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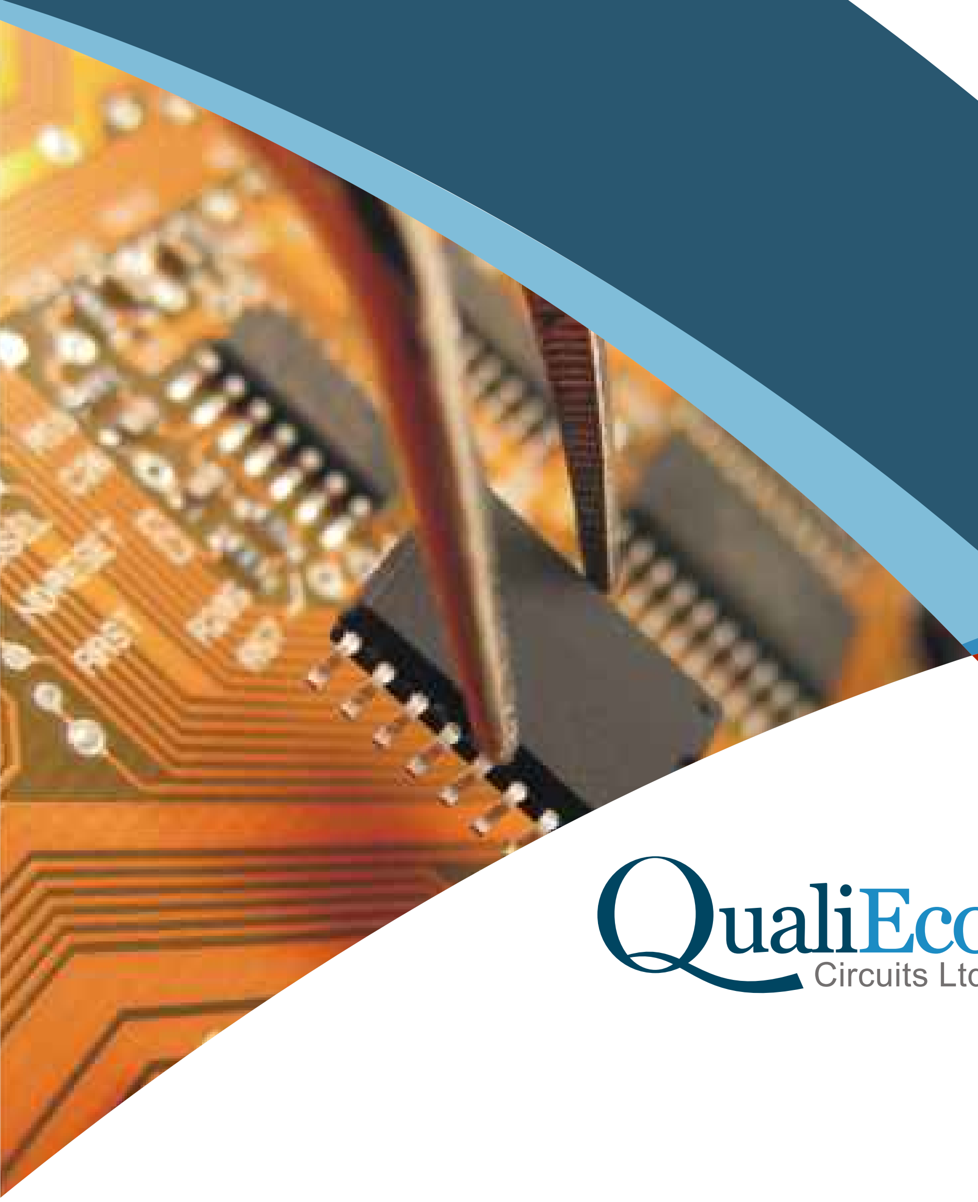

QualiEco Circuits Ltd.

PCB Supplier of
the Best Quality, Lowest Price
and Reliable Lead Time

- Low Cost Prototype
- Standard Prototype & Production
- Stencil
- PCB Design

Stencil, its technology and other aspects

OVERVIEW

A thin sheet material (metal) with a circuit land pattern cut into the material. The most common material is brass and stainless steel.

In surface mount assembly, the stencil is the gateway to accurate and repeatable solder paste deposition. As solder paste is printed through the stencil apertures, it forms deposits that hold the components in place and, when reflowed, secure them to the substrate, generally PCB. The stencil design - its composition and thickness, the size and shape of its apertures - ultimately determines the size, shape and positioning of the deposits, which are crucial to ensuring a high-yield assembly process.

EVOLUTION AND HISTORY

Basic understanding of Stencil Technology and Terms related to it:

- The stencil serves two primary functions. The first is to ensure precise placement of a material, such as solder paste, flux or encapsulant, on a substrate. The second is to ensure the formation of properly sized and shaped deposits.

- Stencil technology evolved to Chemically Etched, laser-cut, and electroformed foils as printing requirements dictated performance enhancements.

- In the beginning, there were thick-film screens; however, the wire mesh weaving across the aperture openings impeded paste transfer. Therefore Chemically Etched stencils were provided for better open areas and worked well for SMT devices with lead pitches down to 0.8 mm.

- The Chemically Etched trapezoidal aperture, along with enabling post processes of electropolish and nickel plating, helped smooth aperture sidewalls, improving paste transfer. One process problem for Chemically Etched apertures was difference between etch rates for small apertures compared to large ones. Band etching help to resolve this problem, but had limitations for small apertures.

- Now to overcome this problem, Laser stencils were used and they were introduced in mid – 90's, just in time to meet the print requirements of 0.65-mm-pitch SMT devices.

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EVOLUTION AND HISTORY

- The small laser beam spot size cut small and large apertures with equal accuracy. Enabling post processes of electropolish and nickel plating again helped smooth aperture sidewalls.
- Early laser-cut speeds were slow, so hybrid stencils were popular where large apertures were Chemically Etched and small apertures were laser-cut.
- Rubber squeegee blades worked well with screens, but scooped paste from larger apertures, reducing paste volume transferred.
- Thus to overcome this problem, metal squeegee blades were used and became very popular.
- With reference to this Contained paste-head delivery systems were also introduced. These systems used pressure to push paste into the apertures, while wiper blades helped to contain the paste in the head and wipe clean after traversing the aperture.
- Design guide for stencil technology was determine by Aspect ratio, defined as aperture width (W) divided by stencil thickness (T) is greater than 1.5.
- With the help of this ratio good paste transfer is performed.
- Aspect ratio is a good guide if the length of the aperture is greater (at least 5×) than the width.
- But again with the introduction of BGA's and QFN's aspect ratio has certain limitations.
- So new design guide was introduced known as Area ratio, defined as the area of the aperture opening divided by the area of aperture walls. The walls of the aperture are trying to hold the paste in the aperture, while the pad under the aperture opening tries to pull the paste away.

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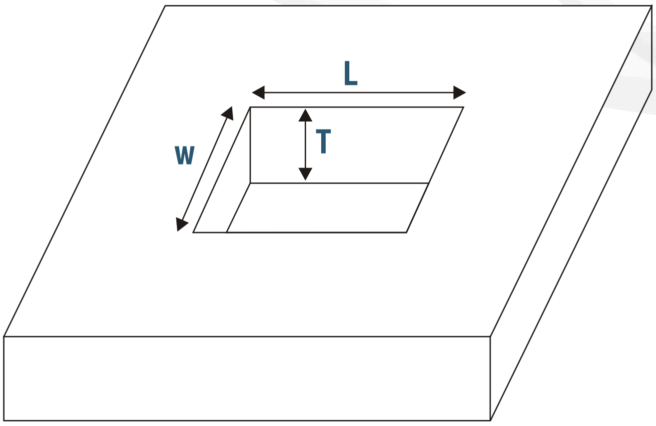
FIGURE



Where,

W = Aperture Width
L = Aperture Length
T = Stencil Thickness

STENCIL TECHNOLOGIES

Basically, five stencil technologies are being used in the industry: laser-cut, electroformed, chemically etched plastic and hybrid. Hybrid is a combination of chemically etched and laser-cut. Chemically Etched is very useful for step stencils and hybrid stencils.

CHEMICAL ETCHING PROCESS

- Metal mask and flexible metal mask stencils are etched by chemical milling from both sides using two positive images. During this process, etching proceeds not only in the desired vertical direction but also laterally. This is called undercutting, the openings are larger than desired, causing extra solder deposit. Because 50/50 etching proceeds from both sides, it results in almost a straight wall tapering to a slight hourglass shape in the center.

- Because electroetched stencil walls may not be smooth, electropolishing, a microetching process, is one method for achieving a smooth wall. Another way to achieve smoother side walls in

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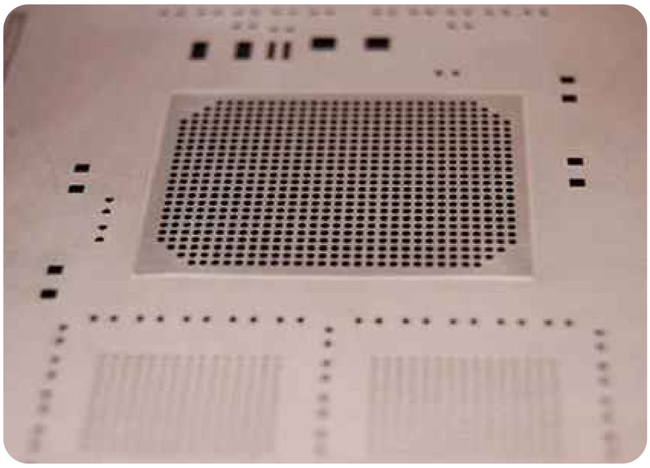
CHEMICAL ETCHING PROCESS

the aperture is nickel plating. A polished or smooth surface is good for paste release but may cause the paste to skip across the stencil surface rather than roll in front of the squeegee. This problem can be avoided by selectively polishing the aperture walls without polishing the stencil surface. Nickel plating further improves smoothness and printing performance. However, it does reduce aperture opening and requires artwork adjustment.



Chemically Etched Stencil

LASER CUT PROCESS

- Laser-cut is a subtractive process. The Gerber data is translated into a CNC-type language that the laser understands. The aperture is cut out by moving the laser head only, moving the table holding the stencil only or a combination of each. The laser beam enters inside the aperture boundary and traverses to the perimeter where it completely cuts the aperture out of the metal, one aperture at a time. The smoothness of cut depends on many parameters, including cut speed, beam spot size, laser power and beam focus. The typical beam spot size is about 1.25 mils. The laser can cut very accurate aperture sizes over a wide range of size and shape requirements. As with Chemically Etched, the laser-cut aperture size must be adjusted to the post-processing treatment employed because aperture size change will occur during this process.

- Laser-cut stencil that is electropolished definitely has smoother inside aperture walls than a non-electropolished laser-cut stencil. Therefore, the former will release a higher percentage of paste than the latter at a given area ratio.

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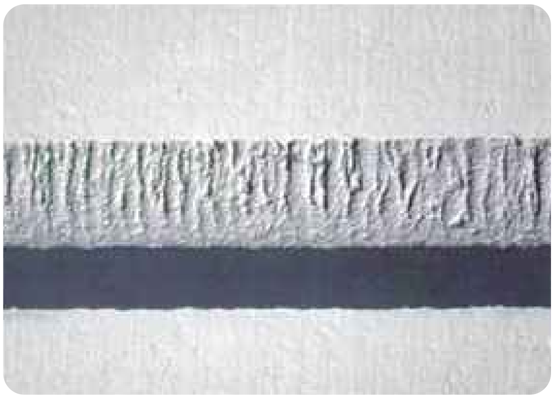
LASER CUT PROCESS

- Some laser-cutting machines are homemade systems, some vintage lasers, and some are fine-cut laser machines. Electro-polishing and nickel-plating are also used to further smooth surface walls and improve solder paste release.



Laser cut no surface treatment side wall

Laser cut with electro-polish wall

- Stencil printing process can be divided into three categories: the aperture-fill process, the paste-transfer process, and the positional location of the deposited paste. All three processes play a vital role in achieving the desired result - a precise volume of paste (a brick) deposited to the correct location on the substrate.

- The first step in printing solder paste is to fill the stencil aperture with paste. This is achieved using a metal squeegee blade. Several factors can contribute to the aperture-fill process. The orientation of the aperture with respect to the squeegee blade has an effect on the fill process.

- An aperture oriented with its long axis in the same direction as the blade stroke does not fill as well as an aperture oriented with its short axis to the blade stroke. Squeegee speed also influences aperture fill. Squeegee speed must be reduced to fill the aperture with the long axis oriented parallel to the squeegee stroke.

- The squeegee-blade edge has an influence on how well the paste fills a stencil aperture. The rule of thumb is to print at the minimum squeegee pressure while still maintaining a clean wipe of the solder paste on the stencil surface. If squeegee pressure is too high, both the squeegee blade and the stencil may be damaged. Excessive squeegee pressure can also cause paste smearing under the stencil surface.

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LASER CUT PROCESS

- If the pressure is too low, one of two events may occur. Paste left on the squeegee side of a small aperture will hold the paste, preventing its release to the PCB pad, resulting in insufficient solder. Paste left on the squeegee side over large apertures will be pulled down through the aperture, resulting in excess solder.

- Proper squeegee pressure is the minimum pressure that achieves a clean wipe of the paste. Minimum pressure is a function of blade type.

- A recent study demonstrated that the minimum squeegee pressure for one squeegee blade* was about 40% of that of the teflon/nickel-coated blade for lead-free solder paste. Tests have confirmed that lead-free solder pastes typically require about 25% more squeegee pressure than tin/lead pastes.

TECHNICAL EXPLANATION OF STENCIL TECHNOLOGY

- Before understanding technical aspect of stencil technology, it is necessary to know the performance issues related to solder paste printing.

  There are three major performance issues, and they are as follow:

  - The aperture size (width and length of the aperture) and stencil foil thickness determine the potential volume of solder paste applied to the printed circuit board (PCB) or substrate.

  - The ability of the solder paste to release from the stencil aperture walls.

  - Positional accuracy of exactly where the solder brick is printed on the PCB or substrate.

- As the squeegee blade travels across the stencil during the print cycle, solder paste fills the stencil apertures. The paste then releases to the pads on the board during the board/stencil separation cycle. Ideally, 100 percent of the paste that filled the aperture during the print process releases from the aperture walls and attaches to the pads on the board, forming a complete solder brick.

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THE STATE OF STENCIL TECHNOLOGY

- In surface mount assembly, the stencil is the gateway to accurate, repeatable solder paste deposition.
- As solder paste is printed through the stencil apertures, it forms deposits that hold the components in place and, when reflowed, secures them to the substrate.
- The stencil design - its composition and thickness, the size and shape of its apertures - ultimately determines the size, shape and positioning of the deposits, which are crucial to ensuring a high-yield assembly process.
- Today, a wide variety of materials and fabrication techniques enable QualiEco Circuits Ltd. to design stencils that meet the assembly challenges of fine-pitch technology, miniaturized components and densely packed boards.
- Stencil technology now serves a full range of mass imaging materials.
- Stencil designers have gained depth knowledge about how aperture size and shape affects deposition. New technologies extend the capabilities of printing platforms and stencils into applications as varied as adhesive deposition and wafer bumping.

IMPORTANCE OF ASPECT AND AREA RATIO FOR DESIGING STENCIL APERTURES

- The ability of the paste to release from the inner aperture walls depends primarily on three major factors:
    1. area ratio/aspect ratio for stencil design
    2. aperture side wall geometry
    3. aperture wall smoothness

  The first factor is aperture design-related while the other two factors are stencil technology-related.

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IMPORTANCE OF ASPECT AND AREA RATIO FOR DESIGING STENCIL APERTURES

- The area ratio is the area beneath the aperture opening divided by the area of the inside aperture wall; Area ratio = [(LXW)/(2(L+W)T)].

- Historically, the aspect ratio is the width of the aperture divided by the thickness of the stencil; Aspect ratio = W/T. The generally accepted design guideline for acceptable paste release is [greater than] 0.66 for the area ratio and [greater than] 1.5 for the aspect ratio.

- The aspect ratio is really a one-dimensional simplification of the area ratio. When the length (L) is much larger than the width (W), the area ratio is the same as the aspect ratio.

- When the stencil separates from the substrate, paste release encounters a competing process.

- This again creates doubt, Will it transfer to the pad on the substrate or will it stick to the side aperture walls?

- And the solution for this is, when the area of the pad is greater than two-thirds of the area of the inside aperture wall, the paste will probably achieve 80 percent or better paste release.

- The aspect ratio and the area ratio are important considerations when designing stencil apertures. For example, a 20-mil pitch quad flat pack (QFP) with an aperture design of 10 mil X 60 mil in a 5-mil stencil has an aspect ratio of 2.0 and an area ratio of 0.86.

- So here you can see the Aspect ratio is greater than 1.5 and also the Area ratio is greater than 0.66. Hence good print performance can be expected with this design using a good quality laser stencil.

- However, consider a 20-mil micro ball grid array (microBGA) with a 10-mil aperture in a 5-mil-thick stencil. Because the aperture is round or is a square with rounded corners, the area ratio is the deciding factor. In this case, the area ratio is 0.5, which is well below the recommended value of 0.66. The aperture design can be changed by reducing the stencil thickness or increasing the aperture size, or a stencil technology can be chosen that gives better paste release at this area ratio.

Stencil, its technology and other aspects

IMPORTANCE OF ASPECT AND AREA RATIO FOR DESIGING STENCIL APERTURES

- For a square aperture, area ratio = S/4T, where S is the side of the square. For a circular aperture, area ratio = D/4T, where D is the diameter of the circle.

DESIGN RULES AND CAPABILITIES

- The size and shape of stencil apertures determine the volume, uniformity and definition of the material deposited onto substrates. Rigorous control of aperture quality therefore is critical to successful stencil design, particularly for fine and ultra-fine pitch applications where small amounts of material must be deposited with great precision.

- Measures such as area ratio (the area under the aperture opening divided by the surface area of the aperture wall) and aspect ratio (aperture width divided by stencil thickness) can be used to determine appropriate aperture sizes.

- The general rule is that, for acceptable paste release, the area ratio should be greater than 0.66 and the aspect ratio greater than 1.5. When designing apertures that adhere to these rules, it is necessary to consider each stencil manufacturing technique on its own merits. For example, it is challenging for the chemical etching process to drop below a 1.5 aspect ratio while, with laser cutting, apertures can be produced that have a 1:1 aspect ratio to the stencil thickness.

- During the printing process, when the stencil separates from the substrate, competing surface tension forces dictate whether the solder paste will transfer to the pad it has been printed on or remain adhered to the stencil aperture walls.

- When the pad area is greater than 66 percent of the aperture wall surface area, the probability of achieving efficient paste transfer is increased. As the ratio decreases below 66 percent, paste transfer efficiency decreases and print quality becomes erratic.

- The finish of the aperture walls can have an impact at these levels. Laser-cut apertures that have been electropolished and/or electroplated during manufacture promote improved paste transfer efficiency.

Stencil, its technology and other aspects

DESIGN RULES AND CAPABILITIES

- The final aperture sizes. This determines the volume of solder paste that will be printed on the PCB. Three dimensions (on rectangular apertures), the length, width and the wall height of the aperture determine the volume of the solder brick printed on the board. The height, or stencil thickness, will have a significant effect on the performance of the stencil and subsequently the product defect rate. Correct specification will minimize product defects and rework. The final aperture sizes will also take into account any reductions required to be made. Reductions will also be discussed in more detail.

- Whether the stencil obeys certain laws of physics that will guarantee successful transfer of solder paste from the stencil to the PCB. During printing, there exists an adhesion of the paste to the pad on the PCB and to the aperture walls of the stencil. The adhesion to the pad must be greater than the adhesion to the stencil to ensure a good transfer. Therefore it can be deduced that the printability will depend on a ratio of the stencil wall area to the open face area. This is of course ignoring other minor influences such as wall roughness and draft angle.

- Stencil dimensional accuracy and printing positional accuracy. Stencil dimensional accuracy is dependent on the quality of transferred cad data, methods and technology used to manufacture the stencil, and the conditions of use (i.e. the stencil is not being used at higher than normal temperatures). The printing positional accuracy will be determined by the alignment methods used.

STENCIL DESIGN GUIDELINES

Considerations with Stencil Design:
Aperture Size vs Pad Size, Aperture Shape, Stencil Thickness, Adhesives Printing, Stencil Manufacturing Method, Stencil Thickness, Aperture Design, etc.

APERTURE SIZE VERSUS PAD SIZE:
It is recommended that finer pitch aperture openings be slightly smaller than the landing pad size. This is primarily for:

- Improved gasketing between the landing pad and the underside of the stencil.

- Prevent bridging on fine pitch component.

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STENCIL DESIGN GUIDELINES

Recommended Pad and Aperture Size

Component Pitch	Industry Standard Pad Width	Industry Standard Aperture Width
50 mil	25 mil	25 mil
40 mil	20 mil	20 mil
31 mil	17 mil	16 mil
25 mil	15 mil	12 mil
20 mil	12 mil	10 mil
16 mil	10 mil	08 mil
12 mil	08 mil	06 mil

- Aperture width reductions must be taken equally from each side so that aperture is centered on the pad. (Fig 1.). Aperture lengths can be reduced by similar dimensions to reduce the potential of solder balling.

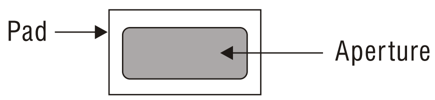

Figure 1

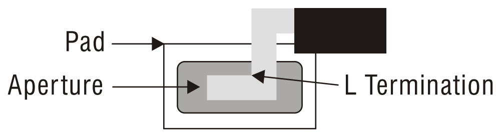

Figure 2

- Apertures can be shifted to the outside edge of a pad to reduce potential for "under chip" solder balls. (Fig. 2).

APERTURE SHAPES

- Different aperture shapes have been found to offer the benefits of less paste utilization, consistent paste release and reduced or eliminated solder balling. Shapes to consider include:


Oval


Home


V-Shaped

Stencil, its technology and other aspects

STENCIL THICKNESS

- Stencil or "foil" thickness is an important part of stencil design. Optimal paste deposition onto a PCB is impacted by the relationship that exists between the pad size, aperture opening and foil thickness. While the aperture may be appropriately sized for a pad, a stencil that is either too thin or too thick may still cause less than optimal deposition of solder paste.

- This relationship is also known as "aspect." Aspect is the difference in forces that either pull paste from an aperture and on to a pad or cause paste to be held within an aperture. These forces can be quantified and represented as a measurement called the Aspect Ratio. In simple terms, for a paste to be adequately deposited on a pad, the paste surface tension must be stronger that the surface tension of the paste to the aperture wall.

- A broad set of rules has been adopted that help us design stencils with appropriate Aspect Ratios depending on the type of stencil ordered. It is important that the smallest aperture on the board be used for this calculation.

Stencil Type Pitch	Ratio of Foil Thickness to Minimum Aperture Width
Chemically Etched	1:1.5
Laser-Cut	1:1.2

- **For example:**
  A laser-cut stencil with a 16 mil leaded component (8 mil aperture width) should have a maximum foil thickness of 6 mil* [6 x 1.2 = 8]

- A stencil should always have a Paste Pulling Tension of 0.2 or greater:

$$\frac{\text{Pad Pulling Tension (P)}}{\text{Retaining Wall tension (R)}} = \frac{\text{Aperture (Length (L) ´ Width (W))}}{\text{Stencil Thickness (T) x Aperture Perimeter (2 x (L + W))}} \geq 0.6$$

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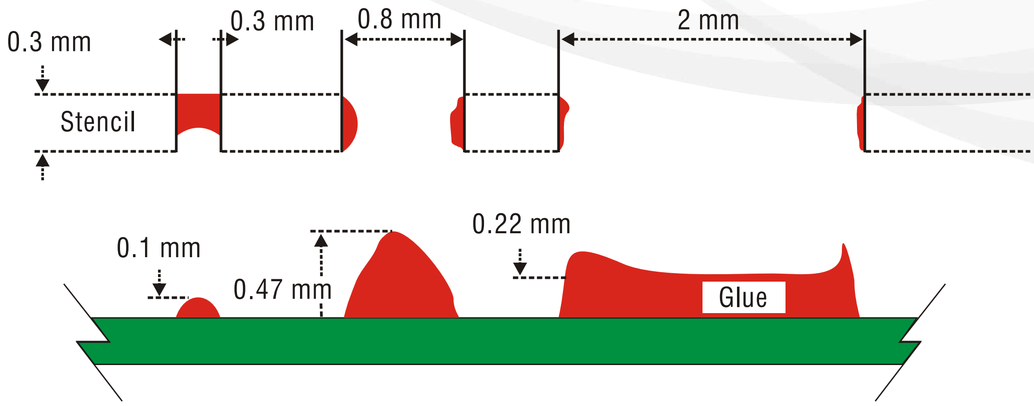
STENCIL THICKNESS



STENCIL FRAME
(Also called "Glue-in" or Mounted Stencils)

Framed stencils are the strongest form of laser-cut stencils available in the market today, which are designed for high volume screen-printing.

Key Features and Advantages:

- Unique Process for Smooth Aperture Walls.
- Very Clean Laser-Cut Apertures.
- Excellent Print Performance.
- Excellent for High-Volume Stencil Printing.
- Unique Process Creates Permanent Non-removable Non-fading Fiducial

CONCLUSION

Chemical etching and laser cutting are subtractive processes for making stencils. The chemical-etch process is the oldest and most widely used. Laser cut is a relative newcomer. To achieve good printing results, a combination of the right paste material (viscosity, metal content, largest powder size and lowest flux activity possible), the right tools (printer, stencil and squeegee blade) and the right process (good registration, clean sweep) are necessary.

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