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 North America for the diameters of round, solid, nonferrous, electrically conducting wire. Dimensions of the wires are given in ASTM standard B 258.[1] The cross-sectional area of each gauge is an important factor for determining its current-carrying capacity.

Increasing gauge numbers denote decreasing wire diameters, which is similar to many other non-metric gauging systems such as SWG. 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 0 gauge wire did. 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 cross-sectional area of the equivalent solid conductor. 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]

Contents

Formulae

By definition, No. 36 AWG is 0.005 inches in diameter, and No. 0000 is 0.46 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. Because each successive gauge number increases cross sectional area by a constant multiple, diameters vary geometrically. Any two successive gauges (e.g., A & B) have diameters in the ratio (dia. B ÷ dia. A) of $\sqrt[39]{92}$ (approximately 1.12293), while for gauges two steps apart (e.g., A, B, & C), the ratio of the C to A is about $1.12293^2 = 1.26098$. The diameter of a No. n AWG wire is determined, for gauges smaller than 00 (36 to 0), according to the following formula:

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

(see below for gauges larger than No. 0 (i.e., No. 00, No. 000, No. 0000).)

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 [3]

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

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 standard **ASTM B258 - 02(2008)** ***Standard Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors*** 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 $\sqrt[39]{92}$ is very close to 2,[5] which leads to the following rules of thumb:

- 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.) This doubles the ampacity.
- 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.) This quadruples the cross-sectional area and the ampacity.
- 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 electrical resistance (and increases the conductance) by a factor of approximately 10.
- For the same cross section, aluminum wire has a conductivity of approximately 61% of copper, so an aluminum wire has nearly the same resistance as a copper wire 2 AWG sizes 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, without insulation		Area		Copper wire							
							Resistance/length[6]		Ampacity,[7] at 20 °C insulation material temperature rating, or 16 AWG and smaller for single unbundled wires in equipment:[8]			Fusing current[9][10]		
									60 °C	75 °C	90 °C	Preece[11][12][13][14]	Onderdonk[15][14]	
	(in)	(mm)	(per in)	(per cm)	(kcmil)	(mm²)	(mΩ/m[a])	(mΩ/ft[b])	(A)			~10 s	1 s	32 ms
0000 (4/0)	0.4600[c]	11.684[c]	2.17	0.856	212	107	0.1608	0.04901	195	230	260	3.2 kA	33 kA	182 kA
000 (3/0)	0.4096	10.405	2.44	0.961	168	85.0	0.2028	0.06180	165	200	225	2.7 kA	26 kA	144 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	21 kA	115 kA
0 (1/0)	0.3249	8.251	3.08	1.21	106	53.5	0.3224	0.09827	125	150	170	1.9 kA	16 kA	91 kA
1	0.2893	7.348	3.46	1.36	83.7	42.4	0.4066	0.1239	110	130	145	1.6 kA	13 kA	72 kA
2	0.2576	6.544	3.88	1.53	66.4	33.6	0.5127	0.1563	95	115	130	1.3 kA	10.2 kA	57 kA
3	0.2294	5.827	4.36	1.72	52.6	26.7	0.6465	0.1970	85	100	115	1.1 kA	8.1 kA	45 kA
4	0.2043	5.189	4.89	1.93	41.7	21.2	0.8152	0.2485	70	85	95	946 A	6.4 kA	36 kA
5	0.1819	4.621	5.50	2.16	33.1	16.8	1.028	0.3133				795 A	5.1 kA	28 kA
6	0.1620	4.115	6.17	2.43	26.3	13.3	1.296	0.3951	55	65	75	668 A	4.0 kA	23 kA
7	0.1443	3.665	6.93	2.73	20.8	10.5	1.634	0.4982				561 A	3.2 kA	18 kA
8	0.1285	3.264	7.78	3.06	16.5	8.37	2.061	0.6282	40	50	55	472 A	2.5 kA	14 kA
9	0.1144	2.906	8.74	3.44	13.1	6.63	2.599	0.7921				396 A	2.0 kA	11 kA
10	0.1019	2.588	9.81	3.86	10.4	5.26	3.277	0.9989	30	35	40	333 A	1.6 kA	8.9 kA
11	0.0907	2.305	11.0	4.34	8.23	4.17	4.132	1.260				280 A	1.3 kA	7.1 kA
12	0.0808	2.053	12.4	4.87	6.53	3.31	5.211	1.588	20	25	30	235 A	1.0 kA	5.6 kA
13	0.0720	1.828	13.9	5.47	5.18	2.62	6.571	2.003				198 A	798 A	4.5 kA
14	0.0641	1.628	15.6	6.14	4.11	2.08	8.286	2.525	15	20	25	166 A	633 A	3.5 kA
15	0.0571	1.450	17.5	6.90	3.26	1.65	10.45	3.184				140 A	502 A	2.8 kA
16	0.0508	1.291	19.7	7.75	2.58	1.31	13.17	4.016	22*free air	13*enclosed	18	117 A	398 A	2.2 kA
17	0.0453	1.150	22.1	8.70	2.05	1.04	16.61	5.064				99 A	316 A	1.8 kA
18	0.0403	1.024	24.8	9.77	1.62	0.823	20.95	6.385	10	14	16	83 A	250 A	1.4 kA
19	0.0359	0.912	27.9	11.0	1.29	0.653	26.42	8.051	—	—	—	70 A	198 A	1.1 kA
20	0.0320	0.812	31.3	12.3	1.02	0.518	33.31	10.15	11	7.5	—	58.5 A	158 A	882 A
21	0.0285	0.723	35.1	13.8	0.810	0.410	42.00	12.80	—	—	—	49 A	125 A	700 A
22	0.0253	0.644	39.5	15.5	0.642	0.326	52.96	16.14	7	5	—	41 A	99 A	551 A
23	0.0226	0.573	44.3	17.4	0.509	0.258	66.79	20.36	—	—	—	35 A	79 A	440 A
24	0.0201	0.511	49.7	19.6	0.404	0.205	84.22	25.67	3.5	2.1	—	29 A	62 A	348 A
25	0.0179	0.455	55.9	22.0	0.320	0.162	106.2	32.37	—	—	—	24 A	49 A	276 A
26	0.0159	0.405	62.7	24.7	0.254	0.129	133.9	40.81	2.2	1.3	—	20 A	39 A	218 A
27	0.0142	0.361	70.4	27.7	0.202	0.102	168.9	51.47	—	—	—	17 A	31 A	174 A
28	0.0126	0.321	79.1	31.1	0.160	0.0810	212.9	64.90	1.4	0.85	—	14 A	24 A	137 A
29	0.0113	0.286	88.8	35.0	0.127	0.0642	268.5	81.84	—	—	—	12 A	20 A	110 A
30	0.0100	0.255	99.7	39.3	0.101	0.0509	338.6	103.2	0.86	0.52	—	10 A	15 A	86 A
31	0.00893	0.227	112	44.1	0.0797	0.0404	426.9	130.1	—	—	—	9 A	12 A	69 A
32	0.00795	0.202	126	49.5	0.0632	0.0320	538.3	164.1	0.53	0.3	—	7 A	10 A	54 A
33	0.00708	0.180	141	55.6	0.0501	0.0254	678.8	206.9	—	—	—	6 A	7.7 A	43 A
34	0.00630	0.160	159	62.4	0.0398	0.0201	856.0	260.9	0.3	0.180	—	5 A	6.1 A	34 A
35	0.00561	0.143	178	70.1	0.0315	0.0160	1079	329.0	—	—	—	4 A	4.8 A	27 A
36	0.00500	0.127[c]	200[c]	78.7	0.0250	0.0127	1361	414.8	—	—	—	4 A	3.9 A	22 A
37	0.00445	0.113	225	88.4	0.0198	0.0100	1716	523.1	—	—	—	3 A	3.1 A	17 A
38	0.00397	0.101	252	99.3	0.0157	0.00797	2164	659.6	—	—	—	3 A	2.4 A	14 A

39	0.00353	0.0897	283	111	0.0125	0.00632	2729	831.8	—	—	—	2 A	1.9 A	11 A
40	0.00314	0.0799	318	125	0.00989	0.00501	3441	1049	—	—	—	1 A	1.5 A	8.5 A

a. or, equivalently, Ω/km
b. or, equivalently, Ω/kft
c. Exactly, by definition

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 mm^2. 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 a wire which is equal in cross-sectional area to the total of all the cross-sectional areas of the individual strands; the gaps between strands are not counted. When made with 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

Alternative 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 mains electricity 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 (NM) sheathed bundle (-B) of *two* solid 14 AWG wires. The insulation surrounding the two conductors is white and black, for neutral and "hot" (electrified) respectively. This sheath for 14 AWG cable is usually white when used for NM-B wiring intended for electrical distribution in a dry location, although older wire may be black. #14 wire is used mainly in lighting circuits with a 15-ampere circuit breaker.
- #12/2 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. It is always used for countertop appliance outlets in kitchens, and often for outlets in bathrooms (for high-wattage hair dryers) and other rooms.
- #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, usually supplying both 120 and 240 volts for clothes dryers. Some cables of this type may be flat to save copper.
- #8 and larger cables are now insulated in black, with 6/3 for 50-amp electric ranges in kitchens, and 0/2 (two black-insulated #0 AWG wires, plus ground) for the main 200-amp cable from the weatherhead and electricity meter to the main breaker panel.

14/3 and 12/3 cables are also available, used mainly between three-way (two-location) switches, and to have separate wall controls for ceiling fans and their attached light fixtures, or to have one half of a duplex outlet switched and the other always on. 10/2 cable is rarely used, except for 120-volt 30-amp recreational vehicles. 12/2 and 14/2 can also be used for the rare 240-volt-only 15- or 20-amp plug by clearly marking the white wire red, since it is not the wire gauge but the insulation (typically rated for 600 volts) that determines the voltage, and there is no neutral wire.

277/480-volt cable is identical to 120/240, except that neutral is grey and hot is yellow (plus an optional orange, used as the red is). The higher voltage, used only in large non-residential buildings, allows more than twice as much electrical power (in watts) to be drawn through the same gauge of wire.

UF-B cable is "underground feeder" cable, which regardless of wire gauge has a solid waterproof grey sheath completely surrounding and filling the space between the conductors, which still have their individual colors. Other types of armored or metallic cable (types AC and MC) have an aluminum casing that may be used as a ground conductor, for which it is not necessary to calculate an equivalent wire gauge.

All new cables are marked as being "with ground" or "w/gnd", since installation of ungrounded cables have been prohibited by electrical codes for decades. The ground wire is typically the same gauge as the others, despite not being intended to carry large amounts of current for more than a few seconds in the event of a short circuit.

Table lamp wire is typically #18, while extension cords are #16, with #14 common on cords grounded for outdoor use, and #12 available. Mini Christmas lights were mostly #24 through 1997, when that gauge was arbitrarily de-rated from 3 to 2.5 amps, preventing manufacturers from getting UL certification for the same products which had already been approved for more than two decades. They were forced to use the formerly heavy-duty standard of #22 wire (itself de-rated from 5 to 4 amps), plus thicker insulation, which in turn caused them to shortchange customers by drastically shortening the light socket spacing and usable length of sets. This change also made light strings stiff and unsightly. Heavy-duty mini lights are now 20 AWG, with larger screw-in bulbs having sockets on 18 AWG lamp wire.

Pronunciation

AWG is colloquially referred to as *gauge* and the zeros in large wire sizes are referred to as *aught* /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 "one aught" wire
- No. 00, typically written 2/0 and is referred to as "two aught" wire
- No. 000, typically written 3/0 and is referred to as "three aught" wire,

and so on.

See also

- Brown & Sharpe
- IEC 60228, the metric wire-size standard used in most parts of the world.
- Circular mil, Electrical industry standard for wires larger than 4/0.
- Standard Wire Gauge (SWG), the British imperial standard BS3737, superseded by the metric.
- Stubs Iron Wire Gauge
- Jewelry wire gauge
- Body jewelry sizes
- Electrical wiring
- Number 8 wire, a term used in the New Zealand vernacular

References

1. "ASTM B258 - 14 Standard Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors". West Conshohocken: ASTM International. Archived from the original on 22 July 2014. Retrieved 22 March 2015.(subscription required)
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, (Not in accordance to NEC Codebook 2014 Ch. 9, Table 8) computed based on 100% IACS conductivity of 58.0 MS/m, which agrees with multiple sources:
   - Mark Lund, PowerStream Inc., *American Wire Gauge table and AWG Electrical Current Load Limits*, retrieved 2008-05-02 (although the ft/m conversion seems slightly erroneous)
   - Belden Master Catalog, 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/en/products/materials-in-wire-and-strip-form/wire/conductive-wire/copper/) lists slightly lower resistances than this table.
7. *NFPA 70 National Electrical Code 2014 Edition (http://bulk.resource.org/codes.gov/)*. Table 310.15(B)(16) (formerly Table 310.16) page 70-161, "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. Reference Data for Engineers: Radio, Electronics, Computer and Communications 7th Ed
9. Computed using equations from H. Wayne Beaty; Donald G. Fink, eds. (2007), *The Standard Handbook for Electrical Engineers* (15th ed.), McGraw Hill, pp. 4–25, ISBN 0-07-144146-8
10. Douglas Brooks (December 1998), "Fusing Current: When Traces Melt Without a Trace" (PDF), *Printed Circuit Design*, **15** (12): 53
11. W. H. Preece (1883), "On the Heating Effects of Electric Currents" (PDF), *Proc. Royal Society* (36): 464–471
12. W. H. Preece (1887), "On the Heating Effects of Electric Currents" (PDF), *Proc. Royal Society*, **II** (43): 280–295
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14. Douglas G, Brooks, Ph.D. and Johannes Adam, Ph.D. (29 June 2015), "Who Were Preece and Onderdonk?", *Printed Circuit Design and Fab*
15. E. R. Stauffacher, (June 1928), "Short-time Current Carrying Capacity of Copper Wire" (PDF), *General Electric Review*, **31** (6)

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.
- File:Gauge Chart.pdf

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