

Keysight

Assurance of Calibration Results: Applying the Power of Visual Information to Improve Quality

Application
Note

Abstract

To help you mitigate the risks inherent in your measurements, Keysight maintains the ongoing reliability and validity of our calibration processes. We start with systematic monitoring of results from our highest-volume instrument calibrations, as performed using automated software at any of our calibration sites around the world. Gathering data is just the starting point. Turning data into information is the next step, and visual information—in the form of control charts—drives decisions about the need for improvement activities and corrective actions. Three success stories show how Keysight ensures the quality of test and calibration results.

Introduction

During the development and manufacturing of your company's products, the specified accuracy of test equipment helps you make key decisions: Is a design meeting its performance goals? Do the products coming off the manufacturing line meet their specifications? Are they satisfactory to ship?

Our calibration services help you answer these questions about pass/fail decisions by mitigating the risks inherent in the measurement process. One important way to do this is by actively monitoring the ongoing reliability and validity of our calibration processes.

We do this through systematic monitoring of results from our highest-volume instrument calibrations, as performed using automated software at any of our calibration sites around the world. We save the individual points for every performance test. All this data is collected in a database that contains billions of data points. Collection happens automatically in the background and has no effect on calibration time.

Gathering data is just the starting point. Turning data into information is the next step, and information drives decisions about the need for improvement activities and corrective actions. Going from data to information to action requires processes, tools and people. Two standards guide our process: ISO/IEC 17025 and ANSI/NCSL Z540.3. Two essential tools support the process and serve the people: graphical presentation of data and our own Calibration Measurement Monitoring System (CMMS).

The key people engaged in the process are quality assurance engineers, service technicians and, when needed, metrologists. Every day, the CMMS sends a summary email to our quality assurance team. If pre-defined conditions are exceeded, the email includes an alert that triggers action by the team. By plotting the data in a consistent and proven format—the control chart—exceptions and their associated trends are instantly visible (Figure 1).

Since launching the CMMS, we have observed a number of success stories. The three described here illustrate the value of the system to us and our customers, and the examples range from "big data" across multiple sites to a single test at a single site.

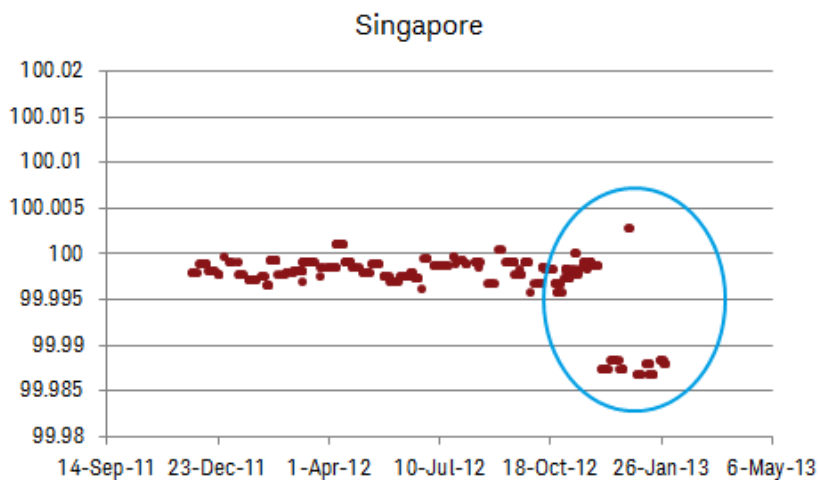


Figure 1. This control chart shows actual calibration data and some of the exceptions (far right) that triggered rapid action and resolution.

Scaling the Problem

We have more than 50 service centers around the world. The technicians who work at those sites calibrate thousands of different models configured with many possible combinations of options. The units they test range from attenuators and digital multimeters (DMMs) to complex, high-performance microwave signal generators, signal analyzers and vector network analyzers (Figure 2).

New or old, a typical instrument has 20 to 30 parameters that must be tested. Each of these includes one to many test points, often resulting in 1,000 measurement points per calibration for a complex instrument. Whether the calibration occurs in Spain, Singapore or the US, data is collected in a single, structured database. The raw data is stored electronically and the associated calibration records are retained as an easily accessible PDF file ¹.

Getting Familiar with the Processes, Tools and People

That mountain of data becomes more meaningful when we can use it to benefit our customers. Going from data to information to action requires three things: processes, tools and people. A closer look at each of these will provide a useful foundation for understanding the implementation of our CMMS.

Guiding the process

The concept underlying our process comes from classic Six Sigma thinking: you improve a process by reducing its variation. By monitoring actual data and flagging exceptions, we are able to reduce the variations in our processes and ensure valid, reliable calibration results. To maximize the rigor of our approach, two standards guide us: ISO/IEC 17025 and ANSI/NCSL Z540.3.

ISO/IEC 17025: This international standard defines the general requirements for the competence needed to perform tests, calibrations, or both. It applies to all organizations that do such work—first-, second- or third-party laboratories—regardless of the number of personnel or the scope of their testing or calibration activities.

The specification document has five major sections: scope, normative references, terms and definitions, management requirements, and technical requirements. Within the technical requirements, section 5.9, “Assuring the quality of test and calibration results,” provides important guidance regarding quality control procedures and the analysis of quality control data.

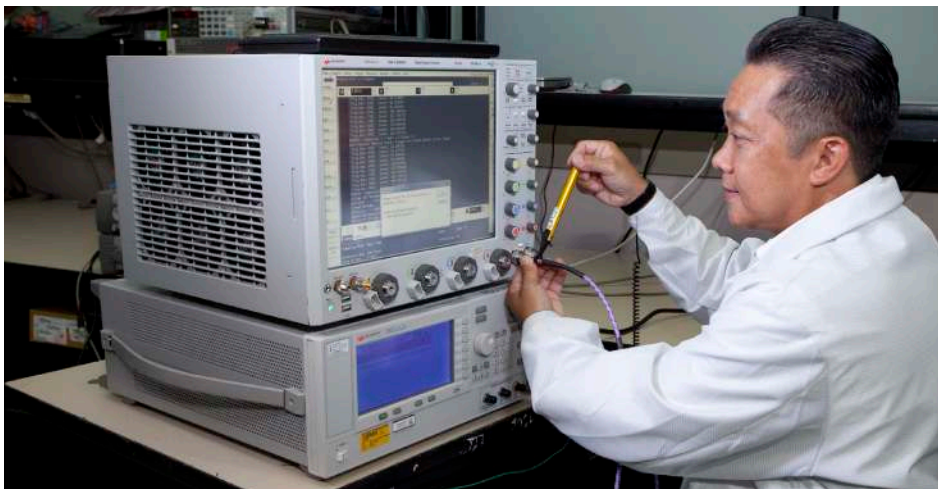


Figure 2. Our service centers are equipped to test virtually every instrument in our catalog—and they measure every spec, on every option, every time

1. Our customers can access their calibration records through our free web-based Infoline service. www.keysight.com/find/service

Specifically, subsection 5.9.1 deals with monitoring of the validity of calibrations, recording of data to ensure detection of trends, and the techniques used to plan and review the monitoring activity. Subsection 5.9.2 specifies the need for plans of action in response to data that falls outside predefined limits. The planned responses must correct the underlying problem and prevent the reporting of incorrect results.

ANSI/NCSL Z540.3: This standard defines the requirements for the calibration of test and measurement equipment. This includes controlling the accuracy of the equipment to ensure that products and services comply with the requirements.

The Z540.3 handbook has six major sections: scope, references, terms and definitions, general requirements, calibration system implementation, and calibration system assessment and improvement. Within the calibration system requirements, subsection 5.3.2, "Measurement assurance procedures," describes the key attributes of the required procedures. There are four major themes: thorough documentation of the adopted procedure; the systematic application of that procedure; criteria that verify attainment of selected goals; and the need for action, including isolation and correction, when indicated by measurement data. The use of control charts is suggested as a useful tool for achieving measurement assurance.

Outlining the essential tools

Graphical presentation of data is a long-standing best practice in quality control, in part because it's an efficient, at-a-glance way to spot trends and otherwise determine if a process is within statistical control. Well-defined control charts are one of the most effective ways to present statistical quality control data.

Calibration data typically falls into a normal distribution, often illustrated as the familiar bell curve (Figure 3).

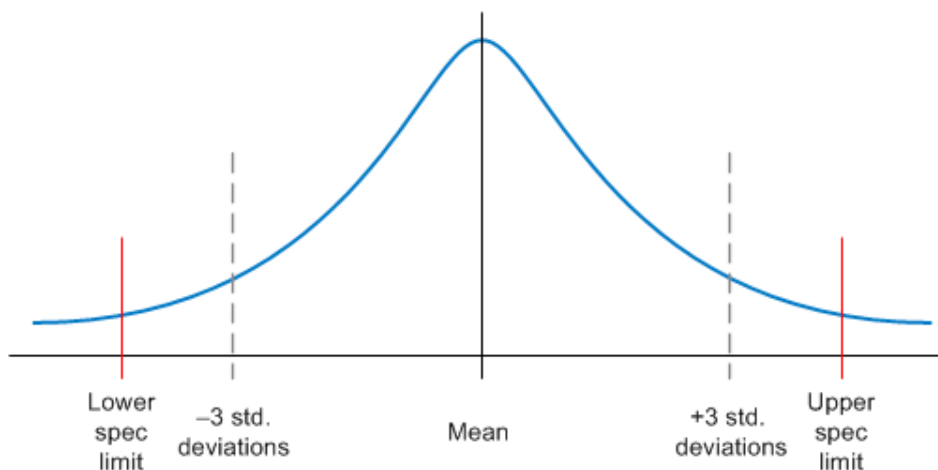


Figure 3. The normal distribution is the foundation of the control chart, which includes the mean, ± 3 standard deviations and specification limits.

When data has a normal distribution, control charts can be used to plot calibration data versus the expected mean (average), ± 3 standard deviations and the relevant specification limits as defined by the engineers who designed the product (Figure 4).

The data engine feeding our control charts is the CMMS. At the time of this writing, the system contained data from more than 170,000 completed calibration procedures and it accumulates new data every day.

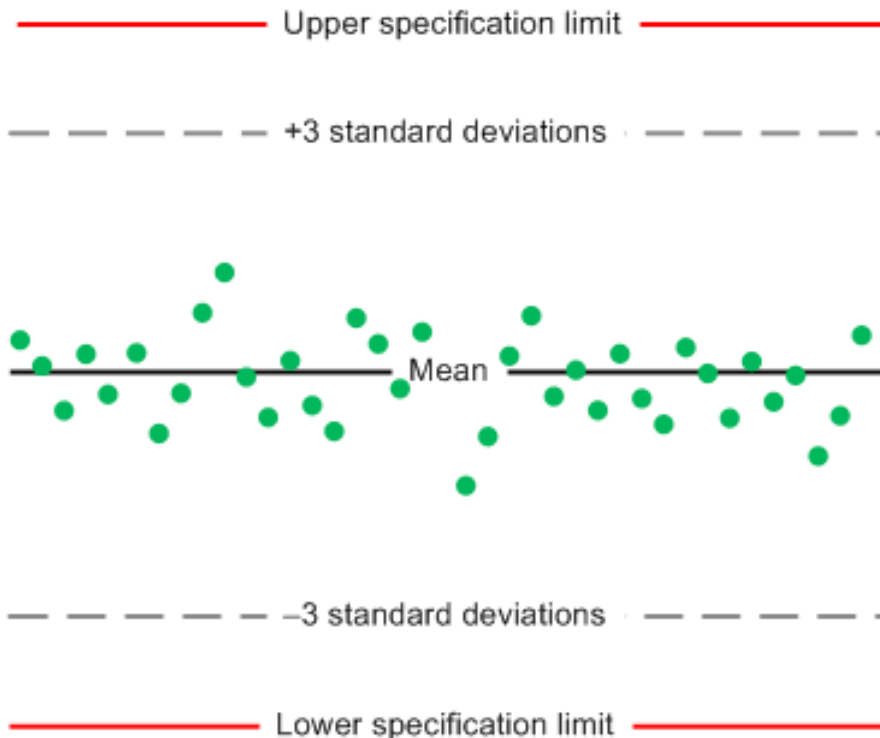
In the background, the system uses a commercial tool that can deal with huge datasets and quickly produce the required charts with all necessary annotation. The CMMS creates a separate control chart for every calibration measurement point and then applies two rules to highlight exceptions:

- Three data points in a row outside the standard-deviation lines
- Seven data points in a row on one side of the mean (average)

Many other rules are possible; however, these two have proven to be strong indicators of issues that warrant prompt investigation.

Once a day, the CMMS sends a summary email to the responsible quality control engineers. If any of the incoming data exceeds either of the two rules, the email includes alerts about potential problems. To facilitate analysis and follow up, the engineers can define and run custom analyses for any Keysight model that has data in the system.

One comment about graphical presentation: From an organizational perspective, showing the right picture at the right time to the right audience is a powerful way to help move people to action. Control charts are especially effective because they provide clear visual evidence that focuses the discussion, accelerates buy-in and fosters agreement around the need for corrective action.



Accepted quality control methods for measurements

ISO 17025 provides guidelines for the planning and reviewing of the monitoring process. In section 5.9.1, suggested methods include but are not limited to the following:

- Proficiency testing and inter-laboratory comparisons
- Regular use of certified reference materials
- Replicate calibrations using the same or different methods
- Correlation of results

Most organizations pursue either or both of the first two methods. This is reasonable because each is easy to implement; each is typically performed once or twice a year.

Keysight utilizes all of these methods but, through the CMMS, emphasizes ongoing correlation of results. Few organizations pursue the correlation approach because it requires access to large amounts of real calibration data. It also requires active monitoring for exceptions and pursuit of corrective action when potential issues arise.

Figure 4. By plotting an array of data samples (green dots) versus the mean, standard deviations and specification limits, a control chart provides an at-a-glance way to spot trends and otherwise determine if a process is within statistical control.

Taking action when exceptions arise

When a quality engineer receives an alert, they record it in the Exceptions Log and initiate the process shown in Figure 5. The alert includes information such as the submitting calibration site, the name of the test station and the name of the test.

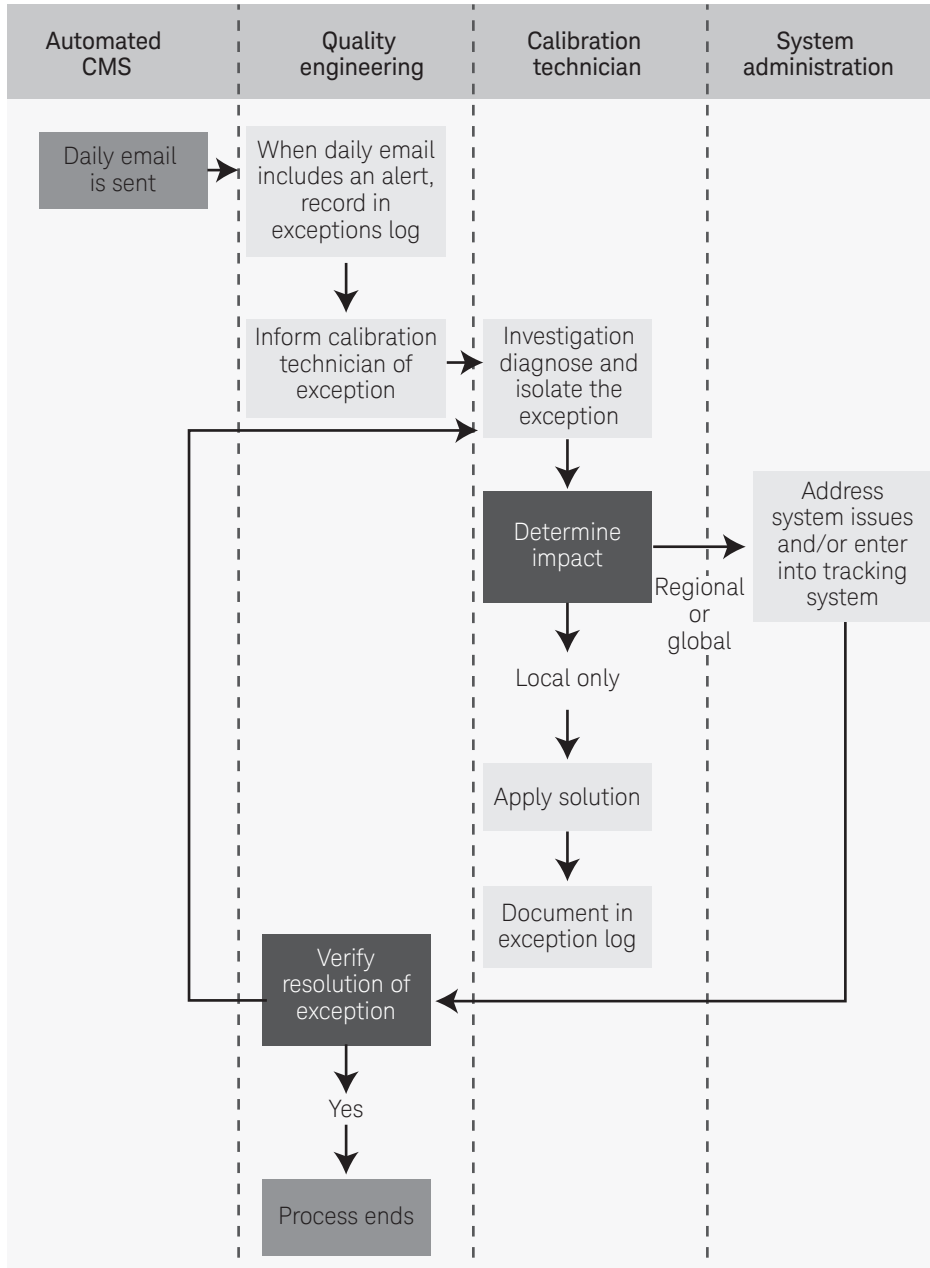


Figure 5. This flow chart illustrates a simplified version of the process used to investigate and resolve any exceptions flagged by the CMMS system.

Taking action when exceptions arise (continued)

Next, the engineer contacts the service technician who manages the test station that produced the exception. The technician initiates an investigation and the process of diagnosing and isolating the exception often starts with a review of four key topics:

- Software: A version change may affect how a point is measured and thereby cause an exception.
- Measured data: Because exceptions are indicated as deviations from normalized data, reviewing the control chart helps pinpoint the actual issue.
- Calibration standards: If used, alternate standards may have different measurement uncertainties or cause atypical results, either of which can cause an exception.
- Other stations: Looking at different stations within one site or across stations at multiple sites can provide valuable clues that help narrow the range of possible causes.

Diagnosis and isolation provide the information needed to determine the impact of the exception, which may be local, regional or worldwide. Local issues may be caused by problems related to cables, cable routing, connectors, calibration standards, calibration accessories and cal-factor files. Widespread issues that affect more than one site may include problems with calibration software, recently updated items calibration standards or accessories. Issues that span multiple sites may point to a specific instrument model used in various test systems, or may indicate a problem affecting multiple units of the model being calibrated.

Once a solution has been implemented, it is documented and subsequent data is checked to verify resolution of the exception. All relevant notes are added to the Exception Log to assist in the resolution of future occurrences of the same issue.

One key point is worth noting: beginning with receipt of the initial email alert and ending with a successful resolution, most exceptions are resolved in less than 24 hours. This is a testament to the power of visual information and to the skill of the calibration technicians in our service centers.

Moving from “Alert” to “Success Story” – Quickly

In the years since the CMMS was first launched, it has generated a small number of alerts—and all were successfully resolved in less than a day. The three examples described here highlight the benefits that come from the interaction of process, tools and people within our organization.

Looking across multiple service centers

The daily email from the CMMS indicated data exceptions in calibration results from three different service locations: Loveland, Colo.; Roseville, Calif.; and Singapore. All were for the Keysight 3458A digital multimeter—and all were triggered by a single data point among the 101 parameters measured during each 3458A calibration.

As part of the investigation, the quality control engineer reviewed data for tests performed in Frankfurt, Germany, and London, England. The problem was not occurring in either of those locations (Figure 6).

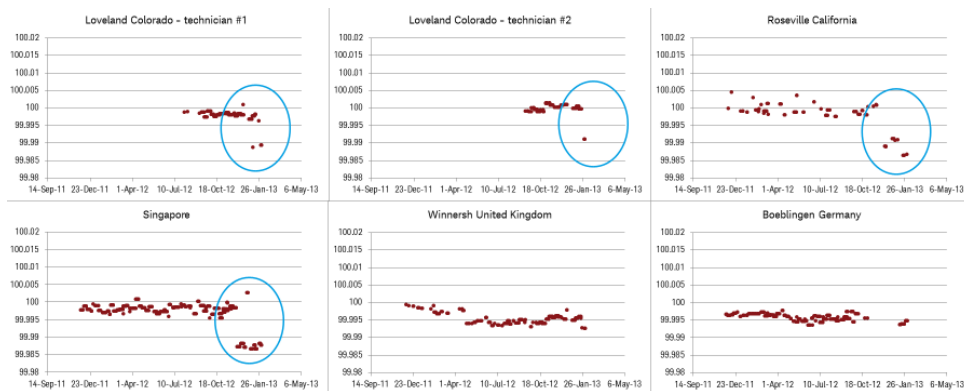


Figure 6. Data from four test stations in three locations generated similar exceptions; data from stations in two additional locations did not show the same issue. The CMMS let the quality team drill down and view the situation on a single screen.

Focusing on Loveland, Roseville and Singapore, local technicians confirmed that the “gold standard” 3458A units used in the test systems at each site had recently been calibrated at the standards lab in Loveland. Although the units used in Frankfurt and London had been calibrated on the same schedule, the work had been done in London.

Back in Loveland, further investigation revealed a typographical error in the correction factor used for the voltage divider in the calibration system. The data offset caused by the typo matched the differences in measurement data from all three sites. After updating the correction factor and rerunning the tests, all three sites reported data that was within the expected test limits.

Because the rules in the CMMS triggered an alert, the issue was quickly corrected. This is especially important for a high-precision instrument such as the 3458A: its accuracy and high-speed measurements have made it a popular choice for use in calibration labs and automated test systems.

Focusing on one test station

Data from our service center in Richardson, Texas, revealed an upward trend in a specific test station. In all cases, the data was related to a specific measurement result and occurred for three units of one model, the E5515C wireless communications test set. Although the measured values for all three units were within the instrument specifications, the trend was outside the historical limits of the measurement (Figure 7).

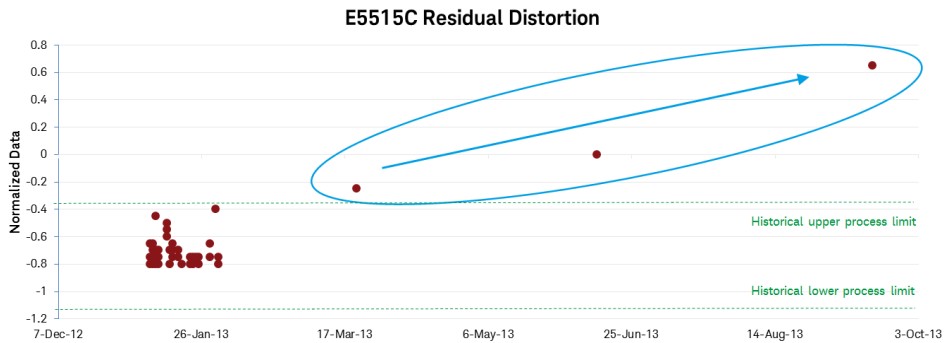


Figure 7. An upward trend in measured data from one test station triggered an exception that was investigated and resolved before it affected the quality of calibration results.

In this case, the investigation isolated the problem to one instrument in the test system: the 8903B audio analyzer, which is the main measuring device used to check residual distortion in the E5515C. Troubleshooting the 8903B pinpointed a connector that had a poor ground connection to the front panel. Even though this was causing intermittent errors in measurement readings, the instrument had not drifted out of spec.

After the local technician repaired the connector, the responsible quality engineer reviewed other results to determine if the problem had affected any other measurements or calibrations: it had not. The 8903B itself was repaired, recalibrated and returned to service, and then all three E5515C test sets were recalibrated and returned to their respective owners.

Because the service site is one of our relatively smaller operations, it handles a highly varied mix of products but deals with a relatively low volume of calibration work on some models. Even so, monitoring with the CMMS was able to detect a problem before it could cause out-of-specification readings for any of our local customers.

Zooming in on a single test

Keysight ENA Series network analyzers are widely used for manual and automated go/no-go testing of electronic components and devices. Any excess noise in a measurement trace can cause a test to exceed the user-defined test limits and generate a “fail” result. If noise is being generated inside the instrument, false failures can lead to unnecessary rework or disposal of otherwise good products.

When the daily CMMS email included an alert for the trace noise test at a single location, the responsible quality control engineer took note. Subsequent investigation showed that three successive data points had jumped outside the historic process limits for the test (Figure 8). While all three points were within the instrument specifications, the change was clearly an anomaly.

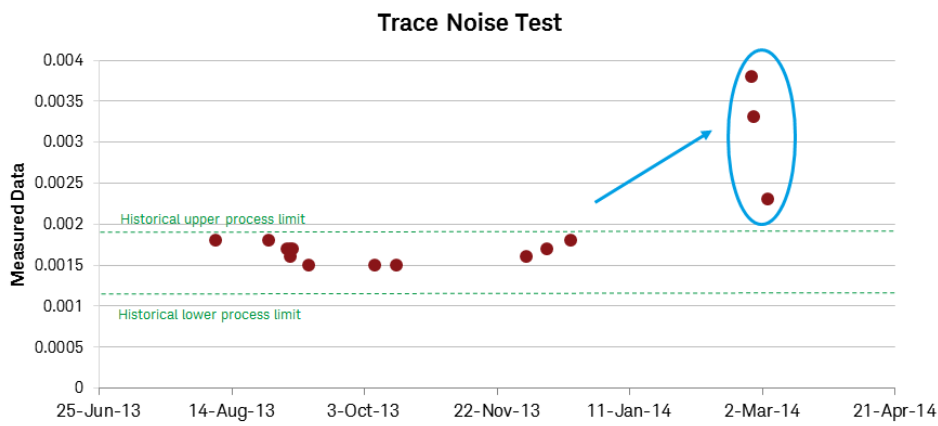


Figure 8. At the far right, three successive out-of-limits data points from the trace noise test triggered an alert—and the dates of the exceptions helped the calibration team isolate the problem.

Because trace-noise tests themselves are highly susceptible to noise, the investigation looked at several possible sources. Initially, the quality control engineer believed the electronic test equipment in the calibration system was the prime suspect.

When the issue was brought to the attention of the technicians in Roseville, Calif., they immediately zeroed in on the dates of the anomalies. This helped pinpoint the root cause: during that time, the team had been reorganizing its cubicle area to improve workflow and efficiency. In addition, the floors had been resurfaced with a special coating to reduce the risk of electrostatic discharge.

While this work was in progress, the system in question had been moved from one area of the calibration bay to another, and it had been plugged into a different electrical outlet. As a possible solution, the team moved the system to another area, plugged it into an AC outlet on a different circuit and reran the tests: the issue disappeared and the trace noise tests were back within limits.

Once again, early detection through CMMS monitoring ensured that our customers were using instruments that they could trust to provide reliable results and thereby avoid false failures and unnecessary rework or disposal.

Conclusion

Today, many organizations develop reference designs in one location and manufacture them in another. In these cases, it's essential to have confidence in the quality of local calibration services. That confidence can save time: when engineers in R&D or manufacturing are troubleshooting issues with a design or test system, they can quickly rule out instrument measurement errors and instead focus on finding the root cause of the problem. Another benefit: your teams will spend less time assessing "false pass" results in design validation or on the production line.

At Keysight, ongoing real-time monitoring of our calibration processes quickly identifies any anomalies, usually before they cause an incorrect pass/fail decision. The result: No matter where we do the testing, when we report that your instrument passes all warranted specs, it really does.

To learn more about how we deliver consistently excellent calibration results, please visit www.keysight.com/find/calibration or contact your local Keysight representative (see www.keysight.com/find/assist).

Related Information

- Application Note: Getting the Calibration You Need, publication 5990-9720EN
- Application Note: Setting and Adjusting Instrument Calibration Intervals, publication 5991-1220EN
- Brochure: Managing Your Equipment's Total Cost of Ownership: What's Your Plan?, publication 5990-9133EN
- Online videos: A series of seven videos highlight how calibration from Keysight Services meets technical and business goals; visit www.youtube.com/KeysightCal-Repair
- Standard: ANSI/NCSL Z540.3, www.ncsli.org
- Standard: ISO/IEC 17025, www.iso.org

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