Useful material properties for PCB design

Material resistivity

Material	Resistance (Ohms/Metre)
Copper	16.8×10^{-9}
Gold	22.1×10^{-9}
Silver	15.9×10^{-9}
Brass	35.0×10^{-9}
Aluminium	26.5×10^{-9}
Aluminium alloy	50.0×10^{-9}
Iron	97.1×10^{-9}
Lead	208×10^{-9}
Tin	109×10^{-9}
Zinc	59.6×10^{-9}
Solder	165×10^{-9}

Resistance per unit length of a material

$$\text{Electrical resistivity} = \frac{\text{Electrical resistance} \times \text{cross sectional area}}{\text{longitudinal length}}$$

Typical line impedances

Type	L (nH/cm)	C (pF/cm)	Z(Ω)	τ (ns/m)
Single Wire (far away from gnd)	20	0.06	500	≈ 4
Space	μ_0	ε_0	370	3.3
Twisted pair cable	5-10	0.5-1	80-120	5
Flat cable	5-10	0.5-1	80-120	5
Wire on PCB	5-10	0.5-1.5	70-100	≈ 5
Coax Cable	2.5	1.0	50	5
Bus Line	5-10	10-30	20-50	10-20

Notes:

$\mu_0 = 4 \times \pi \times 10^{-7}$ (12.56610^{-7}) (permeability constant)
$\varepsilon_0 = 8.86\times10^{-12}$ Farad/metre (permitivity constant)
Typical output impedance of a TTL device is 25 Ω. Of an Op-Amp it is typically >600Ω. Input impedance of a TTL device is >1MΩ, for an Op-Amp, >1MΩ.

PCB trace current carrying capacity as per IPC-2221A

For External traces

Temp. rise	10°C			20°C			30°C		
Copper weight	½ oz. 17.5 μm	1 oz. 35 μm	2 oz. 70 μm	½ oz. 17.5 μm	1 oz. 35 μm	2 oz. 70 μm	½ oz. 17.5 μm	1 oz. 35 μm	2 oz. 70 μm
Trace width	Maximum current in Amps								
.004" (0.1016mm)	0.17	0.4	0.75	0.25	0.5	0.9	0.3	0.55	1.1
.006" (0.1524mm)	0.38	0.6	0.8	0.5	0.8	1.0	0.65	1.0	1.25
.008" (0.2032mm)	0.45	0.72	1.1	0.6	0.85	1.5	0.75	1.1	1.8
.010" (0.254mm)	0.5	0.8	1.4	0.7	1.0	1.65	0.85	1.25	2.0
.012" (0.3048mm)	0.6	1	1.5	0.75	1.2	2.0	0.95	1.5	2.6
.015" (0.381 mm)	0.7	1.2	1.6	0.8	1.5	2.3	1.0	1.7	3.0
.020" (0.508 mm)	0.8	1.3	2.1	1.0	1.7	3.0	1.3	2.1	3.6
.025" (0.635 mm)	0.9	1.7	2.6	1.25	2.2	3.5	1.5	2.8	4.0
.030" (0.762 mm)	1.0	1.75	3.0	1.4	2.5	3.85	1.65	3.2	4.8
.040" (1.016 mm)	1.3	2.2	3.6	1.7	3.0	5.0	2.1	3.7	6.2
.050" (1.270 mm)	1.5	2.6	4.0	2.0	3.6	6.0	2.6	4.6	7.4
.075" (1.905 mm)	2.0	3.6	5.7	2.8	4.5	7.8	3.5	6.0	10.0
.100" (2.54 mm)	2.6	4.4	6.9	3.5	6.0	9.9	4.3	7.5	12.5
.200" (5.08 mm)	4.2	7.0	11.5	6.0	10.0	11.0	7.5	13.0	20.5
.250" (6.35 mm)	5.0	9.0	12.3	7.2	12.3	20.0	9.0	15.0	24.5

PCB trace current carrying capacity as per IPC-2221A

For Internal traces

| Temp. rise	10°C			20°C			30°C		
Copper weight	½ oz. 17.5 μm	1 oz. 35 μm	2 oz. 70 μm	½ oz. 17.5 μm	1 oz. 35 μm	2 oz. 70 μm	½ oz. 17.5 μm	1 oz. 35 μm	2 oz. 70 μm
Trace width	Maximum current in Amps								
.004" (0.1016mm)	0.1	0.2	0.35	0.125	0.25	0.45	0.15	0.28	0.55
.006" (0.1524mm)	0.19	0.3	0.4	0.25	0.4	0.5	0.32	0.5	0.65
.008" (0.2032mm)	0.22	0.36	0.55	0.3	0.42	0.75	0.35	0.55	0.9
.010" (0.254mm)	0.25	0.4	0.7	0.35	0.5	0.8	0.4	0.6	1.0
.012" (0.3048mm)	0.3	0.5	0.75	0.35	0.6	1.0	0.45	0.75	1.3
.015" (0.381 mm)	0.35	0.6	0.8	0.4	0.75	1.15	0.5	0.85	1.5
.020" (0.508 mm)	0.4	0.65	1.0	0.5	0.85	1.5	0.65	1.0	1.8
.025" (0.635 mm)	0.45	0.85	1.3	0.6	1.1	1.75	0.75	1.4	2.0
.030" (0.762 mm)	0.5	0.8	1.5	0.7	1.25	1.92	0.8	1.6	2.4
.040" (1.016 mm)	0.65	1.1	1.8	0.65	1.5	2.5	1.05	1.85	3.1
.050" (1.270 mm)	0.75	1.3	2.0	1.0	1.8	3.0	1.3	2.3	3.7
.075" (1.905 mm)	1.0	1.8	2.85	1.4	2.25	3.9	1.75	3.0	5.0
.100" (2.54 mm)	1.3	2.2	3.45	1.75	3.0	4.95	2.15	3.75	6.25
.200" (5.08 mm)	2.1	3.5	6.25	3.0	5	5.5	3.75	6.5	10.25
.250" (6.35 mm)	2.5	4.5	6.15	3.6	6.15	10.0	4.5	7.5	12.25

PCB Trace fusing currents

To calculate the fusing current of a PCB trace use this formula:

$$I = \frac{0.188 \times A}{t^{0.5}}$$

Where I = current in amps, A = conductor cross sectional area in square thou/mil and t = time in seconds.
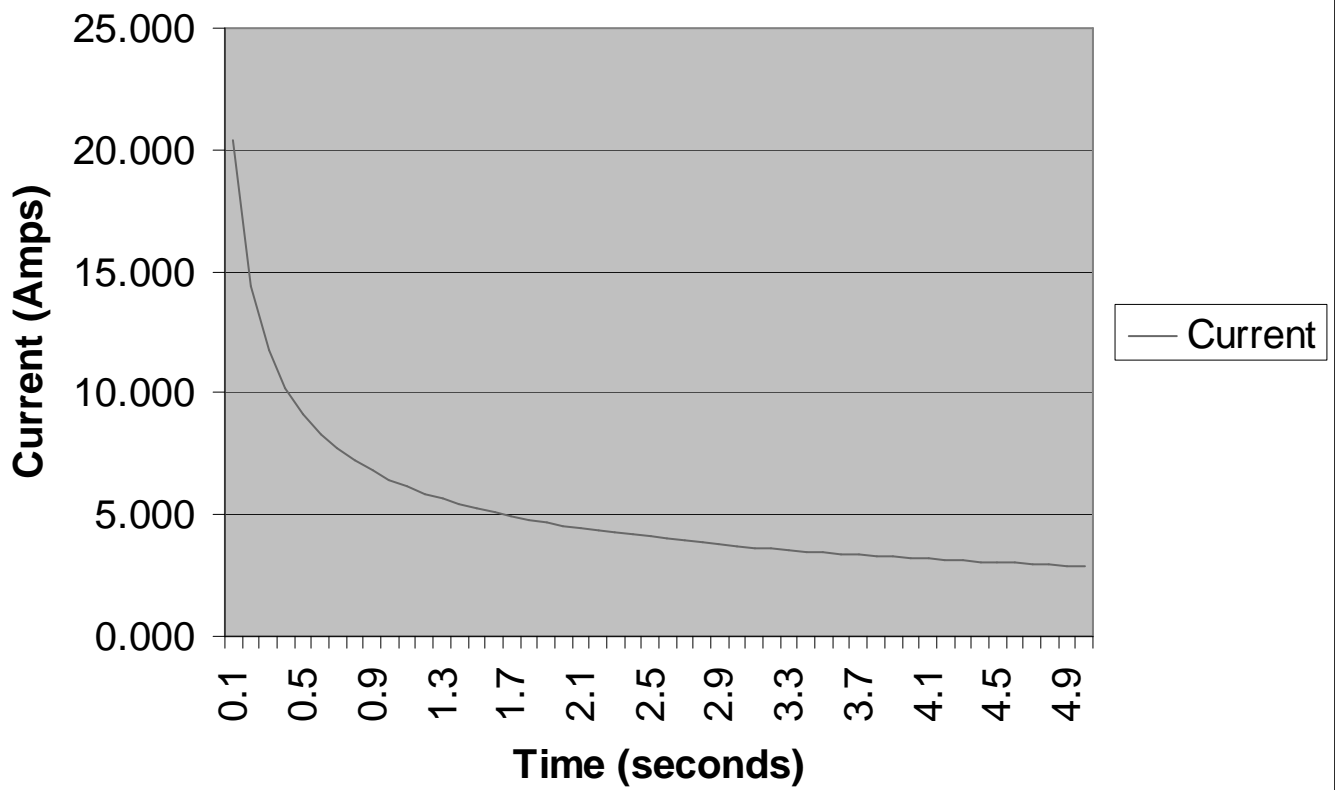
Note: These are theoretical fusing current limits.

Plotting this function you get:
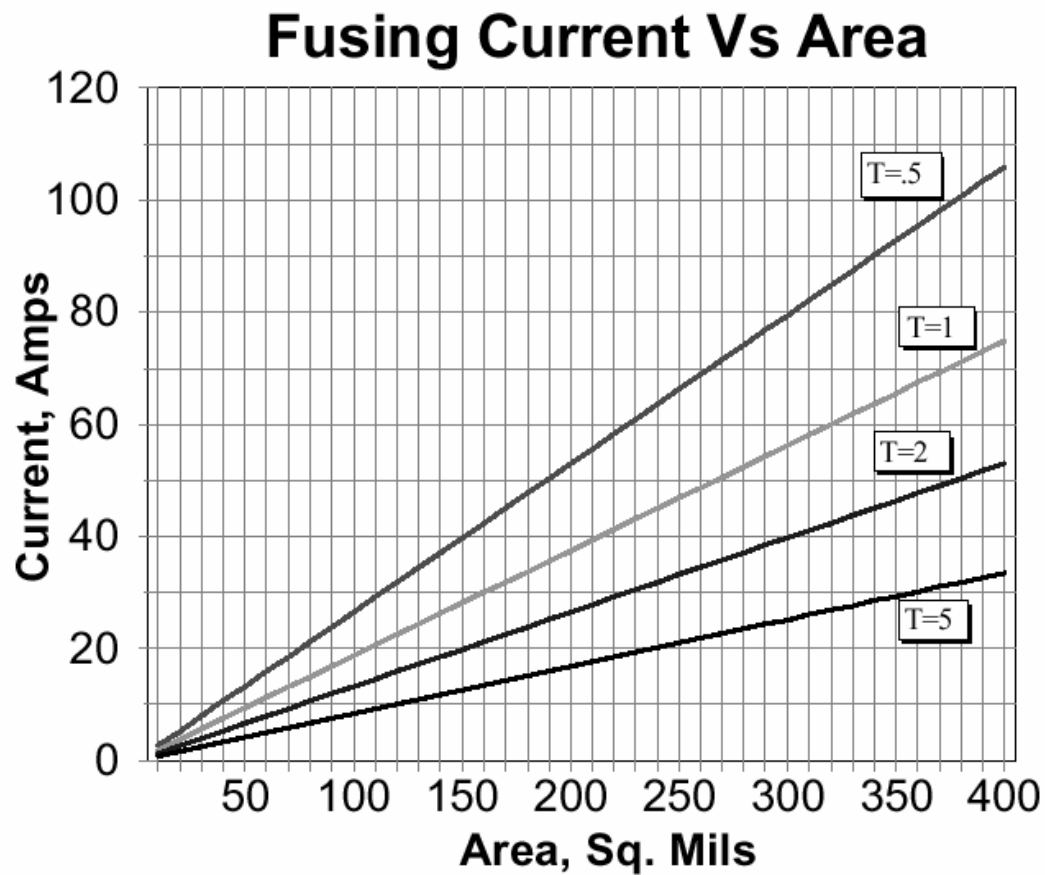
Conversely you can plot the current limits for a given trace width, see the next page.

Fuse current of a 12 thou PCB trace with time

Chart showing Current (Amps) on the y-axis (0.000 to 25.000) versus Time (seconds) on the x-axis (0.1 to 4.9). The "Current" curve decreases sharply from about 20 Amps at 0.1 seconds to around 3 Amps at 4.9 seconds.

American Wire gauge chart

AWG gauge	Diameter Inches	Diameter mm	Ohms per 1000 ft	Maximum amps for chassis wiring
OOOO	0.46	11.684	0.049	380
OOO	0.4096	10.40384	0.0618	328
OO	0.3648	9.26592	0.0779	283
0	0.3249	8.25246	0.0983	245
1	0.2893	7.34822	0.1239	211
2	0.2576	6.54304	0.1563	181
3	0.2294	5.82676	0.197	158
4	0.2043	5.18922	0.2485	135
5	0.1819	4.62026	0.3133	118
6	0.162	4.1148	0.3951	101
7	0.1443	3.66522	0.4982	89
8	0.1285	3.2639	0.6282	73
9	0.1144	2.90576	0.7921	64
10	0.1019	2.58826	0.9989	55
11	0.0907	2.30378	1.26	47
12	0.0808	2.05232	1.588	41
13	0.072	1.8288	2.003	35
14	0.0641	1.62814	2.525	32
15	0.0571	1.45034	3.184	28
16	0.0508	1.29032	4.016	22
17	0.0453	1.15062	5.064	19
18	0.0403	1.02362	6.385	16
19	0.0359	0.91186	8.051	14
20	0.032	0.8128	10.15	11
21	0.0285	0.7239	12.8	9
22	0.0254	0.64516	16.14	7
23	0.0226	0.57404	20.36	4.7
24	0.0201	0.51054	25.67	3.5
25	0.0179	0.45466	32.37	2.7
26	0.0159	0.40386	40.81	2.2
27	0.0142	0.36068	51.47	1.7
28	0.0126	0.32004	64.9	1.4
29	0.0113	0.28702	81.83	1.2
30	0.01	0.254	103.2	0.86
31	0.0089	0.22606	130.1	0.7
32	0.008	0.2032	164.1	0.53
33	0.0071	0.18034	206.9	0.43
34	0.0063	0.16002	260.9	0.33
35	0.0056	0.14224	329	0.27
36	0.005	0.127	414.8	0.21
37	0.0045	0.1143	523.1	0.17
38	0.004	0.1016	659.6	0.13
39	0.0035	0.0889	831.8	0.11
40	0.0031	0.07874	1049	0.09

Table 5-4   Typical Data for Some Logic Families

Logic Family	Typical Edge (nS)		Band Width Frequency	Critical Length				Output Drive Current (mA)		Logic Input Threshold		Typical Buffer Prop. Delay
				Microstrip		Stripline						
	Rise	Fall	(MHz)	in	cm	in	cm	I_{OL}	I_{OH}	V_{IL}	V_{IH}	
AGP	0.350	0.450	1000	0.63	1.60	0.50	1.27	20	-12	1.12	1.52	1.5 nS
BiCMOS 74ABT	1.6	1.4	250	2.5	6.3	2.0	4.9	64	-32	1.1	1.9	3.6 nS
BiCMOS 74BCT	0.700	0.700	500	1.24	3.15	0.98	2.49	64	-15	0.8	2.0	2.5 nS
BiCMOS 74LVT	2.7	2.8	130	4.80	12.2	3.8	9.8	64	-32	1.3	1.7	4.1 nS
CMOS 74AC	1.7	1.5	233	2.7	6.8	2.1	5.3	24	-24	2.2	3.0	7.5 nS
CMOS 74ACT	1.7	1.5	233	2.7	6.8	2.1	5.3	24	-24	0.4	2.1	10.0 nS
CMOS 74ACQ	2.4	2.4	146	4.3	10.8	3.4	8.4	24	-24	2.3	2.9	9.5 nS
CMOS 74ACTQ	2.5	2.4	146	4.3	10.8	3.4	8.4	24	-24	1.2	2.0	7.0 nS
CMOS 74AHCT	2.4	2.4	146	4.3	10.8	3.4	8.4	24	-15	0.8	2.0	7.0 nS
CMOS 74C	35.0	25.0	14	44.4	112.5	35	87.5	12	-14	0.7	3.5	70.0 nS
CMOS 74FCT	1.5	1.2	292	2.1	5.4	1.7	4.2	64	-15	0.8	2.0	3.1 nS
CMOS 74HC	3.6	4.1	97	6.4	16.2	5.0	12.6	6	-6	2.3	2.4	25.0 nS
CMOS 74HCT	4.6	3.9	90	6.9	17.6	5.5	13.7	6	-6	1.3	1.4	25.0 nS
CMOS 74LCX	2.9	2.4	146	4.3	10.8	3.4	8.4	24	-24	1.3	1.8	6.5 nS
CMOS 74LV	3.0	3.0	116	5.3	13.5	4.2	10.5	8	-8	0.9	2.3	7.5 nS
CMOS 74LVQ	3.5	3.2	109	5.7	14.4	4.5	11.2	12	-12	1.6	1.7	9.5 nS
CMOS 74LVX	4.8	3.7	95	6.6	16.7	5.2	13.0	4	-4	1.4	1.7	12.0 nS
CMOS 74VHC	4.1	3.2	109	5.7	14.4	4.5	11.2	8	-8	2.1	2.8	8.5 nS
CMOS 74VCX	2.0	2.0	175	3.6	9.0	2.8	7.0	24	-24	0.8	2.2	2.5 nS
CTT	0.600	0.750	583	1.07	2.70	0.84	2.10	8	-8	1.3	1.7	2.0 nS
ECL 10K	2.2	2.2	159	3.9	9.9	3.1	7.7	50	-50	-1.7	-0.95	2.0 nS
ECL 10KH	1.7	1.7	206	3.0	7.7	2.4	6.0	50	-50	-1.7	-0.95	1.0 nS
ECL 100K	0.600	0.600	583	1.07	2.70	0.84	2.10	50	-50	-1.5	-0.90	0.800 nS
ECL 300K	0.500	0.500	700	0.89	2.25	0.7	1.25	50	-50	-1.7	-0.95	1.55 nS
ECL (E)	0.375	0.375	933	0.67	1.69	0.53	1.31	50	-50	3.3	4.0	0.300 nS
LVPECL (EP)	0.110	0.110	3182	0.20	0.50	0.15	0.39	50	-50	1.6	2.4	0.160 nS
LVPECL (LVEL)	0.220	0.220	1591	0.39	0.99	0.31	0.77	50	-50	1.6	2.4	0.300 nS
PECL (EL)	0.225	0.225	1556	0.40	1.01	0.32	0.79	50	-50	3.3	4.0	0.250 ns
RSECL (SiGe-3.3V)	0.030	0.030	11700	0.06	0.14	0.04	0.11	25	-25	1.9	2.3	0.120 nS
RSECL (SiGe-2.5V)	0.030	0.030	11700	0.06	0.14	0.04	0.11	25	-25	1.1	1.5	0.120 nS
GaAs	0.300	0.100	3500	0.18	0.45	0.14	0.35	30	-30	0.8	2.0	0.250 nS
GTL	1.2	1.2	292	2.1	5.4	1.7	4.2	40	-40	0.75	0.85	3.0 nS
GTL+	0.300	0.300	1167	0.53	1.35	0.42	1.05	40	-40	0.80	1.20	3.0 nS
HSTL	0.620	0.220	1591	0.39	0.99	0.31	0.77	8~48	-8~48	0.75	0.85	1.7 nS
LVDS	0.300	0.300	1167	0.53	1.35	0.42	1.05	3.5	-3.5	1.07	1.41	2.0 nS
SSTL	0.330	0.510	1060	0.59	1.50	0.46	1.17	8~20	-8~20	1.30	1.70	1.8 nS
TTL 74	8.0	5.0	70	8.9	22.5	7	17.5	16	-15	0.8	2.0	20.0 nS
TTL 74ALS	2.3	2.3	152	4.1	10.4	3.2	8.1	24	-15	0.8	1.6	10.0 nS
TTL 74AS	2.1	1.5	233	2.7	6.8	2.1	5.3	64	-15	0.5	1.9	6.2 nS
TTL 74F	2.3	1.7	206	3.0	7.7	2.4	6.0	64	-15	0.9	1.8	6.5 nS
TTL 74FR	2.1	1.5	233	2.7	6.8	2.1	5.3	64	-15	0.6	2.2	3.9 nS
TTL 74H	7.0	7.0	50	12.4	31.5	9.8	24.5	20	-0.25	0.8	2.0	15.0 nS
TTL 74L	35.0	30.0	12	53.3	135.0	42.0	105.0	2	-0.4	0.8	2.0	35.0 nS
TTL 74LS	15.0	10.0	35	17.8	45.0	14.0	35.0	24	-15	0.8	1.8	18.0 nS
TTL 74S	2.5	2.0	175	3.6	9.0	2.8	7.0	64	-15	0.8	1.8	6.0 nS