Acoustics Engineering

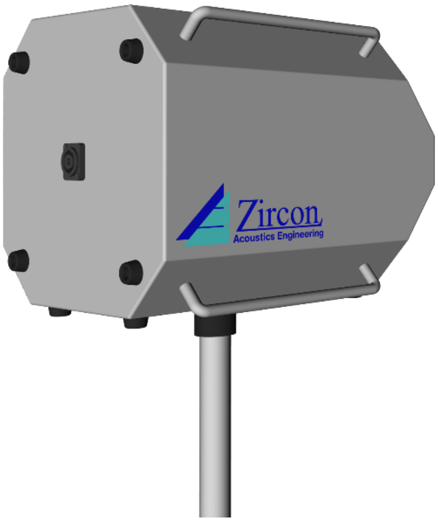
ZIRCON V2

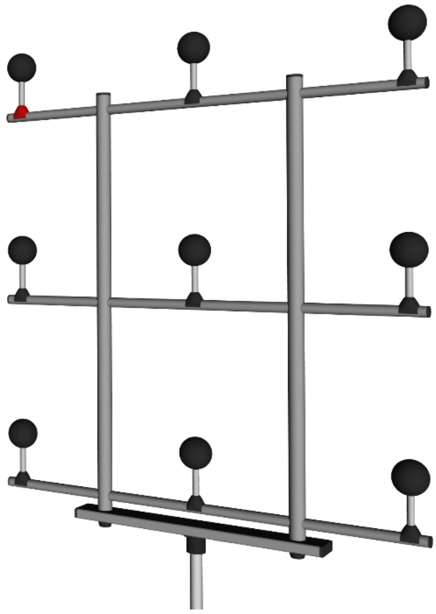
TN014 - Rev. 1.1 - June 2022

Technical Note

Zircon V2 System

Accreditation Notes





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1 Introduction

The EN 1793 standards deal with in situ measurement of the acoustic performance of road traffic noise reducing devices (NRD's). An example of a suitable measurement system is the Zircon V2 by Acoustics Engineering (The Netherlands), which consists of hardware, software and documents, and in some cases requires accreditation.

This document aims to answer questions that might arise during the accreditation of a Zircon V2 system. It lists standards and documents and explains how certain requirements mandated by the standards are met.

2 Standards, hardware, software and documents

2.1 NRD in situ measurement procedures

The basic in situ measurement procedures for noise reducing devices are explained in the following main standards:

1. ***EN 1793-5:2016***, March 2016, "Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 5: Intrinsic characteristics – In situ values of sound reflection under direct sound field conditions".

2. ***EN 1793-6:2018***, June 2018, "Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 6: Intrinsic characteristics – In situ values of airborne sound insulation under direct sound field conditions".

2.2 Zircon V2 hardware

The Zircon V2 hardware is described in datasheet ***Zircon V2 PD002 2022-2.2.pdf*** and mainly consists of a loudspeaker, a 3x3 microphone grid and a 9-channel USB/Audio interface connecting these components to a PC running a measuring program.

2.3 Zircon V2 software

The software used with Zircon V2 is ***DIRAC***, a Windows based acoustics measuring program, developed by Acoustics Engineering (NL) and distributed by Hottinger Brüel & Kjær A/S (DK) as Type BZ-5449. DIRAC 7 (or higher) measures and processes multi-channel impulse responses to provide parameters on site that enable the user to validate and adjust the measurement setup, as described in the standards.

The measurement results are processed on site, making use of (Python) scripts that can be run from within DIRAC 7: ***ProjectReflection.py*** or ***ProjectTransmission.py***, to determine the NRD reflection index versus frequency RI(f) or insulation index versus frequency SI(f). Back at the office, these are transferred to a spreadsheet ***EN 1793-5.xlsx*** or ***EN 1793-6.xlsx*** to arrive at the final NRD single-number quantity DL_{RI} or DL_{SI}.

2.4 Measurement instructions

The measurement processes from setup to results, are described in the step-by-step instructions ***EN 1793-5 AE Measurement Procedure 1.x.pdf*** and ***EN 1793-6 AE Measurement Procedure 1.x.pdf***. Background information on these instructions can be found in Technical Note TN013.

3 Notes on EN 1793-5 requirements

3.1 RI, Cgeo, Cdir, Cgain (5.2)

DIRAC calculates the reflection index RI(j,k) per each microphone and each one-third octave frequency band of interest, featuring the subtraction technique at sub-sample accuracy and Adrienne temporal windowing.

The average over all microphones is calculated in spreadsheet ***EN 1793-5.xlsx***, taking into account 3 weighting factors per microphone: C_{geo}, C_{dir} and $_{gain}$.

C_{geo} and C_{dir} are fixed for a typical Zircon setup, and already included in the spreadsheet. C_{gain} depends on the actual setup and for each measurement is calculated by DIRAC and exported to the spreadsheet.

3.2 Components of the measuring system (5.4.1)

It is stated that *"The microphones shall meet at least the requirements for type 2 in accordance with EN 61672-1 and have a diameter of 1/2 inch (12,7 mm) maximum."* The (third party) microphones are assumed to meet these requirements.

3.3 Sound source (5.4.2)

The Zircon LS24 (as well as its predecessor LS14) meets the requirements mentioned in the standard.

Note A picture of an arrangement with the LS14 is shown in Figure B.2 of the standard.

3.4 Test signal (5.4.3)

A better parameter than the SNR to judge the impulse response quality is the INR[1] (Impulse to Noise Ratio), which is a good estimator of the decay range and not only accounts for the SNR, but also distortion and stimulus length. Good results are obtained if INR > 20 dB for each frequency band of interest. If the INR at a frequency is too low, it can be improved not only by increasing the SNR through the signal level, but also by applying Pre-Averaging (available in DIRAC) or increasing the stimulus length.

If MLS (Maximum Length Sequence) is chosen as stimulus, the loudspeaker will produce less distortion because the energy in each frequency band is distributed over time, hence limited in power. If ESS (Exponential Sine Sweep) is chosen as stimulus, the loudspeaker may produce a high distortion at some frequencies, but due to the nature of this stimulus, this distortion can easily be removed from the

[1] C. C. J. M. Hak, J. P. M. Hak, R. H. C. Wenmaekers: INR as an estimator for the decay range of room acoustic impulse responses. AES Convention, Amsterdam, 2008.

impulse response[2,3], usually resulting in higher INR values than with the MLS stimulus. This technique is also available in DIRAC.

3.5 Calibration (5.5.1)

DIRAC calculates correction factor $C_{gain}(k)$ per microphone to enable monitoring system settings.

3.6 Sample rate (5.5.2)

It is stated that:

1. *"The sample rate f_s shall have a value equal or greater than 44 kHz."*
2. *"The sample rate shall be equal to the clock rate of the signal generator."*
3. *"The cut-off frequency of the anti-aliasing filter, fco, shall have a value: fco ≤ $k_f f_s$, where k_f = 1/3 for the Chebyshev filter and k_f = 1/4 for the Butterworth and Bessel filters."*
4. *"The filter order shall be not smaller than 6."*
5. *"For each measurement, the sample rate, the type and the characteristics of the anti-aliasing filter shall be clearly stated in each test report."*

The sample rate fs is 48 kHz and equals the clock rate of the signal generator and the anti-aliasing filter is a digital phase-linear type with the following parameters:

- Passband (-0.1 dB): 0 - 22.56 kHz, ripple ±0.035 dB
- Stopband: 27.84 kHz, attenuation -95 dB
- Total Group Delay: 0.25 ms

Note Relevance of this clause is limited, as these requirements on the input A/D-converter stem from the late 1980s when it was difficult to sufficiently attenuate signal energy above the Nyquist rate without compromising the level at the highest audio frequencies. Nowadays A/D converters have integrated high order digital phase-linear FIR anti-aliasing filters, the structure of which is normally not explicitly specified, but the performance of which is far superior over the early types in 3 and 4.

3.7 Background noise (5.5.3)

The newly introduced term "effective signal-to-noise ratio" as well as the subsequent note on improved S/N ratios with coherent detection techniques actually apply to the above-mentioned INR, which for impulse responses is the counterpart of SNR for signals.

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[2] MÜLLER, S., and MASSARANI, P., Transfer-Function Measurement with Sweeps. J. Audio Eng. Soc., 49 (2001), pp. 443-471

[3] FARINA, A., Simultaneous measurement of impulse response and distortion with a swept-sine technique. AES 108 th Convention, Paris, 2000 February 19-22, Preprint 5093

3.8 Signal subtraction technique (5.5.4)

DIRAC calculates the reduction factor $R_{SUB}(k)$ per microphone to enable checking the effect of subtraction and correcting the setup during the measurement session, if applicable.

3.9 Adrienne temporal window (5.5.5)

In DIRAC two predefined Adrienne temporal windows as defined in the standard are available. For other sample sizes, Adrienne temporal windows can be added by the user, by setting the window component lengths mentioned in the standard.

3.10 Placement of the Adrienne temporal window (5.5.6)

Placement is done in accordance with the standard.

3.11 Check of the loudspeaker and measurement grid relative position (5.6.2.5)

In the measurement instructions (section 2.4) a flat measurement grid is assumed, reducing the loudspeaker-grid alignment check to inspecting the source-receiver distance (DIRAC parameter SRDIST) of the 4 corner microphones only (k = 1, 3, 7 and 9).

3.12 Check of the measurement grid position (5.6.2.6)

DIRAC provides means to determine the equivalent distance between any two time points, and to generate a short sharp sound pulse through a user-defined stimulus. Nevertheless, because this measurement grid position checking method may be time consuming, a mechanical alternative is assumed, as suggested in the standard.

3.13 Single-number rating of sound reflection DL_{RI} (5.8)

The single-number rating of sound reflection DL_{RI} is calculated in spreadsheet ***EN 1793-5.xlsx*** (section 2.3), based on the normalized traffic noise spectrum, as defined in EN 1793–3.

4 Notes on EN 1793-6 requirements

4.1 SI (4.2)

DIRAC calculates the sound insulation index SI(j,k) per each microphone and each one-third octave frequency band of interest, featuring Adrienne temporal windowing.

The average over all microphones is calculated in spreadsheet ***EN 1793-6.xlsx***.

4.2 Components of the measuring system (4.4.1)

The following is stated:

> *"The complete measuring system shall meet the requirements of at least a class 1 instrument in accordance with EN 61672-1, except for the microphones which shall meet the requirements for class 2 and have a diameter of ½" maximum.*

NOTE 2 The measurement procedure here described is based on ratios of the power spectra of signals extracted from impulse responses sampled with the same equipment in the same place under the same conditions within a short time. In addition, a high accuracy in measuring sound levels is not of interest here. Therefore, strict requirements on the absolute accuracy of the measurement chain are not needed. Nevertheless, the requirement for a type 1 instrument is maintained for compatibility with other European Standards."

The first paragraph is interpreted as follows: with class 1 microphones, the system shall meet the requirements of a class 1 instrument in accordance with EN 61672-1, but during practical use, class 2 microphones are allowed to be used instead. Therefore, assuming the practical use of proper microphones, only the Zircon V2 electrical recording and processing part[4] of the system must be checked against the EN 61672-1 class 1 requirements.

The second paragraph (Note 2) suggests that checking compliance of an EN 1793 measuring system against EN 61672-1 requirements (dealing with sound level meters instead) may require some translation of clauses, if applicable at all.

Hereafter, the Zircon V2 compliance to EN 61672-1 requirements is described for each EN 61672-1 section that is applicable to some extent. EN 61672-1 related section titles are printed in red.

4.2.1 Statement of microphone reference SPL and reference orientation (5.1.13)

The Zircon CI24 input gains are settable, enabling the use of a common 94 dB microphone calibrator for the microphones.

4.2.2 Statement of maximum sound pressure level at microphone (5.1.16)

The Zircon CI24 input gains are settable, enabling the use of measurement microphones over a wide level range.

4.2.3 Applicability to all channels of a multi-channel system (5.1.17)

The specifications hold for each of the 9 Zircon microphone grid channels.

4.2.4 Acclimatizing time before and startup time after power on (5.1.18)

The equipment (here referring to the Zircon CI24) is allowed to reach equilibrium with the ambient environment, suitable for 1793 measurements, before switching on the power. After turning on, it will be ready for use within specification in less than 10 s.

[4] Information on the Zircon V2 components can be found in the Zircon V2 Product Datasheet. In this context, the most important component is the CI24, which contains the USB/Audio interface between the computer and the microphone array.

4.2.5 Statement of usable sound calibrator (5.2.1)

For instance, with ½” microphones, a ½” 94 dB sound calibrator, such as the HBK Type 4231, can be used to check the hardware connections and settings.

4.2.6 Microphone windshield response corrections (5.2.5) and deviations (5.2.6)

In a Zircon setup, the microphones are used at an average angle of 90° and with a windscreen. The microphones shall come with the orientation and windscreen correction data, while deviations from these corrections stay within two thirds of the tolerance limits of table 2 of EN61672-1.

Note This clause is irrelevant, as EN 1793 measurements do not require any correction to be applied due to the relative nature of these measurements.

4.2.7 Microphone directional response requirements within 90 degrees w.r.t. the reference direction (5.3.1 and 5.3.2)

The microphones shall meet the class 2 requirements within 90 degrees w.r.t. the reference direction.

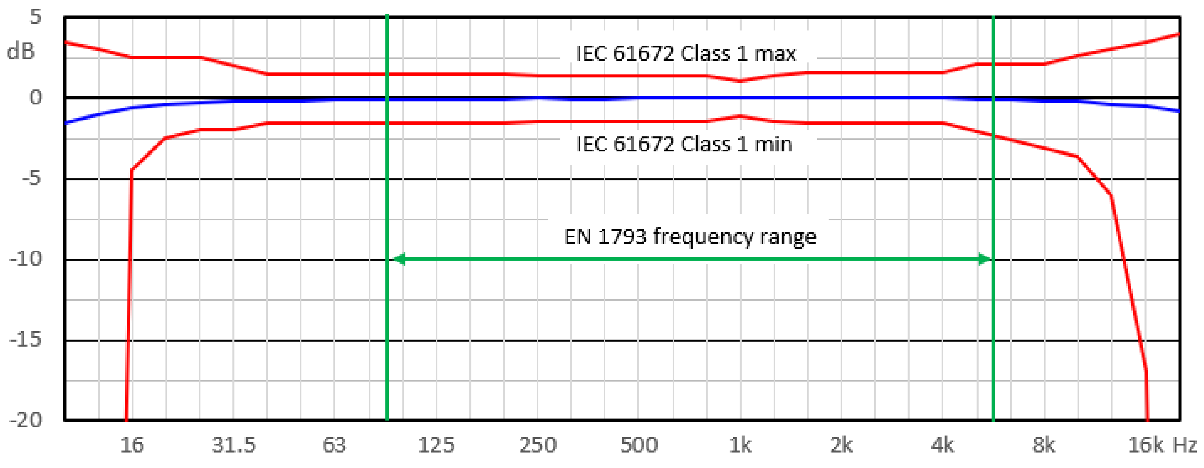
Note Relevance of this clause is limited, as EN 1793 measurements do not require any correction to be applied due to the relative nature of these measurements.

4.2.8 Frequency weightings (5.4)

The electrical microphone input responses are within the class 1 tolerance limits of Table 2 in the standard.

Note 1 Relevance of the class 1 frequency range is limited, as the EN 1793 frequency range of interest is one-third octave bands between 100 Hz and 5 kHz only.

Note 2 Relevance of this clause is limited, as EN 1793 measurements are based on relative energies rather than absolute sound levels.



4.2.9 Signal level linearity (5.5)

Signal level linearity concerns the consistency of displayed sound levels over different sound level meter ranges. The Zircon system uses one range only, which is, by definition, the reference level range, on which the extent of the linear operating range exceeds the required minimum of 60 dB, at an error meeting class 1 with regard to the levels and frequencies mentioned in Table 2 of the standard.

4.2.10 Self generated noise (5.6)

Self-generated noise is mainly determined by the microphone, while a shorted microphone input of the CI24 will produce 0.3 µV (equivalent to an SPL of -6 dB using a microphone with sensitivity 30 mV/Pa). The self-generated noise could affect extremely low sound levels, and its effect on impulse responses can be revealed in DIRAC through the so-called Impulse response to Noise Ratio (INR), which serves as a convenient per frequency band quality parameter of a measured impulse response. If at a certain frequency the INR is below 20 dB, one can try to improve it by increasing the measurement time or the Pre-average value in the DIRAC measurement window.

4.2.11 Overload indication (5.10)

Overload indicators for all microphones are present in the Measurement window of DIRAC and reflect the microphone inputs of the CI24. These can be set to an overload level and an associated clip level, depending on the microphones used. Latches of overload events are provided.

With Zircon V2 measurements, overload is unlikely to occur, even with EN 1793-5 reflection measurements. In addition to the indication of such an event, the INR (see 2.9) again serves as a measurement quality parameter, even after a measurement session. This also holds for many other disturbances during the measurements, making the INR a powerful quality guard in addition to the overload indicator.

4.2.12 RF emissions and disturbances to a public power supply (5.18)

This item is covered by the EMC Emission standards mentioned in the Zircon specifications.

4.2.13 Crosstalk between multiple channels (5.19)

Zircon V2 meets the -70 dB crosstalk requirement over the EN 1793 frequency range of interest, using microphones with a maximum output impedance of 20 Ω and a CA24 cable length of 10 m. The maximum crosstalk over frequency will increase by 6 dB for each doubling of this impedance or length.

Note Relevance of this clause is limited, as the EN 1793 array channel levels are not independent, and even at a 30 dB level difference between any 2 channels, a crosstalk of -60 dB would cause a level error of 0.03 dB, which is negligible in EN 1793 measurements.

4.2.14 Power supply (5.20)

All signal levels stay within the class 1 limits over the specified (mains) power supply voltage and frequency range.

Note Relevance of this clause is limited, as EN 1793 measurements are basically insensitive to small and slow level changes due to the relative nature of these measurements.

4.2.15 Environmental, electrostatic and radio frequency criteria (6)

This clause sets limits on measured sound level changes due to external disturbances. EN 1793 measurements deal with impulse responses, requiring and enabling other ways to judge (and eventually eliminate) the impact of external disturbances, through the impulse response quality parameter INR and other validity parameters mentioned in the EN 1793 standards. In general the INR should preferably exceed 20 dB over the frequency range of interest.

EN 1793 measurement results are basically independent of the system frequency response, but *system changes in between NRD measurements and the corresponding free-field measurements* should be minimized. This holds in particular for the mainly responsible environmental conditions static pressure, ambient temperature and relative humidity.

EN 1793 measurements are allowed to be performed at an ambient temperature of 0…40 °C, while the CI24 operating temperature range is 5…40 °C.

4.2.16 Provision for use with auxiliary devices (7)

CI24 extension cables up to 12 m may be used, which have negligible impact on the Zircon measurement results.

4.3 Sound source (4.4.2)

The Zircon LS24 (as well as its predecessor LS14) meets the requirements mentioned in the standard.

4.4 Test signal (4.4.3)

For the test signal, the same holds as in section 3.4.

4.5 Sample rate (4.5.2)

For the sample rate and anti-aliasing filter the same holds as in section 3.6.

4.6 Background noise (4.5.3)

For the background noise the same holds as in section 3.7.

4.7 Scanning technique using nine microphones (4.5.5)

In the measurement instructions (section 2.4) the use of a 3 x 3 microphone grid and a 9-channel measuring device are presumed.

4.8 Adrienne temporal window (4.5.6)

For the Adrienne temporal window, the same holds as in section 3.9.

4.9 Placement of the Adrienne temporal window (4.5.7)

For the placement of the Adrienne temporal window, the same holds as in section 3.10.

4.10 Single-number rating of sound reflection DL_{SI} (4.8)

The single-number rating of sound reflection DL_{SI} is calculated in spreadsheet ***EN 1793-6.xlsx*** (section 2.3), based on the normalized traffic noise spectrum, as defined in EN 1793–3.

Acoustics Engineering develops systems for the prediction and measurement of acoustical parameters, resulting in user-friendly tools that enable you to perform fast and accurate acoustical measurements and calculations.

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