Solder Preforms in Electronic Packaging

How many times have you looked at a mixed technology assembly job and wished you could eliminate the wave soldering step? Printing paste over or near a through hole is one method that engineers try, usually with marginal results. Dispensing paste into a through hole is very difficult, and designing a stencil that allows paste to remain only on the plated via opening is also difficult at best.

A better solution is to use solder preforms to attach through-hole components to mixed boards. Solder preforms are precisely formed pieces of solder, available in a wide variety of shapes, sizes, alloys and fluxes. They are manufactured in large quantities, so their unit costs are low. However, they have very tight tolerances, typically measured in thousandths of an inch, so their dimensions (diameter, length, width and thickness) are very precise.

Preforms are typically made of 63/37 tin/lead solder, but many other alloys are also available for specific applications. Regarding their shapes, preforms are offered as washers, discs, rings, squares, rectangles, sleeves and washer arrays, which are linked shapes. They can also be externally coated or internally filled with various fluxes.

Working with Mixed Boards

Electronics assemblers working with mixed boards often ask the same questions. For example:

- I’m from XYZ assembly. I have a surface-mount board with one multiple pin through-hole connector. How do I design a solder preform that can be used with my surface-mount process and eliminate wave soldering or eliminate trying to print paste in a through hole?
- I’m using a paste in through-hole application, and I never get enough paste. How can I make sure I’m in compliance with the 75 percent solder volume requirement of IPC Standard B-610?
- I have a large surface-mount assembly that has one through-hole component, requiring wave soldering. Is there any way to eliminate the second thermal cycle required by wave soldering this board after I reflow the paste?

To answer these questions, the volume difference between the connector (or component) lead and the through hole must first be determined. This procedure is quite straightforward, especially if both the pin and the through hole are round. The following formula is used (Figure 1):

$$\pi r_1^2 h - \pi r_2^2 h$$

where $r_1$ is the radius of the through-hole, $r_2$ is the radius of the lead pin and $h$ is the board thickness. IPC Standard B610 calls for at least 75 percent of this difference to be filled with solder and at least 270° of coverage out of a possible 360°.

Most customers use 100 to 110 percent of the required solder volume, and they would rather have 360° coverage with no pinholes. Of course, issues always arise that make this simple calculation slightly more complex.

For example, a customer may want to see a nice, shiny fillet on the bottom side of the board. The answer here is to assume that the fillet is a...
cone and calculate the additional volume required. The potential problem is that too much solder volume could make it more difficult for the component or connector to set down cleanly on the topside of the board. Also, additional solder volume requires a slightly slower conveyor rate in cases where the solder preform reflow is the process rate controller. Such cases are rare, but possible.

If the customer still wants the additional volume, simply add $\frac{1}{3}\pi r^3$ to the above volume calculation, with $r$ as the radius of the through hole (Figure 2).

If the through hole is an oval, the volume calculation becomes $\pi r_1 r_2 h$, where $r_1$ is the larger radius of the oval and $r_2$ is the smaller radius (Figure 3).

Of course, many lead pins are rectangular, so the pin volume calculation becomes $s_1 s_2 h$, where $s_1 = s_2$ in the case of a square pin.

Now that the required volume is known, a preform size must be selected. In most cases, a washer configuration works best. A preform washer is stamped from solder foil and has no seam. It also has a flat profile, versus a ring made from wire solder, and the component is closer to its final location when placed onto a washer (Figure 4).

The most important feature to select next is the inner diameter (ID) of the washer. The washer must fit cleanly over the pin, including the maximum diameter of the pin if all maximum tolerances are stacked; the pin diameter and double the plating thickness.

If the pin is a square or rectangle, the Pythagorean theorem must be used to calculate the minimum diameter of the pin if all maximum tolerances are stacked; the pin diameter and double the plating thickness.

Also, if the preform is to be precoated with dry flux, about 0.002 in. must be added to the minimum ID to account for the flux coating thickness. After all of these factors are considered, add 0.002 to 0.003 in., to make the preform placement easier.

Now that the volume and ID have been determined, the outer diameter (OD) and the thickness of the washer must be determined. The minimum OD is about 0.005 in. greater than the ID of the through hole. The maximum ID is about 0.012 in. less than the pitch of adjacent lead pins, to prevent bridging.

To pick the best size, use a preform manufacturer’s chart that lists the washer sizes for which in-house tooling is available. Once the ID and OD are selected, the thickness is calculated as follows:

$$V_{\text{required}} = \pi \times h \times (OD/2)^2 - \pi \times h \times (ID/2)^2$$

This simplifies to:

$$\frac{1}{4} \pi \times h \times (OD^2 - ID^2)$$

**Preform Placement**

Now that the correct size has been calculated, the customer asks for a free sample. Because of the huge number of lead pin sizes and shapes and the infinite possibilities of through-hole via diameters, no standard size exists. Fortunately, mass production of a single size is relatively easy and only takes a couple of weeks.
With the right size preform, how can they be placed? Three methods are commonly used: fixtures, pick-and-place and continuous arrays.

The first method is to have a fixture, or series of fixtures for large volume applications, produced. The fixture places the preforms in the pattern equal to the connectors being placed. The depth of the fixture openings should be 105 to 125 percent of the preform's thickness. The OD of the fixture opening should be 0.005 to 0.010 in. greater than the OD of the washer.

A series of these fixtures can be mounted to a vibratory table (shaker box). The preforms are poured onto the series of fixtures, and the random vibration of the shaker box along with gravity allows exactly one preform to drop into every drilled opening and lay flat.

The excess preforms are wiped away from the fixtures using a straight edge or a soft brush. At this point, the 105 to 125 percent depth feature comes into play, as only one preform can be in the fixture opening, but the desired preform must be below the surface of the fixture.

The connector or leaded components are then matched to the preforms previously placed in the fixtures. Because eutectic 63/37 Sn/Pb solder is relatively soft, it will tend to bind to the pins after they have been mated, especially if the preform washers are flux coated.

The components or connectors can then be placed into the circuit assembly using the customer’s favorite placement method, prior to solder reflow.

The second method for preform placement is to deliver them with pick-and-place equipment from a tape-and-reel package. Solder paste is printed at the through hole, then the solder washer is placed into the paste. Solder paste affords some tack to secure the preform prior to insertion of the through-hole component.

The third placement method is to have a pattern of washers stamped in a continuous array. This method works well if the linked washers are in one or two rows. However, the reflow profile can be difficult to adjust if three or more rows are used.

The links in the center of the array will reflow after the outer washers have melted. When enough heat has been applied to reflow the center links, oxidation will affect the outer washers. In addition, linked arrays cannot be flux coated as easily as individual washers. Linked arrays are best suited for very high volume applications, where the expensive tooling costs can be readily amortized.

**Conclusion**

Solder preforms allow an assembly engineer to replace difficult paste in through hole processes. They improve finished assembly quality and simplify the inspection of uniform solder joints. Preforms can be designed with the exact size, shape and flux content. This technology assures compliance with the requirements of IPC Standard B610 for solder volume and pin coverage. Also, semi-automatic and automatic processes are available to place solder preforms on thousands of pins per minute. When correctly designed and applied, solder preforms are highly cost-effective, creating extremely high yields of sound, reliable solder joints.

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