Smart wire selection handles the power

Wired: Poor choice of wiring can cause all sorts of problems when installing accessories or repairing machinery. Get it wrong and you can cause damage to equipment and potentially start a fire.

A basic understanding of electrical systems and the relationship between current, voltage and resistance helps immeasurably when working on vehicles and machinery. In this first part of a two-part series on electrical basics, **Josh Giumelli** explains how to choose wiring to handle current. Photos by **Ben White**

Anyone who has ever fitted an accessory, repaired a wiring harness or modified machinery has probably had to face the problem of what size wire to choose.

Selecting the correct size of wire to use for a particular job is a little more complicated than it may first appear and there is no simple "rule of thumb" which can be easily used. While it is often safe to unreel a length of heavy duty cable which is sure to carry the current required, it is also wasteful, bulky, and the cost can quickly add up.

Choose a wire of insufficient size for the job it has to do and it will overheat and melt, possibly damaging components, and in a worst case scenario, start a fire. Wiring that gets hot is a sure sign it is carrying too much current for the size of the conductor, and the resulting voltage drop may lead to poor performance of the device connected to the other end.

Vehicle electrical systems operate at 12 or 24 volts and are particularly susceptible to voltage drop. These systems operate at reasonably high currents compared to a similar device operating of 240V for example, and it is the higher current that causes the temperature rise in the wire which in turn causes the voltage drop. What causes the temperature rise in the wire? The property is called resistance, and understanding it is pivotal for selecting the right size wire for the job.

RESISTANCE EXPLAINED

In basic terms, resistance is a measure of how difficult it is for electrical current to pass through a wire. It is measured in Ohms (Ω), and the higher the resistance, the greater the difficulty of current flow.

You can increase the current flowing through a wire until the heat generated melts the insulation or the conductor itself. But any reliable wiring system needs a fair factor of safety to ensure this does not happen, and eliminate undesirable voltage drop.

There are several factors at play when determining the resistance of a wire and how much current it can carry:

- Conductor cross-sectional area – the larger the diameter of the conductor core, the more current it can carry.
- Ambient temperature – the hotter the environment, less temperature is needed to reach failure of the wire, so the less current it can carry.
- Length of wire – the longer the wire, the greater the resistance, the less current it can carry.
- Material – different metals have different levels of resistance. Copper has lower resistance than steel and will carry more current for a given size and length of wire.

In addition, low voltage systems will carry higher current to do the same job as a higher voltage system, according to the equation below:

$$P = V \times I \quad \text{or} \quad I = P/V$$

where I is current in Amps, P is power in Watts, and V is voltage.

VOLTAGE DROP

The voltage drop can be easily calculated for any wire given the length, material, and cross-sectional area of the conductor. The formula to use is:

$$\textbf{Voltage drop} = (L \times I \times R)/A$$

where L is length in metres, A is the cross-sectional area of the wire in mm², and R is resistance of the wire in Ohms (Ω). We will generally always be using copper wire, which has a resistance of 0.017Ω.

As an example, say we wanted to install a 100W worklight on the roof of a tractor. The total length of wiring from the battery and relay is 5m of single core 12AWG (2.9mm²), and it will be earthed locally at

Table 1. Wire size conversion chart

AWG (B&S)	Conductor area mm²	Conductor diameter mm	Overall diameter mm
15	1.8	1.53	3.2
12	2.9	1.99	4.5
8	8.3	4.05	7.5
4	10.0	7.70	11.1
2	13.5	9.60	12.0
0	15.8	12.20	15.0

the light. To work out the voltage drop, first we need to determine the current. From above, I = P/V = 100/12 = 8.3A (as our tractor has a 12V electrical system).
So to determine the voltage drop,

V = (5 x 8.3 x 0.017)/2.9 = 0.24V drop (perfectly fine)

In actual fact, we could use lower-cost 15AWG (1.84mm2) and voltage drop would still be within reason ((5 x 8.3 x 0.017)/1.83 = 0.38V).

WIRE GAUGE

Understanding how wire sizes are specified is important if we want to be able to select the right sized wire for the job.

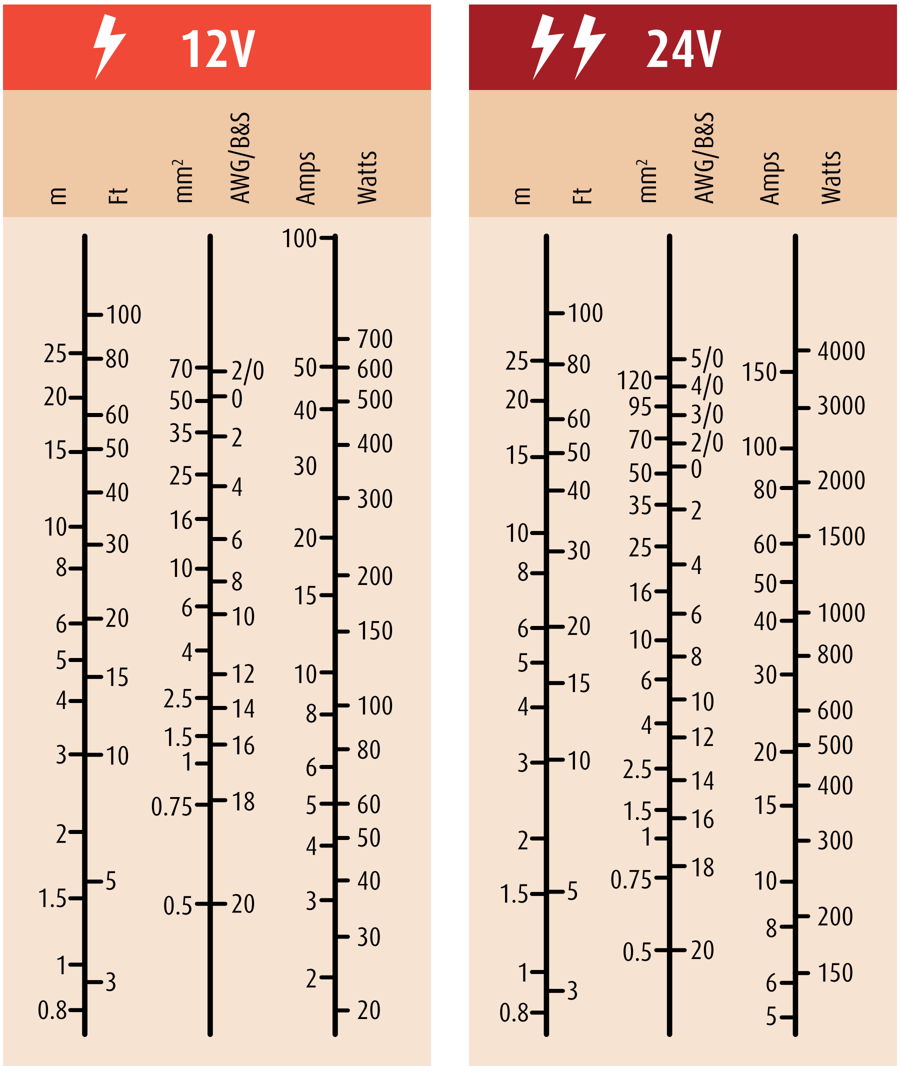
Wire gauge refers to the thickness of the wire, and many people still use the American wire gauge (AWG), sometimes referred to as the Brown and Sharpe (B&S) wire gauge, although they mean the same thing. AWG starts at 7/0 (seven zeros) which is the largest size, and then 6/0, 4/0 etc, then from 1 to 40 once it reaches zero. But not all sizes are relevant for automotive wiring. See Table 1 for common sizes and their metric equivalent.

There is a metric wire gauge (MWG), but it is not in common use and only tends to confuse matters. Many people now specify wire by simply referring to the cross-sectional area of the conductor in square millimetres.

Note that the conductor area is only roughly equivalent to the area calculated from the diameter of the core, as it must take into account the strands in the wire (as it is not a solid core). ▶

Tools sourced from Toolmart where possible

Table 2. Wire gauge selection table



1

Generally speaking, the amount of current a wire can carry is directly proportional to the cross-sectional area, and the length of wire. Note that if you are adding an accessory and running both positive and negative leads, instead of earthing at the load, then the length of wire must include the negative conductor as well.

2

Don't judge a book by its cover, or a wire by the overall diameter. The thicker cable above actually contains less copper and can carry less current.

3

Automotive wiring is multi-stranded to avoid fracture through vibration and flexure of the conductor, but there are differing degrees. In general, choose finer strands as they will stand up to more use and are easier to work with. It is also easier to achieve a higher cross-sectional area for a given size wire, as there are less "air gaps" between finer strands.

4

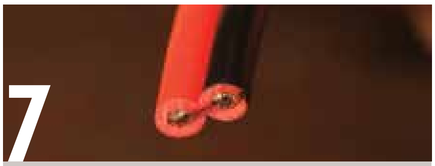
American wire gauge (AWG) is commonly used to designate wire size but note that it refers to the size of the core, not the external diameter of the insulation. Also, the higher the number, the smaller the core.

5

This three-core flex simply states the cross-sectional area of the conductors – three times 1.0mm².

6

Tinned or silver-plated copper is superior to plain copper in corrosive environments and should be the first choice for applications such as sprayers, spreaders and other implements. OFC stands for oxygen-free copper – it's a purer form of copper.



7

Twin core cable is a convenient way of running both positive and negative wires to a device. Remember to double the length when calculating its current carrying capacity.

8

If you have a choice, select double-insulated twin core instead of the single-insulated version shown previously. It costs only a little extra but has significantly more protection.

9

To work out the minimum size cable to operate a lightbar, we need to know its current requirements (or power), and the length of the wire. Then a simple ready-reckoner such as Table 2 can be used to select a wire size. For instance, this 150W light bar is operated off 12V, and the length of wire from the battery to the relay and the bar is 1.5m, but as the earth has been run back to the negative battery terminal, the effective length is 3m.

10

Using Table 2 and selecting the 12V side, we can draw a line from 3m on the left to 150W on the right. This passes through the centre line at about 2.5mm², so that is the minimum sized wire for the job. When choosing the cable, always select one higher on the list, not lower. So a 14AWG or 2.9mm² wire will work perfectly fine (Table 1).