Copper wire

AWG Table

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 1 AWG is 289.3 thousandths of an inch
 2 AWG is 257.6 thousandths of an inch
 5 AWG is 181.9 thousandths of an inch
10 AWG is 101.9 thousandths of an inch
20 AWG is  32.0 thousandths of an inch
30 AWG is  10.0 thousandths of an inch
40 AWG is   3.1 thousandths of an inch
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The table in ARRL handbook warns that the figures are approximate and may vary dependent on the manufacturing tolerances. If you don't have a chart handy, you don't really need a formula. There's several handy tricks:

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Solid wire diameters increases/decreases by a factor of  2 every  6 gages,
  "    "      "          "          "                    3 every 10 gages,
  "    "      "          "          "                    4 every 12 gages,
  "    "      "          "          "                    5 every 14 gages,
  "    "      "          "          "                   10 every 20 gages,
  "    "      "          "          "                  100 every 40 gages,
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With these, you can get around alot of different AWGs and they cross check against one another. Start with solid 50 AWG having a 1 mil diameter.

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So, 30 AWG should have a diameter of ~  10 mils. Right on with my chart.
    36 AWG should have a diameter of ~   5 mils. Right on with my chart.
    24 AWG should have a diameter of ~  20 mils. Actually ~ 20.1
    16 AWG should have a diameter of ~  50 mils. Actually ~ 50.8
    10 AWG should have a diameter of ~ 100 mils. Actually ~ 101.9
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If you are more interested in current carrying ability than physical size, then also remember that a change of 3 AWG numbers equals a doubling or halving of the circular mills (the cross sectional area). Thus, if 10 AWG is safe for 30 amps, then 13 AWG (yeah, hard to find) is ok for 15 amps and 16 AWG is good for 7.5 amps.

The wire gauge is a logarithmic scale base on the cross sectional area of the wire. Each 3-gauge step in size corresponds to a doubling or halving of the cross sectional area. For example, going from 20 gauge to 17 gauge doubles the cross sectional area (which, by the way, halves the DC resistance).

So, one simple result of this is that if you take two strands the same gauge, it's the equivalent of a single wire that's 3 gauges lower. So two 20 gauge strands is equivaent to 1 17 gauge.

Wire Gauge Resistance per foot

4	.000292
6	.000465
8	.000739
10	.00118
12	.00187
14	.00297
16	.00473
18	.00751
20	.0119
22	.0190
24	.0302
26	.0480
28	.0764

Current ratings

Most current ratings for wires (except magnet wires) are based on permissible voltage drop, not temperature rise. For example, 0.5 mm^2 wire is rated at 3A in some applications but will carry over 8 A in free air without overheating. You will find tables of permitted maximum current in national electrical codes, but these are based on voltage drop (not the heating which is no problem in the current rating those codes give).

Here is a small current and AWG table taken from the Amateur Radio Relay Handbook, 1985.

AWG	dia mils	circ mils	open air A	cable Amp	ft/lb bare	ohms/ 1000'
10	101.9	10380	55	33	31.82	1.018
12	80.8	6530	41	23	50.59	1.619
14	64.1	4107	32	17	80.44	2.575

Mils are .001". "open air A" is a continuous rating for a single conductor with insulation in open air. "cable amp" is for in multiple conductor cables. Disregard the amperage ratings for household use.

To calculate voltage drop, plug in the values: **V = DIR/1000**
Where I is the amperage, R is from the ohms/1000' column above, and D is the total distance the current travels (don't forget to add the length of the neutral and hot together - ie: usually double cable length). Design rules in the CEC call for a maximum voltage drop of 6% (7V on 120V circuit).

Resistivities at room temp:

Element	Electrical resistivity (microohm-cm)
Aluminum	2.655
Copper	1.678
Gold	2.24

Silver	1.586
Platinum	10.5

This clearly puts silver as the number one conductor and gold has higher resistance than silver or copper. It's desireable in connectors because it does not combine well with other materials so remains relatively pure at the surface. It also has the capability to adhere to itself (touch pure gold to pure gold and it sticks together) which makes for very reliable connections.

Thermal conductivity at room temp:

	W/cm C
silver	4.08
copper	3.94
gold	2.96
platinum	0.69
diamond	0.24
bismuth	0.084
iodine	43.5E-4

This explains why diamonds are being used for high power substrates now. That's man-made diamonds. Natural diamonds contain sufficient flaws in the lattice that the phonons (heat conductors) get scattered and substantially reduce the ability to transport the heat.

Copper wire resistance table

AWG	Feet/Ohm	Ohms/100ft	Ampacity*	mm^2	Meters/Ohm	Ohms/100M
10	490.2	.204	30	2.588	149.5	.669
12	308.7	.324	20	2.053	94.1	1.06
14	193.8	.516	15	1.628	59.1	1.69
16	122.3	.818	10	1.291	37.3	2.68
18	76.8	1.30	5	1.024	23.4	4.27
20	48.1	2.08	3.3	0.812	14.7	6.82
22	30.3	3.30	2.1	0.644	9.24	10.8
24	19.1	5.24	1.3	0.511	5.82	17.2
26	12.0	8.32	0.8	0.405	3.66	27.3
28	7.55	13.2	0.5	0.321	2.30	43.4

These Ohms / Distance figures are for a round trip circuit. Specifications are for copper wire at 77 degrees Fahrenheit or 25 degrees Celsius.

Wire current handling capacity values

A/mm2	R/mohm/m	I/A
6	3.0	55
10	1.8	76
16	1.1	105
25	0.73	140
35	0.52	173
50	0.38	205
70	0.27	265

Information about 35 mm2 Cu wire

According Strцberg TTT 35mm2 copper wire can take continuous current of 170A on free air and 200 A on ground. The wire can handle 5 kA short circuit current for 1s. DC resistance of the wiure is 0.52mohm/m.

Mains wiring current ratings

In mains wiring there are two considerations, voltage drop and heat buildup. The smaller the wire is, the higher the resistance is. When the resistance is higher, the wire heats up more, and there is more voltage drop in the wiring. The former is why you need higher-temperature insulation and/or bigger wires for use in conduit; the latter is why you should use larger wire for long runs.

Neither effect is very significant over very short distances. There are some very specific exceptions, where use of smaller wire is allowed. The obvious one is the line cord on most lamps. Don't try this unless you're certain that your use fits one of those exceptions; you can never go wrong by using larger wire.

This is a table apparently from BS6500 which is reproduced in the IEE Wiring Regs which describes the maximum fuse sizes for different conductor sizes:

Cross-sectional area	Overload current rating
0.5mmI	3A
0.75mmI	6A
1mmI	10A
1.25mmI	13A
1.5mmI	16A

Typical current ratings for mains wiring

Inside wall

mm^2	A
1.5	10
2.5	16

Equipment wires

mm^2	A
0.5	3
0.75	6
1.0	10
1.5	16
2.5	25

We sizes used in USA inside wall

For a 20 amp circuit, use 12 gauge wire. For a 15 amp circuit, you can use 14 gauge wire (in most locales). For a long run, though, you should use the next larger size wire, to avoid voltage drops.

Here's a quick table for normal situations. Go up a size for more than 100 foot runs, when the cable is in conduit, or ganged with other wires in a place where they can't dissipate heat easily:

Gauge	Amps
14	15
12	20
10	30
8	40
6	65

PCB track widths

For a 10 degree C temp rise, minimum track widths are:

Current	width in inches
0.5A	.008"
0.75A	.012"
1.25A	.020"
2.5A	.050"
4.0A	.100"
7.0A	.200"
10.0A	.325"

Equipment wires in Europe

3 core equipment mains cable

Current	3A	6A	10A	13A	16A
Condictor size(mm)	16*0.2	24*0.2	32*0.2	40*0.2	48*0.2
Copper area (mm^2)	0.5	0.75	1.0	1.25	1.5
Overall diameter(mm)	5.6	6.9		7.5	

Calbe ratings for 3A, 6A and 13A are based on BS6500 1995 specifications and are for stranded thick PVC insulated cables.

Insulted hook-up wire in circuits (DEF61-12)

Max. current	1.4A	3A	6A
Max. working voltage (V)	1000	1000	1000
PVC sheat thickness (mm)	0.3	0.3	0.45
Conductor size (mm)	7*0.2	16*0.2	24*0.2
Conductor area (mm^2)	0.22	0.5	0.75
Overall diameter (mm)	1.2	1.6	2.05

Car audio cable recommendations

This info in from rec.audio.car FAQ (orognally from IASCA handbook). To determine the correct wire size for your application, you should first determine the maximum current flow through the cable (looking at the amplifier's fuse is a relatively simple and conservative way to do this). Then determine the length of the cable that your will use, and consult the following chart:

Current	Length of run (in feet)							
	0-4	4-7	7-10	10-13	13-16	16-19	19-22	22-28
0-20A	14	12	12	10	10	8	8	8
20-35A	12	10	8	8	6	6	6	4
35-50A	10	8	8	6	6	4	4	4
50-65A	8	8	6	4	4	4	4	2
65-85A	6	6	4	4	2	2	2	0
85-105A	6	6	4	2	2	2	2	0
105-125A	4	4	4	2	2	0	0	0
125-150A	2	2	2	2	0	0	0	00

Skin effect

Skin effect is an effect that the electricity in high frequencies does not use the whole condictor area. High frequencies tend to use only the outer parts of the conductor. The higher the frequency, the less of the wire diameter is used and higher the losses. Sin effect must be taken care in high frequency coil designs.

The frequency dependency of the resistance of a cylindrical conductor can be calculated by the following formula, which is surely valid for high frequencies and radii of approx. 50 um:
R(f) = R(DC)* (1 + 1/3 * x^4) with x = Radius/2*sqrt(pi*frequency*permeability*conductivity)

The "formula" for skin effect is the same whether the conductor is rectangular or cyclindrical. That is why the same value of "radius" used in wire size in a switchmode transformer is used to determine half the thickness of a flat foil conductor in the case of foil-wound secondaries.

An approximate equation for the resistance ratio for rectangular conductors (from Terman) is:
rho = 1/(((8PI * f)/(Rdc * 10^9))^0.5)

Skin depth is not an absolute, but only the depth where current through the wire or foil has fallen to a specific proportion of the current at the surface. In fact, current falls off exponenially as you move inward fromm the surface. The depth of the "skin" is also influenced by proximity to nearby conductors (such as in a transformer) so is itself not absolute. Also the formula has to be modified if you use wire that is ferromagnetic (iron for example).

In addition to skin effect a lot of engineers doing their own magnetics design don't consider the 'proximity effect' which 'crowds' the current to one side of the conductor and increases losses.

This condition is worst in thick multi-layer windings. Fortunately, many of the new transformer shapes have a long and skinny window - good for low leakage L and low proximity effect losses.

Wire sizes used in fuses

The Standard Handbook for Electrical Engineers lists the following formula:

33 * (I/A)^2 * S = log((Tm - Ta) / (234 + Ta) + 1)

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I = current in Amperes
A = area of wire in circ. mils
S = time the current flows in seconds
Tm = melting point, C
Ta = ambient temp, C
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The melting point of copper is 1083 C.
See pp. 4-74 .. 4-79 of the 13th edition of the Handbook for more info.

Skin effect

At high frequencies there is one thing to consider on wire resistance besides the DC resistence: skin effect.

The current intensity falls off exponentially with depth. The depth of penetration (s=sigma) is the depth at which the current intensity has fallen to 1/e of its value at the surface, where e equals 2.718.

Where the diameter of the conductor is large compared to the depth of penetration, the total current is the same as if the surface current intensity were maintained to a depth of penetration.

For example, for copper the depth of penetration is as follows:

MHz	Depth of Penetration sigma (mm)
.1	.209
1	.066
10	.021
100	.0066
1000	.0021

For other materials the skin dpeth can be calculated using the formula:

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    s = 503.3sqrt(rho/(urf)) millimeters

    rho = resistivity in ohm-meters
        = 1.72x10e-8 for copper or 2.83x10e-8 for aluminum
    ur  = mu r = relative magnetic permeability
        = 1 for both copper and aluminum
     f  = frequency in magahertz
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