CASE STUDY

How Capacitive-Based Testing Enhances Wire Bond Detection

Proof of concept with s8050 Electrical Structural Tester yields positive results

KEYSIGHT

Background

In the rapidly expanding semiconductor industry, wire bond defects such as sag, sweep, and near-shorts pose significant risks to Integrated Circuits (ICs), particularly in mission-critical applications where reliability is paramount. Ensuring the functionality, reliability, and overall performance of these devices necessitates a thorough and meticulous inspection of wire bonds.

A leading Integrated Device Manufacturer (IDM) sought an advanced solution for an IC in automotive applications to enhance the quality of produced ICs by integrating a wire bond testing process. Faced with the challenge of ensuring the utmost reliability, the IDM collaborated with Keysight to evaluate the performance of the s8050 Electrical Structural Tester (EST). They required a testing solution that could deliver superior defect detection, increased throughput, and the flexibility to adapt to diverse production requirements. The s8050 underwent a comprehensive evaluation to demonstrate its capability to address these critical needs.

Organization

- A leading provider of advanced semiconductor solutions mainly in the automotive industry

Challenges

- Difficulty detecting near shorts, wire sagging, and wire sweep in wire bonding.
- Need to implement stricter quality test controls to screen ICs and ensure they are free from wire bond defects.

Solutions

- Keysight Electrical Structural Tester

Results

- Successful detection of all 5 known rejected units
- Can scale up to 20 sites in parallel with a test time of less than 1 second

The Challenges

For decades, large-scale lot issues related to wire bonding have eluded assembly tests, which rely solely on X-rays for quality control. The current industrial approach to identifying wire bond defects in ICs involves using X-ray optical screening, a non-destructive testing method, to detect sub-surface anomalies, including wire bond deformations. Manual inspection typically involves sampling, which can be as small as 5% of the entire lot. If defects or inconsistencies are found in the sample, it may indicate a broader issue affecting the entire lot. Consequently, the entire lot can be placed on hold for further analysis or corrective action to ensure the quality of the ICs.

Compared to manual inspection, automated X-ray Inspection (AXI) is a preferred solution due to its full automation, good repeatability, high-speed inspection capabilities with minimal human intervention, and, consequently, lower human error. Conversely, 3D X-ray technology offers comprehensive insights into the physical structure of the object being examined; however, this comes with increased costs from the expensive X-ray testers. X-ray imaging also faces challenges with specific materials like aluminum wire bonds, which may appear faint compared to denser materials such as gold.

The Units Per Hour (UPH) of X-ray systems are relatively low for mass production. Conducting 2D rather than 3D inspection is more practical, enabling a throughput of approximately 2-3K UPH. However, detecting vertical deformations of the wires is challenging for 2D X-ray imaging, as it lacks depth information. However, 3D inspection requires additional scanning time for accurate three-dimensional structural analysis. To increase this UPH further, the manufacturer runs multiple X-ray machines concurrently to maintain testing efficiency, but this occupies precious space in the factory. Therefore, with the ever-growing demand for quality improvement, manufacturers seek faster, more reliable solutions that address these challenges and enhance the screening yield.

The Solution: s8050 Electrical Structural Tester

The electrical structural tester, also known as the s8050, transforms the assembly testing by offering a unique solution capable of electrically detecting wire bond deformations through Vectorless Test Enhanced Performance (nVTEP) technology. This capacitive testing method is fast and efficient, enabling quick scanning of each IC pin, which is particularly beneficial for screening large volumes of devices.

The s8050 can test up to 20 sites in parallel, delivering high throughput with a test time of 0.9 seconds per site. When bottlenecked with a handler index time of approximately 3 seconds, an ideal setup can scale up to 18K UPH.

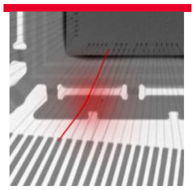
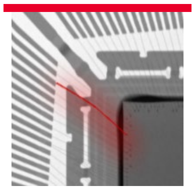
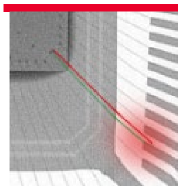
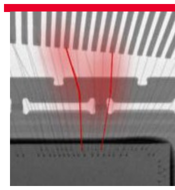
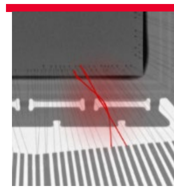
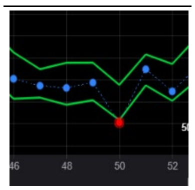
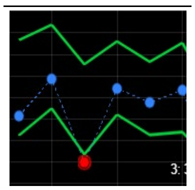
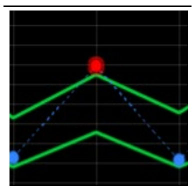
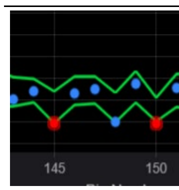
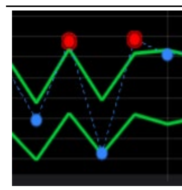
Figure 1. s8050 EST test engine and controller, Actuator and socket (upper left), nVTEP sensor plate stack-up (upper right)

How does it work?

nVTEP technology can detect measurement outliers that present risks to various types of wire bond defects, including shorted, open, and missing wires. It also reveals non-electrical defects such as extra, stray wires, near-shorts, sagging, and sweeping wires, which may not be detected by Automated Test Equipment (ATE) due to test method limitations. The technology operates by grounding all pins while iterating over the pin under test with a low signal stimulus. This method forms a capacitive-like structure, which allows a proportional relationship between the measured value and any physical deformation of the wire.

This enables the s8050 to introduce a revolutionary test engine that pushes the boundaries of detecting wire bond defects prevalent in today's assembly industry.

Types of wire bond defects detected using s8050 electrical structural tester

	Near short	Sag wire	Extra wire	Sweep wire	Lift wire
Defects detected using AXI X-ray					
Outliers detected using s8050					

Evaluation Process

The team collaborated with the customer to resolve near-shorts, wire sagging, and wire sweep issues in the Quad Flat Package (QFP) 100 device for automotive applications. These deformations in market-released Integrated Circuits (ICs) may adversely affect the IC's performance, reliability, and functionality.

This risk can extend from a faulty IC to compromising the entire application system. To evaluate s8050 wire bond detection, a Proof of Concept (PoC) activity was conducted on 124 units, comprising 119 Known Good Units (KGUs) and 5 Known Reject Units (KRUs). This process aimed to detect all deformations in the KRUs, ensuring consistency in defect identification. The evaluation required a load board, Low-Profile Quad Flat Package (LQFP) 14x14 100L 0.5P sockets, and actuators with nVTEP Sensor Plate.

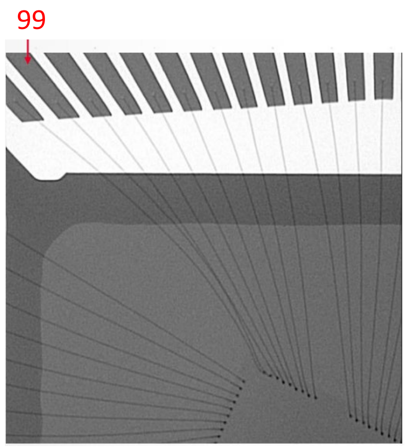
The evaluation involves testing all 119 KGUs to gather data and set limits using the traditional six-sigma distribution based on the population distribution from the known good units. At the minimum, a sample size of over 100 KGUs is sufficient to characterize the distribution, determine the central tendency, and establish stable control limits. Any outlier data from the 5 KRUs indicates the fault location.

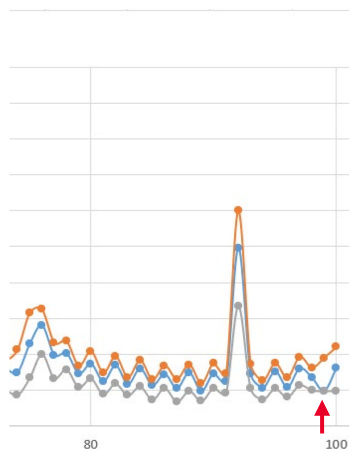
The Result

The s8050 demonstrated its exceptional proficiency in detecting all types of KGUs.

KRU #1: Near-short detection

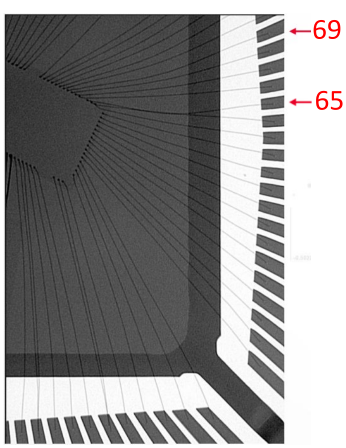
The s8050 detected an anomaly in Pin 99, located on the upper-left section of the IC. The measurement for Pin 99 fell below the lower limit, primarily due to a drop in capacitive coupling as the wire moved closer to its adjacent grounded wire. X-ray imaging validated this detection, revealing a near-short condition.

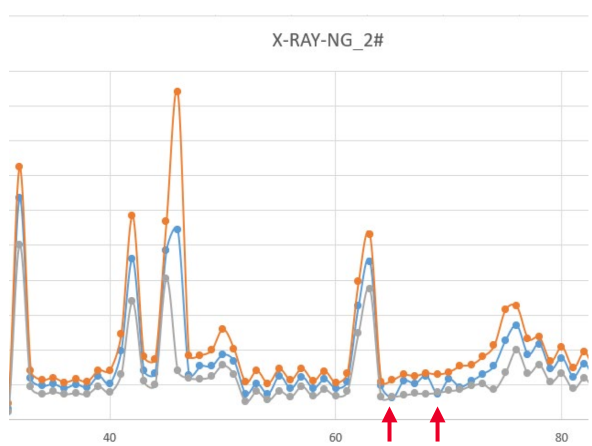




KRU #2: Sag and sweep wire detection

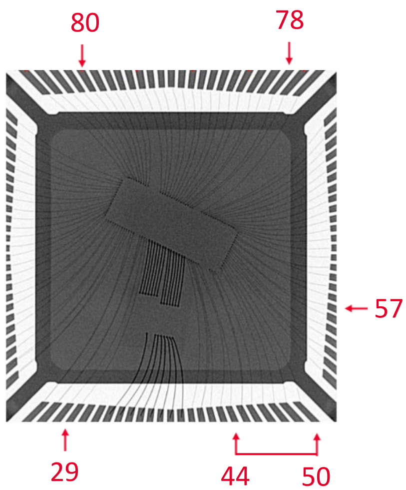
The s8050 identified defects in Pins 65 and 69, located on the right-hand side of the IC. The capacitive coupling values decreased as the wires moved further away from the sensor plate. X-ray imaging validated these detections, revealing sagging and sweeping wires.

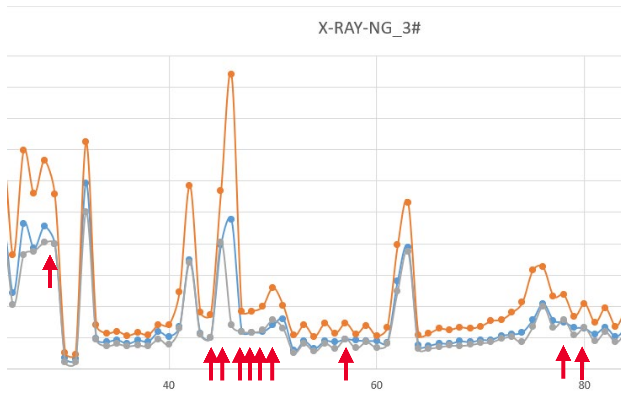




KRU #3: Multiple detections of lifted wires

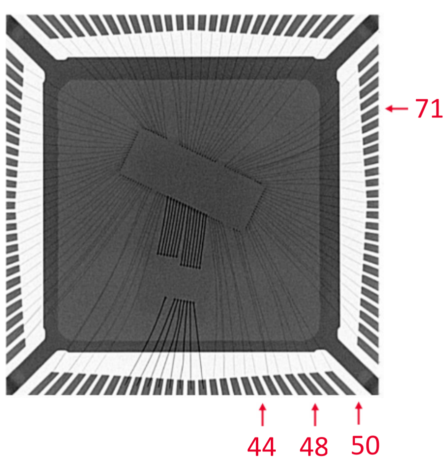
The s8050 detected multiple defective pins, primarily in the lower-right section of the IC. The measurements for these pins consistently fell below the lower limits due to their curvature away from the sensor plate. The increased distance resulted in a shift in capacitive coupling values. X-ray imaging validated these detections, revealing multiple wire lifting and sweeping across most pins. The substantial number of defective pins suggested that the issue was likely caused by defects during the molding process.

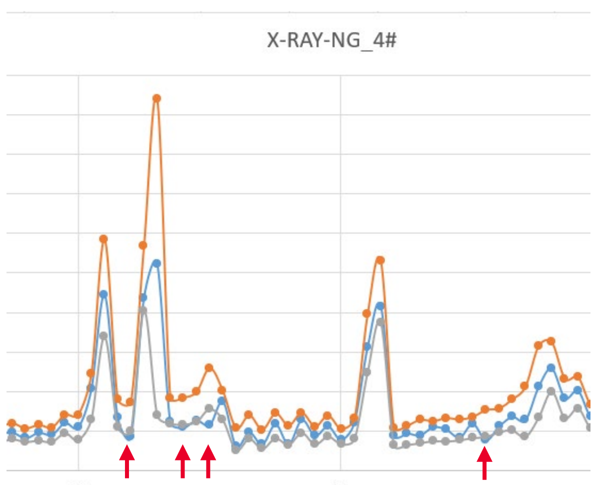




KRU #4: Simultaneous detection of near-short and sag wires

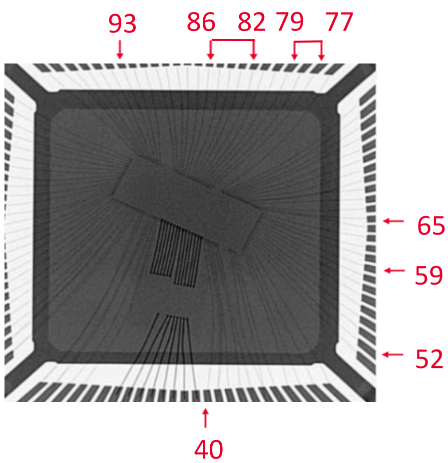
The s8050 detected defects in Pins 44, 48, 50, and 71. The measurements for these pins were below the lower limit, indicating a decrease in coupling response caused by their proximity to other grounded wires or the shifting position of the detecting wire. X-ray imaging confirmed near-short and sagging defects in the identified pins.

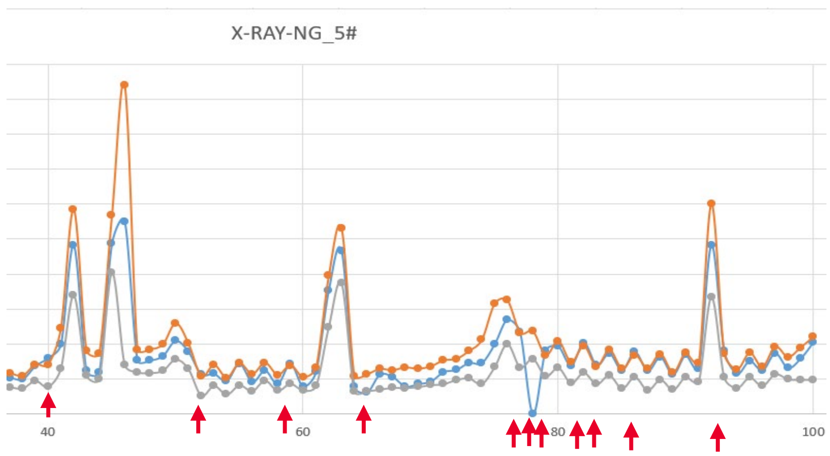




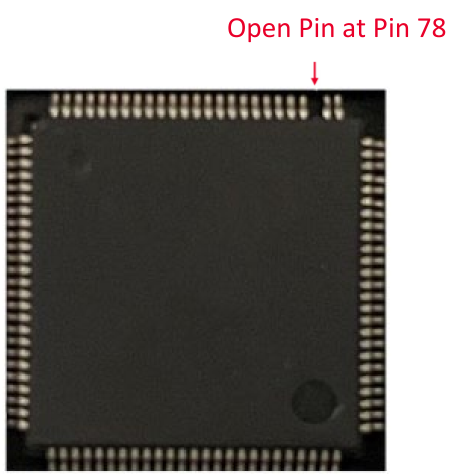
KRU #5: Lifted wire and open detection

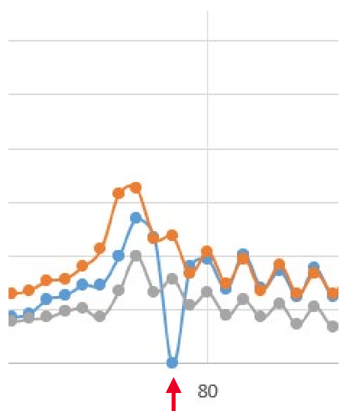
The s8050 identified multiple defective pins. The capacitance values of Pin 82 and several others exceeded the upper limits, indicating an increase in coupling response due to wire lifting, resulting in closer proximity to the sensor.





Pin 78 exhibited a capacitance value of 0, indicating an open pin within the IC. The physical structure of the IC supported the open condition in Pin 78, and X-ray imaging verified the lifting of wires.





Feedback and Impressions

With several engagements and collaborations with leading IC manufacturers in the semiconductor industry, there was a wealth of positive and constructive feedback. Customers appreciated the system's ability to catch wire bond defects and deformations. The automated test development feature, which eliminates the need for programming, was highly valued for its adaptability. Keysight’s s8050 was recognized for its auto-debug feature, allowing for an easy limit-setting generation. The sturdy construction ensures consistent performance in demanding production environments.

Customers observed that the s8050 can be implemented in both strip and pick-and-place testing. Its compatibility with third-party solution providers ensures efficient and seamless production integration. This adaptability and integration capability make it a valuable asset for manufacturers seeking to enhance their testing processes and improve overall production screening capabilities. Given the innovative design and advanced features, the s8050 is well-positioned to become the next screening stage for test and measurement in assembly packages.

Customer visit interview

> We are impressed with the performance of the s8050 Electrical Structural Tester. It can significantly improve the ability to detect wire bond defects, ensuring the highest quality for automotive applications. The automated test development feature and the system's adaptability can simplify test development, making it an invaluable asset to equipping the production line engineers.
>
> **Production Test Engineer**

Conclusion

The s8050 Electrical Structural Tester employing Vectorless Test Enhanced Performance (VTEP) shows a groundbreaking approach to identifying deformations affecting wire bond reliability. Through the analysis of 119 Known Good Units (KGUs) and 5 Known Reject Units (KRUs), the s8050 detected fault locations of all the various wire bond defects, including lifting, sweeping, near-shorts, and sagging wires. X-ray imaging further validated these defects' presence, confirming the testing method's reliability. Identifying multiple defective pins across different ICs further highlights the tester's capability to pinpoint fault regions and its crucial role in the testing industry.

For more information

Ready to discover more about Keysight electrical structural tester? Go to www.keysight.com/find/EST

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