Printed Circuit Board Design Rules & Limits

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Notes:

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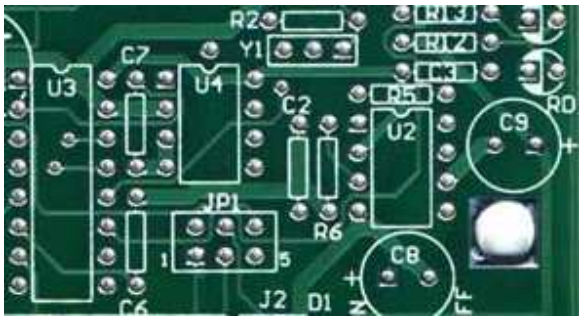
General Design Criteria

- 1oz Copper, 2 or 4 layer board - 0.062" FR4 material
- 2 Layer sizing:
  - 7mil (~0.17 mm) minimum space between traces
  - 7mil (~0.17 mm) minimum trace width
  - 20mil (~0.5 mm) minimum drill size
- 4 Layer sizing:
  - 6mil (~0.15 mm) minimum space between traces
  - 6mil (~0.15 mm) minimum trace width
  - 13mil (~0.33 mm) minimum drill size
  - No blind or buried vias
- Std holes: via = .17" (4.3mm), IC lead .026" (6.5mm), resistors and caps lead .031" (7.7mm).
- No internal routes, no v-scoring, only drill files are sent to the fab house
- Solder mask 1 side
- No limit on the number of vias
- No limit on pads or components
- Multiple designs, multiple copies *are allowed!*

Markings



A	separable assembly	**LS**	loudspeaker, buzzer
AR	amplifier	**M**	meter
AT	attenuator; isolator	**MG**	motor-generator
B	blower, motor	**MH***	mounting hole
BT	battery	**MK**	microphone
C	capacitor	**MP**	mechanical part
CB	circuit breaker	**P**	connector, plug, male
CP	connector adapter, coupling	**PS**	power supply
CN	capacitor network	**Q**	transistor
D or CR	diode	**R**	resistor
D or VR	breakdown diode	**RN**	resistor network
DC	directional coupler	**RT**	thermistor
DL	delay line	**S**	switch
DS	display, lamp	**T**	transformer
E	terminal	**TB**	terminal board, terminal strip
F	fuse	**TC**	thermocouple
FD*	fiducial	**TP**	test point, In-circuit test points
FL	filter	**TZ**	transzorb
G	generator, oscillator	**U**	inseparable assembly, IC pkg
GN	general network	**V**	electron tube
H	hardware	**VR**	voltage regulator
HY	circulator, directional coupler	**W**	wire, cable, cable assembly
J	connector, jack, female	**X**	fuse holder, lamp holder, socket
K	contactor, relay	**Y**	crystal, magnetostriction oscillator
L	coil, inductor, bead, ferrite bead	**Z**	miscellaneous

CAPACITORS & BATTERIES: Footprints for capacitors and batteries should include plus sign (+) polarity marking on the silk screen next to the positive pad. (The positive-end-indicator stripe on the capacitor itself should be placed nearest that plus sign).

LED & DIODES: Footprints for LEDs and other diodes should have a polarity mark -- the "diode arrow symbol" (triangle + bar), or at least the bar, in silk-screen. The bar matches the cathode-end-indicator stripe on the diode itself.

IC: Footprints for ICs should have a polarity mark "dot" or "1" near pin 1. Most people give pin 1 a "squared-off" pad, and all other pins a "rounded pad". Some people also like additional "10", "20", "30", etc., marks in silkscreen next to pin 10, pin 20, pin 30, etc.

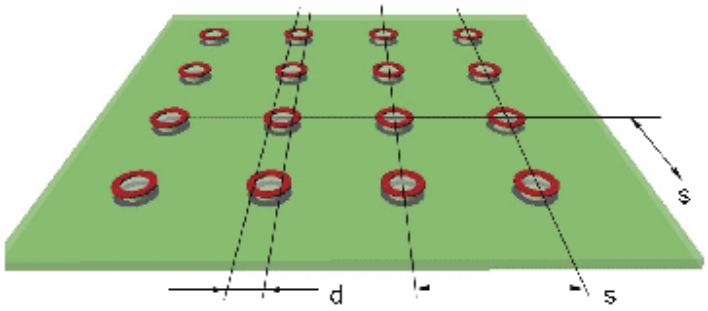
TRANSISTORS: Should have pin numbers or base, emitter, collector abbreviations

Trace Spacing Guidelines

Conductor Spacing							
Voltage Between Conductors (VDC or Peak)	Minimum Spacing (inches)						
	Bare Board				Assembly		
	B1	B2	B3	B4	A5	A6	A7
0 thru 15	.004	.025	.025	.005	.005	.005	.005
16 thru 30	.004	.025	.025	.005	.005	.010	.005
31 thru 50	.004	.025	.025	.005	.005	.015	.005
51 thru 100	.004	.025	.060	.005	.005	.020	.005
101 thru 150	.008	.025	.125	.015	.015	.030	.015
151 thru 170	.008	.050	.125	.015	.015	.030	.015
171 thru 250	.008	.050	.250	.015	.015	.030	.015
251 thru 300	.008	.050	.500	.015	.015	.030	.015
301 thru 500	.010	.100	.500	.030	.030	.060	.030
More than 500	.0001 /Volt	.0002 /Volt	.001 /Volt	.00012 /Volt	.00012 /Volt	.00012 /Volt	.00012 /Volt

B1 - Internal Conductors
B2 - External Conductors, uncoated, sea level to 10,000 ft.
B3 - External Conductors, uncoated, over 10,000 ft.
B4 - External Conductors, with permanent polymer coating (soldermask).
A5 - External Conductors, with conformal coating over assembly.
A6 - External Component lead/termination, uncoated.
A7 - External Component lead/termination, with conformal coating.

Holes



VIAS: All vias on a particular PCB should be the same size. Typical size is 0.025" (0.6mm) diameter, surrounded by a 0.042" (1.0mm) diameter via copper pad, if at all possible. Some very dense SMT boards require small vias down to a 0.012" hole, surrounded by 0.024" diameter via pad.

IC: Typical size is 0.025-0.032" (0.6mm) diameter, surrounded by a 0.042" (1.0mm) diameter via copper pad.

CAPACITOR, DIODE, RESISTOR: 1.0mm or 1.2mm for other components such as axial resisters and larger capacitors.

This list is the standard **finished** hole sizes (in inches). Plating decreases the drilled hole by apx 3-5mils.

.020 .025 .029 .035 .046 .052 .079 .125 .150

Drill Size		Inch	mm
# 66	=	.033”	
# 67	=	.032”	
# 70	=	.028”	
# 73	=	.024”	
# 76	=	.020”	
# 77	=	.018”	
# 79	=	.0145”	
# 80	=	.0135”	

Finished Size	Approximate Use
.017"	via holes
.025"	via holes, fine lead devices such as trim pots etc.
.032"	IC's, 1/4 watt resistors, small diodes, ripple caps etc.
.035"	Square posted pins that measure .025" on the flat.
.039"	TO-220 packages, IDC type square posted headers, 1/2 watt resistors, 1N9000 series diodes, IC chip carriers etc.
.049"	larger connectors, transformer leads, etc.
.057"	similar to .049" above
.083"	TO-220 mounting holes, screw holes, general mounting
.122"	mounting holes

.149"	mounting holes

Preset Finish Drill Sizes - Imperial sizes in inches (mils)

Your drill sizes (contained in your file) in these ranges will be converted to our pre-set **finish** hole sizes:

Your Tool Sizes:	Preset Finished Hole will be:	Tolerance:	** Minimum Copper Pad Dimensions:	*** Minimum Copper Inner Layer Clearances:
0.0000 - 0.0159	0.008 *	.006/-.008	0.0250	0.0330
0.0160 - 0.0179	0.016	+0.002/- 0.006	0.0310	0.0410
0.0180 - 0.0249	0.0200	+/- 0.004	0.0370	0.0450
0.025 - 0.0289	0.0250	+/- 0.004	0.0420	0.0500
0.0290 - 0.0319	0.0290	+/- 0.004	0.0460	0.0540
0.0320 - 0.0349	0.0330	+/- 0.004	0.0500	0.0580
0.0350 - 0.0380	0.0360	+/- 0.004	0.0530	0.0610
0.0381 - 0.0410	0.0405	+/- 0.004	0.0575	0.0655
0.0411 - 0.0449	0.0432	+/- 0.004	0.0602	0.0682
0.0450 - 0.0519	0.0460	+/- 0.004	0.0630	0.0710
0.0520 - 0.0599	0.0535	+/- 0.004	0.0705	0.0785
0.0600 - 0.0659	0.0610	+/- 0.004	0.0780	0.0860
0.0660 - 0.0759	0.0670	+/- 0.004	0.0840	0.0920
0.0760 - 0.0839	0.0800	+/- 0.004	0.0970	0.1050
0.0840 - 0.0899	0.0875	+/- 0.004	0.1045	0.1125
0.0900 - 0.0969	0.0935	+/- 0.004	0.1105	0.1185
0.0970 - 0.1059	0.1005	+/- 0.004	0.1175	0.1255
0.1060 - 0.1160	0.1100	+/- 0.004	0.1270	0.1350
0.1161 - 0.1329	0.1259	+/- 0.004	0.1429	0.1509
0.1330 - 0.1429	0.1410	+/- 0.004	0.1580	0.1660
0.1430 - 0.1529	0.1510	+/- 0.004	0.1680	0.1760
0.1530 - 0.1709	0.1670	+/- 0.004	0.1840	0.1920
0.1710 - 0.2019	0.1930	+/- 0.004	0.2100	0.2180
0.2020 - 10.000	0.2510	+/- 0.004	0.2680	0.2760

* 0.008 Finish Hole Size only available on 4 - 6 layer board orders.

** Recommended minimum pad size guarantees through-hole electrical continuity.

*** Recommended minimum inner layer clearances prevent electrical shorts caused from through-holes connecting directly to ground plane.

Environmental Factors

The environment in which a PCB is to be used will change a number of factors needed to design and test it. The ambient temperature is one of these important factors.

Worst Case Environments				
Cat	**USE**	**Min Temp**	**Max Temp**	**Service**
1	Consumer	0°C	+60°C	1-3 Yrs
2	Computer	+15°C	+60°C	~5 Yrs
3	Telecomm	-40°C	+85°C	7-20 Yrs
4	Civ Aircraft	-55°C	+95°C	~10 Yrs
5	Industrial	-55°C	+55°C	~10 Yrs
	Auto Pass Cmp	-55°C	+55°C	~10 Yrs
6	Mil Gnd/Ship	-55°C	+95°C	~5 Yrs
7	Space	-40°C	+85°C	5-20 Yrs
8	Mil Aircraft	-55°C	+95°C	~5 Yrs
9	Auto Engine	-55°C	+125°C	~5 Yrs

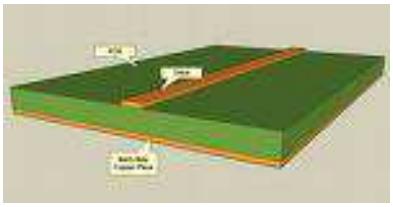
Commercial Circuit Software Formats

- Protel
- Eagle - (Free version available)
- PCB - (Free, Open Source)
- FreePCB - (Win32, Free, Open Source)
- KiCAD - - (*nix, Free, Open Source)
- Orcad
- PCad
- Target
- Boardmaker
- Dex Autotrax
- WinBoard
- Many others also work!

Proprietary formats

- Express PCB
- Pad2Pad

Trace Width Guidelines



Here are some standard trace widths for specific maximum currents. The temperature shown in the table should be subtracted from the delamination temperature for the PCB base material. If the result is negative, the trace is too narrow. For a relatively isolated trace the values may be used directly, but closely spaced traces should be considered as one for temperature calculations. (i.e. an isolated .005" trace carrying 1/2 amp will have a temperature 20°C above ambient. A bus of 10 .005" traces carrying 1/2 amp each will raise the temperature about 30°C) This does not allow for the temperature rise from any parts mounted on the board.

PCB Base Laminate Data

Designation		Dielectric	Max
ANSI	MIL-P-13949	Thickness	Temp
-	PX	-	105°C
-	GE	-	125°C
FR-4	GF	.004-.014"	120°C
		.015 +	130°C
FR-5	GH	.025-.054"	140°C
		.055 +	170°C

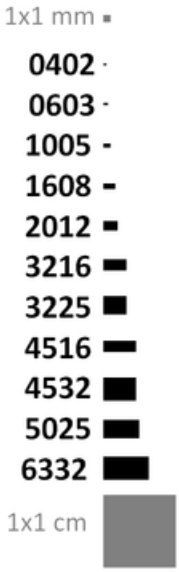
1 Oz. Plating, External Conductors

Width	10°C	20°C	30°C	45°C	60°C
.005"	400 mA	500 mA	650 mA	800 mA	1.0 A
.010"	800 mA	1.0 A	1.3 A	1.6 A	1.9 A
.015"	1.2 A	1.5 A	1.8 A	2.1 A	2.8 A
.020"	1.5 A	1.7 A	2.0 A	2.5 A	3.1 A
.025"	1.7 A	2.2 A	3.0 A	3.5 A	4.0 A
.050"	3.2 A	3.9 A	4.8 A	5.7 A	6.5 A
.100"	4.8 A	6.2 A	8.0 A	9.5 A	10.4 A
.150"	6.0 A	8.5 A	11.0 A	12.6 A	13.5 A

1 Oz. Plating, Internal Conductors

.005"	200 mA	225 mA	250 mA	275 mA
.010"	400 mA	450 mA	600 mA	750 mA
.015"	550 mA	600 mA	750 mA	1.0 A
.020"	650 mA	700 mA	800 mA	1.2 A
.025"	750 mA	1.0 A	1.2 A	1.7 A
.050"	1.5 A	1.7 A	2.2 A	2.8 A
.100"	2.2 A	3.1 A	3.7 A	4.5 A
.150"	3.0 A	4.0 A	5.2 A	6.1 A

Surface Mount Sizes



Chip Size	size (mm)	size (inch)	Solder side	Solder Foot	Height	Resistor Watts
0105	0.40 x 0.20					0.031w
0201	0.60 x 0.30	0.02 x 0.01	0.13	0.25	0.25	0.05w
0402	1.00 x 0.50	0.04 x 0.02	0.20	0.25	0.35	0.063
0603	1.60 x 0.80	0.06 x 0.03	0.20	0.30	0.50	0.063
0805	2.00 x 1.25	0.08 x 0.05	0.40	0.30	0.50	0.100
1008	2.50 x 2.00					
1206	3.20 x 1.60	0.12 x 0.06	0.45	0.40	0.60	0.125
1210	3.20 x 2.60	0.12 x 0.10	0.50	0.40	0.60	0.250
1217	3.00 x 4.20		0.80	0.80	0.90	0.250
1806	4.50 x 1.60					
1812	4.50 x 3.20	0.18 x 0.12				0.75w
2010	5.00 x 2.60	0.20 x 0.10	0.50	0.40	0.70	0.250
2020	5.00 x 5.00		0.80	0.80	0.9	0.500
2045	11.5 x 5.00		0.80	0.80	0.9	1.000
2512	6.30 x 3.10	0.25 x 0.12	0.60	0.50	0.60	0.500
2920	7.40 x 5.10					

The smaller the physical part, the lower the inductance.
Pick the smallest possible package size which still meets the design criteria.

Tantalum capacitors SMD packages

As a result of the different construction and requirements for tantalum SMT capacitors, there are some different packages that are used for them. These conform to EIA specifications.

SMD Package type	Dimensions (mm)	EIA standard
Size A	3.2 x 1.6 x 1.6	EIA 3216-18
Size B	3.5 x 2.8 x 1.9	EIA 3528-21
Size C	6.0 x 3.2 x 2.2	EIA 6032-28
Size D	7.3 x 4.3 x 2.4	EIA 7343-31
Size E	7.3 x 4.3 x 4.1	EIA 7343-43

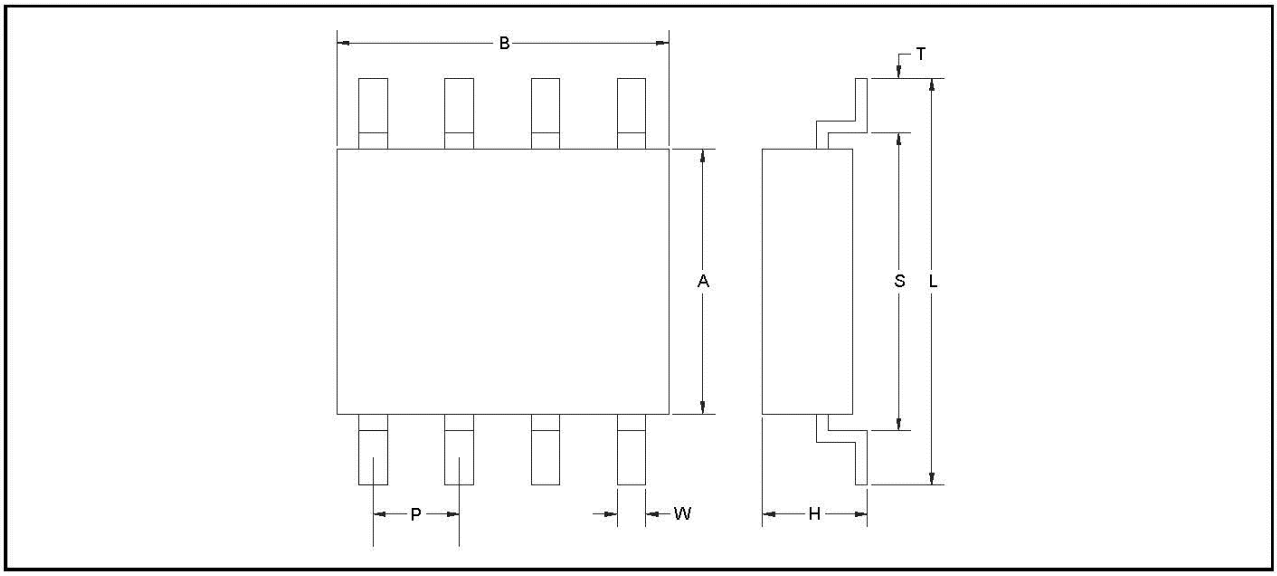


FIGURE 3. Package Dimensions.

PACKAGE	PKG #	L MIN	L MAX	W MIN	W MAX	T MIN	T MAX	A MIN	A MAX	B MIN	B MAX	H MIN	H MAX	P NOM	LEAD COUNT
SO-8	182	0.228	0.244	0.013	0.020	0.016	0.050	0.150	0.157	0.189	0.196	0.053	0.069	0.0500	8
SO-14	235	0.228	0.244	0.013	0.020	0.016	0.050	0.150	0.157	0.337	0.344	0.053	0.069	0.0500	14
SO-16	265	0.228	0.244	0.013	0.020	0.016	0.050	0.150	0.157	0.386	0.394	0.053	0.069	0.0500	16
SO-16W	211	0.394	0.419	0.013	0.020	0.016	0.050	0.291	0.299	0.398	0.413	0.093	0.104	0.0500	16
SO-18	219	0.394	0.419	0.013	0.020	0.016	0.050	0.291	0.299	0.447	0.463	0.093	0.104	0.0500	18
SO-20	221	0.394	0.419	0.013	0.020	0.016	0.050	0.291	0.299	0.496	0.512	0.093	0.104	0.0500	20
SO-24	239	0.394	0.419	0.013	0.020	0.016	0.050	0.291	0.299	0.598	0.614	0.093	0.104	0.0500	24
SO-28	217	0.398	0.419	0.013	0.020	0.020	0.040	0.291	0.299	0.697	0.713	0.093	0.104	0.0500	28
SOT-23-5	331	0.102	0.118	0.010	0.020	0.014	0.022	0.059	0.069	0.110	0.118	0.035	0.057	0.0374	5
SOT-23-6	332	0.102	0.118	0.010	0.020	0.014	0.022	0.059	0.069	0.110	0.118	0.035	0.057	0.0374	6
SOT-23-8	348	0.102	0.118	0.011	0.018	0.004	0.024	0.059	0.069	0.110	0.118	0.035	0.057	0.0256	8
MSOP-8	337	0.189	0.197	0.011	0.015	0.018	0.026	0.114	0.122	0.114	0.122	0.032	0.048	0.0256	8
SSOP-20	334	0.291	0.323	0.009	0.015	0.022	0.037	0.197	0.220	0.272	0.295	0.077	0.079	0.0256	20
SSOP-24	338	0.291	0.323	0.009	0.015	0.022	0.037	0.197	0.220	0.311	0.335	0.077	0.079	0.0256	24
SSOP-28	324	0.291	0.323	0.009	0.015	0.022	0.037	0.197	0.220	0.390	0.413	0.077	0.079	0.0256	28
SSOP-16	322	0.228	0.244	0.008	0.012	0.016	0.050	0.149	0.157	0.188	0.197	0.053	0.069	0.0250	16
SSOP-48	333	0.395	0.420	0.008	0.013	0.020	0.040	0.291	0.299	0.613	0.630	0.053	0.069	0.0250	48
SSOP-56	346	0.395	0.420	0.008	0.013	0.020	0.040	0.291	0.299	0.720	0.730	0.095	0.110	0.0250	56

TABLE II . Package Dimensions—Inches.

PACKAGE	PKG #	L MIN	L MAX	W MIN	W MAX	T MIN	T MAX	A MIN	A MAX	B MIN	B MAX	H MIN	H MAX	P NOM	LEAD COUNT
SO-8	182	5.79	6.20	0.33	0.51	0.41	1.27	3.81	3.99	4.80	4.98	1.35	1.75	1.270	8
SO-14	235	5.79	6.20	0.33	0.51	0.41	1.27	3.81	3.99	8.56	8.74	1.35	1.75	1.270	14
SO-16	265	5.79	6.20	0.33	0.51	0.41	1.27	3.81	3.99	9.80	10.01	1.35	1.75	1.270	16
SO-16W	211	10.01	10.64	0.33	0.51	0.41	1.27	7.39	7.59	10.11	10.49	2.36	2.64	1.270	16
SO-18	219	10.01	10.64	0.33	0.51	0.41	1.27	7.39	7.59	11.35	11.76	2.36	2.64	1.270	18
SO-20	221	10.01	10.64	0.33	0.51	0.41	1.27	7.39	7.59	12.60	13.00	2.36	2.64	1.270	20
SO-24	239	10.01	10.64	0.33	0.51	0.41	1.27	7.39	7.59	15.19	15.60	2.36	2.64	1.270	24
SO-28	217	10.11	10.64	0.33	0.51	0.51	1.02	7.39	7.59	17.70	18.11	2.36	2.64	1.270	28
SOT-23-5	331	2.59	3.00	0.25	0.51	0.36	0.56	1.50	1.75	2.79	3.00	0.89	1.45	0.950	5
SOT-23-6	332	2.59	3.00	0.25	0.51	0.36	0.56	1.50	1.75	2.79	3.00	0.89	1.45	0.950	6
SOT-23-8	348	2.60	3.00	0.28	0.46	0.10	0.61	1.50	1.75	2.80	3.00	0.90	1.45	0.650	8
MSOP-8	337	4.80	5.00	0.28	0.38	0.46	0.66	2.90	3.10	2.90	3.10	0.81	1.22	0.650	8
SSOP-20	334	7.39	8.20	0.23	0.38	0.56	0.94	5.00	5.59	6.91	7.49	1.96	2.01	0.650	20
SSOP-24	338	7.39	8.20	0.23	0.38	0.56	0.94	5.00	5.59	7.90	8.51	1.96	2.01	0.650	24
SSOP-28	324	7.39	8.20	0.23	0.38	0.56	0.94	5.00	5.59	9.91	10.49	1.96	2.01	0.650	28
SSOP-16	322	5.79	6.20	0.20	0.30	0.41	1.27	3.78	3.99	4.78	5.00	1.35	1.75	0.635	16
SSOP-48	333	10.03	10.67	0.20	0.33	0.51	1.02	7.39	7.59	15.57	16.00	1.35	1.75	0.635	48
SSOP-56	346	10.03	10.67	0.20	0.33	0.51	1.02	7.39	7.59	18.29	18.54	2.41	2.79	0.635	56

TABLE III. Package Dimensions—Millimeters.

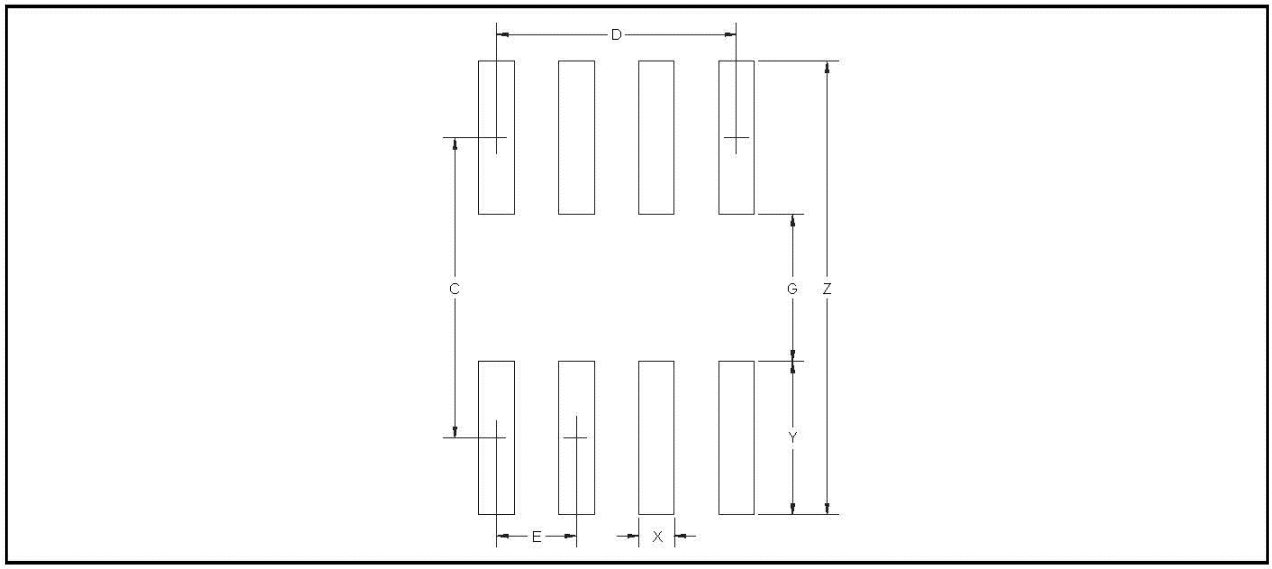


FIGURE 4. Pad Dimensions.

PACKAGE	PKG #	Z MIN	Z MAX	G MIN	G MAX	X MIN	X MAX	Y REF	C/C REF	D REF	E NOM
SO-8	182	0.273	0.277	0.089	0.093	0.018	0.022	0.094	0.183	0.150	0.0500
SO-14	235	0.273	0.277	0.089	0.093	0.018	0.022	0.094	0.183	0.300	0.0500
SO-16	265	0.273	0.277	0.089	0.093	0.018	0.022	0.094	0.183	0.350	0.0500
SO-16W	211	0.447	0.451	0.254	0.258	0.018	0.022	0.099	0.353	0.350	0.0500
SO-18W	219	0.447	0.451	0.254	0.258	0.018	0.022	0.099	0.353	0.400	0.0500
SO-20W	221	0.447	0.451	0.254	0.258	0.018	0.022	0.099	0.353	0.450	0.0500
SO-24W	239	0.447	0.451	0.254	0.258	0.018	0.022	0.099	0.353	0.550	0.0500
SO-28W	217	0.448	0.451	0.278	0.282	0.018	0.022	0.099	0.365	0.650	0.0500
SOT-23-5	331	0.147	0.151	0.034	0.038	0.017	0.021	0.058	0.093	0.075	0.0374
SOT-23-6	332	0.147	0.151	0.034	0.038	0.017	0.021	0.058	0.093	0.075	0.0374
SOT-23-8	348	0.147	0.151	0.015	0.019	0.016	0.020	0.068	0.083	0.077	0.0256
MSOP-8	337	0.226	0.230	0.097	0.101	0.014	0.018	0.066	0.164	0.077	0.0256
SSOP-20	334	0.351	0.355	0.177	0.181	0.013	0.017	0.089	0.266	0.230	0.0256
SSOP-24	338	0.351	0.355	0.177	0.181	0.013	0.017	0.089	0.266	0.281	0.0256
SSOP-28	324	0.351	0.355	0.177	0.181	0.013	0.017	0.089	0.266	0.333	0.0256
SSOP-16	322	0.273	0.277	0.089	0.093	0.011	0.015	0.094	0.183	0.175	0.0250
SSOP-48	333	0.448	0.452	0.275	0.279	0.012	0.016	0.089	0.364	0.575	0.0250
SSOP-56	346	0.448	0.452	0.275	0.279	0.012	0.016	0.089	0.364	0.675	0.0250

TABLE IV. Pad Dimensions—Inches.

PACKAGE	PKG #	Z MIN	Z MAX	G MIN	G MAX	X MIN	X MAX	Y REF	C/C REF	D REF	E NOM
SO-8	182	6.934	7.036	2.261	2.362	0.457	0.559	2.388	4.648	3.810	1.270
SO-14	235	6.934	7.036	2.261	2.362	0.457	0.559	2.388	4.648	7.620	1.270
SO-16	265	6.934	7.036	2.261	2.362	0.457	0.559	2.388	4.648	8.890	1.270
SO-16W	211	11.354	11.455	6.452	6.553	0.457	0.559	2.515	8.966	8.890	1.270
SO-18W	219	11.354	11.455	6.452	6.553	0.457	0.559	2.515	8.966	10.160	1.270
SO-20W	221	11.354	11.455	6.452	6.553	0.457	0.559	2.515	8.966	11.430	1.270
SO-24W	239	11.354	11.455	6.452	6.553	0.457	0.559	2.515	8.966	13.970	1.270
SO-28W	217	11.379	11.468	7.061	7.163	0.457	0.559	2.515	9.271	16.510	1.270
SOT-23-5	331	3.734	3.835	0.864	0.965	0.432	0.533	1.473	2.362	1.905	0.950
SOT-23-6	332	3.734	3.835	0.864	0.965	0.432	0.533	1.473	2.362	1.905	0.950
SOT-23-8	348	3.734	3.835	0.381	0.483	0.406	0.508	1.727	2.108	1.950	0.650
MSOP-8	337	5.740	5.842	2.464	2.565	0.356	0.457	1.676	4.166	1.950	0.650
SSOP-20	334	8.915	9.017	4.496	4.597	0.330	0.432	2.261	6.756	5.842	0.650
SSOP-24	338	8.915	9.017	4.496	4.597	0.330	0.432	2.261	6.756	7.137	0.650
SSOP-28	324	8.915	9.017	4.496	4.597	0.330	0.432	2.261	6.756	8.458	0.650
SSOP-16	322	6.934	7.036	2.261	2.362	0.279	0.373	2.388	4.648	4.445	0.635
SSOP-48	333	11.379	11.481	6.985	7.087	0.305	0.406	2.261	9.246	14.605	0.635
SSOP-56	346	11.379	11.481	6.985	7.087	0.305	0.406	2.261	9.246	17.145	0.635

TABLE V . Pad Dimensions—Millimeters.

IC SMD packages

BGA - Ball Grid Array. Pads are underneath the package. The ball spacing on BGAs is typically 1.27 mm.

CQFP - Ceramic Quad Flat Pack. A ceramic version of the PQFP.

LQFP - Low profile Quad Flat Pack. This package has pins on all four sides. Pin spacing varies according to the IC, but the height is 1.4 mm.

PLCC - Plastic Leaded Chip Carrier. This type of package is square and uses J-lead pins with a spacing of 1.27 mm

PQFP - Plastic Quad Flat Pack. A square plastic package with equal number of gull wing style pins on each side. Typically narrow spacing and often 44 or more pins. Normally used for VLSI circuits.

QSOP - Quarter-size Small Outline Package. It has a pin spacing of 0.635 mm

SOIC - Small Outline Integrated Circuit. This has a dual in line configuration and gull wing leads with a pin spacing of 1.27 mm

SSOP - Shrink Small Outline Package. This has a pin spacing of 0.635 mm

TQFP - Thin Quad Flat Pack. A thin version of the PQFP.

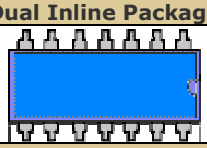
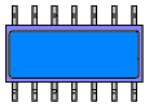
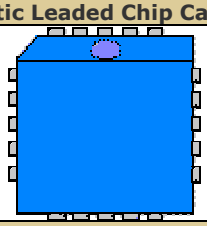
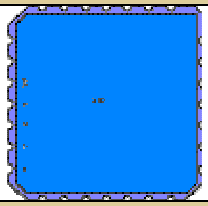
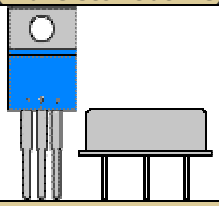
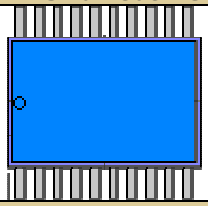
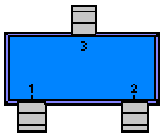
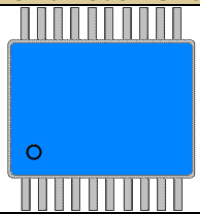
TSOP - Thin Small Outline Package. This package is thinner than the SOIC and has a smaller pin spacing of 0.5 mm

TSSOP - Thin Shrink Small Outline Package.

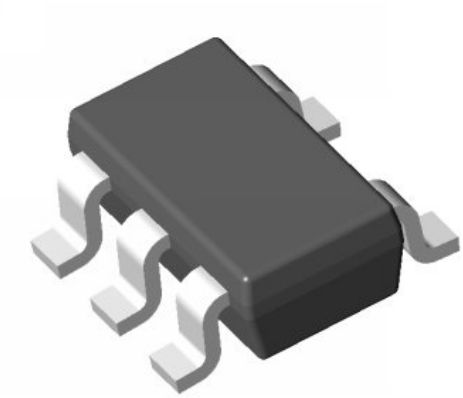
VSOP - Very Small Outline Package. This is smaller than the QSOP and has pin spacing of 0.4, 0.5, or 0.65 mm.

TABLE 2—TINY-IC DIMENSIONS

Package designation and pin count	Nominal body size (L×W×H) (mm)	Total footprint (L×W) (mm)	Lead pitch (mm)
DIP-8	10×6×5	5×7.5	2.54 (0.1 in.)
SO-8	5×4×1.75	5×6	1.27 (0.05 in.)
SSOP-8	3×5.3×2	3×8	0.65
TSSOP-8	3×4.4×1.2	3×6.4	0.65
MSOP-8	3×3×1.1	3×5	0.65
TVSOP-14	3.6×4.4×1.2	3×6.4	0.4
QSOP-16	4.9×3.9×1.7	4.9×6	0.635 (0.025 in.)
SOT23-5	3×1.6×1	3×3	0.95

DIP (Dual Inline Package)	SOIC (Small Outline Integrated Circuit)
	
PLCC **(Plastic Leaded Chip Carrier)**	**LCC**
	
TO **(Transistor Outline)**	**TSSOP** **(Thin Shrink Small Outline Package)**
	
SOT **(Small Outline Transistor)**	**SSOP** **(Shrink Small Outline Package)**
	

SOT



Three terminal packages

- SOT-23 (SC-59, TO-236-3): 2.9 mm × 1.3/1.75 mm × 1.3 mm body: three terminals for a transistor [23]
- SOT-89: 4.5 mm × 2.5 mm × 1.5 mm body: four terminals, center pin large heat-transfer pad [22]
- SOT-223: 6.7 mm × 3.7 mm × 1.8 mm body: four terminals, one of which is a large heat-transfer pad [21]
- SOT-323 (SC-70): 2 mm × 1.25 mm × 0.95 mm body: three terminals [24]
- SOT-416 (SC-75): 1.6 mm × 0.8 mm × 0.8 mm body: three terminals [25]
- SOT-663: 1.6 mm × 1.6 mm × 0.55 mm body: three terminals [26]
- SOT-723: 1.2 mm × 0.8 mm × 0.5 mm body: three terminals: flat lead[27]
- SOT-883 (SC-101): 1 mm × 0.6 mm × 0.5 mm body: three terminals: leadless [28]

Five & six terminal packages

- SOT-23-5 (SOT-25): 2.9 mm × 1.3/1.75 mm × 1.3 mm body: five terminals [32]
- SOT-23-6 (SOT-26): 2.9 mm × 1.3/1.75 mm × 1.3 mm body: six terminals [33]
- SOT-23-8 (SOT-28): 2.9 mm × 1.3/1.75 mm × 1.3 mm body: eight terminals [34]
- SOT-353 (SC-88A): 2 mm × 1.25 mm × 0.95 mm body: five terminals [35]
- SOT-363 (SC-88, SC-70-6): 2 mm × 1.25 mm × 0.95 mm body: six terminals [36]
- SOT-563: 1.6 mm × 1.2 mm × 0.6 mm body: six terminals [37]
- SOT-665: 1.6 mm × 1.6 mm × 0.55 mm body: six terminals [38]
- SOT-666: 1.6 mm × 1.6 mm × 0.55 mm body: six terminals [39]
- SOT-886: 1.5 mm × 1.05 mm × 0.5 mm body: six terminals: leadless
- SOT-891: 1.05 mm × 1.05 mm × 0.5 mm body: five terminals: leadless
- SOT-953: 1 mm × 1 mm × 0.5 mm body: five terminals
- SOT-963: 1 mm × 1 mm × 0.5 mm body: six terminals

Common conversions

1 millimeter	=	0.0394 inch
1 centimeter	=	0.394 inch
1 inch	=	25.4 mm
1/100	=	0.25 mm
1/64	=	0.39 mm
1/32 inch	=	0.79 mm
1/16 inch	=	1.58 mm
3/32 inch	=	2.30 mm
1/8 inch	=	3.17 mm
1/4 inch	=	6.35 mm
1/2 inch	=	12.7 mm

PCB Fabrication Prices

By: Jan Zumwalt
TurboCube.com
2012-04-18

Service Provider	2 layer 3" x 3" board (75mm x 75mm)				2 layer, 6" x 6" board (150mm x 150mm)			
Ranking	**2**	**10**	**25**	**50**	**2**	**10**	**25**	**50**
[1] ourpcb.com *	$41.50	$ 9.50	$ 4.60	$ 3.00	$56.00	$14.75	$ 9.25	$ 5.50
[2] pcbcart.com *	$51.50	$12.00	$ 4.25	$ 3.50	$70.00	$18.00	$ 9.50	$ 7.00
[3] pcbfabrication.com *	$51.00	$13.00	$ 6.00	$ 4.00	$65.00	$18.00	$10.25	$ 8.00
[4] quickturnpcb.co.kr	$41.00	$ 8.50	$ 5.25	$ 4.00	$54.00	$16.75	$?	$?
[5] custompcb.com	$36.00	$12.00	$ 6.00	$ 4.00	$64.00	$17.75	$10.00	$ 7.25
[6] goldphoenixpcb.biz1	$45.00	$ 9.00	$ 6.00	$ 5.50	$45.00	$21.70	$21.75	$21.75
[7] futurlec.com	$37.00	$12.00	$ 8.50	$ 6.00	$54.00	$29.50	$25.75	$20.00
[8] pad2pad.com	$32.00	$10.00	$ 9.25	$ 9.25	$62.50	$33.00	$33.00	$33.00
[9] pcb-pool.com	$55.00	$18.50	$12.25	$ 7.00	$94.00	$38.50	$26.25	$15.00
[10] pcbexpress.com	$48.00	$17.75	$13.00	$11.00	$95.00	$31.25	$22.25	$18.25
[11] pcbontime.com	$75.00	$25.00	$15.00	$ 4.00	$100.00	$30.00	$17.50	$ 6.75
[12] expresspcb.com	$120.00	$26.50	$12.25	$ 7.75	$125.00	$33.75	$19.50	$15.00
[13] pcbnet.com	$125.00	$30.00	$13.00	$ 7.00	$125.00	$31.00	$15.50	$10.00
[14] pcb123.com	$122.00	$28.00	$14.00	$ 9.00	$130.00	$35.00	$22.50	$17.50
[15] my4pcb.com	$130.00	$31.00	$14.00	$ 7.50	$152.00	$37.00	$17.50	$11.75
[16] batchpcb.com *	$22.50	$22.50	$22.50	$22.75	$ 90.00	$90.00	$90.00	$90.00
[17] iteadstudio.com *	$12.50	$2.50	$2.50	$2.50	$ -----	$ -----	$ -----	$ -----

Note: Amounts are total price for ***each*** board, but does ***not*** included shipping.
Prices extrapolated from fabricators' Internet site on January 1, 2010

Table – 1
Price Matrix

* updated 4/2012 (all others 1/1/2010)

Small orders http://iteadstudio.com/store/ 2"x2" 10ea $10, 4"x4" 10ea $25

Thickness:	0.060 – 0.065” = (60 mil) = (1.25 mm)
Min. Tracing/Spacing:	0.008” = (8 mil) = (0.20 mm)
Smallest hole:	0.016” = (16 mil) = (0.40 mm)
Layout:	single (no multiple layouts per panels)
Lead Time:	most economical
Material:	FR4 economy
File format:	gerber
Surface mount:	1 side
Solder mask:	1 side
Silkscreen:	1 side
Max Holes:	200
Copper wt:	1oz
Testing:	no
Layers:	2
Slots:	0

Listing-1
Generic Board Specifications

It’s not very long before the reader of *Nuts & Volts* will want to try their hand at making a printed circuit board. Soon, we will be forced to decide whether to attempt some type of home brew circuit board process or have a professional PCB fabricator do the task for us.

Often the decision to make a home cooked printed circuit is muddled by the need for small size or surface mount technology parts which require precise traces. We must also face the tradeoff in design and production time, against risk of failure and having to make repeated attempts. For myself, I am quickly acquiring onlookers that respect my projects and desire to use many of my circuits. Friends may be more willing to assist in the cost of a homebrew project if the end result looks professional.

For a number of years I have taken notice of several companies that manufactured and sell small boards at very reasonable prices. Olimex (olimex.com) and ETT (etteam.com) are good examples. The PCB fabricators I have been using don’t even come close to the cost that these folks must be using. ETT provides many small boards that retailers are re-selling for around $3 or $4 dollars. Nobody is complaining, and everybody seems to be making money. How are these high quality boards being made at such low prices? Is there some way you and I can get professional results for just a dollar or two?

I spent four days on an Internet research quest and was very surprised at the results (see table-1). I would like to share with you what I found. The cost estimates I am providing have been rounded up to the nearest 25¢. Price rounding increases readability and makes allowance for a little bit of inflation. I believe you will find these prices accurate and useful for at least a year.

Early on I set a goal to try to get a real world “apples” to “apples” comparison. I wanted to be able to judge legitimate pricing trends (I was not really interested in a specific project). This guide is meant to lead us towards low cost PCB fabrication with professional quality. Achieving this turned out to be easier said then done! I had to consider what the typical needs of an average electronic hobbyist might be (if an average exists!). I eventually broke PCB fabrication needs into four major criteria – (1) quantity of boards, (2) board size, (3) number of layers, and (4) typical specifications.

The production quantity that a hobbyist is probably going to need is *one* to *five* circuit boards. However, I also had a personal curiosity about larger production runs. When I spot checked several PCB fabricator’s internet sites, I noticed many did not provide pricing for *one-hundred* or more parts and the pricing seemed to flatten out well before that. Realistically, not very many hobbyists would be laying down the cash needed for a run of *one-hundred* or more boards. Besides, *one-hundred* or more boards is no longer a hobby, it’s a business! I whimsically gazed heavenward, in a rather arbitrarily fashion I picked quantities of *two* and *ten* for *proof of concept* designs, then *twenty-five* and *fifty* for *small production* runs.

What would be an appropriate board size? Admittedly the hobbyist is apt to have very specific needs. We would be wise to eliminate the very small (2” x 2” or smaller) boards. There is a well established niche market that adequately provides for very small boards in quantities of *one* or *two*. Small low quantity boards also do not typically jeopardize significant sums of money. At the other extreme, most PCB fabricator’s production equipment is limited to a maximum board size of about *ten* to *fifteen* inches in the largest dimension, so that narrows the upper size. I pulled from my past experience and chose *two* representative board sizes: 3” x 3” and 6” x 6” form factors.

How many layers would be typical? I think we would agree that many *single* layer boards are apt to be prototyped in an experimenter’s home. *Three* or *four* layer boards are certainly interesting but would add considerably overhead to the data to be acquired and sifted thru. So, I chose to stay with *two* layer boards and was hopeful that we could use a little interpolation to give ball park trends for other needs.

Choosing the specifications was much simpler than I thought it might otherwise be. Many PCB fabricators have (from their own experience) determined what the public is interested in. They frequently advertize “economy” services that are targeted for mass customer appeal. All that was needed, was to document the commonality of these offers. The solution pretty much managed itself (see listing-1).

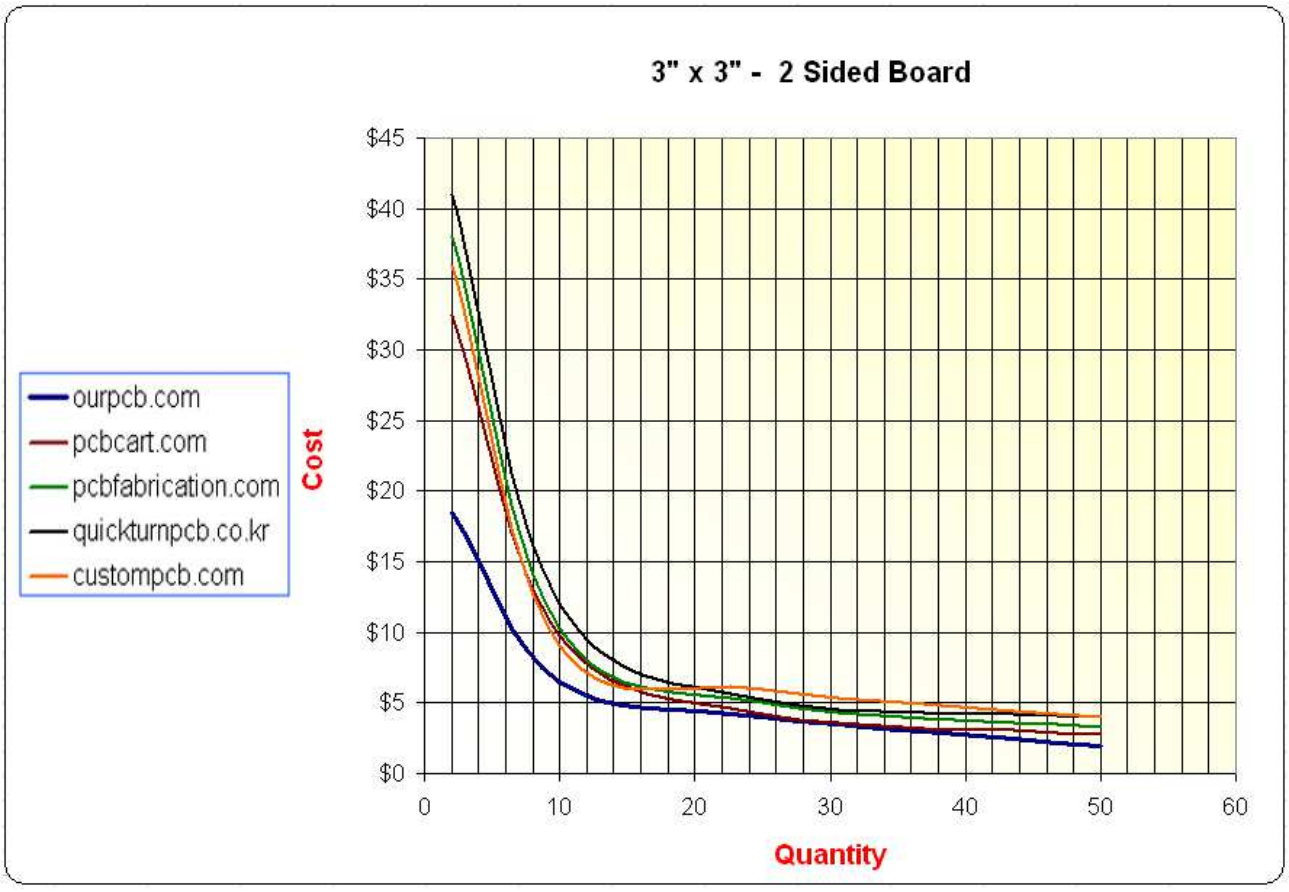


Chart-1
Five Lowest Price Fabricators

Are there any important observations from this data? Positively, *YES!* The first thing that struck me was the conspicuous absence of many vendors that I had been using. Most the fabricators I had used did not even qualify to be on this list! I would have expected the major players to fall within 10%-15% of the lowest prices, but that was certainly not the case. Some fabricators best price is *two* to *five* times higher than other competitors. Chart-1 shows the pricing for the five best quotes from Table-1. Some carful shopping is certainly going to be

prudent. Some vendors literally offer *two* boards for the same price that another vendor will make *ten*! Notice that Table-1 shows we could order ***fifty*** 6”x6” boards from some fabricators for the same price as ***two*** 3”x3” boards from others. Which would you rather have?

It should be pointed out that some fabricators do not offer “economy” pricing. They may automatically include many other desirable options. For example, some insist on testing and/or minimum quantity orders of *three* or *four* boards. There are several vendors that provide two sided solder masks and double silk screening at no additional charge. There may be some fabricators that have lower prices but do not have internet quote systems so they were not researched. Several fabricators offer *first* or *second* time return customers up to 80% discounts and these provisions are not considered in this report.

No attempt was made to compare quality, consistency, lead time, on time delivery, location and accessibility, customer service, problem resolution, shipping, nor combining multiple circuits on panels. These other considerations are certainly worth adjustments to the value that someone is receiving. Still, I hope this helps. As for me, I will soon be trying some new *discount* PCB fabricators. Maybe we can all start sharing our discounted projects and circuits right here in *Nuts & Volts!*

Earth Friendly PCB Etchant

This process works in two ways, when copper is added to hydrochloric (muriatic) acid and hydrogen peroxide it creates *copper chloride2*. The *copper chloride2* turns into *cupric chloride2,* which when exhausted becomes plain *cupric chloride*. That's right, the copper added to the solution forms a chemical that also acts as a copper etchant!

WARNING: When adding these ingredients, remember to always add the ACID to the peroxide, not the other way. Always use a well ventilated area and wear goggles and gloves.

step 1 Ingredients:

Hydrochloric (muriatic acid, "pool acid", etc.) is available at a hardware store. The most commonly available acid is 31.45% (or 10M) and should run around $5 per gallon.
The peroxide available in a drug store is for mouthwash or cleaning cuts is normally 3% and can be purchased for $2-3 for a big bottle.

You'll also need a non-metallic container that fits your PCB and two standardized measuring cups.

step 2 Mix the chemicals:

*WARNING: When adding these ingredients, remember to always **add the ACID to the peroxide,** not the other way.*

For 30% acid and 3% peroxide, the chemicals may be mixed from 1:1 to 3:1. I suggest a 2:1 mix. Add 2 parts hydrogen peroxide into a non-metallic container, and then *SLOWLY* pour in 1 part hydrochloric (muriatic acid).

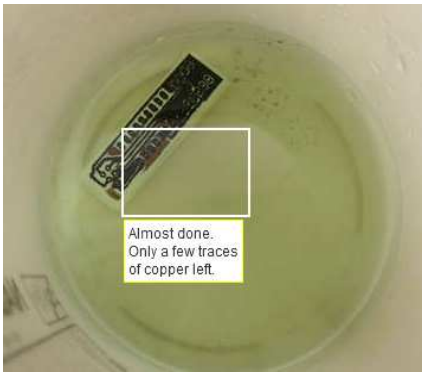
Be careful with the acid. This stuff is strong and will fume a bit. It should not be directly breathed. Have good ventilation such as an open door or window.

The starter etchant you've just made, on the other hand, is not so bad -- around 3M HCl with a medium-strong oxidizer. I find it doesn't fume much at room temperature when I'm re-using a batch.

You've also got to be very careful to keep it away from metal -- especially your stainless-steel kitchen sink. It'll eat the stainless coating right off. Keep plenty of water flowing at all times when you've got any of this (even a drop) near the sink.

You can make quite a bit of this stuff very easily, and since you're re-using it, there's no real reason to skimp; put plenty of etchant in your "tank."

step 3 Add PCB and you're Etching:



Toss the PCB into the solution and it'll take off.

Etching is super fast! Boards 2”x2” or larger will take 2-3minutes. Smaller boards will act faster. A little water can be added to slow down the process.

Also, note how the etchant gets greener over time as it eats away the copper. What's happening is that you're dissolving the copper from the board and turning it into cupric chloride. In the long-run, the cupric chloride will be doing most of the etching (instead of requiring disposal). For now, just watch your solution turn light green. Next time you use it, the color will deepen.
Once you're done etching, pour the etchant back into your storage bottle, rinse off the board, flux, drill, populate, and solder.

Step 4 Chemistry Break:

Before there's much copper dissolved in the solution, Cu + 2 HCl + H2O2 -> CuCl2+ 2H2O is the dominant net reaction. That is, the extra oxygen in the peroxide is oxidizing the copper metal, in the presence of the acid, to make *copper chloride2*. That's our starter etchant. The resulting CuCl2 should be a nice emerald green color.

After you've dissolved a lot of copper into the solution, and used up all the peroxide, the *cupric chloride2* does most of the etching for you: CuCl2 + Cu -> 2 CuCl. When in the presence of copper the *cupric chloride2 turns to plain* 2*cupric chloride*. 2*Cupric chloride* doesn't dissolve copper (and is a yucky brown color).

Step 5 Replenishing:

Two things are needed for the solution to work, *cupric chloride2 (*CuCl2) and acid (HCl).

CuCl2: After all the peroxide is used up, and the solution starts turning brownish, you'll can add oxygen to regenerate the solution. It's impossible to add too much oxygen. You can add a few capfuls of peroxide, bubble air through the solution, swirl it around vigorously, or pour it into an open container and wait. It's easy to tell when you're ready to etch again, because the solution turns *emerald green*.

If you're using peroxide to add oxygen, be sparing -- a little goes a long way, and it's mostly water so you're diluting your etchant by adding it.

Acid: Note that HCl is being consumed in the starter etchant and the regeneration reactions. So we're going to have to add a bit more acid as time goes by. If you notice that it's harder to re-green your brown etchant, it's probably time to start thinking acid.
If you've got too much volume of etchant (it will happen eventually) you can evaporate out the extra water by putting it in a shallow (non-metallic) pan or beaker or whatever and letting it sit for a while. This concentrates the copper in solution, giving you a stronger etchant.

Inch to Metric Conversion

INCHES		METRIC	INCHES		METRIC	INCHES		METRIC
FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm	FRACTIONAL	DECIMAL	mm
.	0.0039	0.1000	.	0.5512	14.0000	.	1.8898	48.0000
.	0.0079	0.2000	9/16	0.5625	14.2875	.	1.9291	49.0000
.	0.0118	0.3000	.	0.5709	14.5000	.	1.9685	50.0000
1/64	0.0156	0.3969	37/64	0.5781	14.6844	2	2.0000	50.8000
.	0.0157	0.4000	.	0.5906	15.0000	.	2.0079	51.0000
.	0.0197	0.5000	19/32	0.5938	15.0813	.	2.0472	52.0000
.	0.0236	0.6000	39/64	0.6094	15.4781	.	2.0866	53.0000
.	0.0276	0.7000	.	0.6102	15.5000	.	2.1260	54.0000
1/32	0.0313	0.7938	5/8	0.6250	15.8750	.	2.1654	55.0000
.	0.0315	0.8000	.	0.6299	16.0000	.	2.2047	56.0000
.	0.0354	0.9000	41/64	0.6406	16.2719	.	2.2441	57.0000
.	0.0394	1.0000	.	0.6496	16.5000	2 1/4	2.2500	57.1500
.	0.0433	1.1000	21/32	0.6563	16.6688	.	2.2835	58.0000
3/64	0.0469	1.1906	.	0.6693	17.0000	.	2.3228	59.0000
.	0.0472	1.2000	43/64	0.6719	17.0656	.	2.3622	60.0000
.	0.0512	1.3000	11/16	0.6875	17.4625	.	2.4016	61.0000
.	0.0551	1.4000	.	0.6890	17.5000	.	2.4409	62.0000
.	0.0591	1.5000	45/64	0.7031	17.8594	.	2.4803	63.0000
1/16	0.0625	1.5875	.	0.7087	18.0000	2 1/2	2.5000	63.5000
.	0.0630	1.6000	23/32	0.7188	18.2563	.	2.5197	64.0000
.	0.0669	1.7000	.	0.7283	18.5000	.	2.5591	65.0000
.	0.0709	1.8000	47/64	0.7344	18.6531	.	2.5984	66.0000
.	0.0748	1.9000	.	0.7480	19.0000	.	2.6378	67.0000
5/64	0.0781	1.9844	3/4	0.7500	19.0500	.	2.6772	68.0000
.	0.0787	2.0000	49/64	0.7656	19.4469	.	2.7165	69.0000
.	0.0827	2.1000	.	0.7677	19.5000	2 3/4	2.7500	69.8500
.	0.0866	2.2000	25/32	0.7813	19.8438	.	2.7559	70.0000
.	0.0906	2.3000	.	0.7874	20.0000	.	2.7953	71.0000
3/32	0.0938	2.3813	51/64	0.7969	20.2406	.	2.8346	72.0000
.	0.0945	2.4000	.	0.8071	20.5000	.	2.8740	73.0000
.	0.0984	2.5000	13/16	0.8125	20.6375	.	2.9134	74.0000
7/64	0.1094	2.7781	.	0.8268	21.0000	.	2.9528	75.0000
.	0.1181	3.0000	53/64	0.8281	21.0344	.	2.9921	76.0000
1/8	0.1250	3.1750	27/32	0.8438	21.4313	3	3.0000	76.2000
.	0.1378	3.5000	.	0.8465	21.5000	.	3.0315	77.0000
9/64	0.1406	3.5719	55/64	0.8594	21.8281	.	3.0709	78.0000
5/32	0.1563	3.9688	.	0.8661	22.0000	.	3.1102	79.0000
.	0.1575	4.0000	7/8	0.8750	22.2250	.	3.1496	80.0000
11/64	0.1719	4.3656	.	0.8858	22.5000	.	3.1890	81.0000

.	0.1772	4.5000	57/64	0.8906	22.6219	.	3.2283	82.0000
3/16	0.1875	4.7625	.	0.9055	23.0000	.	3.2677	83.0000
.	0.1969	5.0000	29/32	0.9063	23.0188	.	3.3071	84.0000
13/64	0.2031	5.1594	59/64	0.9219	23.4156	.	3.3465	85.0000
.	0.2165	5.5000	.	0.9252	23.5000	.	3.3858	86.0000
7/32	0.2188	5.5563	15/16	0.9375	23.8125	.	3.4252	87.0000
15/64	0.2344	5.9531	.	0.9449	24.0000	.	3.4646	88.0000
.	0.2362	6.0000	61/64	0.9531	24.2094	3 1/2	3.5000	88.9000
1/4	0.2500	6.3500	.	0.9646	24.5000	.	3.5039	89.0000
.	0.2559	6.5000	31/32	0.9688	24.6063	.	3.5433	90.0000
17/64	0.2656	6.7469	.	0.9843	25.0000	.	3.5827	91.0000
.	0.2756	7.0000	63/64	0.9844	25.0031	.	3.6220	92.0000
9/32	0.2813	7.1438	1	1.0000	25.4000	.	3.6614	93.0000
.	0.2953	7.5000	.	1.0039	25.5000	.	3.7008	94.0000
19/64	0.2969	7.5406	.	1.0236	26.0000	.	3.7402	95.0000
5/16	0.3125	7.9375	.	1.0433	26.5000	.	3.7795	96.0000
.	0.3150	8.0000	.	1.0630	27.0000	.	3.8189	97.0000
21/64	0.3281	8.3344	.	1.0827	27.5000	.	3.8583	98.0000
.	0.3346	8.5000	.	1.1024	28.0000	.	3.8976	99.0000
11/32	0.3438	8.7313	.	1.1220	28.5000	.	3.9370	100.0000
.	0.3543	9.0000	.	1.1417	29.0000	4	4.0000	101.6000
23/64	0.3594	9.1281	.	1.1614	29.5000	.	4.3307	110.0000
.	0.3740	9.5000	.	1.1811	30.0000	4 1/2	4.5000	114.3000
3/8	0.3750	9.5250	.	1.2205	31.0000	.	4.7244	120.0000
25/64	0.3906	9.9219	1 1/4	1.2500	31.7500	5	5.0000	127.0000
.	0.3937	10.0000	.	1.2598	32.0000	.	5.1181	130.0000
13/32	0.4063	10.3188	.	1.2992	33.0000	.	5.5118	140.0000
.	0.4134	10.5000	.	1.3386	34.0000	.	5.9055	150.0000
27/64	0.4219	10.7156	.	1.3780	35.0000	6	6.0000	152.4000
.	0.4331	11.0000	.	1.4173	36.0000	.	6.2992	160.0000
7/16	0.4375	11.1125	.	1.4567	37.0000	.	6.6929	170.0000
.	0.4528	11.5000	.	1.4961	38.0000	.	7.0866	180.0000
29/64	0.4531	11.5094	1 1/2	1.5000	38.1000	.	7.4803	190.0000
15/32	0.4688	11.9063	.	1.5354	39.0000	.	7.8740	200.0000
.	0.4724	12.0000	.	1.5748	40.0000	8	8.0000	203.2000
31/64	0.4844	12.3031	.	1.6142	41.0000	.	9.8425	250.0000
.	0.4921	12.5000	.	1.6535	42.0000	10	10.0000	254.0000
1/2	0.5000	12.7000	.	1.6929	43.0000	20	20.0000	508.0000
.	0.5118	13.0000	.	1.7323	44.0000	30	30.0000	762.0000
33/64	0.5156	13.0969	1 3/4	1.7500	44.4500	40	40.0000	1016.0000
17/32	0.5313	13.4938	.	1.7717	45.0000	60	60.0000	1524.0000
.	0.5315	13.5000	.	1.8110	46.0000	80	80.0000	2032.0000
35/64	0.5469	13.8906	.	1.8504	47.0000	100	100.0000	2540.0000

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Tutorials

http://alternatezone.com/electronics/pcbdesign.htm

http://www.delorie.com/pcb/docs/gs/gs.html

http://www.ladyada.net/library/pcb/tutorials.html

References

Common electric symbols http://en.wikipedia.org/wiki/Electronic_symbol

http://www.pcb.electrosoft-engineering.com/04-articles-custom-system-design-and-pcb/electrosoft-engineering-articles.html

Free PCB Design Software

http://opencircuitdesign.com/pcb/

http://www.designspark.com/

http://iut-tice.ujf-grenoble.fr/kicad/