Improve Yield and Reduce Risk with the ABCs of Test Accuracy

eBook

KEYSIGHT

INTRODUCTION

For 77% of companies, tighter tolerances, manufacturing complexity, and more demanding customer requirements make product quality harder to achieve.[1]

The risk of inaccurate product testing is immense. Whether your product is a microchip or a large satellite, accuracy, and repeatability are critical to your technical and business success. Test ensures that you meet your product quality standards. Accurate test measurements minimize risk and maximize business returns. Those measurements rely on your test strategy, which comprises three areas:

- test system design
- test system performance — accuracy and repeatability
- test system operation

Test risk could lead to a missed market window opportunity, product recalls, damage to your company's reputation, and missed earnings. A solid test strategy is one of the most powerful tools for lowering risk. Accurate test equipment performance ensures that your products meet their intended specifications and yield targets.

Calibration is key to test equipment accuracy and repeatability. Yet 92% of companies experienced a product recall, increased returns, or lost yield from test equipment that was out of calibration.[1]

1 Dimensional Research on test trends, December 2018.

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CHAPTER 1

A New Era Driving Test

CHAPTER 1

A New Era Driving Test

Product Quality Challenges

Dimensional Research surveyed electronics manufacturers around the globe to better understand technology market shifts. The report determined that the manufacturing objectives for smaller, faster, cheaper, repeatable, and predictable products remain unchanged.

However, 62% of companies report that the biggest challenges to maintaining product quality are tighter tolerances, manufacturing complexity, and more demanding customer requirements.1 Your test strategy is critical to your product's quality.   If this has affected the first and last column spacing, select all of the first column, select the left border icon, and remove the border. Select all of the last column, select the right border icon, and remove the border.

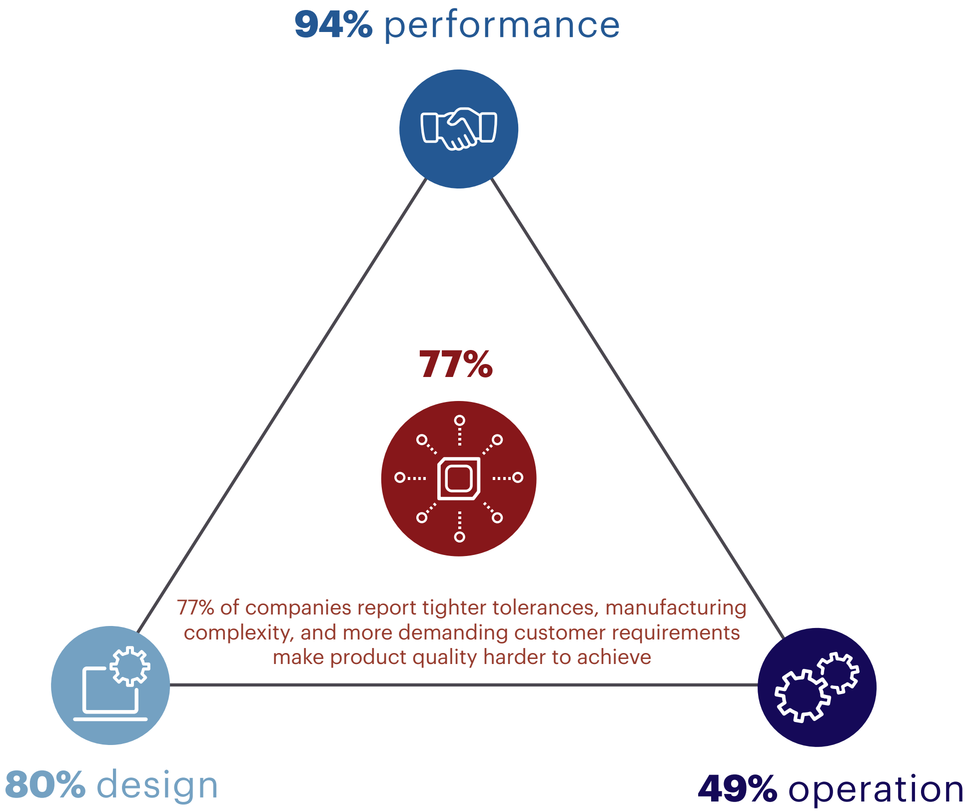
Three Areas of Test System Strategy are Critical

Seventy-seven percent of companies surveyed report that product quality is harder to achieve.[1]

Additional findings are as follows:

- **Test system design:** For **80% of companies**, customer requirements, setting test limits, and tolerance stack-up are the most critical aspects of test system design.
- **Test system performance:** Test equipment accuracy, reliability, and repeatability are the most critical aspects of test equipment performance for **94% of companies.**
- **Test system operation: Nearly half of the companies** say environmental factors are the most critical to optimize test equipment operation. Environmental factors are known to cause instrument drift.

Your test equipment accuracy drives product quality and profit.



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CHAPTER 2

Basics of Test Risk

Basics of Test Risk

Test Error Defined

A simplified definition of error is true value minus the measured value. As an example, consider a weight on a scale. The weight depicts the device under test (DUT) and true value, while the scale output depicts the measured value. The measurement uncertainty (MU) depicts the limits of error statistically, as shown in Figure 1.

Every measurement includes a small amount of error which creates measurement uncertainty.

To set the limits for this error:
Calculate the measured value plus, or minus (±) MU.

The DUT's final quality test is to ensure adherence to design specifications; some DUTs pass and some fail. However, because of measurement uncertainty, it is possible for defective products to pass (false pass) and good products to fail (false fail).

Test error = True value minus measured value

Weight on scale depicts true value and scale display depicts the measured value

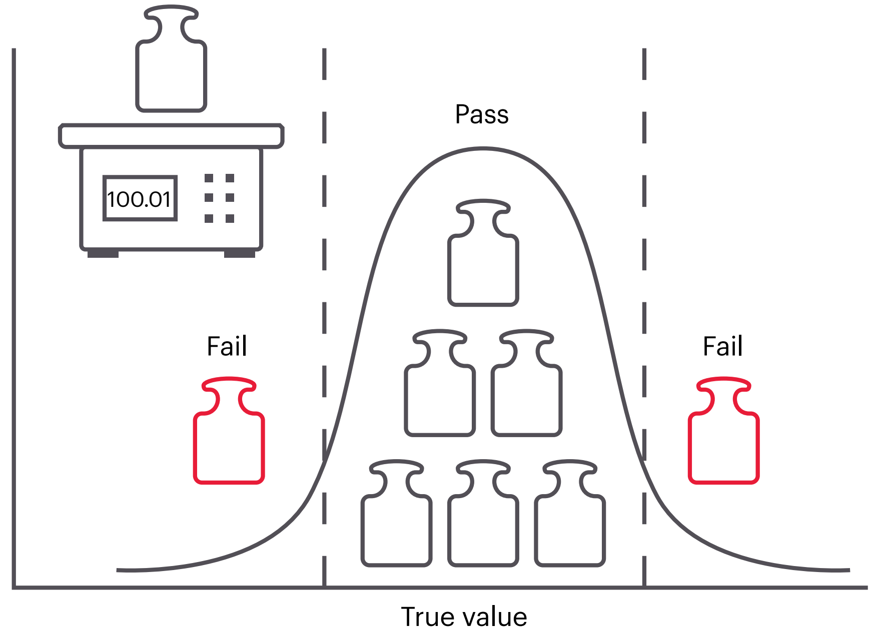

Figure 1. Normalized population distribution of true value of weights

Four Outcomes of Test

False Pass, False Fail, True Pass, True Fail

The matrix in Figure 2 shows the possible test and real-world outcomes of the measured value versus the true value of the DUT. This matrix visualizes the four possible test results: false fail, false pass, true pass, and true fail.

Quantifying a false pass is critical to reducing risk. When a bad DUT passes the test, the result is increased costs from product recalls, warranty obligations, and liability. It can also negatively impact the company's reputation.

Shipping a false pass — an out-of-specification DUT — disrupts the ecosystem of your supply chain. The company must quickly address the quality issue when detecting a test error. It may manufacture more DUTs or purchase better-performing test equipment to try to resolve the error. Shipping a false pass product puts a company at the highest risk.

Quantifying a false fail is critical to cost reduction. When a good product fails its test, it is either scrapped or reworked, adding to the manufacturing cost. A term for a false fail that occurs during manufacturing is a no fault found (NFF). NFF is a critical metric that manufacturing works hard to reduce because of its impact on cost.

Scrapping products occurs when the piece price is low and the labor to perform the repair exceeds the unit product cost. Companies generally rework products when labor and component costs are lower than the product unit cost.

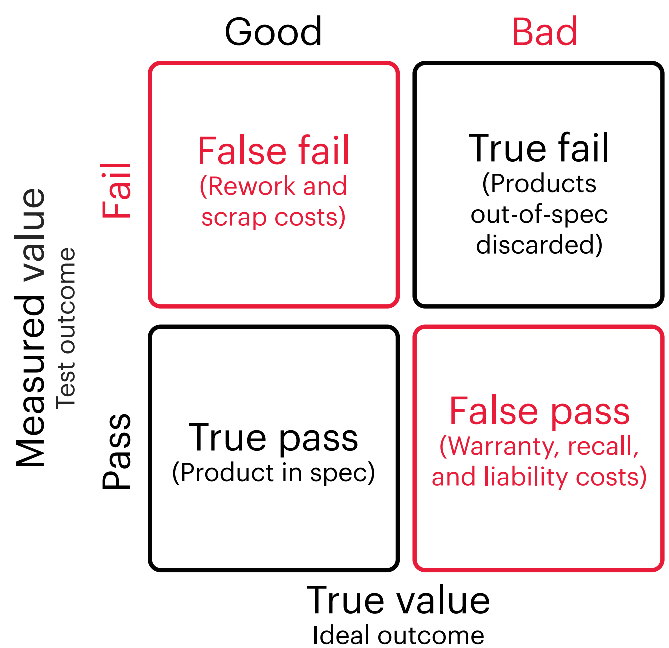

Figure 2. The four possible outcomes for a DUT

Risk defined

The Joint Committee for Guides in Metrology (JCGM), composed of broadly-based international organizations working in the field of metrology, provides the industry with the following definition for risk.

Risk is the probability that a conforming rejected item comes from a future measurement result. A global consumer's risk is the inverse — the probability that an accepted non-conforming item is based on a future measurement result.

Figure 3 shows the four outcomes in a simplified two-dimensional graph: false fail, false pass, true pass, and true fail. The true value is along the x-axis and represents the DUT. This outcome is the weight on a scale.

The measured value is along the y-axis and is the output on a scale. The measured values are the test outcomes. Quantifying the red areas of false pass and false fail reduces test risk and cost, as shown in Figure 3.

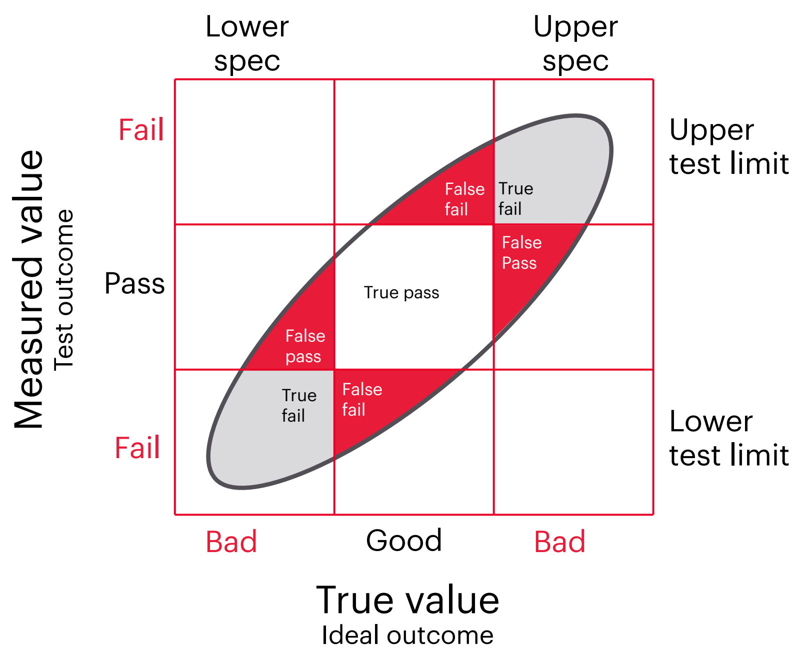

Figure 3. Joint probability density function simplified by projecting on a 2D plane

Risk quantified

JCGM's joint probability density function defines risk

JCGM 106:2012 defines the mathematical formula for calculating global risks in section 9.5, Calculation of Global Risks. The probabilities for the four possible outcomes are based on the joint probability density function, as shown by the following equation:

$$p_0(e_{dut})p_m(y-e_{dut}) = \frac{1}{\sqrt{2\pi}\sigma_0} e^{\frac{-(e_{dut})^2}{2\sigma_0^2}} \; x \; \frac{1}{\sqrt{2\pi}\sigma_m} e^{\frac{-(y-e_{dut})^2}{2\sigma_m^2}}$$

$$\frac{1}{\sqrt{2\pi}\sigma_0} e^{\frac{-(e_{dut})^2}{2\sigma_0^2}} = \text{Device population variation}$$

$$\frac{1}{\sqrt{2\pi}\sigma_m} e^{\frac{-(y-e_{dut})^2}{2\sigma_m^2}} = \text{Test process MU}$$

The equation calculates the four possible risk outcomes. The colors in the scatter graph in Figure 4 illustrate the 3D data points for a normal distribution. The highest concentration of data is in yellow and the lowest in purple.

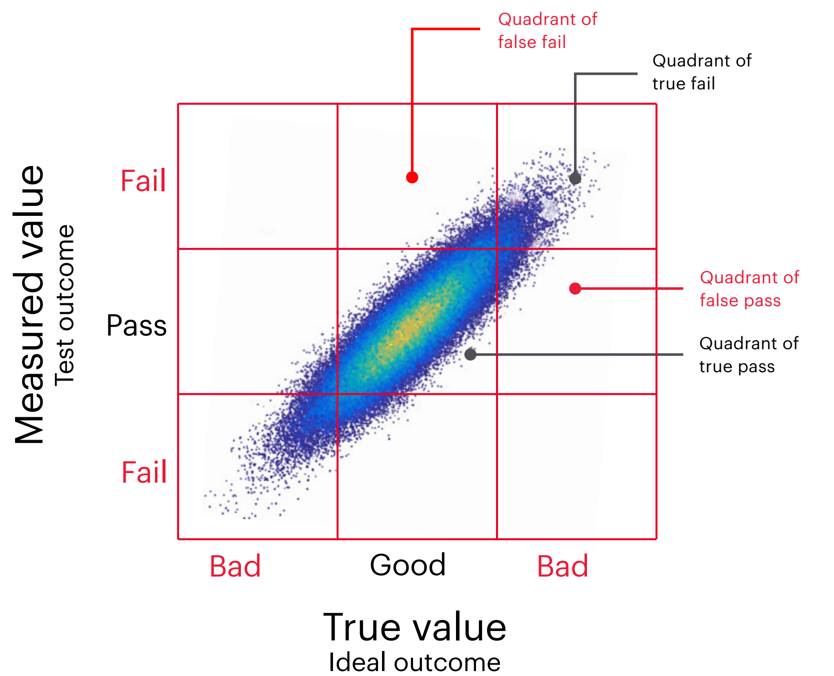

Figure 4. Joint probability density function showing normal distributions for device population variation and test process uncertainty using a 3D image

Risk Quantified – Putting It Together

JCGM's joint probability density function defines risk

The joint probability density function includes the device population variation and the test process uncertainty. The device population variation is the normal distribution under a bell curve, with test limits typically set at a 95 percent confidence level. The devices that pass represent yield. The test process uncertainty is the MU of the total test system.

JCGM's equation can serve as a simple to complex test system as multiple MUs make up the total. Figure 5 shows the joint probability density functions in three dimensions. Bell curves indicate the normal distribution of the device population variation yield and the test process uncertainty. The scatter graph shows the highest concentration of data in yellow and the lowest in purple.

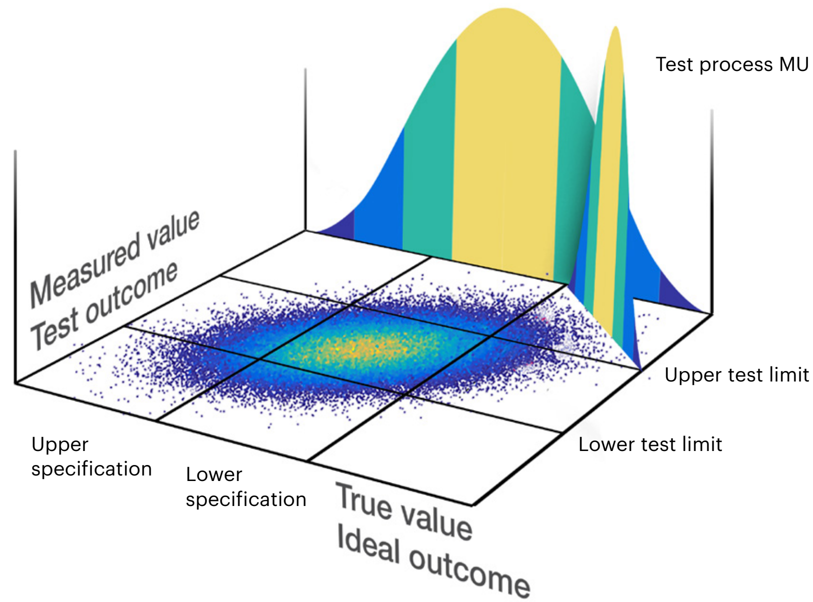

Figure 5. Joint probability density function showing normal distributions for device population variation and test process uncertainty using a 3D image

Out-of-Tolerance Risk

Drift impacts measurement accuracy

All electronic instruments drift. Moreover, all manufacturers of test equipment provide recommended calibration intervals in their products' datasheets. The calibration interval is typically once per year. Environmental factors that cause drift, such as shock, temperature, humidity, current, and voltage, determine the calibration frequency.

When an instrument is outside its specified tolerance, it is known as out of tolerance (OOT). Teams who have been using OOT test equipment may have made inaccurate measurements.

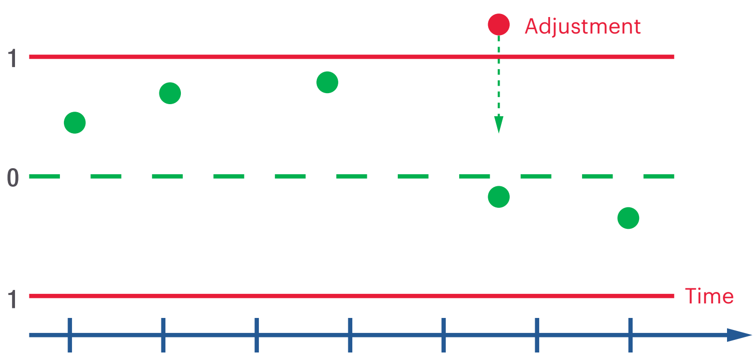

Figure 6. Test results for an OOT adjustment – one measurement point normalized (1M ohm for the 2-wire ohm test)

Products that are tested using OOT instruments and have passed or failed are now suspect. To assess whether an OOT compromised test is valid, your engineering team needs to know where the instrument was out of tolerance and by how much. Engineers will need the test instrument's as-received calibration measurements and the post calibration measurements for analysis.This information enables you to take corrective action, such as retesting or recalling products.

Calibration is necessary to ensure the accuracy of test results. Out of tolerance test equipment impacts your measurement risk. Figure 6 shows calibration test results for an OOT instrument that can cause your test process to be out of control and your test results may be incorrect.

Test System Measurement Accuracy (MU)

Traceable system calibration to the DUT plane

The MU of a test system is the composite of all the individual MUs of the instruments, fixtures, cables, switch matrices, and more. Your test teams need your total test system to be accurate and repeatable to ensure that products meet their intended specifications.

The overall MU can change dramatically or drift at different rates, depending on multiple factors. These factors include environment, maintenance, day-to-day usage, shock, and instrument age. Detecting changes in system performance dramatically reduces risk and cost.

Relying on an uncalibrated golden DUT or self-test is not enough. Traceable system calibration performed at the DUT plane for the entire system of instruments, fixtures, cables, and switch matrices ensures a higher level of accuracy.

Modeling the MU of a total test system and performing system calibration can dramatically reduce measurement risk.

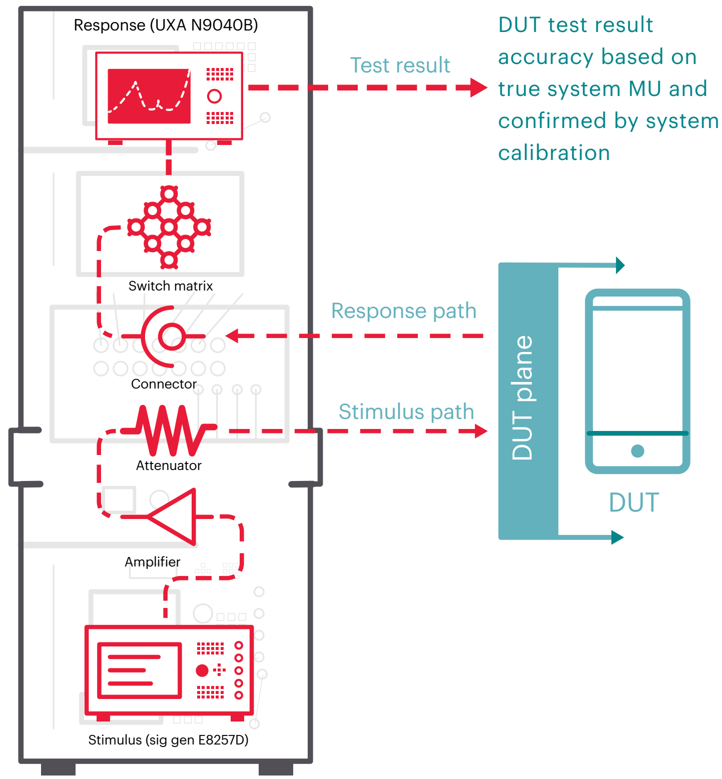

Figure 7. NEW, Demystify test system MU and its contributing sources. Get traceable system calibration to the DUT plane.

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CHAPTER 3

Calculating Risk

Calculating Risk

Reduce Risk by Lowering Measurement Uncertainty

Reduce false pass and false fail

Companies may feel pressure to reduce costs caused by false-pass units and false-fail units. A false pass puts you at greatest risk because of the impact on warranty, recall, and liability costs. False fail costs result from unnecessary rework and scrap. Figure 8 can help you visualize how a lower MU reduces false passes and fails.

Knowing the individual MU values of your test system is helpful when analyzing how to reduce measurement uncertainty. There are multiple methods to reduce MU:

- Use more modern instruments or components with a lower MU along the test system analog path.
- Modify the analog signal path based on the highest contributing sources of each test point's MU calculation.
- Calibrate your test equipment with more modern test equipment.

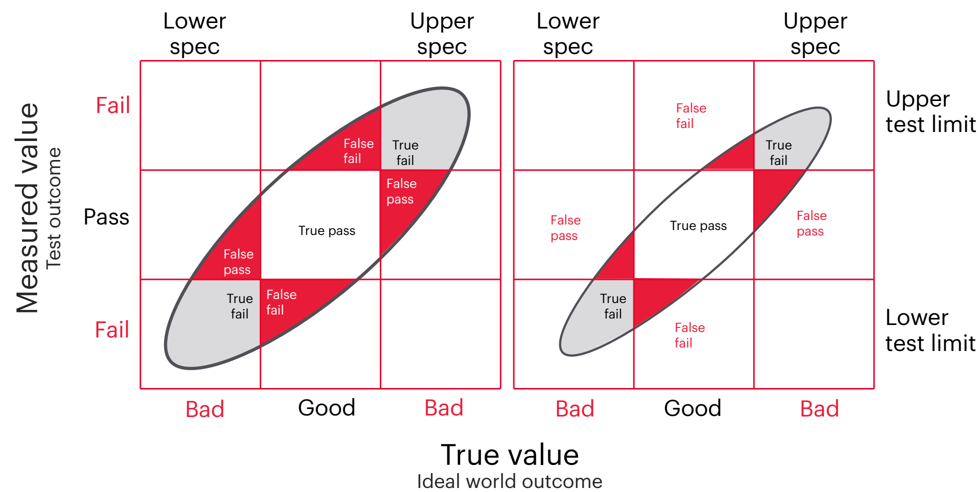


Figure 8. Comparison of two populations to demonstrate reducing the risk of a false pass and false fail with a lower MU. Figure 8 shows that increasing the accuracy of your test system measurement uncertainty reduces the risk of false pass and fail results.

Want to Learn More?

- Case Study: Precision Power Level Accuracy Measurements Reduce Risk
- Case Study: Calibration to Detect Changes in Test System Measurement Uncertainty

Reduce Risk by Using Guard Bands

Optimize false pass and false fail

Measurement uncertainty is a key contributor to false pass and false fail conditions.

One strategy for managing false pass risk is to apply a guard band, so the acceptance limits are more stringent than the tolerance limits. When the MU data is known, you can set guard-banded test limits to reduce false passes. Figure 9 demonstrates how setting a tighter upper and lower test limit can reduce false passes.

With guard banding, you can mitigate risk and optimize between false fail and false pass. Yield and quality goals vary, depending on your product specifications. Based on your goals, you can optimize the trade-offs between false pass and false fails.

Despite the upper and lower test limits established by your test teams, the calibration of your test equipment ensures your equipment performs to warranted specifications.

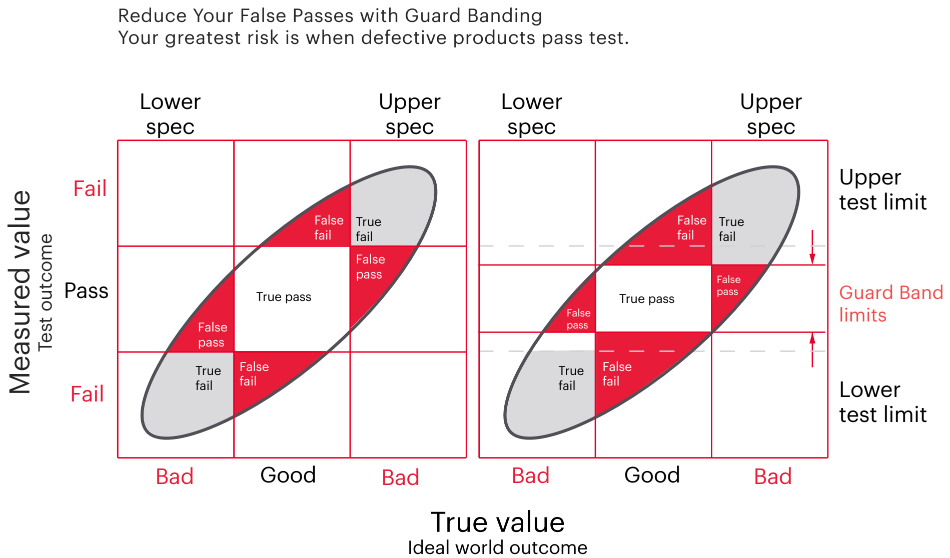
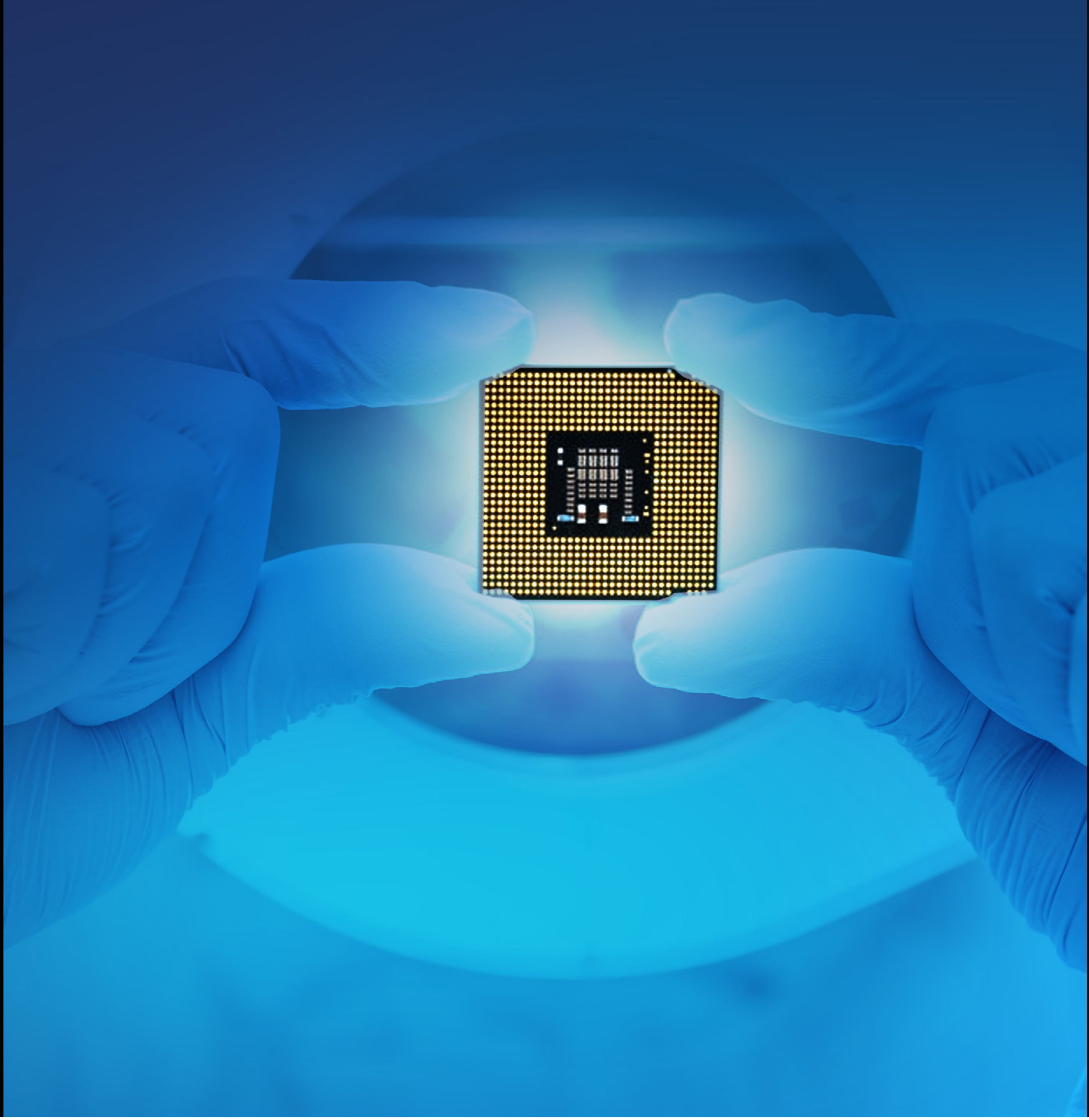


Figure 9. Comparison of two populations with and without guard banding demonstrates how to reduce the risk of false pass results.

Want to Learn More?

Case Study: A Guard Band Strategy for Managing False-Accept Risk

CONCLUSION



SUMMARY

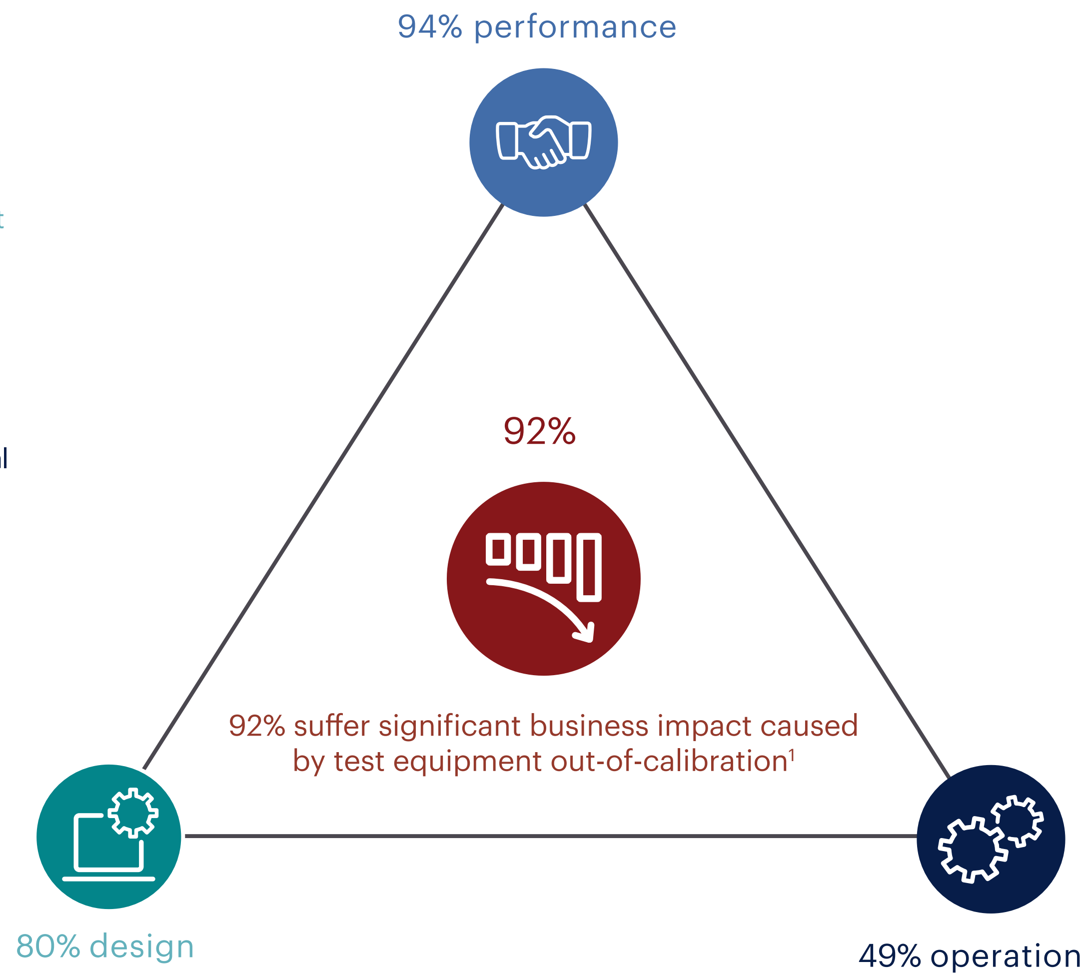
Dimensional Research surveyed companies around the globe and across industries on their challenges around profit and product quality driven by test equipment accuracy. Ninety-two percent said out-of-calibration test equipment caused product recalls, buyer rejections, increased product returns, and lost yield. Your test equipment accuracy drives product quality and profit.

Half of the customers surveyed said a loss of just one percent of product yield costs $100,000 or more.

Reduce Risk and Cost by Evaluating Your Test Strategy

Quantify your trade-offs between yield, test limits, measurement uncertainty, products specifications, and associated costs. According to Dimensional Research's report on test trends:

- **80 percent** of companies report customer requirements, setting test limits, and tolerance stack-up are the most critical aspects of test system design.
- **94 percent** of companies report that test equipment accuracy, reliability, and repeatability are the most critical aspects of test system performance.
- **49 percent** of companies report that repeatability and environmental factors are the most critical to optimize test system operation. Environmental factors are known to cause instrument drift.



KeysightCare Enhanced Keeps Your Instruments Calibrated

It is easy to maintain optimal performance and ensure that measurements meet specifications, just like when the instrument was new. Keysight provides periodic high-quality instrument calibration with KeysightCare Enhanced. Calibration ensures your instruments are always accurate, operate within specifications, and are in compliance. Calibration certificates support the compliance results.

KeysightCare Enhanced provides two-, three-, and five-year plans that include a calibration service of choice with a five-day committed turnaround time. You also get the additional benefits of technical support response in two business hours and repair coverage with a seven-day instrument repair turnaround time. Our calibration services ensure your test system performs to specification and meets local and global standards.

Experience the **KeysightCare** Enhanced level of service that gives you technical support, committed repair, and calibration turnaround times to help you stay on schedule, accelerate test, ensure precision, and optimize uptime.

Get better test results. Simply.

KEYSIGHTCARE

KEYSIGHT

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.