Mezzo I-Track System Kit

User Guide – v1.5.0

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1 Introduction

Congratulations on your purchase of the Mezzo I-Track system kit. This kit along with the Mezzo Sound Intensity Probe provides an innovative and cost-effective solution for sound intensity imagery. More than just an imaging system, the I-Track system provides a very accurate sound power measurement system.

The current user's manual describes the Mezzo I-Track kit and software. For more information on the Mezzo Sound Intensity Probe, refer to the Mezzo Sound Intensity Probe with Mezzo Intensity Analyzer module user guide.

2 Specifications

Included Accessories

Component	Description
Digital Camera	1600x1200, USB 2.0, CMOS Color Digital Camera, Optically Corrected wide-angle lens Manual Iris and Focus, FOV 120° (Wide mode), 82° (Zoom mode)
Tracking Pad	170x170 mm, acoustically transparent
Tracking Pad Holder	Plastic L-shaped tracking pad holder, 85x63mm
USB Cable	3 m USB 2.0 cable with Mini B connector
Case	Plastic transport case, 450x395x115mm (17.75x15.5x4.5")

Module Specifications

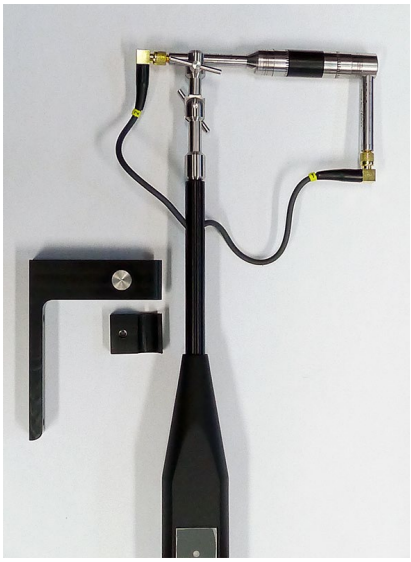
Specifications	
Spectrums	1/1 Octave , 1/3 Octave, 1/24 Octave, or FFT (user defined bandwidth to fit microphone spacer, from 10Hz to 20kHz)
Frequency Weightings	A, C and Z
Metrics (Spectrum and Global levels)	Pressure, Intensity, PI index (F3), P|I| index (F2), Extraneous Sources index (F3-F2), Sound Power
Instant Rate	Variable from 50ms to 1s
Phase Mismatch Compensation	FIR-IIR phase correction filters
Environmental Compensation	Compensation for Atmospheric Pressure, Temperature and Humidity
Tracking	Optical Tracking using digital camera, 6 Degrees of freedom (DOF), Real-World units
Camera Resolution	800 x 600
Measurement Plane	6 DOF Position and Area automatically computed using 3D data points
Interpolation	Constrained Delaunay Triangulation
Averaging	2D Gaussian averaging (user defined size from 0 to 1m radius)
Standard Compliance	IEC 61043 (1993)

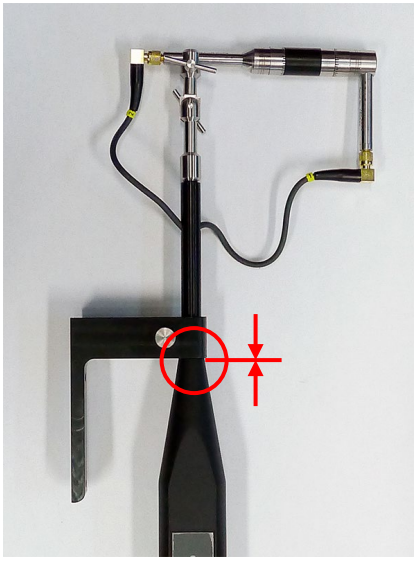
Computer Requirements

Item	Minimum Requirements
Operating System	Windows XP SP3, Windows Vista, Windows 7, Windows 8
CPU	Dual-Core at 2.4 GHz
Memory	2 GB RAM
Hard drive	300 MB free hard disk space
Port	USB 2.0
Display resolution	800 x 600

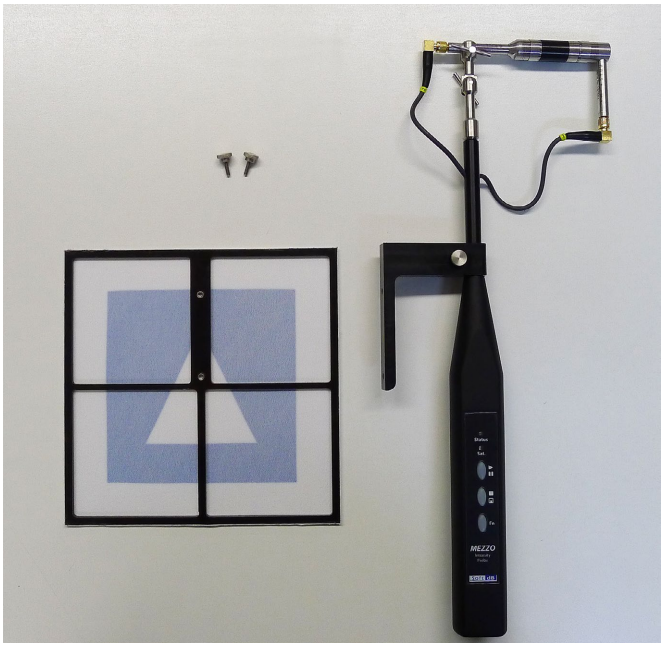
3 Setting Up the Tracking Pad

1) Install the tracking pad holder onto the Mezzo Sound Intensity Probe;
2) Make sure the holder is close fitted to the handle body;

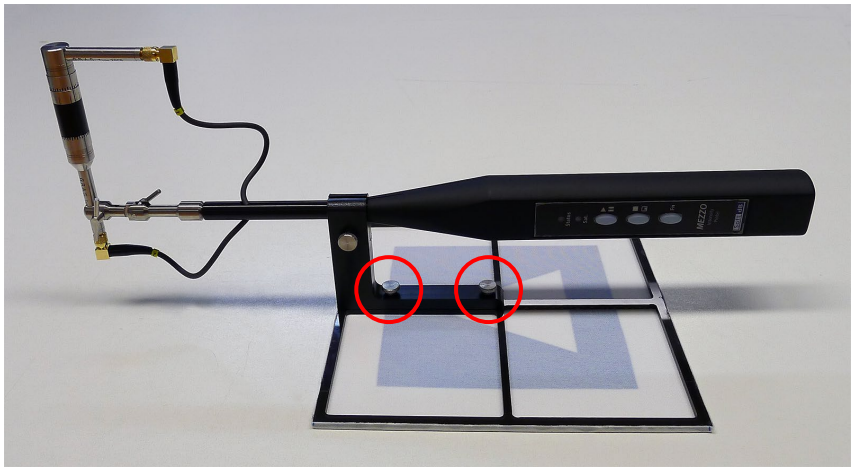




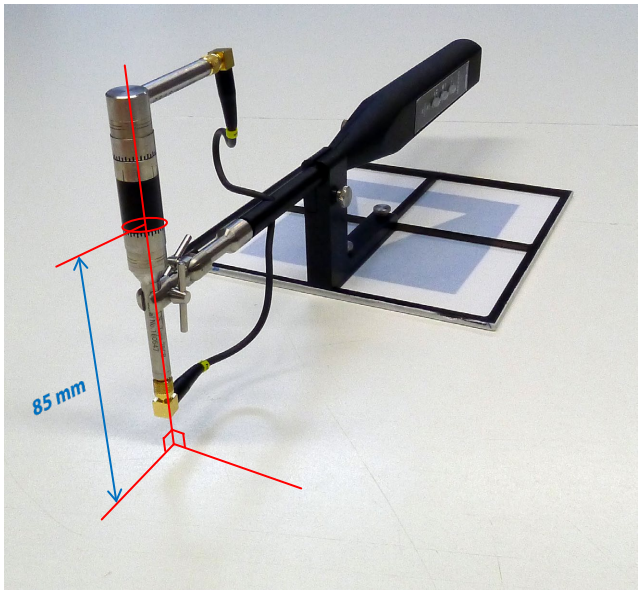
3) Take the tracking pad and place it face down on a table. Make sure the table is clean to avoid staining the fabric;



4) Fasten the tracking pad to the holder using the two thumb screws;



5) Adjust the position of microphone 2, it should be 85mm from the table and the probe reference axis should be perpendicular to the table surface;



4 Setting Up the Digital Camera

1) Install the digital camera on a tripod and position it towards the device under test

* Tripod not included

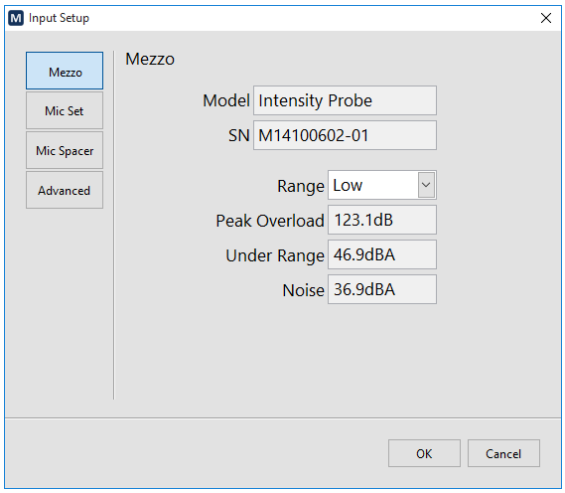
2) Connect the camera using the USB cable
3) Locate the control rings for Iris and Focus, they will be useful during tracking setup (refer to section 5.4, Setting Up Probe Tracking and Background Picture, p.13);

5 Setting Up the Mezzo I-Track Module

5.1 Setting Up Input

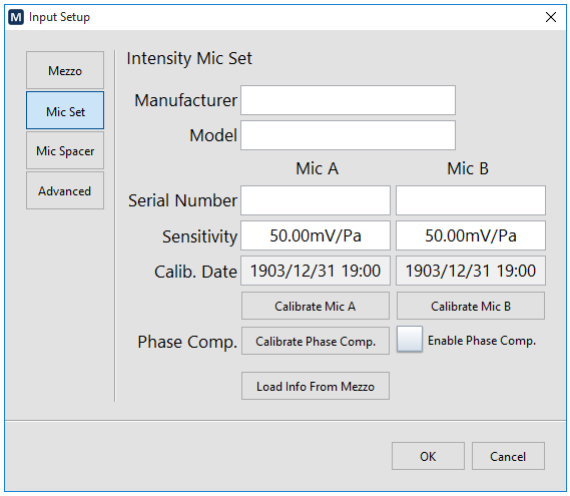
Click on the

button from the "Setup" tab to enter the input setup:

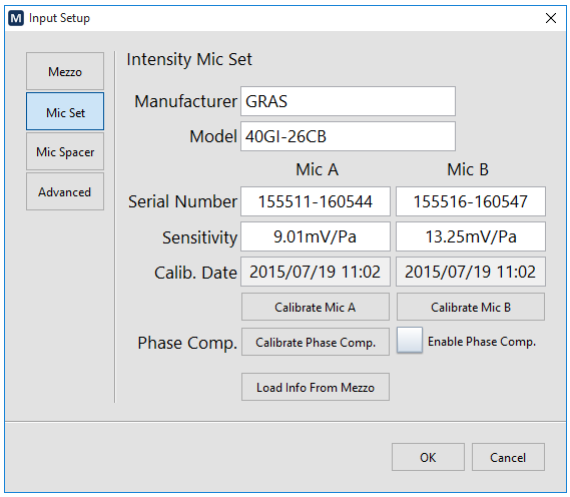


5.1.1 Retrieving Microphone Set Information from Mezzo Sound Intensity Probe

Click on the "Mic Set" button:

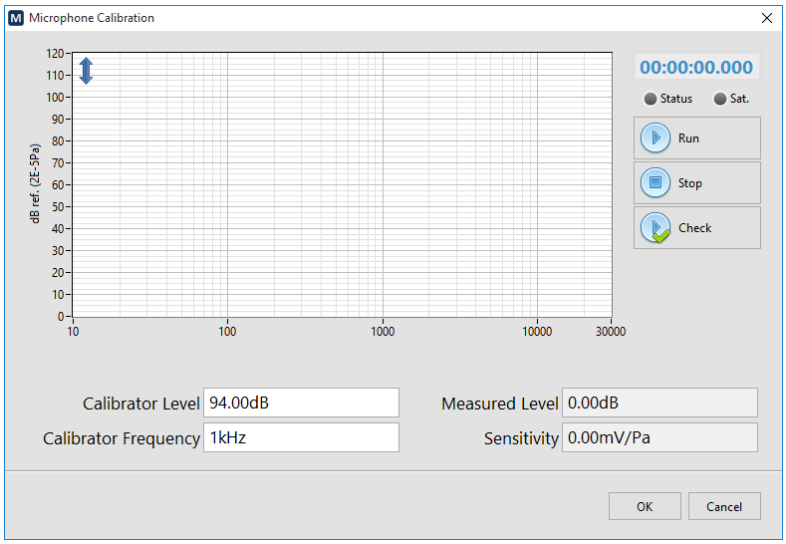


Click on the "Load Info From Mezzo" to load the calibration information from the Mezzo Sound Intensity Probe:



5.1.2 Calibrating each microphone

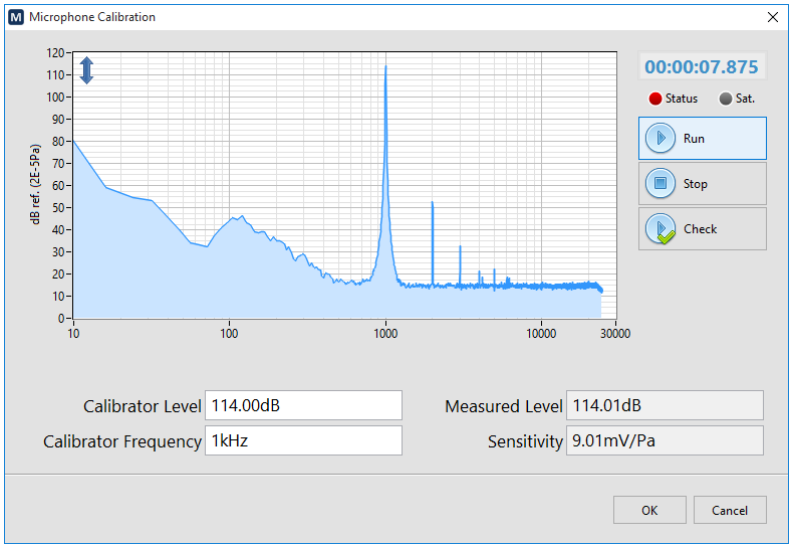
Click on the "Calibrate Mic A" button:



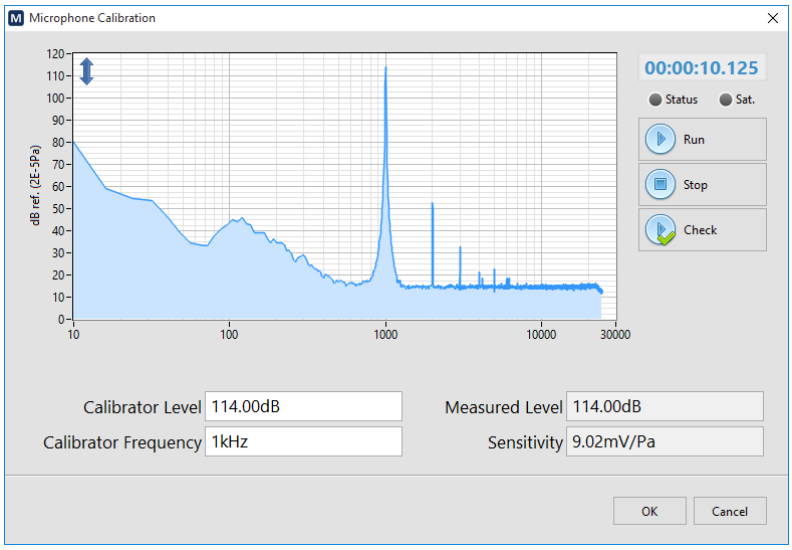
Enter the calibrator level and frequency.

Insert the microphone in the calibrator:

Turn ON the calibrator and click on “Run”



Click on “Stop” when level is stable

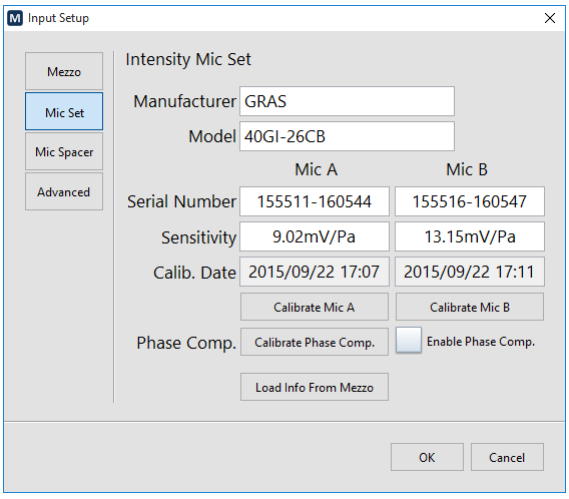


The calibration function will adjust the sensitivity according to the measured level and the calibrator level at the calibrator frequency.

Click OK to accept.

Repeat for the second microphone.

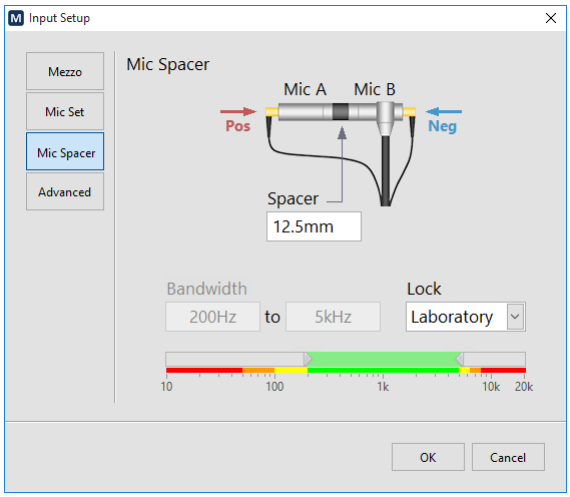
Note: The calibration level can be checked by clicking “Check” instead of “Run”. This allows to measure the calibration level without changing the sensitivity. It is recommended to check the calibration after each measurement campaign to validate the correct operation of the probe.



Click on the “Enable Phase Comp.” button. It is recommended to enable the phase mismatch compensation to increase the Pressure Residual Intensity Index and thus increase the dynamic capability of the probe.

5.1.3 Selecting the Microphone Spacer

Click on the "Mic Spacer" button.



The microphone spacer is an important part of the sound intensity measuring technique using a pair of microphones. Separated by a distance, the two microphones can measure the sound particle velocity by using the pressure gradient. However for this estimation to be right, the separation distance must be adapted to the wavelength. The following table shows the different spacers and their associated bandwidth relative to the degree of precision:

	Laboratory	Expertise	Control
Probe Intensity Response (H-F Limit)	< 1 dB	< 2 dB	< 3 dB
Pressure Residual Intensity Index (L-F. limit)	> 15 dB	> 12 dB	> 9 dB
12.5 mm	200Hz – 5kHz	100Hz – 6.3kHz	50Hz – 8kHz
25 mm	100Hz – 2.5kHz	50Hz – 3.15kHz	25Hz – 4kHz
50 mm	50Hz – 1.25kHz	25Hz – 1.6kHz	12.5Hz – 2kHz

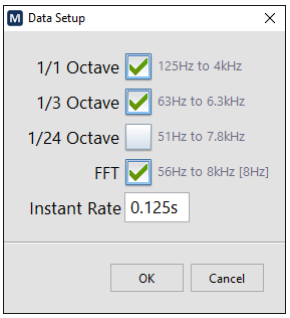
Only the selected bandwidth is considered during the measurement. Hence, only the bands located in the selected spectrum region will be calculated. Also, the Global levels (A, C and Z) will be computed on this reduced bandwidth using a band-pass filter.

To cover a wider range, it is recommended to perform two measurements using two different spacers.

5.2 Selecting Data Type

Click on the

button to select the spectrum type:



Use the spectrum drop-down list to select from the available spectrum types (1/1, 1/3, 1/24 Octave or FFT). The lower indicator shows the resulting bandwidth. Note that the available bandwidth is affected by the microphone spacer bandwidth. Refer to section 5.1.3, Selecting the Microphone Spacer, p. 10 for more information.

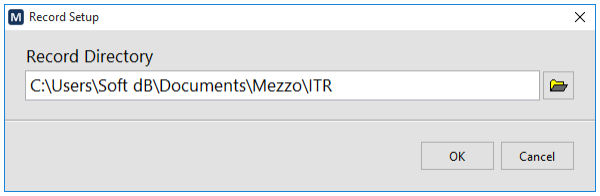
The instant rate is the live data rate. This rate only affects the display rate with the fractional octave spectrums (1/1, 1/3, and 1/24 octave). When using the FFT spectrum, this parameter has also an effect on the frequency definition of the spectrum using the following relationship:

$$dF\ (Hz) = \frac{48832\ (Hz)}{[48832\ (Hz) \times Instant\ Rate\ (s)]}$$

5.3 Selecting the Record Directory

Click the

button from the “Setup” tab:



The I-Track module automatically saves data to a measurement file when the measurement starts, so there is no need to worry about saving afterwards.

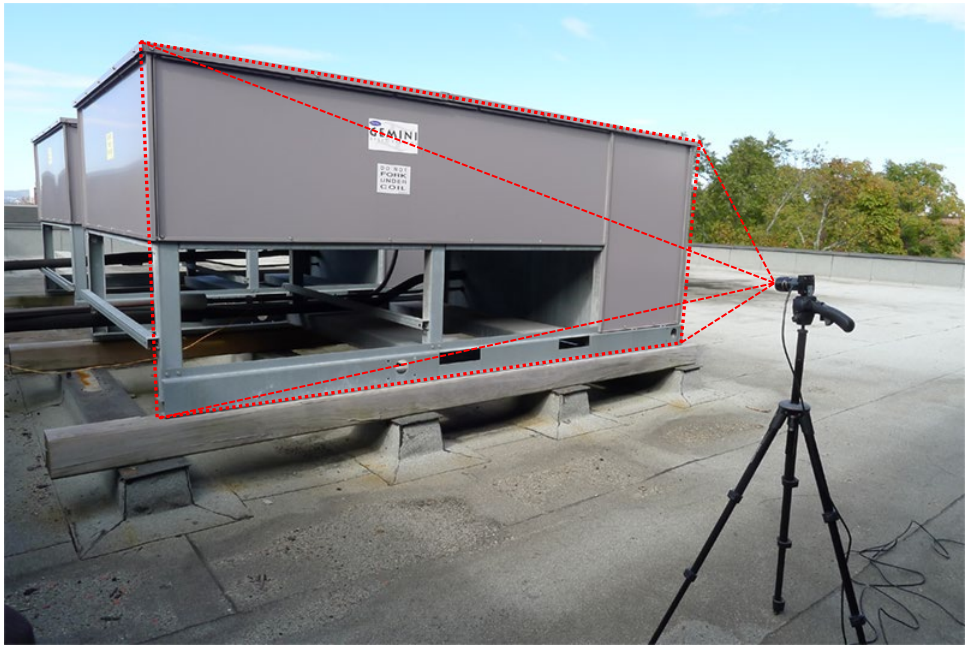
Browse to the desired record directory where measurement files will be saved. The recorded files will have a 0001.itr pattern. It is recommended to create a record directory for each measurement campaign.

The default record directory is C:\Users\CurrentUser\Documents\Mezzo\ITR.

5.4 Setting Up Probe Tracking and Background Picture

5.4.1 Taking a Background Picture

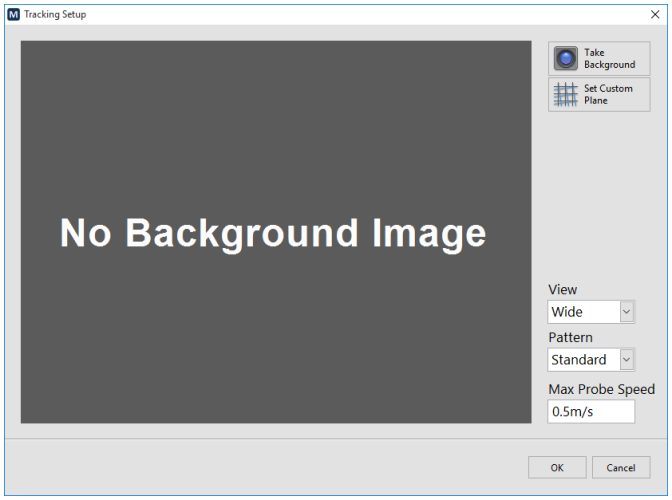
Position the camera at approximately 2 m from the device under test (DUT).

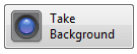


Note that the camera can be closer or farther to view the whole source.

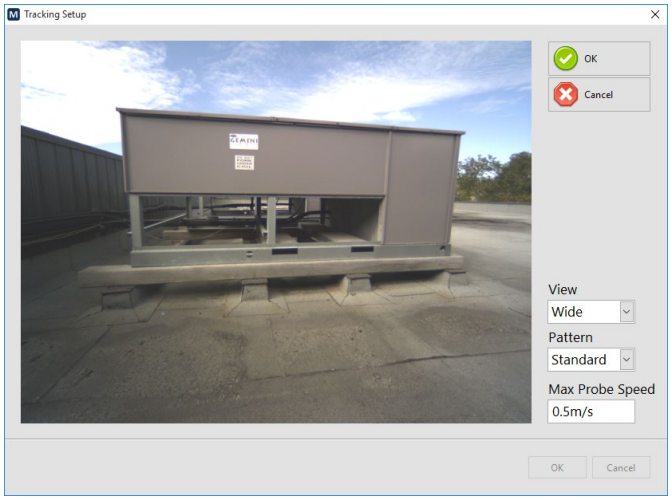
Click the

button from the “Setup” tab to enter the “Tracking Setup” interface:



Click on the 

button to take a background picture:

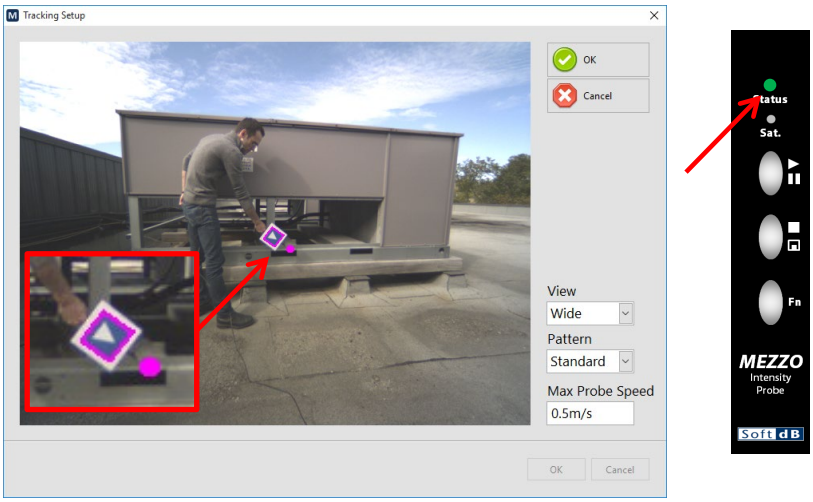


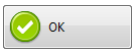
Adjust the iris opening on the camera lens by loosening the thumbscrew and rotating the "open-close" ring until the lighting on the image is appropriate. Usually the iris should be fully open but there might be situations which require less light such as a very bright sunny day. Secure the thumbscrew when the adjustment is performed.

Adjust the focus by loosening the thumbscrew and rotating the "far-near" ring until the image is sharp. This step is important as it will affect the probe tracking. The sharper the image is, the best it will perform.

5.4.2 Testing Probe Tracking

While taking the background picture you can test the probe detection by placing the probe in the measurement plane just like in measurement mode. If the probe is detected, it will be displayed with a magenta square around the pattern and a magenta dot on the microphone position. Also, the status light on the probe will be green:



When satisfied with the background image, click on the  button.

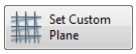
Click “OK”.

Note: Two view settings are available “wide-angle” and “zoom”. The “wide” mode is used most of the time as it allows to place the camera close to the device under test. The “zoom” mode is used when it’s required to place the camera farther from the device under test.

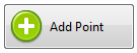
Note : The “Max Probe Speed” allows to define a maximum scanning speed on the probe. The default maximum speed is 0.5m/s which is defined in ISO 9614-2.

5.4.3 Defining a Custom Measurement Surface

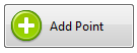
The I-Track system can determine the measurement plane automatically at the end of the measurement using the cloud of measurement points. However, it's possible to determine the plane surface manually. If you don't want to use a manually defined plane, skip these steps.

1) Click on the 

button to start the process;
2) Position the probe at the origin of the plane (0,0,0)

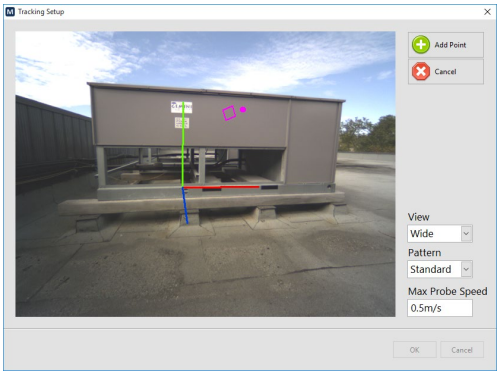
3) Click the 

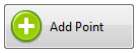
button on the interface or the button on the probe to accept and go to the next step;
4) Position the probe on a second point along the horizontal axis (X axis):

5) Click the 

button on the interface or the button on the probe to accept and go to the next step;

6) Position the probe on a third point on the plane to define the vertical axis (Y axis):



7) Click the 

button on the interface or the button on the probe to accept the third point.

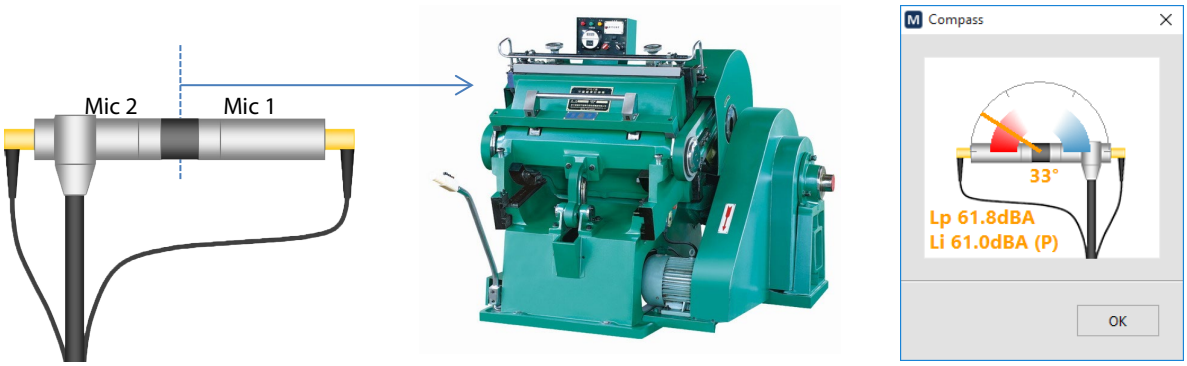
This custom measurement plane will be used to perform the measurement.

6 Performing a Quick Field Check

Click on the

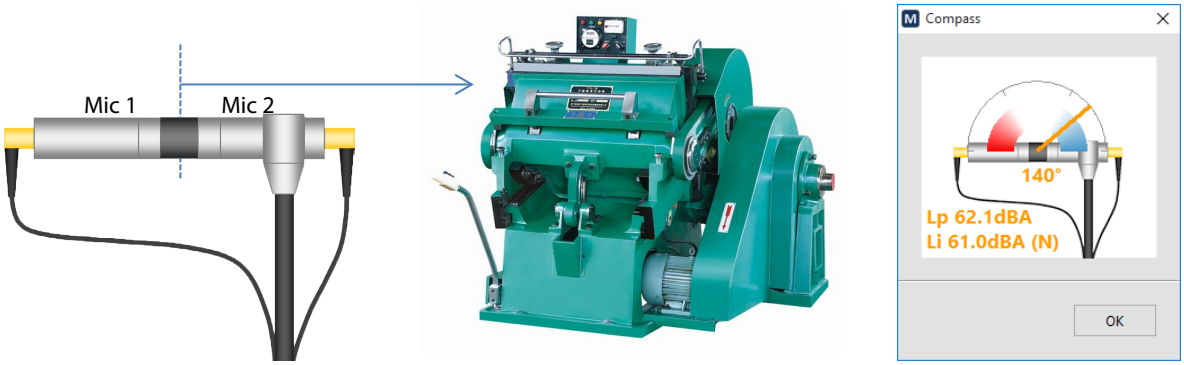
button from the "Tools" tab:

Locate the sound intensity towards the sound source and check the compass indicator:



The compass indicator should be in the red region indicating a PI index inferior to 3 dB and positive intensity.

Locate the sound intensity away from the sound source and check the compass indicator. Be sure to locate the sound probe at the same point. You can use a tripod or a similar object as a reference point.



The compass indicator should be in the blue region indicating a PI index inferior to 3 dB and negative intensity.

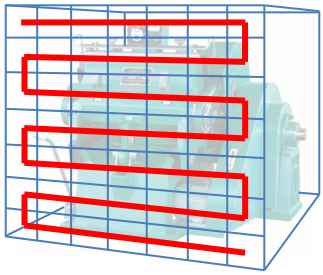
Note that pressure and intensity levels should be very close when pointing towards and away from the source.

7 Performing a Measurement

7.1 Method of Measurement

Sound intensity measurements are performed on an integrating box around the device under test (DUT). Each surface is measured using a scanning technique to measure the sound intensity of this surface. The sound intensity level can then be converted to sound power level using the area of the measuring surface.

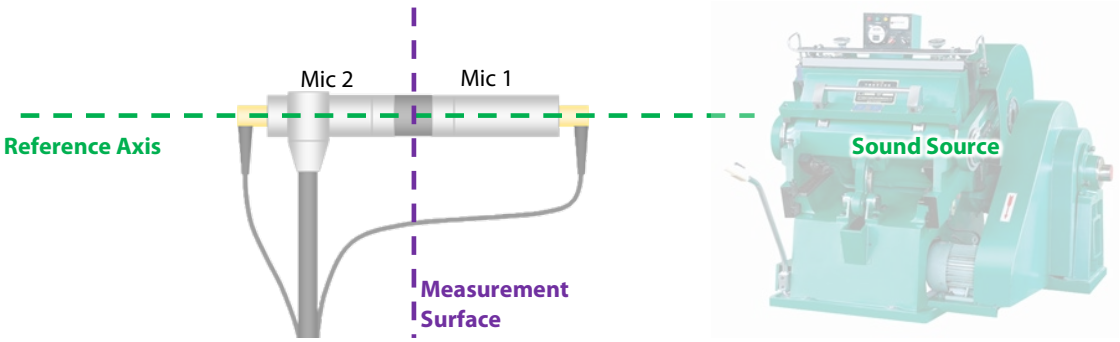
The traditional method requires that the scanning path must be uniformly distributed on the measurement surface and it must be followed with the probe at a constant speed. Great care must be taken to select an appropriate path and measure using a constant speed.



The I-Track system uses direct spatial averaging and does not require to follow a specific path nor does it require a constant scanning speed. However, it's recommended to use a scanning pattern to distribute the points evenly on the surface as it will produce a better looking image and more precise results.

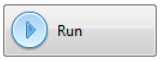
The probe must be held so that:

- The reference axis of the probe is perpendicular to the measurement plane;
- The measurement surface crosses the reference axis of the probe at the reference point of the probe;
- The probe reference direction must be pointing towards the source (into the bounding box).

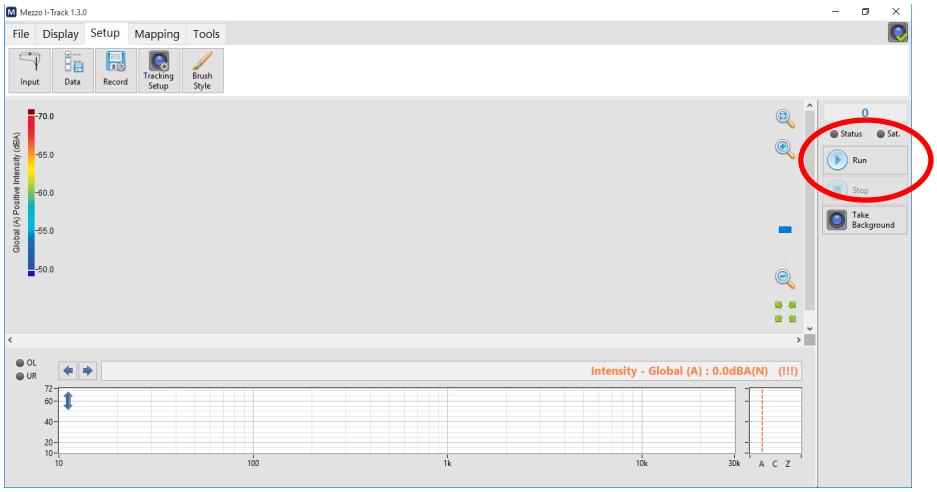


7.2 Step-by-Step Operation

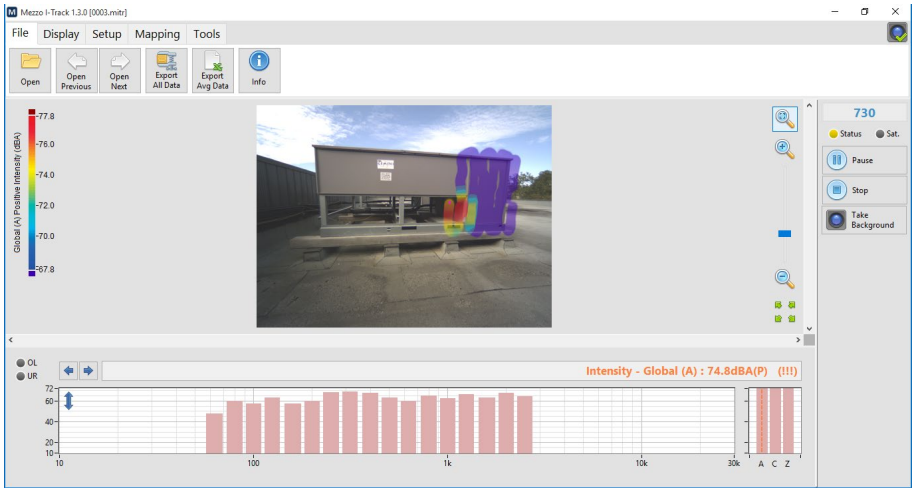
1) Position the probe perpendicularly to the measurement surface.

2) Back to the main interface, click the 

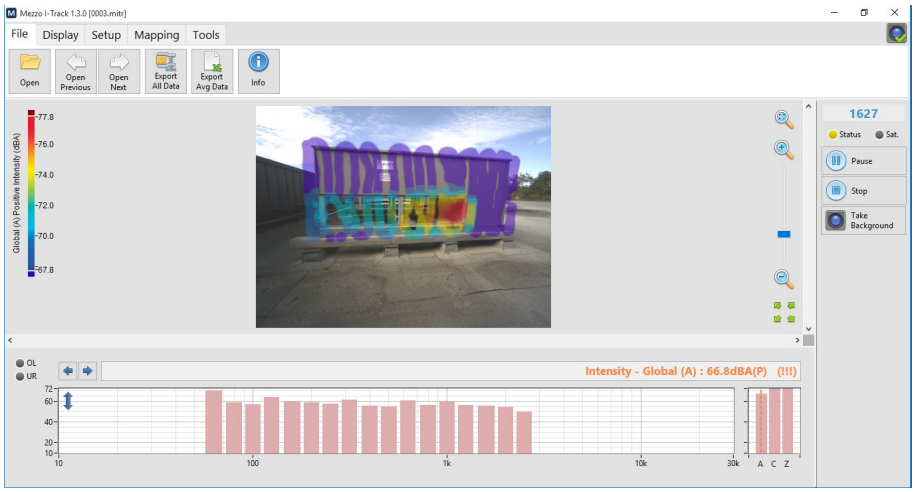
button on the interface or press the button on the probe to start the measurement.



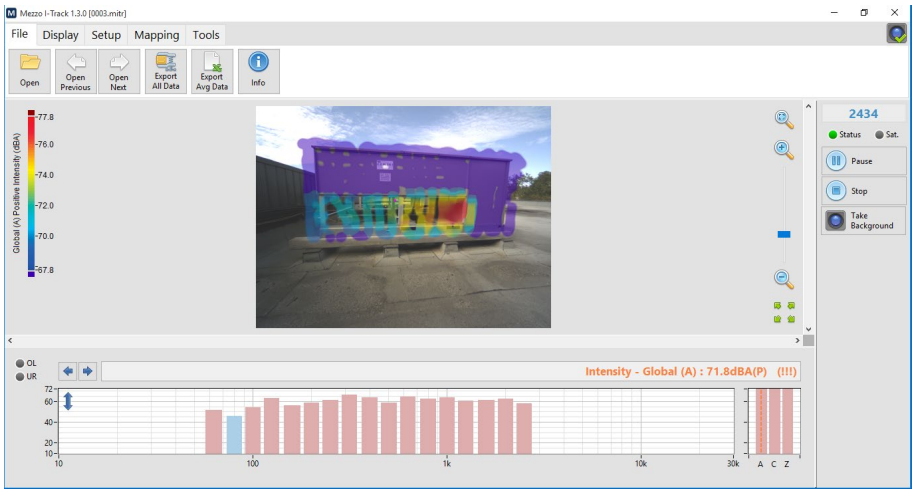
3) Following the measurement start, the background picture will be displayed on the main interface.
4) Move the probe on the measurement plane using a horizontal or vertical scanning path. The acquired data should be displayed on the screen as the measurement progresses.

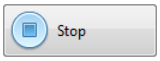


5) Continue the scan to cover the whole measurement plane. You can scan beyond the limits of the scanning plane as you can crop it afterwards in post-processing.

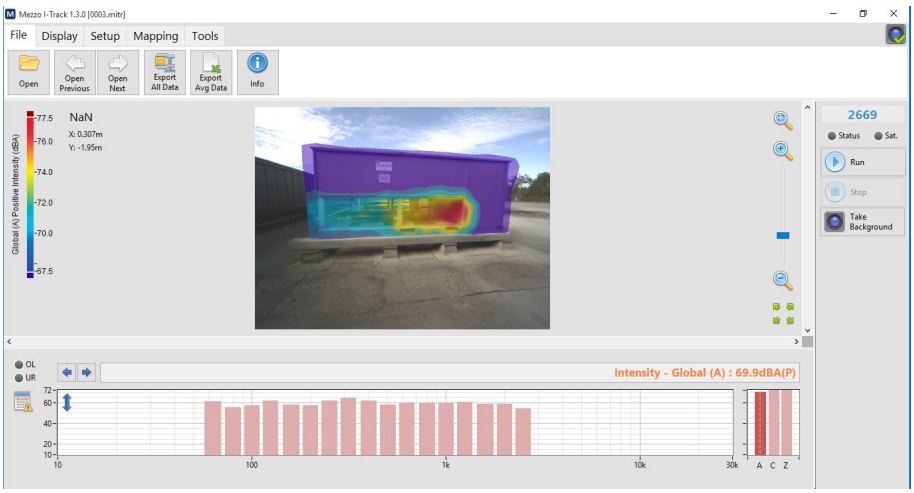


6) Once the first pass is done, it is recommended to perform a perpendicular scanning path. Over the first pass. Hence, if the first pass is a vertical scanning pattern, perform a horizontal scan over the first pass.



7) At the end of the measurement, click the 

button on the interface or press the on the sound intensity probe. The data is automatically saved during the measurement, so don't worry about saving. Once the measurement is done, the following operations are performed automatically:
   - Check validity of each measurement point (over-range and under-range)
   - Compute a measurement plane using the cloud of points in XYZ. (This step is not performed if a manual plane definition was performed before the measurement.)
   - Check the validity of each point in reference to the plane (maximum distance and angle of probe to the plane).
   - Triangulation and interpolation of each point on the measurement plane.
   - Compute sound image and spatial average level for the spectrum cursor.



8) To view the image of a specific frequency band, click on the spectrum graph or the global graph at the bottom of the interface to display the corresponding sound image.

IMPORTANT : Once the measurement is completed, the spectrum and global levels are approximated using the measurement points only. This allows to show the spectrum rapidly, even when using FFT. To compute the exact level, the spatial average must be computed for each band. This can be done by simply clicking on one band in the spectrum or by clicking on the button next to the spectrum to compute all bands at once. Note that bands which are in a light red or a light blue indicates an approximated level. For more information, refer to section 8.2.1, Exact vs Approximate Levels, p. 26.

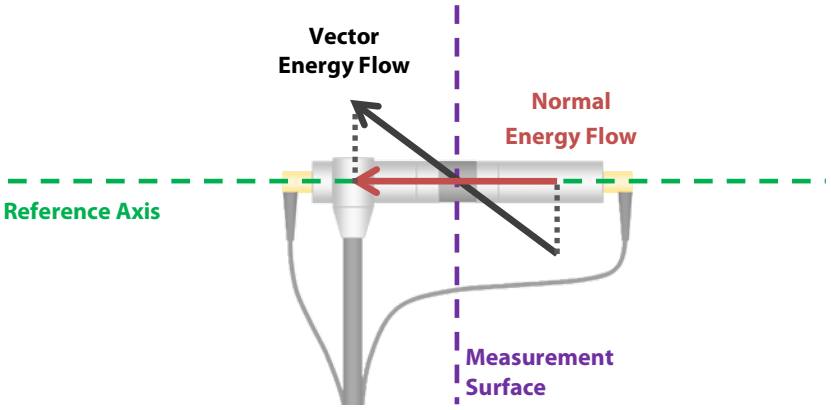
8 Analyzing Data

8.1 Theory

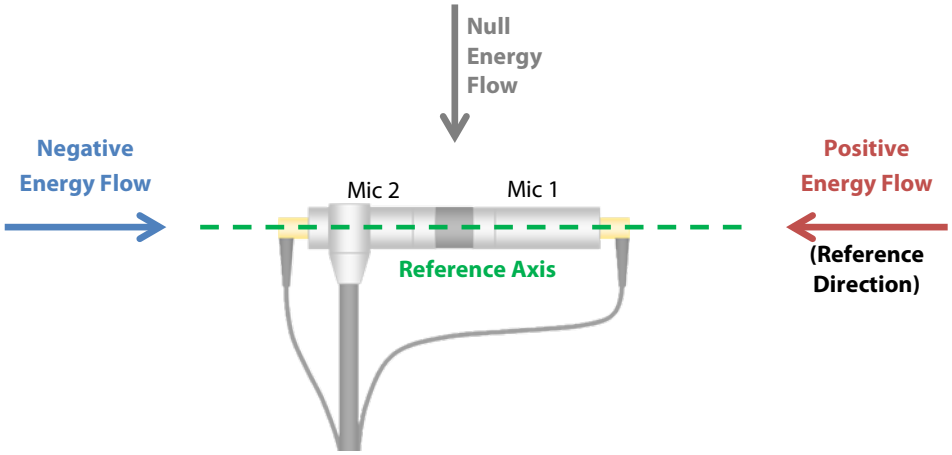
8.1.1 Sound Intensity vs Sound Pressure

Sound Intensity is a vector quantity with a magnitude and a direction. It represents the rate of sound energy flow through a unit area.

A sound intensity probe using a pair of pressure sensing microphones will pick-up only the vector component which is in-line with the reference axis of the probe. Hence, a sound intensity probe measures the normal component of sound energy flow through a surface.

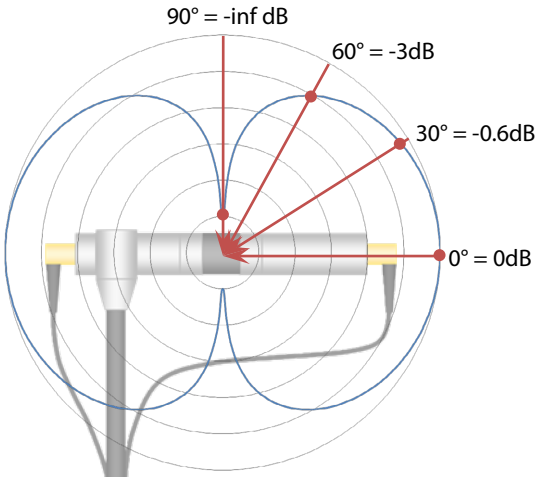


Thus the normal energy flow will equal the full magnitude of the sound intensity vector when the vector is in line with the reference axis. It will be positive when pointing in the reference direction (from mic 1 to mic 2) and it will be negative when pointing in the opposite direction (from mic 2 to mic 1). In addition, a null energy flow will be measured when the vector is perpendicular to the reference axis.



On the other hand, the sound pressure level indicates the sound pressure energy regardless of the direction of the flow of energy. Thus, with the energy flow vector in the reference axis, both sound intensity level and sound pressure level will give the same result. However, with the energy flow vector perpendicular to the reference axis, the sound pressure remains unchanged but the sound intensity will be null.

The following image shows the directivity pattern of the sound intensity probe.



For example, a sound field yielding a sound pressure of 75 dB yields a sound intensity level of 75 dB when the direction of propagation is in-line with the reference axis. The sound intensity level will be 72 dB when the direction of propagation is 60° with respect to the reference axis, and –inf dB when it's 90°.

8.1.2 PI index

In practice, the sound field is not perfectly perpendicular to the measuring surface. Hence, there will always be a difference between the sound intensity level and the sound pressure level. The absolute difference between Pressure and Intensity levels is known as the PI index.

$$PI = Lp - Li$$

A high PI index (> 6dB) indicates a low intensity level compared to the pressure level. This means that the sound field is either reactive or that its propagation is mostly perpendicular to the reference axis.

A low PI index (< 2dB) indicates a sound intensity level close to the sound pressure level. This means that the propagation of the sound field is mostly in-line with the reference axis.

8.1.3 Advanced Indicators

Extraneous Sources

The extraneous sources index (Called F_3-F_2 in ISO 9614-1 and $F_{+/-}$ in ISO 9614-2) indicates the difference between the average sound intensity level and the average of absolute sound intensity levels.

$$Ext.Src. = L|i| - Li$$

When the extraneous sources indicator is close to zero (< 1dB), it means that the sign of the intensity does not change significantly during the measurement.

When the extraneous sources indicator is high (> 6dB), it means that the sign of intensity changes significantly from negative to positive during the measurement. This is a strong sign of reactive field.

P|I| index

This index is called F2, or Surface Pressure-Intensity indicator in ISO 9614-1. It represents the difference between the average sound pressure level and the average of absolute intensity levels. It can be used to determine the extraneous sources index and is generally not used by itself.

Sound Power

This value shows the integrated sound intensity over the measurement plane surface. The sound intensity being expressed in W/m² and area being expressed in m², the sound power is the total power flowing through the defined measurement plane.

$$Lw = 10 \cdot Log\left(\frac{I}{I_{Ref}} \cdot Area\right)$$

$$Lw = 10 \cdot Log\left(\frac{I}{I_{Ref}}\right) + 10 \cdot Log(Area)$$

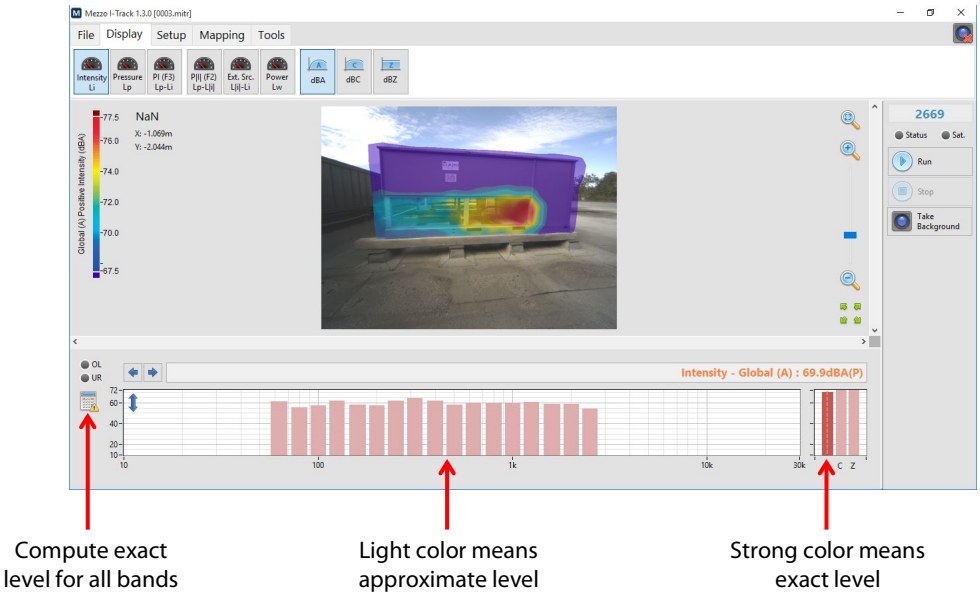
$$Lw = Li + 10 \cdot Log(Area)$$

8.2 Using the Mezzo I-Track Module to Analyze Data

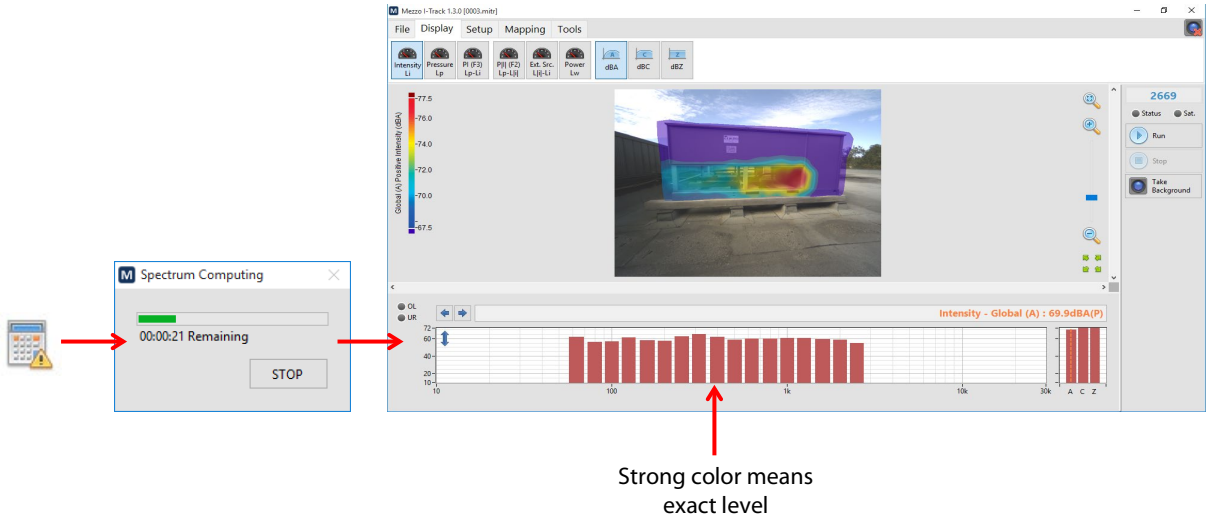
8.2.1 Exact vs Approximate Levels

Once the measurement is completed or when a file is freshly loaded, the spectrum and global levels are approximated using the measurement points only. This allows to show the spectrum rapidly, even when using FFT. Note that bands which are in a light red or a light blue indicates an approximated level.

To compute the exact level, the spatial average must be computed for each band. This can be done by simply clicking on one band in the spectrum to place the cursor on the wanted band or by clicking on the button next to the spectrum to compute all bands at once.

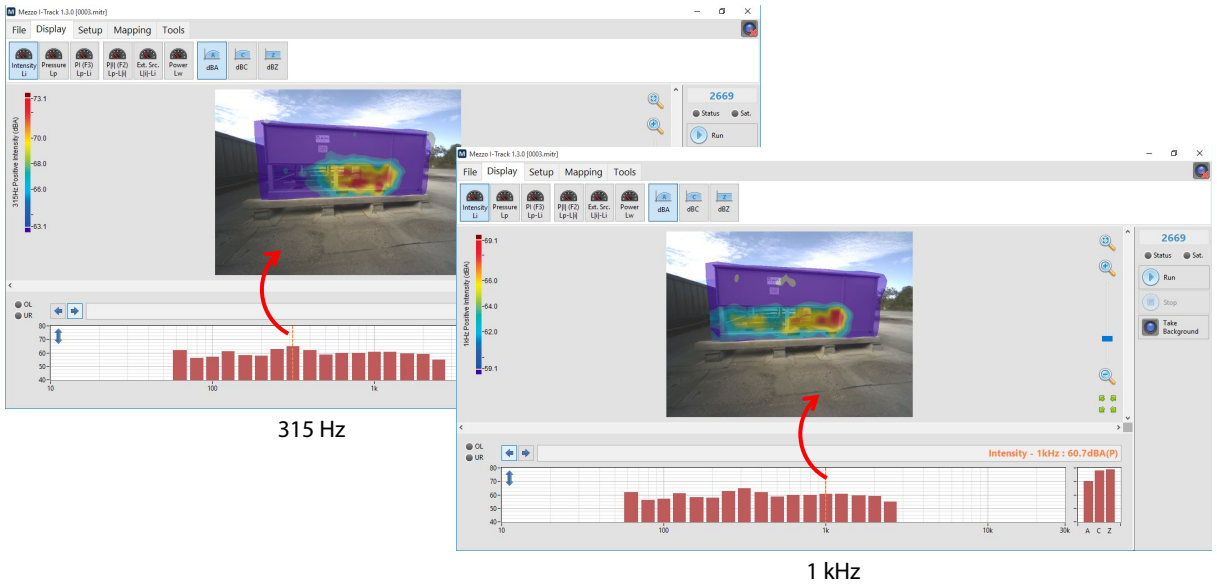


Clicking on the button next to the spectrum computes all bands at once. This process can take more or less time depending on the spectrum type and the number of bands, hence 1/3 octave bands spectrum take less time to compute than FFT spectrum.



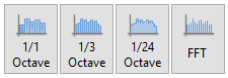
8.2.2 Changing the Sound Image Frequency Band

The sound image displays a specific frequency band or global level. To change the displayed frequency, simply click on the spectrum or global graph or use the buttons above the spectrum to change the frequency band.



8.2.3 Changing Data Type

The “Display” tab shows the available data type to display.

The 

buttons allow to select which spectrum type to display from the recorded spectrums. See section 5.2, Selecting Data Type, p. 11.

The

buttons allow to view the basic data which are Sound Intensity Level, Sound Pressure Level, and PI index. These data will be displayed both on the sound image and on the spectrum. Hence, when selecting Intensity, Intensity levels will be displayed both on the spectrum and on the sound image.

When displaying sound intensity levels, the red bars shows positive sign intensity, whereas the blue bars shows the negative sign intensity.

The

buttons allow to view the advanced field indicators which are P|I| index, Extraneous Sources, and Sound Power. These indicators are only displayed on the spectrum graph because they use the average data in their calculation, hence, they don’t have any meaning on the sound image where only discrete data can be displayed.

The

buttons allow to add a dBA, dBC or dBZ frequency weight to the spectrum. Note that global levels in dBA, dBC and dBZ are always shown on the right of the spectrum.

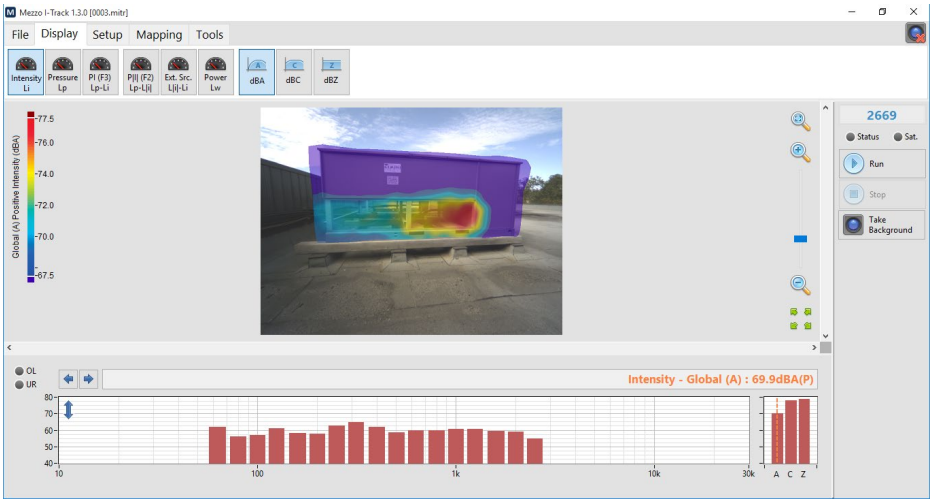
Note that frequency weighting only has meaning when displaying pressure or intensity levels. When displaying PI index the frequency weight of pressure and intensity are algebraically simplified resulting in an unweighted dB unit.

The figures on the following page show respectively sound intensity, sound pressure and PI index. Based on the previous theory, the sound intensity image shows the sound energy component which is perpendicular to the measurement plane whereas the sound pressure image shows the scalar value of sound energy. Hence it is normal that sound intensity levels are lower than sound pressure levels.

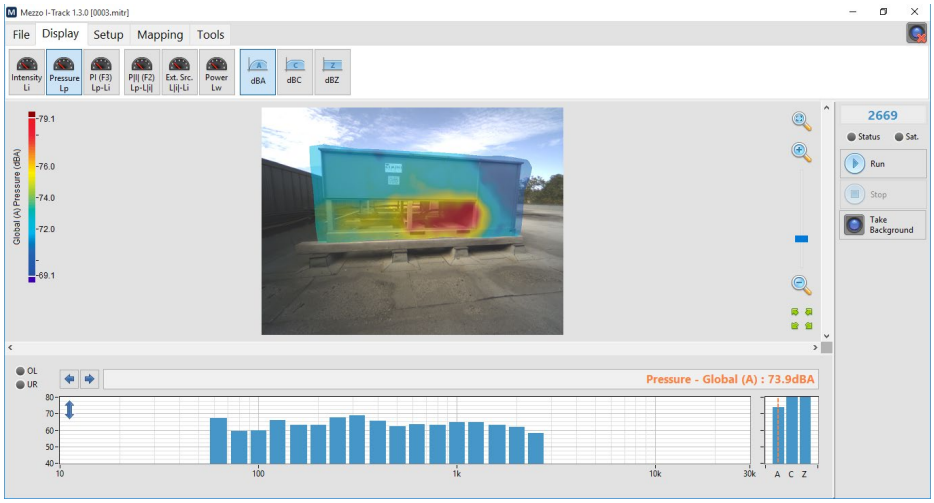
The lowest figure shows the PI index. This image represents the difference between intensity and pressure levels. Using the theory, we can say that a low PI index (<2dB) indicates that the energy flow is mostly perpendicular to the measurement plane. When it is high (> 6dB) we can say that the energy flow is mostly parallel to the measurement plane.

When using sound Intensity levels and PI index together, it’s easy to identify a strong source location: where the sound intensity level is high and PI index is low it’s a strong indication of a significant sound source.

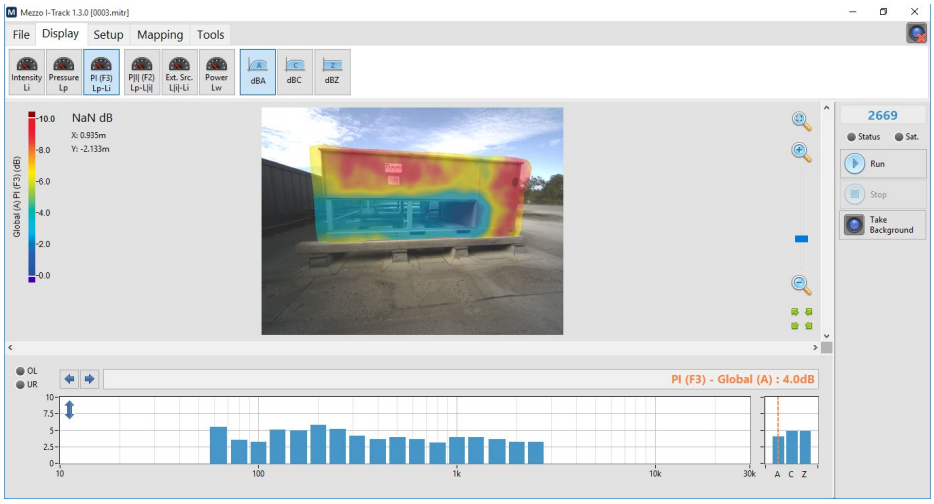
Sound Intensity



Sound Pressure



PI Index



8.2.4 Formatting the Sound Image

Changing the Color Scale

The "Mapping" tab shows several functions to format the sound image.

The

button allows to change the color scale of the sound image. The default color scale setting uses the 10 most significant decibels. Hence if the maximum level of a sound image is 67 dB, the scale maximum (red) will be 67 dB and the minimum will be 57 dB.

When displaying intensity, it is possible to display "positive", "negative" or "absolute" energy. When selecting "positive", only the positive intensity will be colored, negative intensity portions on the sound image will be greyed.

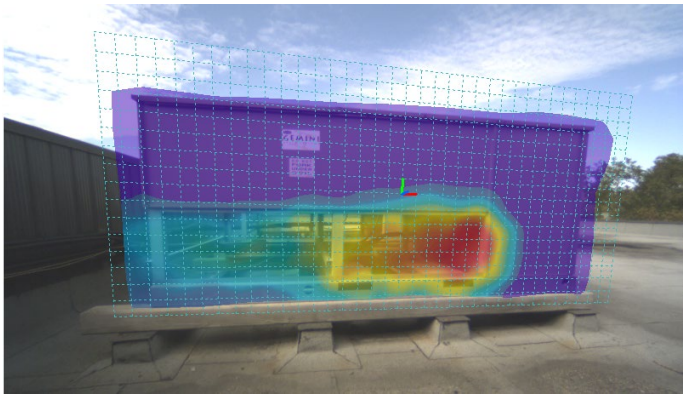
Layering more Information

The

button allows to display layers of additional information on the sound image.

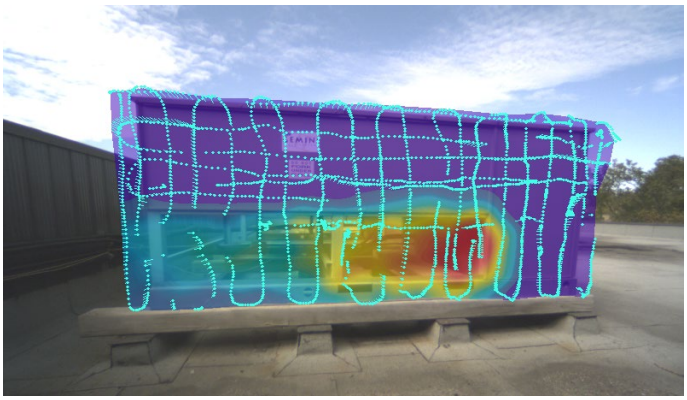
Mapping Grid:

The mapping grid displays the measurement plane in space. Each grid cell has a 10 cm side. This dimension is not used in computing, it is used only to display the plane dimension.



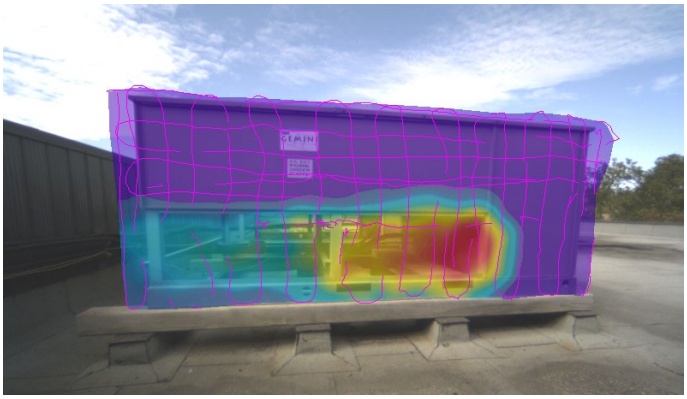
Scanning Points:

The scanning points are all the measurement points considered in the sound image computing.



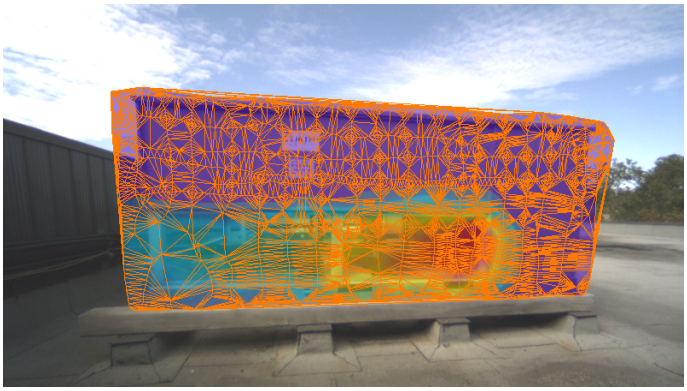
Scanning Paths:

The scanning paths show the continuous datasets acquired during the measurement. The paths may be discontinuous if the probe leaves the camera viewing range or if the user suspends the measurement.



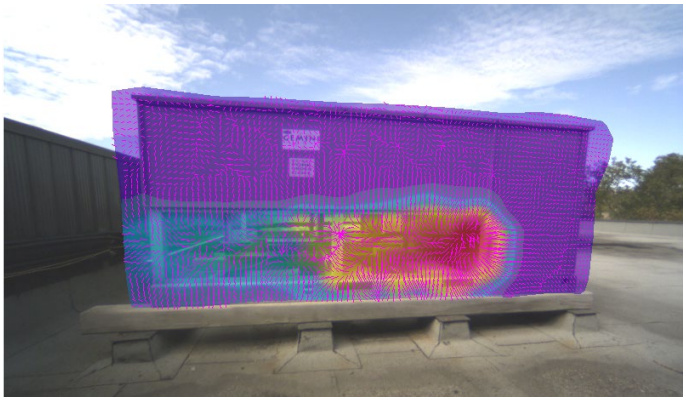
Interpolation Mesh:

The interpolation mesh shows the structure used by the software to interpolate between measurement points. This triangular structure allows interpolating efficiently between data points.



Intensity Vectors:

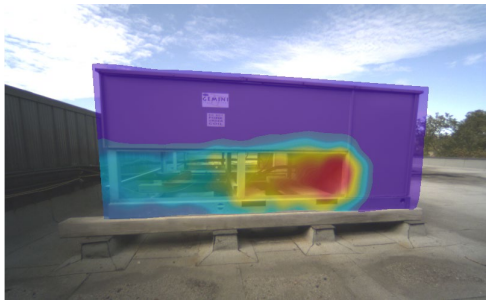
The intensity vectors are estimated by analyzing the Pressure and PI index sound images.

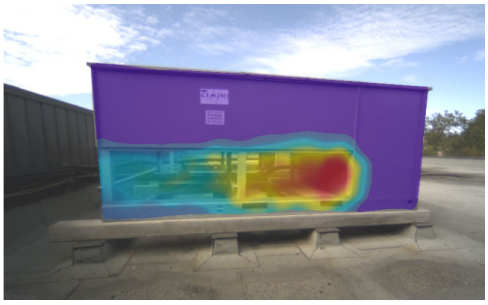


Changing the Geometric View

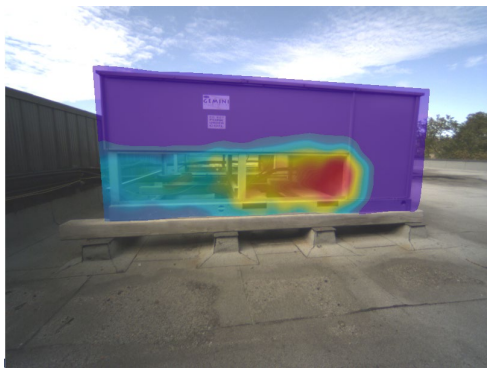
The

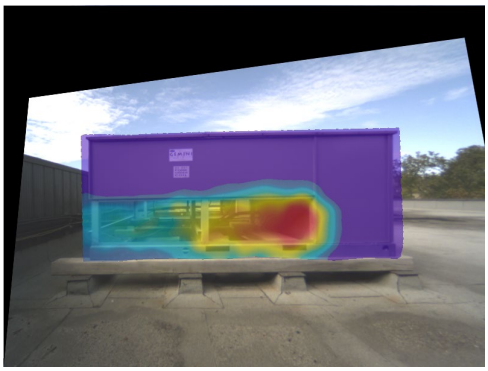
button allows to change the sound image viewpoint. The “Shift Background” function allows to shift the background image towards the measurement plane so that the device under test and the measurement plane are superimposed. This function is mostly useful when the measurement plane is skewed and DUT is far from the measurement plane, causing the DUT image and the sound image not to be perfectly aligned when viewing it on a 2D image.





The “Front View” function allows to view the sound image as if the camera was pointing perpendicularly to the center of the measurement plane.

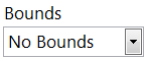




8.2.5 Adding Bounds

When analyzing a sound image, it is often useful to concentrate on sub portions of the sound image. Hence bounds can be drawn on the sound image to restrict computing to a sub portion of the sound image. Thus sound power can be evaluated for specific sub-sources.

Click on the

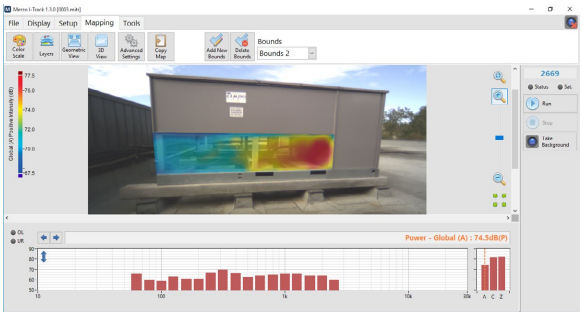
button and click on the sound image to add a new set of bounds. These bounds can be recalled using the 

drop-down menu or deleted using the

button.

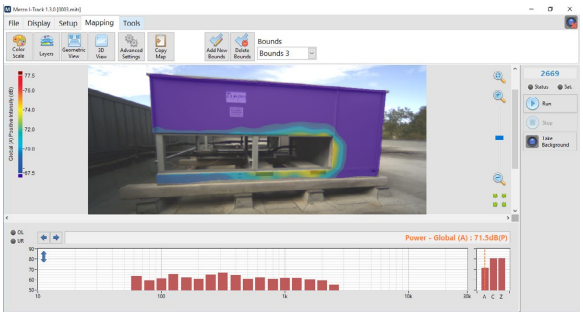
The following example shows 3 bounds and their respective computed sound power:

This first bound delimits a section the intake of the fan enclosure. The sound power level of this subsection is 74.5 dBA.



This second bound delimits the rest of the chiller enclosure. The sound power level of this subsection is 71.5 dBA.

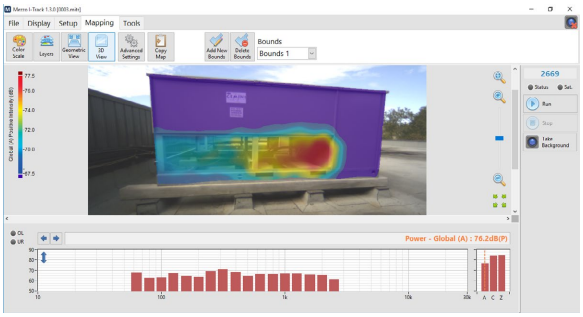
One can notice that this subsection represents less power than the first boundary even if the area is larger.



This third bound delimits the whole side of the DUT. The sound power level of this section is 76.2 dBA.

The power sum of bounds 1 and 2 should be equal to this third one:

74.5 dBA “+” 71.5dBA = 76.2 dBA

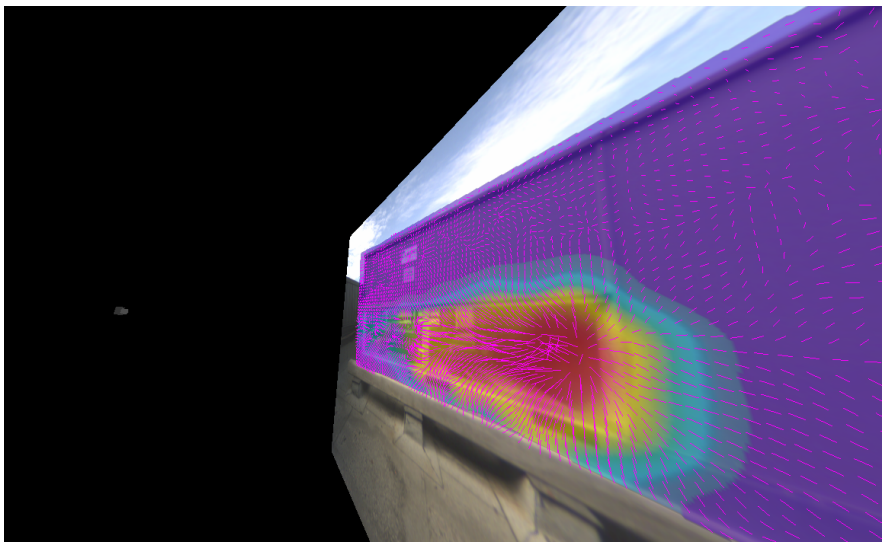


Following the previous analysis, we can demonstrate that the fan intake section is the most significant sub source of the DUT even if it’s smaller in size than the rest of the surface.

8.2.6 Viewing the 3D Scene

Click on the

button to launch the 3D scene viewer. This interface allows to view a 3D rendering of the measurement scene. Use the mouse to navigate in this interface. Ctrl and Shift keys are useful to pan and zoom.



Note that layers are displayed accordingly; hence the intensity vectors can be seen in 3D as if they were coming out of the measurement plane.

8.2.7 Advanced Parameters

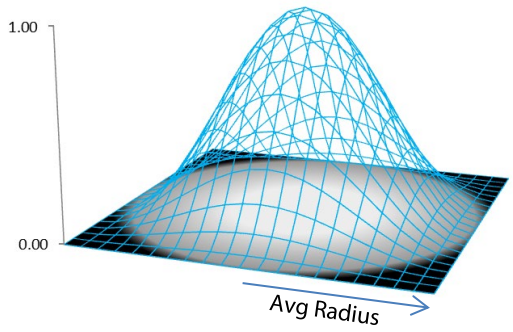
Several parameters can be adjusted to change how the sound images are computed. It is recommended to use the default parameters but these can be adjusted to fit some specific situations.

Click on the

button to access these settings:

Averaging Radius

The averaging radius represents the Gaussian averaging used to average the sound images. This allows to average measurement points located closely to one another with an averaging weight following a Gaussian shape. The default averaging radius is 10cm. A larger averaging radius leads to a smoother sound image and a smaller averaging radius leads to a more edgy sound image. Using 0 leads to no averaging.



Maximum Interpolation Distance

The maximum interpolation distance indicates the distance limit between each measurement point to allow interpolation. If scanning points are positioned too far from their neighbours, it becomes hazardous to determine data from the interpolation between these points. The default value is 0.5m and is considered forgiving. A more restrictive value of 0.2m is recommended but can lead to "holes" in the sound image if the measurement points are not close enough to each other.

Maximum Distance and Angle to Plane

These parameters are thresholds when determining the measurement plane from the cloud of measurement points. Each measurement point has a XYZ coordinate and XYZ angle in space. The measurement plane is determined using the least square distance of each point to the plane. Once the plane is determined, the points that are too far from the plane or not perpendicular enough to the plane will be rejected. Defaults are 0.1m and 20°, values of 0.2m and 40° are more forgiving.

9 Exporting Data

9.1 Exporting a single sound image

Click on the

button from the "Mapping" tab to export the current sound image to the clipboard. This map can then be pasted in another document (MS Word, etc.) as a .png file.

9.2 Exporting average data

Click on the

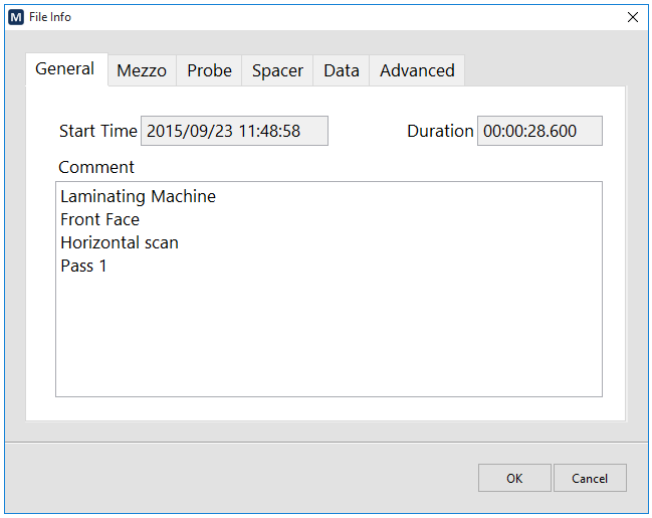
button from the "File" tab to export the average spectrum data to a tab delimited file which you can open in Excel or Matlab.

9.3 Exporting all sound images and average data

Click on the

button from the "File" tab to export the average data and all the sound image files. The exported files are stored in a compressed folder.

10 Viewing Measurement Info

A measurement file contains all the setup information. It's also possible to add a comment to a measurement file to document the measurement. Click on the

button from the "File" Tab to access the file info interface.