Agilent Technologies

Quad Flat No-Lead (QFN) Application Note and Best Practices

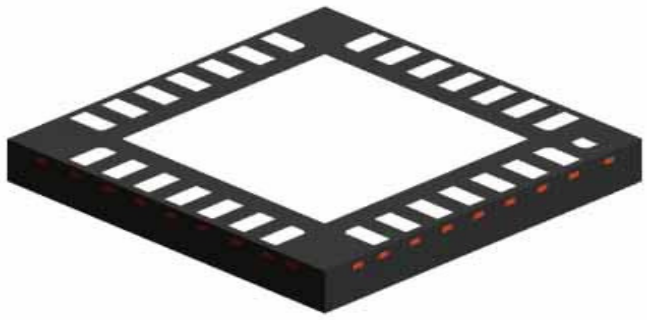
Objective

The purpose of this application note and best practices guide is to describe the QFN type component and provide testing methodology and best practices to ensure robust testing and quality results. The QFN algorithm was introduced in 5DX software version 8.4, and then functionality has been enhanced and simplified in patch version 8.4.1. This application note will begin with a description of the QFN component and then briefly discuss different joint variations which are exhibited with the range of component and land pattern configurations. Next, the common functionality of the QFN algorithm will be discussed, and descriptions provided for each threshold. Finally, best practices regarding the different variety of joint types will be discussed and recommendations provided.

Also included with the QFN functionality is an update to the algorithm tuner help files which should provide a comprehensive explanation of each threshold and variable to assist with the setup of this algorithm

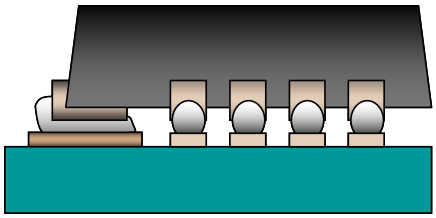
The QFN Description

The QFN component package is a quad flat pack (QFP) with “no-leads”, where the electrical contact to the printed circuit board (PCB) is made through soldering of the lands underneath the package body rather than the traditional leads formed along the perimeter. The popularity of this device package style is primarily due to the superior electrical and thermal performance demonstrated. The joints produced by this component and corresponding pad designs have several variations, and require a different set of algorithm functions than other devices. The best practices for each of the following joint types will be covered in more detail later in this application note.



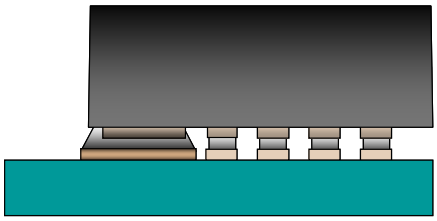
QFN Joint Variations

Outside Edge Terminations:



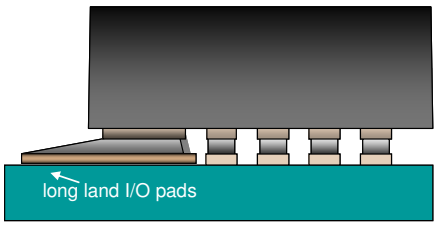
- Quantify good joint with presence of large toe fillet
- Easiest joint type to test, and Fillet Length, Center, Open Signal, Upward Curvature, and Slope measurements provide the most robust results

Bottom Only Terminations:



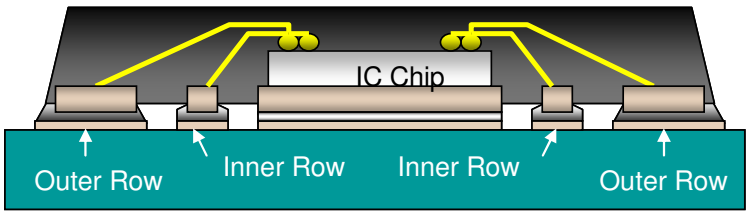
- User relies heavily on Heel, Center, and Insufficient measurements

Bottom Only Terminations with longer pad (QFP drop in):



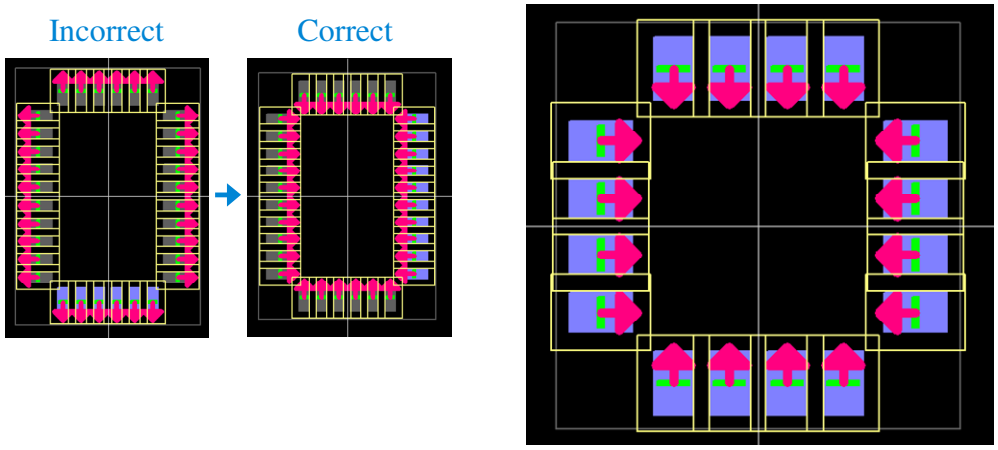
- This joint type is typical where a QFN package has replaced a QFP device on the same land pattern
- Heel placement is critical, and the user relies heavily on Fillet Length, Heel, Center and Insufficient measurements

Bottom Only Terminations – Dual Row (Denoted by Smaller Pads):



- This component utilizes smaller terminations than other QFNs, making it more difficult
- Rely heavily on minimum fillet length, center thickness, heel slope and across center measurements

QFN Preparation – Test Link



Test Link Specific Preparation for QFNs

In order to correctly utilize the QFN algorithm, the joint orientation must be set accurately using Test Link. Note the joint orientation arrows pointing towards the middle of the device. Follow the steps below when editing and making this change:

- Correcting pad orientation
  - Open Test Link within Test Development Workstation (TDW)
  - Open current project
  - Select Assign Packages
  - Select part of interest
  - Note direction of CAD
  - If needed, change the orientation
    - Deselect the checkmark
    - Select row of pins (using CTRL key)
    - Change parts orientation by selecting the opposite rotation under Package Details
    - Pin offset should be set to 0
    - Repeat for all sides
- Select QFN algorithm for all pins if necessary

The QFN Locator Algorithm

A Locator Algorithm is common to all joint tests. The Locator Test Algorithm locates the exact position of the solder joint on the solder pad. The Statistical Process Control (SPC) and Short Algorithms run using the located positions. All Joint Types use the same Locator Test Algorithm and it is always processed first.

- Procedure:
  - Start the search at the center of the CAD defined location
  - Search along the pad
  - Search across the pad
  - Pass the resulting location information to the SPC Algorithm that uses it to locate the regions of interest and to measure the joint

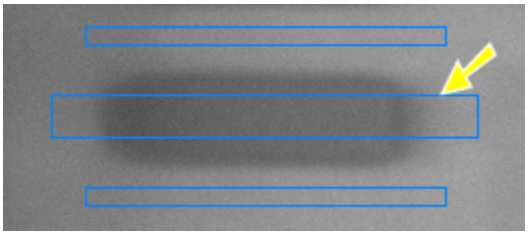
- For all typical solder joints and most atypical joints, the Locator Algorithm works without need of tuning. Therefore, most programmers ignore the algorithm, testing its effectiveness by examining SPC's first text results. When SPC starts work on a joint, it reports that Locator had problems or used the CAD defined location.

The QFN SPC Algorithm

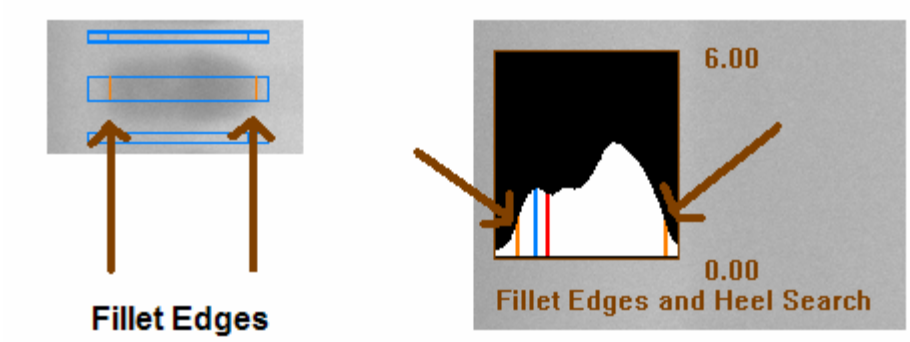
There are two aspects to the SPC Algorithm - Setup & Test

Setup

- Temporarily disable the Short algorithm for all families
- Verify that the Heel, Center, Toe and/or overall solder joint are correctly located using the following steps:
  - Edit the `Effective Pad Length` and `Width` if needed to adjust the size of the test region.



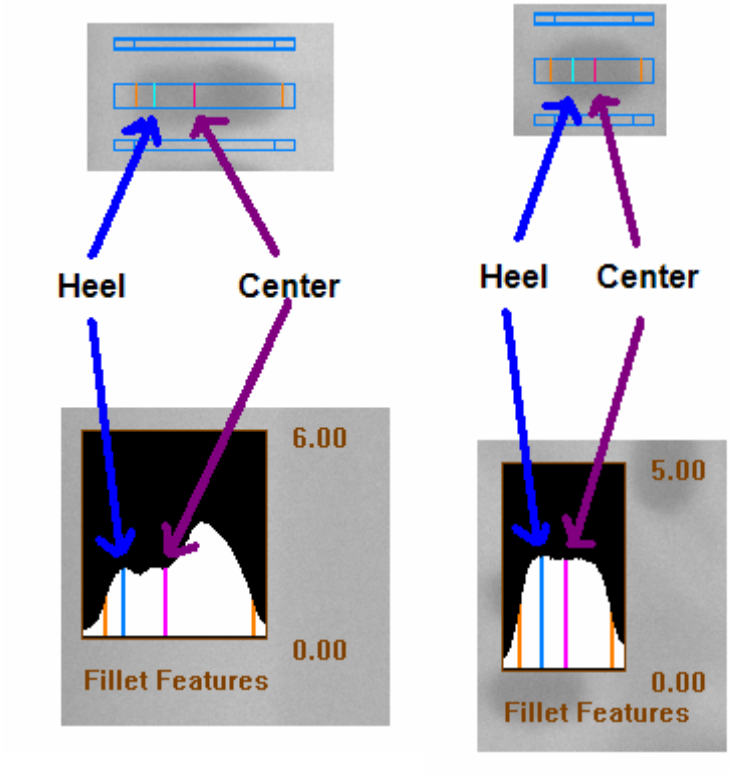
  - Verify the fillet edge locations are finding the most prominent sloped region near the beginning and the end of the joint. Be cautious of locating too far up the joint region on joints which are only slightly sloped. See example of ideal setup:



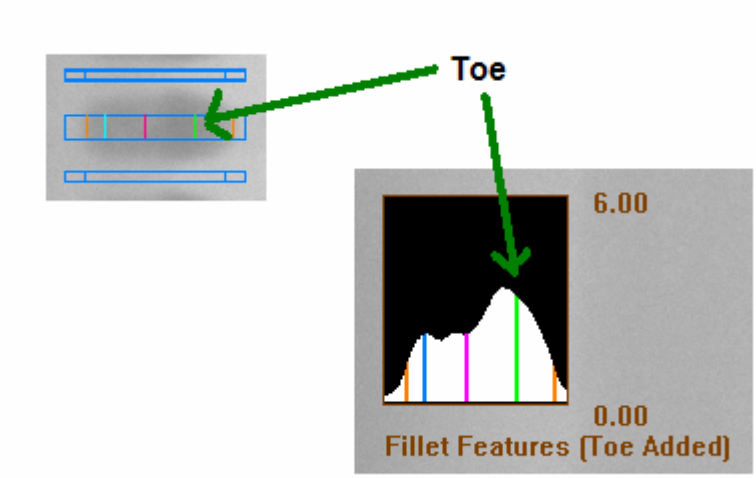
If the fillet edge graphics are near the edge of the Fillet edges and Heel search graphics window, then the pad length needs to be increased to allow the algorithm to find the edges correctly. Adjust the `Pad Profile Length` if necessary.

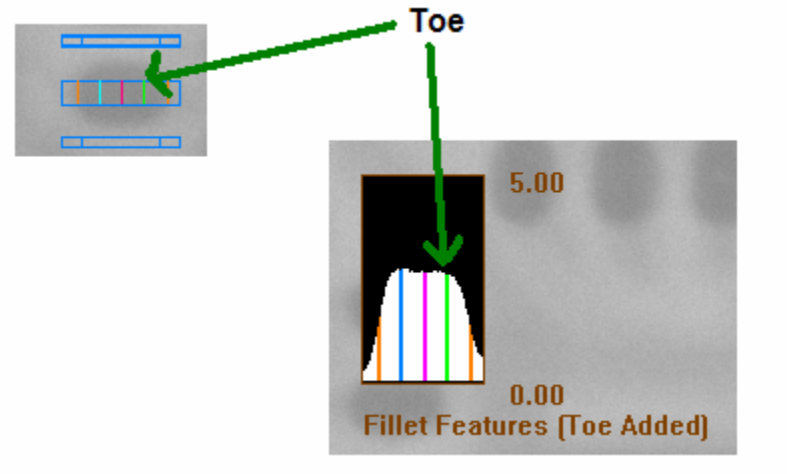
If the default fillet edge location technique is not accurate, adjust the `Fillet Length Technique` from `Max Slope` to `Thickness` and tune the `Heel` and `Toe Search Thickness`.

- Verify the heel location is on the left side of the flat region of the joint which denotes where the termination is sitting. If the heel position (Blue) is being found incorrectly, adjust the Heel Distance Search Marker (Red) percentage higher or lower where the heel can find the appropriate max height within the region. It is best to locate the heel toward the left of the flat region due to optimal open detection.
- Verify the center location is positioned where the amount of solder flattening or depression on a good joint is maximized relative to the height for a solder open. Adjust the `Center Location` threshold to position this more accurately.



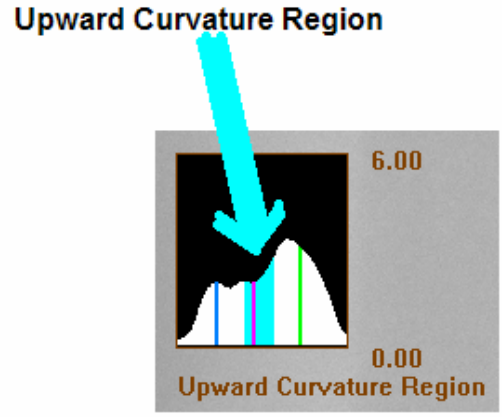
- Here are some examples of heel and center setup on the 2 joint variations
- Verify the toe location is positioned either on or just to the right of the rightmost peak in the case of the large toe joint variation, or the right most side of the flat joint region on a joint which is entirely under the QFN body. If needed, adjust the `Toe Location` threshold which is a fixed distance from the heel fillet.
- See an example of toe location on these 2 joint variations:



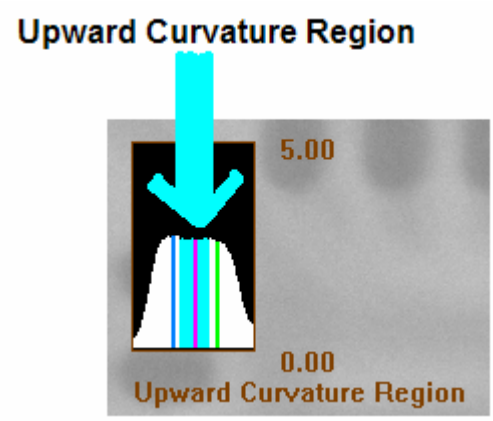


- Verify the location of the upward curvature region. The blue shaded region should be placed on the region of the joint with the most upward (concave) regions as possible.
  - Exclude as many downward (convex) curving regions as possible
  - If surface of joint is smooth or flat, this test region is very effective at differentiation of opens. However, if the surface is very variable, then caution must be taken when tuning not to produce false failures.

- See examples of correctly setup upward curving region:



- For a joint with a large toe region, set the start upward curvature to 35 to 45 and set the end upward curvature to 65 to 75. The goal is the place the search region in blue around the point where the solder flows up to create the toe.



- For the joint that does not contain a toe, upward curvature can be used to inspect for how flat the top of the joint. Start upward curvature is best set near the heel while the end of the upward curvature should be placed near the toe. This allows you to look at the joint as a whole.

- Enable Void Detection in order to fail for voids of a specific size.
  - Note that voiding also has to be enabled through test link for this device type
  - Voiding may be setup within SPC-Advanced and the Voiding tab

- Enable Void Compensation in order to minimize the effect of voiding on other joint measurements related to “Open” testing. This will essentially smooth out the joint profile to improve measurements such as center thickness and upward curvature

- Void Compensation can be adjusted through the `Profile Smoothing Level` in SPC-Advanced thresholds

- The following values can be taught with subtype learning in SPC. Note that the user will not be able to set subtype learning for QFN-Open due to the recommended procedure for setup
  - Nominal Fillet Thickness
  - Nominal Heel Thickness
  - Nominal Toe Thickness
  - Nominal Center Thickness

- After completing setup, the user may utilize Review Measurements to improve the value for each measurement region.
  - Test a known good panel
  - Use Review Measurements to create a Raw Data Sheet
  - Chart the measured values
  - Update the SPC Algorithm with the results
  - Create a Summary Data Sheet and use the Alt. Update process to copy the measurement results into the Algorithm Tuner

Test

- After the Nominal values have been entered, when you test a panel, SPC will:
  - Identify and measure the primary regions (fillet, heel, center and toe)
  - Pass the Nominal values and the measured values to the Analysis algorithms that will determine pass/fail status

Tune the QFN Open Algorithm

The Open Algorithm tests the solder joint to insure there is an actual joint. If the lead does not reach the solder when it is molten, the solder then cools into the shape of a bead; like a drop of water on glass. There are several failure modes for the open algorithm test. Additional information on each algorithm variable can be found in the algorithm tuner "Show Description".

Basic Parameters

- Maximum (Fillet) Length
  - This examines the distance between the heel fillet edge and the toe fillet edge. If it exceeds the maximum set in the algorithm setup, then it fails for fillet length.
  - Use the review measurements to help set the `Maximum Fillet Length`
- Maximum Center Thickness
  - The thickness calculated here is represented by a % of the nominal SPC center thickness
  - The variable is populated but the subtype learning, but also use the review measurements to verify setup

- This test is most effective on finding defects on joints which are located entirely under the QFN package. Also, this is effective in determining misalignment on joints with the large toe region.

- Minimum Open Signal
  - This looks at the relative difference between the height of the heel or toe and the center of the joint. The setup can be changed by adjusting the Advanced `Heel`, `Center`, and `Toe Thickness Multipliers`.
  - This is most effective on joints with a large toe region by setting it to a toe/heel or toe/center measurement.
- Minimum Upward Curvature
  - This parameter examines the curvature of the region specified in the SPC setup. This ideally will produce a higher positive number.
  - Utilize the review measurements to ensure proper setup
  - This is ineffective if highly variable or "wavy" along the surface of the flat joint area
  - Void Compensation can be utilized here to minimize the waviness created from acceptable voiding
- Minimum Slope Techniques
  - Minimum Heel Slope – pertains to measure maximum leading edge slope between heel fillet edge and heel
  - Minimum Sum of Slope Changes – calculates the sum of the changes in slope all along the joint profile. Most good joints should incorporate fairly steep fillet edges and sharp slope changes at the termination and pad interfaces. **This is a primary defect indicator for both variations of joints**.
- Across Heel Measurement Techniques
  - Minimum LT Slope Sum Across Heel – minimum acceptable sum of leading and trailing slopes across heel cross-section
  - Minimum Sum of Slopes Across Heel – minimum acceptable sum of slopes across heel cross-section
  - Minimum Width Across Center Thickness – minimum acceptable width of joint across center cross-section in mils

Advanced Parameters

- Multipliers – These are used in the open signal calculation to identify where the expected peaks and low points will be in an ideal joint. Default is to have Heel set to 0, Toe set to 1 and Center set to -1. This makes the open signal calculation Toe – Center. This is the typical opens test, where the Toe will be larger then the Center. Change the values of the multipliers if it appears heel or center is larger.
  - Heel Thickness Multiplier – Used to set calculation related to heel – 0=disable, 1=if the measurement is greater then, -1=if the measurement is less then.

  - Toe Thickness Multiplier – Used to set calculation related to heel – 0=disable, 1=if the measurement is greater then, -1=if the measurement is less then.
  - Center Thickness Multiplier – Used to set calculation related to heel – 0=disable, 1=if the measurement is greater then, -1=if the measurement is less then.
- Minimum Heel Sharpness – This parameter measures the sharpness of the heel. It computes the curvature of the heel edge at the location where the joint profile has the sharpest changes.
- Minimum Slope Techniques
  - Minimum Toe Slope – pertains to maximum measured trailing edge slope between toe and toe fillet edge
  - Minimum Center Slope – calculates the maximum slope found between the toe and heel
  - Minimum Slope Sum – calculates the sum of the toe and heel slopes
- Across Heel Measurement Techniques
  - Minimum Width Across Heel – minimum acceptable width of joint across heel (in mils)
- Across Center Measurement Techniques
  - Minimum LT Slope Sum Across Center – minimum acceptable sum of leading and trailing slopes across center
  - Minimum Sum of Slopes Across Center – minimum acceptable sum of slopes across center
- Maximum Neighbor Length Difference
  - This calculation examines the relative difference between the joint of interest and other corresponding joint in the view

Tune the QFN Insufficient Algorithm

The Insufficient Algorithm tests the solder joint to insure there is sufficient solder to hold the package on the panel and to provide a viable electrical contact.

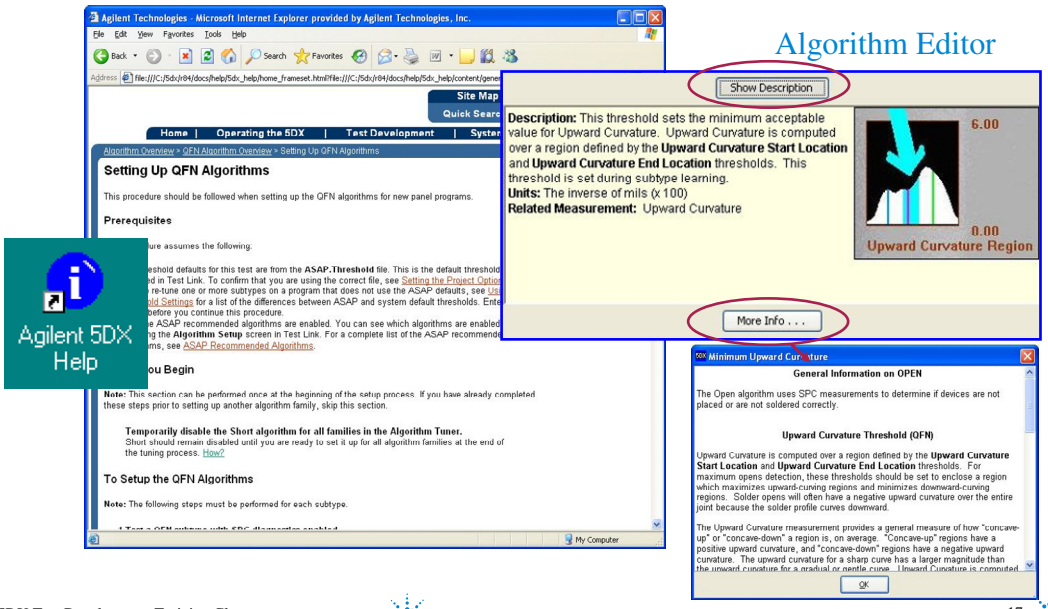
The Insufficient test uses SPC measurements and Nominal Thickness values to determine if there is insufficient solder on the joint. To prevent false calls, it is recommended that thresholds be set to verify the manufacturing process.

- The overall solder thickness for the joint is tested as the Minimum Fillet Thickness.
- The measured solder thickness at the Heel is compared to the Nominal expectation. If there is sufficient solder, the Minimum Heel Thickness test passes.
- The Toe region is tested for thickness and width as well.
- The Fillet Length is tested to verify that it is of acceptable length.
- Use Review Measurements to chart the solder density of all the joints of this subtype.

– If there is a significant difference, explain to yourself why this difference exists. Be sure to verify the measurement region is positioned correctly on the joint. Having explained the difference, adjust the test threshold to test the joint properly.

Tune QFN

Resources: On-Line Help Tools and Descriptions



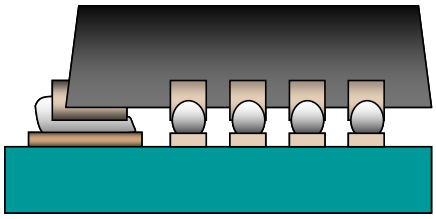
Resources – Online Help Tools and Descriptions

- Online help tools assist with the algorithm tuning flow and explain interaction of the different parameters.
- The descriptions within the algorithm editor provide a detailed description of the parameter being changes and parallel the online help in terms of the shared information.

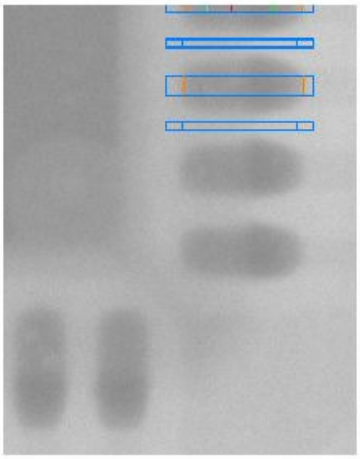
QFN Best Practices

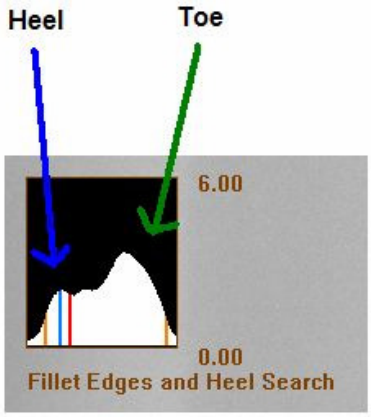
The following best practices have been assembled by applications engineers utilizing customer products in order to achieve optimal performance of the algorithm. The recommendations are a guide to the initial program development, and users will find that they may have to adjust values as necessary. As with all joint types, review measurements must be used to set the thresholds and parameters most actively, and subtype learning will not teach nominals to Open or Insufficient. One other note to make is that the thresholds listed are the recommended thresholds to use on that joint type, and that the others should be disabled or set with a wide tolerance to prevent false fails. Use a bare reflowed board when possible to mimic open solder joints for threshold setting.

Outside Edge Terminations (Large Toe):



- Quantify good joint with presence of large toe fillet
- Easiest joint type to test, and Fillet Length, Center, Open Signal, Upward Curvature, and Slope measurements provide the most robust results





SPC – Set and modify if needed

- Heel – 15-20%
- Center – 45%
- Toe – 75-85%
- Upward Curvature – 40% (Start) to 65% (End)

Open – Use Review Measurements to set the following recommended variables

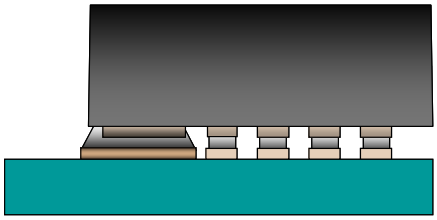
- Max Length
- Max Center Thickness

- Open Signal
- Upward Curvature
- Sum of Slope Changes
- *Disable Remaining*

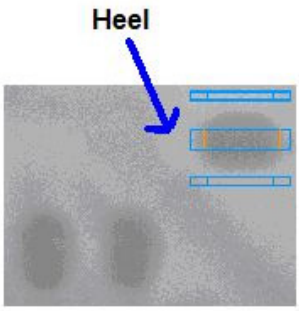
Insufficient – Use Review Measurements to set the following recommended variables

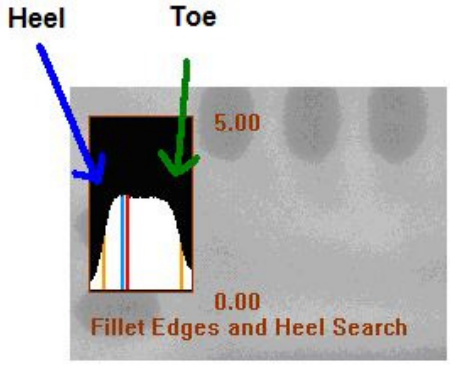
- Min Fillet Thickness
- Min Center Thickness
- Min Heel Thickness
- Min Fillet Length

Bottom Only Terminations:



- Rely heavily on Heel, Center, and insufficient measurements





SPC – Set and modify if needed

- Heel – 10-15%
- Center – 50%
- Toe – 70-90%
- Upward Curvature – 25% (Start) to 65-75% (End)

Open – Use Review Measurements to set the following recommended variables

- Max Length
- Max Center Thickness – 5-10% higher than top in review measurements
  - ➢ It's important to correct nominals if process changes rather than open thresholds
- Upward Curvature

- Across Center Width
- LT Across Heel
- Sum of Slope Across Heel
- *Disable Remaining*

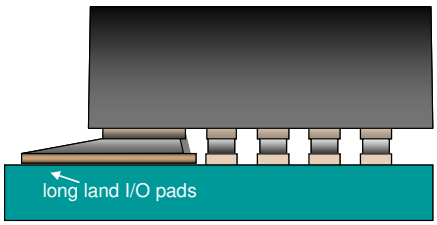
Insufficient – Use Review Measurements to set the following recommended variables

- Min Fillet Thickness
- Min Center Thickness
- Min Heel Thickness
- Min Fillet Length

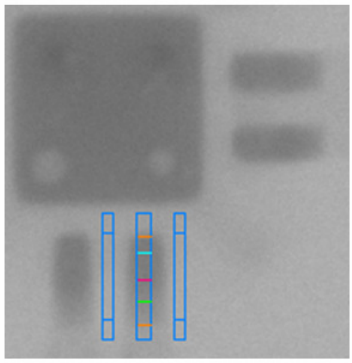
In order to find a specific process indicator related to an open joint, set the following:

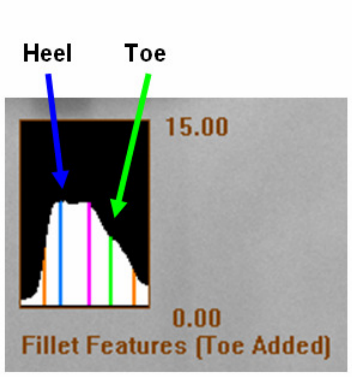
- Open Signal – Set wide to minimize potential false fails

Bottom Only Terminations with longer pad (QFP drop in):



- This joint type is typical where a QFN package has replaced a QFP device on the same land pattern
- Heel placement is critical, and the user relies heavily on Fillet Length, Heel, Center and Insufficient measurements





SPC – Set and modify if needed

- Heel – 15-20%
- Center – 35-50%
- Toe – Use Profile Images to Set%
- Upward Curvature – if unable to differentiate between and open joint a good joint, disable

Open – Use Review Measurements to set the following recommended variables

- Max Length

- Max Center Thickness
- Center Across Width
- Heel Slope
- *Disable Remaining*

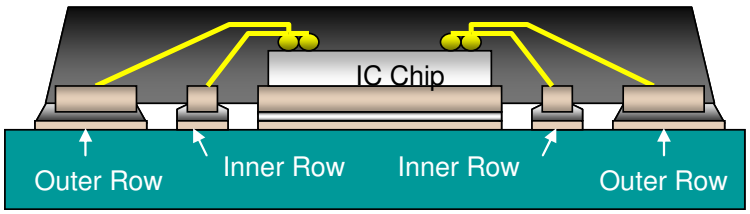
Insufficient – Use Review Measurements to set the following recommended variables

- Min Fillet Thickness
- Min Center Thickness
- Min Heel Thickness
- Min Fillet Length

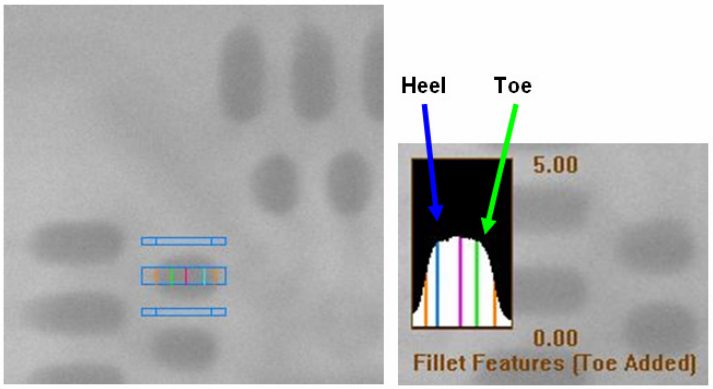
In order to find a specific process indicator related to an open joint, set the following:

- Heel Sharpness – Set wide to minimize potential false fails

Bottom Only Terminations – Dual Row (Denoted by Smaller Pads):



- This component utilizes smaller terminations than other QFNs, making it more difficult
- Rely heavily on minimum fillet length, center thickness, heel slope and across center measurements



SPC – Set and modify if needed

- Heel – 10-15%
- Center – 50%
- Toe – 75-90%
- Upward Curvature – if unable to differentiate between and open joint a good joint, disable

Open – Use Review Measurements to set the following recommended variables

- Max Length

- Max Center Thickness
- Heel Slope
- Across Center Width
- *Disable remaining except if an expert user*

Insufficient – Use Review Measurements to set the following recommended variables

- Min Fillet Thickness
- Min Center Thickness
- Min Heel Thickness
- Min Fillet Length