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Director, EPTAC

The Fundamentals of Solder Joint of Solder Joint Design
– Part 1 –
Through Hole Technology (THT)

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SOLDER JOINT CRITERIA

Designed for:

- Electrical conductivity
- Mechanical stability
- Heat dissipation

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SOLDER JOINT CRITERIA

Solder Joint Must Have

- Ease of manufacturing
- Simplicity of repair
- Inspectable

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SOLDER JOINT DESIGN

Solder joint are typically designed around the weakest cross sectional area of the weakest member of the joint itself.

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Design Evaluation

- Know the weakest part of the solder joint
- Know the environment the solder joint will be subjected to in its useful life
- Understand the metallurgy of cooling solder
- Check stress distribution of the solder joint and the part being soldered.

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Overview of Soldering

What does it take to make a solder joint:

- Properly prepared materials
- Properly designed materials
- Fluxes
- Solder
- Heat
- Metallurgical bond

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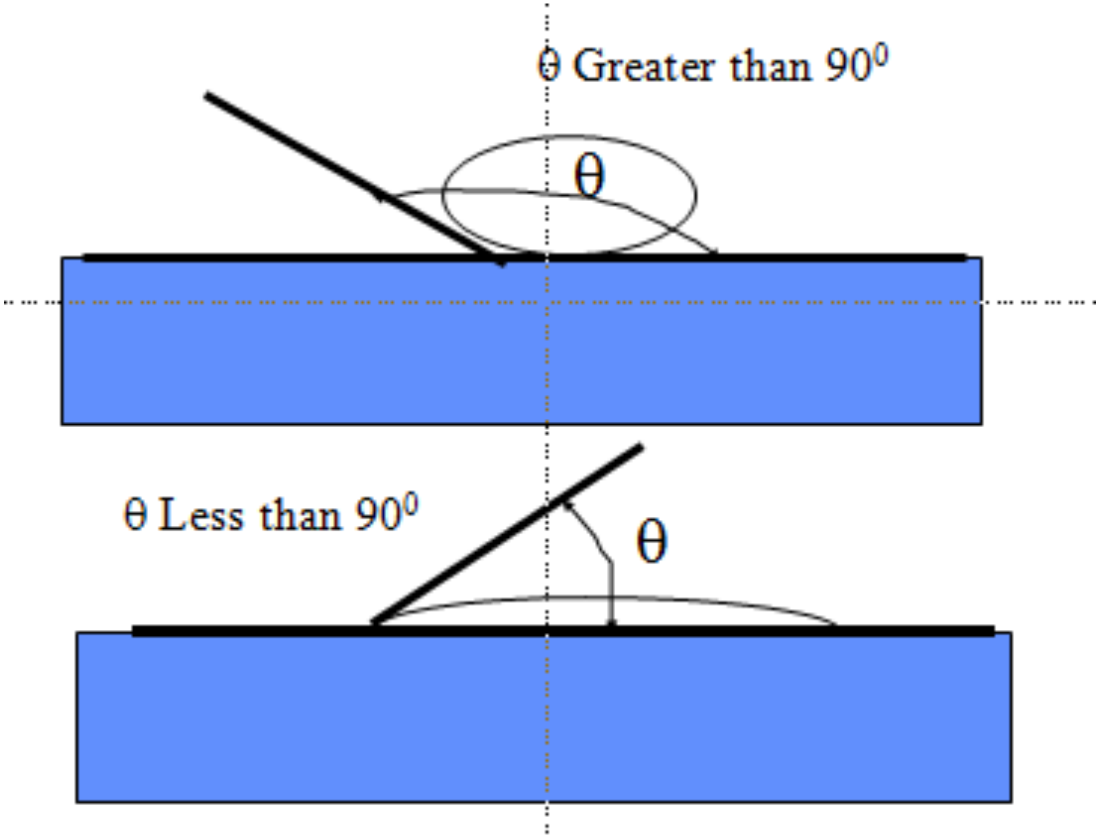
Wetting Angles



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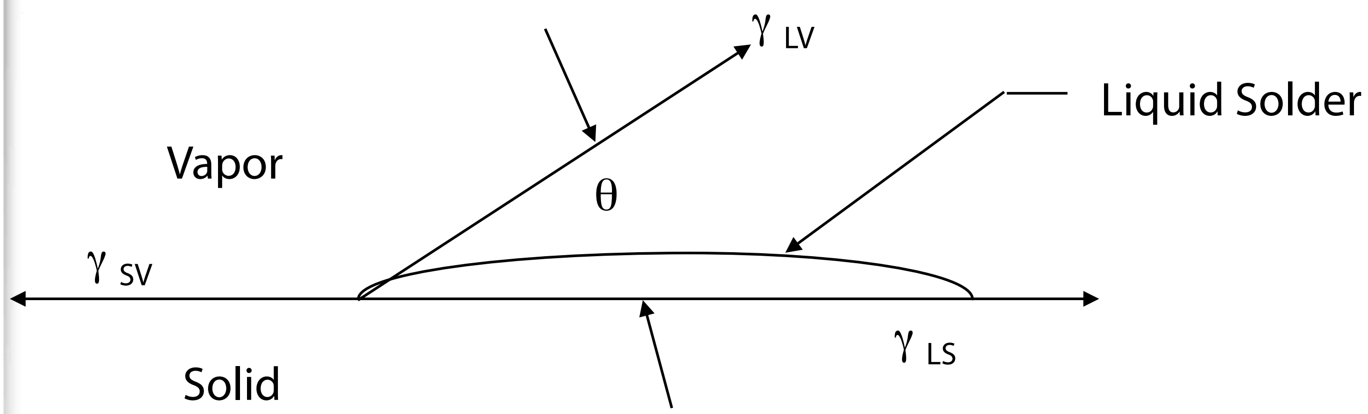
Equilibrium of Wetting

$$\gamma_{SV} = \gamma_{LS} + \gamma_{LV} \text{Cos}\ \theta$$



θ = Dihedral Angle
γ = Forces of the surface energies
γ_{SV} = Solid Vapor interface
γ_{LS} = Liquid Solid interface
γ_{LV} = Liquid Vapor interface

Liquid Forces

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Liquids have two forces:

- Cohesive
- Adhesive

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Cohesive Liquid Forces

Will tend to make the solder ball up on the surfaces

Can create either a:

- Non-Wet condition or
- De-wet condition

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Adhesive Liquid Forces

- Adhesive forces will allow the solder to wet the solid base metal.
- Will create the capillary action up into plated through holes
- Will allow the solder to spread over the surfaces being soldered

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Plated Through Hole Pads

The design is a compromise:

- Board density and minimum electrical spacing require small pads
- Joint strength and reliability require as large a pad as possible

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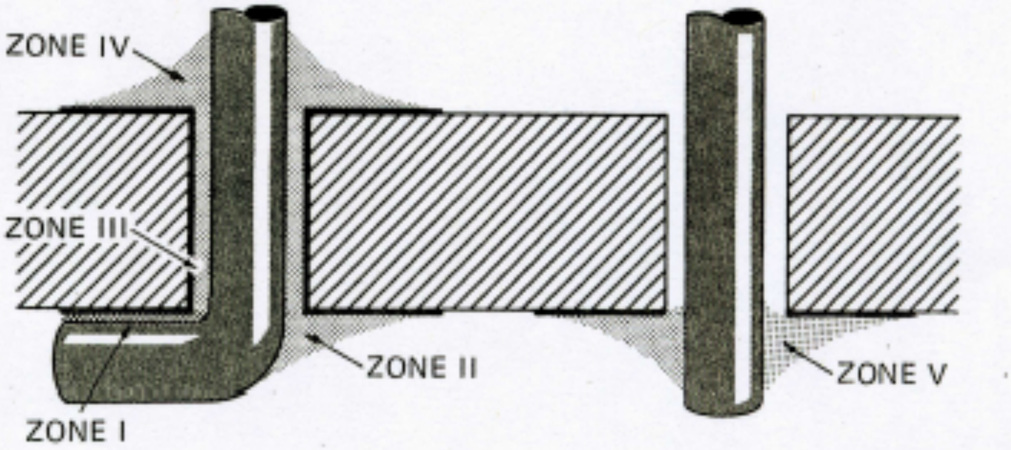
Plated Through Hole Solder Joint



ASSUME:

Board thickness.	0.0625"	Wire Dia.	.032"
Copper	2 oz.	Fillet below board. . . .	.020"
Land trace.	.020"	Fillet above board	.005"
Land Dia. (Hole)	.120"	Solder	Sn 63
Hole Dia.	.040"	Temperature rise	122°F

Fig. 1-1. A schematic of the average fillet used for this calculation.

Adapted from Soldering Handbook for Printed Circuits and Surface Mounting, by Howard H. Manko, Van Nostrand Reinhold

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Parameters

0.02	Land/line width
0.032	D_w = WIRE DIAMETER
0.04	D_h = HOLE DIAMETER
8.04E-04	$A_C = \pi *(Dw/2)^2$
0.12	OUTSIDE DIAMETER OF LAND
8.25	μ = RESISTIVITY RATIO
7.5	2 OZ COPPER WIRE CONDUCTIVITY
0.04	L_j = lap joint length = $\pi/4\mu D$
5.85	The strength ratio of OFHC/SN63 is β
31	Tensile strength of 20 AWG wire in pounds
9.8	20 GAUGE WIRE CAN CONDUCT 9.8 AMPS AT 122F
7.5	Conductivity of 2 oz copper with a land width or 0.020, in amps
10	Peel strength 1 square inch of 1 oz copper in pounds
14	Peel strength 1 square inch of 2 oz copper in pounds
0.778	f function of hole clearance from table 1-4
0.0625	T_b = thickness of the board
0.02	H_C = height for 2 oz copper layer
0.005	H_1 = SIDE 1 FILLET
0.02	H_2 = height for single sided board bottom side
6.28E-02	$L_{cc}=\pi/2*D_h$

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Mechanical Strength	Zone 1 Lead clinched onto pth pad		Zone 2 PTH pad opposite of clinched lead		Zone 3 Plated Through Hole		Zone 4 Top side pth		Zone 5 Straight Through Lead, Single sided board	
Lj = $\pi/4\ \beta$ D	X =	3.68			$A_s = \pi * D_W * T_b$	6.28E-03	$A_s = \pi * D_h * f * H_1$	4.89E-04	$A_s = \pi * D_h * f * H_2$	1.96E-03
X = (p/4) * ((b (DW/Lj))					$X * A_s = \beta * A_c$	0.75	$X * A_s = \beta * A_c$	9.62	$X * A_s = \beta * A_c$	2.41
Critical copper area, $L_{cc} = \pi/2 * D_h$										
	1/X =	27.2%			1/X =	133.5%	1/X =	10.4%	1/X =	41.6%
From table the tensile strength of copper AWG 20 gauge is 31 pounds										
Zone can support	Lbs	8.43		8.43		41.40		3.22		12.88
Comparison to tensile strength of AWG 20 Gage wire at 31 pounds		27.2%		27.2%		133.5%		10.4%		41.6%
Comparison to peel strength of 1 oz copper foil at 10 lbs/in^2		84.3%		84.3%		414.0%		32.2%		128.8%

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Solder Joint Zone I & II

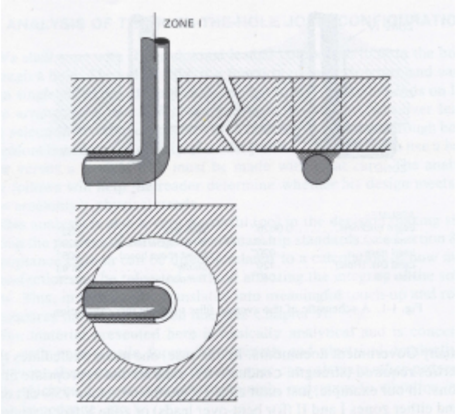

Fig. 1-2. A schematic of Zone I.

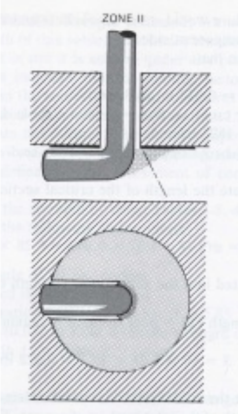

Fig. 1-3. A schematic of Zone II.

Mechanical Strength	Zone 1 Lead clinched onto pth pad		Zone 2 PTH pad opposite of clinched lead	
Lj = (π/4) β D	X =	3.68		
X = (p/4) * ((b (DW/Lj))				
Critical copper area, $L_{cc}=\pi/2*D_h$				
	1/X =	27.2%		
From table the tensile strength of copper AWG 20 gauge is 31 pounds				
Zone I & II can support	Lbs	8.43		8.43
Comparison to tensile strength of AWG 20 Gage wire at 31 pounds		27.2%		27.2%
Comparison to peel strength of 1 oz copper foil at 10 lbs/in^2		84.3%		84.3%

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Solder Joint Zone III

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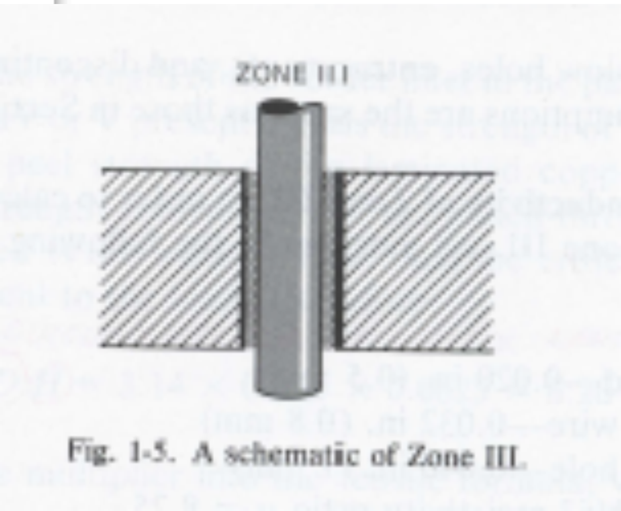

Fig. 1-5. A schematic of Zone III.

	Zone 3 Plated Through Hole	
	$A_s = \pi * D_W * T_b$	6.28E-03
	$X * A_s = \beta * A_c$	0.75
	1/X =	133.5%
From table the tensile strength of copper AWG 20 gauge is 31 pounds		
Zone 3 can support		41.40
Comparison to tensile strength of AWG 20 Gage wire at 31 pounds		133.5%
Comparison to peel strength of 1 oz copper foil at 10 lbs/in^2		414.0%

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Solder Joint Zone IV

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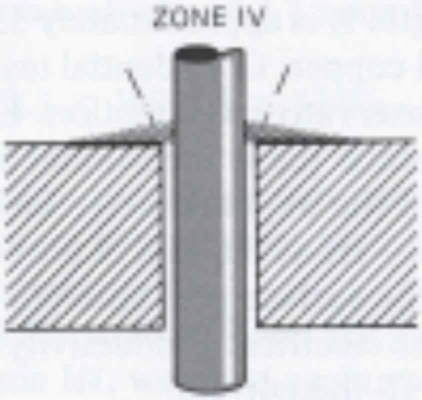

Fig. 1-6. A schematic of Zone IV.

	Zone 4 **Top side pth**	
	$A_s = \pi * D_h * f * H_1$	4.89E-04
	$X*A_s = \beta *A_c$	9.62
	1/X =	10.4%
From table the tensile strength of copper AWG 20 gauge is 31 pounds		
Zone 4 can support		3.22
Comparison to tensile strength of AWG 20 Gage wire at 31 pounds		10.4%
Comparison to peel strength of 1 oz copper foil at 10 lbs/in^2		32.2%

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Solder Joint Zone V

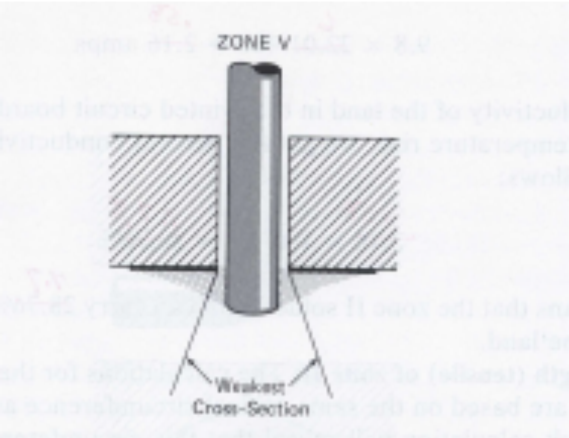

Fig. 1-4. A schematic of Zone V.

	Zone 5 Straight Through Lead, Single sided board	
	$A_s = \pi * D_h * f * H_2$	1.96E-03
	$X * A_s = \beta * A_c$	2.41
	1/X =	41.6%
From table the tensile strength of copper AWG 20 gauge is 31 pounds		
Zone 5 can support		12.88
Comparison to tensile strength of AWG 20 Gage wire at 31 pounds		41.6%
Comparison to peel strength of 1 oz copper foil at 10 lbs/in^2		128.8%

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Comparison of Zones

	Tensile strength of solder joint, psi	Joint strength compare to wire strength, 20 AWG = 31#	Joint strength compared to peel strength of the 1 oz. foil, 1oz = 10psi on FR-4
Zone I	8.43	27.2%	84.3%
Zone II	8.43	27.2%	84.3%
Zone III	41.4	133.5%	414%
Zone IV	3.22	10.4%	32.2%
Zone V	12.8	41.6%	128.8%

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Thank You

Questions?

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Further Information

Our Next session will discuss the design and strength of Surface Mount Leads

For questions regarding this webinar, please contact Leo Lambert at leo@eptac.com or call at

800-643-7822 ext 215

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