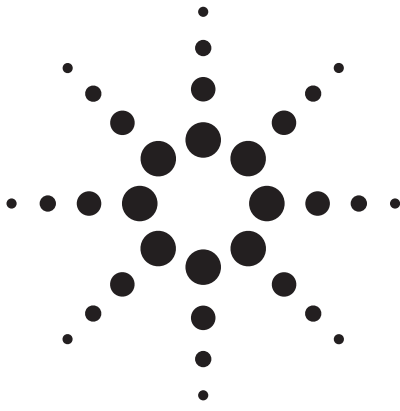# Measurement Repeatability

Application Note

One performance characteristic of an inspection system is its measurement repeatability, that is, its ability to locate and measure a specific feature of a solder joint with minimum variation in the measured value between repeated inspections. This ensures that an inspection system will consistently distinguish between defective solder joints and good solder joints. An inspection system with less measurement variation will have lower false reject and accept rates. Figure 1 below illustrates this fact.

5DX and Gauge Repeatability and Reliability (GR&R) Studies

In order to understand the variability of the electronics manufacturing process, it is necessary to monitor the most significant characteristics of the end product such as solder joint thickness for a printed circuit board assembly. These characteristic values will contain variability produced by the process, by the individual conducting the measurements, and by the measurement tool. The purpose of the gauge tool study (GR&R) is to ascertain the contributions of the measurement tool and the measurement tool operator (repeatability and reproducibility.)
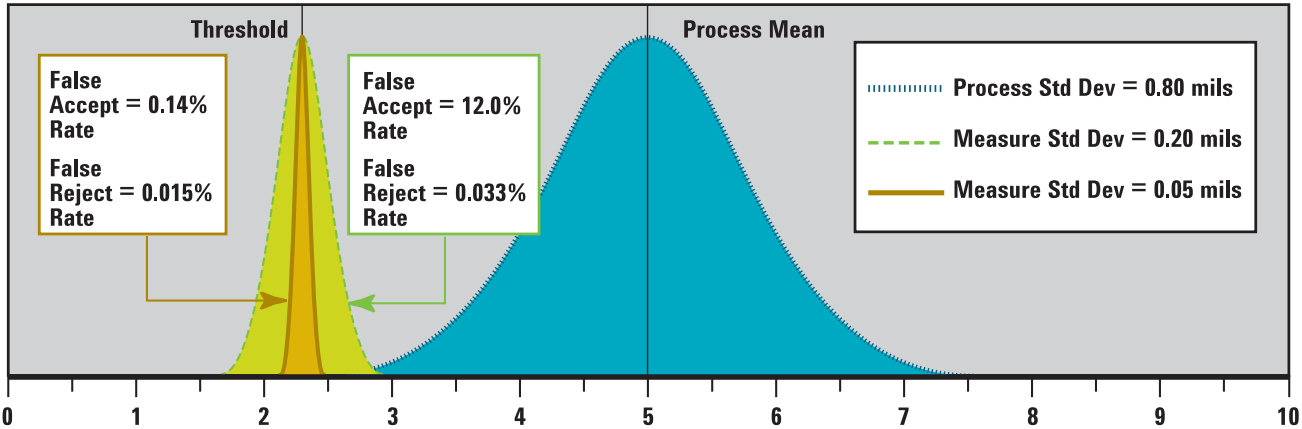

Threshold | Process Mean

False Accept = 0.14% Rate

False Reject = 0.015% Rate

False Accept = 12.0% Rate

False Reject = 0.033% Rate

Process Std Dev = 0.80 mils

Measure Std Dev = 0.20 mils

Measure Std Dev = 0.05 mils

0 1 2 3 4 5 6 7 8 9 10

Figure 1: Comparison of inspection results for systems with different measurement repeatabilities

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In a GR&R study, each system measurement of the 5DX capability is a combination of several individual measurements (XYZ stage, image acquisition system, mapping, software algorithms, etc). Since each measurement in effect has its own GR&R, these can compound to create a total 5DX GR&R measure that can be viewed as too high. The Agilent 5DX x-ray system is intended to be a defect containment inspection tool (versus a high precision measurement instrument) implemented in a manufacturing process to enable reliable product production. The following sections describe some of the individual measurements that combine to create the overall 5DX measurement capability result.

How Agilent Technologies Has Optimized Measurement Repeatability

With the goal of creating a defect containment production tool, Agilent Technologies has put significant engineering effort into optimizing the measurement repeatability of its 5DX systems. The Agilent 5DX does a solder thickness calibration and maps image gray levels to that calibration to consistently predict solder thickness. Solder thickness from 0.05 to 0.25mm (0.002 to 0.010in) are repeatable with typical standard deviations of less than 4% for all component types except for capacitors, through-hole and grid array components. Note the minimum repeatability standard deviation is 0.0025mm (0.0001in). The 5DX employs several methods

in both hardware and software to achieve this level of measurement capability. These include an XYZ positioning stage, surface mapping, automatic system monitoring and self-calibration, and advanced software algorithms for locating and measuring solder-joint features.

XYZ Positioning Stage

The accuracy of the XYZ positioning stage begins with quality components, such as precision ground ball screws, that are assembled and aligned using procedures refined over many years. Furthermore, the z-stage utilizes a micro-stepper that achieves 0.005mm positioning resolution for moves in Z, which results in an accurate positioning of the printed circuit board assembly (PCBA) within the cross-sectional focal plane.

Surface Mapping

The procedure of mapping the board surface is performed by a laser subsystem that takes measurements of the surface position. The laser power and spot size are set such that the laser beam reflects off the surface of the printed circuit board. This technique provides a "map" of the cross-sectional plane that slices through the solder joint at the pad level, and works to minimize the effects of variations in the surface reflectiveness of printed circuit board materials.

Automatic System Monitoring and Self-Calibration

The Agilent 5DX system automatically identifies drifts in cross-sectional imaging characteristics during production and automatically compensates for these drifts. This keeps the quality of the cross-sectional x-ray images constant between inspections and minimizes variations in measurements for those images.

Software Algorithms that Locate and Measure Solder-Joint Features

Agilent Technologies has developed special software algorithms that analyze the cross-sectional x-ray images of PCBAs and locate the solder joints within the image based on provided CAD data. Special techniques are used to consistently "lock" onto features of the solder joint, such as the edges, toe and heel of the joint. Consequently, measurements of these features are always taken at the same point between repeated inspections, which reduces measurement variations.

Example Measurement Repeatability Results

The measurement repeatability of the Agilent 5DX system can be demonstrated by re-inspecting a set of PCBAs several times and determining the standard deviation of the measurements taken of the solder joint features. The data shown in Figure 2 below represents the results of one such test using 10 PCBAs from a disk-drive product that were inspected 10 times each for a total of 100 inspections. The PCBAs had gullwings, j-leads, chip and polarized capacitors, SOTs, chip resistors and PTH joints. Figure 2 summarizes the single-joint standard deviation percentage of the solder thickness measurements, which is the standard deviation divided by the average solder thickness for the particular joint type.

With the exception of chip capacitor joints, the overall average measurement standard deviation percent was 1.5%, which corresponded to a standard deviation of 0.0013mm (0.05mil). Chip capacitor joints are more difficult to precisely locate and measure because the capacitor body is opaque to x-rays, making it difficult to isolate the solder joint from the body in the x-ray image. Additionally, based on the types of joints under inspection, thickness measurement may not be the ideal method to maximize defect detection capability. Plated through-hole (PTH) joints, for example, are more accurately tested for defects by reporting corrected delta gray values rather than thickness.

The Agilent 5DX is an inspection tool that was designed to maximize repeatable defect detection capability in the manufacturing process. Multiple measurement types and methods (thickness measurements, gray level, positioning, calibration, etc) combine to enable the high defect coverage capabilities of the Agilent 5DX X-ray Inspection system.
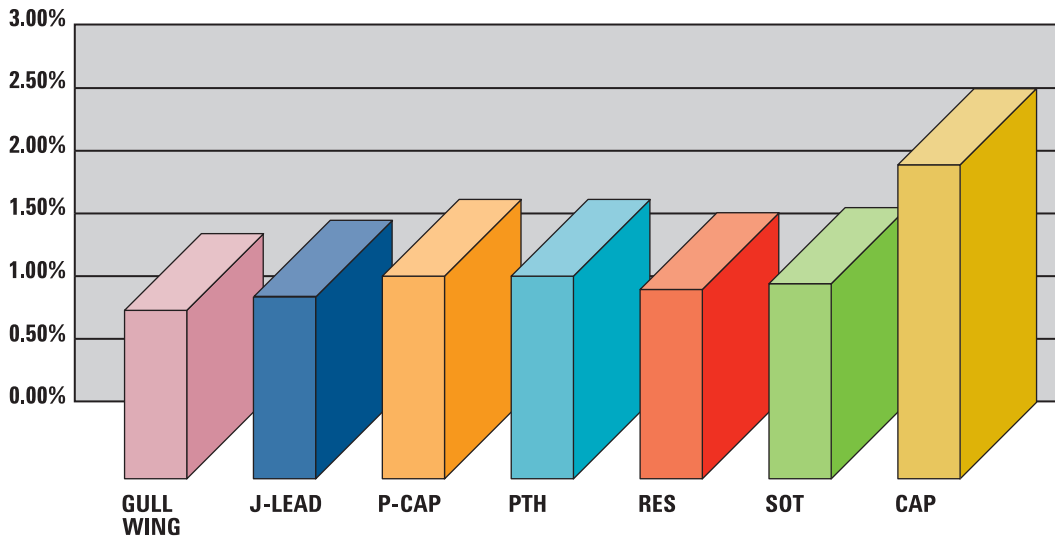

Figure 2: Average measurement standard deviation percent (10 PCBAs inspected 10 times each)

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Additional Information

To learn more about the Agilent
5DX Series 5000 Automated
X-ray Inspection system,
please visit:

www.agilent.com/see/5DX

Contact Information

For more information about
measurement repeatability,
please contact your local Agilent
sales representative.

www.agilent.com/see/contactus