

Applications of Solder Fortification with Preforms

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ABSTRACT

Although many have predicted the demise of through-hole components, they are alive and well with tens of billions assembled each year. In many cases these components are assembled by wave soldering. However, in many mixed product technology (i.e. SMT and through-hole on the same board) products, it makes sense to consider assembling the through-hole components with the pin-in-paste (PIP) process. PIP has been successfully used for several decades now; however in many cases it is not possible to print enough solder paste to obtain an acceptable solder joint. In addition to this “solder starved” condition, the large quantity of solder paste used to form the through-hole joint, results in excess residual flux. This residual flux can lead to difficulties in in-circuit testing and potential surface insulation resistance concerns.

In light of the above need, solder preforms have been developed. These slugs of solder typically come in the same sizes as 0402, 0603, and 0805 passive components. The solder preforms are placed by the component placement machines onto the solder deposit. This additional solder assures that an adequate solder joint is formed with a minimum of solder paste and its residual flux.

Although PIP was an early application of solder preforms, more recently other “solder starved” applications have emerged such as radio frequency (RF) shields and connectors. In addition, the use of ultra thin stencils in the assembly of miniaturized components can result in some other components being solder starved and hence, are candidates for solder preforms.

This paper will cover the design and assembly techniques for using of solder preforms in the “solder fortification” needs described above. Several successful applications will be presented. In some of these applications, defects were reduced by 95% after implementing solder preforms.

THE PIN-IN-PASTE PROCESS

Through-hole technology still remains important in state-of-the-art electronics. There are several reasons for this situation, one being that some components or connectors might only be available in through-hole, but more likely the mechanical strength of through-hole connections is critical for long-term reliability in many applications. As an example, a laptop PC has multiple USB, power, video, audio, and internet connectors. Many of these connectors need the strength of through-hole connectivity to withstand the multiple plugging and unplugging in their service life. Often these connectors are few in number and a full wave solder process to assemble them may not make economic sense. In such situations, as an alternative to wave soldering, selective wave soldering may be an appropriate choice, or perhaps the pin-in-paste (PIP) process.

The pin-in-paste process involves printing solder paste near or over the through-hole. The through-hole component is placed and reflow soldered with the SMT components. The development of an effective PIP process is discussed in references 1 and 2.ⁱⁱⁱ PIP is usually performed with no-clean solder paste.

In many applications, PIP has several challenges. One being that so much no-clean solder paste has to be used to obtain an effective solder joint, that excessive residual flux can make in-circuit electrical testing (ICT) difficult. Figure 1 shows a through-hole pin with excessive flux and Figure 2 shows an ICT probe fouled with residual flux from a PIP process.

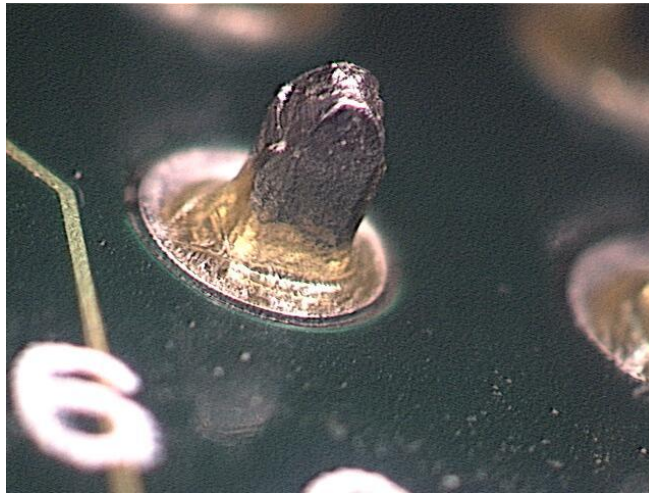


Figure 1. Excessive residual flux on a through-hole pin from the PIP process.

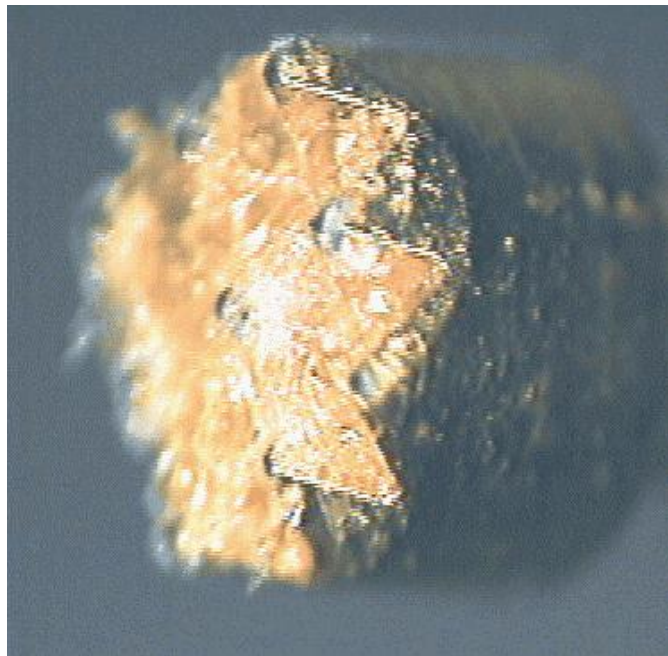
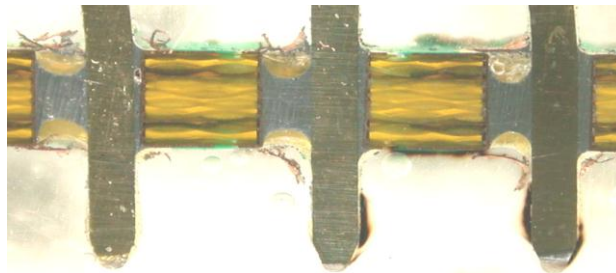


Figure 2. An in-circuit test probe fouled with residual flux.

Another challenge of the PIP process is solder starvation. Solder starvation occurs because it is often not possible to print enough paste to form a complete solder joint. An example of this situation is seen in Figure 3. Although the solder joints in Figure 3 may barely pass ANSI/J-STD-001C, many assemblers would be dissatisfied with the quality of and potential reliability issues with such solder joints. The use of solder preforms to support the PIP process can mitigate the problems shown in Figures 1 – 3.



**Figure 3. Solder starvation in PIP processed solder joints.
Note the excess residual flux also.**

Solder preforms are stamped from rolled solder ribbon to the desired XY dimensions. Preforms are available in numerous shapes, sizes and alloys and are specifically designed to deliver an exact quantity of solder to a desired location. Examples of preform shapes can be found in Figure 4.



Figure 4. Solder preforms come in many shapes and sizes.

Typically solder preforms to support the PIP process are rectangular in shape and are the size of common passive components (e.g. 0201, 0402, 0603, etc) so that they can be placed by component placement machines. These preforms come in tape & reel feeder packaging as shown in Figure 5.



Figure 5. PIP preforms come in tape & reel feeder packaging.

The solder preform process for through-hole connectors on mixed technology boards utilizes current equipment and process expertise. A typical example follows:

Step 1: Solder paste is printed at the site of the connector pin. The solder paste deposit may be an overprint to provide a wicking path for the preform. For example, a preform can be placed in the overprint portion and during reflow the preform solder will wick to the pin. Additional flux is not required because sufficient fluxing activity is available in the solder paste.

Step 2: Preforms are placed in the solder paste using automated placement equipment. The preform shape may be a washer or a 0603 segment as depicted in Figure 6.

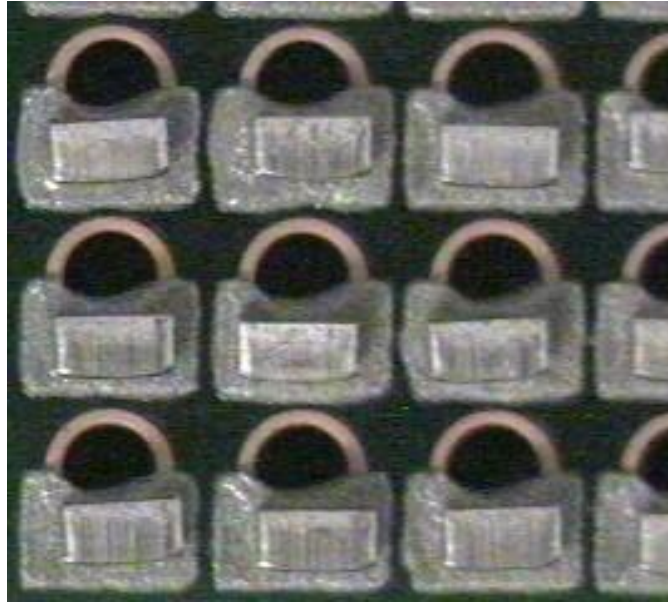


Figure 6. Solder paste is printed and the preform is placed on the paste with a component placement machine.

The process used in Figure 6 was able to achieve excellent results with the solder preform + solder paste solution. The benefits were:

- Full barrel fill that is easily inspected
- No loss of through-put
- Elimination of step stencil with reduced defects at fine-pitch devices
- Reduction of overprint which eliminated solder beads and balls
- Increased flexibility for future designs

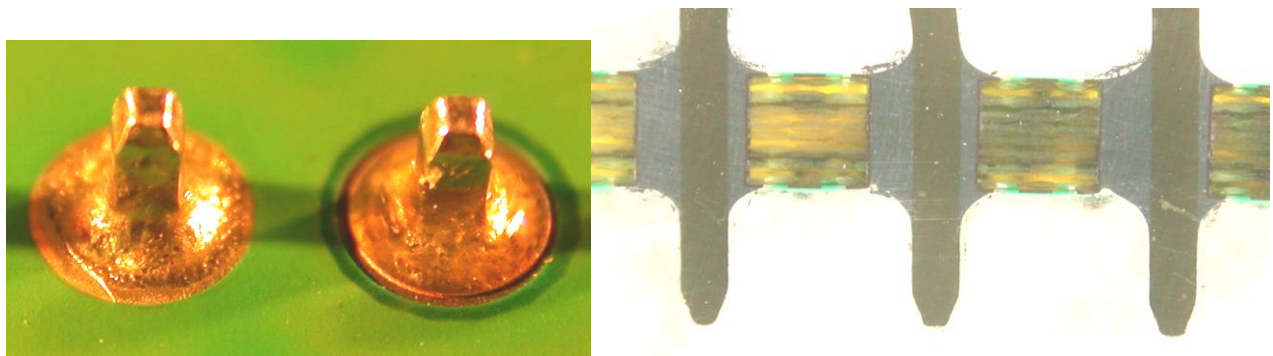


Figure 7. The solder preform + solder paste solution delivered excellent through-hole solder joints.

Figure 7 shows the results of this assembly process. Note the good hole-fill and ease of inspection of these solder joints.

While PIP was an early adaptor of preforms, more recent solder fortification applications may actually be more popular. Two of these applications follow.

GROUNDING OF MOBILE PHONE SHIELDS

Most of us probably don't think about it, but a mobile phone is really a radio. As a radio, it is very susceptible to stray electromagnetic (EM) waves or electrostatic discharge (ESD). These threats could potentially cause a malfunction. In light of

this concern, mobile phone designers encase the most EM/ESD sensitive components in the mobile phones in Faraday shields. See Figure 8. To assemble these shields to the PWB, solder paste is printed onto the receiving pads and the shields are soldered during the normal reflow soldering process.

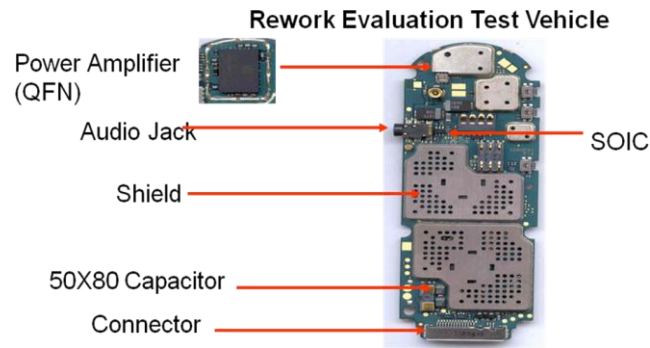


Figure 8. A mobile phone PCB showing a Faraday shield.

Due to the miniaturization and increased functionality of mobile phones, in some designs, it is difficult to print enough solder paste to electrically connect the shield to the PWB pad so that the shield can successfully perform its ESD and EM protection duties.

Solder preforms were proposed as a potential solution to such solder starved conditions. In these processes, the preforms are placed by the component placement machine. See Figure 9.

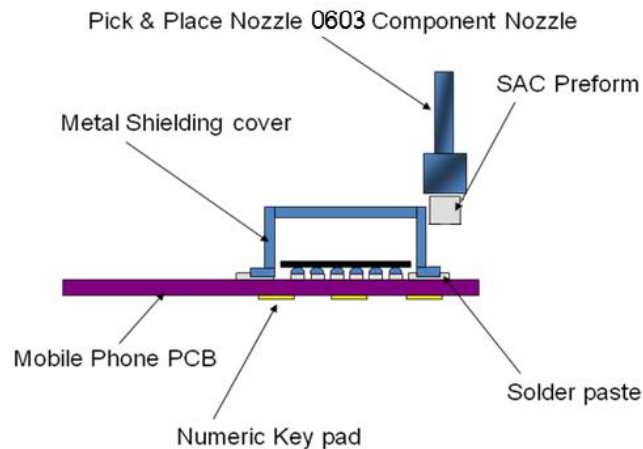


Figure 9. The SAC preform is placed by the component placement machine.

The SAC preform is typically the size of an 0603 passive component. The volume of this preform should be calculated to deliver the needed amount of solder. See Figure 10.

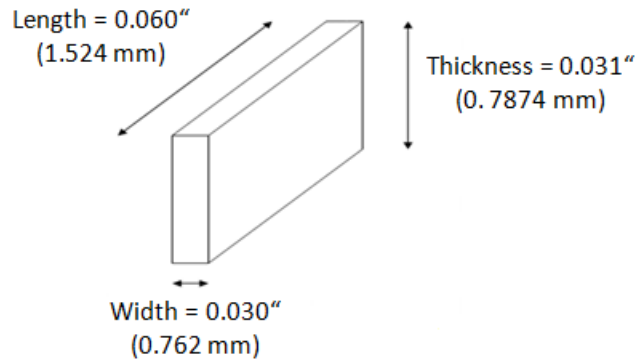


Figure 10. The 0603 preform used in the application as discussed in the text.

Tape & reel feeder packing is typical used in this application for the preforms. The assembly process flow for this application is seen in Figure 11.

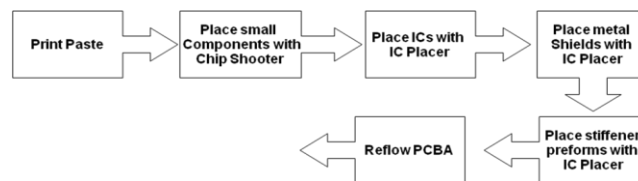


Figure 11. The process flow for shield assembly with solder preforms.

After the solder paste is printed, the passives and small components are placed by the chip shooter. The IC placer places the ICs and then the shields. The solder preforms are then placed by the IC placer. After this step, the PCBA goes to the reflow oven.

The preforms cost about \$0.027 (US) apiece in quantities of 25 million. It is possible, but not likely, that the placement of the preforms could slow the IC placer down. These types of applications have been implemented with high yields and reliability.

In conclusion, solder preforms enable a low cost, reliable solution to solder starvation in Faraday shield assembly for mobile phones. In addition, the process is part of the in-line PCBA assembly and the end result is not visible to the end user.

CAPACITOR TERMINAL APPLICATIONS

Capacitor terminals can also experience solder starvation. In one such application, 0603 size preforms were placed near the capacitor terminals. In this application, the number of solder starved related defects was reduced by 95% after using preforms.

INTEGRATED PREFORMS

Up to this point the preforms mentioned have been separate units of solder. Each provides the same volume of solder where it is required. An Integrated Preform takes the solder fortification idea to a new level. These unique preforms are specifically designed to fit a multiple pad or pin component. When positioned into previously placed solder paste, this Integrated Preform will provide that extra amount of solder at one time.

These preforms units are connected with a small strand of solder that is designed to be very narrow. During reflow, the paste and Integrated Preform reflow along with the strands that hold everything together. This melting of the strands is essential because bridging in the final product cannot be tolerated.

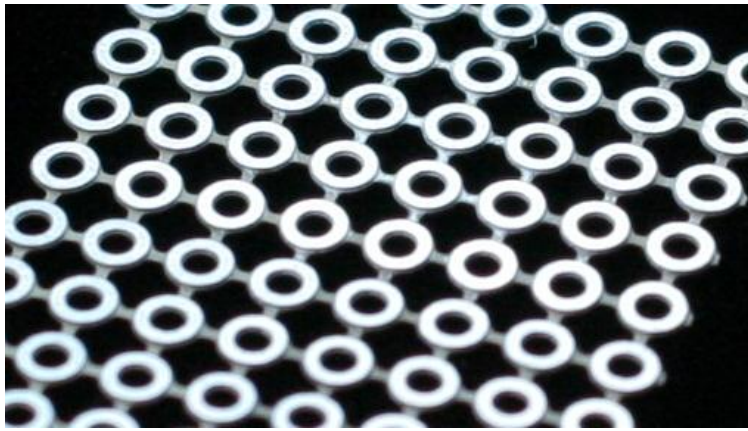


Figure 12. Typical Integrated Solder Preforms

The shape of the Integrated Preform unit is dictated by the configuration of the component being soldered. The Integrated Preform can be placed on the board into the paste or placed on the component and then inserted onto the board into the paste. Either way, it takes less than 15 seconds to place an Integrated Preform. The method of reflow is the same whether a separate preform or an Integrated Preform is used to provide that extra volume of solder.

Integrated Preforms can also be used as a stand-alone source of solder without solder paste. If used in this manner, flux such as a tacky flux, is commonly utilized. The Integrated Preform can be fluxed and placed on the component or the substrate can be fluxed and the component placed on the Integrated Preform. Care must be taken to make sure that the preform is flat against the substrates being joined. Uniform heating is also essential. If non-uniform heating is used, the Integrated Preform will melt in certain areas and not in others. When this happens, the heat will melt one portion of the Integrated Preform and when an adjacent area begins to melt, the mass of already molten solder will cause the newest melted solder to wick over to the larger solder mass. Vapor Phase reflow is ideal for Integrated Preforms because it is an excellent source of even temperature so all of the preforms within the Integrated Preform unit melt at the same time, reducing the chance of solder robbing caused by non-uniform heating.

Integrated Preforms and individual solder preforms come in all of the common alloys typically utilized on printed circuit boards. So, whether you need Sn62 or Sn63 or a lead-free SAC alloy, each can be made into a preform to fit your soldering needs.

The separate preforms can be manufactured into washers, discs, rectangles, and squares. The sizes and thicknesses will vary but each can be packaged in tape & reel for easy placement into the overprinted paste to give that extra volume of solder. Your solder supplier may have the shape in the size you need in their die library. The thickness of the preform can then be determined to yield the correct volume of solder required.

Integrated Preforms are custom-made to fit a specific application. Each is designed to deliver the right amount of solder, whether it is a cluster of washers, rectangles, squares, or discs, or any combination thereof. These clusters are etched, and because of this, the film tool can be designed to make any size and combination of shapes.

Washers are the most typical shape, but pads are also sometimes used. A pitch of 0.100" is common but other pitches of 2mm, 0.050", and 0.025" are also requested. The available maximum thickness of an Integrated Preform is 0.018". This thickness limit allows for a fine definition of the connecting strand, which is essential for the uniform separation of the solder units to insure that bridging will not occur.

Integrated Preforms are not typically packaged in tape & reel due to their size and sometimes fragile construction. Instead, the Integrated Preforms are layer-stacked in sheets, separated with lint-free paper and stiff backed spacers. Each sheet will contain several units of Integrated Preforms that can be easily cut apart and used in the soldering application. Many times, the sheets contain rows of washers or pads in both vertical and horizontal directions, rather than discrete units of connected shapes. The spacing between solder units match the pitch of the holes or pads on the substrate so, when it is cut it can be easily placed with perfect alignment.

When a component has very long leads, Integrated Preforms can replace the current method of soldering by hand, which can be difficult, especially when the leads have a fine pitch. Integrated Preforms can be placed on the top side of the board flat against the component and the pads, or inserted onto the pins that protrude through the board once the component has been

mounted. Once again, the preform needs to be placed flat against the back of the board. This flatness insures that the solder will be evenly dispersed as required during the reflow process.

If Integrated Preforms are used in conjunction with paste on the same component, no flux is required. However, if Integrated Preforms are used alone, an appropriate flux must be used to remove oxides and insure excellent wetting where required. It is important to note that the connecting strands also need to be fluxed because they need to melt at the same time, if not a little before, the connected solder preforms. If solder paste is also being used on the board to attach other components, the flux placed on the preforms must be compatible with the flux that comprises the flux vehicle of the paste. That way, the same cleaning method, or no cleaning method will be consistent throughout the assembly.

If Integrated Preforms are to be placed on the component and then inserted into the board, there is some apprehension that the preform will fall off or partially slip from the pins. To eliminate this concern, a small tongue can be designed into the ID of the washers so this solder protrusion will touch the pins and, through friction, will hold the preform in place when it is inverted during placement. The same holds true if the Integrated Preform is placed on the bottom side of the board onto the pins of a through-hole component. The tongue will hold the preform up close to the bottom side of the board insuring excellent reflow and uniform distribution of the solder. The pins generally heat up first during reflow, so the tongue actually has a dual role of not only holding the preform in place, but also helps to transmit the heat from the pin to the washer to help speed up the reflow.

If the same alloy is utilized (less than 70% lead content), the shelf life of Integrated Preforms is the same as individual preforms. Generally, the shelf life is 2 years from date of manufacturing when stored in the original unopened container in a nitrogen dry box.

CONCLUSION

Solder preforms can be an economical way to solve solder starved conditions in various types of SMT assembly applications. It is always best to consult with the Technical Support Team at your solder supplier to be sure that the correct solder, solder form, and flux best suit your application.

ACKNOWLEDGEMENT

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REFERENCES

ⁱ Lasky, R. C., Jensen, T., *Practical Tips in Implementing the "Pin in Paste" Process*, at SMTAI, Chicago, IL, Sept 2002.

ⁱⁱ Berntson, R. B., Lasky, R. C., Pfluke, K. P., *Through-Hole Assembly Options for Mixed Technology Boards*, SMT Magazine, August 2004.

APPLICATIONS OF SOLDER FORTIFICATION WITH PREFORMS

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Solder Preforms

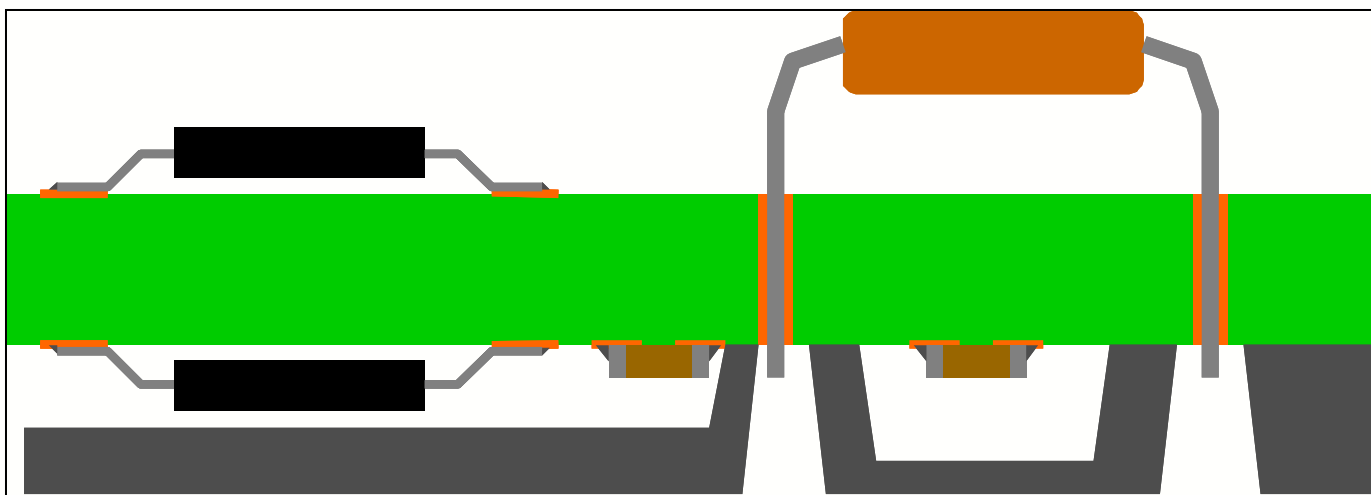


Solder Fortification Overview

- Pb-Free Wave Soldering Challenges
- Implementing a Pin-in-Paste Process
- Optimizing PIP w/ Solder Preforms
- Case Study
- Other Fortification Examples
 - Grounding of Mobile Phone Shield
 - Large Capacitors



Traditional Mixed Technology Process



1. Bottom side surface mount assembly
2. Top side surface mount assembly
3. Palletize and place through hole components
4. Wave solder

Pb-Free Wave Challenges

- High Pb-Free Ingot Costs
- Slow Wetting Speed of Pb-Free
- Hole Fill
- Sn Corrosion of Stainless Steel



The Pin in Paste(PIP) Process

Definition: Pin in paste is the utilization of surface mount techniques to assemble through hole components on mixed technology PCB's.

- Reduction in process steps
(eliminate wave)
- Cost reduction
- Yield improvement
- Reduction in inventoried materials
(no bar or wave flux)



PIP Stencil Design Calculation

1. Determine the quantity of solder necessary to form an acceptable joint.
2. Determine how much solder paste is necessary to form that acceptable joint.
3. Approximate the amount of hole that the solder paste will fill during printing
4. Determine the appropriate stencil design to deposit the necessary amount of solder paste.

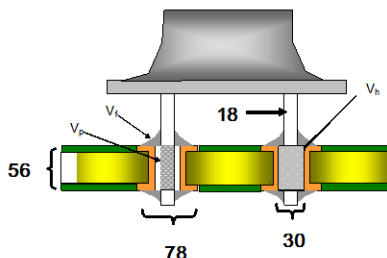


Sample Calculation

Solder Paste Volume Calculation

Parameters (mils)

- Solder paste reduction factor = 0.5
- Printed wiring board thickness = 56
- Component pin diameter = 18
- Through hole diameter = 30
- Solder pad diameter = 78

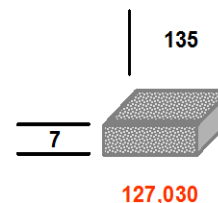


- $2V_f$ (fillet for 2 sides) = 38,181 cubic mils
- V_h (hole volume) = 39,584 cubic mils
- V_p (pin displacement) = 14,250 cubic mils
- V (solder volume) = 63,515 cubic mils
- V_s (paste volume) = 127,030 cubic mils

Stencil Aperture Design Example

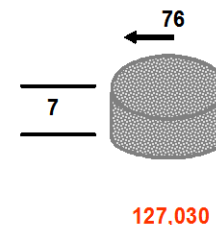
Square aperture side

- $(V_s / \text{stencil thickness})^{0.5}$
- V_s (paste volume) = 127,030 cubic mils
- Stencil thickness = 7 mils
- Aperture side = 135 mils



Circular aperture radius

- $r = (V_s / (\text{stencil thickness} \times \Pi))^{0.5}$
- V_s (paste volume) = 127,030 cubic mils
- Stencil thickness = 7 mils
- Aperture radius = 76 mils



It is essential to understand the area restrictions and thickness restrictions...One of these variables must be a constant.

PIP Stencil Design: The Easy Way

Microsoft Excel - StencilCoach.xls [Read-Only]

File Edit View Insert Format Tools Data Window Help

Arial 10 B I U

I46 =

$V_{\text{solder}} = 2V_f + V_h - V_p$

V_f = Fillet Volume (Pappus-Guldin)

V_h = PWB Hole Volume

V_p = Pin Volume

Inputs		Outputs	
Solder Pad Diameter (mil)	82	$V = 2V_f + V_h - V_p$	Cubic Mils
Pin diameter mils	20	V_f	21972.560
PTH diameter mils	32	V_h	48254.863
PWB Barrel Length mils	60	V_p	18849.556
Paste Reduction Factor	0.5	V	73350.427
Square Pin?		Solder Paste Volume Needed	146700.854
Length - mils	18	Stencil Parameters	
Width - mils	22	Stencil Thickness - mils	8
Equivalent Pin Dia mils	22.454	Side: If Square Aperture - mils	135.416
		Radius: If Round Aperture - mils	76.401
		Rectangular? If First Side is	100
		Second Side should be (mils)	183.376

INDIUM CORP

Standard Apertures / Passive Apertures / Pin-in-Paste Apertures /

Draw - AutoShapes -

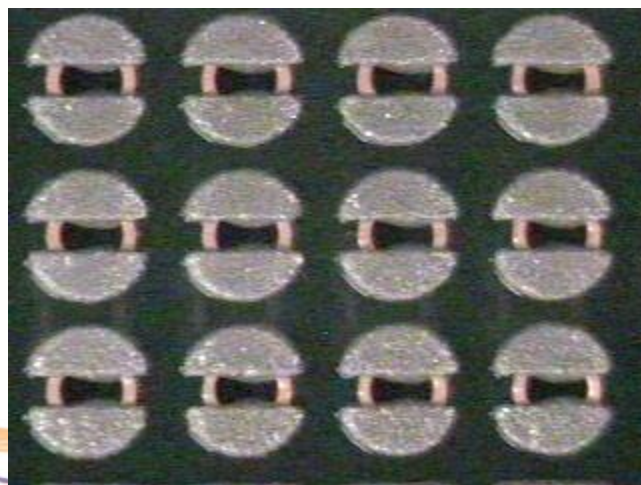
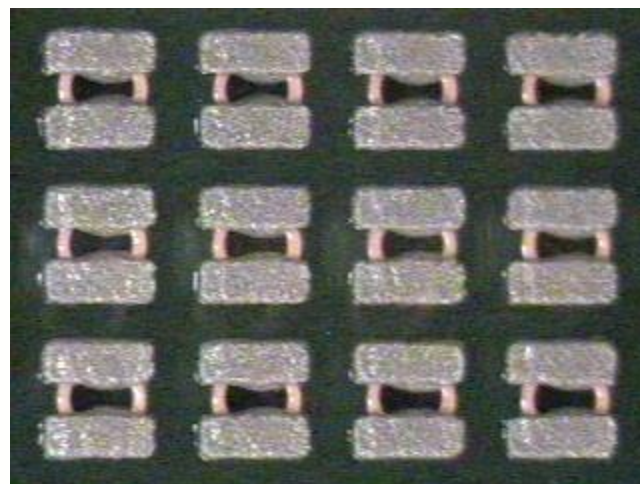
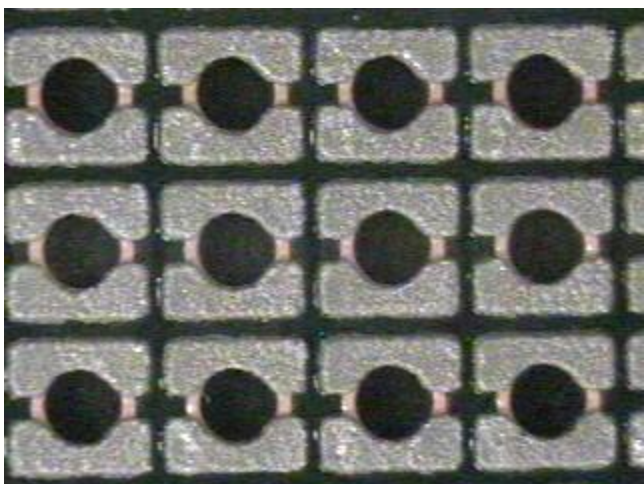
Ready

NUM

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Indium Corporation developed StencilCoach™ software to perform all of the calculations necessary to determine the ideal stencil design.

Common PIP Stencil Designs

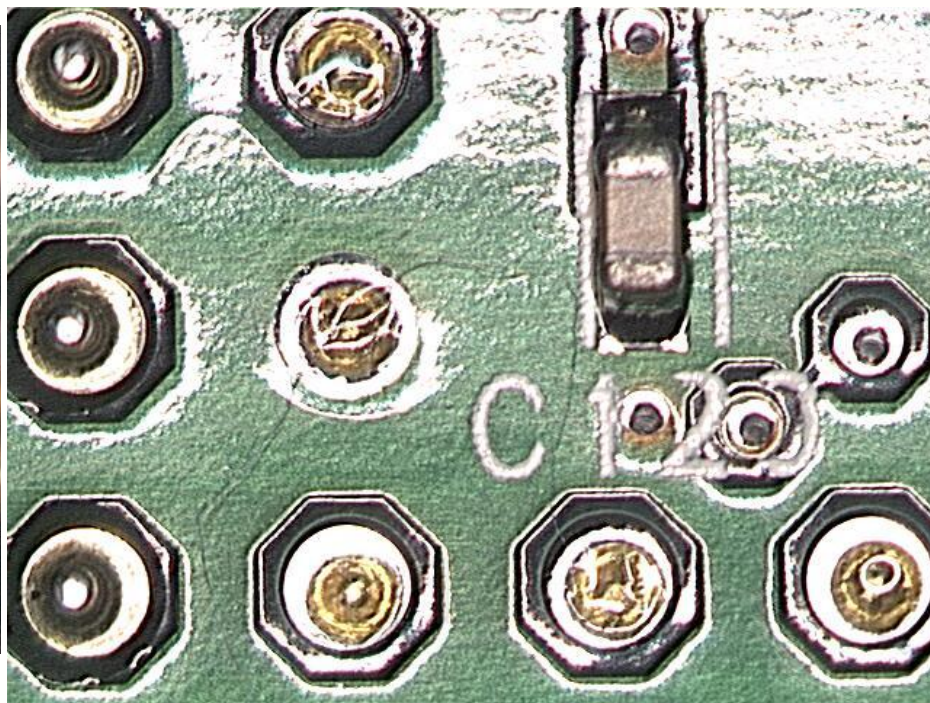


Main PIP Issues

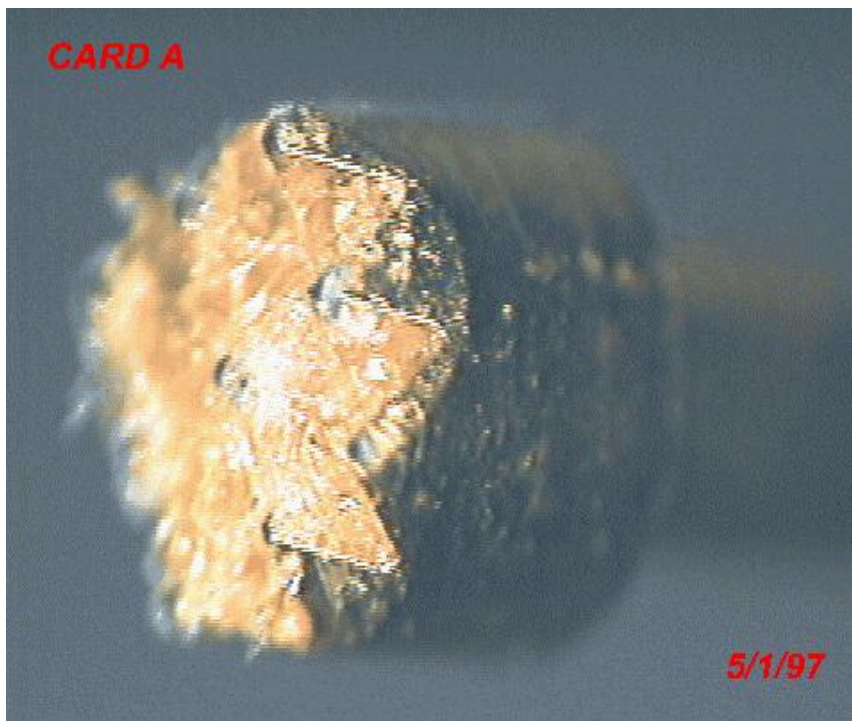
- Quantity of Flux Residue
- In-Circuit Testing
- Barrel Hole Fill



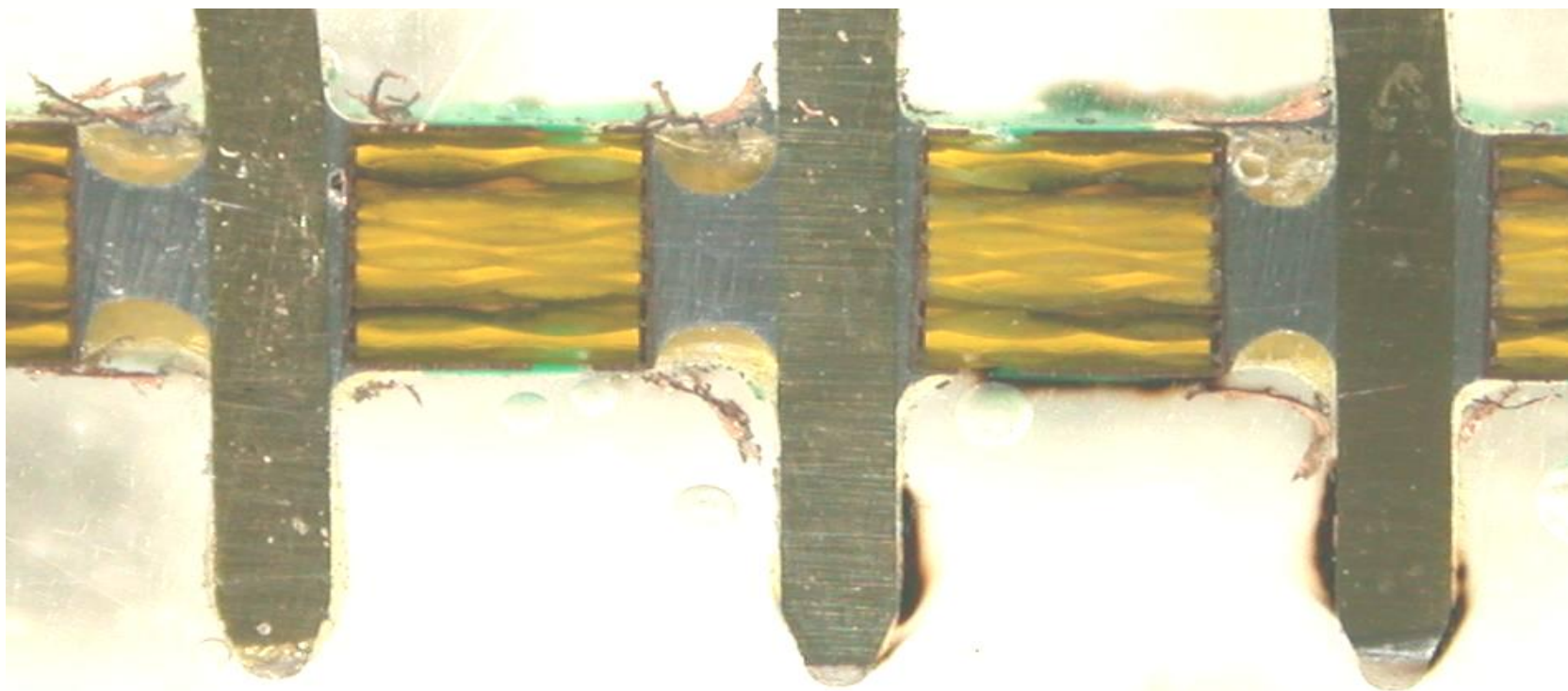
Solder Paste is 50% Flux



ICT: A Potential PIP Drawback?

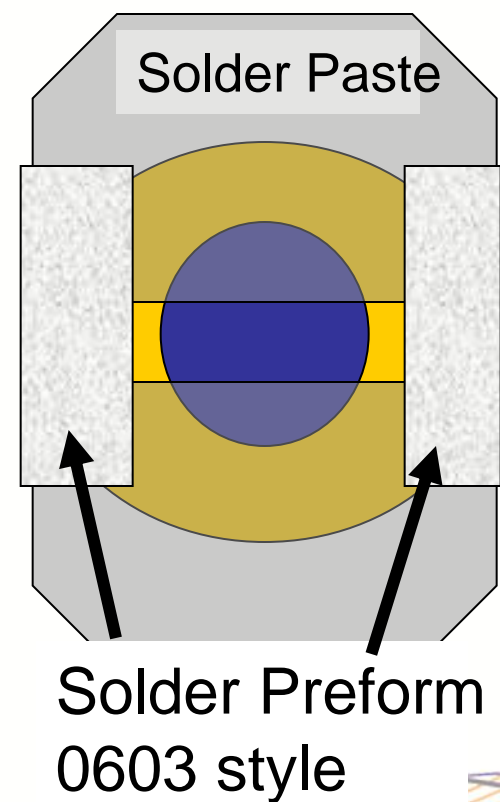


Poor Hole Fill: 5-mil Stencil



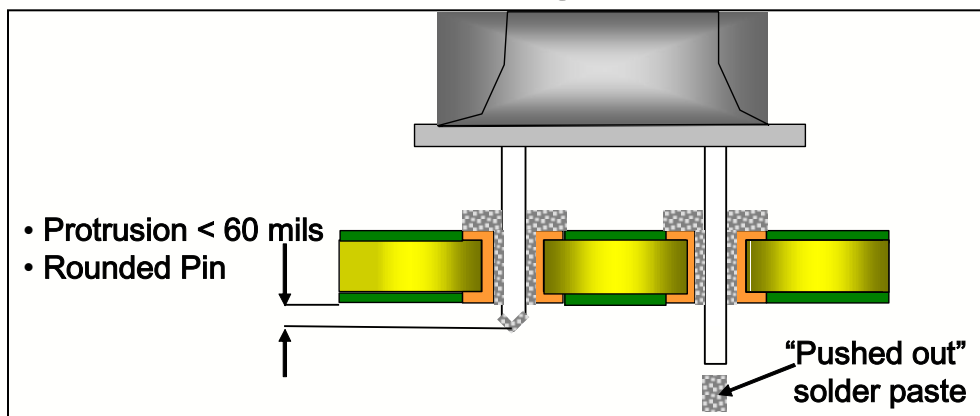
PIP w/Preforms is the New Option

- Sufficient solder volume to promote high-reliability
- Can utilize existing equipment
- Minimizes flux residue
- Eliminates step stencils
- Potential cost savings



PIP Component Selection

- High Temperature Capabilities
 - Reflow ovens subject components to much more heat than wave
- 60 mil Protrusion Maximum
- Hole should be 0.1 to 0.25 mm larger in diameter than pin
- Rounded Leads

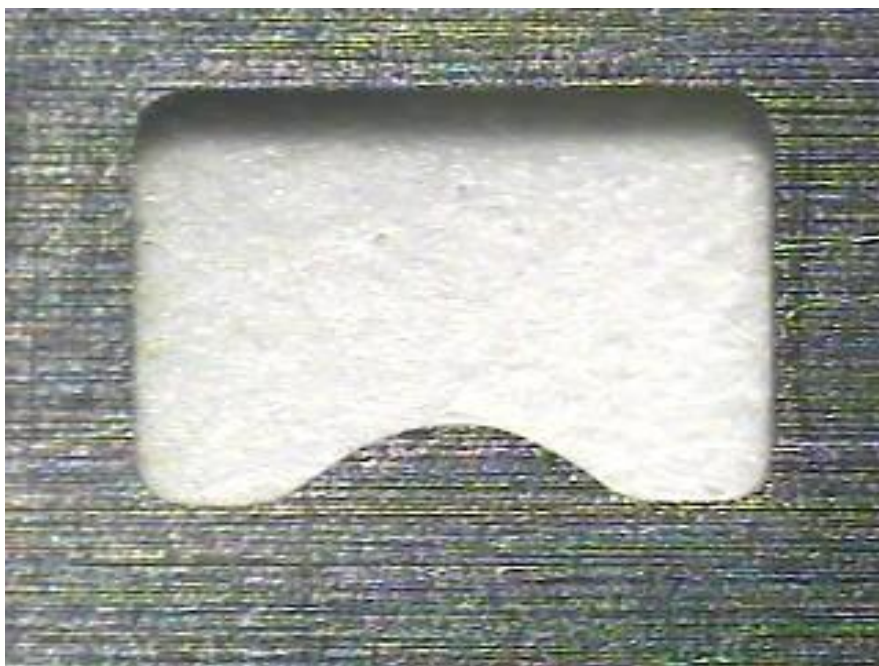


Proof of Concept Study

- Pin In Paste
- Solder Preforms In Paste
- No-Clean Solder Paste; Type 3
- Sn95.5 Ag3.8 Cu0.7
- OSP Finish
- NiAu Leads

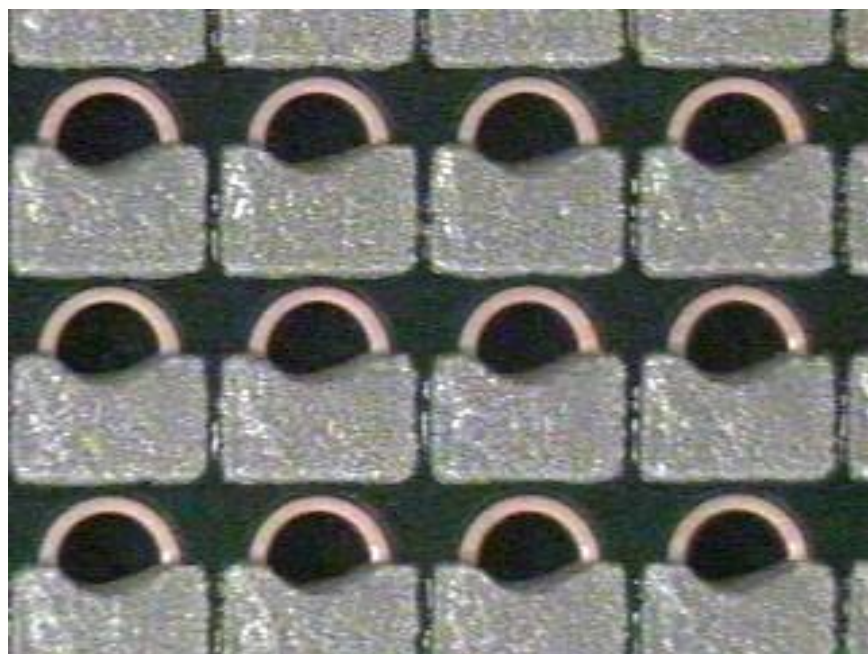


Stencil Design



- 6 mil stencil
- .0915" X .0465"
- Stainless Steel
- Laser Cut

Printing

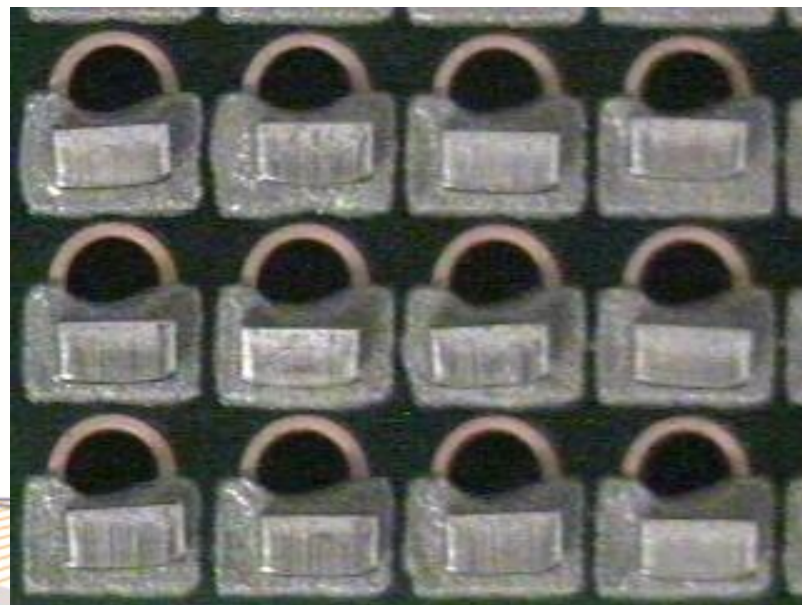


- Board ID = .0475"
- Board Thickness = .062"
- Offset Printing

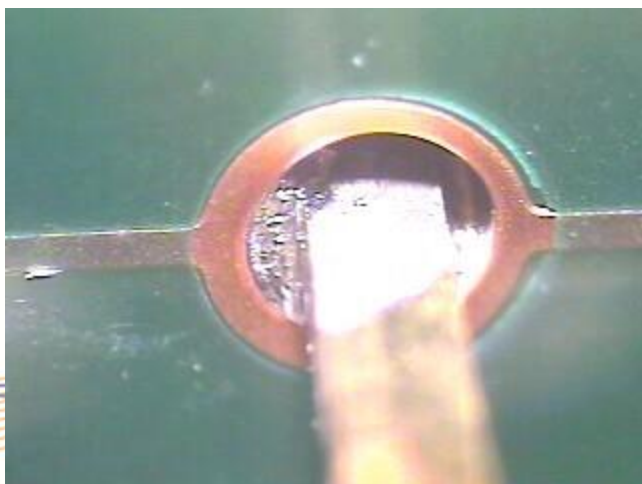
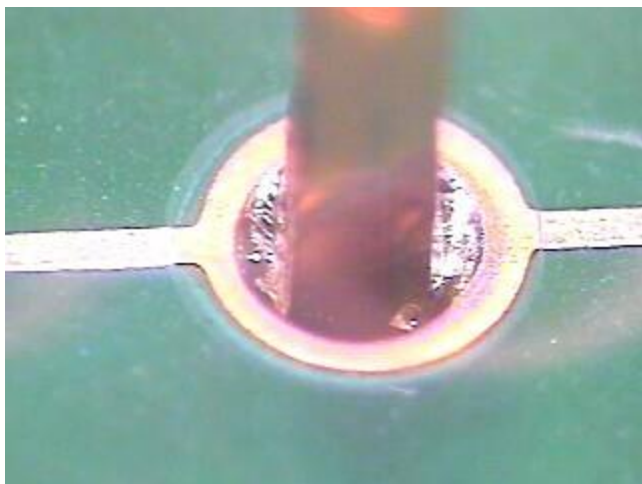
Solder Preform Addition



- Preforms are packaged in Tape and Reel
- “0603” size
- Pick and Place equipment

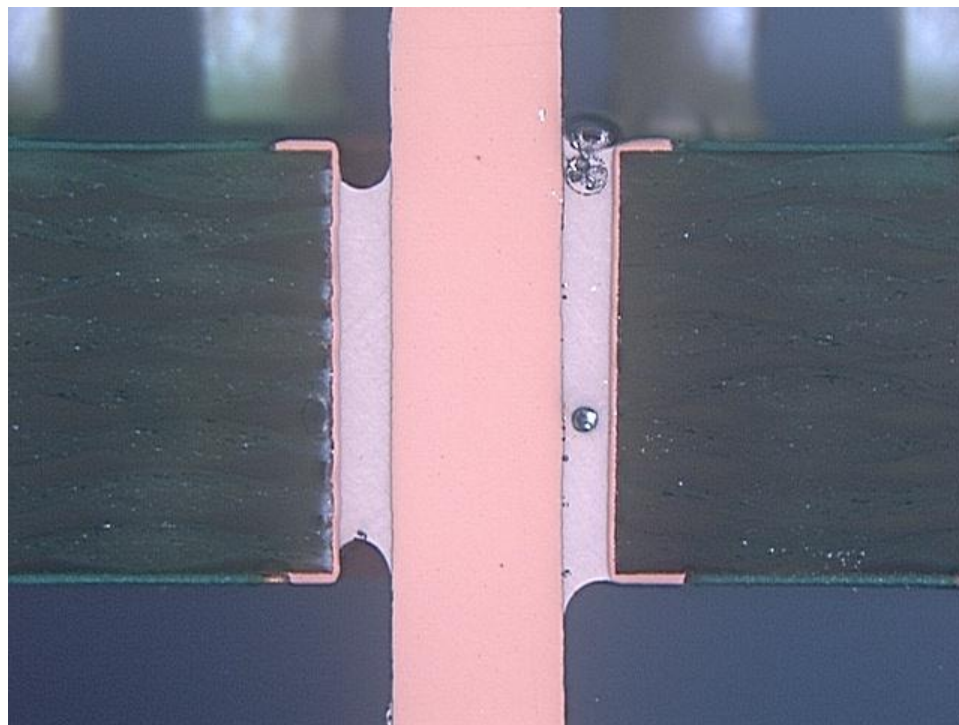


Bottom Side PIP



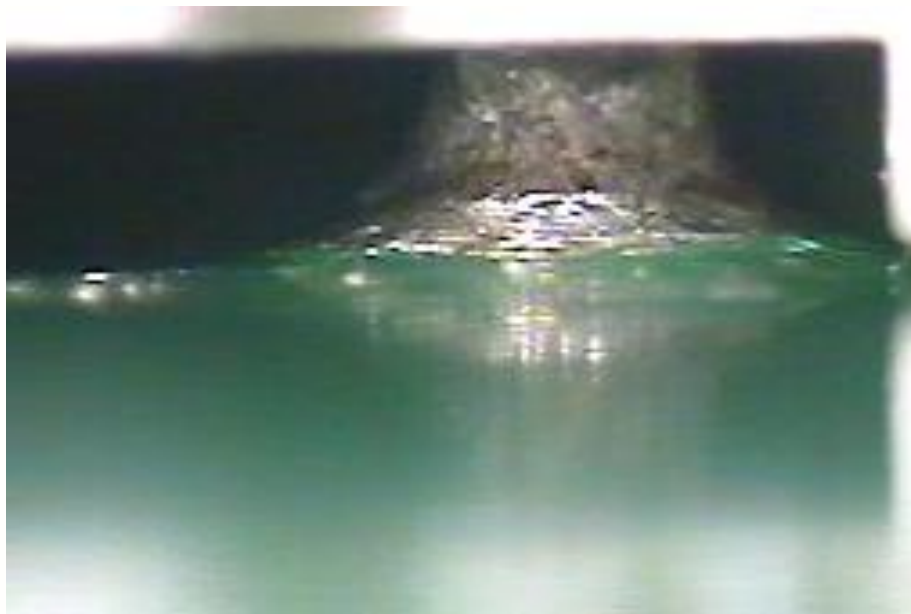
- Paste Only
- No fillet
- Lack of Solder Volume

Cross Section PIP



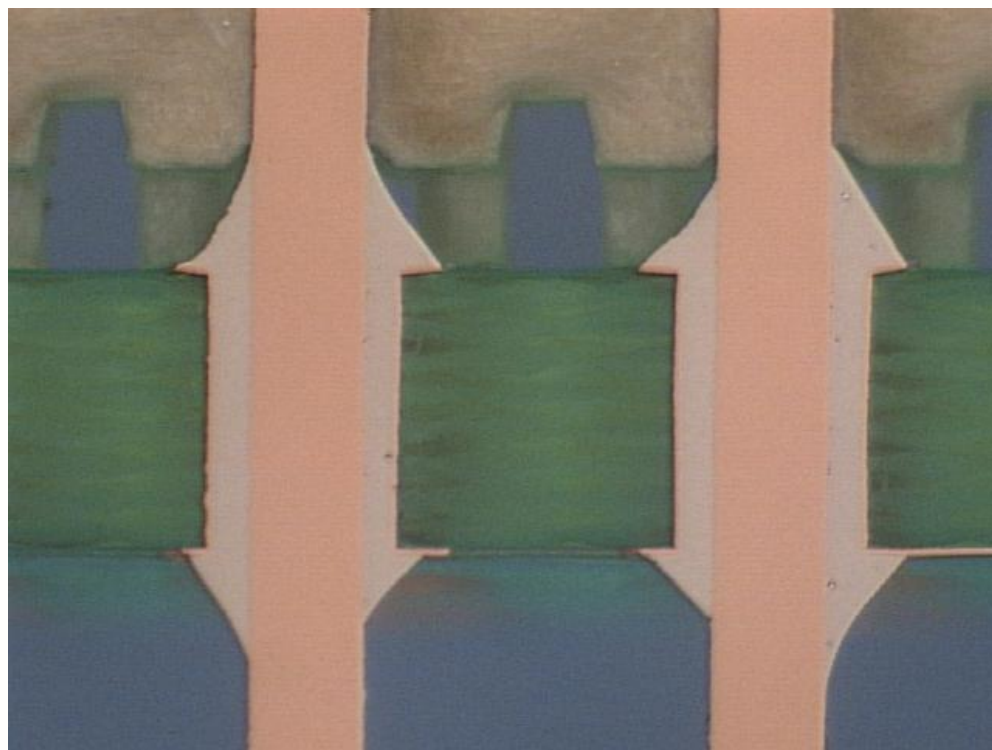
- **Solder Paste only**
- **Would pass IPC-B-610 Class 3 specifications**

Top Side Fillet PIP w/Preform

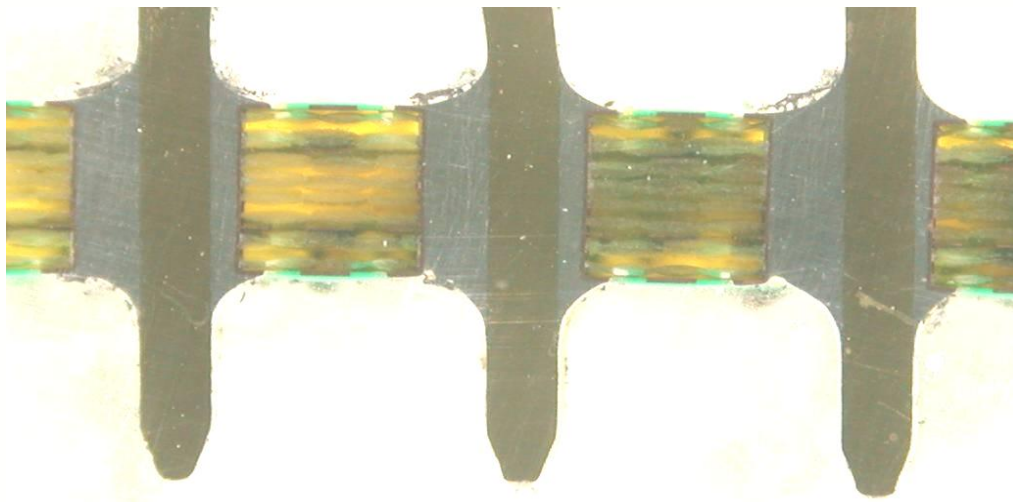


- Proper standoff height
- Top side of board exhibits acceptable fillet

Section PIP w/Preforms 20X



- **Top and Bottom side fillets**
- **Full barrel fill**
- **Robust and reliable solder joints**



Section PIP w/Preforms 130X



- **Bottom Side Fillet**
- **Excellent wetting**
- **Minimal Voiding**

Grounding of Mobile Phone Shields

Rework Evaluation Test Vehicle

Power Amplifier
(QFN)

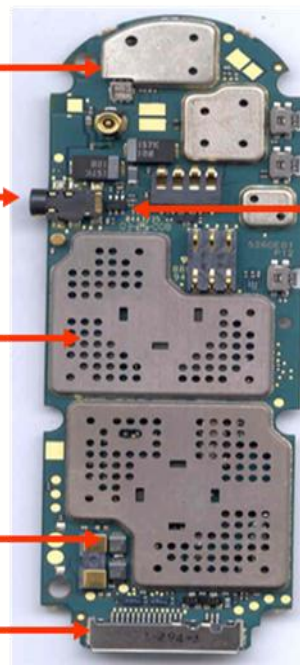


Audio Jack

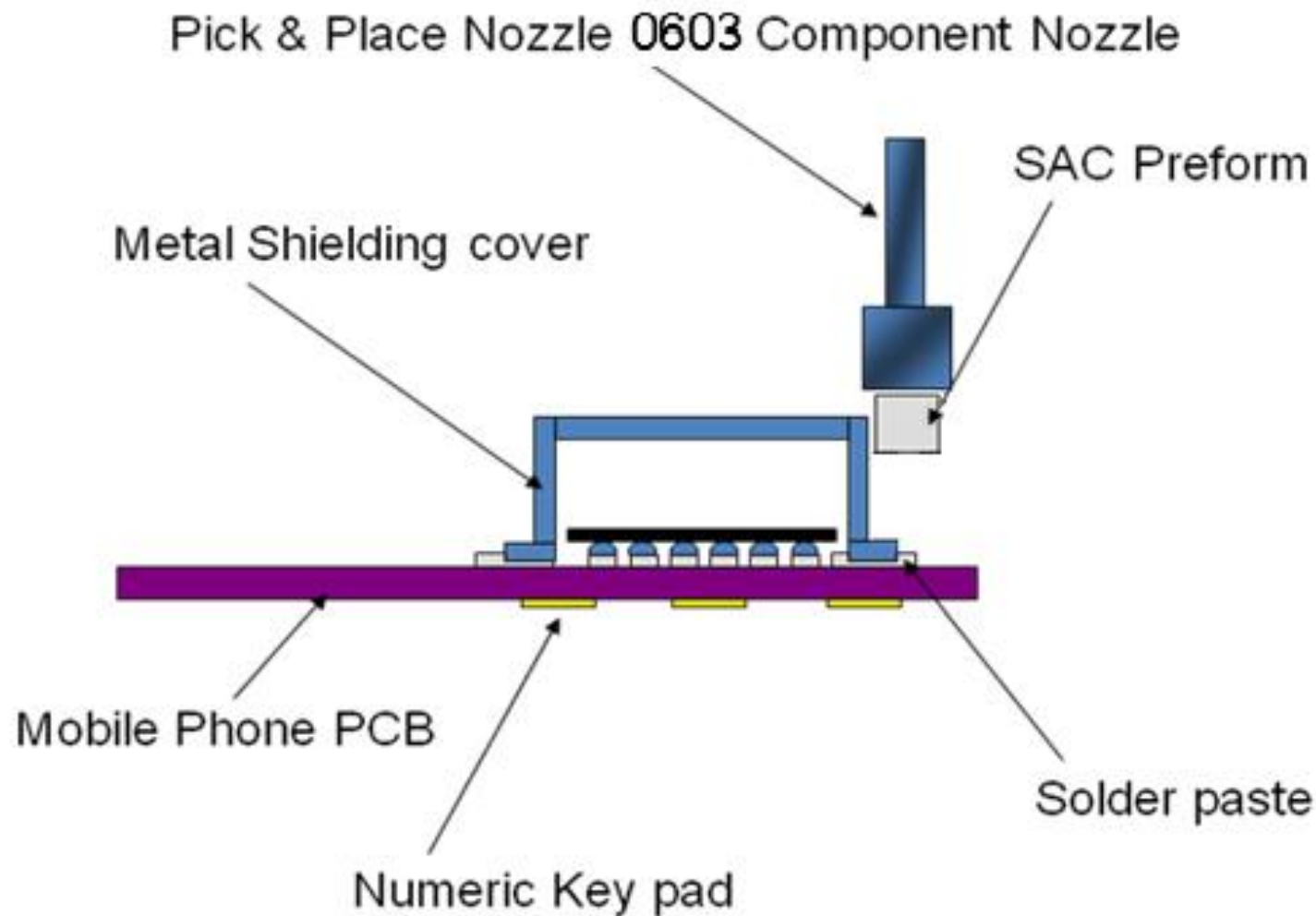
Shield

50X80 Capacitor

Connector

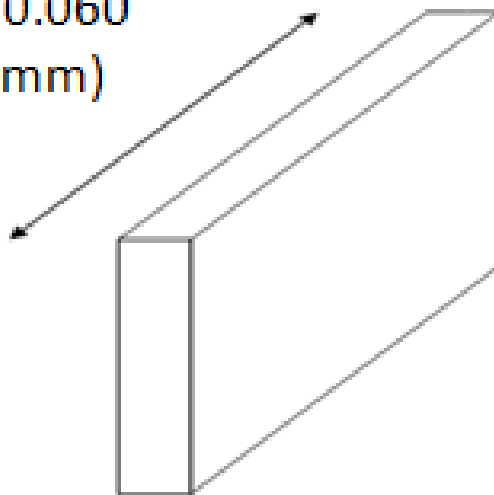


SOIC



Preform Dimensions

Length = 0.060"
(1.524 mm)

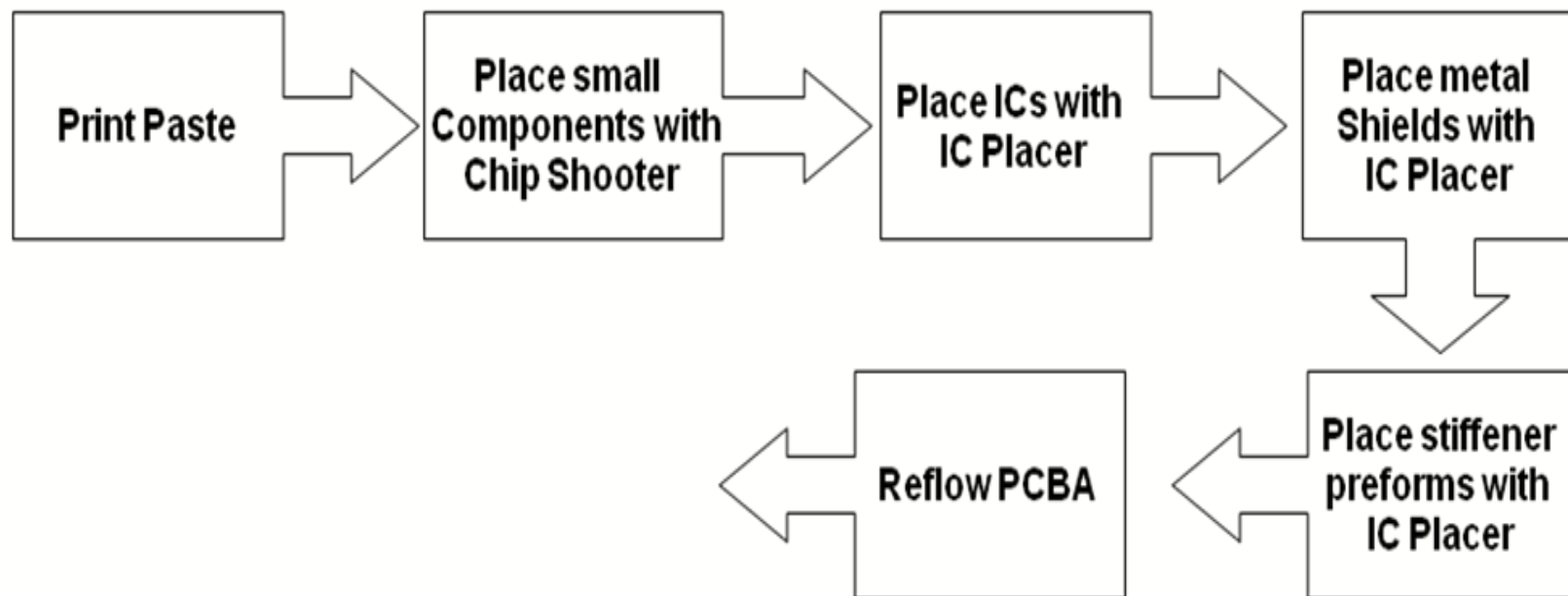


Thickness = 0.031"
(0.7874 mm)

Width = 0.030"
(0.762 mm)

Typical cost is in the \$0.02-0.03 range

The Process



Other Applications....Where paste just
doesn't quite deliver enough solder



Summary

- In many applications, supplementing solder volume with preforms may make the difference between success or failure
- In other applications it may provide a cost benefit

