INSTRUMENTATION CORNER

Calibrating instrumentation

Verification of measurements (except those of environmental noise) – when do you need more than a finger in the air?

By Mark Dowie and Tony Higgins

Calibration is defined as *'The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measurement system, and the corresponding values of a quantity realized by a reference standard.'* ISO 10012.1 (VIM, 6.13).

For many applications the calibration requirements are clear. BS 4142:2014, for example, dictates the use of a sound level meter that meets BS EN 61672-1 and a calibrator that meets BS EN 60942, Class 1. These must be verified to the relevant part of the standard.

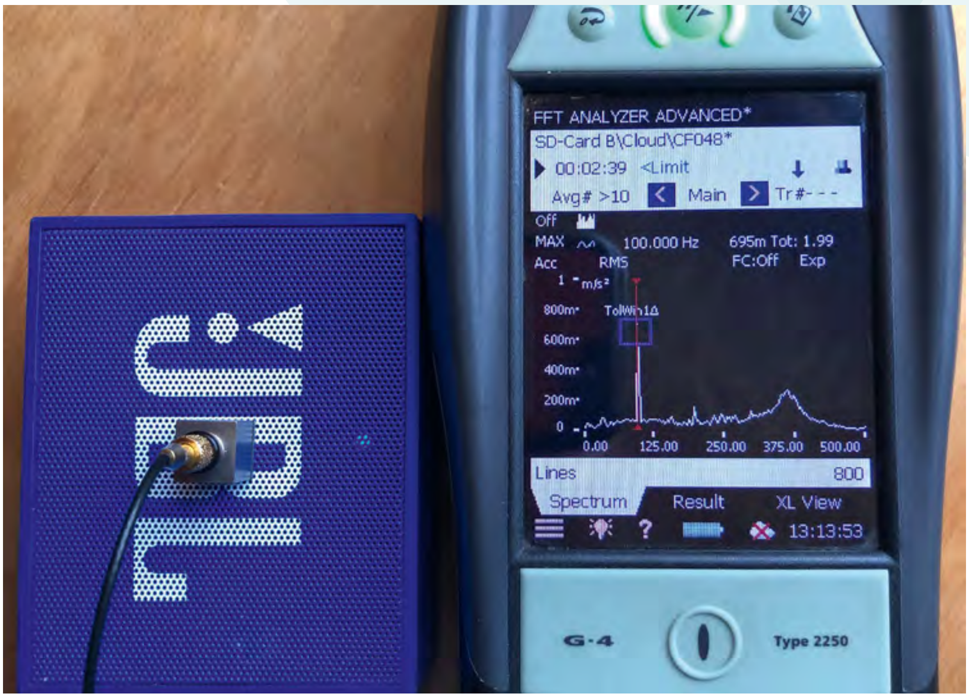
The recommended verification periods come from the UKAS LAB23 document which suggests that sound calibrators are calibrated at intervals not exceeding one year and the conformity of the sound level meter to BS EN 61672-1 is verified at intervals not exceeding two years. These should be accredited calibrations performed in a laboratory that is accredited to ISO17025 by the national accreditation organisation, UKAS in the UK, DANAK in Denmark, COFRAC in France, etc. This is the standard practice for environment noise and sound insulation measurements in the UK.

Practical application

As an example, let us assume that you have no need to work to a standard with clearly defined calibration requirements, then what should you do to ensure there is value and repeatability in your measurements? Any form of measurement implies compliance against a particular specification or standard, so the first step is to ask yourself "why are we making these measurements?"

If, for example, you have designed a product which makes a sound or vibrates, and you want to qualify or quantify that sound or vibration in order to assess the impact of design changes, then you may not need accredited calibration. As long as you have one measurement system and all of your results are used for comparison of design changes, then consistency and repeatability are more important than absolute levels.

But even in this case, some form of reference should be used to check the measurement system before any set of measurements are taken to ensure that the data is representative, and will provide you with useable results. If budgets are limited, then something as simple as using a tone generator app on a smartphone with a Bluetooth speaker can provide a useful quick check. While this will do little to verify the amplitude accuracy, generating a single frequency then checking your analyser can clearly measure that tone; provides some reassurance that your equipment is working. In effect, you qualify the operation of the device for one parameter, and assume that the others are working in line with the original manufacturer's specification. Please be aware that this is a BIG assumption and in no way guarantees the performance of the measurement system but offers a low-cost method to eliminate issues such as broken cables.



Below: Figure 1: Accelerometer on Bluetooth speaker measuring 100Hz Tone

A more reliable option is to have an acoustic or vibration calibrator (often referred to as field calibration). These hand-held calibrators will produce a known level at a known frequency.

Most acoustic calibrators produce a tone at 1kHz of 94 dB. The A, C and Z frequency weightings all have the same value at 1kHz, and 94 dB is derived from 1 Pascal.

Vibration calibrators typically use 159.2 Hz at a level of 10 m/s^2. These values are chosen as they correspond with 10 mm/s velocity and 10 µm displacement. Using this form of calibrator now gives you an amplitude and frequency reference.

There are also calibrators that will work across a range of frequencies and amplitudes, these are less commonly used but can be a very quick way to perform a more comprehensive system verification. The net result is that you now have a device that has a known quantifiable level and an ability to qualify data. Deviations from the calibration level will provide you with part of the uncertainty budget for your measurements and this can be factored into your assessment of the sound or vibration.

The calibrators conform to the relevant specification standard and are tested in a laboratory that has been accredited for that specific method. This laboratory will use a calibration system that includes a reference (microphone or accelerometer) calibrated to primary standards. Primary calibrations are typically performed by National Metrology Institutes (NMIs) such as PTB in Germany, DPLA in Denmark and LNE in France, who are responsible for the national standards. The national standard should have the lowest measurement uncertainty in the country.

Above:
Figure 2: Hand-held calibrators for sound and vibration. It is common practice to have calibrators calibrated to ensure that they are performing to the standard they were design to conform to (e.g. EN/IEC 60942 for acoustic calibrators)

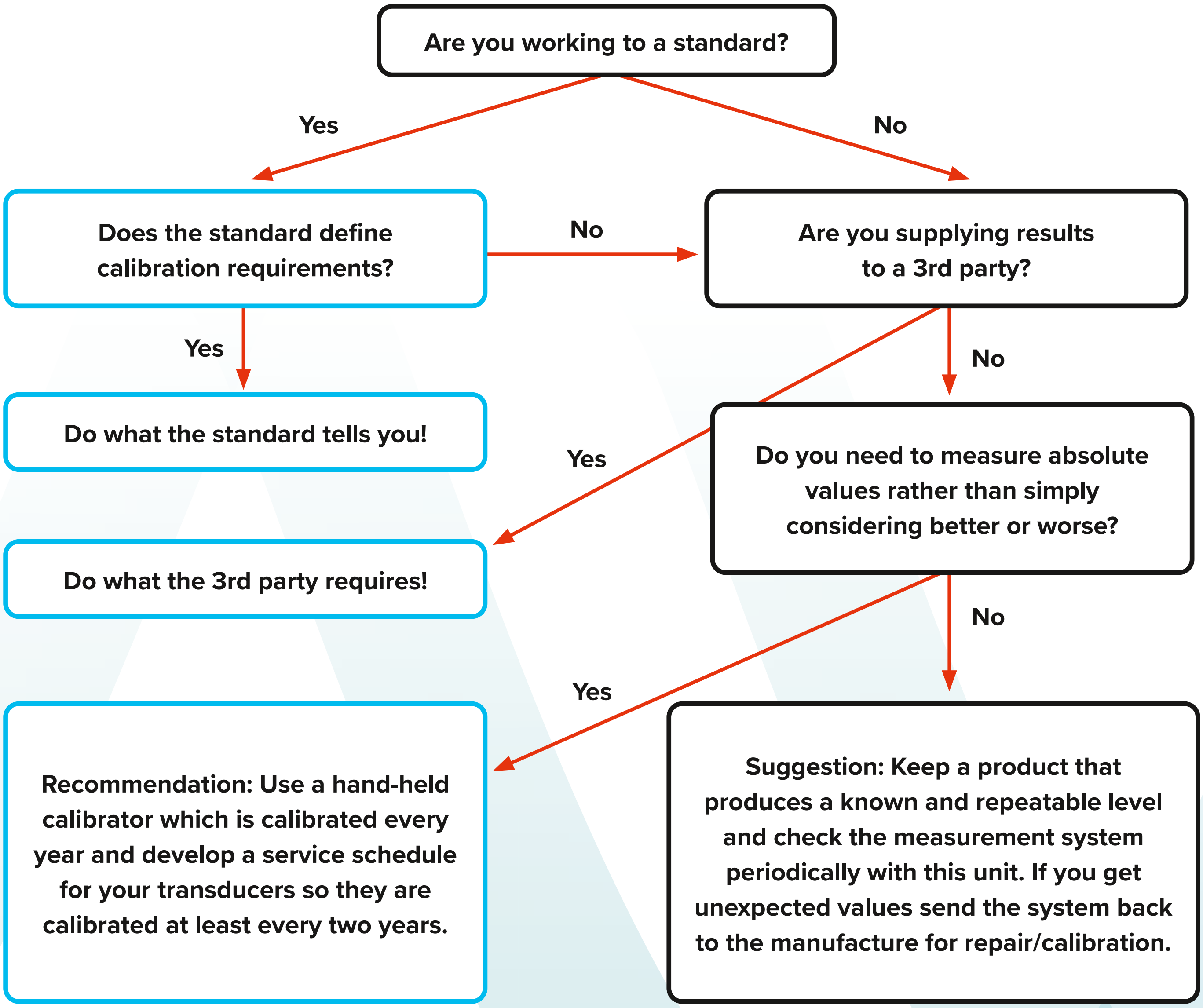
Traceability

It is often desirable to have some traceability to your measurement, i.e. a reference that connects your measurements back to the primary standard. Having a calibrator with an accredited calibration certificate from within the last 12 months is an effective and low-cost way to achieve this.

So why is all this actually important? The simple answer is that it may not be for some users when they take measurements, a fully calibrated system may be less important than the variation in comparative levels. But consider this, even if no formal traceable calibration is required, whenever we take a measurement and use it comparatively, there is always a desire to use the measured output for comparison to other historic measurements.

Returning to our product example; if you are supplying your product to a third party that intends to integrate your product into their product, e.g. a motorised wing mirror on to a car, then they may want some detail about the noise and/or vibration levels. Your customer may dictate which measurements need to be supplied with a part and that your measurement equipment must be calibrated – although they may not specify how the measurement system is calibrated. The chart below provides a simple schematic to help decision making as to whether verification or calibration is necessary for your requirements. P48

Figure 3. Calibration decisions tree



Inevitably, there will be other factors influencing the desire or need to formally verify or calibrate instrumentation, where it is necessary the user of equipment defines the periodic re-calibration intervals but a number of factors will to be taken into account include:

- legal requirements;
- contractual requirements;
- Type of equipment
- usage (R&D, PRODUCTION, LEGAL measurements);
- how frequently the instrument is used;
- number of engineers using the same equipment;
- environment in which it is used;
- age (after 10 years wear and tear may start to evolve); and
- experience with stability of previous calibrations.

Above:
Figure 3: Calibration decisions tree

The verification and calibration of equipment provides comfort that measured data is accurate, that instrumentation uncertainty is minimised and that the results can be relied upon. The reason for carrying out monitoring in the first place is to verify compliance, in most cases this is to ensure demonstration of compliance with product specifications. P50

Paragraph 1.7.4.2 of the EU Machinery Directive 2006/42/EC clearly states:

1.7.4.2. Contents of the instructions (u) the following information on airborne noise emissions:

- the A-weighted emission sound pressure level at workstations, where this exceeds 70 dB(A); where this level does not exceed 70 dB(A), this fact must be indicated;
- the peak C-weighted instantaneous sound pressure value at workstations, where this exceeds 63 Pa (130 dB in relation to 20 μPa);
- the A-weighted sound power level emitted by the machinery, where the A-weighted emission sound pressure level at workstations exceeds 80 dB(A).

Such data can only be verified using fully calibrated equipment.

Calibration of complex measurement systems

While there are accredited calibration methods for microphones, accelerometers and sound level meters, these may not be applicable for more complex measurement system such as multi-channel systems incorporating microphones and accelerometers. Aspects of this may change in the future due to the IEC/TC29 international standardisation work that is ongoing to produce standards for 'Modular instrumentation for acoustic measurement'. However, in the meantime, calibration laboratories can offer a traceable calibration service if you would like your measurement chain verified and no recognised standard exists for that particular set-up. The calibration lab can devise their own method to measure the accuracy of the system, however, this still needs to be done with calibration equipment that has accredited or primary calibration – therefore providing traceability back to the national standards.

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