Keysight Technologies
The Six Axes of Calibration

Application Note

Abstract

Selecting a supplier of calibration services may seem fairly straightforward – it would seem that a calibration is a calibration and, as long as the supplier has the usual badges of office (ISO9000 registration, ISO17025 accreditation etc.), the service ought to be reasonably similar whichever service or supplier you choose. However, this is not the case and the lack of regulation on calibration allows for a wide variance in the deliverables and value of calibration.

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights

Introduction

To help demonstrate these variances and help lead the non-technical buyer to appreciate the importance of each, I have split them into six different axes, each of which can have an impact on the usefulness of the calibration or the direct or indirect cost to the organization buying the service. This document discusses each of these axes, which are:

1. Extent of testing (How many parameters? How many test points per parameter?)
2. Information provided (What data is provided? Pre and post adjustment data?)
3. Measurement uncertainty (How good is the testing?)
4. Periodicity (How often does it need calibrating? Can this vary?)
5. Speed (How long are you without the instrument?)
6. Packages (What financial and service packages are there? What is included in the service?)

Axis 1. Extent of Testing

Clearly the more thoroughly an instrument is tested, the greater the confidence in the measurements made by the instrument. Generally the manufacturer will suggest the parameters that should be tested and the number of points at which each parameter should be checked. It is not uncommon however for a supplier at the cheap end of the scale to omit many of these tests. Since there is generally no technical body that stipulates the extent of testing necessary to perform a legitimate calibration in our industry, this practice is not breaking any rules or guidelines.

The tests are omitted for three key reasons:

1. The supplier does not have the equipment to perform the test
2. The tests are complex and take a long time to perform, or require special skills
3. The price agreed does not allow for all tests to be performed

Often this means that important parts of the instrument are inadequately tested and the equipment may unwittingly be making erroneous measurements as a result.

This can result in one of two detrimental situations arising when you test your products with the equipment:

1. Good products can appear to fail the test, resulting in expensive rework and an increase in NFF (no fault found) occurrences in the rework department (a key measure in manufacturing circles)
2. Bad products can appear to pass the test, resulting in increased warranty returns and repair costs, along with a damaged reputation.

Example

One company was sending a Scalar Analyzer Detector Head to a reputable company for calibration. The company's procedure was to test the device at three spot frequencies at the low, mid and high end of its range. The device was reported to be performing to specification and the calibration certificate issued. The company was experiencing strange measurements using this particular device and sent it to Keysight Technologies, Inc. for a second opinion.

The Keysight procedure is to use a swept frequency across the device's entire range. This testing showed clearly that the head had a problem at a frequency not tested by the first supplier. If it had been calibrated using the swept method originally, the customer would have saved a great deal of time and money.

An analogy might be a sailing ship's look-out up in the crow's nest, looking through his telescope at exactly due East, then due North, and then due West, and reporting "I see no ships".

Exception

It is important to stress that less testing is not necessarily a bad thing when properly controlled. For equipment used in a specific application in which only well defined aspects of the instrument's capability are used, it is certainly acceptable and may well be advantageous to focus the calibration on those particular functions or ranges. This might be especially true if more extensive testing is made in those areas than would have been performed in the normal, full calibration.

However, this approach would be unsuitable for equipment used in multiple applications, or in a general equipment pool.

Axis 2. Information Provided

The information provided by the calibration supplier about the testing performed during calibration forms the basis for many decisions and so it is important that you get the information you need and also that the information is accurate.

Consequently, it is desirable for the full data showing the equipment's performance at each test point to be supplied with the calibration. This information is evidence of the extent of testing and can be used to make objective comparisons between suppliers.

But the information is valuable in more important ways. When an instrument is found by the calibration supplier to be outside of its specified tolerance (OOT – out of tolerance) it means that you have possibly been making bad measurements with that equipment for some time. To assess whether this will have compromised the validity of your testing you will need to know where the instrument was OOT and by how much. You are then in a position to decide whether you need to take corrective action such as re-testing or recalling your products. Without this information you would either be unaware that the testing could have been erroneous, or if the calibration simply reported that the equipment was OOT but provided no supporting data, you would not be able to make an informed decision.

The really useful data is a full set of performance test information taken exactly as the equipment performed when received by the calibration supplier. Any attempts to adjust the equipment during this testing will destroy the integrity of tests later in the procedure. A second set of data taken after adjustments confirms that the instrument is now within tolerance, giving confidence in the future testing made with the equipment.

Another key piece of information is 'measurement uncertainty'.

In its simplest form this is a statement that the accuracy of equipment used to test your instrument is at least a factor of four better than the equipment being calibrated. (Four is usually considered the minimum test accuracy ratio, TAR, useful for calibration).

More detailed uncertainty information comes in the form of a summary table listing the parameters and the associated uncertainties. The figures can either be expressed in relative (e.g. ±0.5%) or absolute terms in the units of measurement (e.g. ±0.2 mV).

The most detailed uncertainty information is provided with the measurement data itself, appearing alongside each reported value and, ideally, with the measured value, specification and uncertainty all expressed in the same terms.

Axis 3. Measurement Uncertainty

Measurement uncertainty is a way to express how good the testing is – the accuracy of the measurements made by the calibration supplier. This is an axis that is invisible unless the measurement uncertainty is known, but one that can have a significant impact on whether or not the calibration is actually useful.

The uncertainty gives a clear indication as to whether the supplier has the technical capability to make the measurements. Uncertainties may be self-assessed or accredited. Accredited uncertainties are more valuable as they have been independently assessed by a recognized accrediting body such as Britain's UKAS, Japan's JCSS, Germany's DKD, the United States' A2LA, etc.

It is possible to review the best measurement uncertainty figures for accredited calibration laboratories as this information is in the public domain, often made available via the organization's website. This gives a valuable insight into the technical competence of the laboratory and allows comparison of ability to make certain measurements. It is also possible to determine that a lab may not really have the credentials to undertake some calibrations.

On the subject of accreditation, it is not uncommon for a lab to gain such recognition for a few specific tests and then accept calibration work for equipment requiring competence outside of their scope of accreditation. Gaining accreditation for just one measurement allows them to display a Certificate of Accreditation and advertise that they are an accredited lab, although their capability would obviously be inadequate for most instruments.

Illustration

An assessment of the Accreditation Schedule or Scope of calibration suppliers in Britain for two fairly fundamental measurements showed interesting observations.

The selected measurements were 10 MHz frequency, and 1-volt dc. The information was from the UKAS website.

In the case of 10 MHz, the spread of accredited uncertainties was large. The best being one part in 10^{12}, the worst being three parts in 10^{6}. So when measuring 10 MHz, the best could boast an uncertainty of ±0.00001 Hz and the worst ±30 Hz. Since the specification for most crystal oscillators is far narrower than ±30 Hz, it is clear that a calibration performed by this company for a crystal oscillator or any instrument that measured frequency to any degree of accuracy would be meaningless.

In the case of 1-volt dc, the spread was less large but still significant; the best being four parts in 10^{7}, the worst being two parts in 10^{5}. Many digital multimeters resolve to 6½ digits. This means it should be able to display a measured 1-volt dc as 1.000000 volts (i.e. to one microvolt). An uncertainty of 4 parts in 10^{7} would measure accurately to 0.4 microvolts – sufficiently accurate for the task. An uncertainty of two parts in 10^{5} would only measure accurately to 20 microvolts. In relation to its accuracy the last digit of the multimeter would be entirely untrustworthy.

One thing to remember is that the published “best measurement capability” may not be the same as the actual uncertainty assigned to the calibration of a particular product. Comparing example certificates/reports for a few typical models may give a different perspective.

Axis 4. Calibration Periodicity

Calibration periodicity is about how often an instrument is calibrated. Usually the manufacturer will recommend a calibration interval for each instrument type. This is often a period of one or two years. This is based on mean drift rates for the various components. Great emphasis is placed during development on designs that demonstrate minimal drift, however drift is a factor that can't be eliminated altogether, which is why calibration is necessary at all.

In order to assess whether the manufacturer's recommended periodicity can be overridden, two pieces of information are needed.

1. The calibration history for the particular instrument
2. The application in which the instrument is used

The first point refers directly to the Information discussion (Axis 2). One generally accepted algorithm is that if on three consecutive calibrations the instrument has remained within specification, the period may reasonably be increased. Similarly, if it requires adjustment on two consecutive calibrations, it should be reduced. This sequence is ongoing.

The second point is about risk. If the measurements made by the instrument are critical, it may be prudent to reduce the cal interval to reduce the risk of bad measurements. Alternatively the application may be such that if bad measurements are made it would not matter greatly, and so the interval could reasonably be extended.

Where both risk and history are considered, an effective periodicity management solution can be maintained such that the risk of critical measurements being bad is minimized, and costs are also controlled.

Axis 5. Speed

Calibration generally means removing your instrument from doing the job you bought it to do and sending it somewhere to be calibrated. This usually takes the instrument off-line for a week, often more. This means that you would either stop the work you were doing with the instrument or, in a mission-critical environment, buy or rent a spare one while yours is away.

Knowing that the equipment will be away for two weeks means that you can plan for that event, arranging for use of the spare or rental replacement accordingly. But if the promised two weeks becomes three or more, the costs escalate and the control is lost. It is therefore very desirable to ensure that the delivery turnaround promises made by the calibration supplier are short, but equally importantly, can be reliably met.

Companies that can provide the service on your site are able to reduce the turn-around times to just a few hours – in fact just the time it takes to do the calibration. This may add to the service price but the additional cost can be insignificant in comparison to the savings gained through the reduction of spare instrument purchase and rental.

A word of warning here. An on-site delivery may seem like an ideal solution but it is still necessary to be sure that the technical aspects of the calibration meet your needs. It is common for companies offering calibration on-site to deliver a subset of testing, perhaps also with larger measurement uncertainties. This situation may not be apparent until they arrive at your premises with a limited range of test equipment and with reduced capability.

Keysight delivers the same standard and quality of calibration whether it's undertaken at its service centre or at the customer's site.

Axis 6. Packages

When looking at calibration costs it is common for the fundamental service price to be the main consideration. But by considering service packages it is possible to reduce the less visible costs such as those associated with raising purchase orders, paying invoices, etc., as well as getting a reduced service price by taking out a service agreement of some description.

Keysight offers a wide range of packages that are aimed at reducing both the direct and indirect costs of purchasing calibration. Many of these can spread the cost of service evenly over a year, removing peaks and troughs in expenditure.

There are also other considerations in this area. Consider shipping costs and minor repairs. If these are included in your package the savings can be significant. Alternatively the extra costs can be a surprise.

Example

One company quoted US$15 per calibration of *AVO-Meters* (general purpose analogue multimeter). It was only after some time that the customer spotted that the price charged for his *AVO-Meter* calibration was always US$40.

When this was queried it transpired that with *AVO-Meter* calibration it is appropriate to replace the batteries. Replacement of batteries constituted a repair with this supplier, and there was an additional cost of US$25 for a repair.

This example may be a small amount, but this can add up to a large extra cost over 12 months.

Conclusions

The six axes each have an impact on the cost and quality of the calibration you buy. I hope that this helps you to make an informed decision rather than one based entirely on the Axis 7 – price.

As is usually the case in any purchase decision, you get what you pay for. Understanding what these things are and what they might mean to your company should make that decision more of a science and less of an art.

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