

The Utilization of X-ray to Effectively Test Quad Flat No-Lead Packages

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Introduction

The Quad Flat No-Lead or QFN packages are increasing in their utilization in the printed circuit board market. This is being driven largely by the shrinking size both in profile and footprint, higher operating speeds from 2 GHz to 10 GHz, effective thermal dissipation all in a low cost package. The relatively inexpensive nature of leadframe-based CSPs (chip scale packages) such as QFN's without solder balls has led to the popularity of these devices being utilized in commercial electronics. TechSearch International reported that there was an increase in the utilization of these devices in subcontractors from 77% to 85% from 2004 to 2005.¹ Another example of the increase in utilization, focused in Japan, is that for portable consumer products such as digital video cameras the QFN was found in 5% of applications in 2004 and is predicted to be at 10% in 2014.^{1,2} Even package vendors such as Amkor Technologies now advertise that they have sold over 1 billion QFN packages.³ As QFN usage grows, they will eventually replace the currently dominate format, fine-pitch gullwing & quad flat IC package,

As with the increase in any type of joint usage, there is an increase in the opportunity for defects. Currently, only generic test requirements for the QFN exist in the industry. Like area array grid packages, the QFN solder joint is below the joint, hidden from most types of optical inspection test. X-ray inspection provides an effective solution in testing these types of joints.

Current QFN Standards

The Joint Industry Standard IPC/EIA J-STD -001 C and IPC A-610D give generic requirements for testing QFN joints. The joint are considered to be "Bottom Only Termination" by industry standards as QFN packages don't have an exposed lead or the lead is not solderable on the edge of the package. Because of this package attribute, the standards industry specifies solder joint length, width and thickness but no joint fillet height. QFNs "toe fillet" formation also is not of any concern and is not considered as a key indication of the overall solder joint quality.

Table 1 - IPC A-610D Requirements

| Features | Class 1 | Class 2 | Class 3 |
|--|---|---------------|---------|
| Max Side Overage hang | 50% W Notes 1 | 25% W Notes 1 | |
| Toe overhang (outside edge of component termination) | Note Permitted | | |
| Min End joint width | 50% W | 75% W | |
| Min side joint length | Not a visually inspectable attribute | | |
| Solder fillet thickness | Wetting is evident | | |
| Min toe (end) fillet height | Unspecified parameter or variable in size as determined by design Toe fillets are not required | | |
| Termination height | Toe fillets are not required | | |
| Solder coverage of thermal pad | Not a visually inspectable attribute | | |
| Land width | Unspecified parameter or variable in size as determined by design | | |
| Termination width | Unspecified parameter or variable in size as determined by design | | |

IPC A-610D requirements on QFNs are vague when describing the acceptance of the solder joint. The document does not describe what should be considered as an insufficient joint or how much voiding should be acceptable. The document just mentions that the features are "not a visually inspectable attribute". However, it must be noted that QFN solder joints are hidden just like BGA and so X-ray is commonly used to inspect them.

Figure 1 shows the variation of QFN solder joints under X-ray. The ones highlighted shows solder is present but whether they are sufficient to be considered as reliable is unknown. Unless there is a clear specification on the QFN solder joints acceptance, there will always be argument on whether these solder joints should be accepted.

Figure 2 shows extensive voids found under the package body which acts as a thermal pad. As void in BGA always provoke serious discussion on the health of the process, should we also be concern on the QFN thermal pad voiding? IPC A610D requirement only mention that the solder coverage of thermal pad is not a visually inspectable attribute.

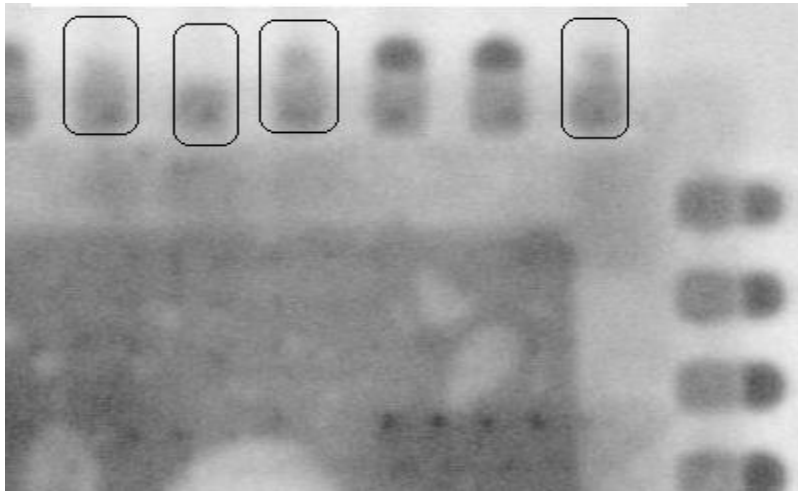


Figure 1 – Potential Insufficient solder on joints

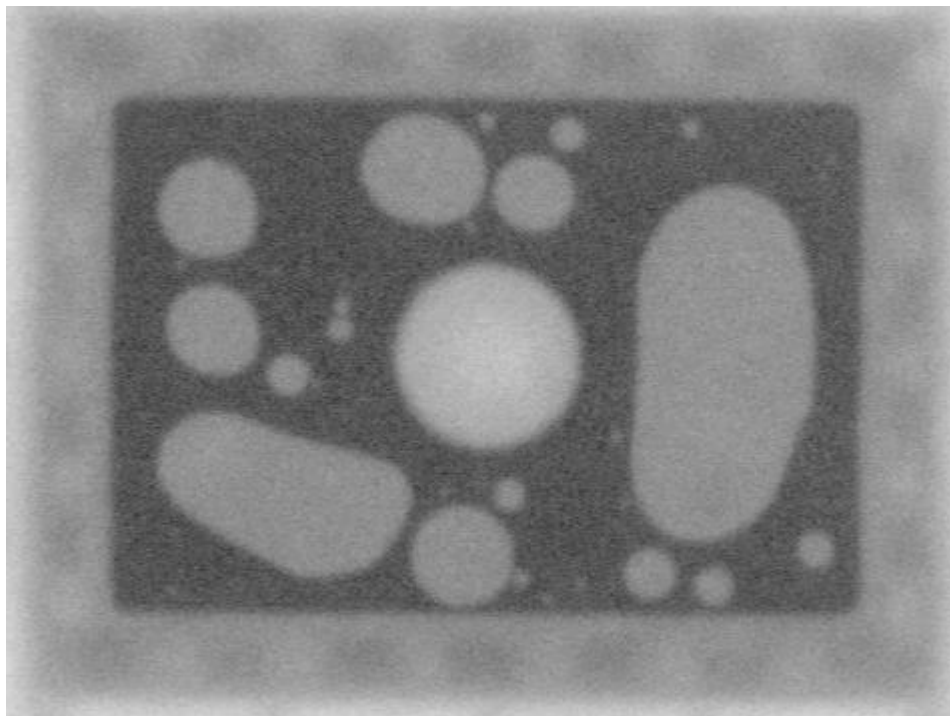


Figure 2 – Center thermal pad voiding

Therefore there is a need for the industry community to drive for a much clearer specification on what is an acceptable QFN solder joint.

Available Techniques for testing QFN's

Being defined as “Bottom Only Termination” leaves only very few options when testing the solder joint. Optical inspection is limited to only being able to view only the perimeter of the package which has little to no detail on whether the joint actually reflowed to the package. Both ICT and functional test are both available in determining if the package is functioning correctly, whether an electrical connection exists and no solder shorts are present. Though, using these technique's may not expose joints that might have sever voiding, insufficient amount of solder or even a non-reflowed (cold) solder fillet. When testing QFN's, X-ray test is a reliable and efficient strategy to ensure that a proper solder joint exists.

Various X-ray test techniques exist that can ensure the solder joint forms properly. Manual X-ray Microscopes allow for a close inspection of each joint and have options of rotating the source and detector to view the joint at different angles. Manual X-ray inspection is really useful when performing QFN joint analysis in a lab environment. When requiring testing of QFN joints in a manufacturing environment, automated X-ray tests offer both the speed and test effectiveness to ensure QFN quality.

How does the Automated X-ray Laminography inspect a QFN

QFN packages are unlike typical gullwing or area array package types which have a unique and repeatable set of features. The features of a QFN solder joint which can be inspected are not as obvious and vary from package type to package type. A challenge for automated x-ray test equipment is to provide a set of tests which can be used to reliably catch defects and limit the amount of false defects indictments. To create a set of reliable tests, a set of features needs to be found to separate a good joint from a bad joint.

A good QFN joint generates a solder profile which reflows across both the board and package pads creating a strong joint. According to QFN specifications, the “heel” of joint forms under the package while the “toe” forms on the outside of the package. The following illustrates the various good formations that a QFN solder joint might exhibit along with the defined feature locations.

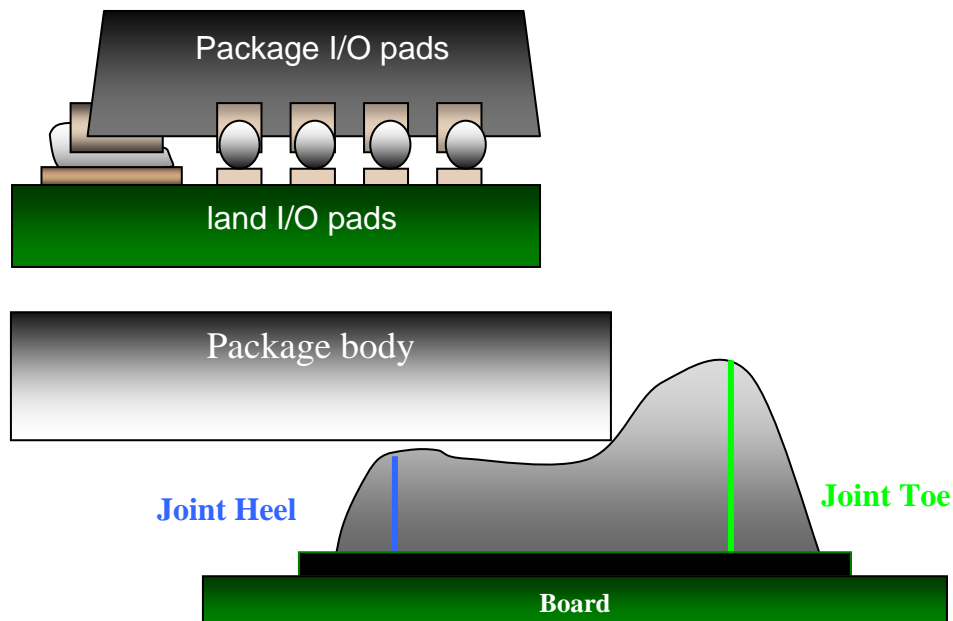


Figure 3 - Illustration of a good QFN joint which generated a large toe region outside of the package. The board pad extends out from the edge of the package allowing the solder to flow outside and form. Solder does not wick up the edge of the package.

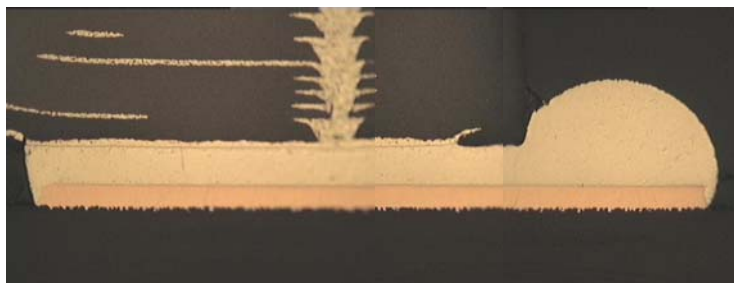


Image 1a: Cross-section of a QFN joint. The board pad extends past the QFN joint, forming a large toe.

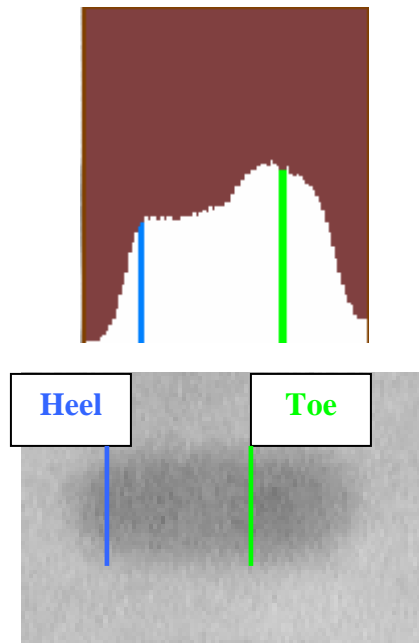


Image 1b: The bottom is an X-ray image of a good QFN joint that has a pad that extends outside of the package. The top is the profile that is generated based off of the x-ray image.

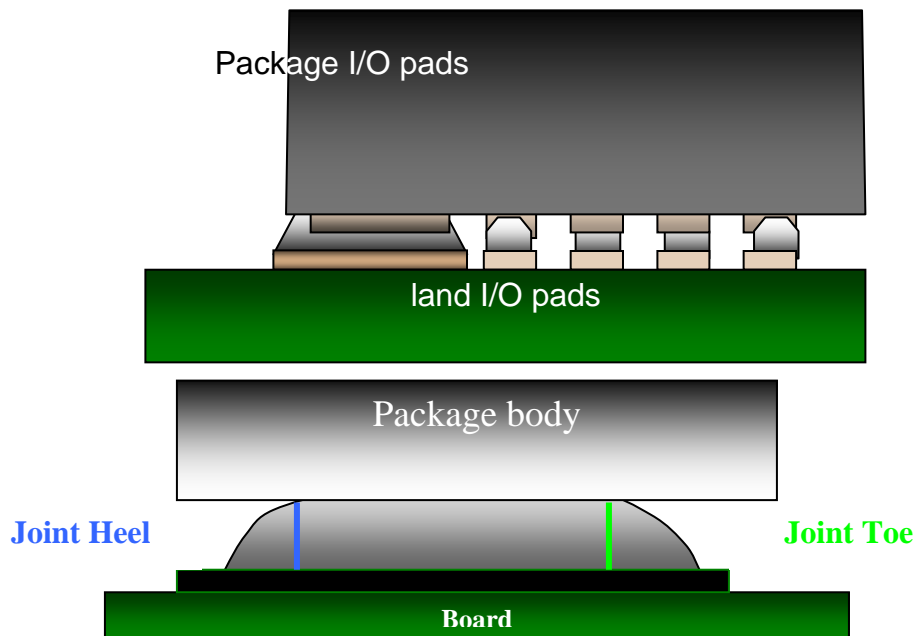


Figure 4: Illustrates a good QFN joint which forms under the package. The pad for both the board and package are offset from the edge of the package.

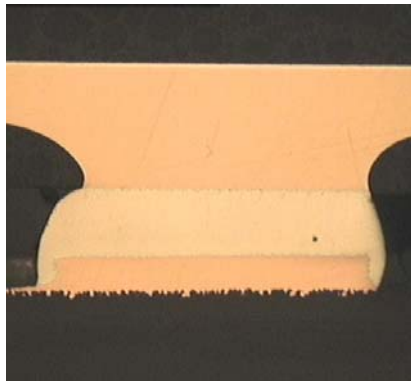


Image 2a - Cross-section of a good QFN joint which forms under the package. The pad for both the board and package are offset from the edge of the package.

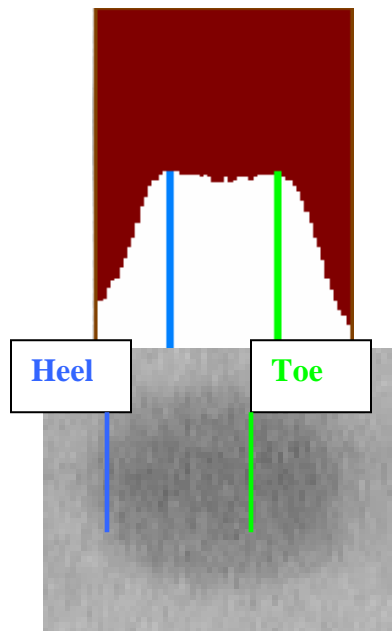


Image 2b - Bottom is an X-ray image of a good QFN joint under the package. The top is the profile that is generated based off of the x-ray image.

When using automated x-ray tests, there are a set of features that can be extracted even though QFN solder joint profiles may differ greatly. One thing to note, due to the difference in joint formation, certain features may exist on one type of joint while they may not exist on another type of joint. To account for this variability, a large set of options should be made available to measure various regions which represent the joint on the whole.

The measurements included within automated x-ray are as follows:

- Thickness in Mils for the total fillet, toe, heel and center regions
- Length in Mils of the fillet
- Slope defined as Gray level per pixel analysis along the total fillet and around just the heel and toe regions.
- Curvature of the region between the heel and toe.

Thicknesses of the various regions of the joint are measured and used to determine the shape of the joint. The overall fillet thickness is used to determine whether solder is present and whether enough solder is present. The heel and toe regions are measured and then can be compared to the center region. For specific joints, heel and toe regions are desired to be thicker than the center region while other joints may want the heel and toe to be approximately the same as the center. The heel, toe and center thicknesses often assist in describing the joint formation and can often help in determining if a joint reflowed properly and wetted to the package's pad.

Another technique in measuring proper solder reflow and solder presence is by the fillet length. For joints that did not properly wet to the package pad, the joint may reflow across the entire pad, generating a larger than normal fillet. For example an average joint may measure 35 mils in length while a non-wetted or open joint may measure to be 45 mils in length. In another cases, if an insufficient amount of solder was used, the joint profile may be too short. In the previous example, if the measured joint was less than 20 mils in length, the joint would be considered to have insufficient amount of solder.

Measuring the slopes of the various regions of the QFN joint is another approach at determining whether a proper solder joint fillet was formed. Slope is defined as number of gray levels per pixels. For example, a good joint will have a nice step slope (approximately 3 to 4) from the board to the package. If the solder did not reflow to the package, the slope would be much shallower (less than 1). Using this technique, the slope is measured at the heel, toe and summed across the entire length of the measured fillet region.

In both of the figure 3 and figure 4 illustrations above, the top part of the joint which is soldered to the package appears to be concave. This concavity can be calculated as curvature. Curvature is calculated by using an “osculating circle” or “tangent circle” at each point along a line within a region of interest, resulting in either a positive number which represents an upward curvature or a negative value which represents a downward curvature. Image 1b and 2b show a profile of 2 different types of QFN joints. The curvature is calculated between the 2 lines on the images. A good joint may have a positive or concave up region or flat region. In both of these cases, the package may have formed a solid joint. If the concave down or negative region is identified, then the joint may have just reflowed across the pad, generating an open joint.

The approach so far has been to analyze the QFN fillet from the heel to toe region. Though, when looking at a QFN, it is often necessary to also look at regions across the joint to get a more detailed picture of how the joint might be forming. Automated X-ray has the ability to look across the heel and across the center of the joint to measure fillet width. Figure 3 illustrates a good QFN joint and a bad QFN joint and the measurements across the center region.

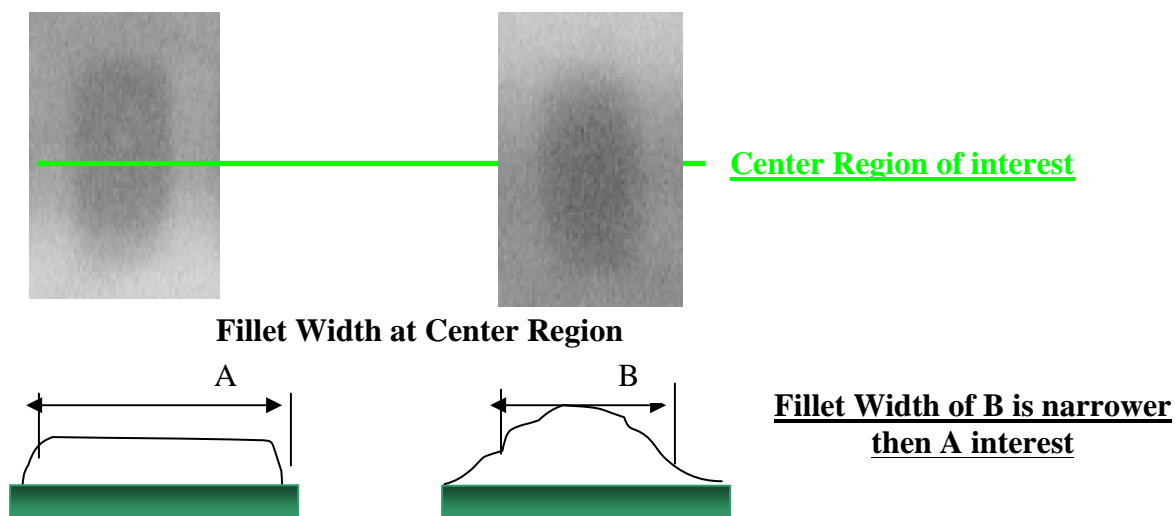


Figure 5 - Along with these techniques for identifying insufficient and open solder fillets, algorithms are available to identify the percentage of voiding and the presence of a solder bridge between joints.

Applying Automated X-ray QFN inspection

Over the past year, Agilent worked with a major PCB manufacturer in utilizing the set of QFN testing techniques that automated X-ray laminography provided. The PCB that was chosen to be inspected had the following types of QFN packages.

- Dual row QFN MLF– 109 pin
- MLF QFN - 25 pin
- FEM QFN – 37 pin

All QFN joints used a Tin/Silver/Copper lead free solder formulation. For initial analysis of the QFN algorithm suite, an initial series of boards both populated and unpopulated were manufactured and then run through Automated X-ray test.

The dual row QFN was separated into 2 different sets of tests, the first set was on the outside row while the second set was on the inside row.

The outside row was setup to measure fillet length, sum of total slope change across the fillet and curvature. The other available tests were found not to differentiate a good joint vs. a bad joint. The following examines these measurement techniques for this set of pins.

A set of 6 populated boards with known good solder joints were initially tested. Then a set of 6 unpopulated boards with reflowed solder were tested. This second set represented what an open solder joint would look like in X-ray. The following charts compare the results of both sets of panels. The right hand side of the chart shows the populated pin measurements and the left hand side shows the unpopulated pin measurements.

In chart 1, the populated panel fillet length for each pin is compared to the fillet length of the unpopulated panel. The good joints on the populated panel had an average fillet length of 26 mils while the open joints had an average of 23 mils.

For this set of pins, we use an algorithm which sums the slope changes across the entire fillet. The resulting value is then reported for each pin. Chart 2 shows the results of the populated panel's vs. the unpopulated panels for the sum of slope changes.

The last test that showed a good difference in measurements was curvature. It was found that the populated panels had joints which formed a slight upward curvature in the profile, chart 3. This upward curvature effectively differentiates between a good joint and an open.

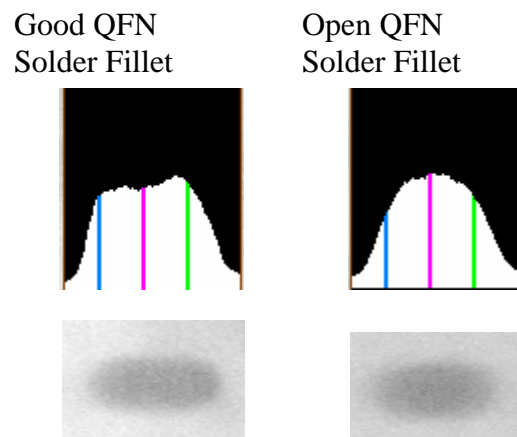


Figure 6 - Good solder fillet vs. a bad solder fillet as seen by automated laminographic x-ray for the perimeter joints of the dual row QFN

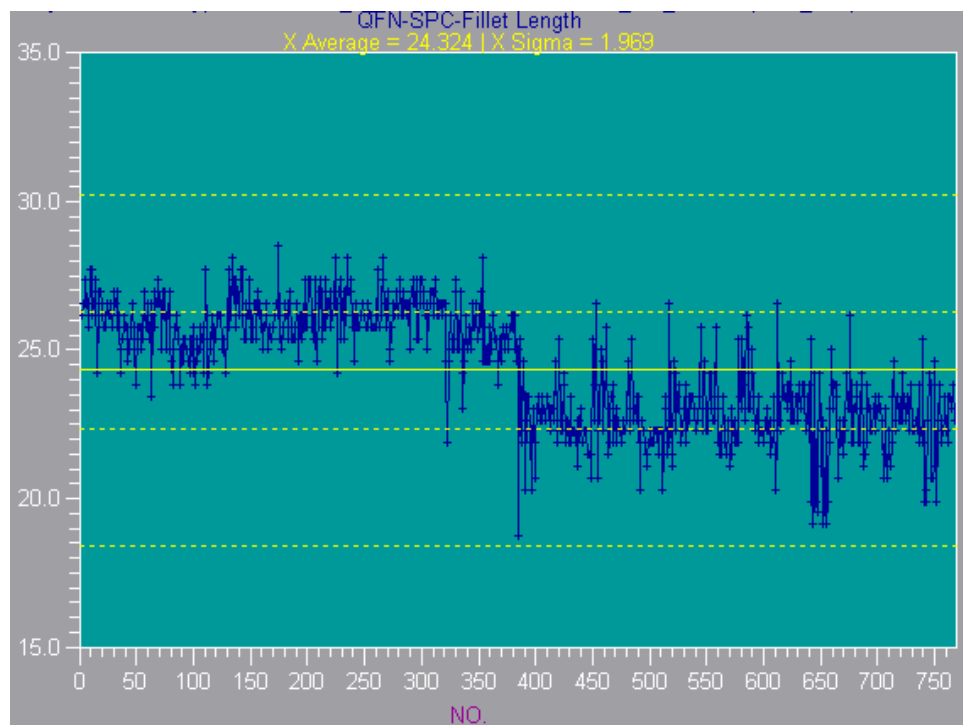


Chart 1: Measured fillet length in Mils of populated pins vs. unpopulated pins

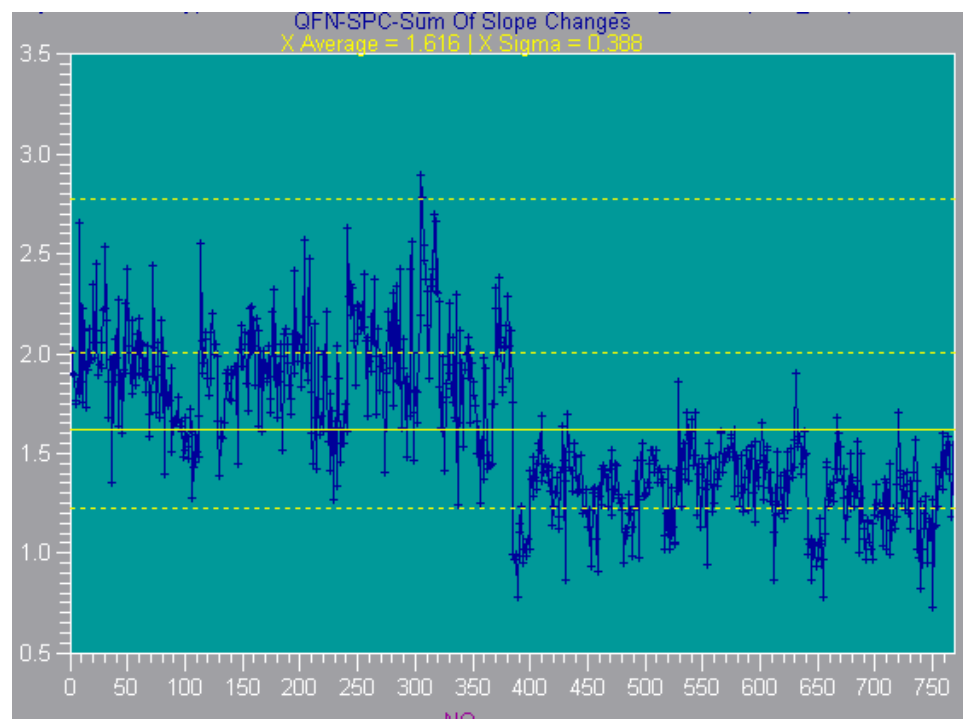


Chart 2: Measured sum of slope changes across the fillet of the populated pins vs the unpopulated pins.

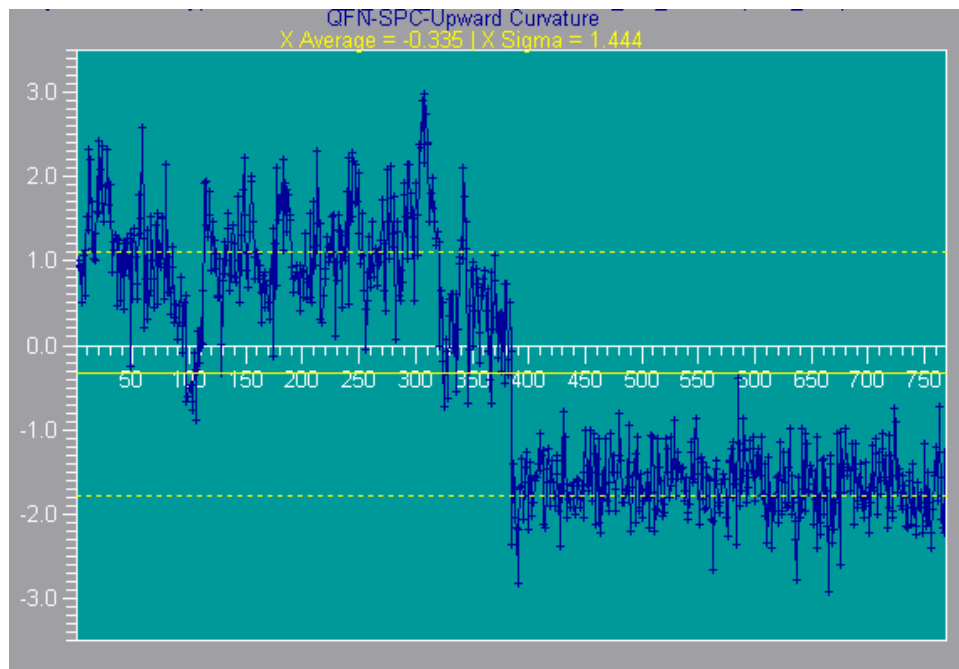


Chart 3: Measured Curvature of the fillet of the populated pins vs. the unpopulated pins

The inside row contained a set of joints which formed slightly different then the outside row. The joints were found to be successfully tested using fillet length, curvature and a technique called Open Signal which compares the heel thickness to the center thickness.

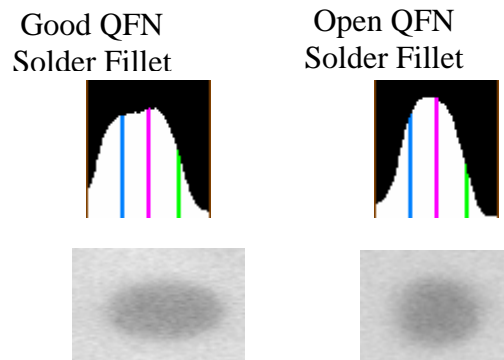


Figure 7 - Good solder fillet vs. a bad solder fillet as seen by automated laminographic x-ray of the inside row of the dual row QFN

The following charts compare the results of both sets of panels for the inside row of the QFN. The right hand side of the chart shows the populated pin measurements and the left hand side shows the unpopulated pin measurements

The fillet length for the inside row is much lower then the outside. Inside fillet length measures on average 17 Mils for the good joints. For the open pins, the fillet length measures on average around 14 mils. Chart 4 shows the results of a populated panel on the left vs unpopulated panel on the right.

The next test that differentiated good vs. bad joints is curvature. Chart 4 shows that a good joint has a slight curvature upwards while the bad joints have a pronounced dome shape which generates curvature value of less then zero. In this case the bad joints on average have a curvature ratio value of -5 while the good joints have an average around -1.

The last test that was found to be effective is open signal. Open signal take the measured heel thickness and then subtracts it by the measured center thickness. Chart 6 shows that for an unpopulated panel, center measures thicker then the heel generating a negative value. The negative value of the opens joints are higher then the measured values of the populated panel.

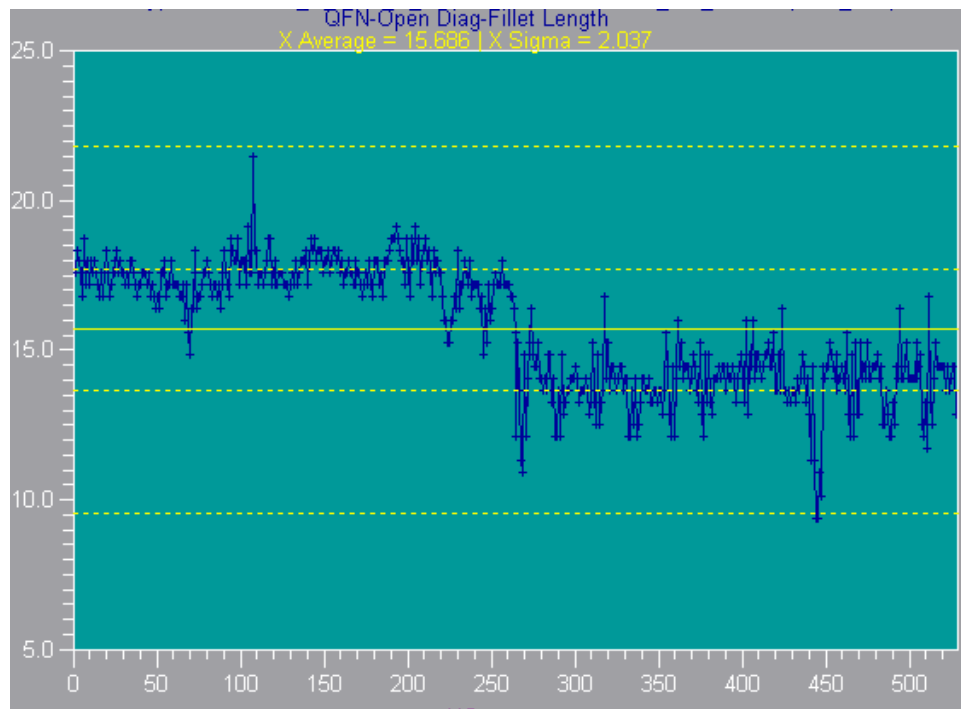


Chart 4 - Measured fillet length in Mils of populated pins vs. unpopulated pins

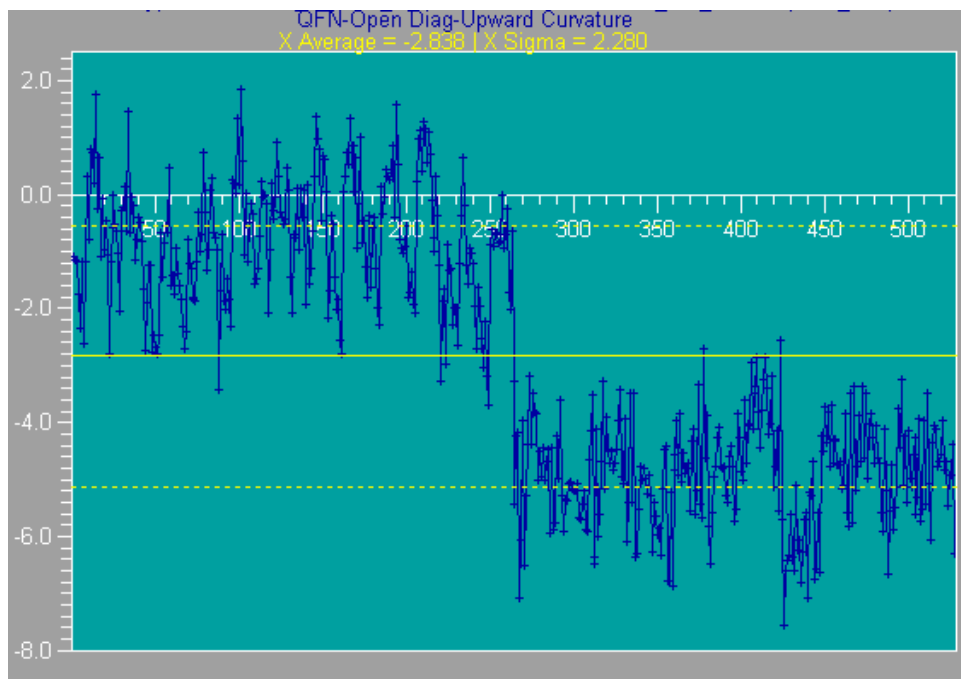


Chart 5 - Measured Curvature of the fillet of the populated pins vs. the unpopulated pins

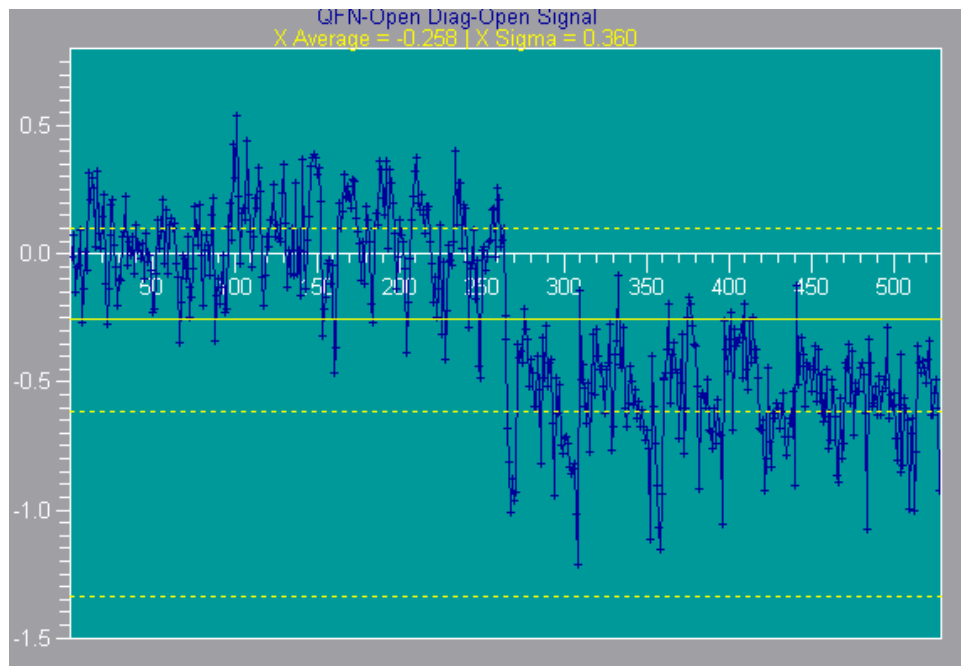


Chart 6 - Measure open signal of the fillet of the populated pins vs. the unpopulated pins.

The 25 pin MLF QFN has a much different joint profile then the previous dual row QFN. The board pads extend past the perimeter of the package leaving a large toe joint formation. Figure 9 shows the joint profile of a good joint vs a bad joint.

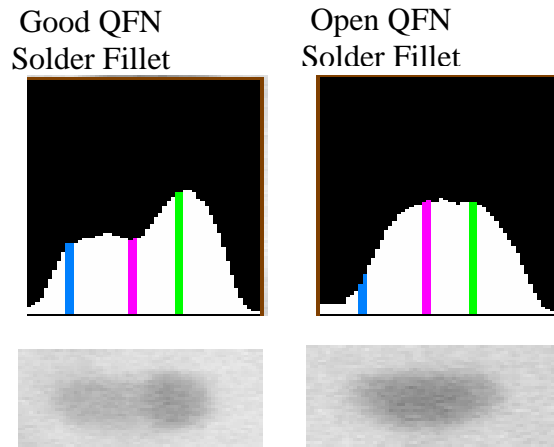


Figure 8 - Good solder fillet vs a bad solder fillet as seen by automated laminographic x-ray of 25 pin MLF QFN

Because of the different profile, fillet length, open signal, upward curvature and center thickness percent is used to effectively test these joints. Chart 7 and Chart 8 show fillet length and center thickness percent have a slight separation between a good joint and an open joint. Chart 9 and 10 show a much larger separation between good and bad joints for using open signal and curvature.

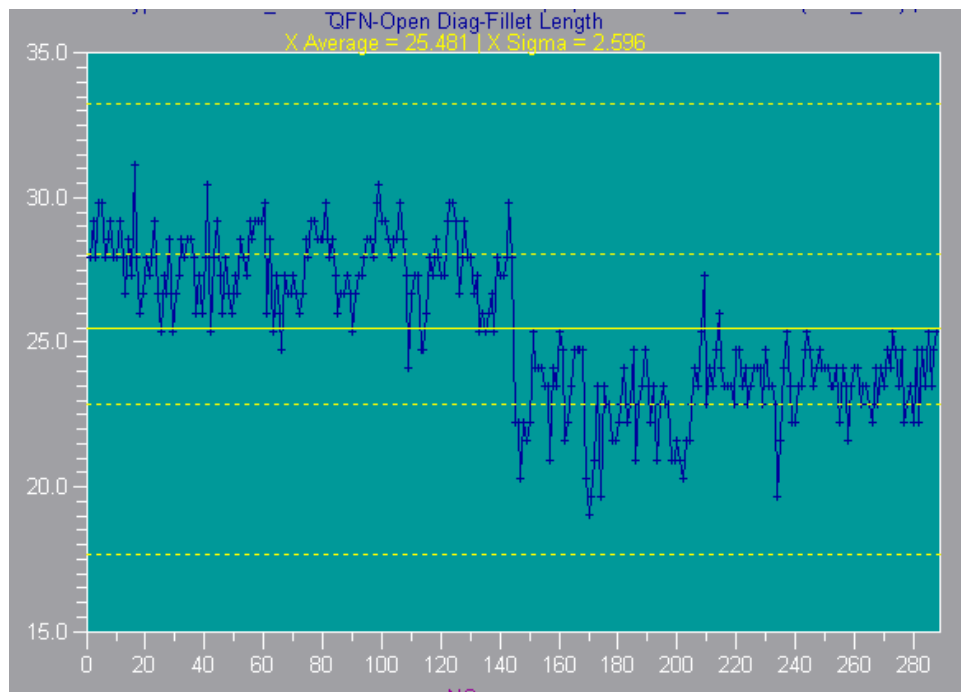


Chart 7: Measured fillet length in Mils of populated pins vs. unpopulated pins

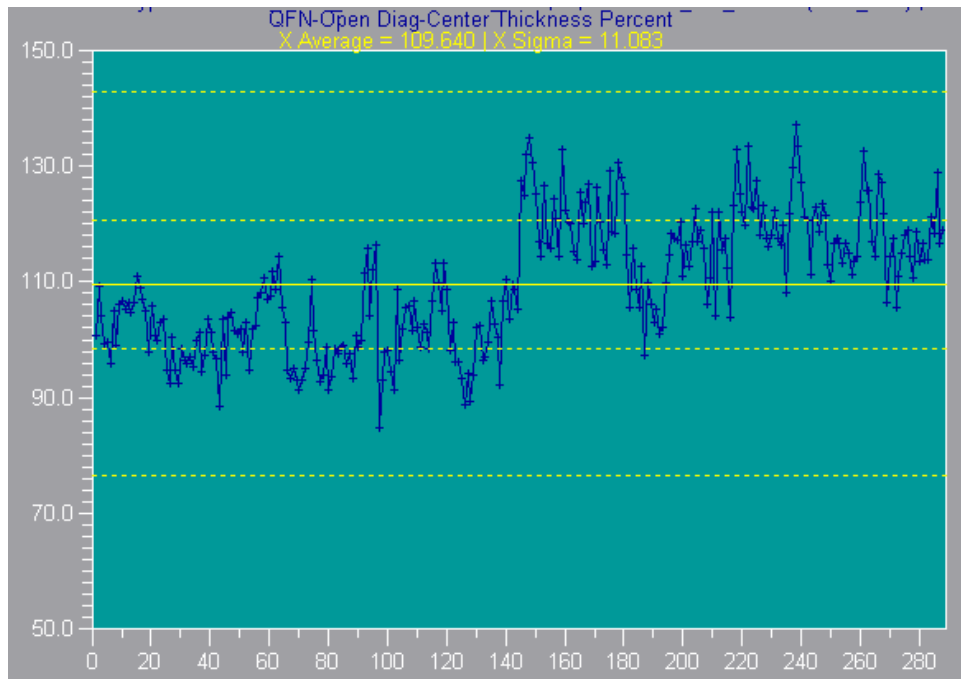


Chart 8: Measure percentage of the nominal center thickness of populated pins vs. unpopulated pins

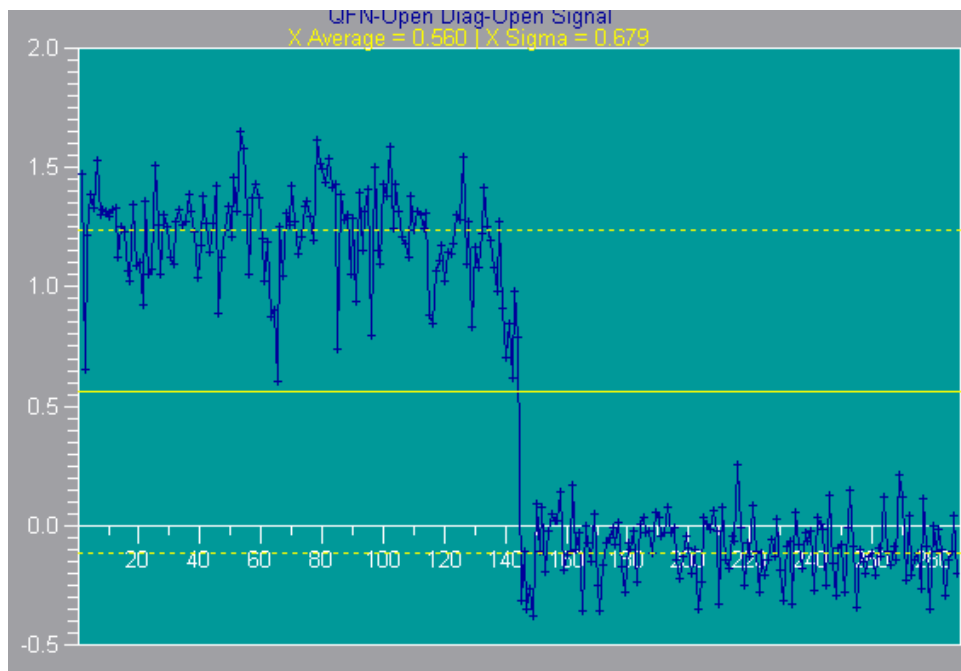


Chart 9: Measured Open Signal of the populated pins vs. unpopulated pins

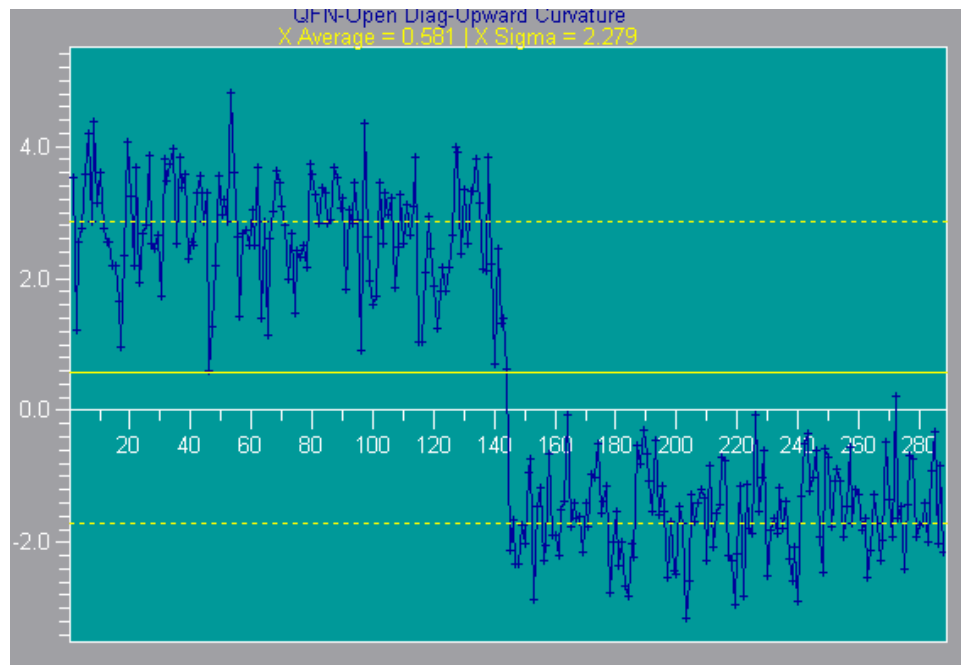


Chart 10: Measured Curvature of the fillet of the populated pins vs. the unpopulated pins

The last package for this discussion on this board is the 37 pin QFN. The pad extends to the perimeter of the package, leaving no overlap. The packages pad extends over the edge of the QFN but is a non-reflowable on the perimeter. This creates a solder joint profile that is a mix of the previous types of joints.

Figure 7 shows a typical good solder fillet compared to a typical open solder fillet for this QFN type.

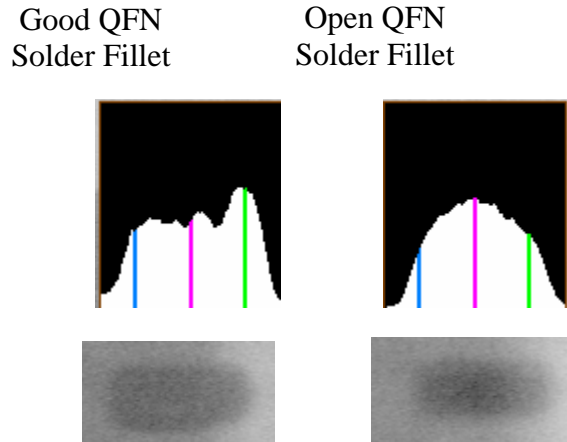


Figure 9: Good solder fillet vs. a bad solder fillet as seen by automated laminographic x-ray of 37 pin QFN joint

The fillet profile of this joint is different in regards to its length is different then the previous joint types. Chart 1 compares the populated panel to an unpopulated panel. Note that in this case, the fillet length does not change between a good joint and an open joint.

To differentiate between a good joint and an open joint, the other techniques need to be utilized. Charts 11 through 15 show the usage of several types of measurements that show a difference between a populated panel and an unpopulated panel. Charts 12 and 13 show Center thickness percent and open signal which have been used previously. Other techniques which show a large difference between a good joint and an open joint are in charts 14 and 15.

Chart 14 shows the measured width of the joint across the center. Normal solder joints show an average width of around 21 Mils while the open joints show an average of 18 Mils. The joint profiles across the center region are much flatter when the joint reflows to the package. When the joint is open, the solder fillet forms a peak which shortens the width as seen in chart 14.

Chart 15 shows a measurement which uses a ratio value of Center width over Center thickness. This technique is used when an open joints measurements for center width and center thickness have a limited separation of good vs bad. Using this ratio, we find that when a joint is truly opened, the solder creates a peak which in turns gives both a thicker solder measurement (chart 13) and a smaller width (chart 14). The bad joints will have a much smaller ratio then the good joints. For this example, we see the average good joints measure on average 12 versus an average of 6 for the open joints. This ratio allows for further separation between a good joint and an open joint.

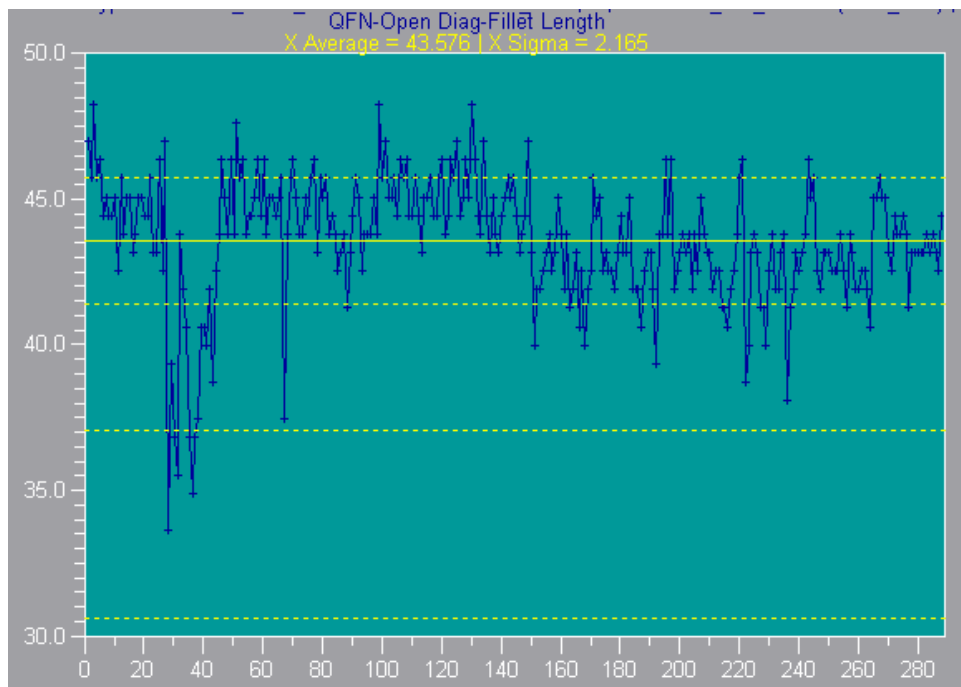


Chart 11: Fillet Length measured in Mils compares a populated panel to an unpopulated reflowed panel

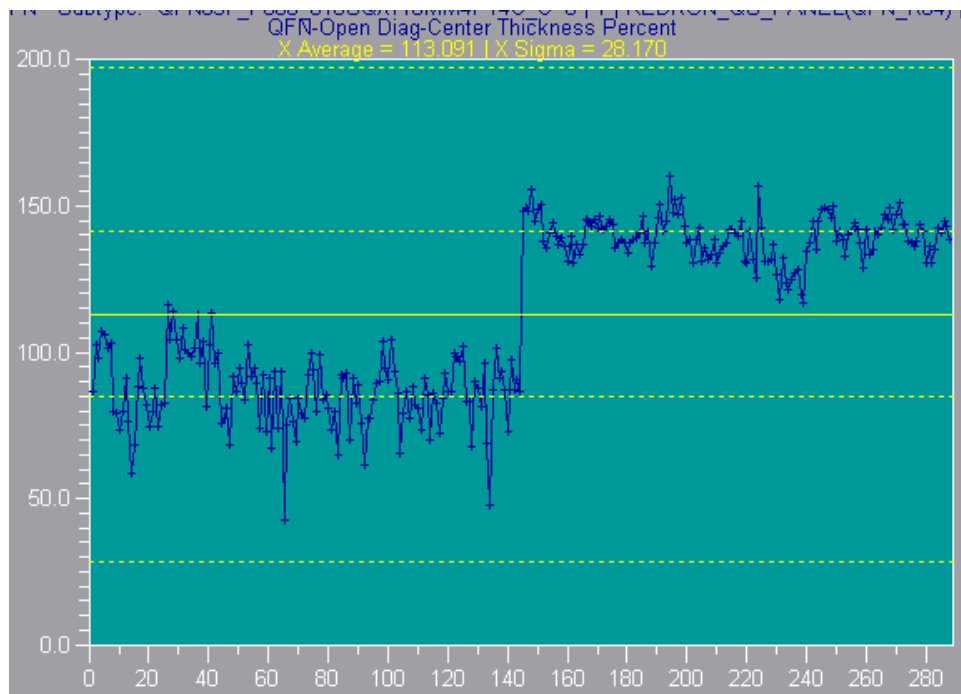


Chart 12: The percentage of nominal center thickness for each pin on the populated panel vs. the unpopulated panel

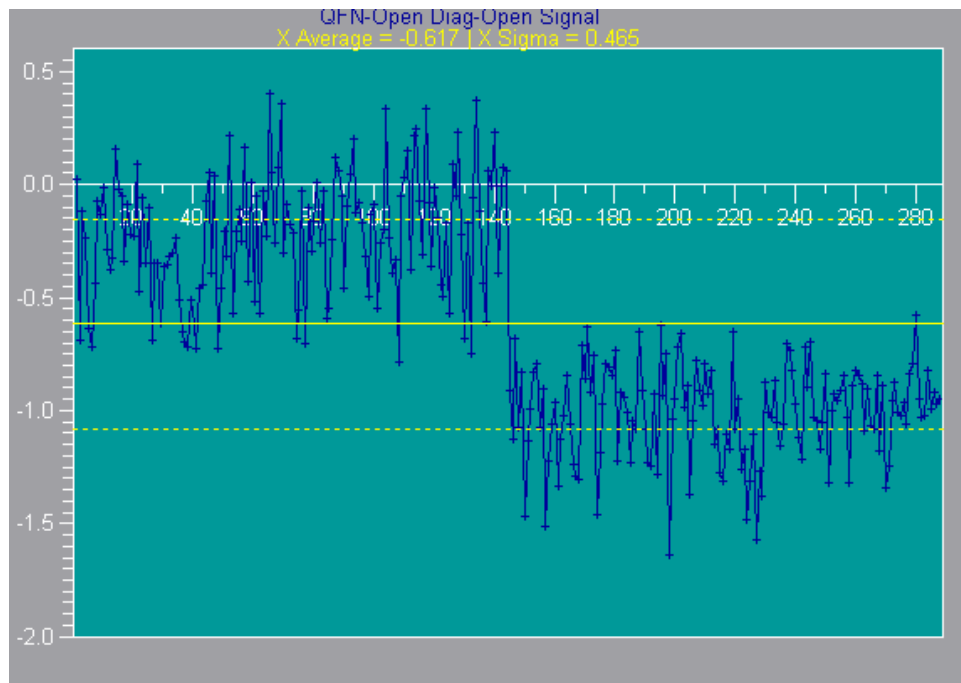


Chart 13: Measured Open Signal of the populated pins vs. unpopulated pins

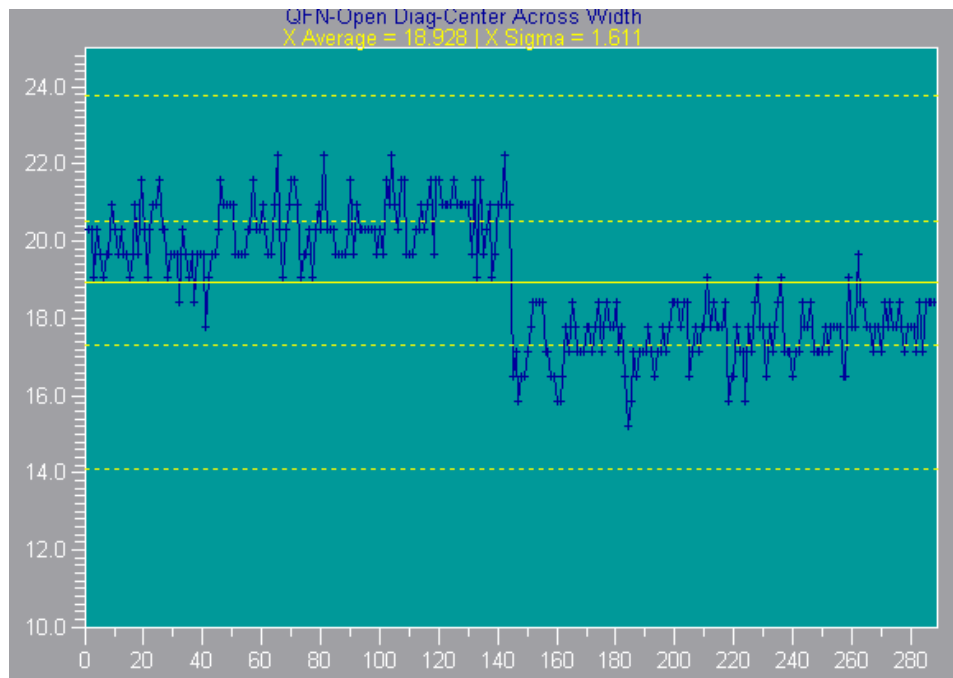


Chart 14: Measure width across the center in Mils of the populated pins vs. unpopulated pins

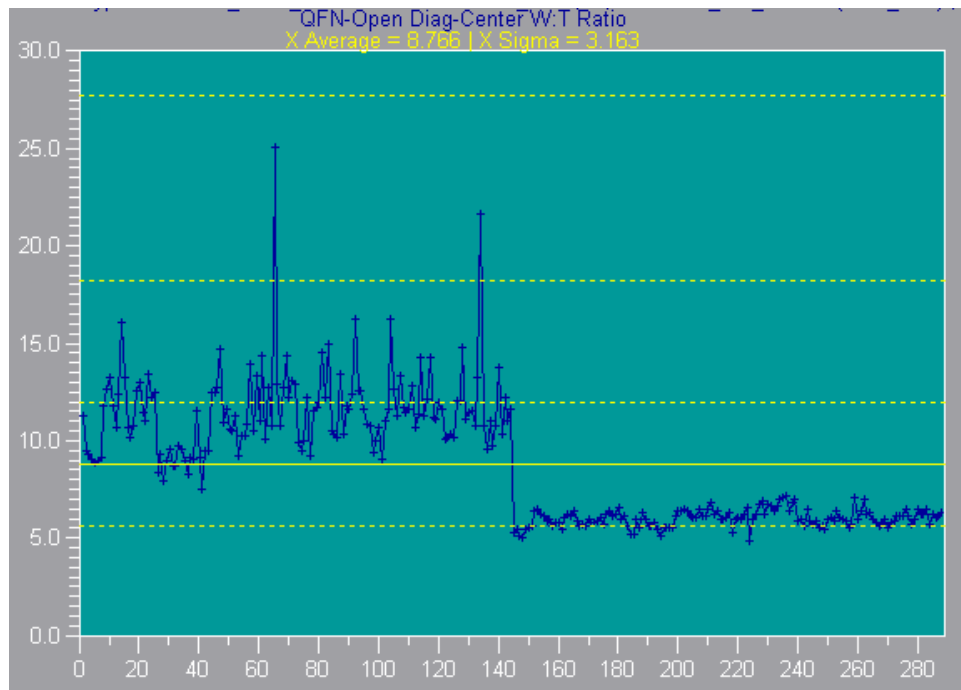


Chart 15: Ratio of the center width over the center thickness of the populated pins vs. unpopulated pins

Manufacturing Test Run Results

383 panels were manufactured that contained the 3 types of QFN packages. Each panel was run through a 3D AXI laminography and used the various algorithm techniques to identify defects. Chart 16 is the defect Pareto generated from a 3D AXI laminography test. For the manufacturing run, the overall top algorithms that caught the most number of defects were slope across the center of the joint, slope of the joint at the heel, and center width measurements.

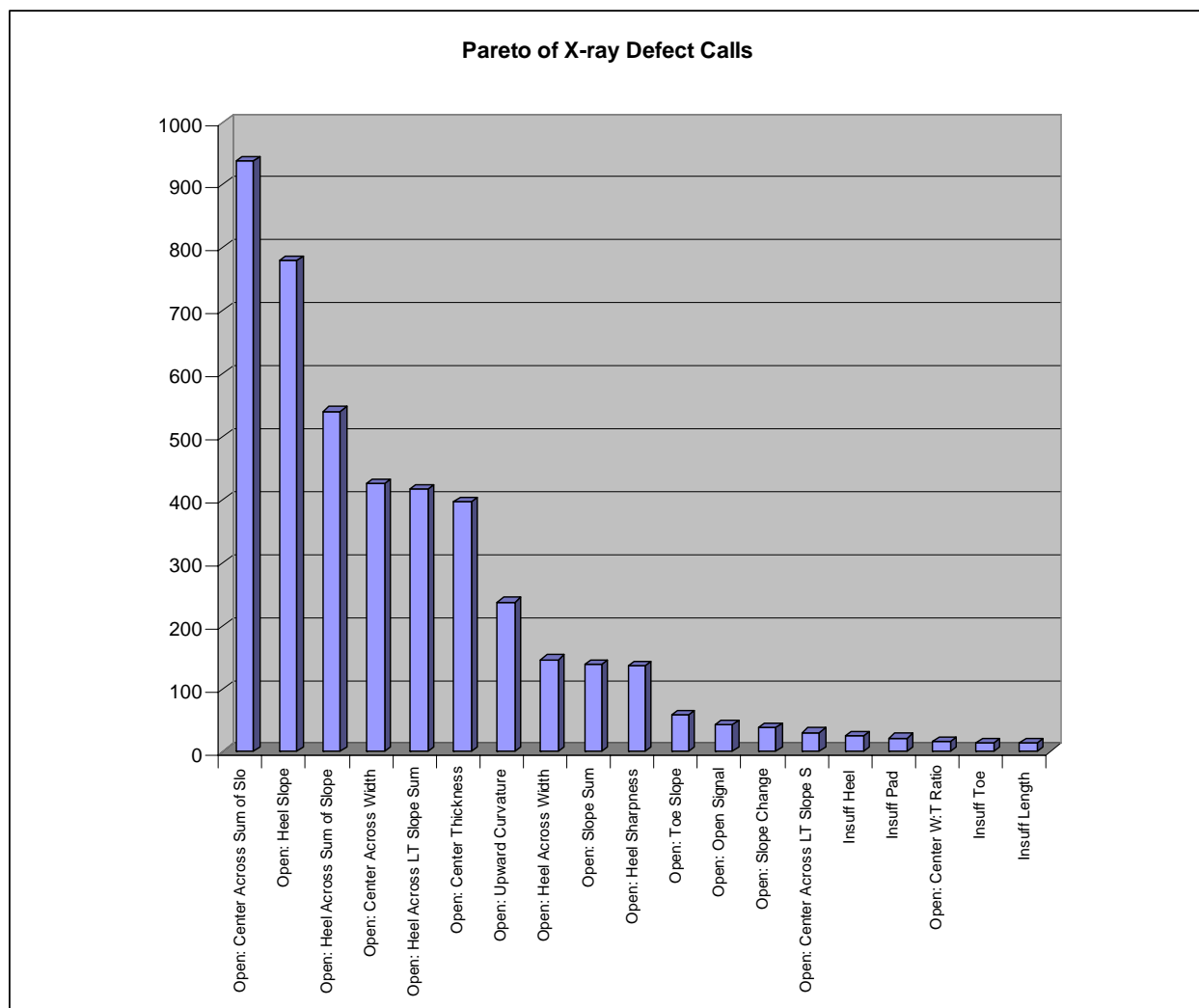


Chart 16: Overall defect Pareto of the multiple QFN package types

For each package type tested, the defect pareto varied. Charts 17 to 20 break out each package type's defect pareto based off of the failure in from a 3D AXI laminography test. For the dual row QFN, the outside row found a majority of the opens using upward curvature. For the inside row, open joints were found with center. The 37 pin QFN packages top open defect calls were caught using slope across the center and slope of the heel both identifying number of defects. The last package, the 25 pin QFN, opens were easily identified using the open signal test between the measured heel and center thickness.

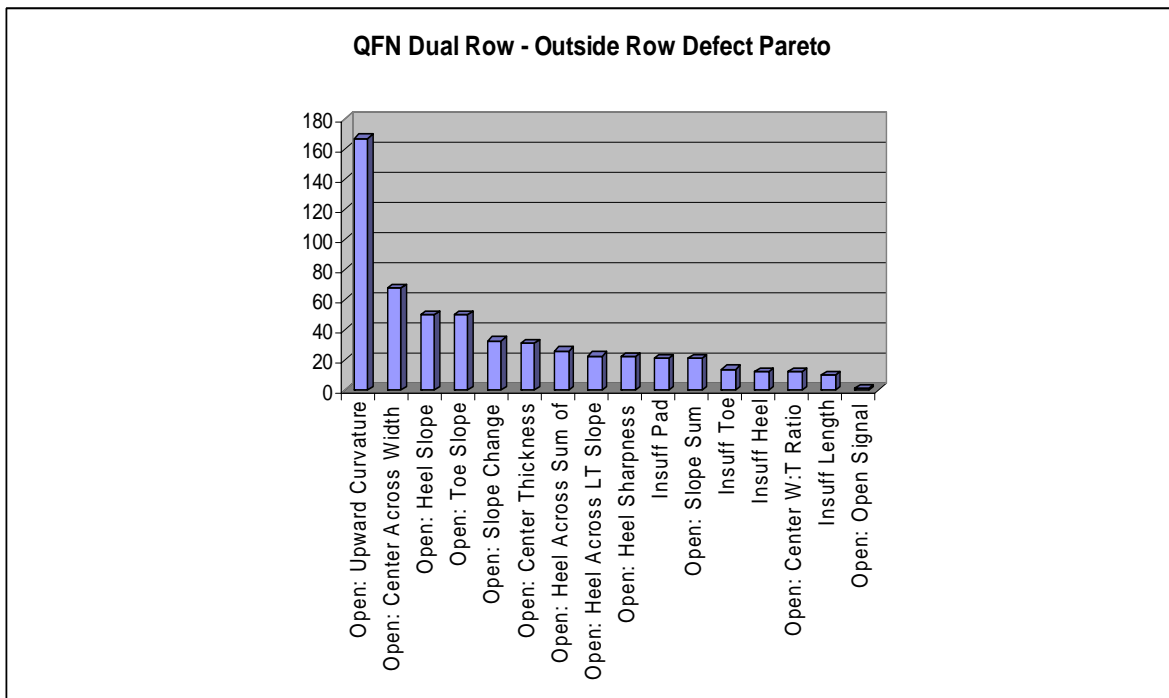


Chart 17: Defect Pareto for the outside row of the Dual Row QFN

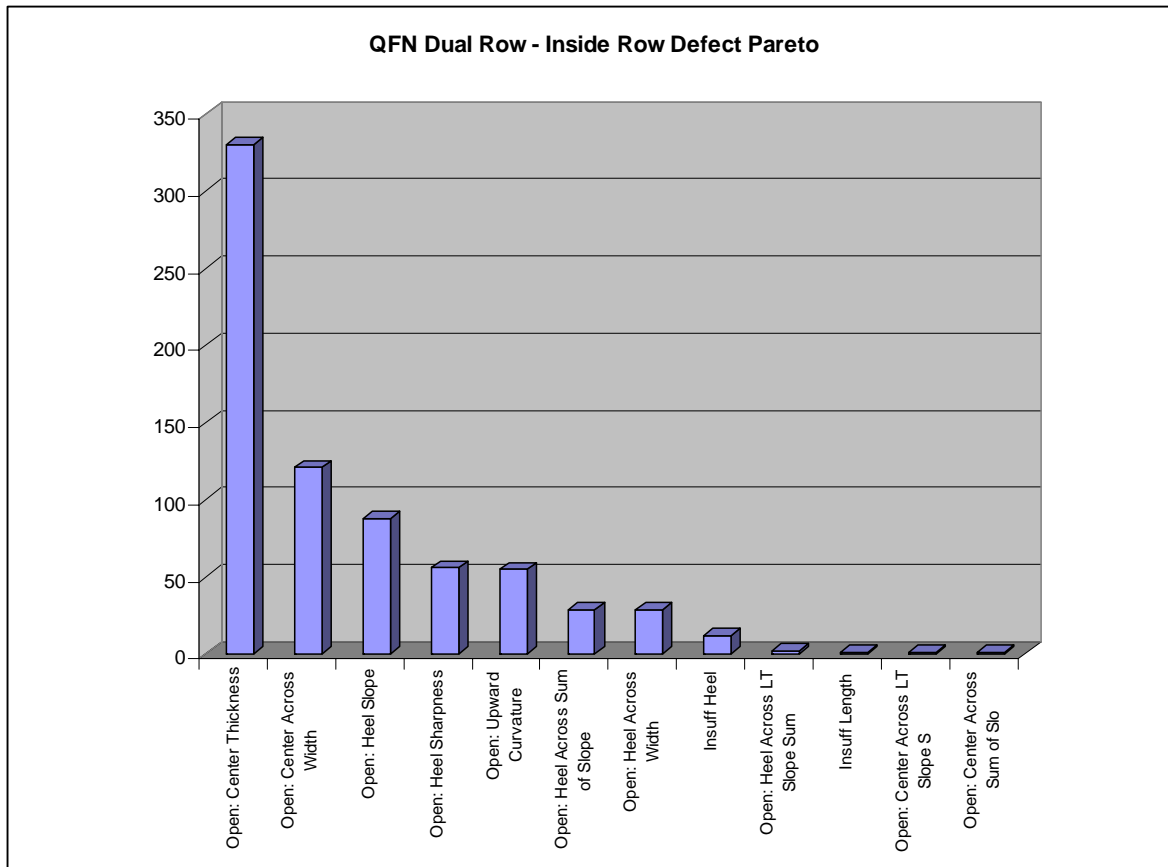


Chart 18: Defect Pareto for the inside row of the Dual Row QFN

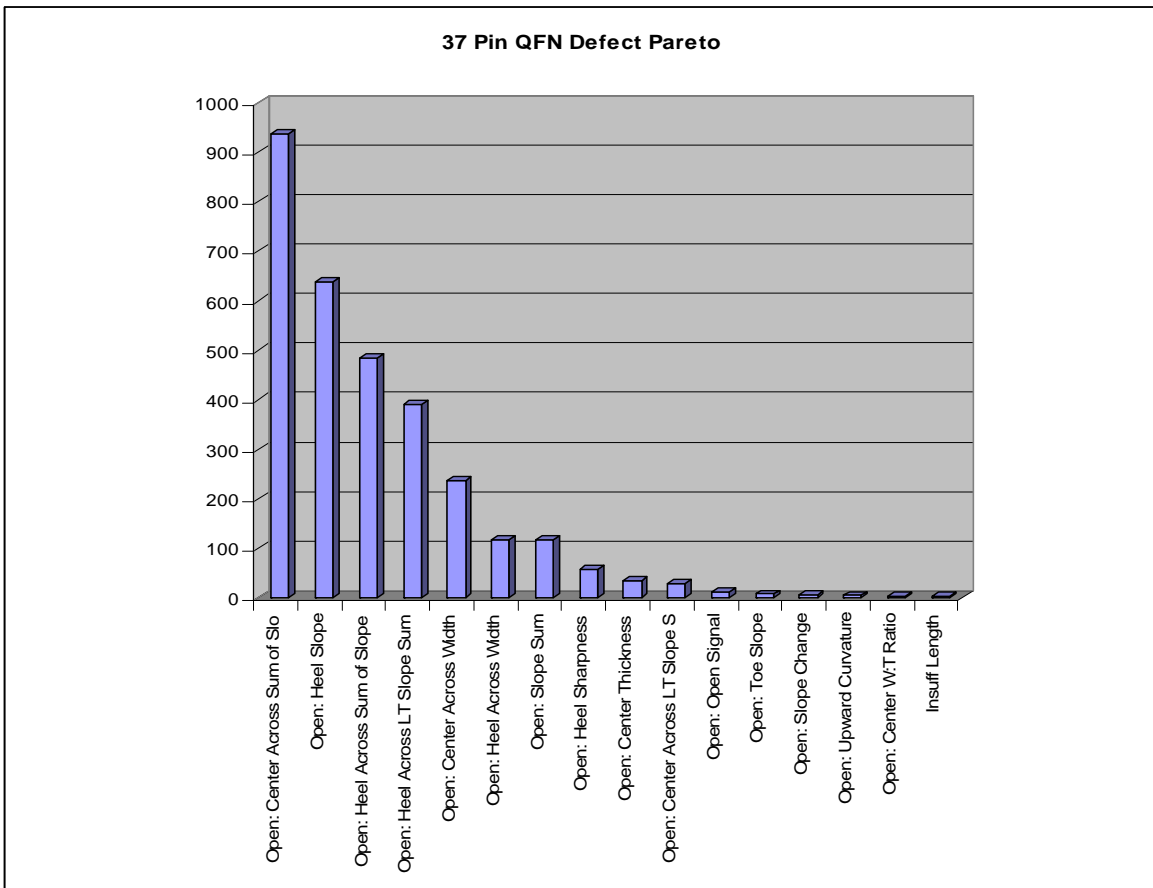


Chart 19: Defect Pareto for the 37 Pin QFN

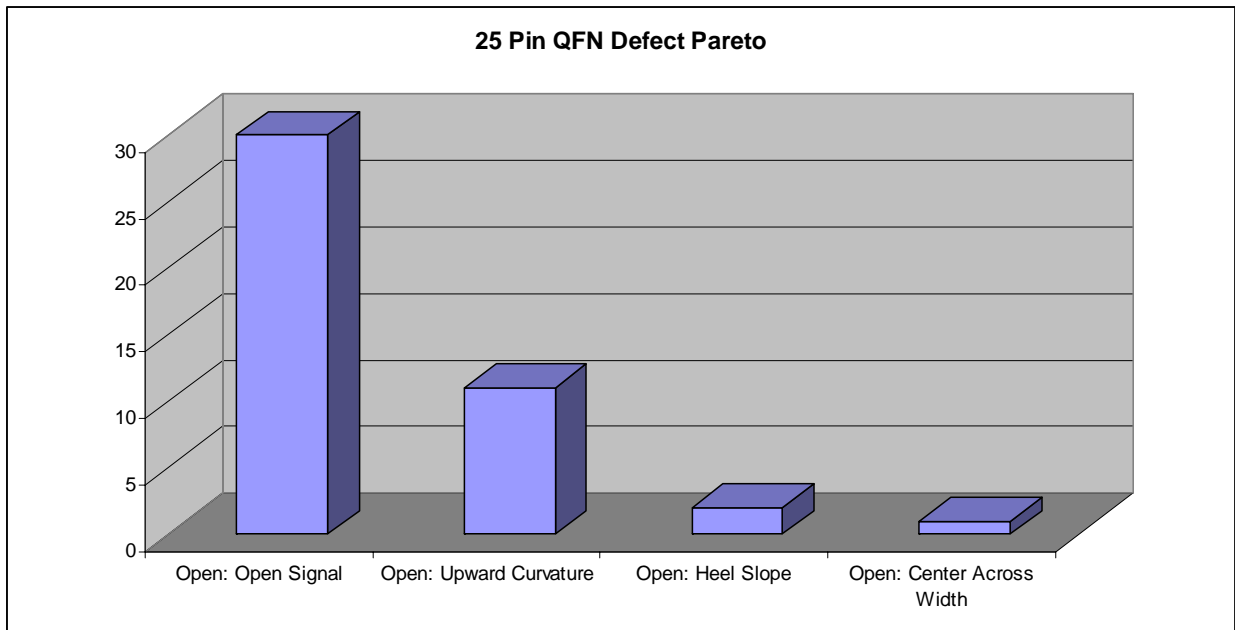


Chart 20: Defect Pareto for the 25 Pin Defect Pareto

Manufacturing Test Run Summary

Each of the panels produced were sent through a repair station to validate the defects and perform any necessary repairs. Out of the 168 joints that were inspected, on average there were roughly 5 false calls. Each QFN was further analyzed to determine how effective the tests were at catching opens. For this set of production boards, the Automated X-ray laminographic test had an effective 90% defect detection rate.

Conclusion

This paper demonstrates how much variation can occur with QFN packages and how to effectively utilize Automated X-ray laminography to test each solder fillet. Using X-ray tests, various testing techniques can be incorporated which include measuring the fillet length, various fillet region thicknesses, various slopes and various widths across the fillet. When using these test techniques, more than one type of test should be utilized to catch all potential solder defects.

We see that testing an unpopulated panel not a single test will even catch all of these defects types. Rather, it requires multiple tests such as center thickness measurements along with a center width across measurement to catch all of the defects. By using multiple testing techniques, the failing criteria may be set lower. Setting the failing criteria lower allows for fewer false calls to be generated and increasing the number of tests utilized increases the potential of catching all of the potential solder defects.

Automated X-ray Laminography proves a capable solution in testing QFN solder joints which provides effective test coverage for finding QFN solder defects in a manufacturing environment.

Future Work Consideration

QFN is a type of low Z height package; the solder formations do not have clear distinction between open and good solder joint. More low Z packages are coming with product getting thinner and smaller. As such, this is pushing the AXI technology and inspection methodology to the limit.

In order to continue to have effective inspection, AXI suppliers need to continue to develop and improve the current inspection methods to cater to future technological packages.

It is equally important to develop good DFI (design for inspection) on either the packages or PCB that will enable AXI inspection to be more effective. This effort will require close collaboration work among AXI suppliers, package suppliers and OEMs.

Finally, industry groups like IPC need to update current standards to reflect the changing needs and advances in the PCBA industry.

Sources

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Utilization of X-ray to effectively test Quad Flat No-lead Packages

Presented by
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SP50

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Agenda

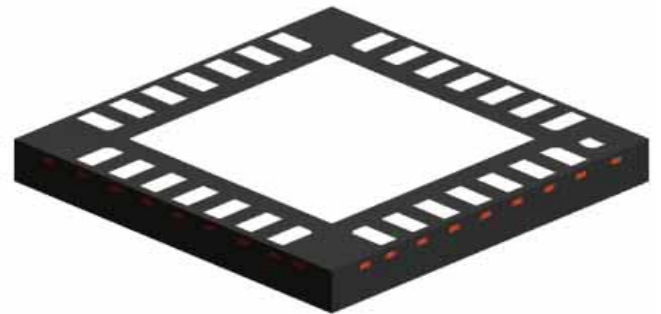
What is a QFN

A look at today's QFN testing standards

How to effectively use the 5DX to inspect QFNs

- **An overview of the QFN features**

Real world example of inspecting different variations of QFNs



The Quad-Flat No-Lead Package

QFN Package provides in inexpensive leadless package which

- **performs at higher operating speeds of 2GHz to 10Ghz with improved heat dissipation capability**
- **and accommodates for both decreasing board real-estate and package size**

Increasing usage

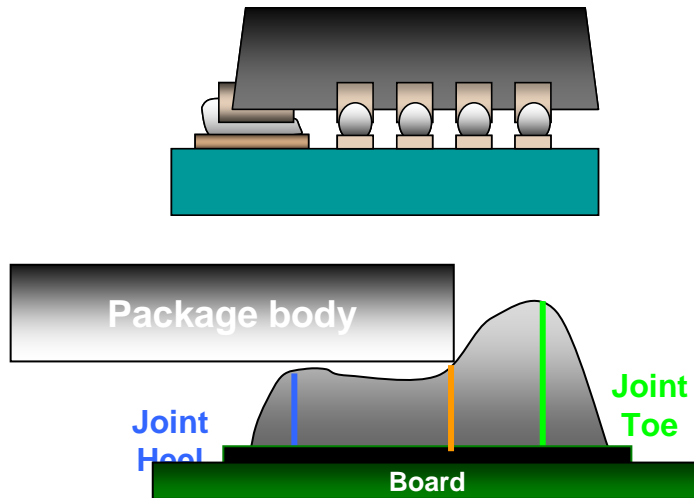
- **TechSearch International reported an increase in utilization of QFNs from 77% to 85% from 2004 to 2005.**
- **Amkor Technologies advertise that they have sold over 1 billion QFN packages to date.**

QFN's are quickly replacing fine-pitch gullwing and quad-flat IC packages

The Quad-Flat No-Lead Package

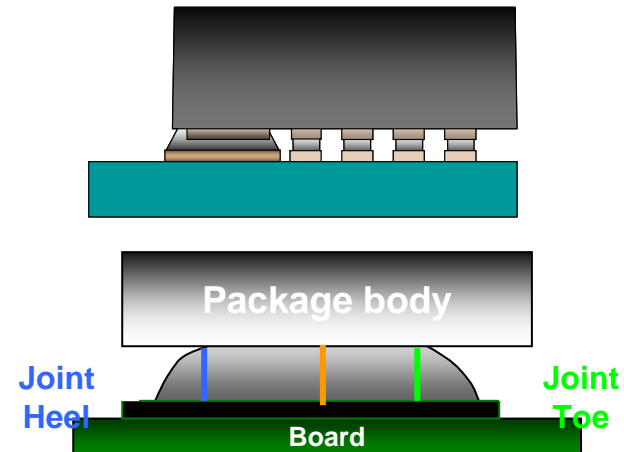
Variations of QFN Solder Joints

Outside Edge Termination



1. Termination extends from underneath to along the edge of the package.
2. Forms a solder joint with a large outside toe.

Bottom Only Termination



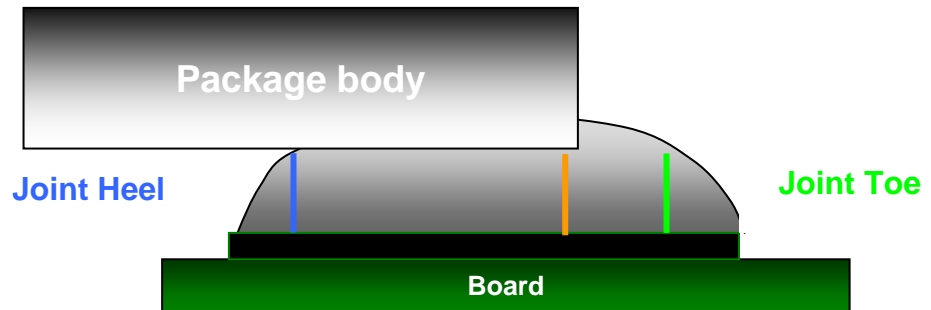
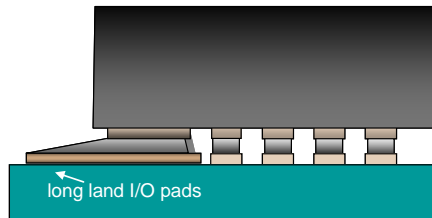
1. Termination is completely under the package
2. Forms a solder joint with a flat top profile with no toe.

The Quad-Flat No-Lead Package

Variations of QFN Solder Joints

1. This joint type is typical where a QFN package has replaced a QFP device on the same land pattern
2. Forms a solder joint which similar to Outside edge termination but with out a well defined toe.

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



Current QFN Testing Standards

IPC A-610D & IPC/EIA J-STD-001 recognize the QFN as a “Bottom Only Termination”

| Features | Class 1 | Class 2 | Class 3 |
|--|---|---------------|---------|
| Max Side Overage hang | 50% W Notes 1 | 25% W Notes 1 | |
| Toe overhang (outside edge of component termination) | Note Permitted | | |
| Min End joint width | 50% W | 75% W | |
| Min side joint length | Not a visually inspectable attribute | | |
| Solder fillet thickness | Wetting is evident | | |
| Min toe (end) fillet height | Unspecified parameter or variable in size as determined by design Toe fillets are not required | | |
| Termination height | Toe fillets are not required | | |
| Solder coverage of thermal pad | Not a visually inspectable attribute | | |
| Land width | Unspecified parameter or variable in size as determined by design | | |
| Termination width | Unspecified parameter or variable in size as determined by design | | |

Table 1: IPC A-610D Requirements

Available Manufacturing Testing Techniques

“Bottom Only Termination” definition – limits testing techniques

Optical Inspection

- Limited to no access available

Electrical (ICT/Functional)

- Package functionality & presence

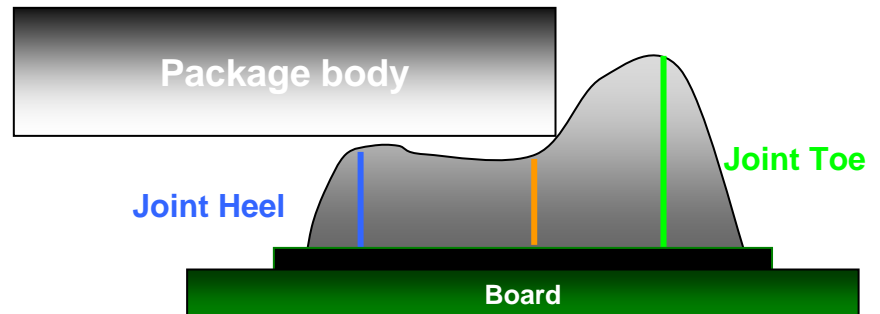
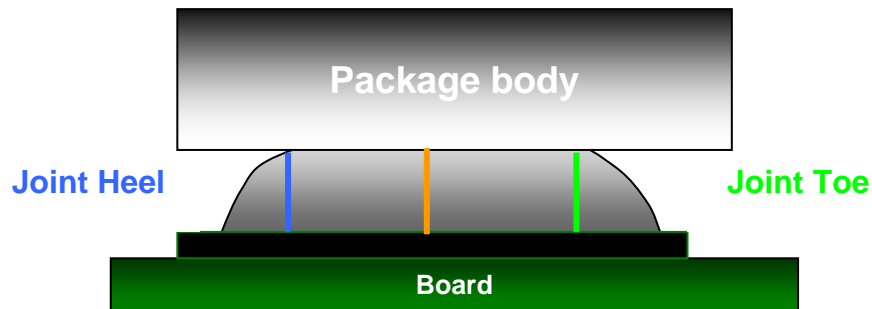
X-ray Inspection

- Allows for inspection of the entire solder joint, including both the termination joints and center thermal pad
- Effective at identifying: insufficient & malformed fillets, excessive voiding, bridging, missing & partially lifted packages.

Automated X-ray Techniques

Wide range of Opens tests

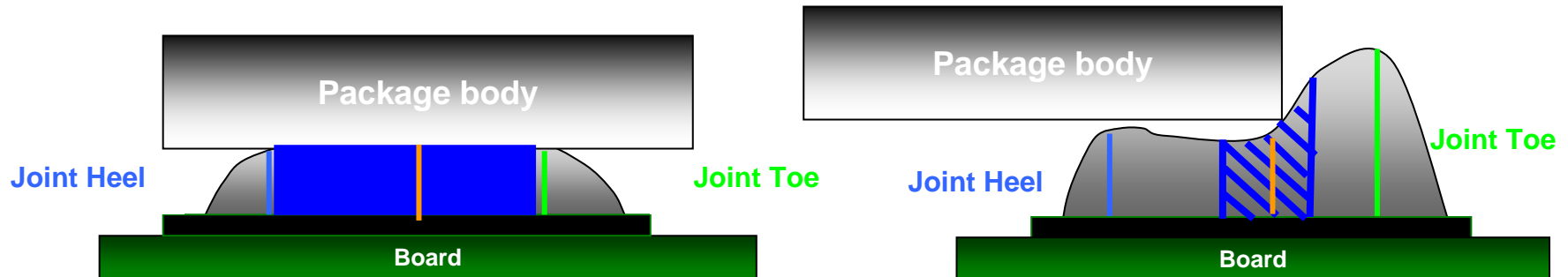
- Thickness of total fillet & toe, heel and center regions
- Length of the fillet
- Slope defined as Gray level per pixel along the total fillet



Automated X-ray Techniques

Opens test continued

- Curvature of user specified regions
- Used to identify flat regions or upward sloping regions



Automated X-ray Techniques

Opens Test continued

- width across both the heel and center
- Slope across both the heel and center

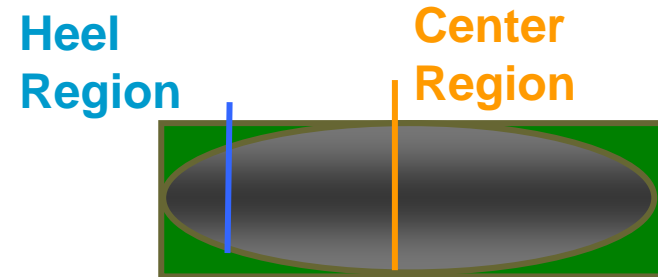


Illustration of the top of a joint



Example of Center Across Joint Profiles:

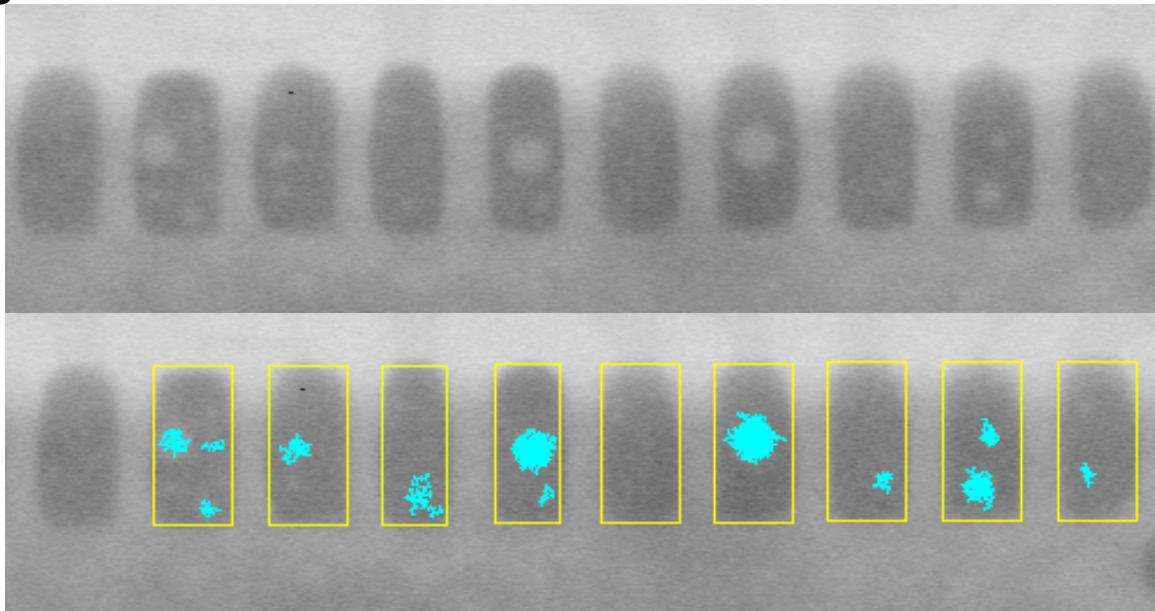
A is a good joint

B is an open joint

Automated X-ray Techniques

Void Inspection

- New approach to finding voids – eliminates noise around the edge

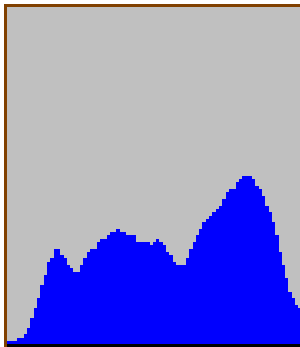


- Currently no specified void – though anything larger than 20% of the total area should be considered bad

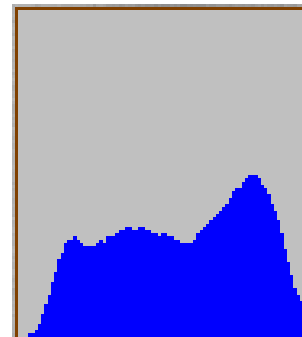
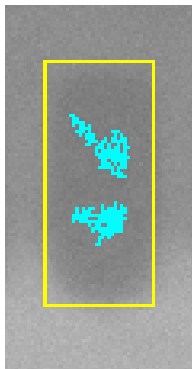
Automated X-ray Techniques

Void Compensation

- Accounts for small voids and removes them from the SPC measurements – eliminates potential noise
- Uses the voiding inspection results
- Gives the ability to set a specific void size to compensate and also a specific void size to fail on



Fillet Profile before Void Compensation



Fillet Profile after Void Compensation

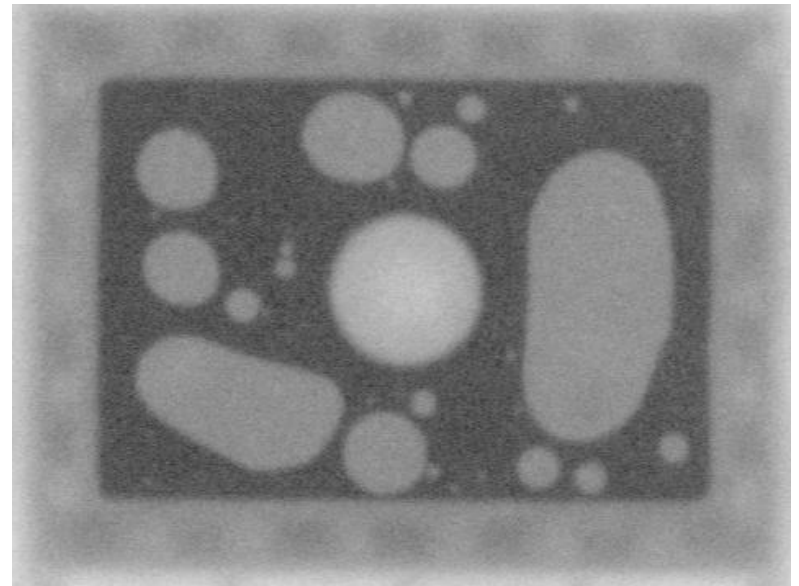
Automated X-ray Techniques

Insufficient Solder Tests

Solder Bridging

Center Thermal Pad

- Use either just the QFN voiding technique or Paste Voiding
- Still under investigation



Applying Automated X-ray QFN Inspection

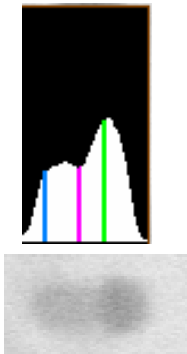
Agilent & Intel have worked together over the past year to understand QFNs and how to effectively use Automated X-ray laminography to differentiate between good and bad solder joints.

The following are examples of this work

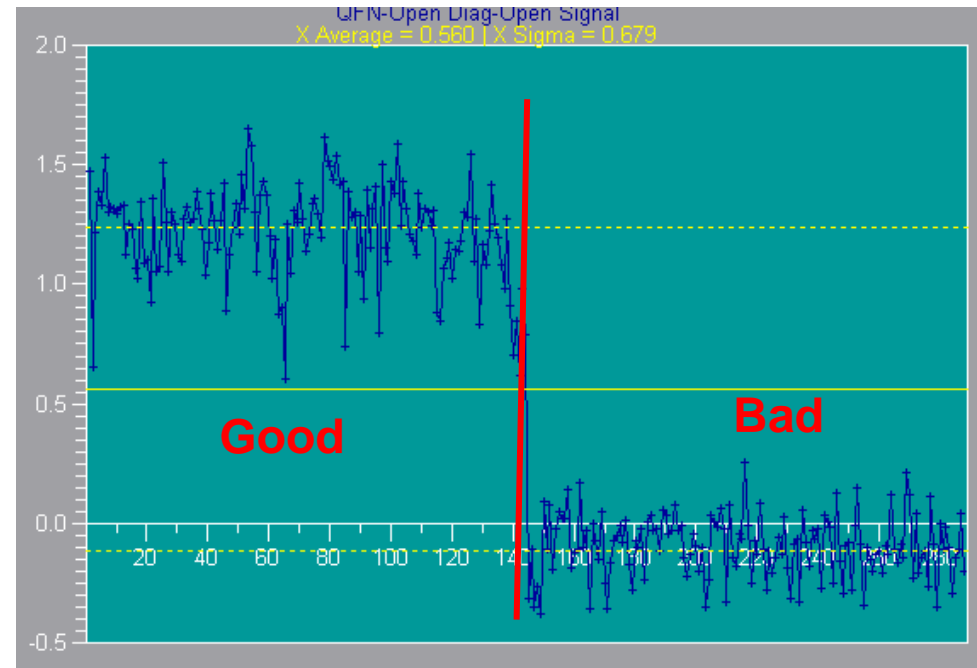
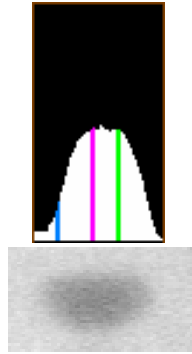
QFNs with a large toe fillet

QFNs with a metallic perimeter edge allow for a large Toe Fillet to form

Good Joint Profile

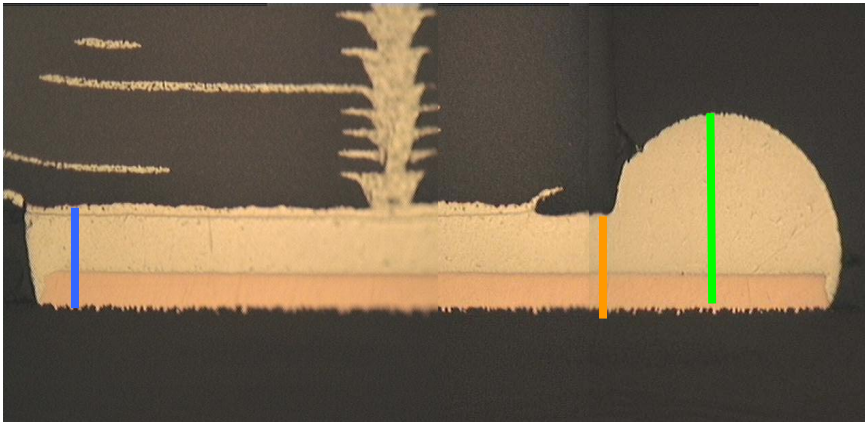


Open joint Profile

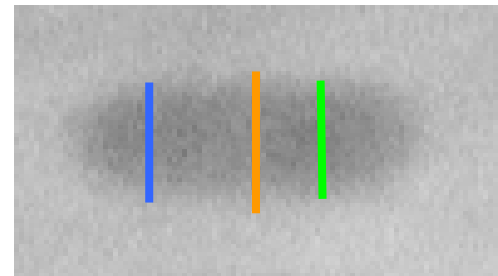
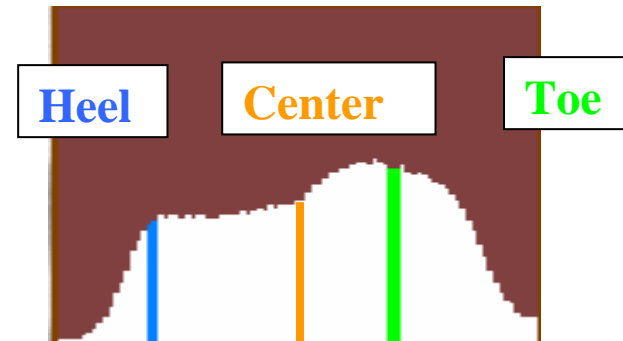


Difference between the toe region and center region of a populated good panel vs an unpopulated panel

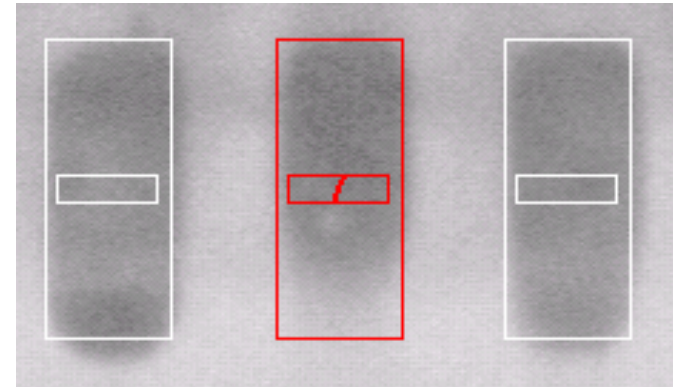
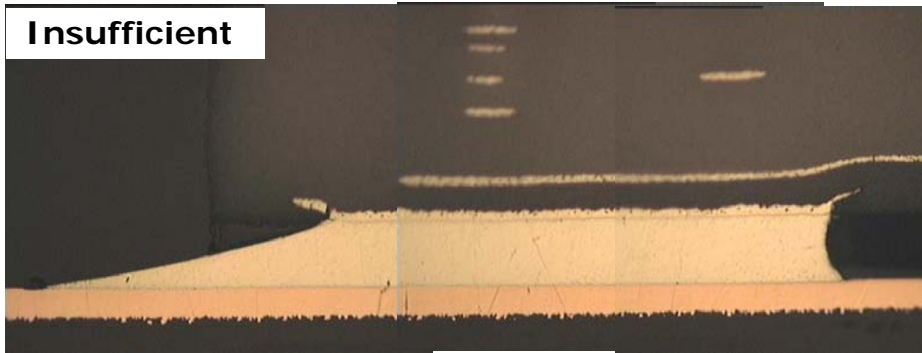
Example of a Large toe fillet



Cross-sectioned image of a QFN with a large pad and metallic perimeter with allows for some reflow of solder up the edge of the device



Example of a Large toe fillet

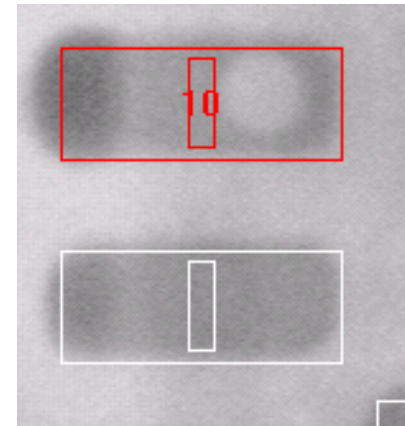
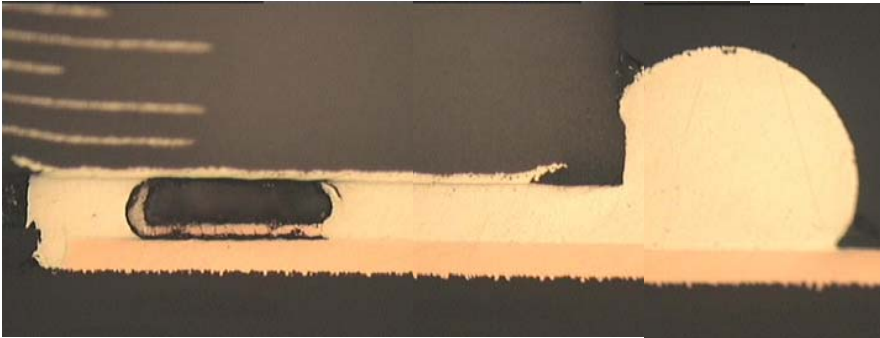


5DX Image

5DX Results:

- Fillet Length: 25 mils

Example of a Large toe fillet



5DX Image

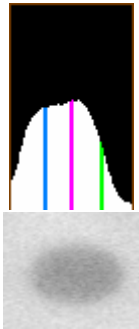
5DX Results

- Void % = 23.02%

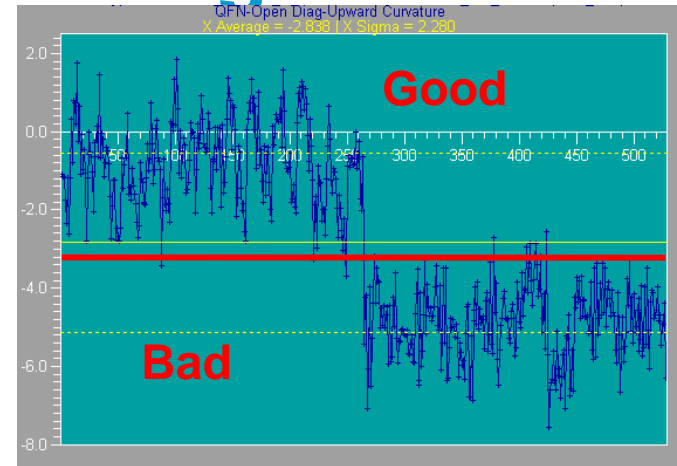
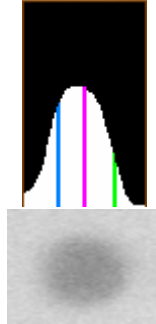
Example of a fillet under package

Fillets under a package form just a flat top and no toe

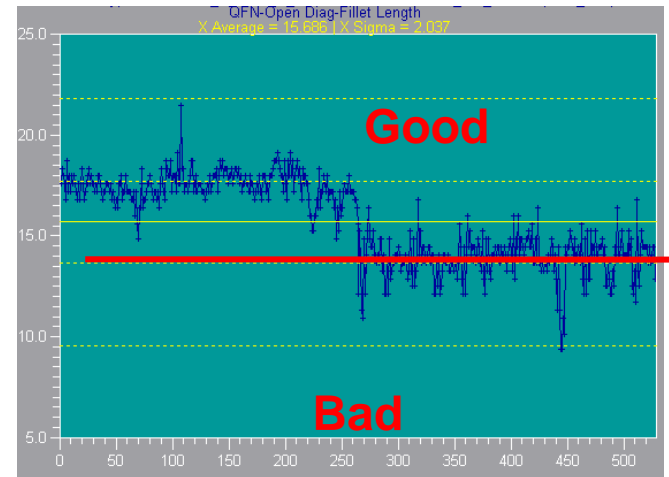
Good Joint Profile



Open joint Profile

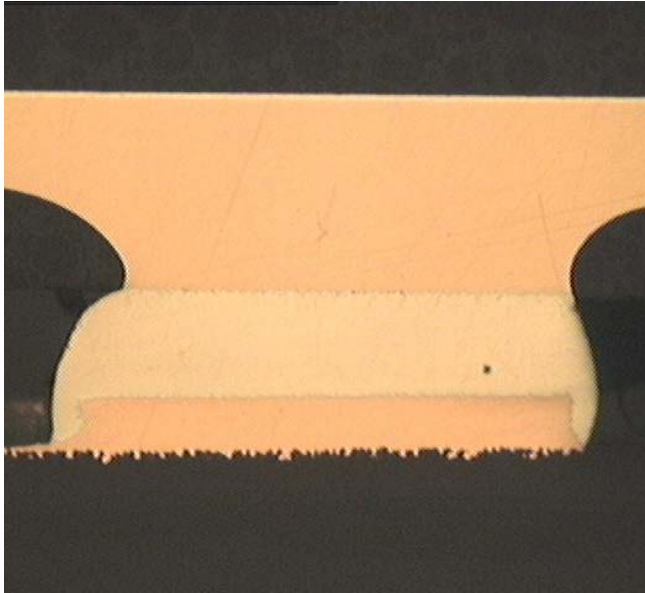


Measured Curvature of a populated good panel vs an unpopulated panel

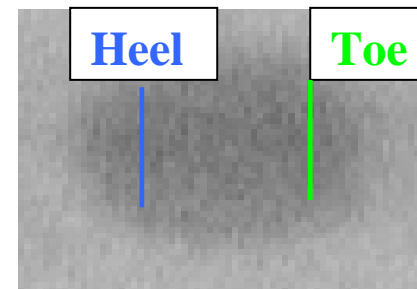
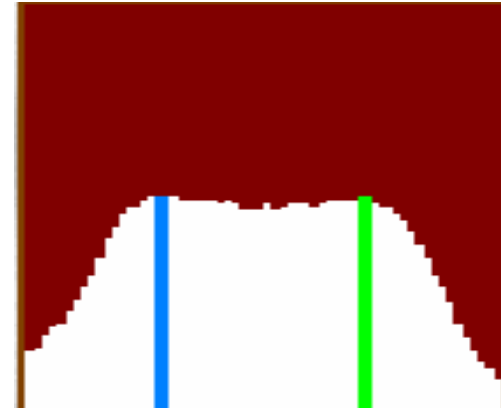


Measured fillet length

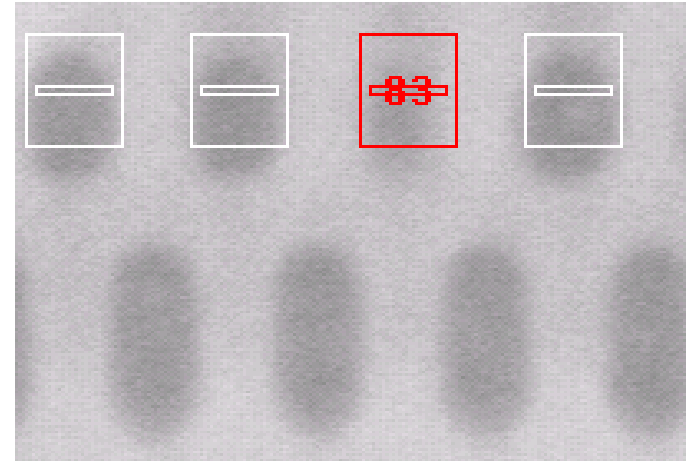
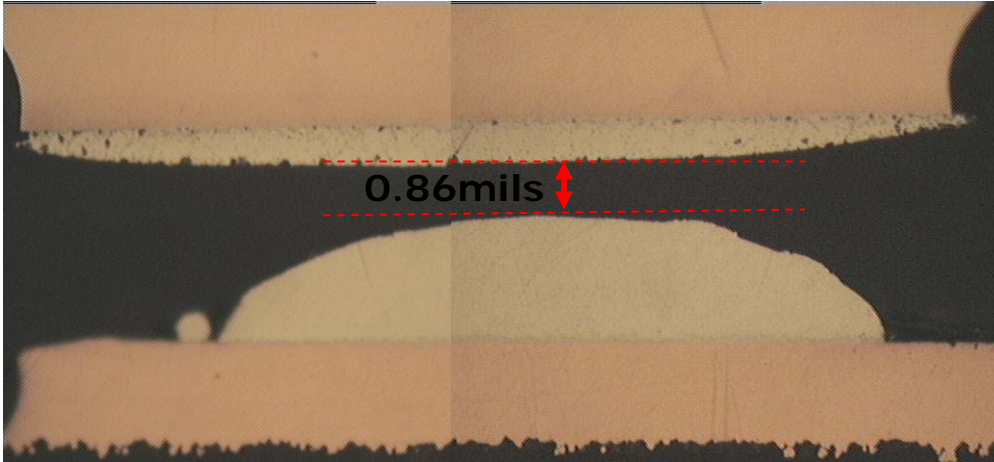
Example of a fillet under the package



Cross-sectioned image of a QFN completely under the package. Joint forms with no large fillet.



Example of a fillet under the package



5DX Image

5DX Results

Failed for Fillet length = 17.19 mils

Large quantity build of PCB with QFN's

Number of Boards Build

- 27,000

QFN Package Types

- 1 Dual row QFN MLF – 109 pin
- 1 PMU QFN - 25 pin
- 2 FEM QFN Package Types – 37 pin & 45 pin

Solder Formulation

- Tin\Silver\Copper – Lead Free

Verification of Defects

- All defects were validated by both the customer and an Agilent AE on-site

Results of large quantity build

| | |
|--|------------------|
| Total Number of Boards Inspected | 26,336 |
| Total Number of QFNs Pins Inspected | 5,688,576 |
| Total Number of QFN Defects | 1,415 |
| % of QFN defects caught by 5DX | 98.72% |
| Total Number of False Calls – customer was able to retune application and remove false calls – generated 27 escapes | 0 |

Summary

- 1. QFN fillet joint profiles vary unlike the common leaded packages**
- 2. X-ray provides the flexibility by offering a wide range of measurement and testing techniques**
- 3. Automated X-ray Laminography proves a capable solution in testing QFN solder joints which provides effective test coverage for finding QFN solder defects in a manufacturing environment.**

Source's

- Advanced Packaging Update: Market and Technology Trends. Developments in Fourth Quarter 2005. TechSearch International. March 2006.
- Japan Jisso Technology Roadmap. 2005.
- Board Level Assembly and Reliability Considerations for QFN Type Packages. Ahmer Syed and WonJoon Kan, Amkor Technology Inc.
- Quad Flat Pack No Lead (QFN). Feescale Semiconductor. Application Note.Rev. 3.0. December 2005
- The QFN Smaller, Faster and Less Expensive. David Comley and Paul Smit, Carsem Inc. Chip Scale Review. August/September 2002
- Application Notes for Surface Mount Assembly of Amkor's MicroLeadFrame (MLF) Packages. Amkor Technology. December 2003



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