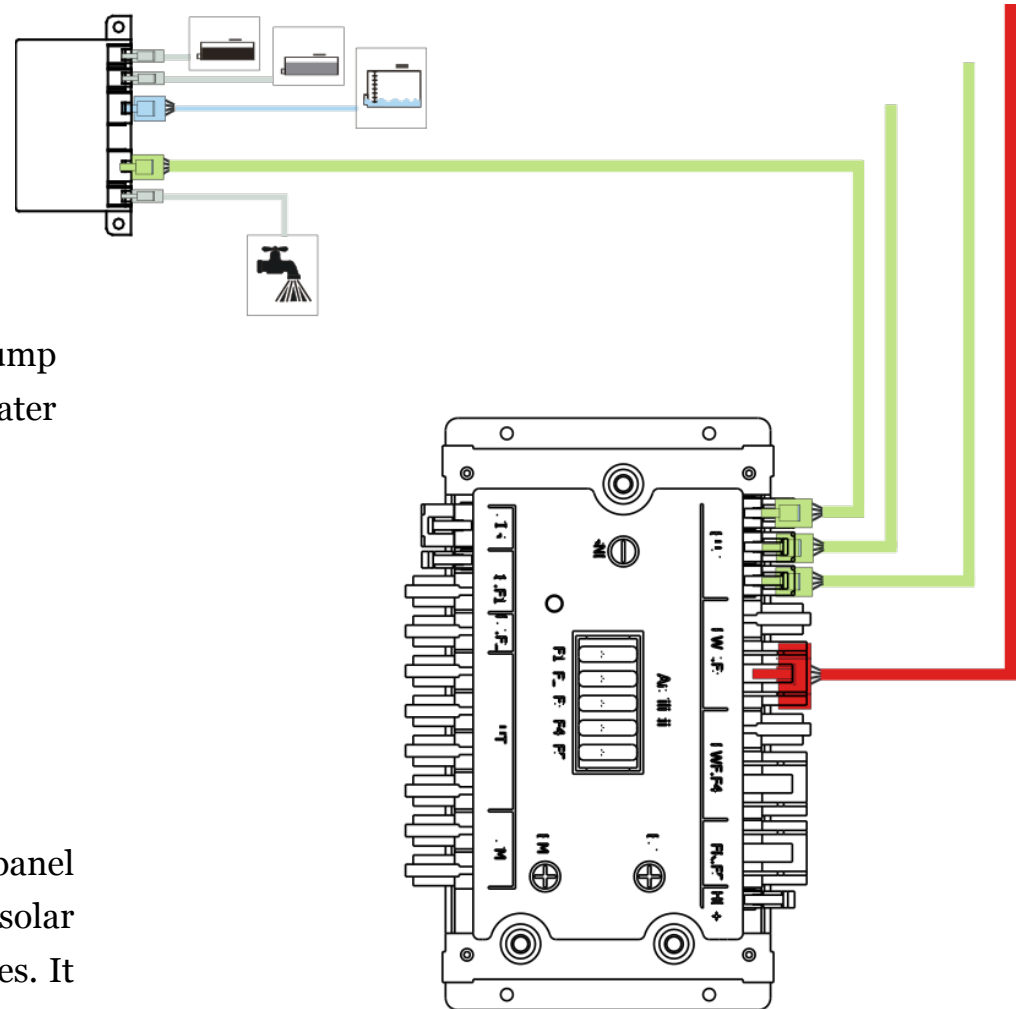
Since these wires run parallel to the power lines, special custom cables hosting under the same skin both powerline and bus are often used for cleanliness of the wiring harness. These wires too stand under the rules of cables sizes and protection as illustrated in Appendix A and B.

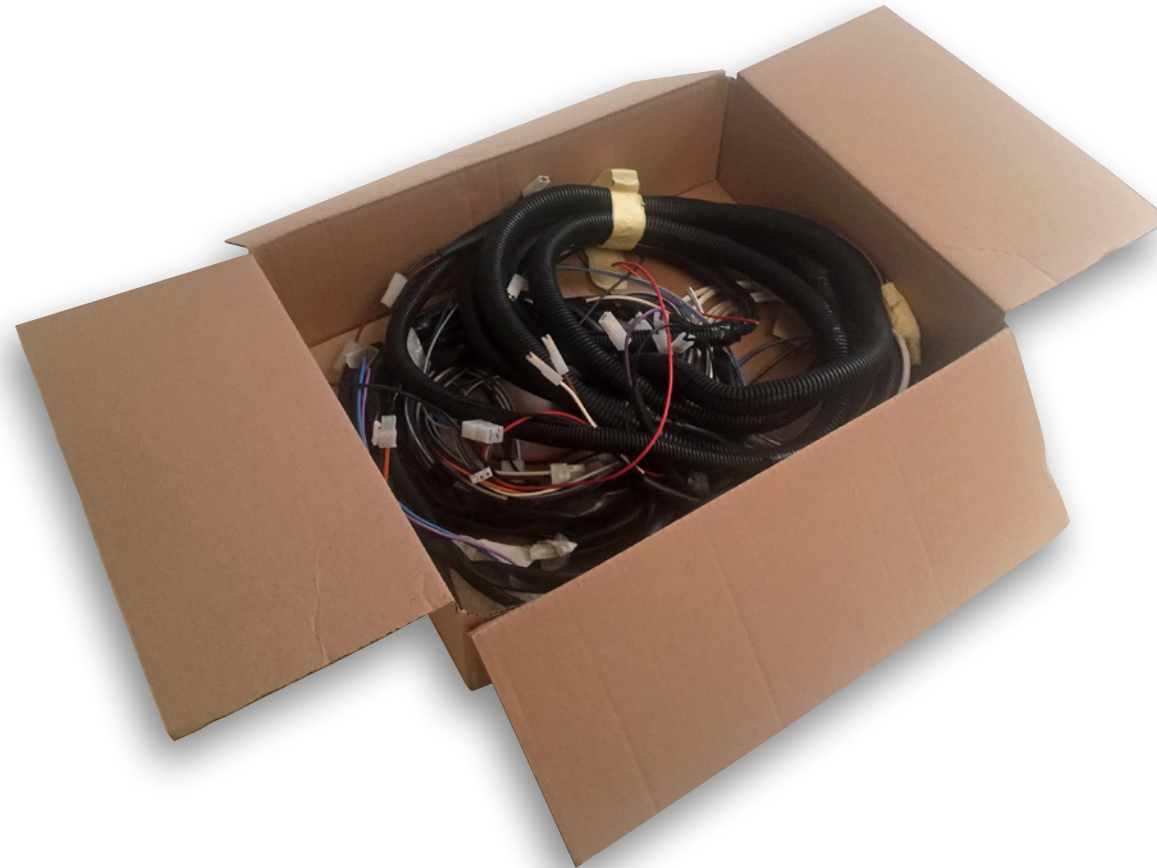


ArSilicii water pump node, can drive the pump with full protection, and monitor one clear water tank levels and 2 waste water tanks.



Another quite popular node is the solar panel node which can be connected with up to two solar panel, and can charge two separate batteries. It might operated both locally and remotely via bus through one of our control panels. It monitors in real time, Voltages, ampere and effective delivered Power.





# EVERYTHING IN A BOX!

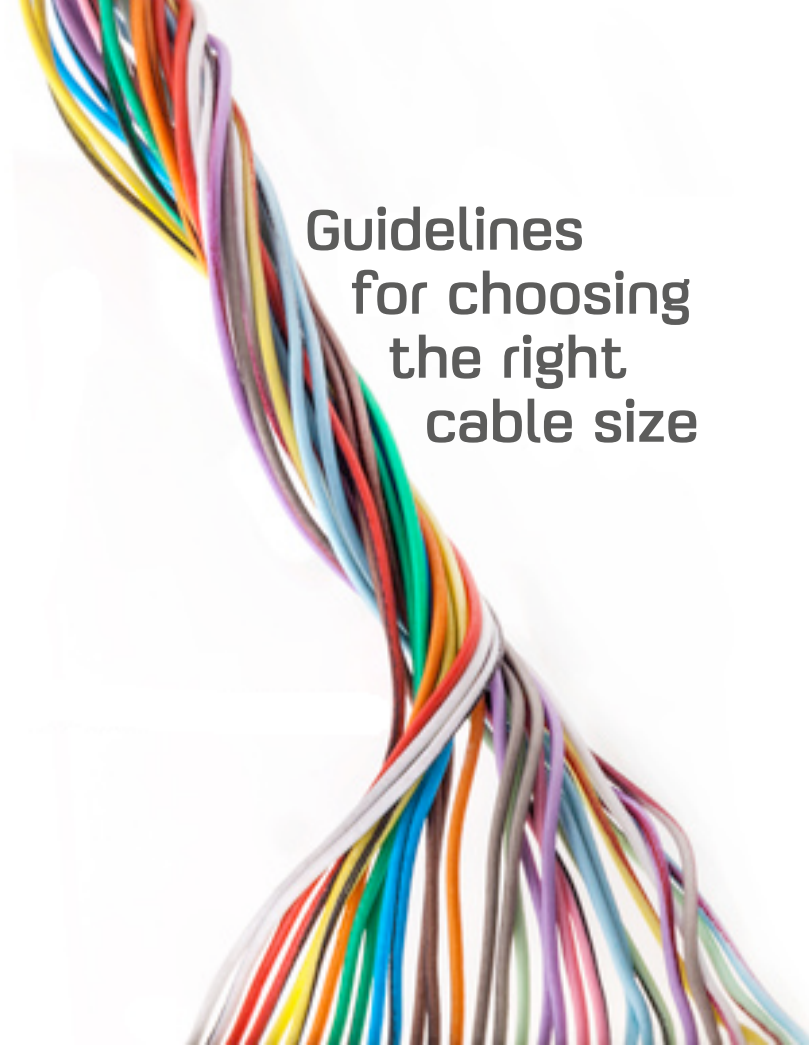
*If you have read and understood all the previous chapters, you should have a quite clear picture of all the steps necessary for designing a complete motorhome electrical system.*

*The good news is that ArSilicii can perform all this for you!*

*Beside selling all the electronic components, the wiring harness pre-cut with all the connectors, ArSilicii can design the complete wiring harness for you, and deliver you the plans.*







Guidelines  
for choosing  
the right  
cable size

# CABLES SIZING

## Overview

*One of the most important aspects of designing and building any part of a vehicle electrical system is determining the correct size and type of cable to use for each circuit. Too small a cable size and you'll run the risk of generating heat in the cable; too large and you'll be wasting money on copper you don't need. The following article should give you an insight into how electrical cable is specified and allow to you choose the right one for your application.*



## Selecting cable

The following are some points you should consider when selecting cable for a particular application:

### 1. Current carrying capacity

Each component or appliance connected to a circuit will have a current draw associated with its operation and it is important that the cable supplying power to these is capable of carrying the normally expected current, plus a margin of safety. If it is not capable then it is likely to result in the cable becoming hot and potentially catching fire. Although fuses are used in the circuit to protect the cable, the cable itself should be of an adequate rating to prevent this overheating occurring under normal circumstances. If we wanted to wire up a light that we know has a power rating of 50W, then using  $I = P/V$  the current draw would be  $50W/12V = 4.17A$ . This tells you that you could use a cable with a rating of 4.17A or above, however it is good practice not to design a circuit operating at the upper end of the cable's rating and so you should select a cable with some additional capacity. In this case  $0.5mm^2$  (11A) cable would be appropriate.

### 2. Voltage drop

All elements of an electrical circuit have resistance, including electrical cable, which means that there will be energy loss in the form of voltage drop experienced along the length of the cable. Just as a bulb converts electrical energy into heat and light due to its resistance, and so induces a voltage drop, a copper conductor has resistance and will convert some of the energy it conducts, causing a voltage drop in the same way. The difference is that voltage drop across a bulb (or other load) is great as that's what makes it work, but voltage drop along cable and other passive parts of a circuit is not desirable as it's not a useful conversion of energy.

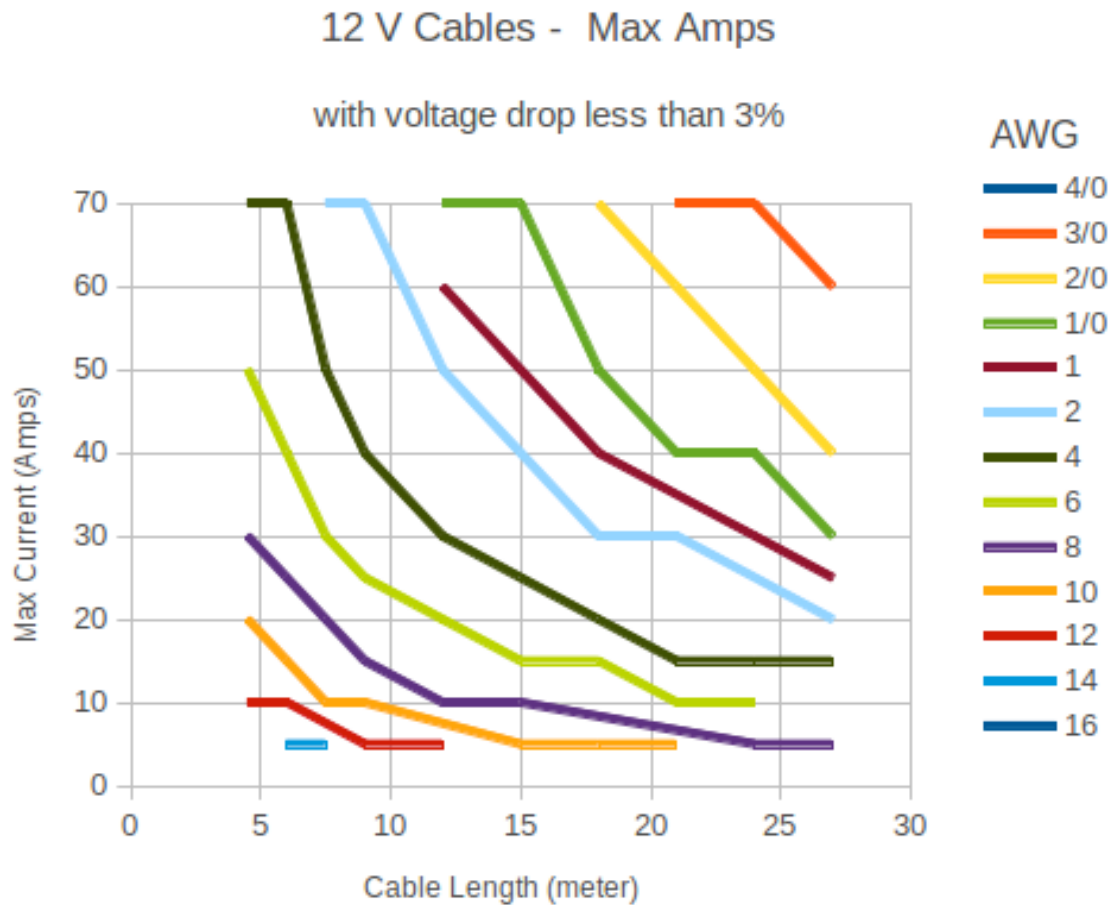
In low voltage systems cable length can have a significant impact on voltage drop. Even a cable run of a few meters for small cross-section conductors can produce significant voltage drops and this problem is demonstrated well on some vehicles where the headlights are not as bright as they could be. If you check the voltage at the bulb connectors you might find that the bulbs are not receiving a full 12V from the circuit due to the conductor size being too small for the cable run length.





Some owners opt to improve their headlight circuit by using cable with a larger conductor over a shorter distance which allows the circuit to provide full supply voltage to the bulbs, often with very significant improvements in lighting. So we want to select a cable to make sure that

the voltage drop is not so large that it will cause problems, how do we calculate the right cable size to use? Well the generally acceptable voltage drop for DC circuits is around 3% and we can use the tables below to select the size according to current and length of the wire.



In the above table the cross section area of the cables is expressed in terms of AWG which is the default unit of measure, but it can be easily converted in square mm. with this table:

American Wire Gauge (#AWG)	Diameter (inches)	Diameter (mm)	Cross Sectional Area (mm <sup>2</sup> )
0000 (4/0)	460	11.7	107
000 (3/0)	410	10.4	85.0
00 (2/0)	365	9.27	67.4
0 (1/0)	325	8.25	53.5
1	289	7.35	42.4
2	258	6.54	33.6
3	229	5.83	26.7
4	204	5.19	21.1

## Summary

So in selecting your cable you need to make sure that:

- a** It has sufficient current rating for the expected load in the circuit, including a margin of safety.
- b** The intended cable run length will not cause a voltage drop of more than about 3%.
- c** The material properties are appropriate for the application.

Get these right and you can be confident that your cable is right for the job!



Guidelines for choosing the  
right protection scheme

# FUSES SIZING



## Overview

Fuses are critical in any electrical system and are used to protect a circuit and its components from excessive current that could lead to damage and, very often, an electrical fire. Excessive current is most likely to be caused by three things:

- Incorrect wiring - wrong connections as a result of human error.
- Damage to the circuit - e.g. a wire working loose or insulation wearing through and causing a wire to short to ground.
- Overloading the circuit - e.g. connecting one or more pieces of equipment that draw more current than the circuit is designed to carry or, conversely, using cable of insufficient size for the current draw of the intended equipment.

## Where and when to use fuses

In an ideal world each individual section of positive cable would be fused as this would provide the most protection and make fault finding relatively straight forward, because it would allow you to narrow down the problem to a single section of cable (i.e. where the fuse has blown).

Having said that this is ideal it is nearly always

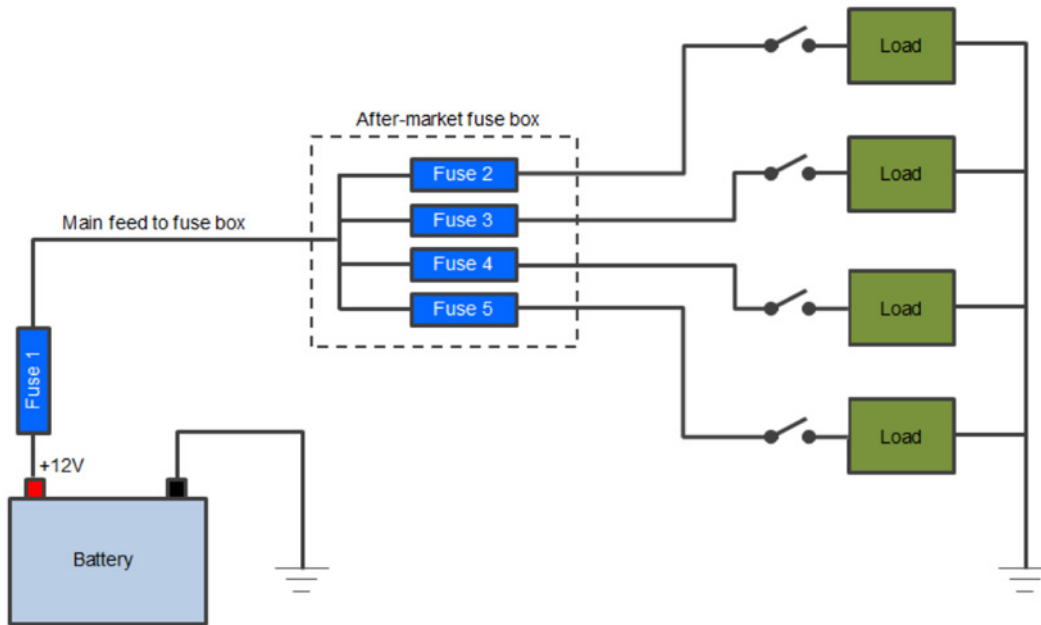
impractical as it would lead to many fuses fitted throughout an electrical system. A good compromise is that every individual circuit should be fused as this provides a good degree of protection and at least allows you to narrow down the problem to one circuit.

## Selecting the correct fuse rating

The fuse rating should lie somewhere between these two values to allow normal operation but blow on overload. For example, if the normal expected current draw is 10A and the cable size is adequate for 25A, then a fuse rated at 15A would be appropriate.

Every time a wire size is changed, there should be an adequate fuse. Below there is an example of this. Note that the main feed from the battery is fused to protect this section of cable and this cable should be large enough to supply the current required by all the loads operating at the same time (worst case). Consequently the fuse used for this cable (fuse 1) will be of a higher rating than fuses 2-5 (see next page for selecting a fuse rating) . Each of the four circuits supplying the loads are then fused individually in the fuse box (or the electronic fuses inside a Power Hub)





at the beginning of each circuit (and before the switches). This is important because if a section of cable shorts to ground it will only be protected if there is a fuse before the shorting point (otherwise the fuse will not experience the excess current because it will be outside of the short-circuit).

Fuses are marked with the current that they will continuously pass (at a standard temperature) without blowing, known as the continuous rating. It is good practice not to allow the continuous current to exceed 75% of the fuse's rated value to accommodate momentary current surges that might cause the fuse to fatigue over time or blow

unnecessarily (nuisance blow).

- Blow rating

In simplified terms this is the current rating at which the fuse will blow. Most fuses have a blow rating around twice that of the marked continuous rating.

So a 5A continuously rated fuse will have a blow rating of 10A.

## Electronic fuses and protections

The output of the PowerHubs and PowerLinks are protected against short circuit. Their rating is fixed and specified.

A standard PowerHub might have an output protection of 4A, this has two basic implications: Obviously loads larger than 4Amps should not be used.

Cables size must be chosen so that for the given length it allow at least 8 Amps to flow without heating (low losses)!!!!

Therefore when designing motorhome cabling using electronic components which already incorporate protections, the conscious cable size selection is quite critical!!



## DESIGNING MOTORHOMES WIRING HARNESS

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