Acoustics Engineering

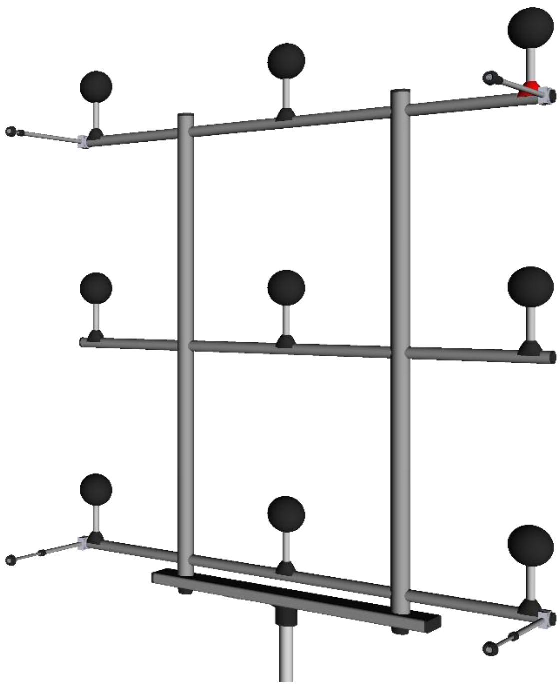
Measuring SI

TN021 - Rev. 2.0 - April 2025

Technical Note

EN 1793-6 and EN 16272-6 Measurement Procedure

Using the Zircon system



Standards: EN 1793-3 [1], EN 1793-6 [2]
EN 16272-2-3 [3], EN 16272-6 [4]

Hardware: Loudspeaker source: Zircon **LS24**
Microphone array: Zircon **MA24**
Control interface: Zircon **CI24**

Software: CI24 driver: X18 Windows Driver 5.72.0 2025-02-19
Zircon measurement: **DIRAC 7.3+** or **ZIRCON 1.0+**

Version 2.0 - April 2025

Contents

1 Introduction

This document presents a procedure to measure the in-situ sound insulation of road traffic noise reducing devices in compliance with EN 1793-6, or of railway noise barriers in compliance with EN 16272-6, and is based on the following standards, equipment and software:

1. EN 1793-3, normalized traffic noise spectrum [1].
2. EN 1793-6, in-situ sound insulation of road traffic noise reducing devices [2].
3. EN 16272-3-2, normalized railway noise spectrum and single number ratings [3].
4. EN 16272-6, in-situ sound insulation of railway noise barriers [4].
5. Zircon hardware (by Acoustics Engineering), consisting of the **LS24** (or **LS14**) loudspeaker source, the **MA24** microphone array with 9 microphones (measurement grid) and the **CI24** control interface between a computer running Zircon software and mentioned devices.
6. Zircon software (by Acoustics Engineering), being **DIRAC 7.3+** or **ZIRCON 1.0+**, acoustics measurement software that produces a stimulus to the source, captures response signals from the measurement grid, processes these to verify the validity of the measurements, and calculates the to be reported results according to the standards.

In this procedure, familiarity with EN 1793-6 or EN 16272-6 and Zircon software is assumed. The explanations and screenshots are based on **DIRAC**, but largely similar with **ZIRCON**.

In this document, a *road traffic noise reducing device* or *railway noise barrier* is denoted by **NRD** (Noise Reducing Device).

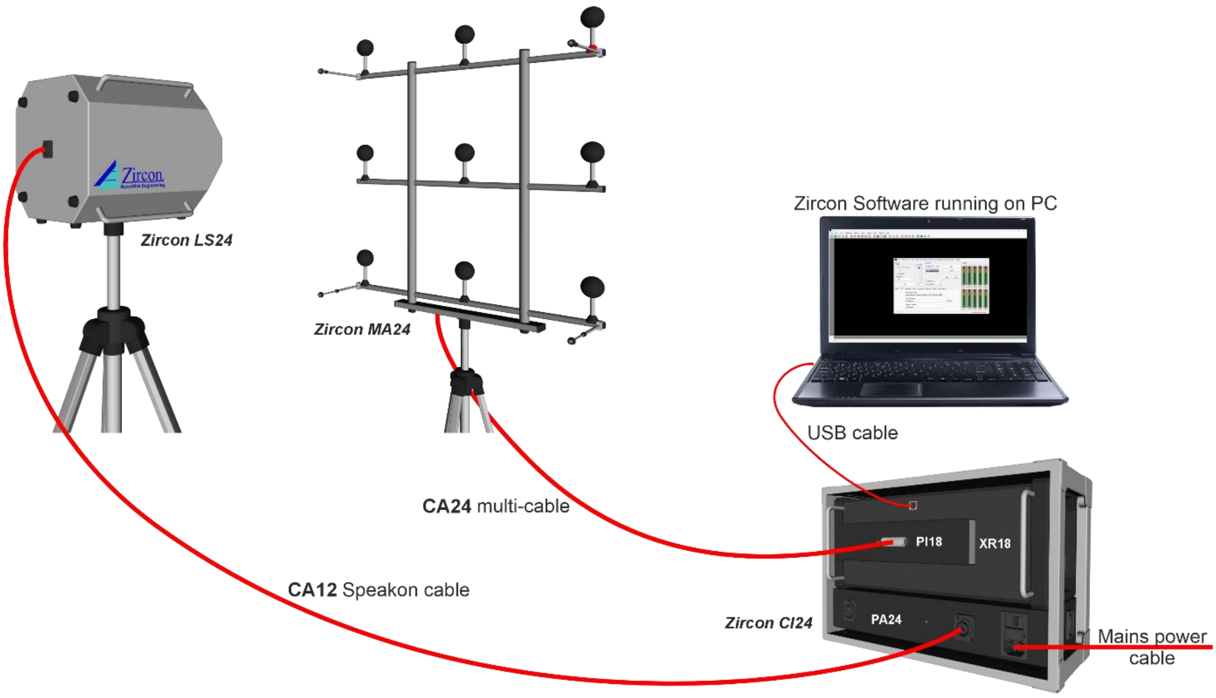
This procedure presumes that, as prescribed by the standards, the complete measurement system is kept at least 2 m from any object potentially causing substantial parasitic reflections that might affect the measurement results.

Where the loudspeaker unit is denoted as **LS24**, it may be substituted by its predecessor **LS14**, the electric and acoustic characteristics of which are substantially the same.

2 Measuring Equipment

The measuring equipment consists of the following components:

1. Loudspeaker unit: Zircon **LS24**, placed on its tripod.
2. Microphone array: Zircon **MA24** with 9 IEPE microphones, placed on its tripod.
3. Control interface: Zircon **CI24**, comprising a multi-channel USB/Audio interface device with IEPE microphone inputs, and a power amplifier for the **LS24**.
4. Speakon cable: **CA12** (10 m)
5. Multi-cable: **CA24**
6. Windows PC running Zircon software.



2.1 Cables

The long distances may require long cables to the LS24, the MA24 or both. Note that a long speaker cable is preferable to a long microphone cable.

If a speaker cable length of 20 m is required (**CA12-20m**), but not needed in most other measurement situations, coupling two 10 m cables (**CA12**) may be a good alternative option.

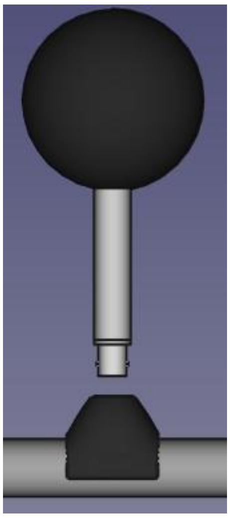
3 In-Office Installation and Preparation Procedure

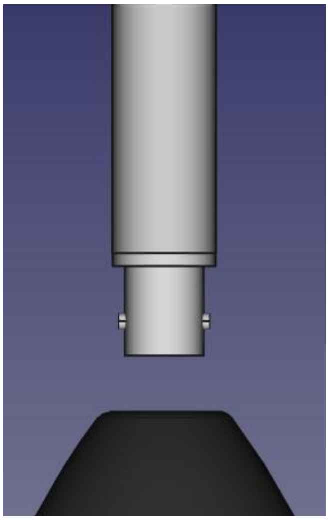
3.1 Introduction

Hereafter, a kind of checklist is given for the in-office preparation of field measurements. Not all the instructions apply each time preparing a field measurement session, such as the CI24 driver installation.

1. Set up the MA24 tripod and take off the tripod head (with UNC 5/8” screw).

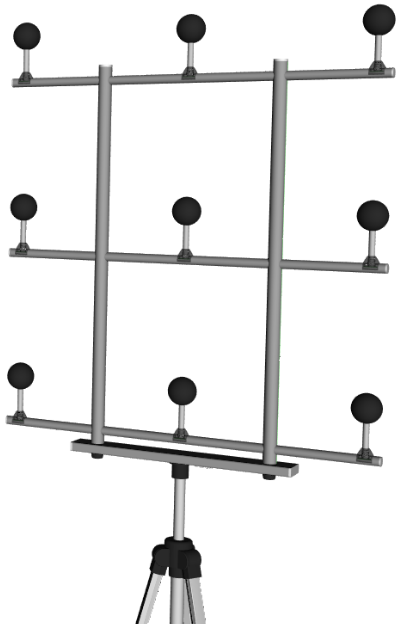
2. Screw the tripod head tightly enough in the MA24 bottom plate to avoid any play.
3. Place the **MA24** on its tripod and secure the tripod head with its screw.
4. Insert 9 microphones (bayonet movement).





5. Set up the LS24 tripod and take off the tripod head (with UNC 5/8” screw).
6. Screw the tripod head tightly enough in the LS24 bottom plate to avoid any play.
7. Place the **LS24** on its tripod and secure the tripod head with its screw.

8. Position the **LS24** roughly 1.25 m + the barrier thickness from the **MA24** center.



7. At the right side of the **CI24**, insert the short mains power interconnection cable and set the **XR18** power switch to the On state.

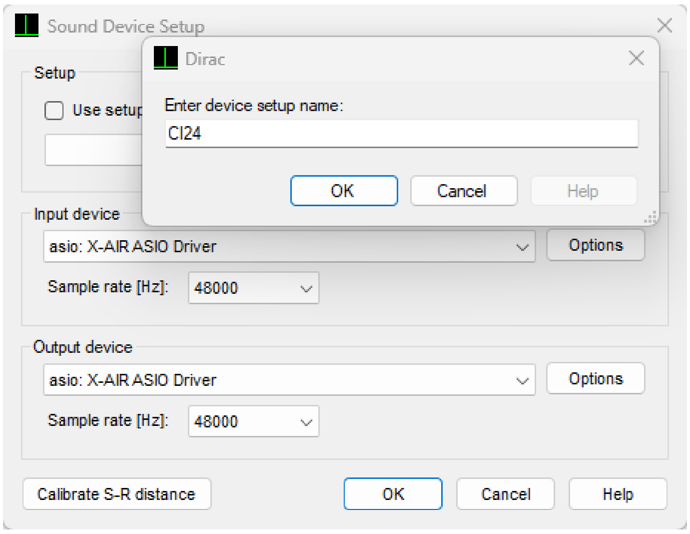
CI24 mains power interconnection cable

8. Connect the **CI24** to the mains power through the included mains power cable.
9. Connect the **CI24** to the PC through the included USB cable.
10. Attach the multi-cable to the **MA24** and the **CI24**.
11. Attach the Speakon cable to the **LS24** and the **CI24**.
12. Turn on the **CI24** by the switch above the mains power inlet. If the green LED on the power amplifier does not light, check the power. If the orange LED on the **XR18** unit does not light, turn on the **XR18** by the switch at the right side or check the interconnection cable there.

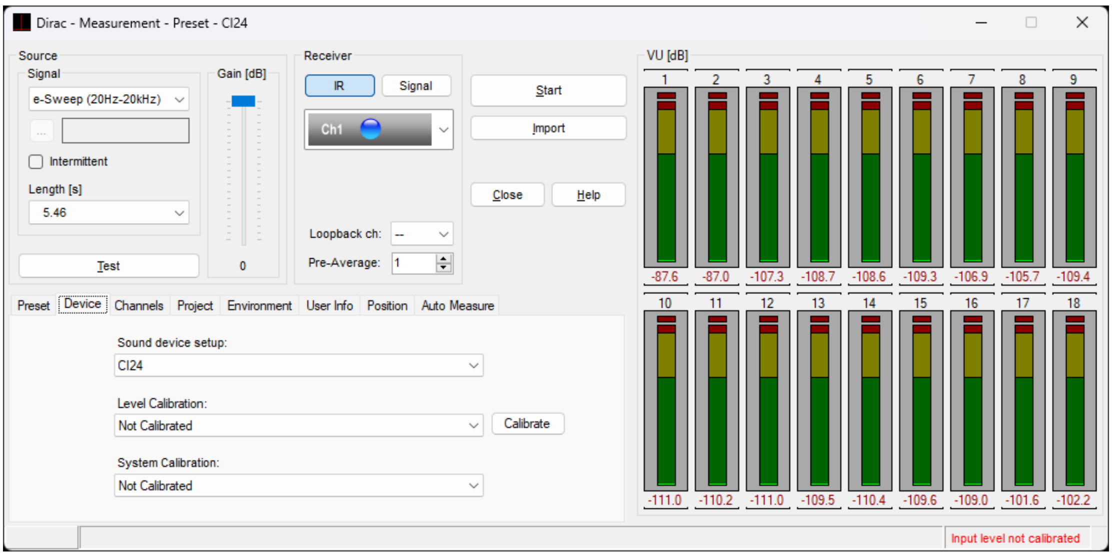
13. Install **X18 USB Audio Driver** on the PC (version 5.72.0, 2025-02-19). This driver can be found on the Behringer website by entering “XR18 driver” in the search field of the Download Center:

    [Behringer | Downloads]

14. On the PC, start the Zircon software and then from the **Setup** menu choose **Sound Device**.
15. From the **Sound Device Setup** window, select the line **asio: X-AIR ASIO Driver** for both input and output. Click ‘OK’ to save this setup under the name *CI24*.



16. The **Measurement** window now displays the VU meters for all **XR18** input channels:



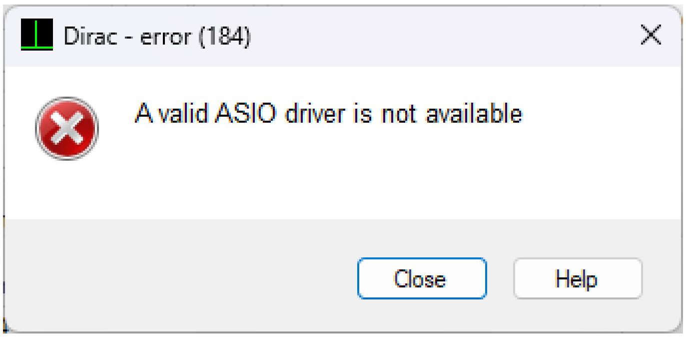
3.2 Startup sequence

After setting up the **XR18** in the Zircon software, the following startup sequence will normally be successful:

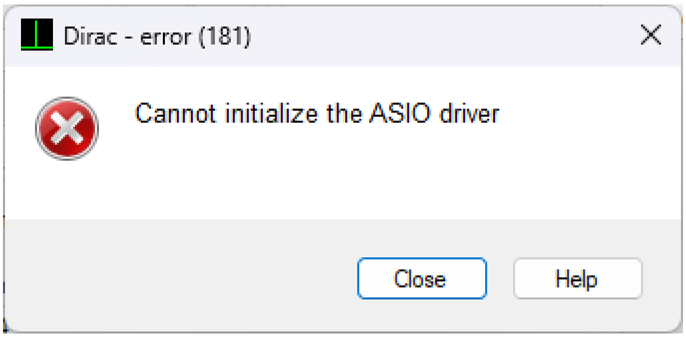
1. Connect the USB cable and turn on the CI24
2. Wait at least 11 seconds
3. Start the Zircon software and open the Measurement window

Note however, that connection and startup order matters. After turning on the CI24, it takes 11 seconds to complete starting up and, if the USB cable is connected, register with the Windows Device Manager, which then gets the ASIO driver up and running. When the Zircon software is started, it will only once check the availability of a valid ASIO driver and, upon opening the Measurement window, initialize it. Therefore:

- If the Zircon software is started while the ASIO driver is not (yet) running, opening the Measurement window will display the following error message, and require a restart of the Zircon software, but now with the ASIO driver running:



- If the Zircon software is started while the ASIO driver is running, after which the CI24 has been turned off or the USB cable disconnected, opening the Measurement window will display the following error message, and require a reopening of the Measurement window after restoring the connection:

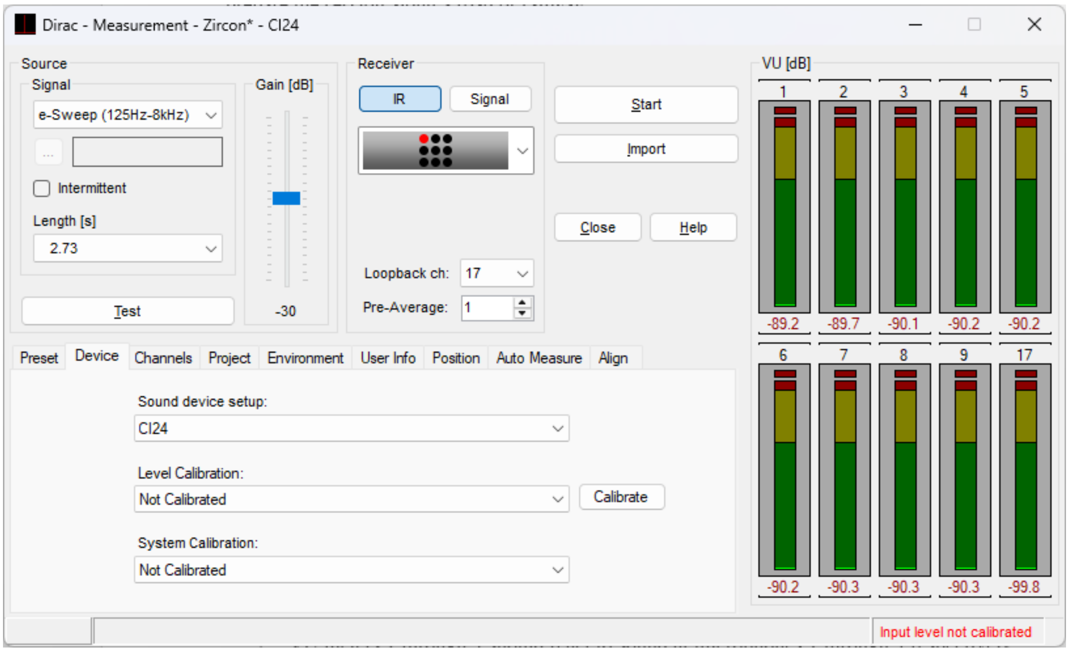


3.3 Dry run test

The dry run test simulates part of a field measurement in order to recall procedure steps and prepare the session along a road or railway.

3.3.1 Alignment (dry run)

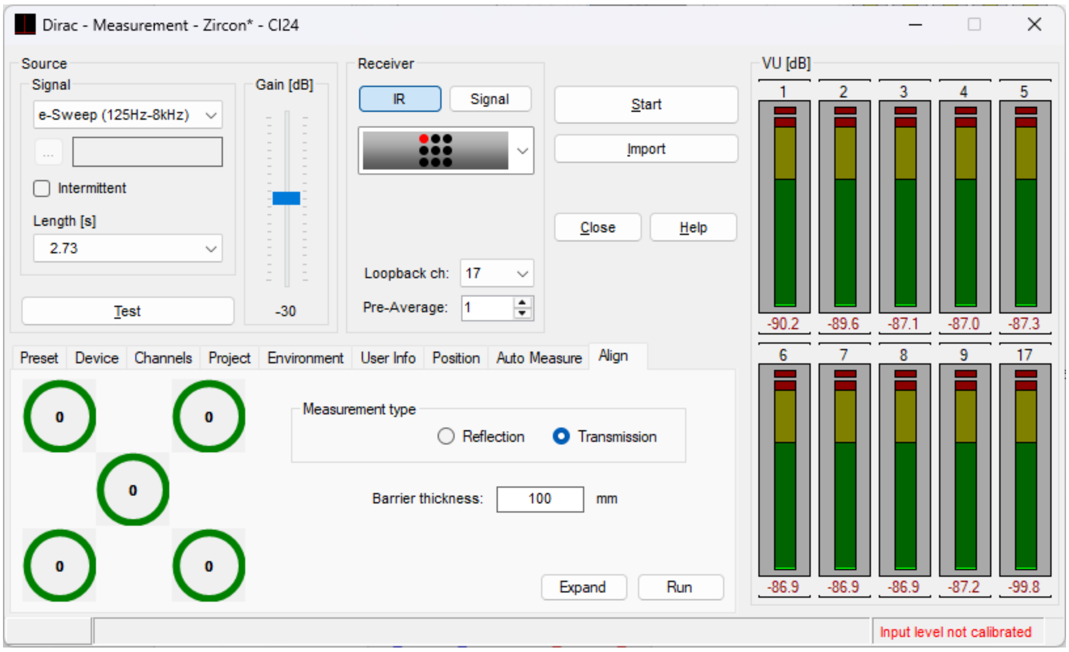
1. If applicable, on the **Preset** tab, load the **Zircon** setup. The preset name and associated sound device are displayed in the title bar. On the **Device** tab, sound device *CI24* is selected.

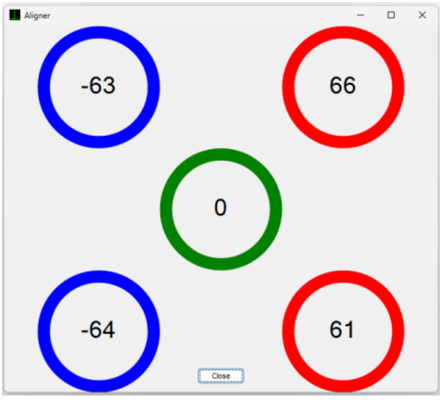


2. VU meters 1 through 9 should react to sound at microphones 1 through 9 respectively, and after clicking the Test button (mind the Gain!), a sweep should be heard from the **LS24**. Click the same button again to stop the sweep.
3. Select the array from the Receiver dropdown to make the Align tab visible
4. On the **Align** tab, select Measurement type **Transmission** (for SI measurements), enter the barrier thickness and then click the Run button.

Now, a repetitive short sweep is heard, and the distance errors in mm between the **LS24** and the **MA24** center and corner microphones are shown in color-coded circles. Note that for accurate source-receiver distance measurements, the **loopback channel** is used and set to 17.

5. If the numbers within the circles are not changing and remain at 0, close and re-open the Measurement window.
6. To maximize the circles for a better view, click the Expand button and then maximize the Aligner window.





RED = too far away (error positive)

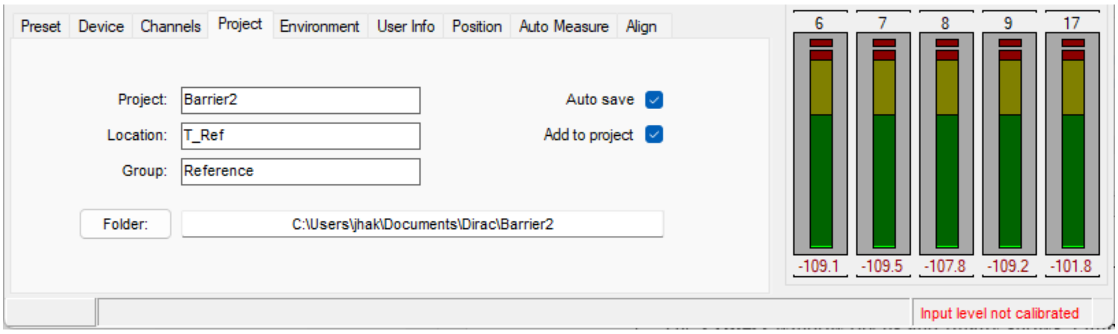
GREEN = OK (within ±25 mm)

BLUE = too close (error negative).

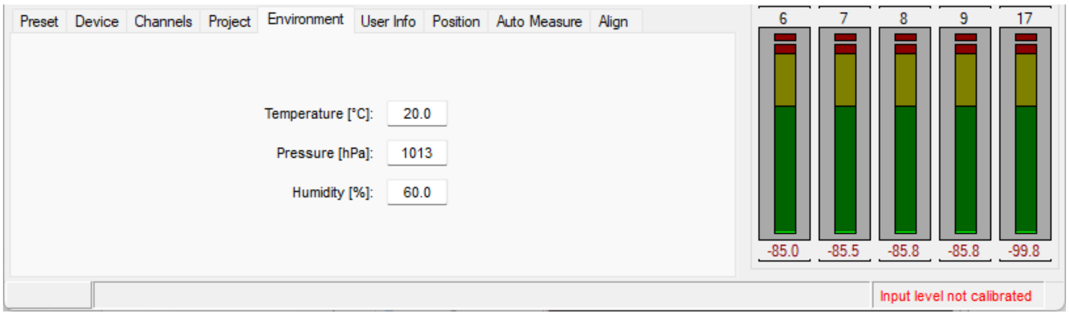
7. If the distance errors look evidently unrealistic, the sound level may be too low for the distance measurements, hence must be raised.
8. Adjust the **LS24** or **MA24** position to get 5 green circles, and then click the Stop button. Now the distance between loudspeaker plane and the microphones is sufficiently close to 125 cm + the barrier thickness.

3.3.2 Measurement (dry run)

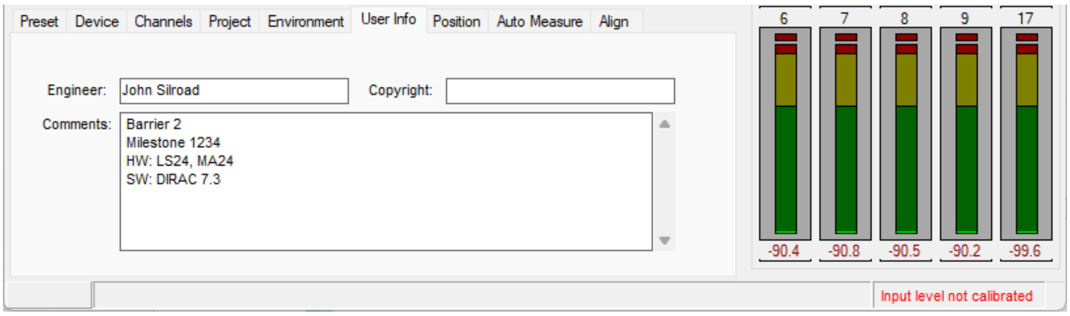
1. Fill out the **Project** tab. Measured files will be saved in the entered folder, and the file names will optionally include the Project and Location designations (menu **Setup** > **Options** > **Autoname**). In this example, Autoname is set to include the Project name (*Barrier2*), the Location name (transmission reference *T_Ref*) and the receiver/ microphone number (*R0n*) in the file names.



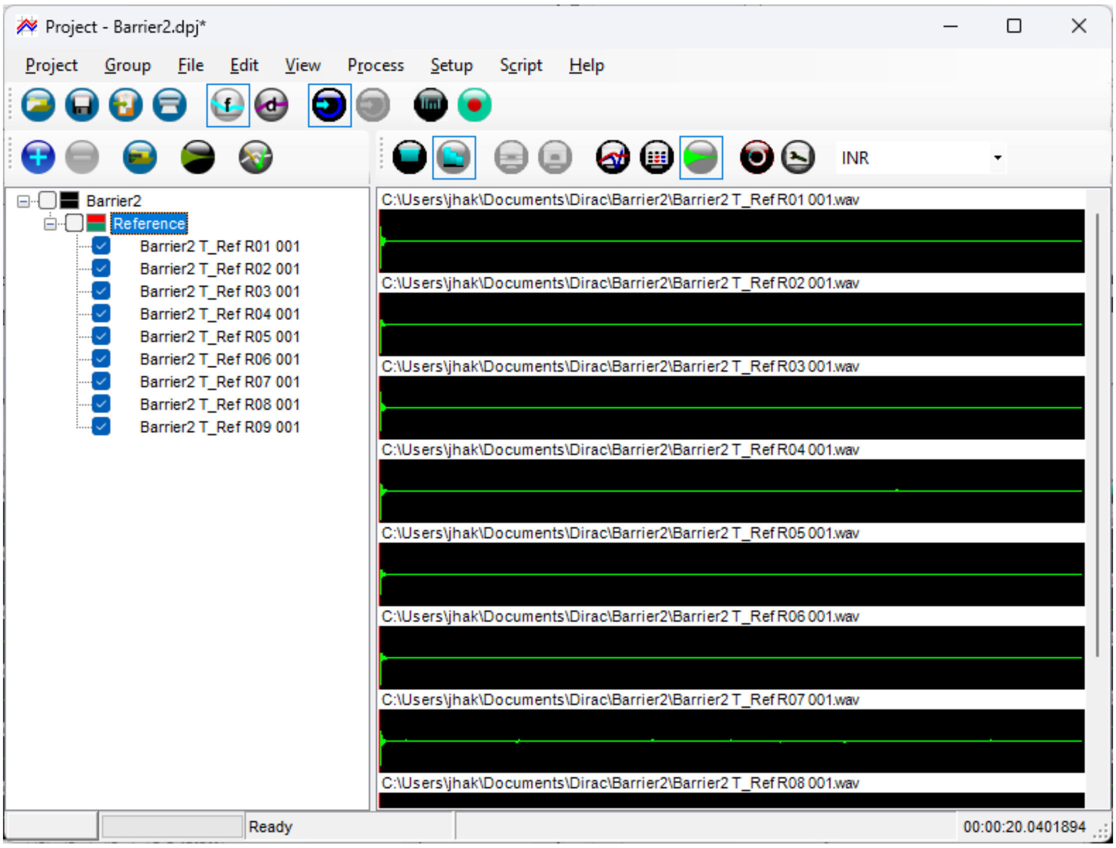
1. On the **Environment** tab, you can enter the expected environmental conditions in the field.



2. On the **User Info** tab, enter all remaining relevant measurement info.



2. Click the Test button, set the Gain slider to a reasonable sound level with respect to the background noise, and then click the Start button to perform the test measurement.
3. The **Project** window opens and finally shows 9 impulse responses, representing the free-field results.
4. By double-clicking an impulse response, DIRAC will display it in Impulse Response view, and you can zoom in to see more details. The window can be closed again by clicking the top right corner.
5. Select the Graph view (menu **View** > **Graph** or ***Graph*** button).
6. Open the **Properties** dialog (**Setup** menu or ***Properties*** button).


Project - Barrier2.dpj*
Project Group File Edit View Process Setup Script Help
INR
Barrier2
Reference
Barrier2 T_Ref R01 001
Barrier2 T_Ref R02 001
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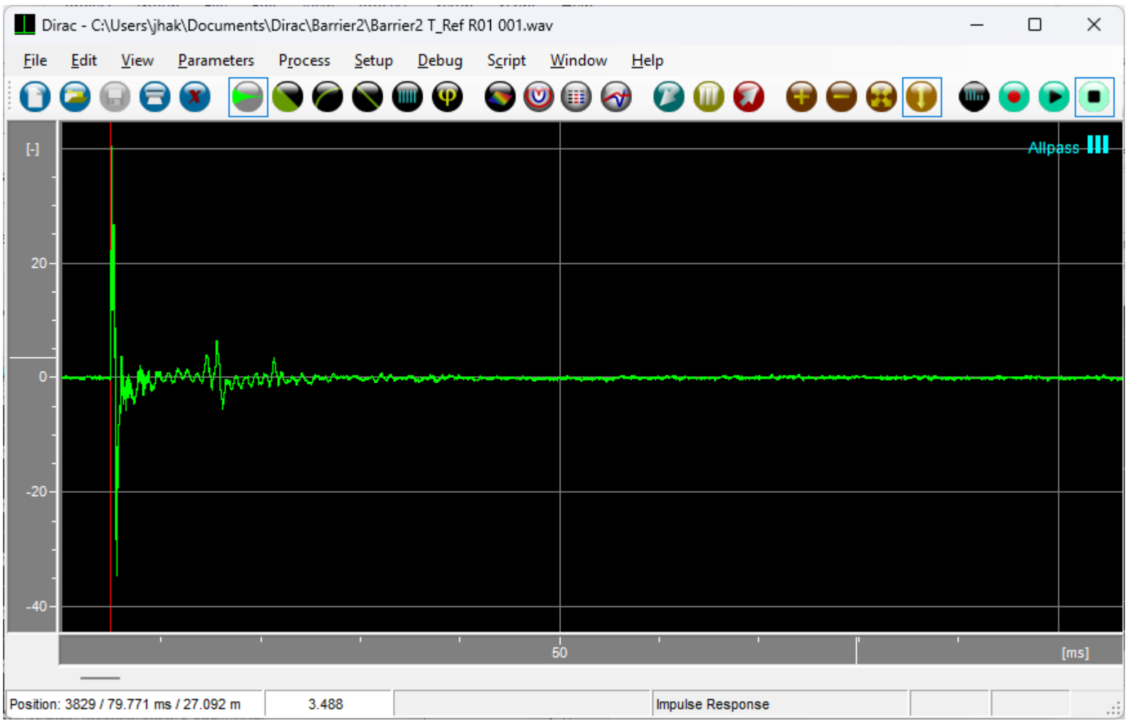
Dirac - C:\Users\jhak\Documents\Dirac\Barrier2\Barrier2 T_Ref R01 001.wav
File Edit View Parameters Process Setup Debug Script Window Help
Allpass
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0
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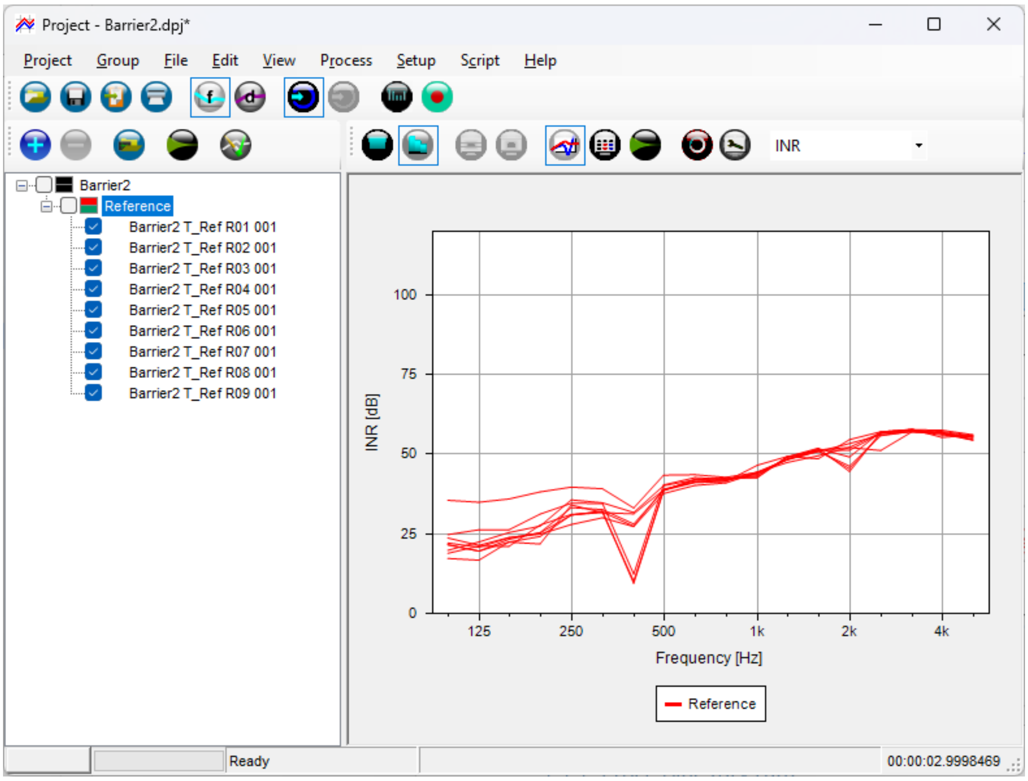
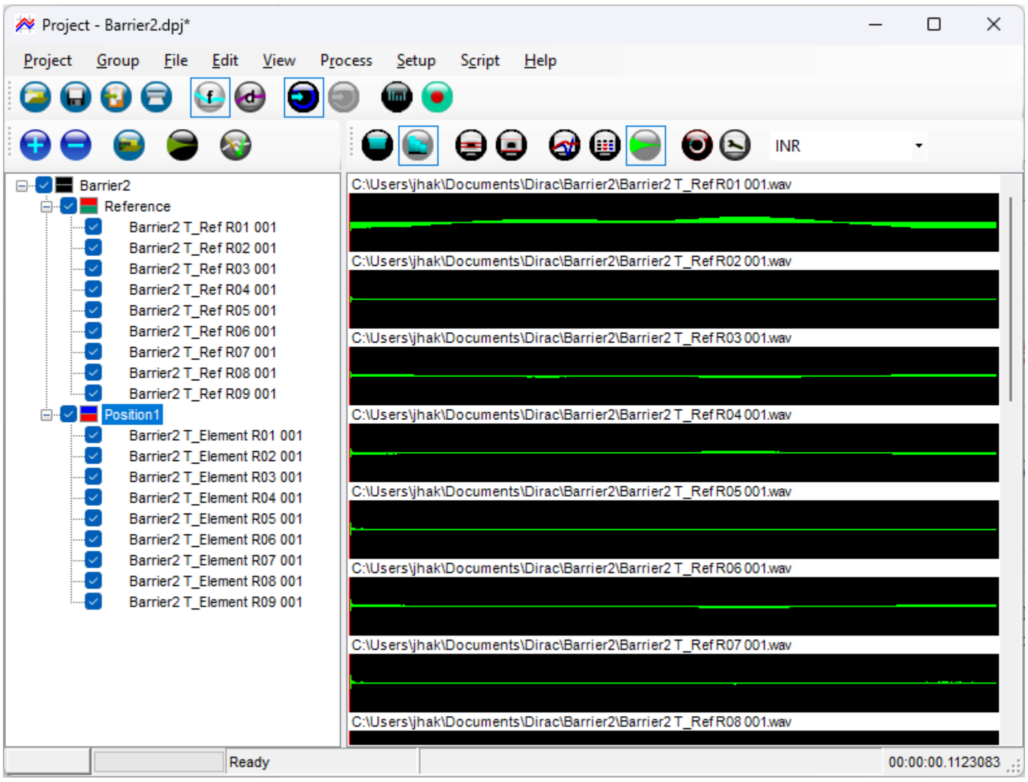
50
[ms]
Position: 3829 / 79.771 ms / 27.092 m
3.488
Impulse Response

7. From the **Parameter** list on the left, select Levels > **INR** (Impulse response to Noise Ratio), and wait for the INR curves to appear.
8. The INR reflects the quality of an impulse response measurement and should preferably exceed 25 dB for each microphone and at all third octave frequencies from 100 Hz through 5 kHz. If this is not the case, then this might be due to background noise, environmental fluctuations or an incorrect setup.

   So, if necessary, repeat the measurement with a corrected setup and/or under improved conditions, such as an adjusted source signal level or a higher Receiver Pre-Average value in the **Measurement** window, until the INR values are good or at least optimal.



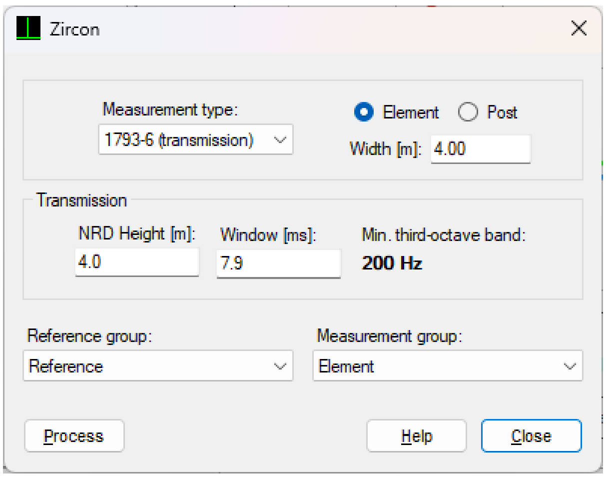
9. If the measurements were repeated under different conditions to optimize the INR, delete all intermediate trial impulse response files in the folder, and then restart the measurement under the current optimal condition.
10. To simulate measurements around an NRD, on the **Project** tab, set *Location* to “T_Element” (denoting the insulation measurement at an NRD element), set *Group* to “Position 1”, and on the **Position** tab, enter *Source:* 1 and *Receiver:* 1.
11. Because indoor SI measurements are meaningless anyway, keep the setup as is, and click the Start button to perform a test measurement.
12. The **Project** window opens and finally shows another 9 impulse responses, now representing the sound insulation results for an NRD element at source position 1.



3.3.3 Processing (dry run)

After performing all simulated measurements, each of the resulting 18 impulse responses has its correct source and receiver number, which is required to enable subsequent processing.

1. In the Project window, from the **Process** menu, select **Zircon**.
2. Fill out the **Zircon** dialog box. Select between an *element* or *post* measurement. For elements, enter the element Width. Enter the proper NRD height and Window length (if applicable) and select a reference group and a measurement group to be processed.



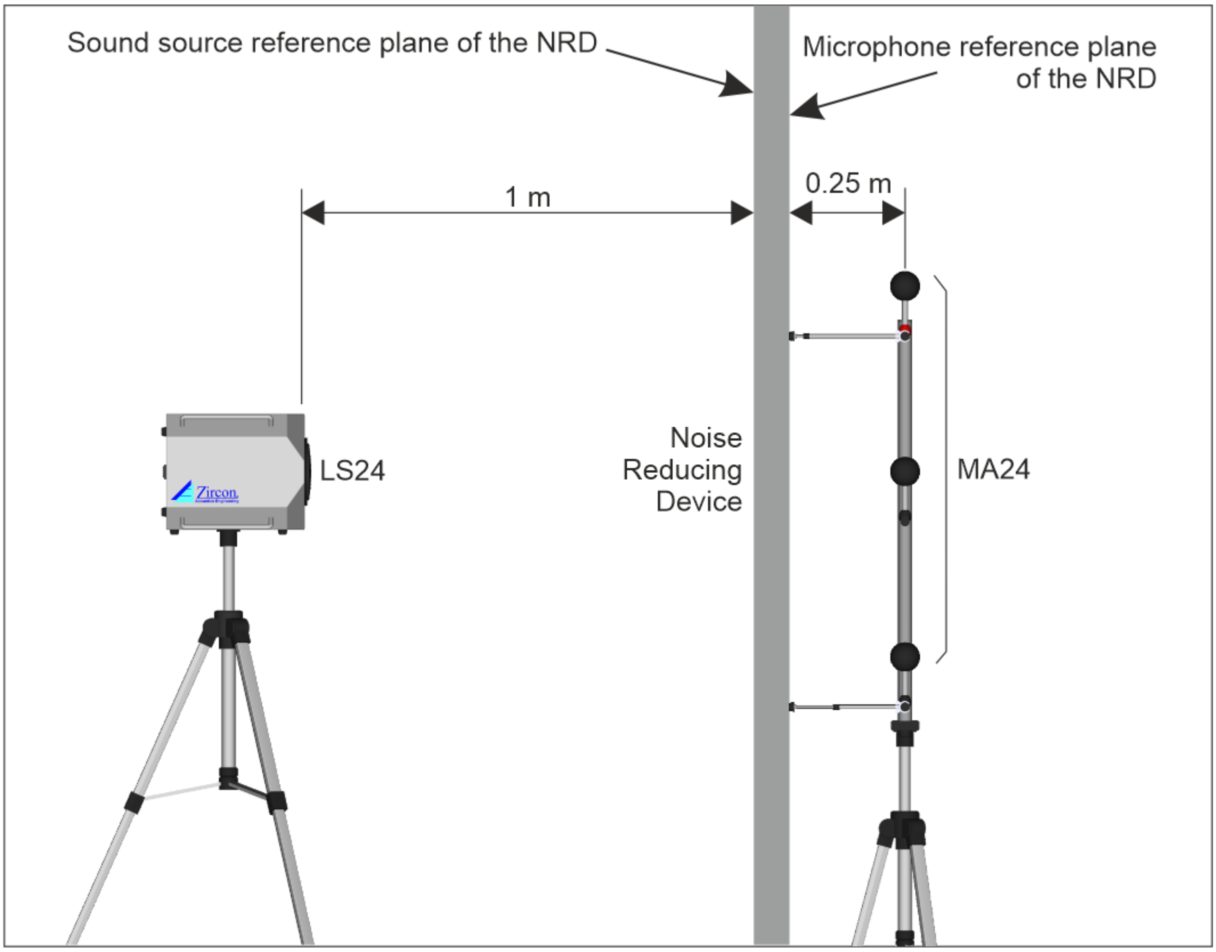
3. If you enter a NRD height different from the default 4 m, Dirac will automatically adjust the (Adrienne) Window length, but you can also enter a Window length explicitly.
4. Close the **Zircon** dialog box and in the **Measurement** window, set the *Receiver Pre-Average* value to 16: the minimum required according to the standards.
5. Sound insulation measurements usually require longer stimulus lengths, so as a starting point you can for instance set it to 10.9 s.
6. Quit Dirac and turn off the **CI24** unit.
7. If necessary, the dry-run folder can be deleted.

3.4 Some tips

1. If for the **MA24** a hanging construction is required, because of a very high or inclining NRD, please refer to technical note **TN018 – Zircon – Alignment** [10].
2. The cable roll ties can also be used to tie the cables to the tripods.
3. It may be convenient to have both a tape measure and a laser measure.
4. Bring rubber bands to secure typically loose parts of the source tripod, such as the crank, that otherwise might rattle during loud sine sweeps. Although it will usually not affect the measurements, it may be annoying.
5. Avoid any contact of connectors with the ground. After releasing a connector, do not drop it on the ground, put it in a clean place.

The setup is now ready for field measurements.

4 Field Measurement Procedure



Notes

1. Hereafter, text printed in italics refers to the terminology as used in the standards.
2. The screenshots shown hereafter are for illustration purposes only.
3. This procedures starts with the reference measurements, but it is also possible to start with the NRD measurements.
4. Alignment of the *source* and *measurement grid*, mutually as well as with the *noise reducing device* (NRD), is usually the most elaborate part of the whole measurement process and may be particularly challenging and time consuming on irregular terrain or with non-flat complex devices for which the *reference plane* does not coincide with the NRD. Therefore:
   - The tripods included with the Zircon provide bubble levels and (direct-gear) cranks to adjust the height, which can be used as first order alignment tools.
   - The **MA24** is equipped with adjustable spacers to simplify alignment with the NRD.
   - The Zircon software features an alignment function that simplifies alignment of the **LS24** with the **MA24**.

4.1 *Free-field* (Reference) Measurements

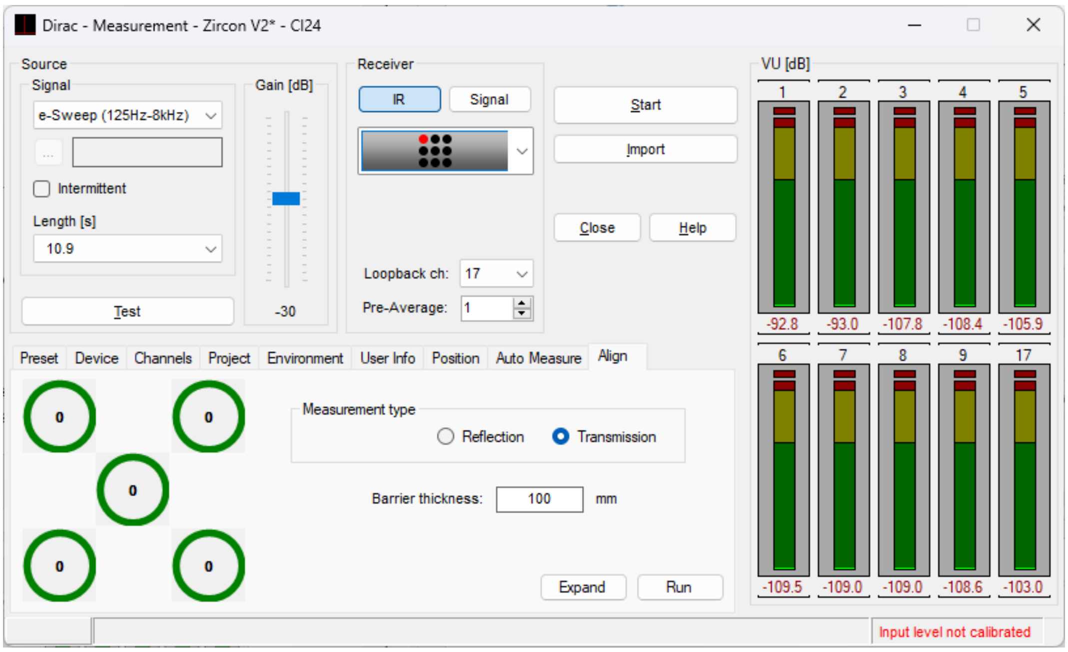
4.1.1 Introduction

Reference measurements must be repeated for each measurement session, or when measurement conditions such as temperature or relative humidity have changed significantly since the previous *free-field* measurements.

1. Connect the **CI24** to mains power, the laptop, the **LS24** and the **MA24** and turn it on.
2. Wait at least 11 s (see section 3.2) and then start the Zircon software.
3. Open the **Measurement** window and, if applicable, on the **Preset** tab, load the **Zircon** setup.

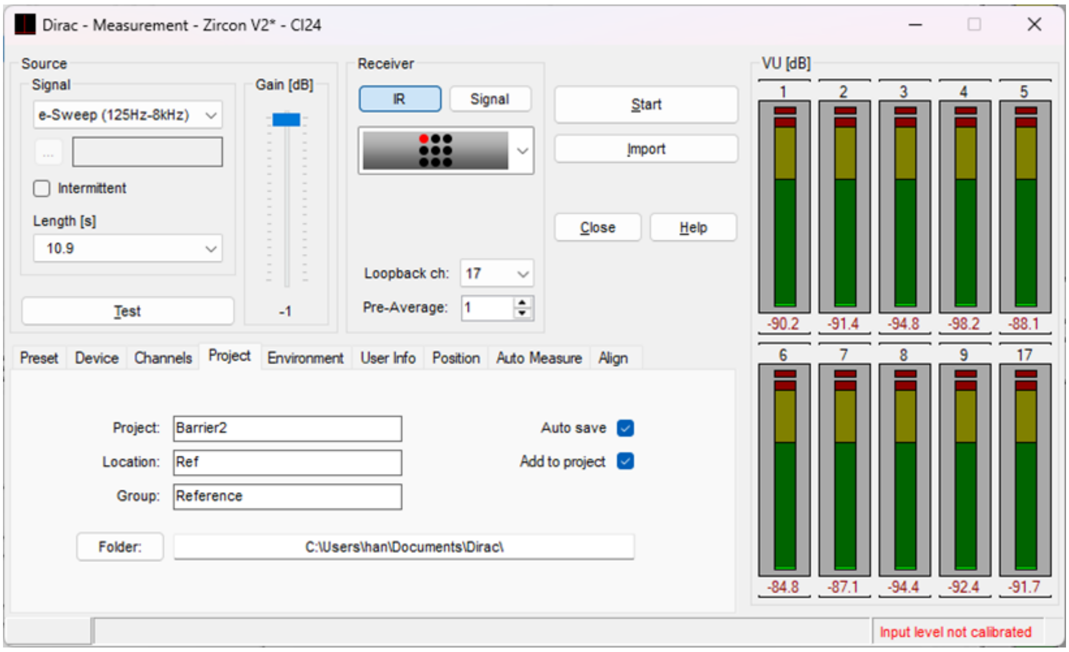
4.1.2 Alignment (free-field)

1. Place the **LS24** and **MA24** on their tripods, at least 2 m away from the NRD and any object potentially causing substantial parasitic reflections.
2. Place the **LS24** visually perpendicular to the **MA24** such that the loudspeaker grille center has a distance of roughly 1.25 m + the barrier thickness to the center **MA24** microphone capsule (#5).
3. Select the array from the Receiver dropdown.
4. On the **Align** tab, select Measurement type **Transmission** (for SI measurements), enter the barrier thickness and then click the Run button.
5. Adjust the **LS24** position to get 5 green circles and click the Stop button.



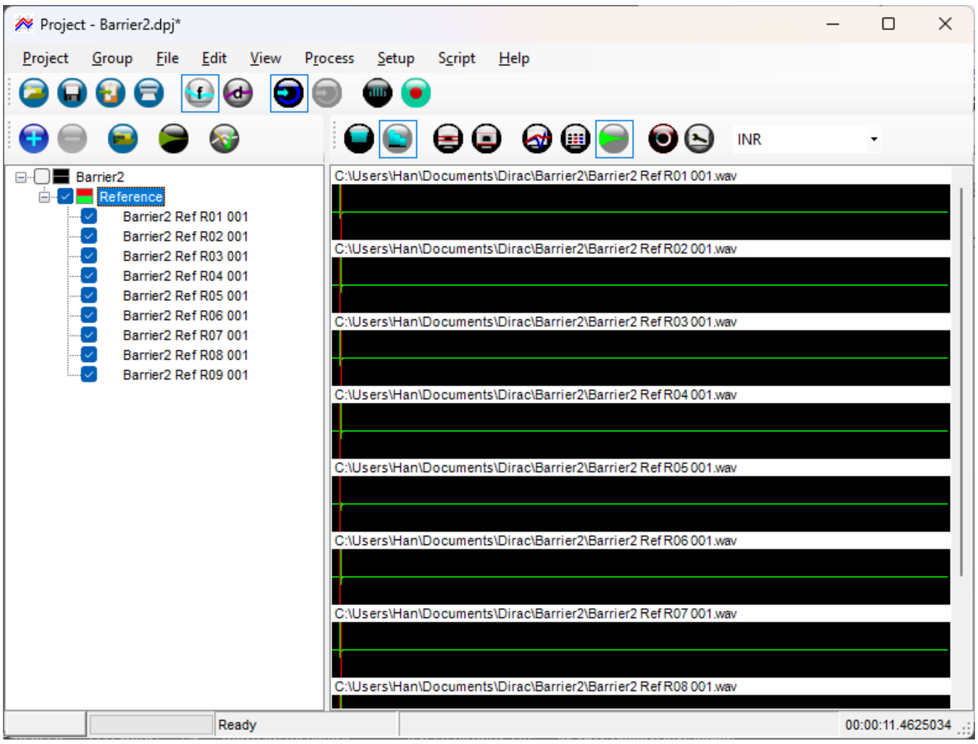
4.1.3 Measurement (free-field)

1. Fill out the **Project** tab. Measured files will be saved in the entered folder. In this example, Autoname is set to include the Project name (*Barrier2*), the Location name (reference *Ref*) and the Receiver/microphone number (*R0n*) in the file names.



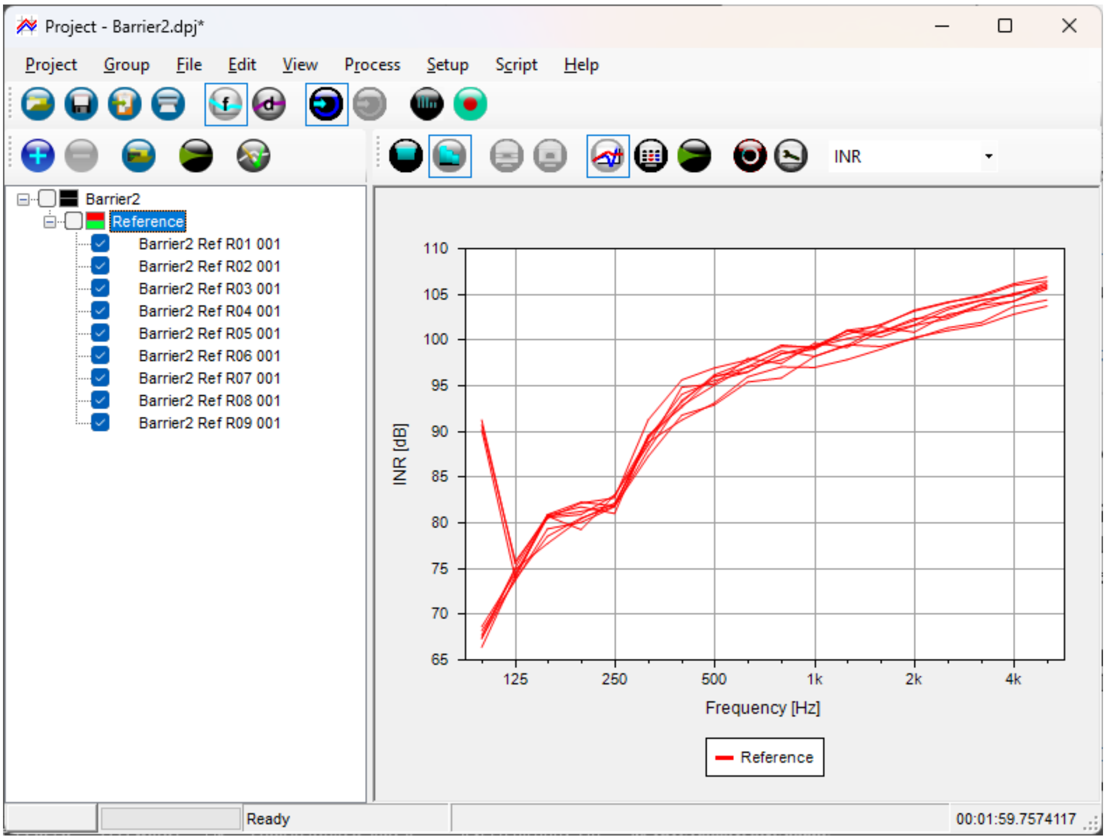
2. Set the sound level well above the background noise level.

3. Click the Start button to perform the measurement.



4.1.4 Validation (free-field)

1. Select the ***Graph*** view.
2. Select parameter **INR** and wait for the INR curves to appear.
3. If necessary, repeat the measurement with a corrected setup and/or under improved conditions, such as an increased Source Signal Gain or Receiver Pre-Average value, set in the **Measurement** window, until the INR values are good or optimal.



4.2 NRD Measurements

This part of the procedure must be executed for each measurement position at the NRD. In particular, in front of an NRD 'element' and an NRD 'post'.

4.2.1 Alignment (NRD)

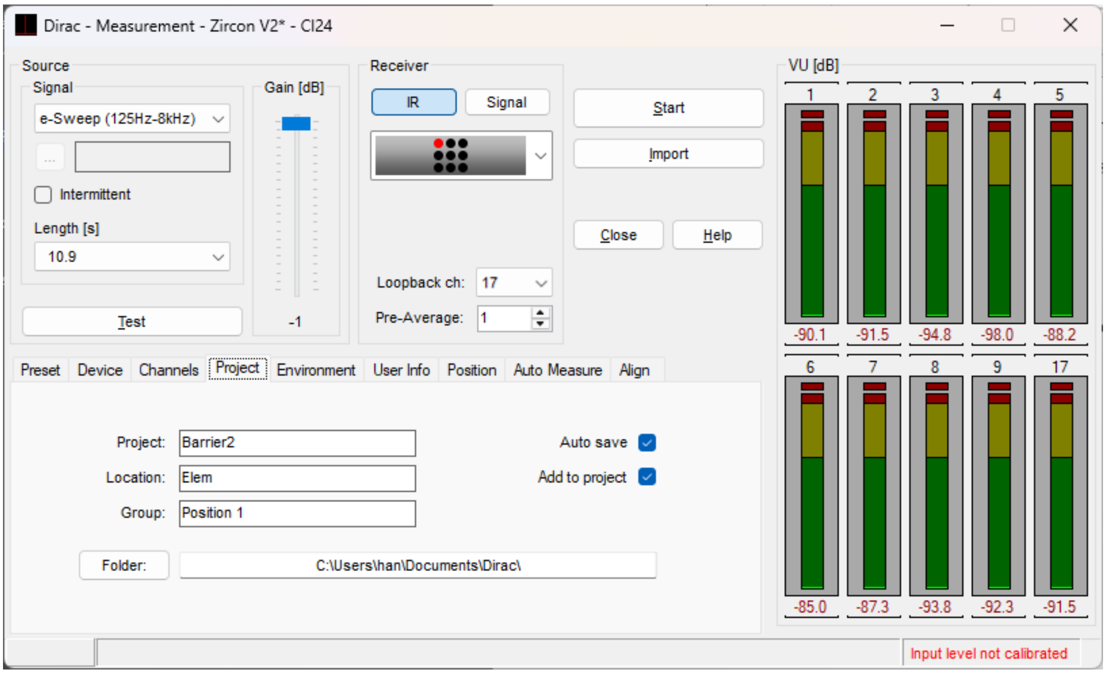
1. Move the **MA24** to the correct position in front of the NRD and align it with the *reference plane*, ensuring a distance of 25 cm between the center microphone and this plane. Use can be made of the spacers in the corners.

With sound insulation measurements, the Zircon software real-time aligner, described in section 4.1.2, cannot normally be used to align the **LS24** on one side of this NRD with the **MA24** on the other side. In this case, the use of mechanical tools for the correct placement of the **LS24** is assumed.

2. Place the **LS24** perpendicular to the **MA24** on the other side of the NRD such that the loudspeaker grille center has a distance of 99 cm to the reference plane.

4.2.2 Measurement (NRD)

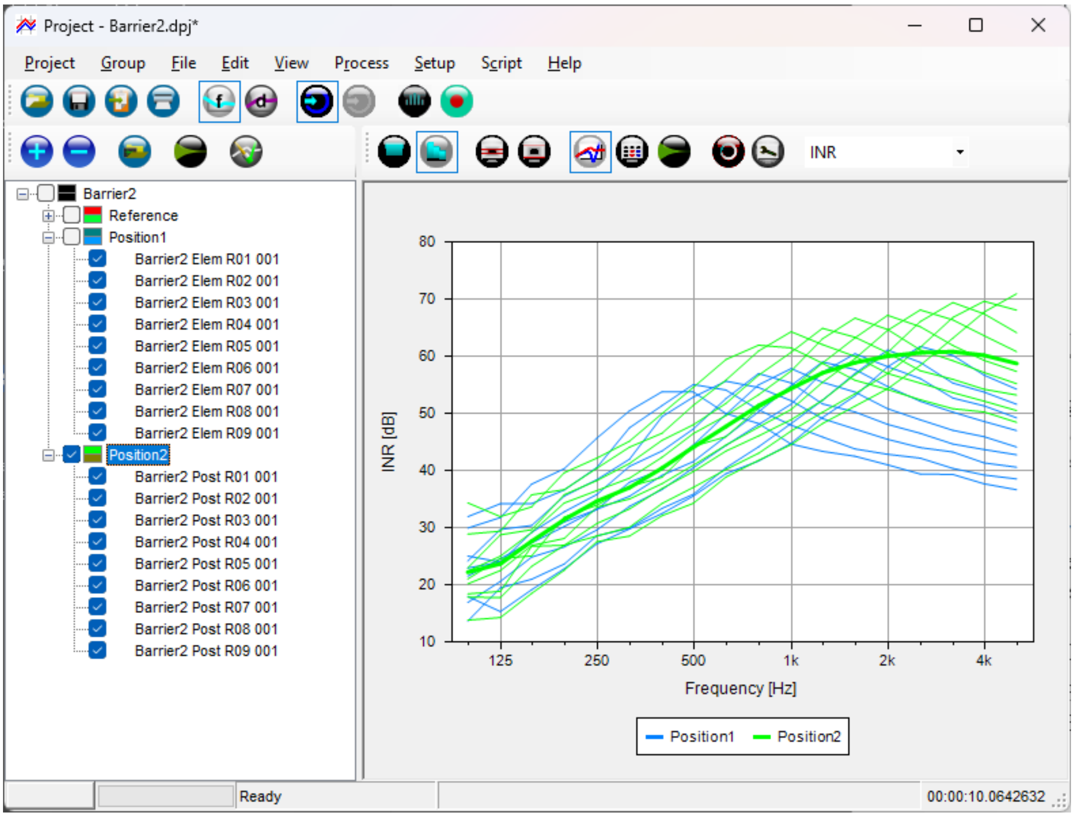
1. Fill out the **Project** tab. Measured files will be saved in the entered folder. In this example, Autoname is set to include the Project name (*Barrier2*), the Location name (transmission position 1 *Elem* or position 2 *Post*) and the Receiver/microphone number (*R0n*) in the file names.



2. Set the Gain slider at the same value as with the reference measurement.
3. Click the Start button to perform the measurement, resulting in 9 impulse responses.

4.2.3 Validation (NRD)

1. In Graph view, select parameter **INR** and wait for the curves to appear.
2. If necessary, repeat the measurement under improved conditions for better INR values.

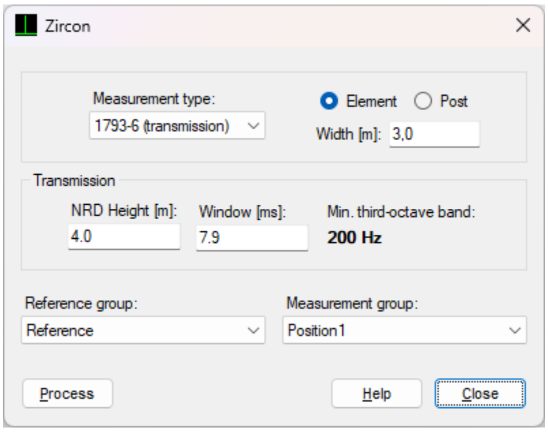


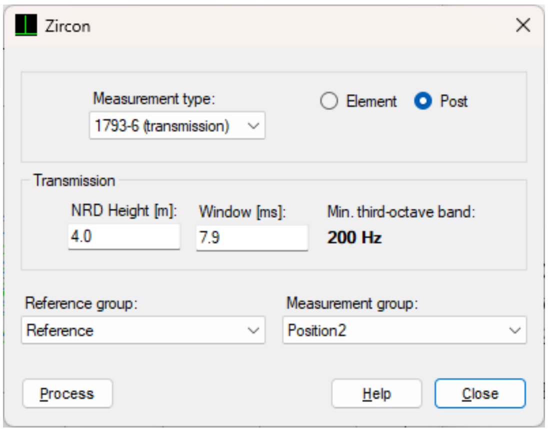
With high sound insulation, it may be difficult to achieve INR values exceeding 25 dB. If this happens to be the case, the next best goal is to get an SNR (S/N) value exceeding 10 dB (see section 4.3.1).

4.3 Processing

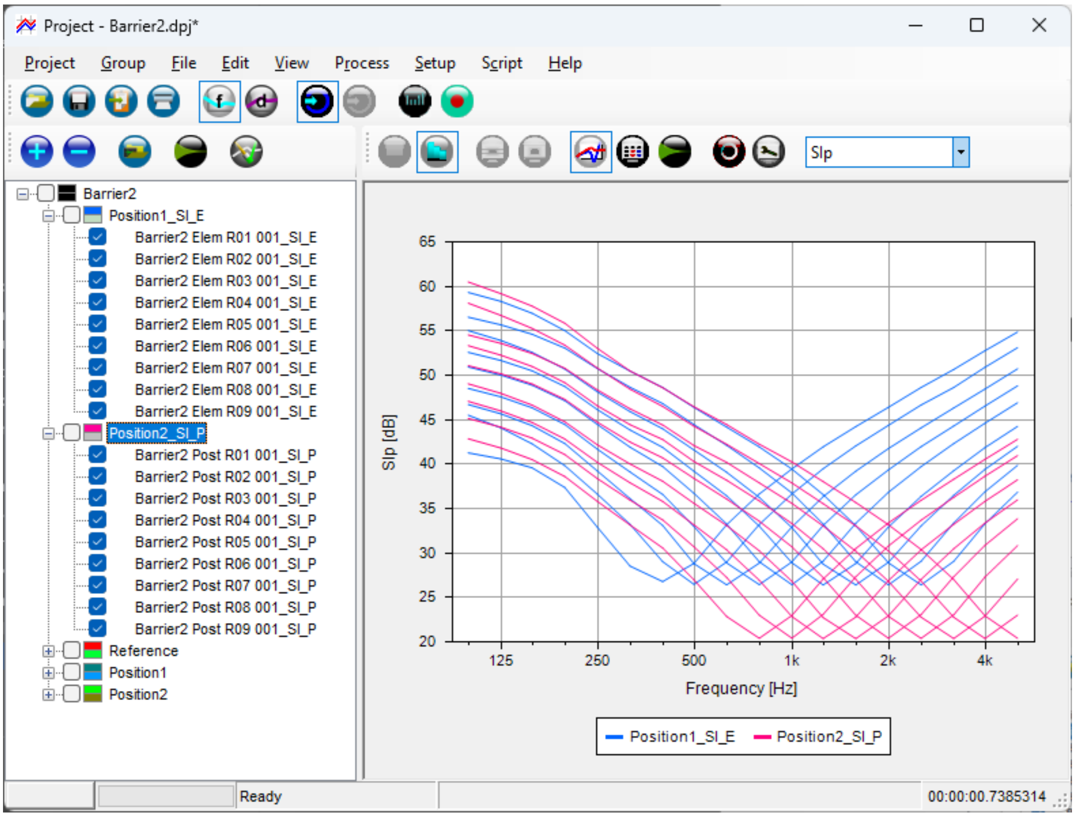
In this example, the NRD is measured at 2 positions, ‘Elem’ and ‘Post’, but normally more measurement grid positions apply.

1. In the Project window, from the **Process** menu, select **Zircon**.
2. Fill out the **Zircon** dialog box, entering the name of the Reference group and the Element group. Set the proper *NRD height* and optionally the Adrienne *Window* width.
3. Click **Process**, resulting in a group with the name of the processed measurement group, with the postfix “_SI_E” attached, and containing 9 new 2-channel SI files with the name of the processed files, also with postfix “_SI_E”.
4. Repeat 2 and 3 for the ‘post’ measurements. This will result in a new group with 9 files, all having the postfix “_SE_P”.

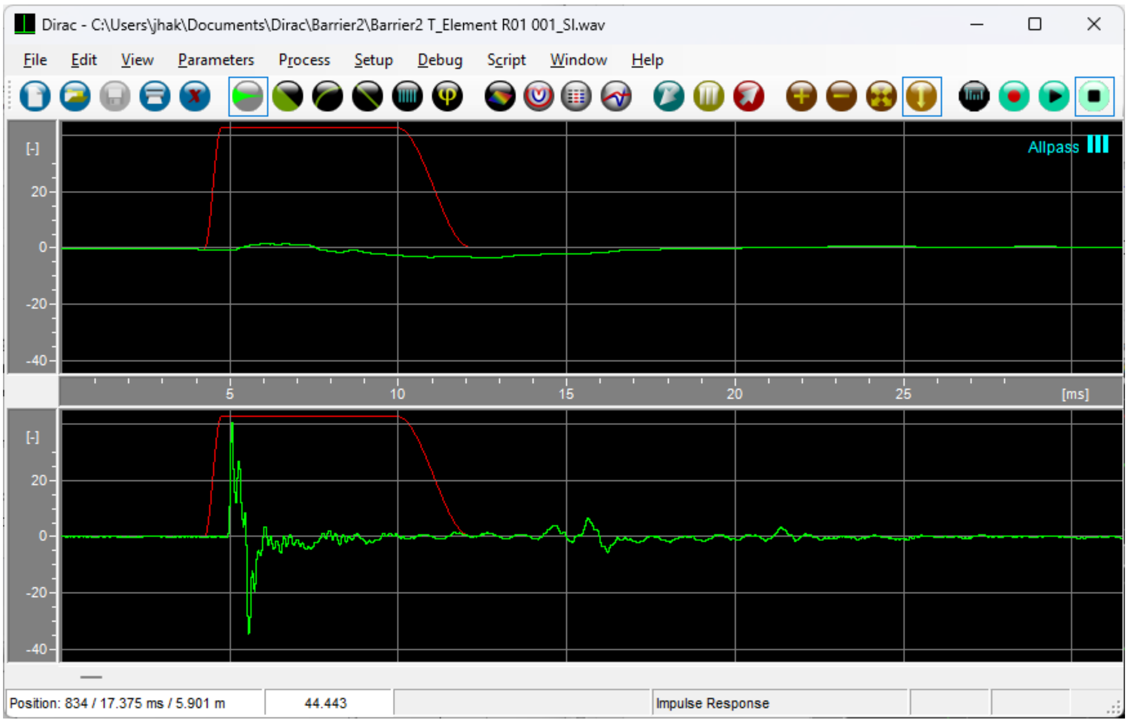




5. The SI files contain the transmitted sound in channel 1 and the reference (free-field or incident) sound in channel 2, from which the partial Sound Insulation Index (SIp) can be calculated.

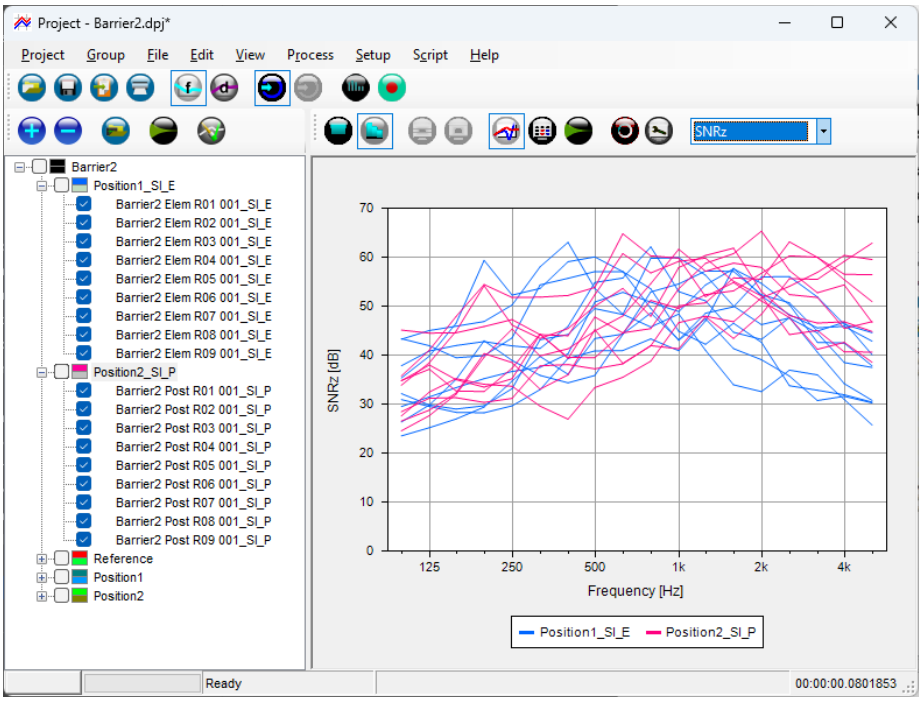


6. The figure below shows a single SI file in Impulse Response view, showing the Adrienne windows in red.



4.3.1 Validation of the calculated SI-files

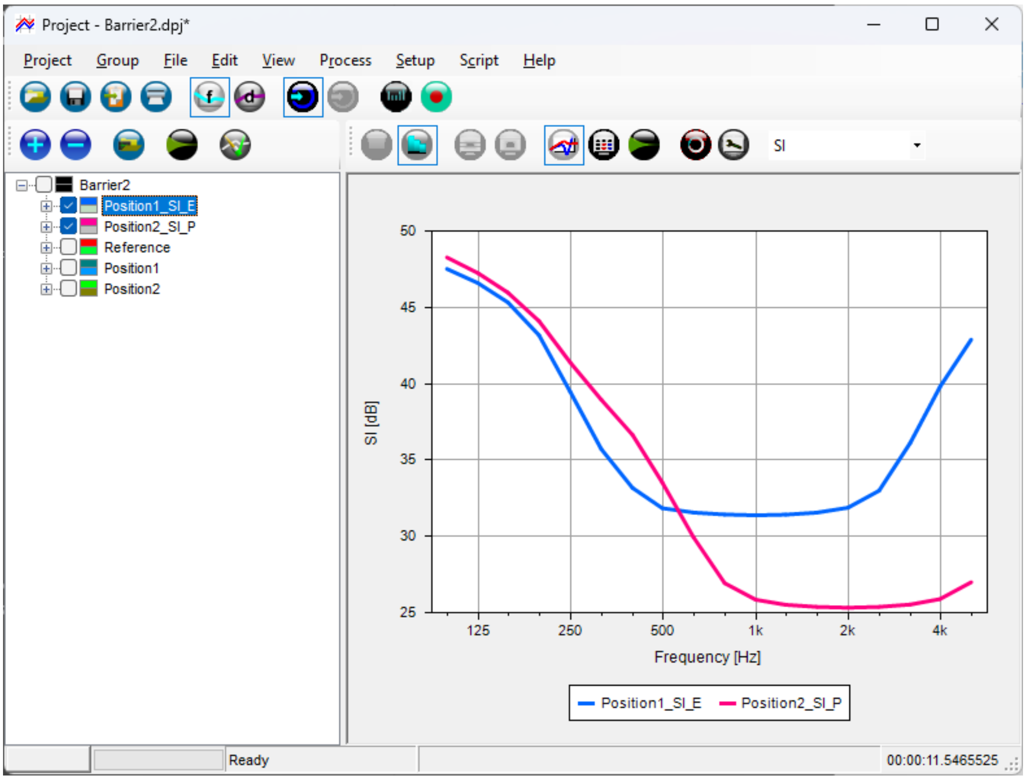
1. In the **Properties** dialog select parameter Zircon/**SNRz**. This is the SNR in the context of Zircon measurements, not to be confused with the conventional SNR.
2. All *SNRz* values of the SI files should **exceed 10 dB**. If this is not met, the measurement should be repeated at a lower background noise level, or the signal level should be increased, if possible.



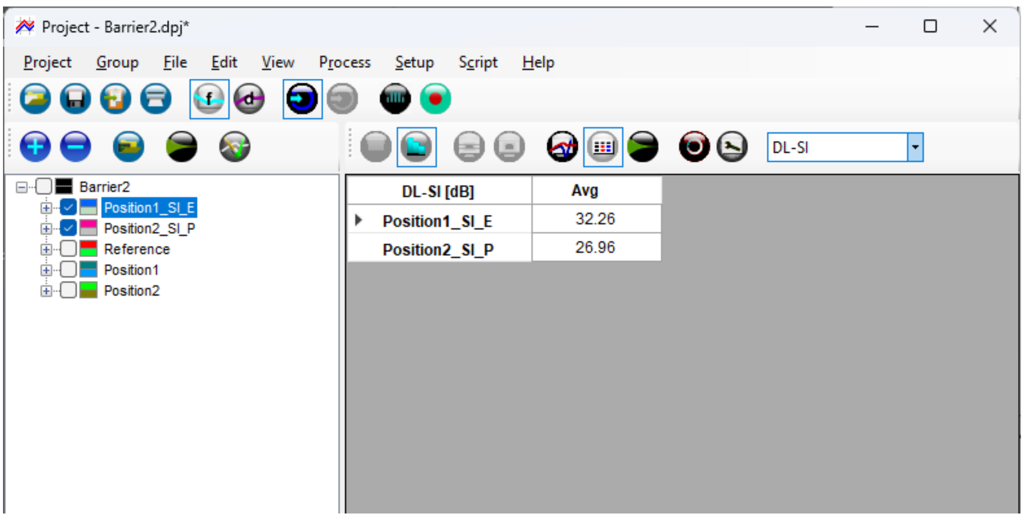
Note
For each SNRz value below 10 dB, the corresponding SI value should be interpreted as a lower limit for the actual SI value (the actual SI is at least the result obtained).

4.3.2 Results

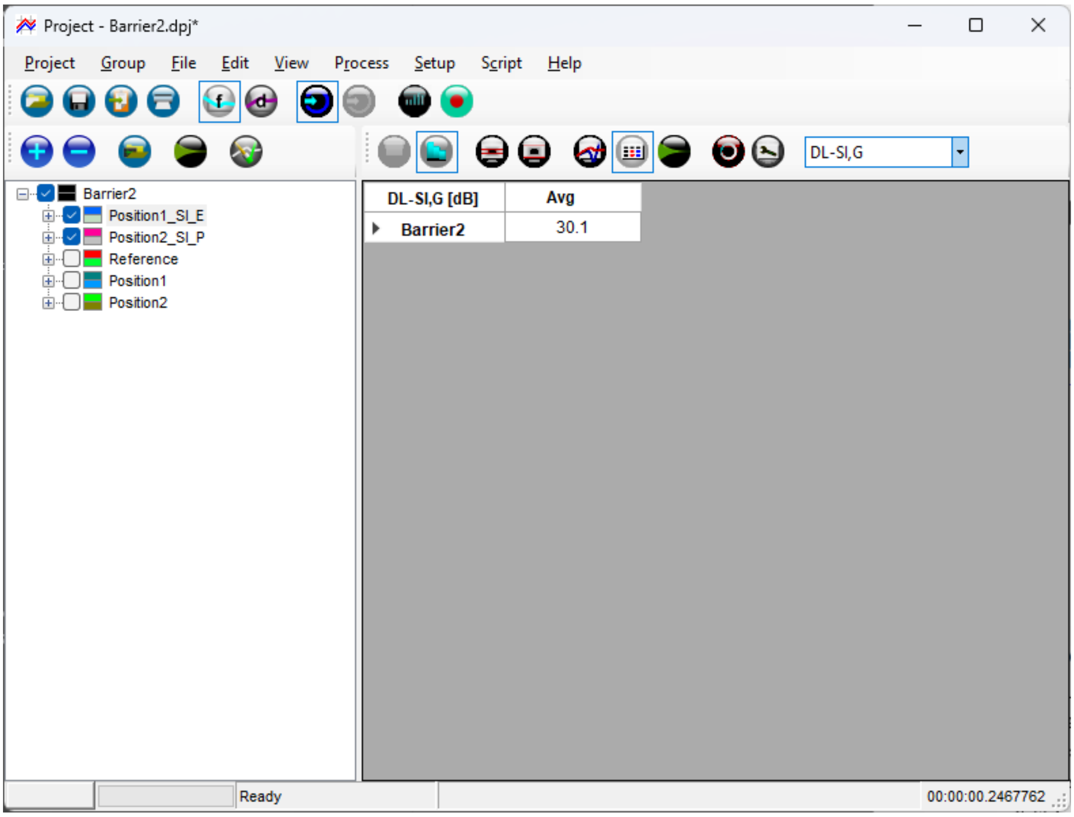
1. Check the Group level boxes to view the Sound Insulation Index (SI) for each group.



2. Check processed groups with a '_SI_E' or '_SE_P' postfix to view their single number rating of sound insulation (DL_{SI}).



3. Check a processed *Element* group (_SI_E postfix) and a *Post* group (_SI_P postfix). Also check the project level node to view the global single number rating of sound insulation $DL_{SI,G}$.



5 Measurement Uncertainties

For measurement uncertainties of *SI(j)* at each third octave frequency band j and DL_{SI} [dB], use the standard deviations of tables C.1 and C.2 in EN 1793-6:2018 after the QUIESST project. These values represent estimations and are based on the median *standard deviations of reproducibility* and a Gaussian distribution with a coverage factor of 1.96 or 95 % confidence level.

6 References

Standards

[1] EN 1793-3:1997: Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 3: Normalized traffic noise spectrum

[2] EN 1793-6:2018: 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

[3] EN 16272-3-2:2023: Railway applications - Infrastructure - Noise barriers and related devices acting on airborne sound propagation - Test method for determining the acoustic performance - Part 3-2: Normalized railway noise spectrum and single number ratings for direct sound field applications

[4] EN 16272-6:2023: Railway applications - Infrastructure - Noise barriers and related devices acting on airborne sound propagation - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - Airborne sound insulation under direct sound field conditions

Papers

[5] M. Garai, P. Guidorzi, “Sound reflection measurements on noise barriers in critical conditions”, accepted for the publication on Building and Environment, (2015). DOI: http://dx.doi.org/10.1016/j.buildenv.2015.06.023

[6] M. Garai, E. Schoen, G. Behler, B. Bragado, M. Chudalla, M. Conter, J. Defrance, P. Demizieux, C. Glorieux, P. Guidorzi, “Repeatability and reproducibility of in situ measurements of sound reflection and airborne sound insulation index of noise barriers”, Acta Acustica united with Acustica, 100, 1186-1201, (2014). DOI: http://dx.doi.org/10.3813/AAA.918797

[7] P. Guidorzi, M. Garai, “Advancements in sound reflection and airborne sound insulation measurement on noise barriers”, Open Journal of Acoustics, 3(2A), 25-38, (2013). DOI: http://dx.doi.org/10.4236/oja.2013.32A004

[8] QUIESST. (2012). Inter-laboratory test to assess the uncertainty of the new measurement methods for determining the in situ values of sound reflection and airborne sound insulation of noise reducing devices under direct sound field conditions, Università di Bologna, https://www.unibo.it/en/research/projects-and-initiatives/Unibo-Projects-under-7th-Framework-Programme/cooperation-1/transport/quiesst

Technical Notes

[9] TN013 - Zircon V2 - Usage

[10] TN018 - Zircon - Alignment

[11] TN019 - Zircon - EN1793-4 - EN16272-4 Measurement Procedure - V2.0

[12] TN020 - Zircon - EN1793-5 - EN16272-5 Measurement Procedure - V2.0

Product Datasheets

[13] DIRAC 7 - HBK Type 7841 - bp1974

For technical notes and product datasheets, visit Acoustics Engineering:

https://acoustics-engineering.com/index.html

For the DIRAC product datasheet, visit Hottinger Brüel & Kjær:

https://www.bksv.com/-/media/literature/Product-Data/bp1974.ashx

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