

Tolerances

HOLE TOLERANCES

Feature	Tolerance
Hole Diameter	+/- 0.005 in. (0.127mm)
Hardware Hole Diameter	+0.003 in./-0.000 in. (0.0762mm/-0.000mm)
Cut Countersink Major Diameter	+/-0.010 in. (0.254mm)
Cut Countersink Minor Diameter	+/-0.010 in. (0.254mm)
Formed Countersink Major Diameter	+/- 0.015 in. (0.381mm)
Formed Countersink Minor Diameter	+/- 0.015 in. (0.381mm)
Counterboring & Spotfacing 0.063 in. to 0.250 in.	+0.010 in./-0.005 in. (0.254mm/0.127mm)
Counterboring & Spotfacing 0.251 in. to 0.500 in.	+0.015 in./-0.005 in. (0.381mm/0.127mm)
Counterboring & Spotfacing >0.500 in.	+0.020 in./-0.005 in. (0.508mm/0.127mm)

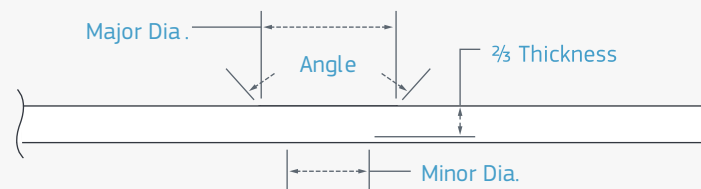


Figure 1: Punch Press Formed Countersinks 2/3 Rule (This rule minimizes material displacement distortion.)

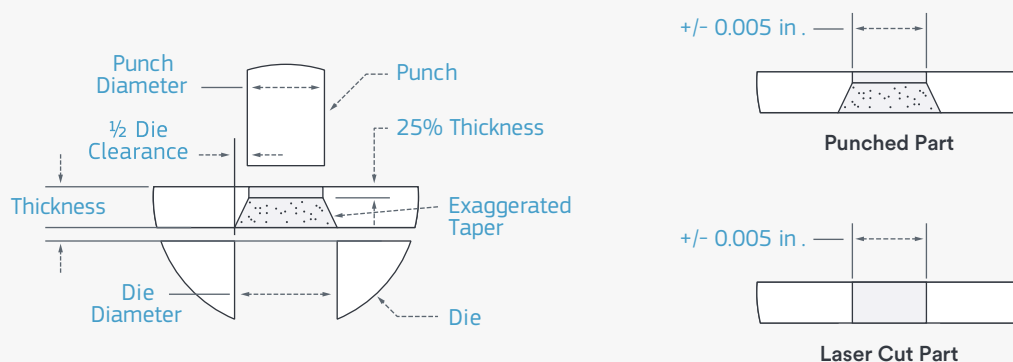


Figure 2: Punched Hole vs. Laser Cut Hole

TOLERANCES ON ONE SURFACE

Feature	Tolerance +/-	Dimension
Edge to Edge	0.005 in. (0.127mm)	A
Edge to Hole	0.005 in. (0.127mm)	B
Hole to Hole	0.005 in. (0.127mm)	C
Hole to Hardware*	0.010 in. (0.254mm)	D
Edge to Hardware*	0.010 in. (0.254mm)	E
Hardware to Hardware*	0.015 in. (0.381mm)	F
Bend to Hole	0.015 in. (0.381mm)	G
Bend to Hardware*	0.015 in. (0.381mm)	H
Bend to Edge	0.010 in. (0.254mm)	I
Bend to Bend	0.015 in. (0.381mm)	J

*Hardware includes studs, nuts, standoffs, or any other self-fastening product

TOLERANCES ON MORE THAN ONE SURFACE

Feature	Tolerance +/-	Dimension
Bend to Bend (2 bends)	0.015 in. (0.381mm)	A
Bend to Bend (3 or more)	0.030 in.* (0.762mm)	B
Edge to Hole (2 bends)	0.015 in. (0.381mm)	C
Bend to Hole (2 bends)	0.030 in.* (0.762mm)	D
Bend to Hole (3 or more bends)	0.030 in.* (0.762mm)	E
Hole to Formed Feature	0.010 in. (0.254mm)	F
Hole to Formed Feature (2 or more bends)	0.030 in.* (0.762mm)	G
Edge to Formed Feature	0.010 in. (0.254mm)	H
Edge to Formed Feature (2 or more bends)	0.030 in.* (0.762mm)	I
Hole to Hole (2 or more bends)	0.020 in.* (0.254mm)	J
Edge to Edge (2 or more bends)	0.030 in.* (0.762mm)	K
Edge to Bend (more than 1 bend)	0.030 in.* (0.762mm)	L

*Non-cumulative

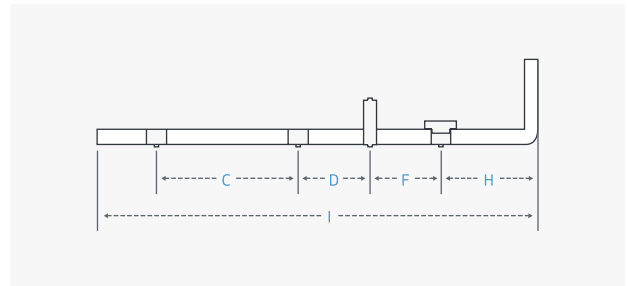


Figure 3: Tolerances on one surface

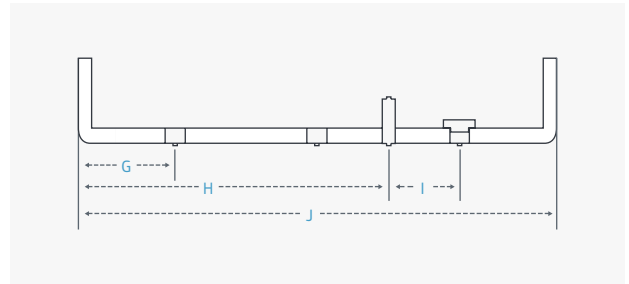


Figure 4: Tolerances on one surface

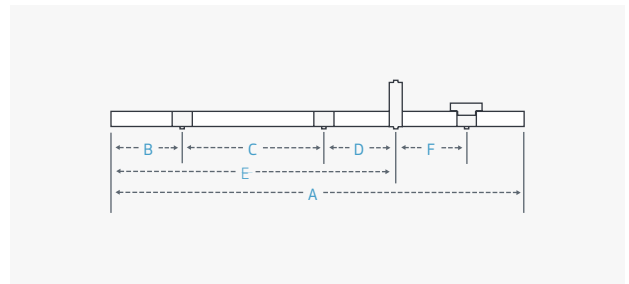


Figure 5: Tolerances on one surface

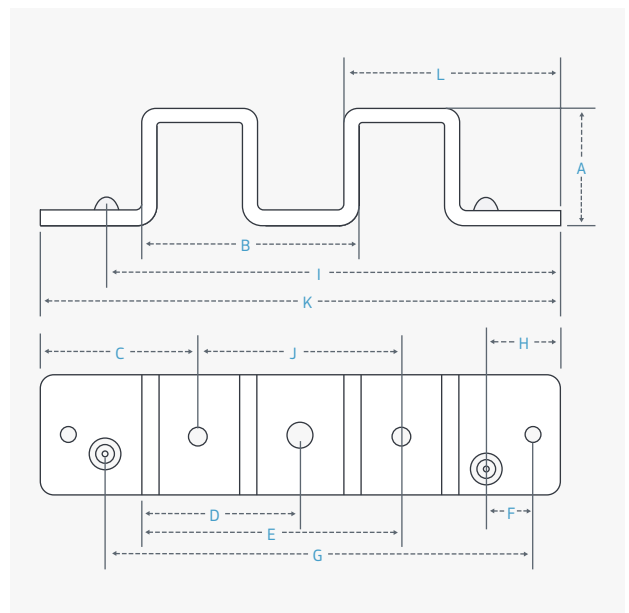
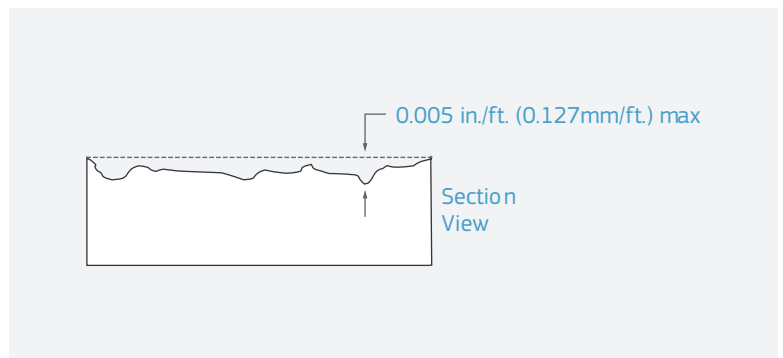
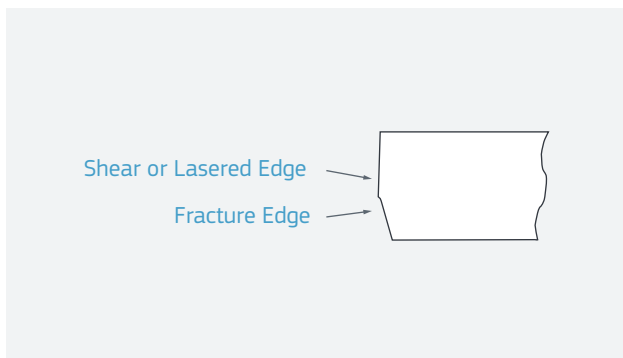
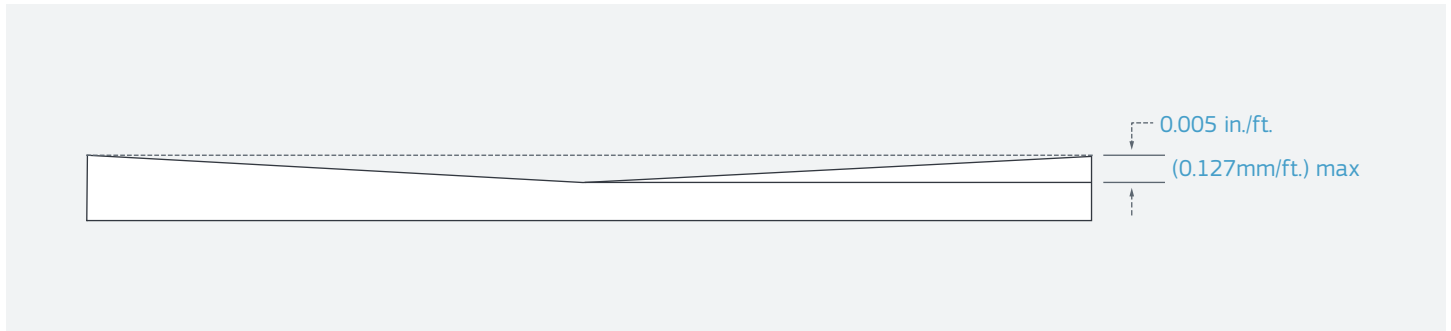


Figure 6: Tolerances on more than one surface

CUT STRAIGHTNESS

When measuring the edge per cut for straightness, the deviation from the theoretical straight edge that is measured shall not exceed 0.005 in./ft. (0.127mm/ft) per length of a cut. This will be measured along the sheared line, and not the fracture line.



FLATNESS OF SHEET

Imperial		Metric	
Surface Length	Flatness Tolerance	Surface Length	Flatness Tolerance
0 in. to 1.50 in.	0.005 in.	0mm to 38mm	0.127mm
1.50 in. to 4.00 in.	0.005 in. per linear in.	38mm to 102mm	5µm/mm of length
4.00 in. or more	0.020 in. plus 0.004 in./in. of length	102mm or more	0.51mm plus 4µm/mm of length

SQUARENESS OF SHEET

Side Squareness Between	Formed Edge	Sheared Edge
Formed edge	0.020 in./ft. (0.508mm)	0.015 in./ft. (0.381mm)
Sheared edge	0.015 in./ft. (0.381mm)	0.020 in./ft. (0.508mm)

Note: Sheared or formed edges will be square within the tolerances listed.

BEND ANGLES AND MEASUREMENT

There is a ± 1 degree tolerance on all bend angles (A). Location of material at the end of the bend (L) will vary depending on the length of the bend (X) in relation to the angle tolerance. Measurement of bends (M) are as shown. Features like holes, forms, and hardware will be measured in the same manner. Obtuse angle measurements are taken from a contact point approximately $1/16$ in. from the surface, as shown.

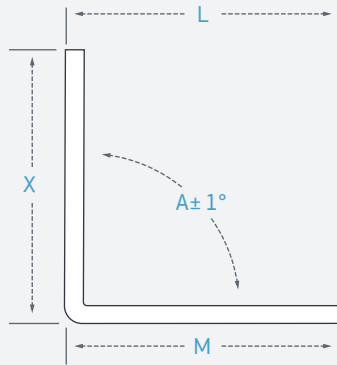


Figure 7: 90° Angle

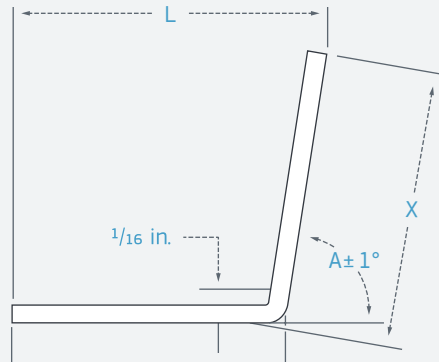


Figure 8: Obtuse Angle

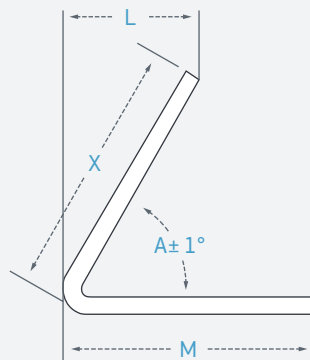


Figure 9: Acute Angle

STANDARD FORMING & MANUFACTURING GUIDELINES

Protolabs will use a standard 0.030 in. (0.76mm) tool radius to bend parts of 1/8 in. thickness or thinner unless specified differently on a supplied document. For models supplied above 1/8 in. thickness, Protolabs will use the closest tool radius available.

Bend radii will be kept the same across all bends whenever possible to minimize the amount of brake setups unless specified differently on a supplied document, thus keeping cost down.

Parts with formed gussets in the bend will be formed with a bend radius that matches Protolabs gusset tools, which measure 0.030 in. (0.76mm) or 0.120 in. (3.05mm) unless a different radius is required (supplied document), for which a tool charge will apply.

Minimum flange width should be 4x material thickness to avoid additional machining. When it gets smaller than this, the tooling will tend to mark the surface of the workpiece. Alternatively, a technician will have to use a sacrificial material backup strip to force the bend to come over, or the flange will require milling after forming causing additional costs to manufacture.

Tangent edges of holes and edges of cuts should be minimum 4x material thickness to the outside of the bend to avoid distortion or post machining.

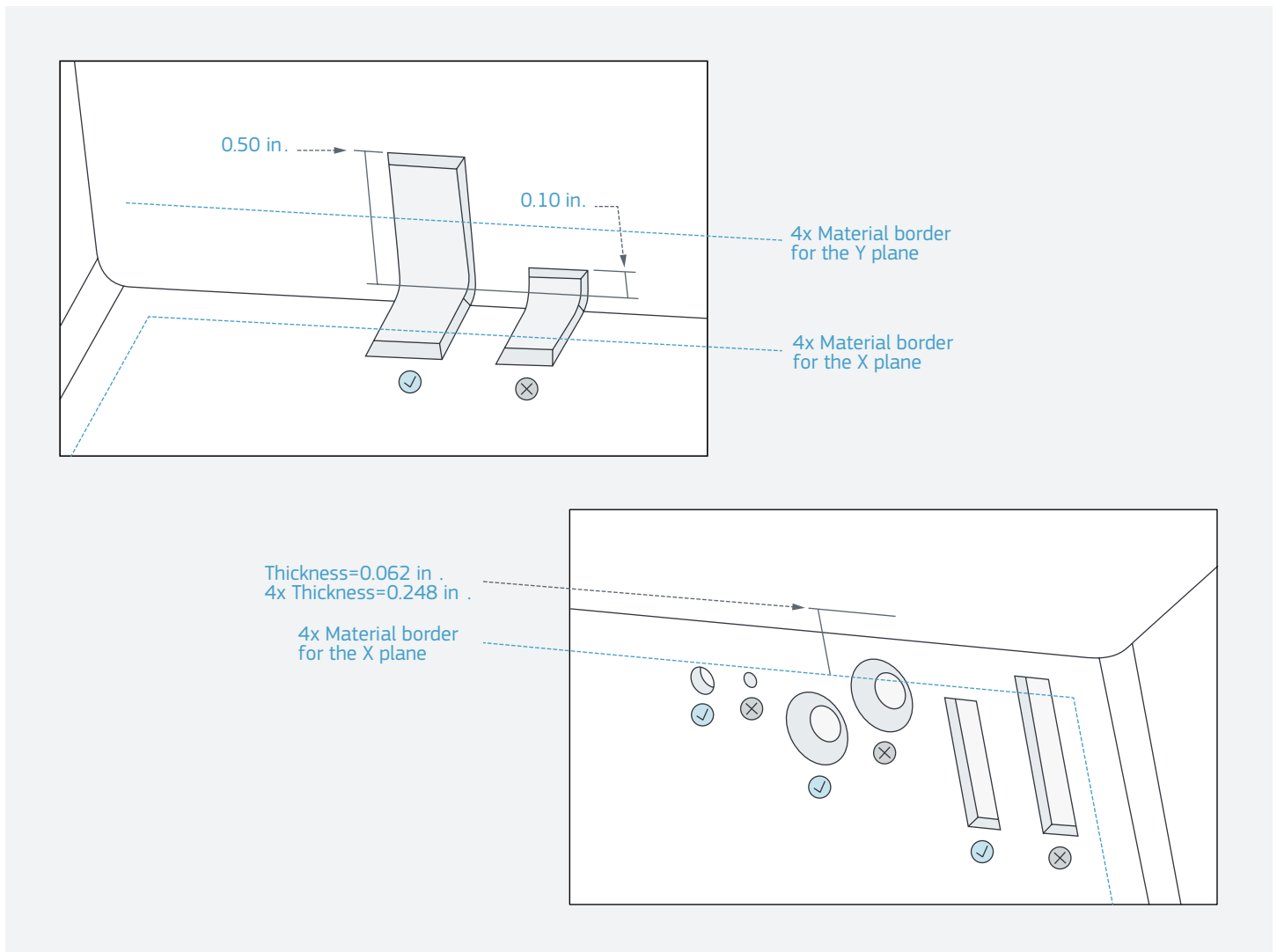


Figure 10: Hole sizes should be a minimum of material thickness in diameter. Holes should be 0.062 in. (1.58mm) from an edge in material that is 0.036 in. (0.92mm) or thinner, and at least 0.125 in. (3.18mm) from an edge on thicker material to avoid any distortion. Holes that require hardware inserts should be spaced according to the manufacturer's specifications.

WELDING

Protolabs will modify supplied CAD models for proper welding construction (as per industry standard).

Protolabs will tack weld in areas that cannot attain a proper spot weld without adversely affecting structural integrity.

Specific welding requirements must be accompanied by a supporting document.

Protolabs interprets weld symbols on supporting documents per AWS A2.4 standard.

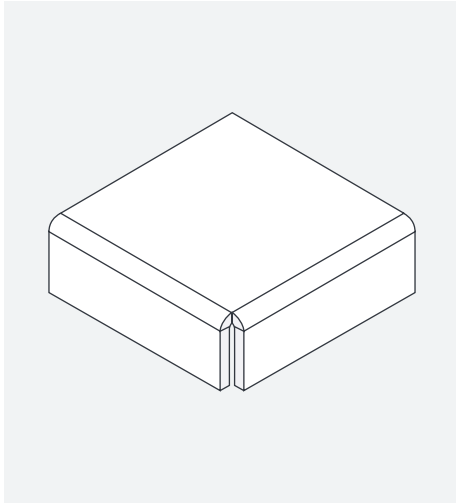


Figure 11: Supplied Model

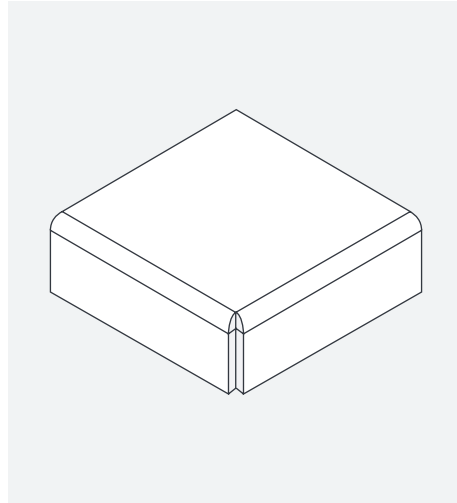


Figure 12: Closed for Aluminum Weld

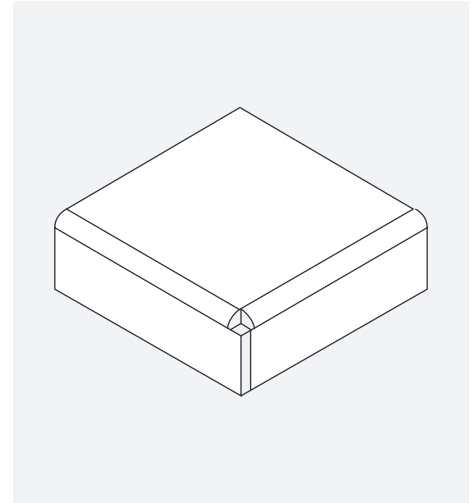


Figure 13: Closed for Steel Weld

POWDER COAT AND SILKSCREEN INFORMATION

Protolabs offers in-house powder coating and silkscreening to ensure we can meet delivery needs.

Powder coatings are applied electrostatically and baked in industrial ovens. Powder coating differs in materials and application method when compared to wet coat systems.

Silkscreening is done in our own silkscreen department where trained personnel provide quality screenprinting as quickly as possible.

We can use your existing artwork or create new artwork for you. Artwork files are accepted in a variety of formats including: CorelDraw, Encapsulated PostScript (EPS), DXF, or PDF. Bitmap files will not be accepted.

Protolabs has strict guidelines and preparation methods to achieve the best possible finish results.

A list of stock powder colors can be found on [Protolabs.com](https://www.protolabs.com). In addition to these colors, we can order any other powder based on need which will affect lead times and pricing.

Silkscreen colors can be closely matched to any Pantone number provided. Additional lead time may be required.

We supply industrial finishes but do not have clean-room environments to obtain a class-A finish.

Contact Protolabs for more details.

HARDWARE INSTALLATION GUIDELINES

Protolabs will install hardware per the Manufacturer's specifications to ensure proper seating in the material.

Protolabs will substitute hardware as required to achieve proper installation or for finish considerations.

Protolabs will use specified hardware or an approved equivalent when lead times are tight.

The PEM website has more detailed information: catalog.pemnet.com/category/all-categories

PROTOLABS SURFACE FINISHING GUIDELINES

Chromate/Silkscreen

Straight grain, separate with clean paper and or cardboard between each row of parts

Anodize/Silkscreen

Straight grain, separate with clean paper and or cardboard between each row of parts

Silkscreen

Straight grain, separate with clean paper and or cardboard between each row of parts

Chromate & Anodize

Vibrate unless straight grain is called for by customer document

Powder coat, no outside plating

Save time with brushes or vibrate, or straight grain

No weld

Straight grain

With weld

Vibrate unless there is a grain call-out

PROTOLABS STOCK MATERIALS AND THICKNESSES

Because sheet metal parts are manufactured from a single sheet of metal, the part must maintain uniform wall thickness. Sheet metal thickness ranges from 0.024 in. (0.609mm) to 0.250 in. (6.35mm). Other gauges and materials can be ordered but will affect price and lead times.

Steel			Stainless Steel			Aluminum		Copper		Brass
CRS/HRPO	Galvanneal	Galvanized	304-2B	304 #4	316-2B	5052-H32	6061-T6*	C1010	C1100	C260
0.024	0.024	0.024	0.024	0.024	0.024	0.025	0.025	n/a	0.025	0.025
0.029	0.029	0.029	0.03	0.03	0.03	0.032	0.032	0.032	0.032	0.032
0.036	0.036	0.036	0.036	0.036	0.036	n/a	n/a	n/a	n/a	n/a
0.042	n/a	n/a	n/a	n/a	n/a	0.04	0.04	0.04	0.04	0.04
0.047	0.047	0.047	0.048	0.048	0.048	0.05	0.05	0.05	0.05	0.05
0.059	0.059	0.059	0.059	0.059	0.059	0.063	0.063	0.063	0.063	0.063
0.074	0.074	0.074	0.074	0.074	0.074	0.080	0.080	0.080	0.80	0.080
0.089	0.089	0.089	0.089	0.089	0.089	0.093	0.093	0.093	0.093	0.093
0.104	0.104	0.104	0.105	0.105	0.105	0.10	0.10	n/a	n/a	n/a
0.119	0.119	0.119	0.119	0.119	0.119	0.125	0.125	0.125	0.125	0.125
0.134	0.134	0.134	0.134	0.134	0.134	n/a	n/a	n/a	n/a	n/a
0.160	n/a	n/a	n/a	n/a	n/a	0.160	0.160	n/a	n/a	n/a
0.179	n/a	n/a	0.1875	n/a	n/a	0.190	0.190	n/a	n/a	n/a
0.250	n/a	n/a	0.250	n/a	n/a	0.250	0.250	n/a	n/a	n/a

Note: The thicknesses of both Galvanized and Galvanneal that are RoHS compliant are: 0.029, 0.036, 0.047, 0.059. All other thicknesses for these two materials are not RoHS compliant.

*6061-T6 typically used on flat parts

INDUSTRY THICKNESS TOLERANCE OF SHEET STOCK

Sheet thickness tolerance charts below are mill specifications. Material thickness requirements that are tighter than mill standards may be possible. Please contact Protolabs to see if these materials can be located, or if additional processing for your requirements will be required.

ASTM-AISI Thickness Tolerance Ranges				
Carbon Steel Sheets (Hot Rolled, H R P & O, Cold Rolled)				
Gauge	Thickness, Inches			Lbs. Per Sq.Ft.
	Decimal Equivilant	Tolerance Range		Weight Equivilant
		H R P & O	CR	
4	0.2242	0.2332 0.2152		9.375
5	0.2092	0.2182 0.2002		8.75
6	0.1943	0.2182 0.2002		8.125
7	0.1793	0.1873 0.1713	0.1883 0.1703	7.5
8	0.1644	0.1724 0.1564	0.1734 0.1554	6.875
9	0.1495	0.1575 0.1415	0.1585 0.1405	6.25
10	0.1345	0.1425 0.1265	0.1405 0.1285	5.625
11	0.1196	0.1276 0.1116	0.1256 0.1136	5.0
12	0.1046	0.1126 0.0966	0.1106 0.0986	4.375
13	0.0897	0.0967 0.0827	0.0947 0.0847	3.75
14	0.0747	0.0817 0.0677	0.0797 0.0697	3.125
15	0.0673	0.0733 0.0613	0.0723 0.0623	2.812
16	0.0598	0.0658 0.0538	0.0648 0.0548	2.5
17	0.0538	0.0598 0.0478	0.0548 0.0498	2.25
18	0.0478	0.0528 0.0428	0.0518 0.0438	2.0
19	0.0418		0.0458 0.0378	1.75
20	0.0359		0.0389 0.0329	1.5
21	0.0329		0.0359 0.0299	1.375
22	0.0299		0.0329 0.0269	1.25
23	0.0269		0.0299 0.0239	1.125
24	0.0239		0.0269 0.0209	1.0
25	0.0209		0.0239 0.0179	0.875
26	0.0179		0.0199 0.0159	0.75
27	0.0164		0.0184 0.0144	0.688
28	0.0149		0.0169 0.0129	0.625
29	0.0135		0.0155 0.0115	0.562
30	0.0120		0.0130 0.0110	0.50

ASTM-AISI Thickness Tolerance Ranges (cont.)				
Galvanized Steel Sheets				
Gauge	Thickness, Inches		Lbs. Per Sq.Ft.	
	Decimal Equivilant	Tolerance Range	Weight Equivilant	
10	0.1382	0.1472 0.1292	5.78125	
11	0.1233	0.1323 0.1143	5.15625	
12	0.1084	0.1174 0.0994	4.53125	
13	0.0934	0.1014 0.0854	3.90625	
14	0.0785	0.0865 0.0705	3.28125	
15	0.0710	0.0770 0.0650	2.96875	
16	0.0635	0.0695 0.0575	2.65625	
17	0.0575	0.0625 0.0525	2.40625	
18	0.0516	0.0566 0.0466	2.15625	
19	0.0456	0.0506 0.0406	1.90625	
20	0.0396	0.0436 0.0356	1.65625	
21	0.0366	0.0406 0.0326	1.53125	
22	0.0336	0.0376 0.0296	1.40625	
23	0.0306	0.0346 0.0266	1.28125	
24	0.0276	0.0316 0.0236	1.15625	
25	0.0247	0.0287 0.0207	1.03125	
26	0.0217	0.0247 0.0187	0.90625	
27	0.0202	0.0232 0.0172	0.84375	
28	0.0187	0.0217 0.0157	0.78125	
29	0.0172	0.0202 0.0142	0.71875	
30	0.0157	0.0187 0.0127	0.65625	

Various ASTM Specs for Steel Sheets

A366; Cold Rolled Commercial Quality
A569; Hot Rolled Commercial Quality
A570; Hot Rolled Structural Quality
A526; Zinc Coated (Galvanized Steel
A526/A527; Galvanneal
A591; Electrolytically Zinc Plated

**Aluminum Sheet Thickness Tolerances (Inches +/-)
By Alloy Group and Width**

Nominal Thickness	36"		48"		60"	
	1100 3003 5052 6061	2024 7075	1100 3003 5052 6061	2024 7075	1100 3003 5052 6061	2024 7075
0.250	0.014	0.0125	0.015	0.014	0.016	0.015
0.190	0.007	0.0055	0.009	0.007	0.011	0.009
0.160	0.007	0.0055	0.009	0.007	0.011	0.009
0.125	0.0045	0.0035	0.0055	0.0035	0.007	0.0045
0.100	0.0045	0.0035	0.0055	0.0035	0.007	0.0045
0.090	0.0035	0.0025	0.0045	0.0035	0.006	0.004
0.080	0.0035	0.0025	0.0045	0.0035	0.006	0.004
0.063	0.003	0.002	0.0035	0.003	0.005	0.003
0.050	0.003	0.002	0.0035	0.003	0.005	0.003
0.040	0.0025	0.002	0.0035	0.002	0.0045	0.003
0.032	0.002	0.0015	0.0025	0.002	0.0035	0.003
0.025	0.0015	0.0015	0.002	0.0025	0.003	0.003
0.020	0.0015	0.0015	0.002	0.002	0.003	0.004

Stainless Sheet Thickness Tolerance

Gauge	Decimal Equivalent	Tolerance Plus/Minus
7	0.1864	0.007
8	0.165	0.007
10	0.135	0.006
11	0.12	0.005
12	0.1054	0.005
13	0.09	0.004
14	0.0751	0.004
16	0.0595	0.003
18	0.048	0.003
19	0.042	0.003
20	0.0355	0.002
22	0.0293	0.002
24	0.0235	0.0015
26	0.0178	0.0015
28	0.0151	0.0015