



Agilent

Using the FET Algorithm on the *Medalist* 5DX AXI to Analyze Non-Standard Joints

Application Note

Introduction

As the circuit design for printed circuit boards becomes more complex and demanding in terms of power and speed requirements, it has become vital for the board to be able to dissipate heat efficiently so as not to create thermal fatigue on the components and cause potential failure.

A new leadless design for the MOSFET (metal oxide semiconductor field effect transistor) package allows heat to be removed from the top and bottom surfaces at better efficiencies. This is achieved by having relatively large thermal pads on both sides of the package. An example of such a design is shown in Figure 1.

In X-ray inspection, it is the bottom side pads that require more attention for solder integrity, since these pads represent the gate, source, and drain pins of the MOSFET device. A new algorithm family called FET has been developed for the Agilent *Medalist* 5DX automated X-ray inspection (AXI) system in order to effectively analyze such non-standard joints for insufficient or no solder, non-reflowed or cold solder, and excessive voiding.

The following sections describe and explain the various thresholds.

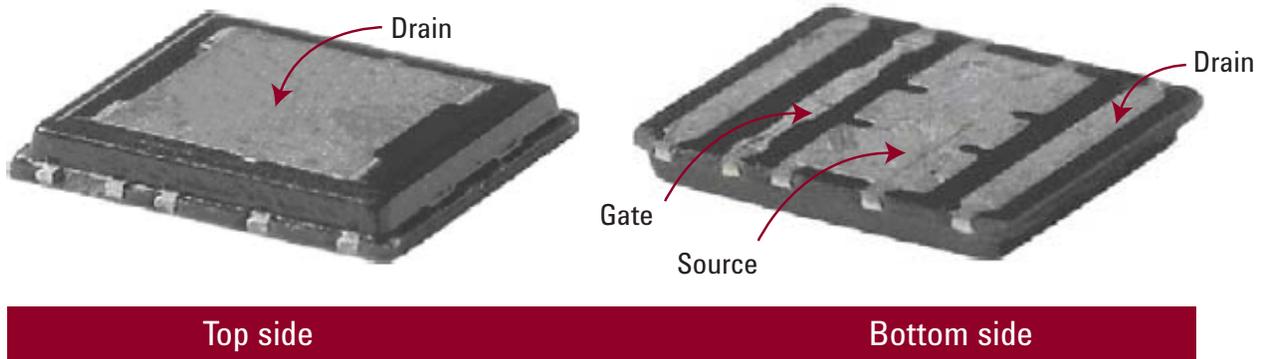


Figure 1. Top, bottom sides and pins of new MOSFET package

Algorithm Tuner

The following sections describe and explain each of the thresholds on the tabs found in the algorithm tuner.

Locator

The locator algorithm defines a region on the X-ray image to search for and lock on to the joint to be analyzed. There are parameters in the Basic and Additional tabs that affect how the software finds the joint.

It is important that the locator algorithm locks on to the joint properly so that accurate measurements are made.

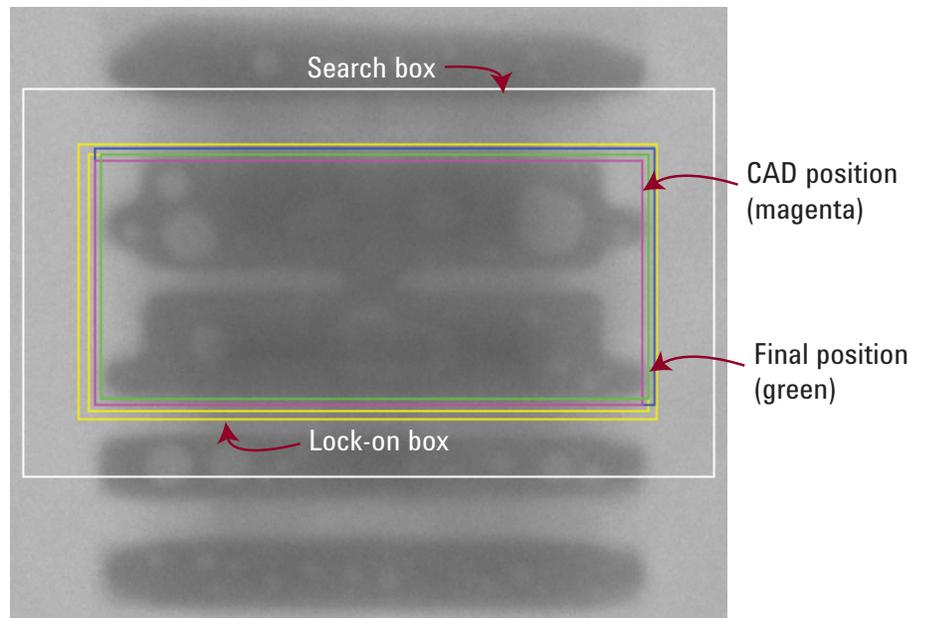


Figure 2. Locator search and lock-on boxes

Locator - basic

Search distance along

This threshold sets the search distance for the rectangular locator template (white box) along the joint, as a fraction of the pitch.

Units: Fraction of pitch
Low limit: 0
High limit: 2
Default: 1
Previous name: SEARCH_DIST

Search distance across

This threshold sets the search distance for the rectangular locator template (white box) across the joint, as a fraction of the pitch.

Units: Fraction of pitch
Low limit: 0
High limit: 2
Default: 1
Previous name: SEARCH_DIST_ACROSS

Effective pad length

This threshold sets the length of the locator search region (yellow box) as a fraction of the pad length.

Units: Fraction of pad length
Low limit: 0.1
High limit: 1.5
Default: 1
Previous name: EFFECTIVE_PAD_LEN

Effective pad width

This threshold sets the width of the locator search region (yellow box) as a fraction of the pad width.

Units: Fraction of pad width
Low limit: 0.1
High limit: 1.5
Default: 1
Previous name: EFFECTIVE_PAD_WID

Snap back distance along

Sets the maximum distance along the pad that a located position can vary from the reference position, before being “snapped back” to the reference position. The reference position is the average position for all the joints in the sub-view that have the same orientation.

Units: Mils
Low limit: 3
High limit: 100
Default: 3
Previous name: SNAP_BACK_ALONG_PAD

Snap back distance across

Sets the maximum distance across the pad that a located position can vary from the reference position before being “snapped back” to the reference position. The reference position is the average position for all the joints in the sub-view that have the same orientation.

Units: Mils
Low limit: 3
High limit: 100
Default: 3
Previous name: SNAP_BACK_ACROSS_PAD

Locator - additional

Effective pad location along

This threshold changes the final located position (green) of the CAD along the pad as a fraction of pad length. A positive value for this threshold shifts the located position away from the component. A negative number shifts the located position toward the component.

Units: Fraction of pad length
Low limit: -0.5
High limit: 0.5
Default: 0
Previous name: EFFECTIVE_PAD_SHIFT

Effective pad location across

This threshold changes the final located position (green) of the CAD across the pad as a fraction of pad width. A positive value for this threshold shifts the located position to the left relative to the pin orientation. A negative number shifts the located position to the right relative to the pin orientation.

Units: Fraction of pad width
Low limit: -0.5
High limit: 0.5
Default: 0
Previous name: EFFECTIVE_SHIFT_ACROSS

Shape

This threshold sets the technique used by Locator to locate the joint. Either rectangular or circular can be chosen. Joints with rectangular pads and pins should use rectangular shape; joints with circular pads and pins should use circular shape.

Units: Rectangular or circular
Low limit: None
High limit: None
Default: Rectangular
Previous name: SHAPE_OF_LOCATOR

Statistical process control

The basic and additional tabs contain statistical process control (SPC) parameters that enables user to define how the algorithm performs the analysis. Parameters set here can affect nominal measurements and the outcome of defect analysis.

SPC - basic

The following describes the various parameters found under SPC with basic selected:

Use pad profile

Determines if the software is to use the CAD data or the actual pad location for insufficient analysis. Set to "Yes" to use actual pad location; "No" to use CAD data.

Units: Yes or no
Low limit: None
High limit: None
Default: No
Previous name: None

Pad profile width

Defines the percent of the pad width, for the width of profile taken along the joint. SPC and defect analysis are performed within the blue rectangle.

Units: Percent of Pad Width
Low limit: 0
High limit: 100
Default: 25
Previous name: None

The diagrams in Figure 3 show the effects of the values of pad profile width.



Pad profile width = 25



Pad profile width = 60

Figure 3. Impact of different pad profile widths

Background profile location

Determines how far the background profiles are from the joint. This is measured as a fraction of the inter-pad distance. A higher value places the profiles further away from the joint. There are 2 along profiles and 2 across profiles. See Figure 4.

Units: Fraction of inter-pad distance
 Low limit: 0
 High limit: 1
 Default: 0.5
 Previous name: None

Obtaining a joint solder profile

A typical X-Ray image of a joint is in gray-scale mode where there are 255 levels of gray scale. It consists of the region of interest (ROI) of the joint under analysis and the surrounding background. During diagnostics, the software evaluates the average gray level from the background profiles and subtracts this from that of the pad profile, thus giving a more accurate solder thickness measurement of the joint. See Figure 5.

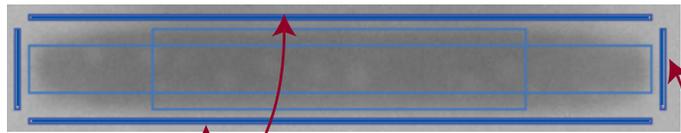
Slope search region

Determines the percent of the pad profile to search for the maximum slope.

Slope is defined as the change in gray level per pixel along the solder fillet. Maximum slope is the point along the solder fillet where the change in gray level is the largest.

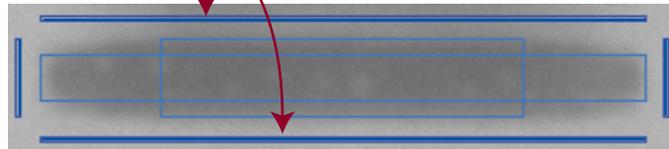
Units: Percent of pad profile
 Low limit: 0
 High limit: 100
 Default: 10
 Previous name: None

Background profile
 Location = 0.5 (default)



Profile along

Profile across



Background profile
 Location = 1.0 (default)

Figure 4. Effects of background profile location

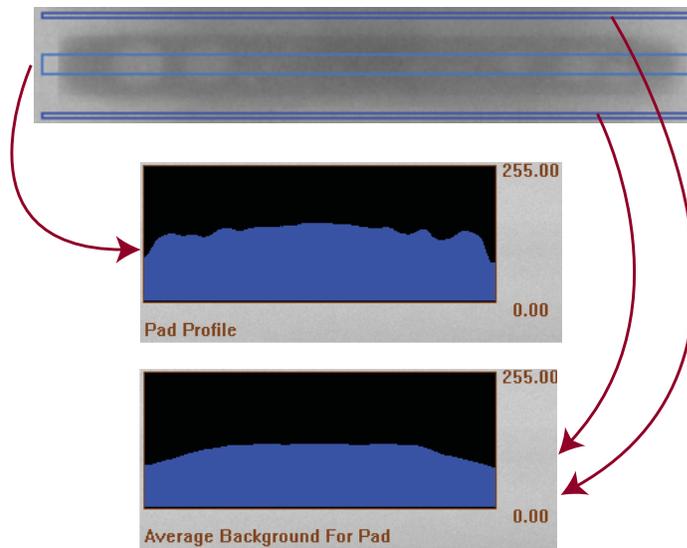


Figure 5. How a joint solder profile is obtained

Leading slope and trailing slope are two points near the solder joint ends, where the slope is the maximum.

Maximum slope at the leading and trailing edge of the solder joint can provide a good indication of whether the joint is good, has insufficient solder or a missing component. See Figure 6.

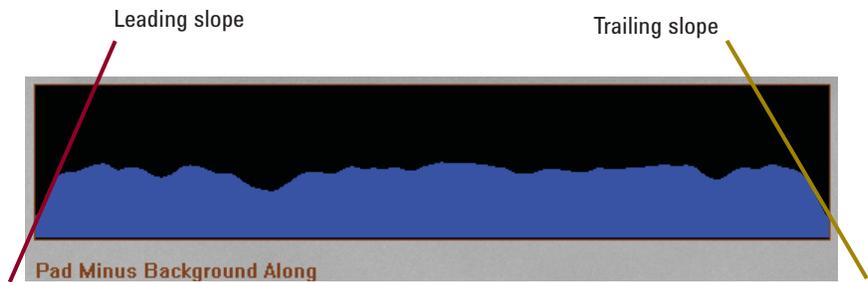


Figure 6. Leading and trailing slopes along a profile

Enable gap along msmt/enable gap across msmt

Certain FET packages have a source pad design that consists of sub-pads with gaps between them. By enabling gap measurements along or across the pad profile, it is possible to determine a good joint from that of an insufficient or missing component. This is explained in more detail later.

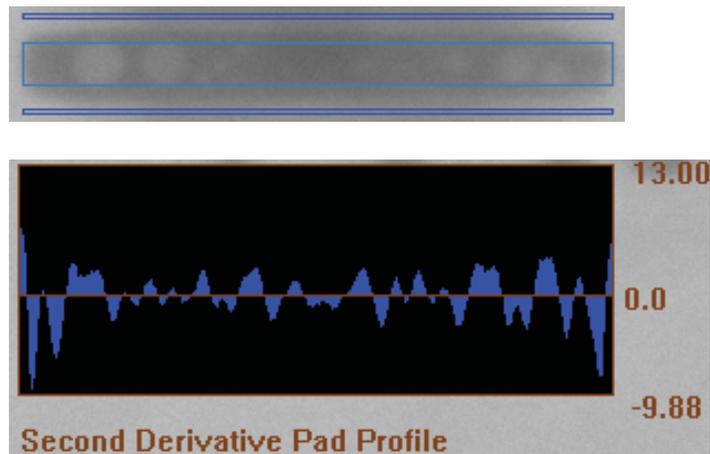
Units: Yes or no
 Low limit: None
 High limit: None
 Default: No
 Previous name: None

Span size

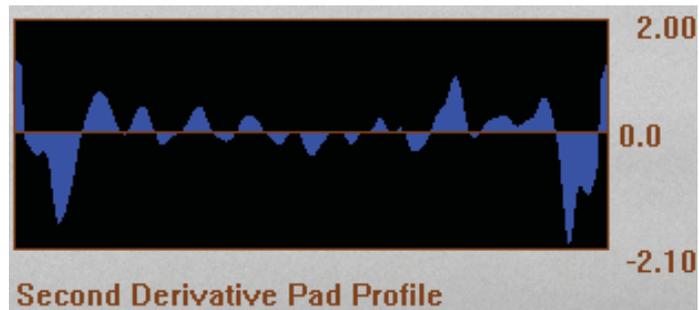
Used for insufficient analysis, a larger number smoothens the 2nd derivative profile representing the sum of slope changes. See Figure 7.

In Figure 7, increasing the span size to 30 results in a 2nd derivative profile that is less erratic.

Units: None
 Low limit: 0
 High limit: 40
 Default: 6
 Previous name: None



Span size = 6 (default)



Span size = 30

Figure 7. Effect of span size on sum of slope changes profile

Voiding thickness

Sets the minimum difference in the solder thickness required, between the inspection image and the learned or “expected” image, to consider a pixel as voided.

The concept of learned or “expected” image in voiding analysis is discussed later in detail.

Increasing the voiding thickness value has a tendency to reduce voiding sensitivity and reduce the overall voiding area in the joint.

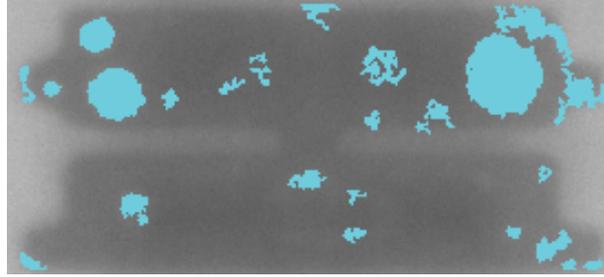
Units: Mils
Low limit: 0
High limit: 100
Default: 8
Previous name: None

Minimum void area

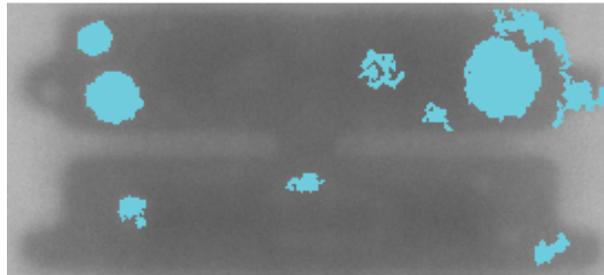
Defines the minimum area of the voids that will be included in calculating the overall void area on the joint. The void areas that are less than this value are not considered in the analysis.

An increase in the value has a tendency to reduce the overall void area. Fewer areas in the joint are also highlighted. See Figure 9.

Units: Square mils
Low limit: 0
High limit: 100
Default: 10
Previous name: None

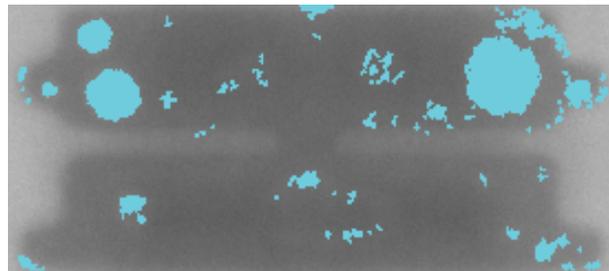


Voiding thickness = 10 mils
Voiding area = 11.6%

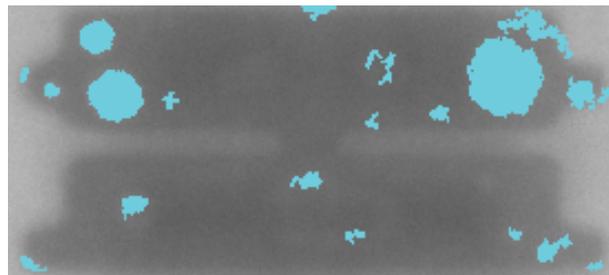


Voiding thickness = 50 mils
Voiding area = 9.5%

Figure 8. Effect of voiding thickness in voiding area



Min void area = 2 sq mils
Void area = 10.04%



Min void area = 10 sq mils
Void area = 8.7%

Figure 9. Effect of minimum void area

SPC - additional

Minimum thickness

This value determines the minimum solder thickness in mils (default 1 mil), on the joint that will be included for paste coverage and paste volume calculation and measurements used in Insufficient analysis.

A larger value generally reduces the paste coverage and paste volume.

Units: Square mils
Low limit: 0
High limit: 25
Default: 1
Previous name: None

During the diagnostic run of SPC, various measurements are performed and displayed:

----- FET SPC -----

Pad profile (sky blue) is being used for paste volume, coverage and thickness measurements.

Entering ProcessJointVoidMeasurements.

3.53 Median Paste Thickness [Mils]
24.53 Pad Coverage [Percent]
4997.3 Paste Volume [cubic Mils]
...

The minimum thickness value set will affect the above measurements.

Gap across position/gap along position

When gap measurements are enabled, these values determine the position of the gap measurement profiles. A larger value pushes the profiles away from the center of the joint.

The diagrams in Figure 10 show the effect of the gap profile locations on varying their positions:

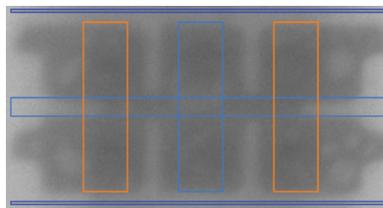
The width of the gap profiles may be changed according to the value set for pad profile width under SPC - basic. This may be necessary in order to place the gap profiles nicely over the gaps in the joint for optimal measurements.

Gap across position

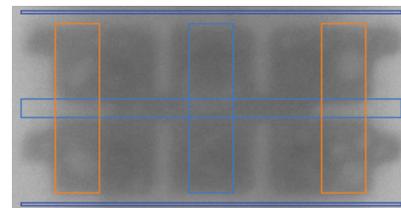
Units: Percent of pad across
Low limit: 0
High limit: 50
Default: 25
Previous name: None

Gap along position

Units: Percent of pad along
Low limit: 0
High limit: 50
Default: 25
Previous name: None



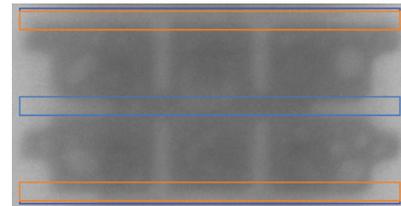
Gap across position = 25% (default)



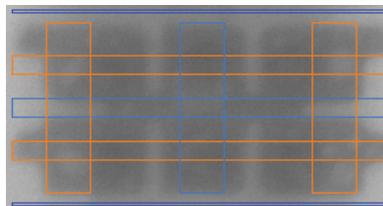
Gap across position = 35% (good)



Gap along position = 25% (default)



Gap along position = 50% (too far out)



Enabling both along and across gap measurements

Figure 10. Gap across and along position on gap measurement profiles

Minimum voiding region thickness

This value sets the minimum thickness, in mils, to exclude from the learned or "expected" image. The black areas in the learned image are not taken into account for voiding analysis. The objective is to set a value such that the black areas on the learned image represent the regions that are not expected to have any solder. The diagrams in Figure 11 show the effect of this value on the learned image.

From Figure 11, it can be observed that as the minimum voiding region thickness value increases, there are more black regions.

For the above joint at 0.5 mils and 1 mil, the black regions do not cover the gaps; at 5 mils the black regions cover the areas that are expected to have solder. At 2.5 mils the black regions cover the gaps but yet do not include the actual solder connection. This is the best setting to represent an expected good joint.

Units: Mils
Low limit: 0
High limit: 25
Default: 1
Previous name: None

Open - basic

The thresholds to determine a potential open joint all relate to slope on the leading and trailing ends of the solder joint

Minimum leading slope along

Sets the minimum threshold for the leading slope along the joint profile. If the measured value is less than this, the joint fails open.

Units: Gray level/pixel along joint
Low limit: -25
High limit: 25
Default: 4.5
Previous name: None

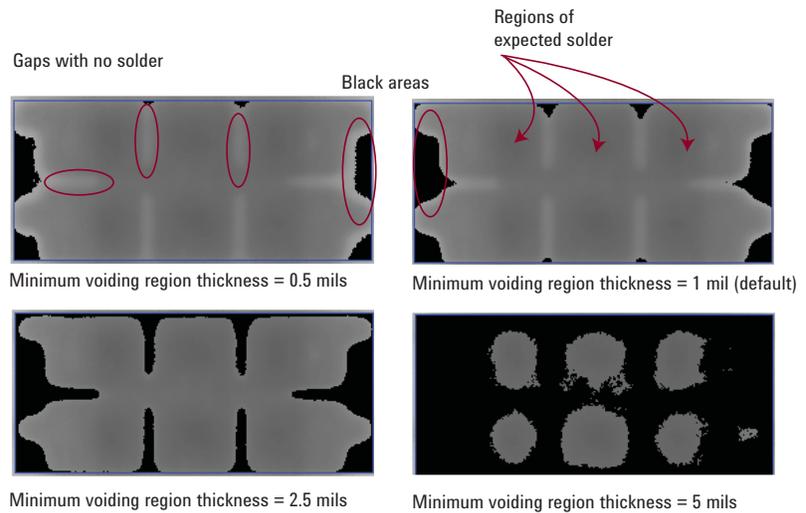


Figure 11. Minimum voiding region thickness on learned image.

Minimum trailing slope along

Sets the minimum threshold for the trailing slope along the joint profile. Measured in units of gray level per pixel, the default is 4.5. If the measured value is less than this, the joint fails open.

Units: Gray level/pixel along joint
Low limit: -25
High limit: 25
Default: 4.5
Previous name: None

Min slope sum along

This value is the addition of the leading slope and trailing slope along the joint under analysis. Set at a default of 9 gray levels per pixel, if the measured value is less than the set value, the joint fails open.

This threshold is an extra condition for the joint to be able to pass the open test. Not only must the joint satisfy the minimum leading and trailing slopes along - their sum must also be above this value.

Units: Gray level/pixel along joint
Low limit: -25
High limit: 25
Default: 9
Previous name: None

Minimum leading slope across

Sets the minimum threshold for the leading slope across the joint profile. Measured in units of gray level per pixel, the default is 4.5. If the measured value is less than this, the joint fails open.

Units: Gray level/pixel along joint
Low limit: -25
High limit: 25
Default: 4.5

Minimum trailing slope across

Sets the minimum threshold for the trailing slope across the joint profile. Measured in units of gray level per pixel, the default is 4.5. If the measured value is less than this, the joint fails open.

Units: Gray level/pixel along joint
Low limit: -25
High limit: 25
Default: 4.5

Minimum slope sum across

This value is the addition of the leading slope and trailing slope across the joint under analysis. Set at a default of 9 gray levels per pixel, if the measured value is less than the set value, the joint fails open.

This threshold is an extra condition for the joint to be able to pass the open test. Not only must the joint satisfy the minimum leading and trailing slopes across - their sum must also be above this value

Units: Gray level/pixel along joint
Low limit: -25
High limit: 25
Default: 9
Previous name: None

Insufficient - basic

Minimum paste thickness

This value sets the minimum solder paste thickness in mils that the solder joint must have. If the calculated value is less than this the joint fails insufficient.

This value is directly affected by the minimum thickness threshold found under SPC - additional. Decreasing the minimum thickness value has a tendency to increase the measured average solder thickness of the paste. Setting it to 0 virtually turns this threshold off.

Units: Mils
Low limit: 0
High limit: 25
Default: 1.5
Previous name: None

Maximum gap along/maximum gap across

This value sets the maximum allowed distance in mils for the gap (default 30 mils). The algorithm makes two gap measurements on the along profile and two measurements on the across profile. If any of the measured gaps is more than the set value the joint fails insufficient.

Units: Mils
Low limit: 0
High limit: 100
Default: 30
Previous name: None

Maximum sum of slope changes

This value sets the maximum allowed sum of slope changes on both the along and across solder profile. The profile corresponding to the slope sum changes is the 2nd derivative pad profile (See Figure 7). In general, a high sum of slope changes indicates a larger number of voids along or across the profile, giving rise to more alternating dark and light gray levels.

Units: Gray level/pixel along joint
Low limit: 0
High limit: 100000
Default: 100000
Previous name: None

The default value of 100000 virtually turns off this threshold. Based on the average measured values for the good joints in the sub-type, set an appropriate value. For example, if the majority of the joints have a sum of slope changes around 85, setting the threshold to around 100 is appropriate.

Insufficient - additional

Minimum sum of slope changes

This value sets the minimum sum of slope changes required to pass the joint for Insufficient. The default value of 0 virtually turns this threshold off.

Units: Gray level/pixel along joint
Low limit: 0
High limit: 100000
Default: 0
Previous name: None

Minimum paste coverage

This value sets the minimum acceptable paste coverage as a percentage of paste area.

Units: Percent of paste area
Low limit: 0
High limit: 300
Default: 70

Previous name: None
Paste coverage is affected greatly by the minimum thickness threshold under SPC - additional and the pad profile width. As the minimum thickness is increased, the paste coverage decreases. This is because fewer solder areas on the joint are included for analysis.

Minimum paste volume

Sets the minimum acceptable amount of solder paste volume.

Units: Cubic mils

This value sets the maximum allowed voiding area as a percentage of the joint area (or expected solder area) after removing the learned image. This value is represented by the addition of all the areas, identified as voids in the joint, highlighted in cyan color. The joint fails if the measured void area is larger than the set threshold (default 30%).

Units: Percentage of joint area
Low limit: 0
High limit: 100
Default: 30
Previous name: None



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Revised: March 27, 2008

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Printed in USA, July 21, 2008

5989-9208EN



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