American wire gauge

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American wire gauge (**AWG**), also known as the **Brown & Sharpe wire gauge**, is a standardized wire gauge system used since 1857 predominantly in the United States and Canada for the diameters of round, solid, nonferrous, electrically conducting wire.[1] The cross-sectional area of each gauge is an important factor for determining its current-carrying capacity.

Contents

The steel industry does not use AWG and prefers a number of other wire gauges. These include Washburn & Moen (or W&M) Wire Gauge, US Steel Wire Gauge, and Music Wire Gauge (see Piano wire).

Increasing gauge numbers give decreasing wire diameters, which is similar to many other non-metric gauging systems. This gauge system originated in the number of drawing operations used to produce a given gauge of wire. Very fine wire (for example, 30 gauge) required more passes through the drawing dies than did 0 gauge wire. Manufacturers of wire formerly had proprietary wire gauge systems; the development of standardized wire gauges rationalized selection of wire for a particular purpose.

The AWG tables are for a single, solid, round conductor. The AWG of a stranded wire is determined by the total cross-sectional area of the conductor, which determines its current-carrying capacity and electrical resistance. Because there are also small gaps between the strands, a stranded wire will always have a slightly larger overall diameter than a solid wire with the same AWG.

AWG is also commonly used to specify body piercing jewelry sizes (especially smaller sizes), even when the material is not metallic.[2]

Formula

By definition, No. 36 AWG is 0.0050 inches in diameter, and No. 0000 is 0.4600 inches in diameter. The ratio of these diameters is 1:92, and there are 40 gauge sizes from No. 36 to No. 0000, or 39 steps. Using this common ratio, wire gauge sizes vary geometrically according to the following formula: The diameter of a No. *n* AWG wire is

$$d_n = 0.005\ \mathrm{inch} \times 92^{\frac{36-n}{39}} = 0.127\ \mathrm{mm} \times 92^{\frac{36-n}{39}}$$

or equivalently

$$d_n = e^{-1.12436-0.11594n}\ \mathrm{inch} = e^{2.1104-0.11594n}\ \mathrm{mm}$$

The gauge can be calculated from the diameter using

$$n = -39 \log_{92}\left(\frac{d_n}{0.005\ \mathrm{inch}}\right) + 36 = -39 \log_{92}\left(\frac{d_n}{0.127\ \mathrm{mm}}\right) + 36$$ [3]

and the cross-section area is

$$A_n = \frac{\pi}{4} d_n^2 = 0.000019635\ \mathrm{inch}^2 \times 92^{\frac{36-n}{19.5}} = 0.012668\ \mathrm{mm}^2 \times 92^{\frac{36-n}{19.5}},$$

The ASTM B 258-02 standard defines the ratio between successive sizes to be the 39th root of 92, or approximately 1.1229322.[4] ASTM B 258-02 also dictates that wire diameters should be tabulated with no more than 4 significant figures, with a resolution of no more than 0.0001 inches (0.1 mils) for wires larger than No. 44 AWG, and 0.00001 inches (0.01 mils) for wires No. 45 AWG and smaller.

Sizes with multiple zeros are successively larger than No. 0 and can be denoted using "*number of zeros*/0", for example 4/0 for 0000. For an *m*/0 AWG wire, use *n* = −(*m*−1) = 1−*m* in the above formulas. For instance, for No. 0000 or 4/0, use n = −3.

Rules of thumb

The sixth power of this ratio is very close to 2,[5] which leads to the following rules of thumb:

- When the *diameter* of a wire is doubled, the AWG will decrease by 6. (e.g., No. 2 AWG is about twice the diameter of No. 8 AWG.)
- When the *cross-sectional area* of a wire is doubled, the AWG will decrease by 3. (e.g., Two No. 14 AWG wires have about the same cross-sectional area as a single No. 11 AWG wire.)

Additionally, a decrease of ten gauge numbers, for example from No. 10 to 1/0, multiplies the area and weight by approximately 10 and reduces the resistance by a factor of approximately 10.

Aluminum wire has a conductivity of approximately 61% of copper, so an aluminum wire has the almost same resistance as a copper wire 2 AWG smaller. (Which has 62.9% of the area.)

Tables of AWG wire sizes

The table below shows various data including both the resistance of the various wire gauges and the allowable current (ampacity) based on plastic insulation. The diameter information in the table applies to *solid* wires. Stranded wires are calculated by calculating the equivalent cross sectional copper area. Fusing Current (melting wire) is estimated based on 25°C ambient temperature. The table below assumes DC, or AC frequencies equal to or less than 60 Hz, and does not take skin effect into account. Turns of wire is an upper limit for wire with no insulation.

AWG	Diameter		Turns of wire (no insulation)		Area		Copper resistance[6]		NEC copper wire ampacity with 60/75/90 °C insulation (A)[7]	Approximate standard metric equivalents	Fusing Current (copper)[8][9]		
	(inch)	(mm)	(per in)	(per cm)	(kcmil)	(mm²)	(Ω/km) (mΩ/m)	(Ω/kFT) (mΩ/ft)			Preece (~10s)	Onderdonk (1s)	Onderdonk (32ms)
0000 (4/0)	**0.4600***	11.684	2.17	0.856	212	107	0.1608	0.04901	195 / 230 / 260		3.2 kA	31 kA	173 kA
000 (3/0)	0.4096	10.404	2.44	0.961	168	85.0	0.2028	0.06180	165 / 200 / 225		2.7 kA	24.5 kA	137 kA
00 (2/0)	0.3648	9.266	2.74	1.08	133	67.4	0.2557	0.07793	145 / 175 / 195		2.3 kA	19.5 kA	109 kA
0 (1/0)	0.3249	8.252	3.08	1.21	106	53.5	0.3224	0.09827	125 / 150 / 170		1.9 kA	15.5 kA	87 kA
1	0.2893	7.348	3.46	1.36	83.7	42.4	0.4066	0.1239	110 / 130 / 150		1.6 kA	12 kA	68 kA
2	0.2576	6.544	3.88	1.53	66.4	33.6	0.5127	0.1563	95 / 115 / 130		1.3 kA	9.7 kA	54 kA
3	0.2294	5.827	4.36	1.72	52.6	26.7	0.6465	0.1970	85 / 100 / 110	196/0.4	1.1 kA	7.7 kA	43 kA
4	0.2043	5.189	4.89	1.93	41.7	21.2	0.8152	0.2485	70 / 85 / 95		946 A	6.1 kA	34 kA
5	0.1819	4.621	5.50	2.16	33.1	16.8	1.028	0.3133		126/0.4	795 A	4.8 kA	27 kA
6	0.1620	4.115	6.17	2.43	26.3	13.3	1.296	0.3951	55 / 65 / 75		668 A	3.8 kA	21 kA
7	0.1443	3.665	6.93	2.73	20.8	10.5	1.634	0.4982		80/0.4	561 A	3 kA	17 kA
8	0.1285	3.264	7.78	3.06	16.5	8.37	2.061	0.6282	40 / 50 / 55		472 A	2.4 kA	13.5 kA
9	0.1144	2.906	8.74	3.44	13.1	6.63	2.599	0.7921		84/0.3	396 A	1.9 kA	10.7 kA
10	0.1019	2.588	9.81	3.86	10.4	5.26	3.277	0.9989	30 / 35 / 40		333 A	1.5 kA	8.5 kA
11	0.0907	2.305	11.0	4.34	8.23	4.17	4.132	1.260		56/0.3	280 A	1.2 kA	6.7 kA
12	0.0808	2.053	12.4	4.87	6.53	3.31	5.211	1.588	25 / 25 / 30		235 A	955 A	5.3 kA
13	0.0720	1.828	13.9	5.47	5.18	2.62	6.571	2.003		50/0.25	198 A	758 A	4.2 kA
14	0.0641	1.628	15.6	6.14	4.11	2.08	8.286	2.525	20 / 20 / 25	64/0.2	166 A	601 A	3.3 kA
15	0.0571	1.450	17.5	6.90	3.26	1.65	10.45	3.184		30/0.25	140 A	477 A	2.7 kA
16	0.0508	1.291	19.7	7.75	2.58	1.31	13.17	4.016	— / — / 18		117 A	377 A	2.1 kA
17	0.0453	1.150	22.1	8.70	2.05	1.04	16.61	5.064		32/0.2	99 A	300 A	1.7 kA
18	0.0403	1.024	24.8	9.77	1.62	0.823	20.95	6.385	— / — / 14	24/0.2	83 A	237 A	1.3 kA
19	0.0359	0.912	27.9	11.0	1.29	0.653	26.42	8.051			70 A	189 A	1 kA
20	0.0320	0.812	31.3	12.3	1.02	0.518	33.31	10.15		16/0.2	58.5 A	149 A	834 A
21	0.0285	0.723	35.1	13.8	0.810	0.410	42.00	12.80		13/0.2	49 A	119 A	662 A
22	0.0253	0.644	39.5	15.5	0.642	0.326	52.96	16.14		7/0.25	41 A	94 A	525 A
23	0.0226	0.573	44.3	17.4	0.509	0.258	66.79	20.36			35 A	74 A	416 A
24	0.0201	0.511	49.7	19.6	0.404	0.205	84.22	25.67		1/0.5, 7/0.2, 30/0.1	29 A	59 A	330 A
25	0.0179	0.455	55.9	22.0	0.320	0.162	106.2	32.37			24 A	47 A	262 A
26	0.0159	0.405	62.7	24.7	0.254	0.129	133.9	40.81		1/0.4, 7/0.15	20 A	37 A	208 A
27	0.0142	0.361	70.4	27.7	0.202	0.102	168.9	51.47			17 A	30 A	165 A
28	0.0126	0.321	79.1	31.1	0.160	0.0810	212.9	64.90		7/0.12	14 A	23 A	131 A
29	0.0113	0.286	88.8	35.0	0.127	0.0642	268.5	81.84			12 A	19 A	104 A
30	0.0100	0.255	99.7	39.3	0.101	0.0509	338.6	103.2		1/0.25, 7/0.1	10 A	15 A	83 A
31	0.00893	0.227	112	44.1	0.0797	0.0404	426.9	130.1			9 A	12 A	65 A
32	0.00795	0.202	126	49.5	0.0632	0.0320	538.3	164.1		1/0.2, 7/0.08	7 A	9 A	52 A
33	0.00708	0.180	141	55.6	0.0501	0.0254	678.8	206.9			6 A	7 A	41 A
34	0.00630	0.160	159	62.4	0.0398	0.0201	856.0	260.9			5 A	6 A	33 A
35	0.00561	0.143	178	70.1	0.0315	0.0160	1079	329.0			4 A	5 A	26 A
36	**0.00500***	0.127	200	78.7	0.0250	0.0127	1361	414.8			4 A	4 A	20 A
37	0.00445	0.113	225	88.4	0.0198	0.0100	1716	523.1			3 A	3 A	16 A
38	0.00397	0.101	252	99.3	0.0157	0.00797	2164	659.6			3 A	2 A	13 A
39	0.00353	0.0897	283	111	0.0125	0.00632	2729	831.8			2 A	2 A	10 A
40	0.00314	0.0799	318	125	0.00989	0.00501	3441	1049			2 A	1 A	8 A

*Exact measurement

In the North American electrical industry, conductors larger than 4/0 AWG are generally identified by the area in thousands of circular mils (**kcmil**), where 1 kcmil = 0.5067 mm². The next wire size larger than 4/0 has a cross section of 250 kcmil. A *circular mil* is the area of a wire one mil in diameter. One million circular mils is the area of a circle with 1000 mil = 1 inch diameter. An older abbreviation for one thousand circular mils is *MCM*.

Stranded wire AWG sizes

AWG gauges are also used to describe stranded wire. In this case, it describes the total cross-sectional area of the conductor; the gaps between strands are not counted. Using circular strands, these gaps occupy about 10% of the wire area, thus requiring a wire about 5% thicker than equivalent solid wire.

Stranded wires are specified with three numbers, the overall AWG size, the number of strands, and the AWG size of a strand. The number of strands and the AWG of a strand are separated by a slash. For example, a 22 AWG 7/30 stranded wire is a 22 AWG wire made from seven strands of 30 AWG wire.

Nomenclature and abbreviations in electrical distribution

Main article: Electric power distribution

Alternate ways are commonly used in the electrical industry to specify wire sizes as AWG.

- **4 AWG** (proper)
  - **#4** (the number sign is used as an abbreviation for "number")
  - **No. 4** (No. is used as an abbreviation for "number")
  - **No. 4 AWG**
  - **4 ga.** (abbreviation for "gauge")
- **000 AWG** (proper for large sizes)
  - **3/0** (common for large sizes) Pronounced 3 aught
  - **3/0 AWG**
  - **#000**
  - **#3/0**

The industry also bundles common wire for use in electric power distribution in homes and businesses, identifying a bundle's wire size followed by the number of wires in the bundle. The most common type of distribution cable, NM-B, is generally implied:

- #14/**2** (also written "14-2") is a nonmetallic sheathed bundle of *two* solid 14 AWG wires. The insulation surrounding the two conductors is white and black. This sheath for 14 AWG cable is usually white when used for NM-B wiring intended for electrical distribution in a dry location. Newly manufactured cables without a separate ground wire (such as #14/2) are obsolete.
- #12/**2 *with ground*** (also written "12-2 w/gnd") is a nonmetallic sheathed bundle of **three** solid 12 AWG wires having a bare ground in the middle of two insulated conductors in a flat-shaped NM-B yellow-colored sheath. The color is a North American industry standard for cables made since 2003, and aids identification.
- #10/**3 *with ground*** (also written "10-3 w/gnd") is a nonmetallic sheathed bundle of **four** solid 10 AWG wires having a bare ground and three insulated conductors twisted into a round-shaped NM-B orange-colored sheath. The insulated conductors are black, white, and red. Some cable of this type may be flat to save copper.

Pronunciation

AWG is colloquially referred to as *gauge* and the zeros in large wire sizes are referred to as *aught* (pron.: /ˈɔːt/). Wire sized 1 AWG is referred to as "one gauge" or "No. 1" wire; similarly, smaller diameters are pronounced "*x* gauge" or "No. X" wire, where *x* is the positive integer AWG number. Consecutive AWG wire sizes larger than No. 1 wire are designated by the number of zeros:

- No. 0, typically written 1/0 and is referred to as 1 "aught" wire
- No. 00, typically written 2/0 and is referred to as 2 "aught" wire
- No. 000, typically written 3/0 and is referred to as 3 "aught" wire,

and so on. [10]

See also

- IEC 60228 for international standard wire sizes
- Standard wire gauge (former British standard)
- A chart comparing all known wire gauges (PDF)
- Number 8 wire, a term used in the New Zealand vernacular
- Stubs Iron Wire Gauge
- Electric power distribution
- Electrical wiring
- Cable
- Power cord
- Extension cord
- Magnet wire
- Body jewelry sizes

References

1. ^ ASTM Standard B 258-02, *Standard specification for standard nominal diameters and cross-sectional areas of AWG sizes of solid round wires used as electrical conductors*, ASTM International, 2002
2. ^ SteelNavel.com Body Piercing Jewelry Size Reference — illustrating the different ways that size is measured on different kinds of jewelry (http://www.steelnavel.com/reference.asp)
3. ^ The logarithm to the base 92 can be computed using any other logarithm, such as common or natural logarithm, using $\log_{92} x$ = (log *x*)/(log 92).
4. ^ ASTM Standard B 258-02, page 4
5. ^ The result is roughly 2.0050, or one-quarter of one percent higher than 2
6. ^ Figure for solid copper wire at 68 °F, computed based on 100% IACS conductivity of 58.0 MS/m, which agrees with multiple sources:
   - http://www.eskimo.com/~billb/tesla/wire1.txt
   - Mark Lund, PowerStream Inc., *American Wire Gauge table and AWG Electrical Current Load Limits* (http://www.powerstream.com/Wire_Size.htm) , http://www.powerstream.com/Wire_Size.htm, retrieved 2008-05-02 (although the ft/m conversion seems slightly erroneous)
   - Belden Master Catalog (http://www.belden.com/03products/03_MasterCatalogSection.cfm) , 2006, although data from there for gauges 35 and 37–40 seems obviously wrong.

   High-purity oxygen-free copper can achieve up to 101.5% IACS conductivity; e.g., the Kanthal conductive alloys data sheet (http://www.kanthal.com/C12570A7004E2D46/062CC3B124D69A8EC1256988002A3D76/F6421C7808255963C12572BB001C8704/$file/5-C-4-3%20conductive%20alloys.pdf?OpenElement) lists slightly lower resistances than this table.
7. ^ *NFPA 70 National Electrical Code 2008 Edition (http://bulk.resource.org/codes.gov/)* . Table 310.16 page 70-148, *Allowable ampacities of insulated conductors rated 0 through 2000 volts, 60°C through 90°C, not more than three current-carrying conductors in raceway, cable, or earth (directly buried) based on ambient temperature of 30°C*. Extracts from NFPA 70 do not represent the full position of NFPA and the original complete Code must be consulted. In particular, the maximum permissible overcurrent protection devices may set a lower limit.
8. ^ Computed using equations from H. Wayne Beaty; Donald G. Fink, eds. (2007), *The Standard Handbook for Electrical Engineers* (15th ed.), McGraw Hill, p. 4-25, ISBN 0-07-144146-8
9. ^ Douglas Brooks (December 1998), "Fusing Current: When Traces Melt Without a Trace" (http://www.ultracad.com/articles/fusing.pdf) , *Printed Circuit Design* **15** (12): 53, http://www.ultracad.com/articles/fusing.pdf
10. ^ Glossary of Power Terms | Event Solutions (http://www.event-solutions.com/web_extras/february_2006/glossary_of_power_terms)

Further reading

- Donald G. Fink and H. Wayne Beaty, *Standard Handbook for Electrical Engineers, Eleventh Edition*,McGraw-Hill, New York, 1978, ISBN 0-07-020974-X, page 4-18 and table 4-11.

External links

- Wire Gauge to Diameter—Diameter to Wire Gauge Converter (http://www.66pacific.com/calculators/wire_calc.aspx) - Online calculator converts gauge to diameter or diameter to gauge for any wire size.
- How to Gauge Traces (http://www.ultracad.com/articles/wiregauge.pdf)
- Conversion and calculation of cable diameter to AWG and vice versa (http://www.sengpielaudio.com/calculator-cross-section.htm)
- Table of wire resistivities for bigger gauge (insulation included) (http://www.bnoack.com/index.html?http&&&www.bnoack.com/data/wire-resistance.html)
- Bare copper wire AWG NEMA/IEC metric standard sizes (http://www.litz-wire.com/wirediminsions.html)
- Reference for conversions and maximum safe current loads (http://www.powerstream.com/Wire_Size.htm)

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