

WHITE PAPER

WHY THE AWG SPECIFICATION IS NO LONGER APPROPRIATE

In communication networks, energy transmission is now just as important as reliable and efficient data transmission. However, the AWG specification has proven to be too imprecise to accurately determine the diameter of a copper conductor. The technical parameter that should be applied, rather, is loop resistance.

With the increasing use of Power over Ethernet (PoE), attention is turning to the conductor diameter of the copper data cables used. Because when transmitting power, it is important to pay attention to cable heating. The current version of EN 50174-2 therefore refers to a sufficiently low ohmic resistance of the copper conductors. The principle here is: the larger the diameter, the lower the ohmic resistance of the cable.

This is represented by the formula $R = \rho \cdot l / A$.

R stands for the ohmic resistance of the conductor, **ρ** for the resistivity of copper, **l** for the length of the copper conductor and **A** for the cross section (surface area) of the conductor.

In technical data sheets, the diameter of a copper conductor is usually given in AWG (American Wire Gauge) – and, for some manufacturers, also in millimetres.

Today, PoE applications are mainly planned with the “large copper cross-section” AWG 22. This is done under the assumption that the diameter is precisely specified by the AWG rating.

Wikipedia shows the following table:

AWG	Diameter		Cross section		R (Ohm/km)	Metric equivalent (mm²)
	Zoll	mm	kcmil	mm²		
22	0.02535	0.6438	0.6424	0.3255	54.68	0.34

Source: Wikipedia

In this case the conversion from AWG to diameter in millimetres uses a formula given on the Wikipedia page. The resistivity of copper is assumed to be **0.0178 Ω mm²/m**. The diameter specified here – 0.64 mm – corresponds to the maximum diameter of the data cables currently available on the market.

So everything seems fine. But is that really the case?

Lack of precision in the AWG system

On the same page we learn that the AWG system was introduced in 1857 by Joseph Rogers Brown at Brown & Sharpe. It originally described the number of drawing operations to bring a copper wire into a desired diameter range. The larger the AWG number, the more times the wire had been passed through the drawing dies – and the thinner the wire.

A “gauge” is not a measuring device, but rather a verification template.

It might look like this:



Source: Wikipedia

In the American standard UL 444 on the safety of communication cables there is a table in appendix A entitled "AWG to diameter in mm". It specifies the following, for example:

Size AWG	min. Ø in mm	max. Ø in mm
AWG 23	0.546	0.609
AWG 22	0.610	0.687

Source:
ANSI/UL 444,
Appendix A,
Table 5

The diameter of a wire with AWG 22 should therefore be between 0.610 mm and 0.687 mm.

However, there is a footnote under this table with the following note: "Minimum acceptable diameter is 0.95 x nominal diameter." This means that even a diameter of 0.58 mm (= 0.61mm x 0.95) can still be referred to as AWG 22.

The diameter of 0.6438 mm given by Wikipedia is approximately in the middle, between the nominal minimum or maximum value – and does not reflect the actual values from the underlying standard UL 444.

In short: AWG apparently has a very generous, but not exactly defined, range.

Better in millimetres!

For copper data cables, some manufacturers also specify the conductor diameter in millimetres. This is a metric unit of measurement commonly used in all areas. Metric measurements are also a basic unit of the SI system, which is used throughout the world.

In most countries, the use of the SI system for official and commercial transactions is required by law. The United States is an exception: although the SI system is used in the USA as well, the Anglo-American system of measurements is also permitted in official and commercial transactions, including "customary units" such as AWG.

In a time when lengths are measured to the hundredths and thousandths using a micrometre screw or a laser, the indication in AWG – from the year 1857! – does not seem to meet current accuracy requirements.

Ohmic loop resistance

In order to assess the required performance of a cable, it is necessary to know the actual conductor diameter. But how

can you determine this when most technical data sheets only contain AWG information?

It helps here to consider the (ohmic) loop resistance, which is specified in most data sheets. If not, the "conductor resistance" information can be found. This is simply half the loop resistance.

Using the assumption made on Wikipedia regarding the resistivity of copper ($0.0178 \Omega \text{ mm}^2/\text{m}$), you can calculate the loop resistance back to the conductor diameter – see the formula in the upper part of this White Paper.

If common copper diameters are converted into loop resistance (or conductor resistance = half loop resistance), the following table results:

CU Ø [mm]	Loop resistance [Ω] ±2%	Conductor resistance [Ω] ±2%
0.64	110	55
0.63	113	57
0.62	117	59
0.61	121	60
0.60	125	63
0.59	129	65
0.58	134	67
0.57	139	69
0.56	144	72
0.55	149	74
0.54	154	77

Because different cable types also have different lengths of lay when twisting the conductor pairs, a slight deviation in resistance values of +/- 2% is possible.

*Note:
only valid for
shielded (PiMF)
horizontal cables*

Conclusion

Great precision is required today when dimensioning and calculating data cables. This can only be achieved if the technical data sheet gives exact details of the necessary parameters. A "range specification" for individual parameters according to the American AWG system is too imprecise and therefore no longer up-to-date.

As a simple measure for determining the conductor diameter or verifying the specified values, the actual dimension of a copper conductor can be calculated at any time using the aforementioned formula ($R = \text{raw} \cdot l / A$) – via the ohmic resistance.