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APPLICATION NOTE 38

Understanding Power Calibration – 10 Questions and Answers

Given the increased complexity of modern power conversion techniques combined with the need for improved product efficiency, power electronics engineers require greater certainty of measurement instrument accuracy than has been necessary in the past. This is not because engineers today are more critical than before, it is the inevitable result of power conversion techniques that involve a wider range of frequency components while achieving levels of efficiency not expected or achieved in older designs. As we move closer to the optimum efficiency of electronic devices, it follows that instruments being used to quantify small but important improvements in efficiency will require increased measurement accuracy.

In response to this growing need, many instrument suppliers have become engaged in a specification race that often confuses rather than assists potential users and it can become almost impossible to derive a meaningful specification or make a true comparison of different measurement instruments.

An increasingly popular approach is to follow the adage that in measurement, “you should trust what is proven and not what is claimed”. There is much to be said for such an approach since evidence is much more compelling than a marketing claim but without an understanding of appropriate techniques and clarity of data, there remains the potential just to move from the problem of a confusing product specification to a confusing definition of meaningful calibration.

By providing answers to 10 common questions, this document aims to dispel some misunderstandings related to calibration and explain where calibration does or does not bring value to an engineer who seeks to establish the most appropriate solution to a measurement need.

1. Does calibration improve an instrument accuracy?

The simple answer is no.

In the field of metrology, calibration is a process of comparing the reading of a measurement device with that of a known source or measurement ‘standard’. The traceability of the standard and the processes used in calibration will influence the level of calibration being offered but any calibration is simply a comparison with another device of known accuracy.

It may be that a calibration laboratory will also offer an adjustment or optimisation service (which as a matter of interest, N4L do as standard) but this is distinct from the calibration process and unless specifically defined, you should assume that no change to instrument accuracy is achieved by calibration, you simply confirm what the existing accuracy is.

2. Are all calibrations equal?

Again no.

The standard being used combined with the laboratory accreditation and associated processes will dictate the level of calibration that a laboratory or service provider can offer.

A ‘standard’ is a known and traceable point of reference and higher levels of calibration combine the uncertainty of their standard(s) with quantifiable uncertainties of the calibration system and proven repeatability of the product being calibrated. Using statistical analysis of this data, a total ‘uncertainty’ with a defined ‘confidence level’ over a defined measurement band is derived.

At the highest level of calibration, a laboratory will be ISO17025 accredited and this accreditation is managed by an accreditation body which in the UK is UKAS, the ‘United Kingdom Accreditation Service’.

3. Does a calibration need to be ISO17025 accredited to be of value?

This depends on the specific purpose of calibration.

Where a user needs only to verify that a product remains within a tolerance that is easily proven by an in-house reference of sufficient known accuracy and there is no requirement for calibration traceability beyond a comparison with this reference, then it would not be necessary to seek higher levels of calibration.

Where documented traceability is required, calibration against an ISO17025 certified calibrator can be used to achieve a ‘traceable’ calibration. An ISO17025 certified calibrator is sometimes referred to as a ‘secondary standard’ and this becomes a traceable reference because it is calibrated against a ‘primary standard’. The equipment used and nominal accuracy of the results will satisfy most applications where there is no requirement for accredited certification.

Where the highest level of calibration is required and certification must be accredited, for example with measurement products that will themselves be used as a traceable standard, that measurement product would need to be calibrated and certified by an ISO17025 ‘accredited’ laboratory.

4. How do I know that an ISO17025 accredited laboratory is suitable for a specific need?

When an accreditation body issues a laboratory with ISO17025 accreditation, this is always done with reference to a defined ‘Schedule of Accreditation’, sometimes referred to as the ‘scope of accreditation’ or simply, the ‘schedule’. The schedule of any laboratory may change over time and the prevailing schedule for any ISO17025 accredited laboratory is defined by the issuing accreditation body. For example, the latest Schedule of Accreditation for the N4L Laboratory is always published on the UKAS website.

It follows that the suitability of a laboratory for any specific calibration should be based upon the specific quantities defined in its Schedule of Accreditation, not simply the fact that a lab is ISO17025 accredited.

Having established some basic principles of calibration, we now focus on calibration questions specifically associated with the world of precision power analysis

5. Why are power measurement products commonly supplied without a calibration certificate covering the complete frequency range?

This is partly due to historic power applications where the frequency of interest was predominantly a 50/60Hz sine wave with phase shift between voltage and current and partly because, commercially available calibration systems did not and to this day still do not cover with sufficient accuracy, the frequency range over which modern power analyzers are required to operate.

6. Without complete calibration, how can a measurement instrument supplier support a claimed specification?

The term 'meeting a specification by design' is commonly used and is a viable process. There are many examples of products that rely on meeting a specification by design either because it is not practical to provide calibration on each and every product shipped or the specification has been sufficiently proven during the design validation stage to argue that calibration on every subsequent product is not necessary.

Unfortunately, there are many instances where a 'specification by design' argument is used to justify the absence of calibration without any evidence that the design has been verified at any stage in a meaningful or traceable way. This raises the justifiable question, "how do you know that your design meets the specification if it has never been proven in practice?"

7. Is it possible to calibrate a modern power analyzer over its complete frequency range?

Yes.

Based upon the principal mentioned earlier that "you should trust what is proven and not what is claimed", users might reasonably expect a measurement instrument to be calibrated, i.e. proven, over its complete operating frequency range. After all, if a user has paid for a wideband measurement instrument, we could imagine that there is an interest in proven accuracy over that frequency range. It would therefore appear normal to expect full range calibration to be a standard process for a precision measurement instrument but surprisingly, N4L are the only power analyzer manufacturer to do this.

The development of calibration systems that can adjust and traceably verify the accuracy of wideband power measurement instruments is not trivial but it is certainly possible if the associated manufacturer wishes to do it. With 12 automated systems that routinely calibrate all products shipped over their complete operating range, N4L prove that it can be done and a potential user of any precision measurement instrument should reasonably expect this.

8. Why is AC power calibration usually carried out only with a sine wave excitation signal?

Since the key to precision calibration is traceability and minimising uncertainty, AC calibration usually involves only one frequency component. This is particularly true where a calibrator is generating a reference signal because it is relatively easy to verify low distortion on a pure sine wave but almost impossible to achieve a similar level of confidence on a harmonically distorted signal.

9. Will sine wave calibration at high frequency assure power accuracy in a distorted waveform application?

No.

As most precision power calibration is based upon single frequency sine wave excitation as mentioned above, it is easy to imagine that by calibrating with a series of sine wave frequency points over a frequency range that includes harmonic components of interest, we could assume that the total power accuracy will be the sum of each proven frequency component. Unfortunately, this assumption is usually incorrect for two key reasons.

First, we cannot reliably assume that any adjustment to measurement accuracy proven at a single frequency calibration point will be equally true of a complex waveform harmonic of the same frequency and second, the multiple frequency components of a complex waveform can interact in a manner that is not equivalent to a single frequency calibration.

So, while there is merit in calibration across a wide range of frequencies to verify the integrity of measurements over a complete frequency range as we have discussed above, it would be wrong to state that the wideband power accuracy of a measurement instrument faced with highly distorted waveforms is reliably proven by such a process.

10. What is the best way to prove wideband power accuracy for non-sinusoidal applications?

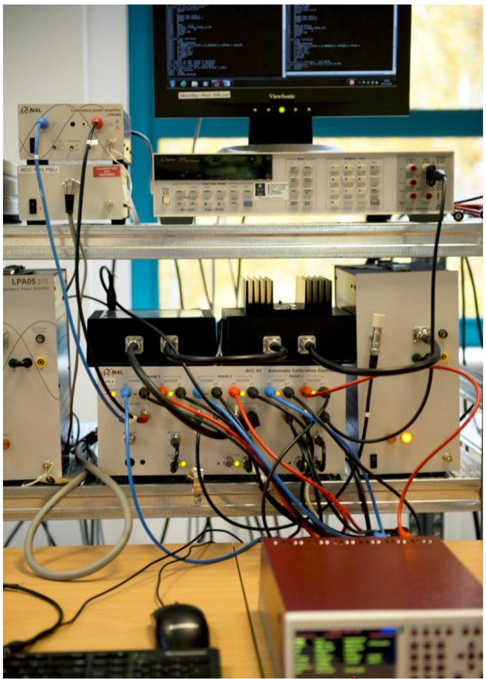
The main challenge to calibration in a non-sinusoidal power environment is to overcome a complex array of uncertainties associated with multiple frequency and phase components. The sum of all component uncertainties almost certainly results in a total uncertainty greater than the measurement instrument that is being calibrated.

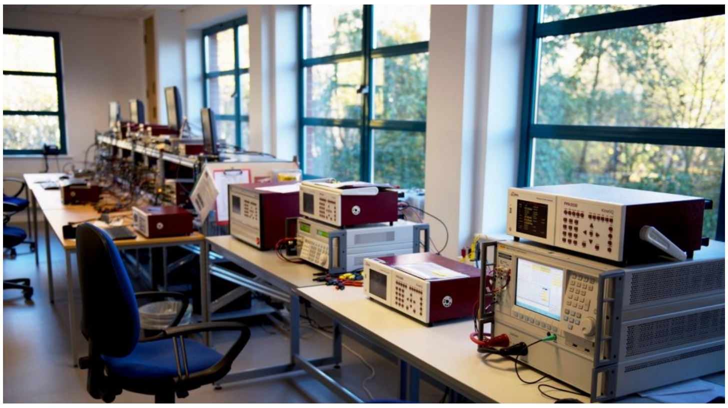
These problems are overcome by adopting a power measurement technique that has no dependency on either frequency or phase; Calorimetry.

Calorimetry is recognised in the world of metrology as the optimum reference for real power calibration because, in an electrical system generating no light, sound or vibration, real electrical watts will produce only one form of energy, heat.

Since temperature can be measured with exceptional precision, it follows that high accuracy fully traceable power calibration can be achieved with no dependency on frequency or phase. Furthermore, such is the independence of calorimetry to frequency components, power measurement is equally accurate on sine-wave or distorted waveforms within the defined frequency range, so calibration is no longer limited to sinusoidal signals.

(Should you be interested to learn more about the subject of calorimetry, more detail is provided in our Technical Note 003 “Closed Loop Calorimetry”)





N4L: 10mHz to 2MHz Sinewave Calibration

Wideband and ISO17025 Calibration

ISO17025 45Hz to 2MHz Calorimeter