Stencil and Screen Printing: Frequently Asked Questions

General Printing Applications

Q - How fast can I print solder paste?

A - There is a relationship between force, speed and paste formulation that must be maintained to get acceptable solder paste prints. Some formulations have to be printed fast while other formulations must be printed slowly to provide the best results. If the squeegees hydroplane and leave a thin coat of paste or flux on the top of the stencil, the force should be increased to wipe the stencil top clean. The force should not be increased to a point where the paste will no longer roll. The rolling of the paste during the print stroke is an indicator you will get an acceptable print. Printing too fast can result in incomplete fill of apertures, especially on the leading edge of a pad while hydroplaning will result in extremely peaked prints and incomplete coverage due to paste not properly releasing from the apertures.

Q - Why is paste left on my stencil after the squeegee prints the board?

A - There are a few things that could cause this problem. We will discuss two of the most common causes. First, although you may have the correct force applied to the squeegees, the “downstop” or “the distance the squeegees travel down into the stencil” may be too small. The second possible reason for this could be a lack of appropriate support under the board. With inadequate board support, the board can deflect downward under the pressure of the squeegees and the resulting blade angle does not allow the squeegees to clean the stencil. Inadequate support under the board could also cause differences in squeegee pressure applied to the board as it deflects downward.

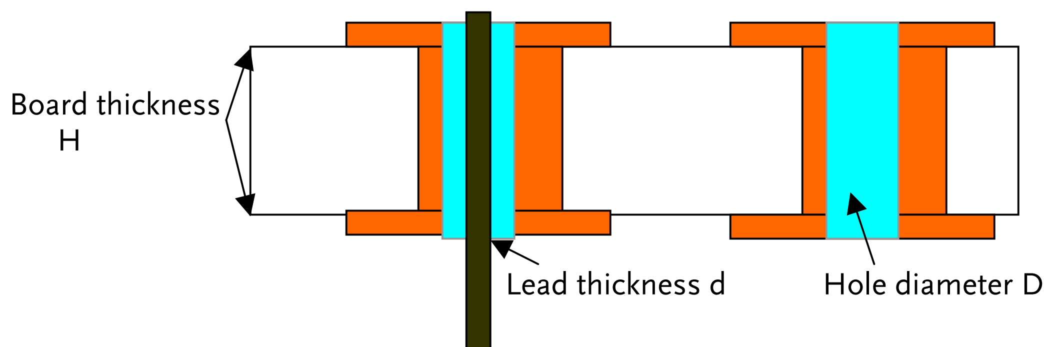
Q- Why are my paste heights higher on one side of my PCB than the other?

A –

- You might have a bent or damaged squeegee blade. Inspect the blade edge on a flat surface and look for damage. Replace if necessary.
- It is also possible the squeegee attack angle may not be adjusted properly. Double-check the attack angle on the squeegee holder with a right angle. For the 0 degree setting to work, the printing blade holder should be at 90 degrees to the stencil at both ends.
- The blade might not be seated into the blade holder properly. Remove and re-install the blade, level the blades and try again.
- Another common cause for this effect has to do with inadequate or uneven support under the portion of the board where the paste height is higher. The board supports and/or worktable may be contaminated with solder paste. This will cause uneven support of the PCB and may result in higher than expected paste heights.
- If your printer is equipped with MPM’s Balance Control Programmable Print Head (“Prohead”), the issue could be related to inconsistent force distribution from left to right. There is a parameter that can be adjusted to apply more force to one side of the blades than the other. Make sure the setting is set to 50/50 %.

Q - Can I use solder paste for printing through-hole devices?

A - Yes, printing has become an accepted process for this type of board assembly. The process of using solder paste to fill via-holes in a PCB for through-hole assembly is most commonly called "intrusive soldering" or "pin in paste printing". The stencil aperture must be designed properly to get the correct amount of solder to fill the via-holes to ensure reliable joints. Understanding that solder paste generally has a shrink factor of 50%, the first step is to calculate the volume of paste required. To do this, the volume of paste required to fill the hole minus the lead volume should be calculated. The solder paste volume is twice the solid solder requirement and the aperture can be calculated using the stencil thickness and available area around the through hole pad. The paste can be overprinted and it will pull back to the solderable surface during reflow. See the MPM application notes on the Speedline website for more information (www.speedlinetech.com).

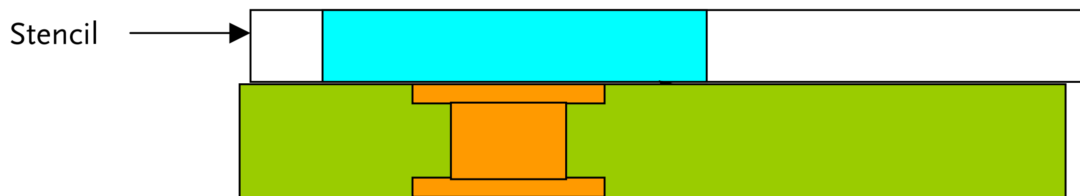


Volume of solder paste required to fill the hole = hole volume – volume of lead multiplied by 2

$$V= (3.14*D*D/4 - 3.14*d*d/4) *2 \text{ or } V=3.14(D*D-d*d)/2$$

To calculate the required stencil aperture for a square aperture, the size = square root (volume of paste required /stencil thickness)

$$A=(V/T)^{1/2}$$



Squeegee Blades

Q - Why are there different rubber squeegee durometers, and when should I use them?

A - Squeegees can be obtained in several different durometers for stencil and screen-printing. Typically when printing with screens, one would use polyurethane blades with a range from 60 to 80 shore A. The screen's mesh should prevent the blade from scooping material off the substrate when the softer materials are used. Blades ranging between 90 to 110 shore A are normally used for stencil printing. However, when using polyurethane blades with stencils, scooping on larger apertures can become a problem. Metal blades are preferred for stencil printing. However, for stencils with only fine apertures or step-stencils, a polyurethane blade will produce more consistent prints and may reduce wear on the stencil. Step stencils are stencils that contain sections that are relieved, or stepped to a smaller thickness than the rest of the stencil. This is typically used for boards with mostly large apertures and one or two fine pitch devices.

Q - What is the contact angle for squeegee blades?

A - The contact angle for trailing edge blades with no pressure applied is 60 degrees for metal blades and 50 degrees for rubber blades. With MPM's Balanced Control Programmable Print Head ("Prohead"), the contact angle can be adjusted ± 5 degrees from the nominal value. The force on the blade should be sufficient to give a clean wipe of the top surface of the stencil, but not so high that it will coin the stencil and cause premature failure. Coining is the term given to the creation of a permanent impression of the board edges left in the bottom of the stencil when excessive pressure is applied to the stencil outside of the board edges.

Downstop and Snapoff

Q - What is downstop?

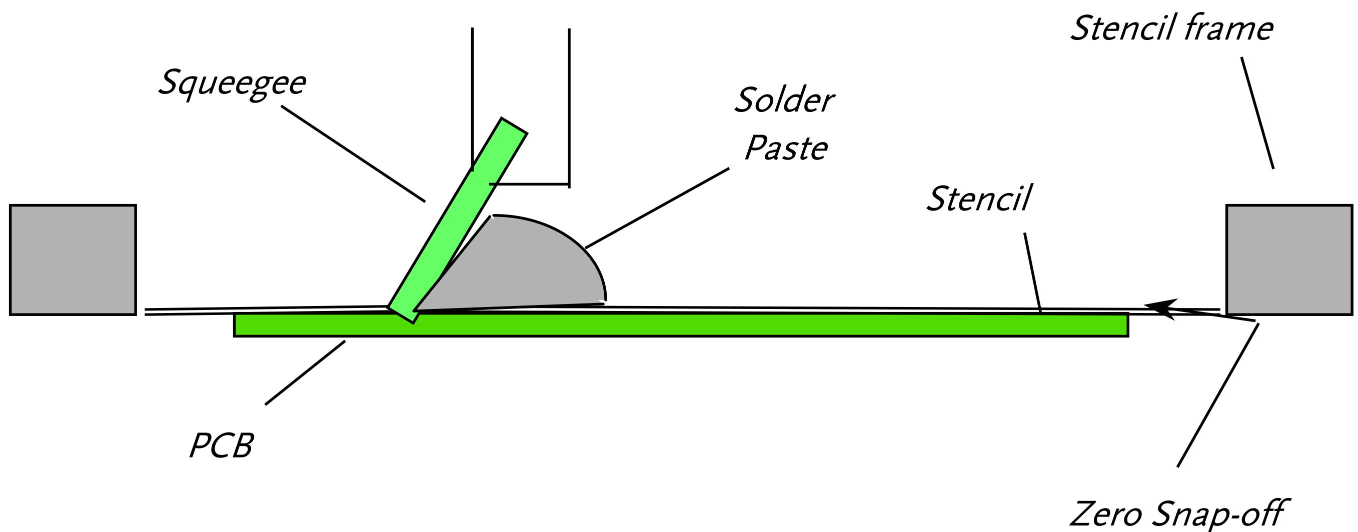
A - The term "downstop" is used as the distance the squeegee blade is programmed to travel below the top of the substrate during a print stroke. The substrate will support the stencil during the print stroke, however, if the blade travels beyond the edge of the substrate and supporting rail, the stencil can be deflected and cause premature fatigue of the stencil. Properly setting the downstop will prevent this effect since it will not allow the blade to provide enough squeegee travel to apply this excessive force on the unsupported stencil. However, if the downstop is set too low the desired print pressure will not be achieved due to its inability to properly flex the squeegee blade. Typical downstop settings are 0.065" (1.6 mm) to 0.075" (1.9 mm).

Q - What are the differences between contact printing, snap-off printing and the term slow snap-off?

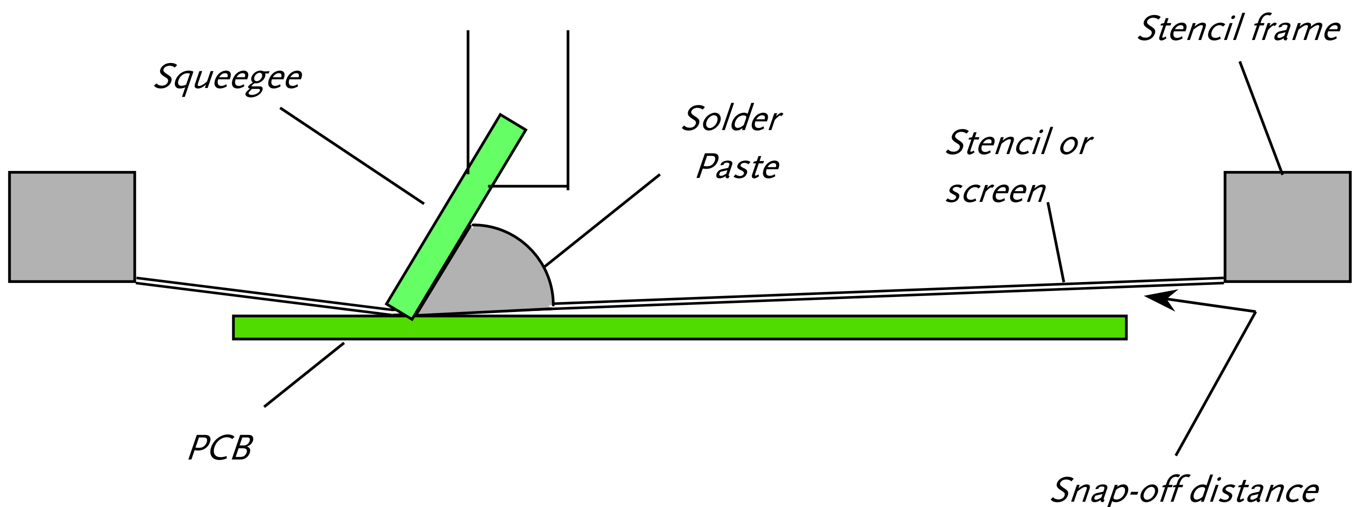
A - Contact printing is achieved when the entire stencil contacts the substrate during the print process. After the material is squeegeed through the apertures, the stencil and substrate are separated in a vertical and uniform rate. Snap-off printing is achieved when the stencil or screen

have a desired gap between them when at rest. During the print stroke, the squeegee deflects the stencil to bring it into contact with the substrate. Only at the point where the squeegees apply force on the stencil is the stencil and board in contact. The stencil or screen will peel away from the substrate as the squeegee blades move forward. Snap-off printing is used in stencil printing for high-density substrates where uniform release rates do not occur repeatably, when faster cycle times are desired, and when screen-printing is performed. Slow snap-off printing is a term used for the process of the stencil and substrate *slowly* separating after the print stoke is complete. Since different pastes have varying aperture release characteristics, this adjustable setting is used to allow the paste to settle down after the print stroke and more cleanly release from the apertures.

Contact print



Snap –off print



Q - When would snap-off printing be appropriate to use?

A - Snap-off printing is used when high-density stencil printing or screen-printing is performed. The snap off setting is the distance between the stencil/screen when at rest before the squeegee blades deflect the stencil / screen to the surface of the substrate being printed. This process allows the stencil or screen to roll-on and peel-off the substrate and produces a uniform release rate of the material being printed from the apertures. For high-density printing, the separation of the stencil or screen will be different from the edges and center due to the cohesive forces if contact printing is used.

Stencil design

Q - I would like to put two images on a stencil - how far apart should the images be?

A - Normally the images should be at least 3"apart for trailing edge blade printing. If allowance is made for a little print over-travel the distance should be increased to 4" (100mm). The maximum board size for a 29x29" stencil would be limited to no larger than 6" (150mm). When printing with MPM's Rheometric Pump Print Head, the space between images can be reduced to 0.75" (19 mm) and the overall board width increased to 8.9" (226 mm).

Q - What is the minimum size stencil foil I can use for effective print results?

A - When using trailing edge blades, the minimum size stencil foil in the Y direction is calculated by taking the substrate size and adding 7" (178 mm). When using diamond shaped blades, the minimum size stencil foil is the substrate size plus 1" (25 mm). The X direction should be a minimum of 1" (25 mm) greater than the squeegee blade length.

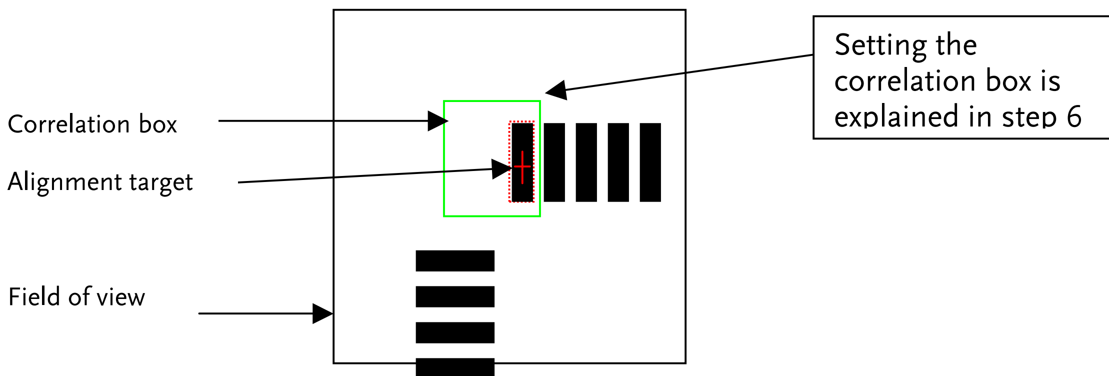
Q - Why is it recommended that the board images be centered on the stencil?

A - To get a true vertical separation of the stencil from the substrate the image should be centered on the stencil. If the image is offset there will be some uneven peel as the separation occurs due to the cohesive forces of the flux that seeps between the stencil bottom and substrate.

Q - Do I need always need fiducials for proper board to stencil alignment?

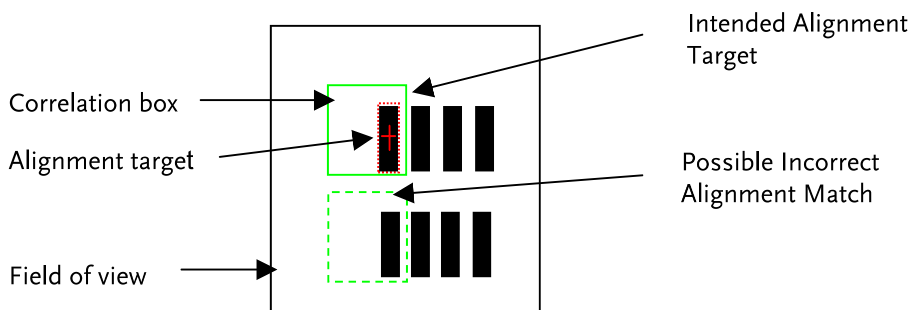
A - Fiducials are always preferred for best alignment results. However, if traditional fiducials are not available, using board pads and stencil apertures as fiducials can provide acceptable results. A unique area on the board should be used, such as an end pad of a QFP on the substrate and stencil can be used for alignment. It must be noted that care must be used to keep the stencil apertures clean since clogged apertures can cause alignment problems since the size and shape of the aperture will be different from the clean aperture used during programming.

Example 1 (Example of a good setup utilizing a QFP device)



As seen above, this creates a UNIQUE image because the system also learned the empty space to the left of the target pad, and there is no other acceptable match to this image anywhere else in the camera's field of view.

Example 2 (Example of a bad setup utilizing a DIP device)



The problem with this setup is that the Correlation box has not been created in a way where it is unique, and therefore there is the possibility the system would find an incorrect image match. This would cause the system to align to the pad at the bottom of the field of view rather than the intended top pad.

2D inspection

Q – Why Should I Use 2D Verification?

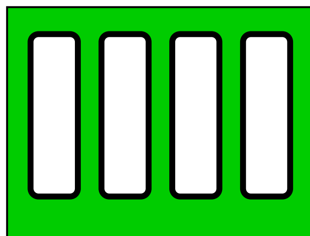
A – A 2D system is designed to be process verification tools (they are not inspection systems and should not be used to replace one). Simply put, it helps you develop your process and verifies that your process stays in control. If your process never changed, you would not need an inspection or verification system. However, most printed circuit boards have challenging components or applications, specifically in fine-pitched devices, which require some form of verification. 2D systems are designed to help you verify that you are getting consistent stencil release and paste coverage according to your pre-established benchmarks. It will help alert you to any deviation from the established process, enabling you to make necessary adjustments before costly additional processes such as washing or rework takes place.

Q – How does 2D Work?

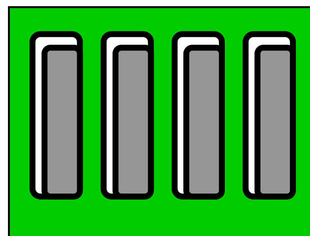
A - It is estimated that up to 90% or more of all print defects and trends can be identified by verifying the amount of paste covering the target pad. This method identifies the lack of paste being deposited on the pad resulting in unacceptable solder joints.

The most effective type of 2D Inspection incorporates a gray scale comparison technique to determine the percentage of paste that is covering the target PCB pad. This technique compares the uncovered area of a printed pad against the saved area of the bare pad, determined at the time the device is first programmed. (see diagram below) With this data, the following calculation is used to determine the percentage of paste coverage:

$$\left(1 - \frac{\text{Post Print Uncovered Pad Area } \textit{(remaining white area)}}{\text{Taught Pad Area } \textit{(original white area)}}\right)100$$



(original white area)



remaining white area)

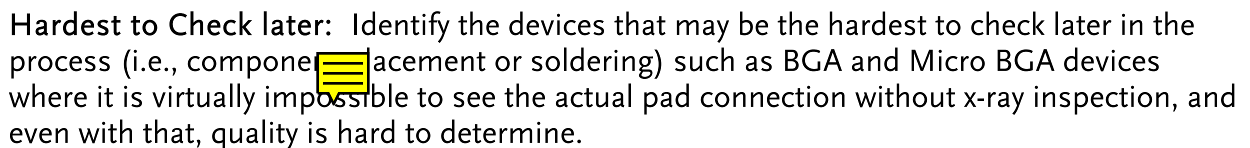
Q – What are some strategies for optimizing the process?

A - Finding and correcting paste application problems is best done as they occur. Given that, with some exceptions, in-line inspection is not designed to inspect every single pad on every single board, there must be ways to determine how to program the inspection system to take advantage of the key devices and areas to use as data models. Inspection of these will transfer over to all devices on all boards being processed in any given run. To learn how to develop the best data models, it is necessary to understand how to check an assembly for the type of components that fit into these categories. It is also important to fully understand the flexibility of the tools available in the inspection software to best determine how to apply these data models in the most effective manner for any individual stencil printing application.

Q – How do I use prioritization in determining which 2D devices to inspect?

A - Single out the devices on any given assembly that will cause the most trouble for printing. Use these as the "representative" components to test. If these problem generators are within print specifications, it can be assumed that the simpler devices on the board should also be within the required parameters. Since, with some aggressive cycle times, not enough time will be available to inspect a sample of all device types, the following list is prioritized by the items most likely to experience solder coverage defects:

> Pinpoint Difficult Devices: Determine which devices will be the most difficult to print. These can be critical sites for fine pitch QFPs where the very small paste volumes are typically very difficult to inspect and measure, or CSP devices.
>
> Find Solder Thieves: It is also wise to identify the devices that have large components or pads on the left and right side of the board. These large components will require more solder to be deposited and therefore, will generally show insufficient solder coverage well before other critical areas become a problem.
>
> Pattern the Inspection: Program the components to be checked as a spread across the entire board. This will help to detect regional issues such as board support weaknesses or areas of high paste consumption. It is advisable to inspect components in several different quadrants of the board such as left, right, top, bottom and center.



> Hardest to Check later: Identify the devices that may be the hardest to check later in the process (i.e., component placement or soldering) such as BGA and Micro BGA devices where it is virtually impossible to see the actual pad connection without x-ray inspection, and even with that, quality is hard to determine.

SPC and Data Collection

Q - What is SPC?

A - Statistical Process Control is the use of statistical techniques such as control charts to analyze a process or its outputs so as to take the appropriate actions to achieve and maintain a state of statistical control and to improve the process capability.

Q - What are Control charts?

A - Control charts are simply effective tools to achieve statistical control. They give the people closest to the operation reliable information on when to take action and when action should NOT be taken. A graphical representative of a characteristic of a process, showing plotted values of some statistic gathering from that characteristic, a central line or mean, and one or two warning and control limits.

Q - What is a "Common Cause" problem?

A - A source of variation that affects all the individual values of the process output being studied. This action usually needs to be corrected by management level personnel (example: board quality, design, paste selection etc.)

Q - What is a " Special Cause" problem?

A - A source of variation that is intermittent, unpredictable, or unstable. These causes of variation are not common to all boards in the flow and usually require a local action (example a board put in backward or a wrong board in the batch). Anything that would cause an unpredictable jump in the data collected would be considered a special cause problem.

Q - What does the term "Mean" indicate?

A - The average of the values in a group of measurements

Q - What does the term "CP" mean?

A - The process capability, or in short the "Repeatability" of the process. The Cp value does not consider the target value.

Q - What does the term "CPK" mean?

A - The process capability index, or in short the "Accuracy and Repeatability" of the process with regard to the target process specification value.