Implementation of pattern evaluation and verification requirements

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1. Introduction

The proposal for a new sound level meter instrumentation standards formalise the requirements for the type approval and routine calibration. The new standard for sound level meters IEC61672 will have at least 3 parts

- Requirements to the instrumentation (e.g. construction, time constants, averaging possibilities, marking, instruction manual etc)
- Requirements to the type approval test
- Requirements to the periodic verification tests

In some countries the type approval tests have existed side by side with the standard single unit calibration / periodic verification tests for many years already.

The OIML has also had the setup for pattern evaluation and verification tests.

Example: Germany where you can get "Type approval under German law" (Innerstaatliche Bauartzulassung)

2. What's in it for Norsonic?

The quality of our products certainly benefits from this.

Test institutes (such as the PTB in Germany) run tests on specific combinations of microphones, preamplifiers and sound level meters and verify that they fulfil the DIN /IEC standards as *systems*. This restricts the approvals to apply to specific combinations of a certain (set of) microphone cartridge(s), a certain (set of) preamplifer(s) and a certain sound level meter to be used as type 1 or type 2 *systems*. This implies that any approved microphone cartridge cannot be combined with any approved sound measuring instrument – the approval is strictly on system level!

The test institutes run other types of measurements and tests than we normally would do being a manufacturer. This means more measurements and improved quality assurance.

The type-approving laboratory influences the specifications on the instruments so they are more comparative to the specifications from other manufacturers, and vice versa.

This serves to keep non-serious manufacturers off the market.

3. Manufacturers must be prepared to allocate resources, time and money

As a manufacturer we must provide up to 5 units for the test. They will be returned after the test period, but since they now are no longer unused they become second hand instruments, which we cannot sell at full price. Very often they end up as "eunuchs" used for internal testing and demonstration purposes. When expensive instrument types are exposed to this type approval testing we are talking about a considerable amount of money.

Type approval tests are time consuming, extending the development time considerably. In addition, the length of the sales window is shortened if the testing takes more time than expected.

We must be prepared to invest quite a lot of efforts and human resources in order to work seriously with the test institute. A skilled and clever local representative or someone with a good command of the local language is vital.

Unfortunately, the authorities in other countries do not automatically recognize type approval tests performed in one country.

The laboratory that does the type approval also gives guidelines to other laboratories on how to do the periodic verification tests. These guidelines are more detailed then the instructions given in OIML58 and 88, and it includes all the weak points of the equipment, of course.

Requirements to the manufacturer: It is difficult to pass this type approval test without having to change the construction – hopefully the quality has improved.

4. Our solution

4.1 A Calibration Laboratory

We set up our own calibration laboratory: the NCL (Norsonic Calibration Laboratory). The NCL staff is not involved in the design, development or production of any of the devices tested by NCL.

The Norsonic Calibration Laboratory (NCL) is an accredited laboratory (Norwegian Accreditation No. K022) for the calibration of measuring microphones, sound calibrators and sound measuring instruments such as sound level meters and sound analysers. NCL has its own quality system separated from the system of Norsonic.

NCL is a "secondary" laboratory and gets its references from a primary – national laboratory (PTB).

NCL is accredited by Norwegian Accreditation, which again is one of the signatories to the EA Multilateral Agreement for mutual recognition of calibration certificates (European Co-operation for Accreditation). The accreditation states that the laboratory meets the NA requirements concerning competence and calibration system for all the calibrations contained in the accreditation. It also states that the laboratory has a satisfactory quality assurance system and traceability to accredited or national calibration laboratories (as described in EAL-G12).

4.1.2 Acoustical References

In Norway there are no National Standards for acoustical quantities. At NCL there is a hierarchy of acoustical references. Working standard calibrators, pistonphones and microphones that are compared on a regular basis against the laboratory's primary references. These primary references are again calibrated against national standards at PTB.

The acoustical references used are controlled and verified prior to any calibration of sound level/microphone sensitivity. Compensations for ambient pressure, temperature and humidity are made.

NCL also participate in round robin tests of acoustical test objects whenever possible.

4.1.3 Environmental references

Environmental parameters, such as the ambient temperature, humidity and atmospheric pressure may influence on the calibration results. Hence, it is important to apply corrections to the reference microphones, sound calibrators and the measuring results from the device under test due the influence of ambient parameters. The laboratory has a set of pressure, temperature and humidity sensors of high quality and stability.

The accuracy of sensitivity calibrations of pistonphones and certain sound calibrators (those prone to significant ambient pressure sensitivity) is closely connected to the accuracy of the system barometer itself.

This means that the barometer accuracy contributes to the total uncertainty of the measured values of the calibration laboratory.
The environmental references are calibrated by other accredited laboratories on a regular basis.

4.1.3 Electrical (Volt or dBV) references

A multifunction voltmeter serves as the reference for all electrical results. This meter has a good resolution, accuracy and stability and it is calibrated by another accredited laboratory on a regular basis.

Distortion measurements are made by means of a simple distortion meter. This distortion meter is calibrated using a signal generator and the above-mentioned voltmeter as reference.

Level stability measurements are dB measurements with high resolution. A sound level meter with special firmware (Nor-110) is capable of delivering results with 1/100 dB resolution.

4.2 A calibration system

Norsonic has developed a calibration system for use in NCL. The system is designed to handle the wide variety of instruments currently in use to enable all types to be verified using fully or semi automatic methods. The calibration system utilises the above-mentioned references.

The system is capable of calibrating virtually any type of sound measuring instruments, sound calibrators and microphones commercially available, provided that they have been designed in accordance with applicable international standards.

The process of verification and calibration of sound level meters in accordance with international standards is in general divided into an electrical and an acoustical part. The standards mainly used are the IEC60651 for sound level meters and the IEC 60804 for integrating-averaging sound level meters. National standards, like the ANSI S1.4, which in general is similar to the IEC 60651, come in addition to this.

The calibration system also covers special national instrumentation standards that have been designed to cover special needs. A typical example is the German DIN45657 which describes the testing of time constant F down to 0.25ms; testing of statistical calculations and the Takt-maximal 3 and 5.

The IEC60651 and the 60804 both describe tests that partly have been designed for type approval of an instrument design only. They do, however, also include tests meant to be made on a regular basis. The *Organisation Internationale de Métrologie Légale* (the International Organisation for Metrology) has made a recommendation for testing instruments in accordance with IEC 60651 and 60804. This recommendation describes the tests applicable to type evaluation (pattern approval) as well as the tests applicable on a more regular basis (periodic verification).

The Norsonic Calibration System for sound measuring instruments - our type Nor-1504A - is mainly designed for calibration, but by using anechoic and climatic chambers etc., it is possible to apply the system to type approvals as well, since all the test signals needed are generated.

The system is also prepared to meet the upcoming proposed IEC standard which will replace the current IEC 60651 and 60804. The new standards will require some other test signals than those in the present (sine burst / half sine).

4.2.1 Calibration of Calibrators and Pistonphones

- Measurements according to IEC 60942
- Observed sound level in dB re. 20μPa
- Sound level corrected for pressure, temperature and humidity
- Short term stability expressed in dB
- Output frequency in Hz
- Frequency stability in %
- Total distortion in %

Calibrators and pistonphones are calibrated in accordance with the IEC 60942 by the use of a reference microphone, designed as a WS2P as defined by IEC01094.4. The frequency and level are adjusted, whenever applicable and the calibration data is printed out and/or stored on disc. The ambient pressure, temperature and humidity are read via the RS-232 directly into the program, where the calibration data are normalised to the reference conditions as defined by the IEC 60942.

The complete measurement procedure, including verification of the reference microphone and test system is controlled by software running on the Microsoft® Windows® platform.

Pistonphones are supplied with barometers in order to correct for the atmospheric pressure. This barometer is checked against the system barometer.

A calibration certificate can be printed out once the tests selected are completed.

4.2.2 Calibration of Microphones

- Measurements made in accordance with IEC61094
- Sensitivity of the microphone as mV/Pa and dB rel.1V/Pa.
- Cartridge capacity in pF
- Frequency response in the range 250 – 20k Hz (1 Hz to 100 kHz as option)

Absolute sensitivity is measured in mV/Pa and dB re 1V/Pa by using the insert voltage technique. This ensures a very high degree of calibration accuracy. The calibration results are corrected for the influence of the ambient pressure, temperature and humidity.

Frequency response measurements. Frequency response is measured either by use of the electrostatic or the acoustical method. The electrostatic method is a fast and reliable method and hence used to the extent possible. However, there are cartridges to which the electrostatic method cannot be applied and there are cases where the conversion factors needed to convert the electrostatic frequency response into the corresponding free field or diffuse field response remain unknown. In these cases the acoustical method can be applied instead. Method selection is made in a menu in the program controlling the measurements.

Electrostatic method. The microphone cartridge protection grid is replaced by an electrostatic actuator and the microphone is placed in the sound isolating measurement chamber. The signal generator generates a sine wave signal, which is incremented in sixth-octave steps up to 20kHz. The sine wave is fed to the sound insulated measurement chamber via the test unit in which a high voltage amplifier boosts the signal and a 800Vdc is added to generate the electrostatic field. The microphone signal is fed via the microphone preamplifier into the test unit again where the signal is amplified by 40dB and spurious noise is removed by a bandpass filter. The filtered signal is measured by the voltmeter and the values transferred via the IEEE interface to the computer. The frequency response measured is the electrostatic frequency response, which closely resembles the pressure response of the microphone cartridge. The free field correction is added to the actuator response curve. The measurement is fully controlled from the PC.

Acoustical method. There is an option for frequency response measurements using an anechoic chamber. The software supports two different ways of obtaining the acoustical frequency response:

The first method measures the frequency response by use of a reference microphone. Then the microphone that shall be calibrated replaces the reference microphone.

The second method measures the reference microphone and the microphone to be calibrated simultaneously. This method is described in the IEC61094-5 (for the time being this standard is at committee draft level only).

Low frequency response using sound calibrator type 1504A/7 down to 0.03Hz (option)

Cartridge Capacitance

The microphone cartridge capacitance is determined by measuring the voltage division ratio when the microphone cartridge forms a part of a capacitive voltage divider. A special preamplifier is used for this.

Since the cartridge capacitance depends on the polarisation voltage applied, measurements are carried out using the stated polarisation voltage for the cartridge under test – i.e. 200V for non-polarised and 0V for pre-polarised cartridges.

A calibration certificate can be printed out once the tests selected are completed.

4.2.3 Periodic Verification of Sound Measuring Instruments

- Measurements made in accordance with IEC60651, IEC60804, DIN/IEC651, DIN/IEC804, ANSI S1.4, ANSI S1.43, DIN45657, IEC61260. The periodic verification can be performed according to IOML58 & 88.
- Accuracy of input range selector
- Level linearity
- Spectral weighting networks A, B, C, Lin and Flat
- F, S, and I time constants. Pulse measurement capability
- RMS detector capability
- Overload detector
- Inherent noise using microphone equivalent
- Integrating averaging functions Leq and SEL

For the electrical tests, the microphone is removed and the electrical signal is fed via a BNC to preamplifier adaptor Nor-1447 in to the sound measuring instrument under test.

Depending on the instrument design one of three available control modes will be used.

Manual mode. The test equipment (signal generator, voltmeter etc.) is controlled by the computer. The user must set up the device under test and read the results from its display and key the results into the computer.

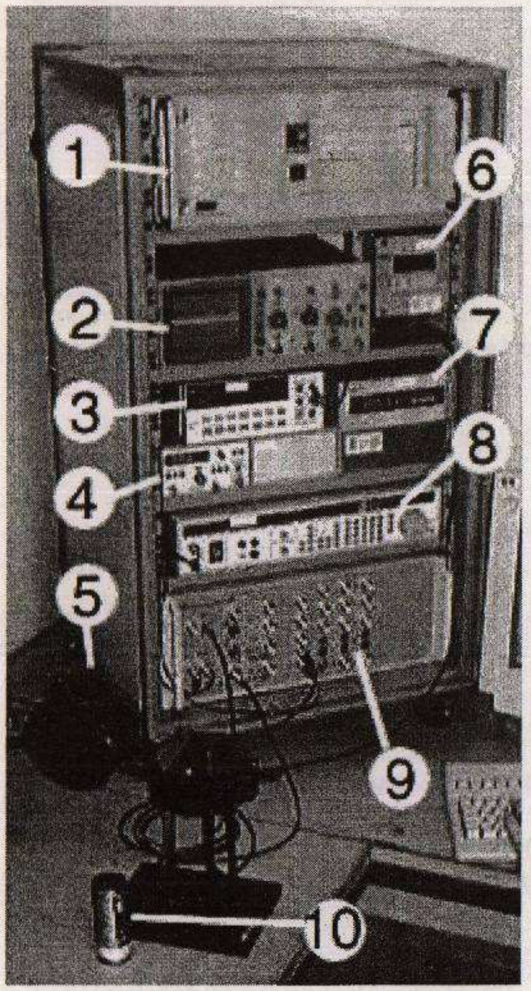
Semi-automated mode. The computer controls the test equipment. The user must set up the device under test. The measurement values are measured with the voltmeter connected tothe DC output port on the device under test and then transferred via the IEEE interface to the computer.

Automated mode. The test equipment and the device under test are fully controlled by the computer. This requires an RS-232 or IEEE interface on the device under test.

A total measurement report can be presented at the end of the test and may be printed out and/or stored for later use.

4.3 System Description

Typical configuration:



1. Computer
2. Oscilloscope (extra)
3. Voltmeter
4. Distortion meter
5. Sound isolating measurement chamber
6. Thermometer/hygrometer
7. Barometer
8. Signal generator
9. Test Unit
10. Sound Calibrator

The test system is based on a PC controlling the signal generator, voltmeter, test unit and the DUT (Device Under Test).

The computer also reads the barometer, the hygrometer and the thermometer, which all are included with the system in order to provide the required environmental data in a fast and accurate manner for the calibration reports.

A logging program runs always in the background on the computer to verify that the environmental parameters are always kept within the limits of the laboratory.

A calibration is normally divided into three main parts; viz. electrical calibration of the sound measuring instrument, calibration of the microphone and - if applicable - calibration of the sound calibrator. An overall system calibration is made at the end in order to adjust the sound measuring instrument to the correct microphone sensitivity.

The system measures the quality of the sound measuring instrument's time-integration capabilities. Measured values are compared to the theoretically correct values. The deviations recorded are listed along with the tolerances permitted. Click on the image for a better view.

The techniques and methodology developed allow cost effective calibration without sacrificing the accuracy of the process.

5 Conclusion

Using the references and calibration system outlined here we believe that we are able to measure and calibrate sound level measurement equipment with sufficient accuracy and quality to make sure the instruments pass all tests for type approval and verification tests.

It is necessary to calibrate the complete sound level meter chain – both for new instruments and periodically. Between 5 and 10% of the equipment “out there” can show incorrect results and is in need of readjustment.

Our hope for the new Type Approval and Periodic Verification standards

When IEC61672 part 2 and 3 are available we hope they will wipe away any uncertainties on what to test, and how the different tests shall be performed. And then hopefully all sound measuring equipment shall be measured and calibrated the same way, taking their specifications into account.

We hope they will include information on how to handle the uncertainties associated with the measurements and the calibration laboratory itself, following the guidelines given in the GUM (Guide to the Expression of Uncertainty in Measurements) and which uncertainties are important to take into account when evaluating the real noise and sound level measurements. Then it will provide vital information to both the manufacturer and the user of the instrument about the periodic verification intervals.