CAPILLARY ACTION ENHANCED SURFACE MOUNT CONNECTORS

by

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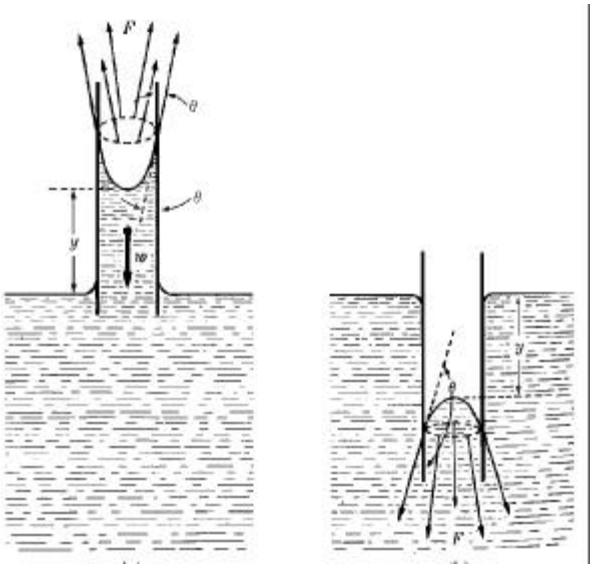
Abstract

This paper describes a new family of surface mount terminals. The common characteristic of these terminals is that they take advantage of the melted solder's interaction with small capillaries. Capillary action enhanced surface mount components have a stronger solder joint and reduce the incidence of solder joint fracture. Capillary action is also an effective means of holding the precise location of components on the pcb during and after reflow. It also minimizes board warpage and co-planarity problems. Through examples, one will gain an understanding as to how and why capillary action improves solder joint strength, quality, and productivity.

Introduction

Capillary action is defined in the dictionary of science as "the general term for phenomena observed in *liquids* due to unbalanced inter-molecular attraction at the liquid boundary; e.g. the rise or depression of liquids in narrow tubes, the formation of films, drops, bubbles, etc."[1] Our application makes use of the 'rise of liquid in the narrow tube' (Figure 1) [2].



Rise of Liquid Depression of Liquid

Figure 1

The first SMT terminal Zierick developed was a test point as shown in Figures 2 and 3. The terminal consists of a .025" square body, .375" long with a .075" square base perpendicular to the body. The part is made by stamping it from .012" thick

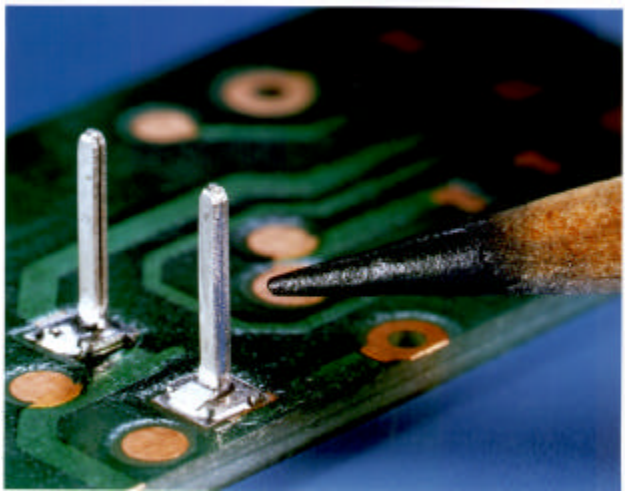


Figure 2

brass strip and folding it to create the .025" square body. The resulting space between the two halves of the pin's body acts as a narrow tube into which the melted solder flows, providing the capillary action. The two halves of the base snap together like a tongue and groove to form the base. They are connected to a carrier strip and are

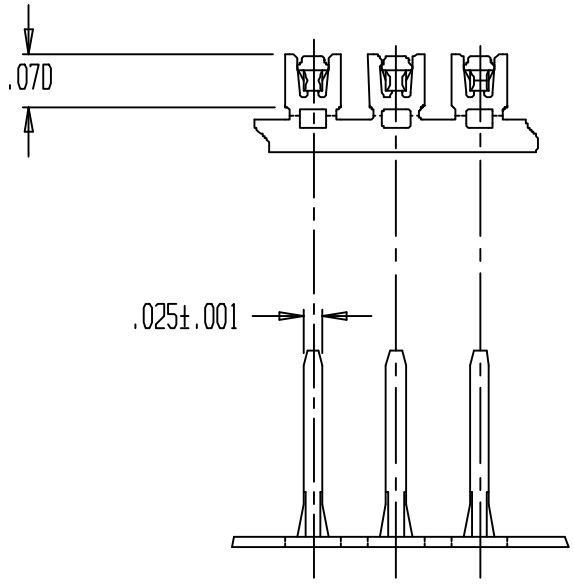


Figure 3

produced on a continuous chain. This product originally was developed as a test point where the locational tolerances and perpendicularity were not critical, but actual testing showed that terminal location and perpendicularity could be held to very tight tolerances. Therefore, this product lent itself for use as an .025" square post.[3]

The development and the testing process of this part led us to discover the importance of the capillary action in the SMT process and the benefit it provides if applied properly.

Surface Mount Post

One of the best ways to demonstrate the effects of capillary action is by illustration, using a surface mount post. We compared two very similar posts. The only difference between them is that one has a small capillary tube at the center and the other does not.

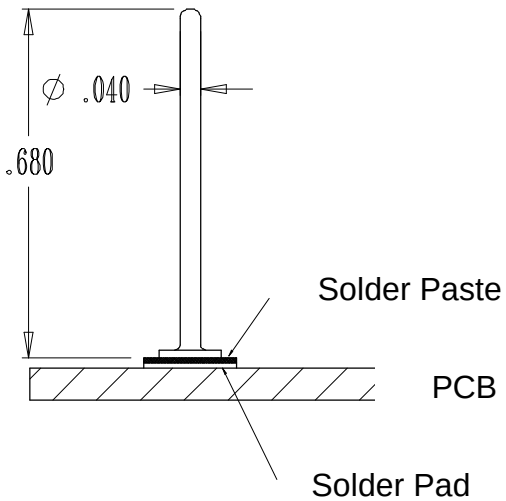


Figure 4

The solid pin, without the capillary tube, is shown in Figure 4. The post with the capillary tube going all the way through the center of the part is shown in Figure 5.

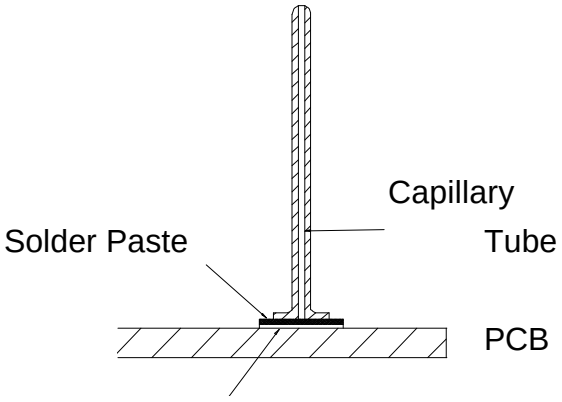


Figure 5

Both posts are placed on .010" thick solder paste which is printed on a copper solder pad. Figures 4 and 5 show the pins just before solder paste reflow. The posts are tower like structures with small bases and high centers of gravity. They are sitting in the solder paste, perpendicular to the pcb. Figures 6 and 7 show what happens during reflow when the solder paste becomes liquid (before solidifying). The solid pin, without the capillary tube, will float on the top of the melted solder. Notice in Figure 6 that the liquid solder is somewhat dome shaped, and the post is perpendicular to the surface of the solder dome, but not necessarily to the surface of the pcb. The degree of the pin's perpendicularity to the pcb depends on the pin's location on the solder dome. In our experiments, using pins of the dimensions shown in Figure 4, less than 10% of the pins were perpendicular to the pcb. If the pin has

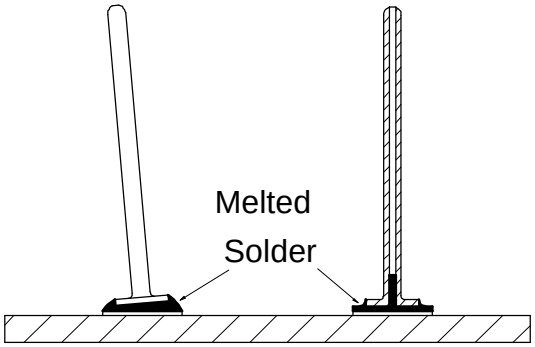


Figure 6 Figure 7

a capillary tube, the melted solder will rise in the tube as seen in Figure 9. While the solder is being pulled up into the capillary tube from under the terminal, the same force will concurrently pull the pin down to the surface of the copper pad. This post does not float on top of the melted solder and is always perpendicular to the pcb. Once the solder solidifies, the solid post without the capillary tube will stand on top of the solder dome and most pins will not be perpendicular to the pcb (Figure 6). In our experiments, about 20% of those solid pins actually fell down during reflow.

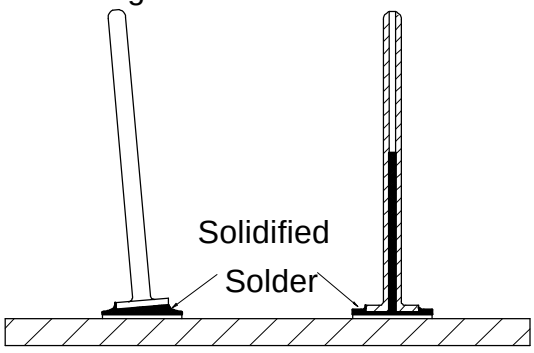


Figure 8 Figure 9

Pins which exhibit capillary action will sit directly on the copper solder pad (Figure 9). There is only about .002" thick layer of solder between the base of the pin and the copper pad. The post reflow location of the pin on the pcb is exactly the same as it was before reflow since it does not float on top of the melted solder, but instead will be pulled down to the surface of the solder pad by the capillary action.

Pull force tests[4] reveal that a post with proper capillary action has a much higher retention to the printed circuit board than a post without the capillary action feature. We attribute the higher retention force to two things:

- First, there is only a very thin layer of solder between the base of the pin and the solder pad. Solder is a weak alloy with a low yield stress. A thicker layer of solder will fail before a thinner layer will. This fact becomes more apparent if one thinks of solder as behaving in the same way as an adhesive, because it is undeniable that a thinner layer of adhesive provides a stronger bond than a thicker layer.

- Second, as the solder paste reflows, there is a certain amount of out-gassing because of flux and other active ingredients in the solder paste. These gasses get trapped under a relatively large surface like the base of the pin. Those trapped gasses create voids in the solder which are clearly visible when the pin is pulled off or the solder joint is cross-sectioned. Pins with capillary action have fewer and smaller voids since the capillary tube provides a way for the gasses to escape. Actual field evaluations show that capillary action enhanced posts are more resistant to the effects of thermal cycling because cracks in solder joints grow from such gas-created voids.

Precise locational tolerances during solder reflow, stronger solder joints, and resistance to thermal cycling are some of the benefits of a capillary action enhanced component. Additionally, it eliminates the need to fixture the surface mounted post during reflow. The post without capillary action needs fixturing to keep it in place and prevent its falling down during the reflow process.

Feeders

Since no fixturing is needed, it is possible to place the capillary action enhanced SMT post and other terminals the same way as all the other SMT components being placed. The only thing needed is a special feeder which can fit in the standard

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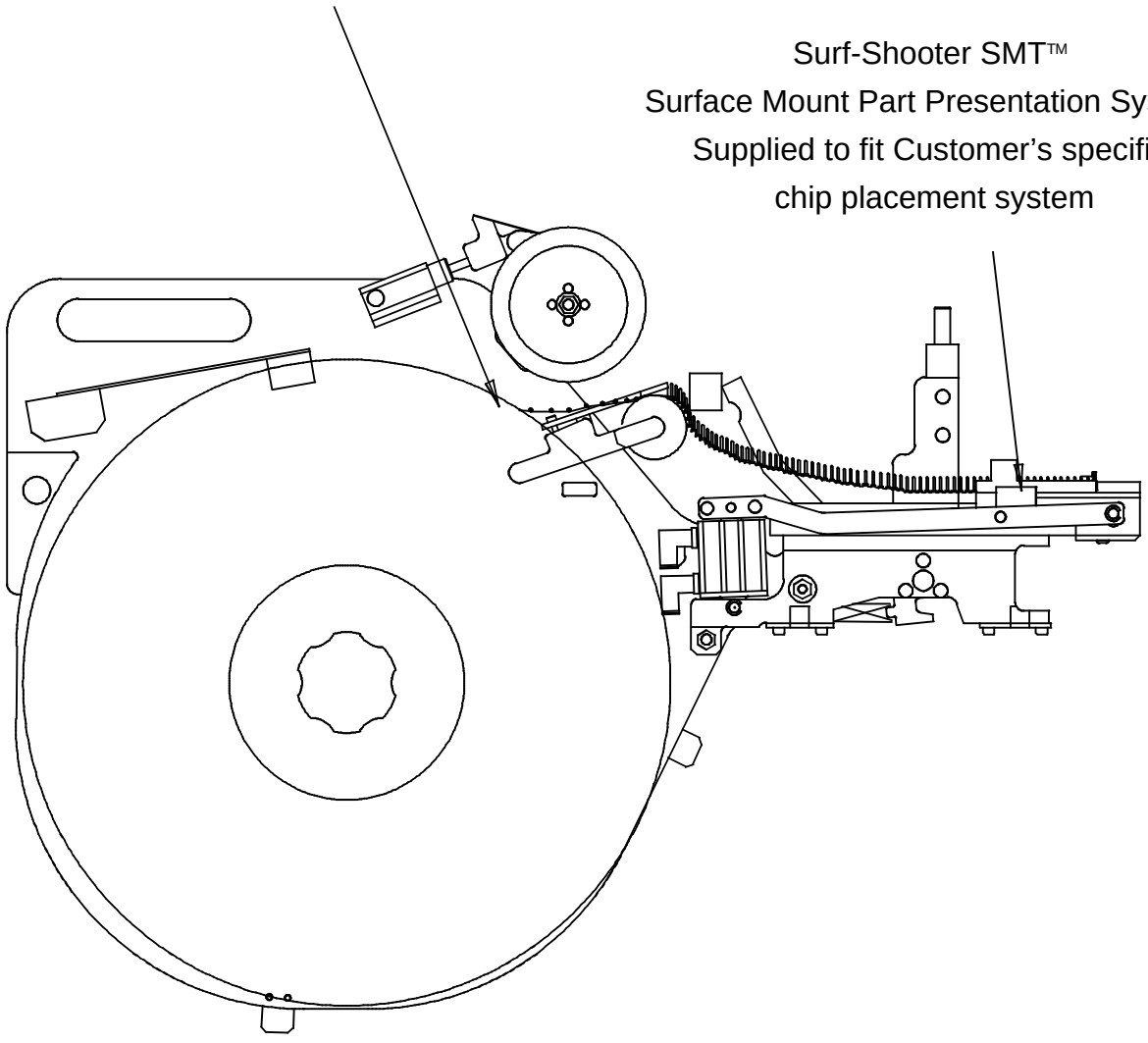

Figure 10

feeder slot of the applicable placement system (Figure 10). The feeder consists of a mechanism which unreels and guides the continuous strip of terminals. The shear/clamp mechanism shears off one single terminal from the strip, holds it in a precise pick-up position and releases the terminal when it makes contact with the vacuum pick-up nozzle. Feeders can be used for a whole family of surface mount pcb terminals, and eliminates the need for taping of parts. It provides a very substantial savings since the taping of surface mount terminals very often costs more than the terminal itself.

Capillary Action Enhanced Pin Headers

Another benefit of a capillary action enhanced component is that it can eliminate problems associated with co-planarity and pcb warpage. This can be demonstrated best by using an SMT header for example.

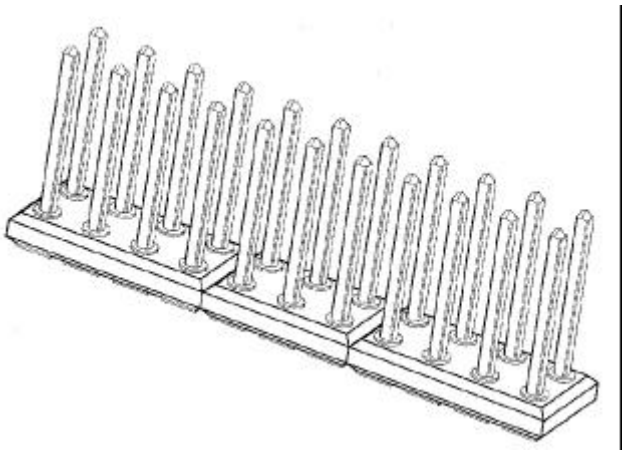

Figure 11

The header assembly consists of square posts press-fit into round plated through-holes on a “header printed circuit board” (see Figure 11). The end of the pin is flush

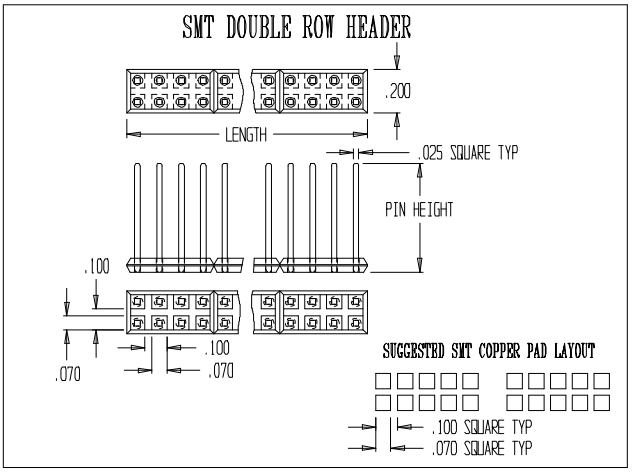

Figure 12

with the bottom of the “header printed circuit board”. The plated through-holes are located at the center of a square solder pad on the bottom of the board. On the top side of the board there is a small circular solder pad centralized around the plated through-hole. Both the bottom solder pad and the top solder pad are connected to the conductive wall of the plated through-hole. The size of the hole is such that it holds the square press-fit pin firmly in place, but will allow for four cavities on the four sides of the pin. The cavities are defined by the flat side of the pin and the curved wall of the plated through-hole. The function of those cavities is to promote capillary action. There are deep

score lines running across on both the top and the bottom of the header base (board). This makes the board very flexible (see Figure 12). The printed circuit board which receives the header assembly must have surface mount solder pads of the same size and located at the same pitch as the solder pads on the bottom side of the surface mount header assembly. The solder paste is stenciled over the pads on the printed circuit board, and the header assembly is placed over the solder paste in such a way that the solder pad on the receiving pcb and the solder pad on the bottom of the assembly align. When the solder paste heats and reflows in the oven, the capillary action provided by the four cavities around the pin will suck up most of the melted solder and solder the pin into the plated through-hole at the same time it solders the header assembly to the pcb. The force which sucks the melted solder into the cavities will also pull the header board assembly and the printed circuit board tightly together. Since the score lines make the pcb header assembly very flexible, it will conform to the shape of the printed circuit board even if either or both boards are warped. The capillary action forces provide two additional benefits: they will pull the header to the right position to be aligned with the solder pad even if it is placed off-center and they produce a much stronger solder joint between the header and the pcb. Since solder is a weak alloy, as has been previously stated, it is preferable to have the minimum amount of solder between the two surfaces being attached. The capillary action will siphon away all the excess solder, thereby making the solder joint much stronger. The melted solder will run up the plated through-hole to the top side of the header assembly board and form a ring (fillet) around the pin which indicates that the reflow process is complete and ample solder was used. This provides a quick, easy visual inspection which assures the quality of the process. See Figure 13.

Cross Section of the SMT Header

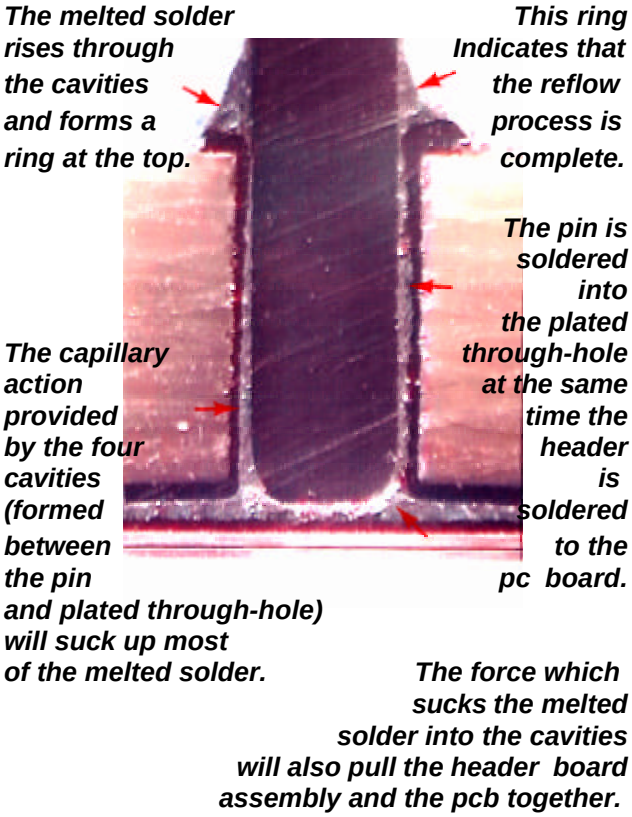

Figure 13

The capillary action feature on the header results in the following benefits:

- 50 percent higher pin retention force compared with a J-Lead type of surface mount header;
- no co-planarity problems; board warpage is allowed;
- more forgiving header placement tolerances – capillary action forces will pull the header into the correct position even if only half the header was placed on the solder pad of the pc board;
  (This feature is especially beneficial if being placed by hand.)
- visual indicator assures quality process;
  (The solder ring around the pin on the top side of the header indicates perfect reflow, the right amount of solder paste was used, and the header is in the right position on the board.)
- highest resistance to thermal shock and thermal cycling;
  (Since the board material and the header material is identical, there are no thermally induced stresses on the solder joint which guarantees long term reliability.)
- minimal board real estate required.

Summary

Components which would float or fall over during reflow can be kept in a precise location during and after reflow with the proper application of capillary action. The resulting solder joint is also stronger and withstands more thermal shocks and thermal cycles. When there are a number of solder joints on a component, the capillary force will pull a semi-flexible assembly together eliminating the issues associated with co-planarity problems and pcb warpage. Also, if there are several solder pads on a component, this same force will center the assembly over its correlating pads even if it was not aligned precisely before reflow. In general, the capillary action enhanced solder joint is more robust, more reliable, and more forgiving in surface mount assembly.

References

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