PC Tolerances

Magnetic Tolerance

Material (Mix No.)	-2	-8	-14	-18	-19	-26	-28	-30	-33	-34	-35	-38	-40	-45	-52	-267	-275
A_L Tolerance	ą5%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	ą10%	+35% -25%	+35% -25%

The cores are manufactured to the A_L values listed; the permeability for each material is for reference only. In all cases, **the A_L values are based on a peak AC flux density of 10 guass (1mT) at a frequency of 10kHz.** Measurements made under other conditions will produce results in accordance with the magnetic curves shown in the Percent Initial Permeability vs. Peak AC Flux Density Graph.

The toroidal cores are tested with an evenly-spaced full single-layer winding in order to minimize leakage effects. Iron powder cores tested with a small number of turns which are not evenly distributed will produce higher inductance readings than expected. The E cores are tested with 100 turns.

The Magnetic Characteristic curves shown are have a typical tolerance of ą10%. The curves on Core Loss characteristics have a typical tolerance of ą15%.

Dimensional Tolerances (inches)

TOROIDS*	OD	ID	Ht	TOROIDS*	OD	ID	Ht
T16-T20	ą.010	ą.010	ą.010	T150-T225	ą.025	ą.025	ą.030
T25-T38	ą.015	ą.015	ą.020	T249-T400	ą.030	ą.030	ą.030
T40-T72**	ą.020	ą.020	ą.020	T520-T650	ą.050	ą.050	ą.050
T44-T72**	ą.020	ą.020	ą.020				
T80-T141	ą.020	ą.020	ą.025				

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COMPOSITE*	OD	ID	Ht	COMPOSITE*	OD	ID	Ht
ST50	ą.015	ą.015	ą.020	ST150	ą.040	ą.030	ą.030
ST83-ST102	ą.030	ą.020	ą.025	ST200	ą.050	ą.040	ą.040

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BUS BAR*	A	B	D	E	L
HS300-HS400	ą.015	ą.020	ą.005	ą.005	ą.020

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U CORES	A	B	C	E	F	G
U61-U80	ą.010	ą.010	ą.010	ą.010	ą.010	ą.010
U350	ą.020	ą.020	ą.015	ą.020	ą.015	ą.030

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E CORES	A	B	C	D	F	G	MAX GAP***
E49-E118	ą.010	ą.010	ą.005	ą.007	ą.005	ą.007	.0015
E125-E162	ą.015	ą.015	ą.007	ą.010	ą.007	ą.010	.0015
E168-E225	ą.015	ą.015	ą.010	ą.010	ą.007	ą.010	.0020
E305-E450	ą.030	ą.030	ą.015	ą.020	ą.015	ą.020	.0030
E610	ą.040	ą.040	ą.025	ą.030	ą.025	ą.030	.0050

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EF CORES	A	B	C	D	E/F	G	MAX GAP***
EF60-EF80	ą.010	ą.010	ą.005	ą.010	ą.005	ą.007	.0030

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EM CORES	A	B	C	D	G	H	MAX GAP***
EM145	ą.015	ą.015	ą.010	ą.020	ą.010	ą.015	.0020
EM168-EM220	ą.015	ą.015	ą.010	ą.020	ą.010	ą.015	.0030

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PLAIN CORES	OD	L
Pxx24-Pxx40	+.000/-.005	ą.015
Pxx48-Pxx76	+.000/-.005	ą.020

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HOLLOW CORES	OD	ID	L
Hx10-Hx12	+.000/-.005	+.005/-.000	ą.010
Hxx14-Hxx20	+.000/-.005	+.005/-.000	ą.015
Hxx21-Hxx25	+.000/-.005	+.005/-.000	ą.020

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DISCS	OD	CB	ID	T
D45-D80	+.000/-.010	+.005/-.000	+.005/-.000	ą.007

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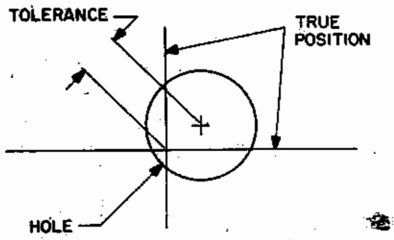
*Tolerance includes coating

**Gap per piece

** OD for T50-8/90 and T50-8B/90 is + 025/- .015

P.C. Board Artwork Tolerances

Printed wiring terminal area sizes for the military are specified by the requirements of MIL-P-55110A, MIL-P-46843 and MIL-STD-275B. But to specify terminal area tape sizes that will result in a finished panel which will meet these requirements is not too easily done. You must consider all of the dimensional tolerances starting with the artwork tape, all the way through to the finished product. (See Fig. 1)



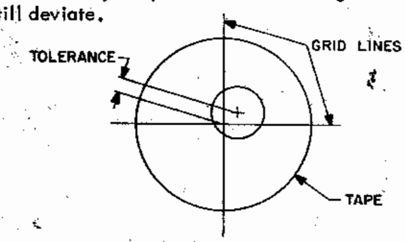
HOLE LOCATION TOLERANCE

ARTWORK TOLERANCES

In the following discussion, all dimensional references are in inches.

"Off-the-Shelf" tape terminal areas have a tolerance on the diameter of ± .005 at scale. This is a diametral tolerance and will be used as such in the terminal area size calculation. Precision terminal areas cut on a co-ordinatograph have a tolerance of ±.001 on the diameter.

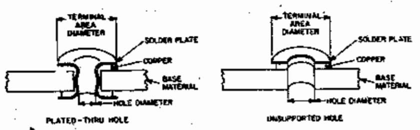
When placing a terminal area on Mylar film we allow a tape placement tolerance within .010 diameter of true position. The tolerance is a human factor and is repeatable without strain. Again this will be a diameter in our final calculations. If your artwork is done at one to one, you must include a grid deviation tolerance from true position of .001 inch/inch. The deviation is due to grid manufacture and atmospheric conditions, and must be figured over the longest diagonal dimension of the panel. It is a radial dimension and hence must be multiplied by two to make it useable in the diameter formula. For example, if your diagonal measurement is nine inches, the total tolerance would be 9 x .001 x 2, or .018, a diameter. If you are working at a scale other than one to one, the photographic reduction dimension will control the extremities of your panel but the center grid lines will still deviate.



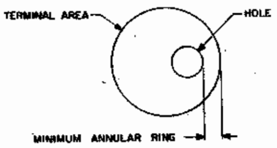
TAPE PLACEMENT TOLERANCE

PHOTOGRAPHIC TOLERANCES

When your tape artwork is reproduced photographically at the same scale, such as in auto positive, error from exposure shadows and from over and under developing must be included. The sum of these tolerances is ±.002 on a diameter. Do not include another grid deviation here if your work is at a magnified scale because the photographic reduction tolerance will override. However, if your artwork is at one to one, another .0005 radial tolerance must be included for atmospheric influences on the reproduction. For the nine-inch diagonal we have another diametral tolerance of 9 x .0005 x 2 or .009.



2. **Configuration of two** types of holes in printed wiring: plated-through (left) and unsupported (right).



3. **Determination of minimum** annular ring. MIL-P-55110A sets limit of .005 in.

Reducing magnified artwork to one to one introduces a tolerance of ± .002 on your reduction dimension. Use the longest side of your panel to minimize error. The error is a radial dimension and must be multiplied by two to make it a diameter. Multiply by scale to bring it up to the tape level. Because we are down to one to one scale we will not include diametral tolerances introduced in photo developing since they are negligible.

MANUFACTURING TOLERANCES

When a printed wiring manufacturer places an artwork on a blank panel for photographic exposure he requires an artwork placement tolerance within .010 diameter of true position. Multiply this diameter by scale for use in the final equations. Include the tolerance only once even if the board is double-sided and specify that each individual artwork be positioned with respect to true position.

Printed wiring manufacturers require a full scale tolerance at least ±.004 on the finished product as compared to the one to one artwork. This is a diameter in the calculations. Photographic exposure and subsequent developing and etching contribute to this error.

Printed wiring manufacturers also require a deviation from true position when locating holes. Ten thousandths diameter of true position for boards drilled one at a time is practical. If boards are stacked (up to four) for drilling, the manufacturer can be expected only to be within .014 diameter of true position. Both X-Y positioning and drill wander make up the error.

Hole size is essentially a function of your component lead diameter, drill selection, drill wear, and the thickness of through-plating if any. Since the designer is concerned only with the finished hole size that is all he should specify (See Fig. 2) However, to properly specify hole size you must know the working tolerances involved. You should specify a minimum hole size of at least .003 inch greater than the maximum lead diameter. In specifying maximum hole size include at least two drill sizes in your range. To meet the requirements of MIL-STD-275B, however, do not specify a maximum hole size that is .028 (.035 for plated-through holes) greater than the minimum lead diameter. A greater clearance is apt to give you a void in your solder fillet if the lead is unclinched. A clinched lead can stand a clearance of .050 in either case. For ease of manufacture, plated-through holes must have a maximum diameter at least .010 greater than minimum.

MILITARY REQUIREMENTS

MIL-P-55110A sets a limit of .005 on the minimum annular ring for plated-through holes unless you specify otherwise; for plain holes .015, Fig. 3. These are ring dimensions (radius) and must be doubled to make diameters.

To meet the requirements of MIL-STD-275B, you must provide a terminal area that is at least .020 greater than the maximum diameter of plated-through holes. For plain holes the terminal area must be .040 greater. These figures are diameters and need only be multiplied by scale for the equations.

FINAL EQUATIONS

Calculate nominal tape terminal area size to meet the requirements of MIL-P-55110A with this formula;

$$\text{Tape terminal area diam.} = \text{Scale} \times \begin{bmatrix} \text{minimum over-hole} \\ \text{maximum hole diam.} \\ \text{process tolerance} \end{bmatrix} + \begin{bmatrix} \text{auto-positive tolerance} \\ + \text{ tape size tolerance} \end{bmatrix}$$

If your drilling is done to indicated centers rather than by grid of X-Y coordinates you can eliminate the "artwork placement". Also, "2 x grid deviation" and "tape placement" terms can be eliminated from the equations.

As an example suppose we wish to meet the minimum MIL requirement of .005 annular ring. The maximum component lead is .025. Therefore, specify a plated-through hole size of .027-.037. We will drill to grid and allow a hole location deviation of .010 diameter. Our supplier requires ± .004 on his process with artwork placement not to exceed .010 diameter of true position. For a photo-reduction tolerance we allow ± .002. Our four to one artwork has 20 inches diagonal (five inches at one to one) and thus a grid deviation of 20 x 1/2 x .001 or .010. With an auto-positive reproduction tolerance of ± .002, tape placement allowance within .010 diameter of true position, and tape size tolerance of ± .005 we can write the equation as:

$$\text{Tape terminal area} = 4 \times \begin{bmatrix} 2 \times .005 \\ + .037 \\ + .010 \\ + .004 \\ + .010 \\ + 2 \times .002 \end{bmatrix} + \begin{bmatrix} 2 \times .010 \\ + .002 \\ + .010 \\ + .005 \end{bmatrix} = .337 \text{ diam.}$$

You can determine the tape terminal area sizes to meet the requirements of MIL-STD-275B with this formula.

$$\text{Tape terminal area diameter} = \text{Scale} \times \begin{bmatrix} 2 \times \text{minimum annular ring} \\ + \text{ maximum hole size} \\ + \text{ hole location deviation} \\ + \text{ artwork placement} \\ + \text{ process tolerance} \\ + \text{ 2 x photo reduction} \end{bmatrix} + \begin{bmatrix} 2 \times \text{grid deviation} \\ + \text{ auto-positive tolerance} \\ + \text{ tape placement} \\ + \text{ tape size tolerance} \end{bmatrix}$$

For the conditions of the previous calculation with the additional requirement that the terminal area be .020 greater than the maximum plated-through holes we have:

$$\text{Tape bullseye} = 4 \times \begin{bmatrix} .020 \\ + .037 \\ + .004 \end{bmatrix} + \begin{bmatrix} .002 \\ + .005 \end{bmatrix} = .51 \text{ diam.}$$

From the example we will have to select .337 as our tape diameter. This is a nominal dimension since we included the tape tolerance in our calculations. Under the conditions given, this is the smallest terminal area we can use. As a matter of economics, it would be well to choose the next largest stock size, say .375. Worst case tolerancing is used in these calculations. By employing statistical tolerancing techniques the required tape size will be substantially reduced. Our experience has shown, however, that the military prefers worst case tolerancing.

Standard Printed Circuit Design Tolerances

1.00 DIAMETERS

1.01 Holes

Drilled	± .002"	
Reamed	± .002"	
Counterbored or fly cut (dias. 5/16" - 4")	± .005"	
Plated through holes (after plating)	± .005"	
	Paper Base	**Glass Base**
Punched (1/16" thick) up to 1/2" dia.	± .003"	± .004"
1/2" to 1" dia.	± .004"	± .004"
over 1" dia.	± .005"	± .005"

Add ± .001" to above for thickness of 3/32" through 1/8"

Routed Slots and Notches up to 2"	± .005"
Punched, Milled or Broached Slots and Notches up to 2"	± .003"

1.02 Holes to Outside Diameter Tolerances

I.D. to O.D.: Regular Total Indicator Runout	.010"
Premium Total Indicator Runout	.005"

2.00 LINE WIDTH AND SPACING - Minimum .021" - Standard Grade
Minimum .010" - Premium Grade

Increase all line widths and spacing in art work by the following dimensions to compensate for process tolerances:

Unplated	Regular .010" Premium .005"
Plated	Regular .015" Premium .010"

NOTE:

Line width tolerances do not include nicks, pin holes and scratches. Such imperfections are considered acceptable provided the line is not reduced any more than 20%. It is suggested that line width and spacing be specified as minimums based on tolerances listed in this Manual.

3.00 PLATING THICKNESS

All plating is normally specified as a minimum thickness with a tolerance of plus 100% minus zero. On boards with plated through holes having a minimum of .001" plating on the walls of the holes, plating build up will normally add as much as .002" to the metal thickness on both sides of the board. Close tolerance laminate is normally used in such applications.

4.00 WARP

The following values can be used as a guide in determining anticipated warpage of copper clad:

Pattern on one side	Paper Base	Glass Base
1/16" stock thickness	.025"	.015" per inch of length
3/32" stock thickness	.020"	.010" per inch of length
1/8" stock thickness	.012"	.008" per inch of length
1/4" stock thickness	.008"	.006" per inch of length
Pattern on two sides		
All stock thicknesses	.015"	.010" per inch of length

5.00 HOLE SPACING

Spacing up to 6" - holes less than .100" dia.	± .003"
Spacing up to 6" - holes .100" and greater	± .005"
Spacing 6" and greater - holes less than .100" dia.	± .005"
Spacing 6" and greater - holes .100" and greater	± .007"

6.00 LAND PATTERNS

Around each hole should be at least 0.015" in width. In other words, the diameter of the finished metal pad, at actual size, should be at least 0.030" larger than the hole size.

7.00 LEGEND TO CIRCUIT SPACING

There should be at least 0.031" spacing between any inked legend and etched conductor.