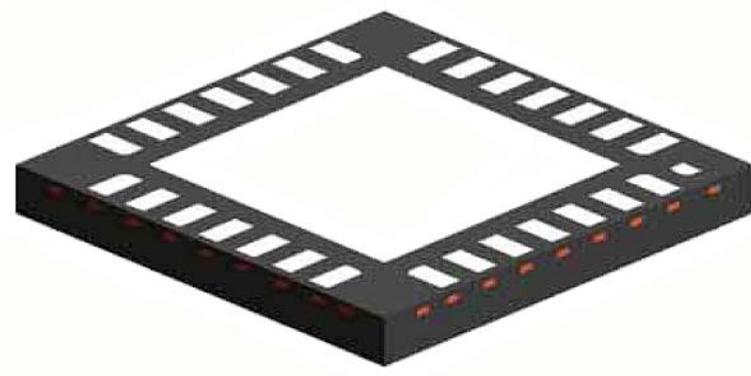


Agilent Medalist 5DX Automated X-Ray Inspection (AXI) Quad Flat No-Lead (QFN) Best Practices

Application Note



Objective

The purpose of this application note and best practices guide is to describe QFN-type components and provide testing methodologies 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 QFN components and then briefly discuss different joint variations that 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 a 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.

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 joint types will be covered in more detail later in this application note.

QFN Joint Variations

With outside edge terminations, good joints are characterized by the presence of a large toe fillet.

This is the easiest joint type to test; Fillet length, center, open signal, upward curvature, and slope measurements provide the most robust results.

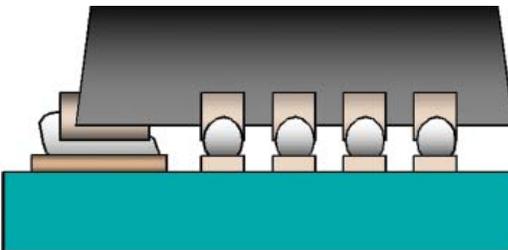


Figure 1. Outside edge terminations

The primary tests for bottom-only terminations are heel, center and insufficient measurements.

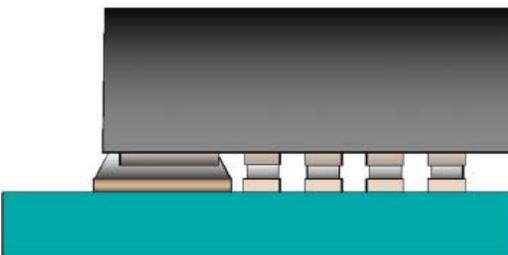


Figure 2. Bottom-only terminations

Bottom-only terminations with long pads are typical where a QFN package has replaced a QFP device on the same land pattern. Heel placement is critical. Primary tests include fillet length, heel, center and insufficient measurements.

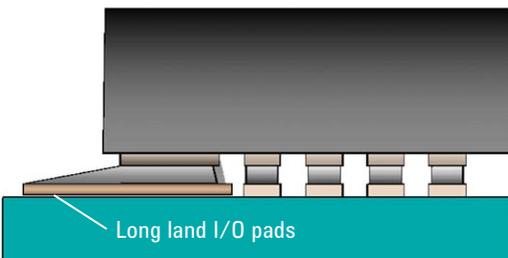


Figure 3. Bottom-only terminations with longer pad (QFP drop-in)

Dual-row bottom-only components utilizes smaller terminations than other QFNs, making it more difficult to test. Primary tests include minimum fillet length, center thickness, heel slope and across-center measurements.

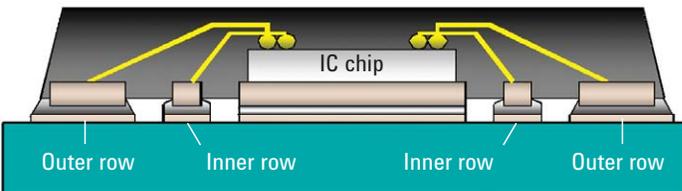


Figure 4. Bottom-only terminations – dual row (denoted by smaller pads)

QFN Preparation Test Link

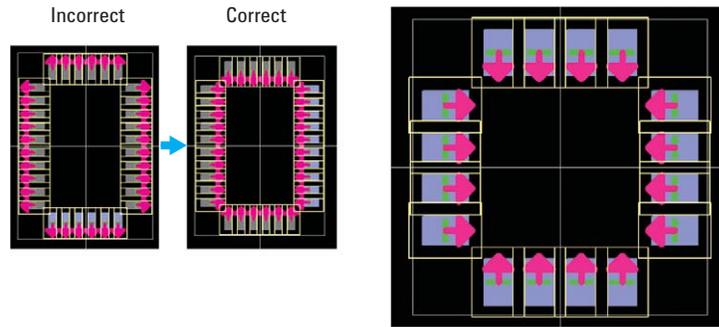


Figure 5. Joint orientation

Test-Link-Specific Preparation for QFNs

To correctly use 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:

Correct pad orientation

1. Open Test Link within the test development workstation (TDW)
2. Open current project
3. Select Assign Packages
4. Select part of interest
5. Note direction of CAD
6. 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
7. 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:

1. Start the search at the center of the CAD defined location
2. Search along the pad
3. Search across the pad
4. 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 needing to be tuned. Therefore, most programmers ignore the algorithm, testing its effectiveness by examining the SPC's first test results. When the SPC starts work on a joint, it reports that the locator had problems or uses the CAD-defined location.

The QFN SPC Algorithm

The SPC algorithm - Setup and Test

Setup

Temporarily disable the short algorithm for all families.
Verify that the heel, center, toe and overall solder joint are correctly located using the following steps:

1. Edit the effective pad Length and width if needed to adjust the size of the test region.

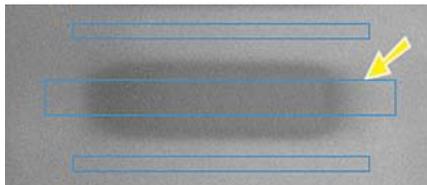


Figure 6. Test region

2. 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 that are only slightly sloped. See example of ideal setup in Figure 7.

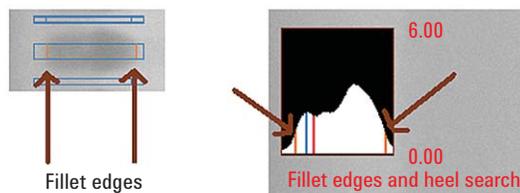


Figure 7. Ideal setup

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, change 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.

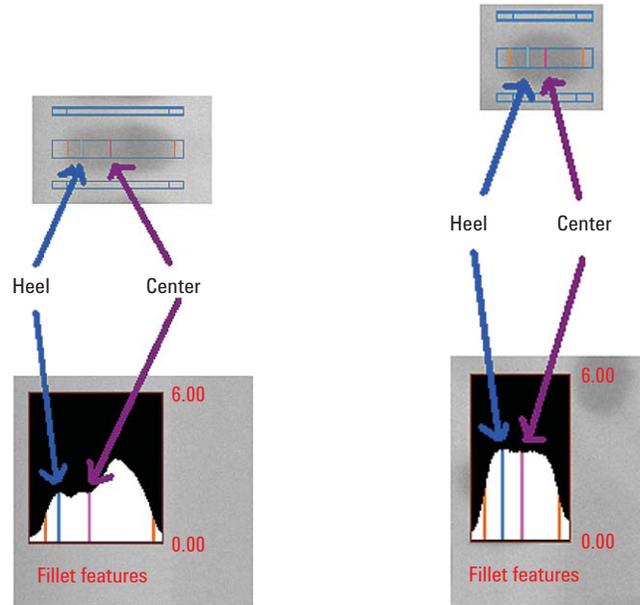


Figure 8. Examples of heel and center setup on the two joint variations

- 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.

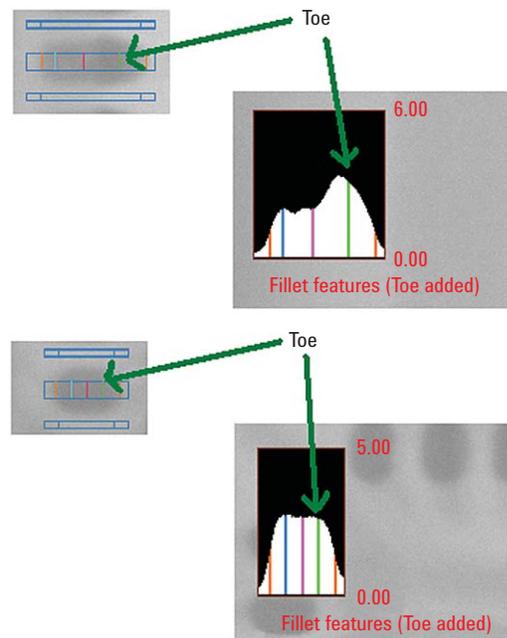
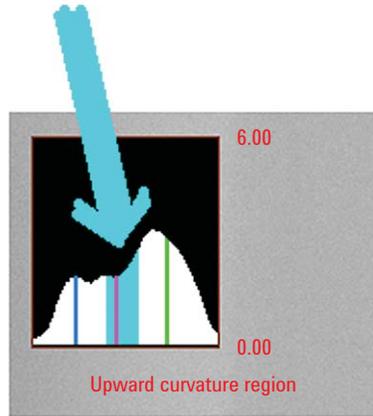


Figure 9. Example of toe location on these two joint variations

6. 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 you must be careful when tuning not to produce false failures.

Upward curvature region



Upward curvature region

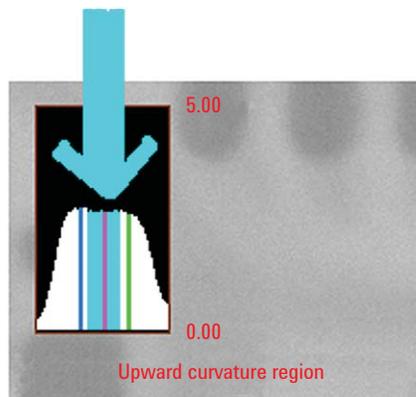


Figure 10. Examples of correctly setup upward curving region

- 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 to 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 flatness at 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.
7. 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 set up within **SPC-Advanced** and the **Voiding** tab
 8. 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

9. The following values can be taught with subtype learning in SPC. Note that you 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
10. After completing setup, you 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 that are located entirely under the QFN package. Also, this is effective in determining misalignment on joints with a large toe region.

Minimum open signal

- This test 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 than 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 than, -1 = if the measurement is less than.
- Toe thickness multiplier – Used to set calculation related to heel – 0 = disable, 1 = if the measurement is greater than, -1 = if the measurement is less than.
- Center thickness multiplier – Used to set calculation related to heel – 0 = disable, 1 = if the measurement is greater than, -1 = if the measurement is less than.

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 GFN 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: Online Help Tools and Descriptions

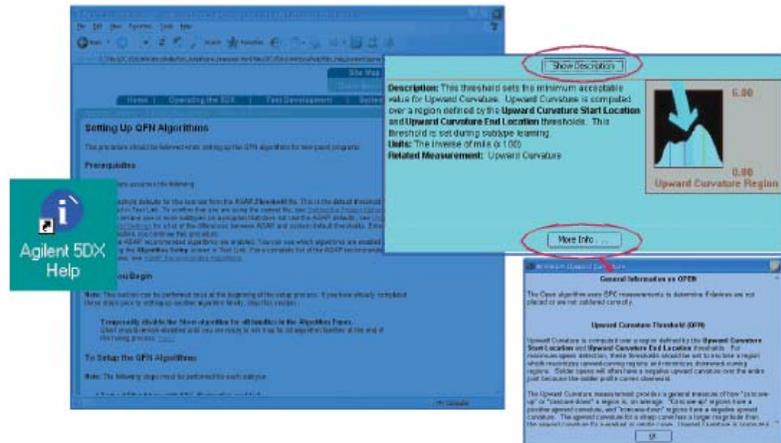


Figure 11. Online tools

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 using customer products to achieve optimal performance of the algorithm. The recommendations are a guide to initial program development, and you will find you 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. Please note, the thresholds listed are the recommended thresholds to use on that joint type, and 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.

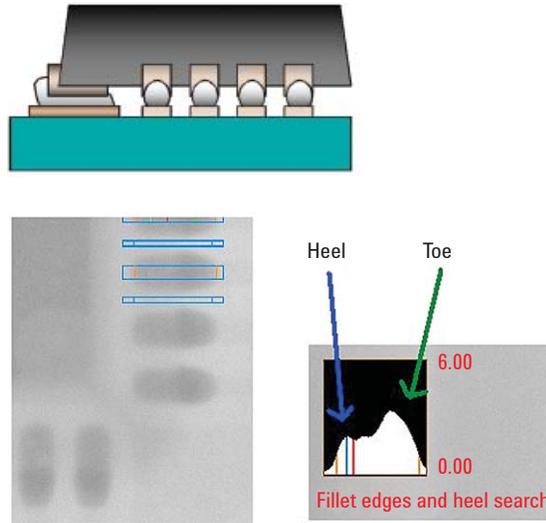


Figure 12. Outside edge terminations (large toe)

Quantify good joint with presence of large toe fillet. This is the 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 to 20%
- Center – 45%
- Toe – 75 to 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

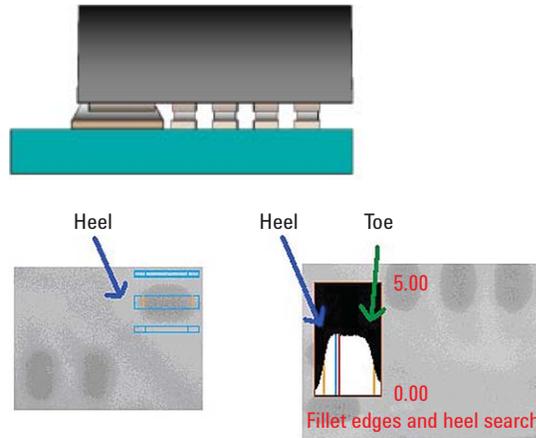


Figure 13. Rely heavily on heel, center, and insufficient measurements

Bottom-only terminations

SPC – Set and modify if needed

- Heel – 10 to 15%
- Center – 50%
- Toe – 70-90%
- Upward curvature – 25% (start) to 65 to 75% (end)

Open – Use **Review Measurements** to set the following recommended variables

- Max length
- Max center thickness – 5 to 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 **Open Signal** wide to minimize potential false fails.

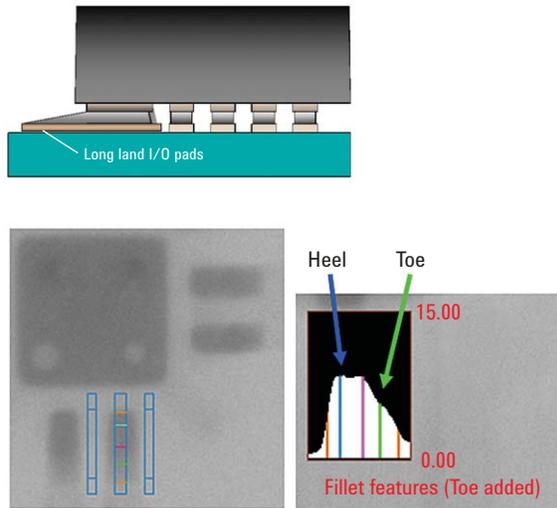


Figure 14. Bottom-only terminations with longer pad (QFP drop in)

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 to 20%
- Center – 35 to 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 **Heel Sharpness** wide to minimize potential false fails.

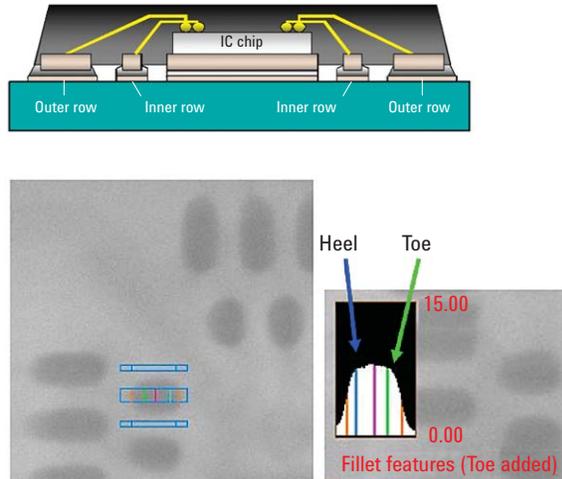


Figure 15. Bottom-only terminations – dual row (denoted by smaller pads)

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

SPC – Set and modify if needed

- Heel – 10 to 15%
- Center – 50%
- Toe – 75 to 90%
- Upward curvature – if unable to differentiate between an open joint and 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



Agilent Email Updates

www.agilent.com/find/emailupdates

Get the latest information on the products and applications you select.

www.agilent.com

www.agilent.com/find/5DX

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:

www.agilent.com/find/contactus

Americas

Canada	(877) 894-4414
Latin America	305 269 7500
United States	(800) 829-4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Thailand	1 800 226 008

Europe & Middle East

Austria	01 36027 71571
Belgium	32 (0) 2 404 93 40
Denmark	45 70 13 15 15
Finland	358 (0) 10 855 2100
France	0825 010 700*
	*0.125 €/minute
Germany	07031 464 6333**
	**0.14 €/minute
Ireland	1890 924 204
Israel	972-3-9288-504/544
Italy	39 02 92 60 8484
Netherlands	31 (0) 20 547 2111
Spain	34 (91) 631 3300
Sweden	0200-88 22 55
Switzerland	0800 80 53 53
United Kingdom	44 (0) 118 9276201

Other European Countries:

www.agilent.com/find/contactus

Revised: July 17, 2008

Product specifications and descriptions in this document subject to change without notice.

© Agilent Technologies, Inc. 2007 - 2008

Printed in USA, August 26, 2008

5989-6469EN



Agilent Technologies