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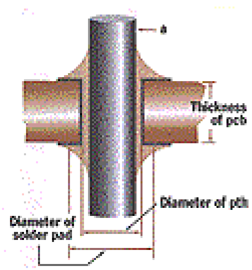
Electronics

Solder Volumes for Through-Hole Reflow-Compatible Connectors

The success of surface-mount technology has not meant the end of through-hole connectors. For reasons ranging from availability to user concerns over reliability, through-hole connectors remain widely used. Even so, production efficiencies desire a single soldering process -- all components must be capable of being reflow soldered. Separate wave soldering of through-hole components is fast becoming an unacceptable secondary operation. While many connectors today are compatible with surface-mount processing, users must calculate the amount of solder paste that must be deposited to achieve a reliable solder joint.



The fillet volume must only be calculated once, since top and bottom fillets are assumed to be equal.

A through-hole solder joint obviously requires more solder than a surface-mount joint. The solder must fill the plated-through hole and form solder fillets on the top and bottom of the board. The correct amount of solder to be deposited is determined by the diameter of the hole, the diameter of the solder pad, the thickness of the board, and the diameter of the contact (or cross-sectional area of a rectangular contact). Reflow soldering, fortunately, does not require changes to the board layout already established for wave soldering application of a through-hole connector.

The total volume of solder is the sum of three individual volumes:

- Through-hole (with lead inserted)
- Top fillet
- Bottom fillet

Calculations
The basic calculations are:

Solder Paste Volume Calculations at a Glance:

1. Determine the final solder volume of the fillet:
   $Vf = 0.215(rr) \text{ x } (0.2234r+a) \text{ x } 2pi$
2. Determine the final solder volume of the plated-through-hole with lead in place:
   $Vpth = pi \text{ x } h\,[(RR) - (aa)]$
3. Determine the total final solder volume:
   $Vtot = (2 \text{ x } Vf) + Vpth$
4. Determine the amount of solder paste to be deposited:
   $Vs = 2 \text{ x } Vtot$
5. Determine the amount of solder paste that must be deposited on the surface of the board (the difference between the total volume required and the amount deposited in the plated-through-hole):
   $Vsurf = Vs - Vhole$, where $Vhole = pi \text{ x } (RR)\, h$
6. Determine the length and width of the stencile aperture:
   Length x Width = Vsurf/Stencil Thickness

a = diameter of contact /2 *for a circular contact*
a = square root of Length x Width/pi *for a rectangle contact cross section*
r = (solder pad diameter - contact diameter)/2
R = plated-through hole diameter/2
b = thickness of printed circuit board

Graphic presentation of the equations:

Solder Paste Volume Calculations at a Glance:

1. Determine the final solder volume of the fillet:

   $V_f = .215\, r^2 \times (.2234r + a) \times 2\pi$

2. Determine the final solder volume of the plated-through hole with lead in place:

   $V_{pth} = \pi\, h\, (R^2 - a^2)$

3. Determine the total final solder volume:

   $V_{tot} = (2 \times V_f) + V_{pth}$

4. Determine the amount of solder paste to be deposited:

   $V_s = 2 \times V_{tot}$

5. Determine the amount of solder paste that must be deposited on the surface of the board (the differance between the total volume required and the amount deposited in the plated-through hole):

   $V_{surf} = V_S - V_{hole}$, where $V_{hole} = \pi R^2 h$

6. Determine the length and width of the stencil aperture:

   $$\text{Length} \times \text{Width} = \frac{V_{surf}}{\text{Stencil Thickness}}$$

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a = diameter of contact /2 for a circular contact

$a = \sqrt{\frac{\text{Length} \times \text{Width}}{\pi}}$ for a rectangle contact cross section

$r = \frac{\text{solder pad diameter} - \text{contact diameter}}{2}$

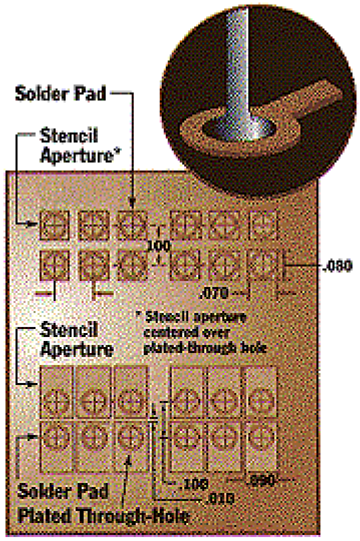
$R = \frac{\text{plated-through hole diameter}}{2}$

h = thickness of printed circuit board

The amount of solder paste to be deposited is roughly twice that needed for the end solder joint. Most solder pastes today have a high metal content, about 90% solids by weight, which equates to about 50% solder by volume. Other components include flux and viscosity-determining compounds.

The stencil aperture is determined from the solder volume calculations. Since the thickness of the stencil is typically fixed -- ranging between 0.004 and 0.008 inch -- the majority of the solder available for reflow is deposited in the plated-through hole. Thus the stencil aperture accommodates the remaining solder paste on the top of the board.

The length and width of the stencil aperture are usually larger than the diameter of the plated-through hole. Ideally, the aperture should be centered over the hole, although it may also be offset away from the connector centerline. The spacing between deposits should be less than 0.010 inch.



The preferred solder joints show consistent, voidless coverage. Stencil apertures can be centered or offset over the hole.

Test Before Using Sample soldering runs should be made to ensure that acceptable solder joints are being formed. Connector solder joints should adhere to Class 3 requirements of ANSI/J-STD-011 for soldered electrical and electronic assemblies. Class 3 joints require a 95% complete fillet and put strict limits on the kind and extent of voids in the joint. The preferred joint has the following characteristics:

- No void area or surface imperfections
- 100% solder fillet around the contact
- Solder covers the contact and feathers to a thin edge on the solder pad
- Solder coverage is neat and bright.
- Solder pad and contact are well wetted, and the contour of the contact is well defined

As useful as the calculated solder paste volume is, nothing beats confirmation of the accuracy of the stencil aperture and placement of the solder paste through actual soldered samples. Finally, the approach outlined here is not affected by the type of refold process -- vapor phase, infrared, or forced-air convection.