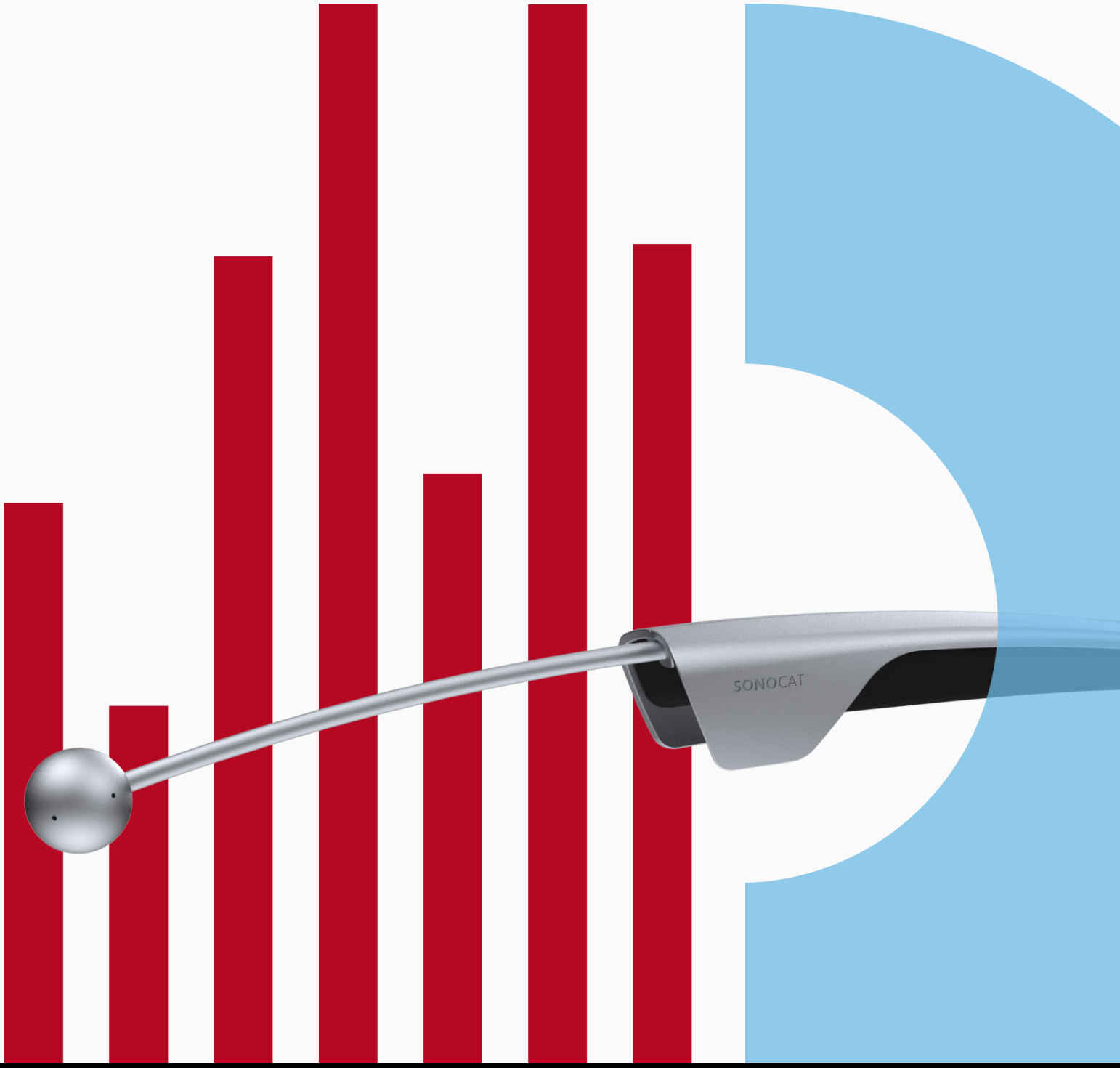

Sonocat software
User manual 1.1.9.6

Sonocat User Manual

Sonocat Software version 1.1.9.6

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Preface

Thank you for purchasing Sonocat, a hand-held measurement device for measuring sound pressure, intensity/power and *in-situ* absorption! This user manual will guide you through all the capabilities and full advantages of Sonocat to guarantee that you will use Sonocat at its best. Please read this document carefully before using Sonocat.

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1 Precautions and safety considerations

Before using Sonocat, please be aware of the following precautions and safety considerations:

- Use Sonocat and its accessories as a hand-held, high-end measurement device and treat it carefully.
- Please **DO NOT TOUCH** the sphere under any conditions, and specifically the holes in the sphere, as in that event the microphones behind the holes can be permanently damaged by static pressure build-up.
- Please do not expose Sonocat to sound pressure levels above 120 dB(A), as the microphones can be permanently damaged above this level.
- Please use proper ear protection when measuring in (too) noisy environments.
- Keep Sonocat and its accessories away from water and dust.
- Avoid damaging Sonocat and its accessories. Avoid Sonocat impacting with hard surfaces.
- Avoid any contact of the sphere with other objects/surfaces. Only store Sonocat and its accessories in its box or on a table.
- Soundinsight BV is not responsible for any damage due to above listed events or due to any other improper use of Sonocat and its accessories.

2 Introduction

Sonocat contains eight digital micro-electro-mechanical system (MEMS) microphones in a spherical (array) enclosure. The diameter of the sphere is 30mm. The number of microphones and their positioning on the sphere allow Sonocat to capture the acoustic field in 3 dimensions.

Thanks to a precise and elaborate calibration, Sonocat measures the pressure level and the intensity level in the three directions, i.e. x y and z. It is able to calculate the sound power and the sound absorption coefficient of a material in real-time by simply scanning its surface.

Sonocat comes along with the Sonocat Software to monitor, record and analyse the captured soundfield.

3 Suitcase contents

Sonocat and its accessories are delivered in a suitcase, which protects its contents from shocks, dust and water. You will find the following items inside:

1. the Sonocat
2. USB Sonocat connection cable
3. USB flash drive (black colored) with the Sonocat Software installer, the USB driver, the calibration report, the user manual and your Firm Code
4. the calibration report

4 Installing software and drivers

The software and drivers for Sonocat and the Sonocat Software are delivered on the USB flash drive in the suitcase. To install the software and drivers, insert the drive into your workstation (PC/Laptop) and open its folder. The following files are present:

- `sonocat_software_installer_v1.1.9.6.exe`
  The Sonocat Software installer.
- `sonocat_software_user_manual_v1.1.9.6.pdf`
  This user manual.
- `zadig_2.7.exe`
  The USB device driver installer.
- `cal_report_SC#####.pdf`
  The calibration report for this particular Sonocat with serial number SC#####.
- `#####`
  The Firm Code, needed to generate a license key for your PC.

Note: we require a Windows operating system (7 SP1 or higher) with 64-bits instruction set, see also the system requirements in Section 10.3.

→ Section 10.3

The next steps will guide you through the installation process of the Sonocat Software. Please allow the program to make changes to your computer.

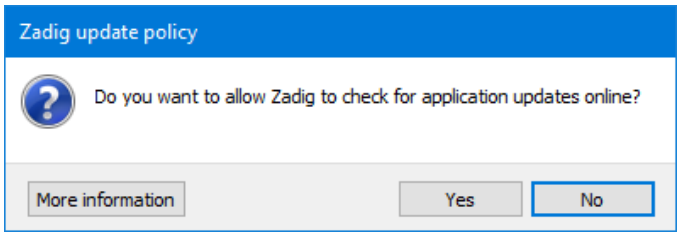
4.1 Installing the device driver

If this is a first time install of the Sonocat Software, you also need to install the WinUSB driver as described in this section. You can skip this step if the WinUSB driver is already installed on your system.

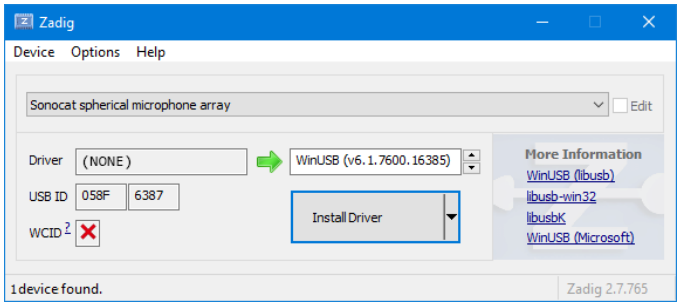
The Sonocat USB connection uses the LibUSB library to communicate over USB. Therefore, the WinUSB driver needs to be installed, which is done using Zadig. Please connect the USB cable **to the Sonocat first and then to the workstation**. Now install the driver by executing `zadig_2.7.exe`, which you can find on the USB drive provided in the suitcase.

Note: sometimes Windows Update will block Zadig from installing the driver. In this event, please temporary quit Windows Update in the system tray.

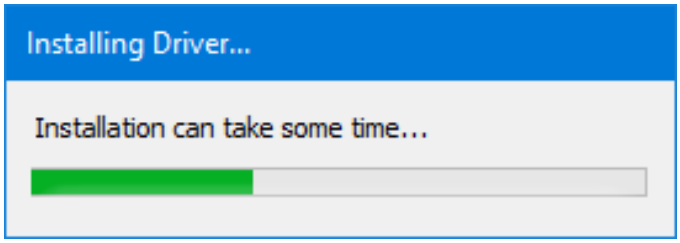
The following dialog will appear:



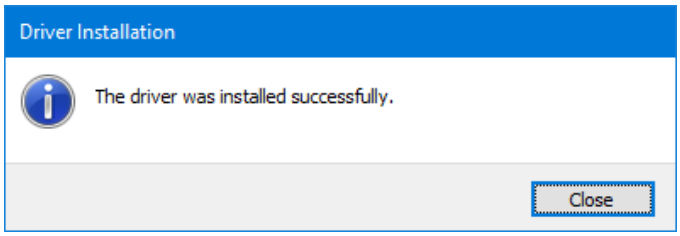
Please click *No*. If the Sonocat is connected, Zadig will automatically detect the Sonocat spherical microphone array (**if the Sonocat is not detected, please enable *Options > List All Devices* and disable *Options > Ignore Hubs or Composite Parents***):



Please click *Install Driver*.



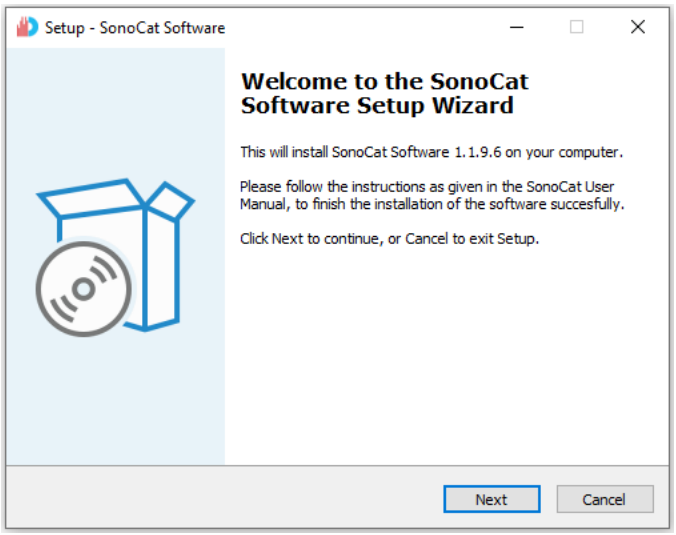
Please wait until the driver installation was successfull.



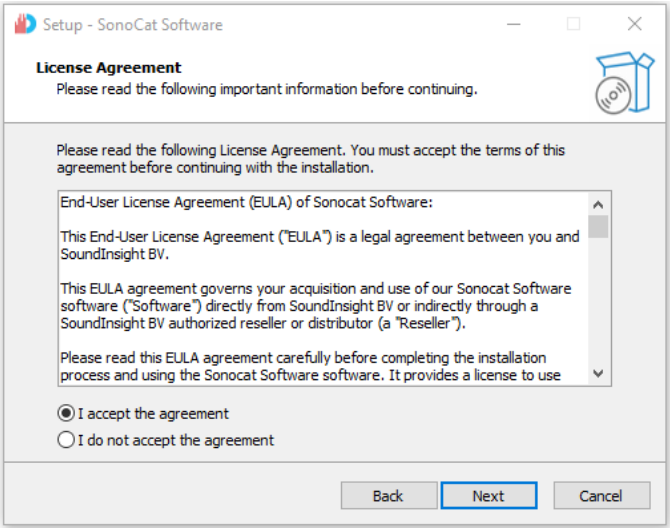
If you see this figure, the driver is installed correctly. You can now close Zadig.

4.2 Installing the Sonocat Software

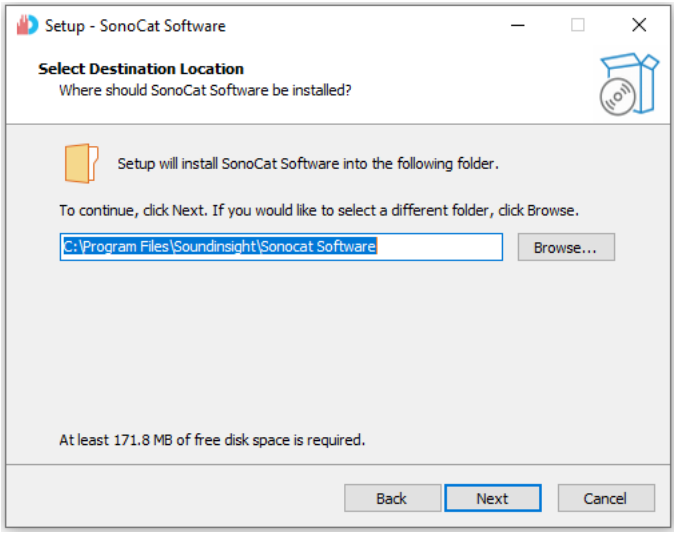
Please locate the `sonocat_software_installer_v1.1.9.6.exe` file and double-click on it. A wizard will now guide you through the installation process. The following dialog will appear:



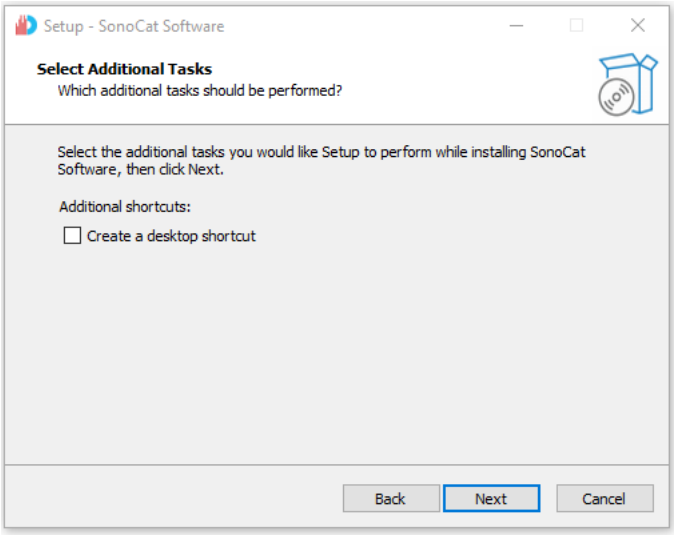
Please click *Next*.



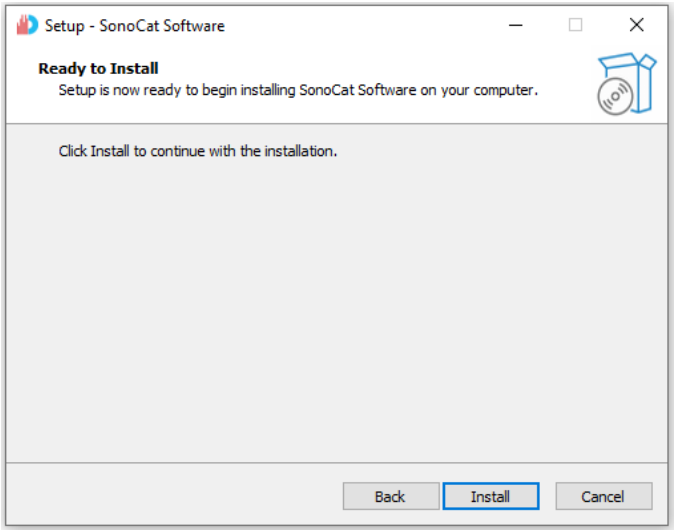
Please read the license agreement carefully and, if agreed, select *I accept the agreement* and click *Next*.



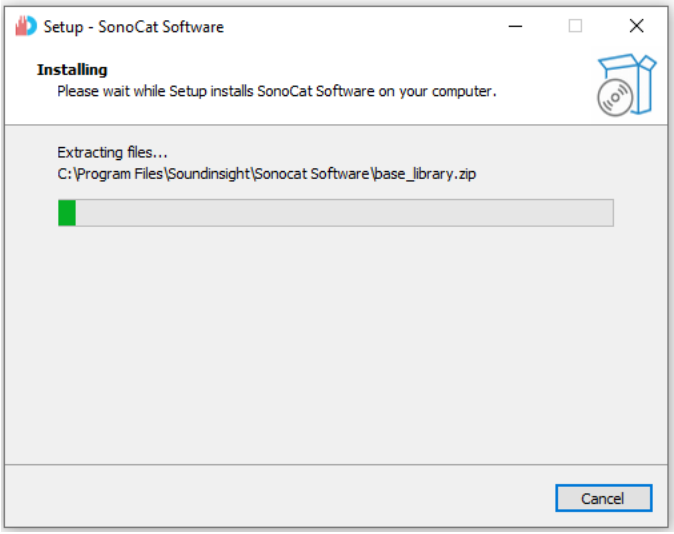
Please select the installation location and click *Next*.



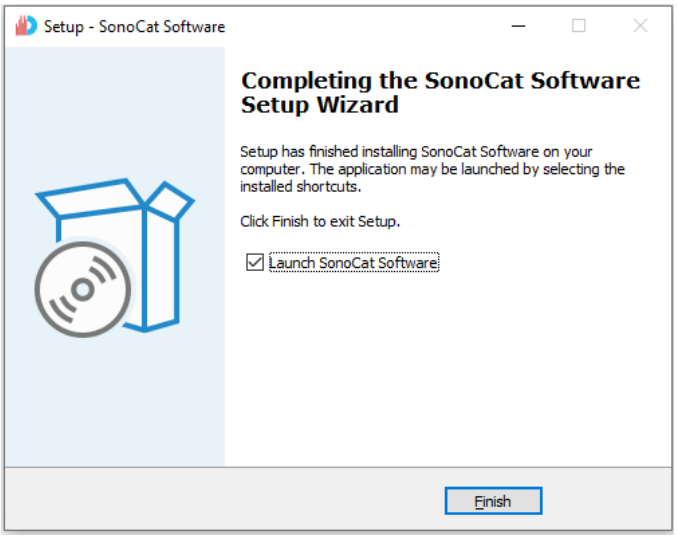
Optionally, you can choose to put a shortcut on the desktop. If you wish to have one, please check *Create a desktop shortcut*. Please click *Next*.



Please click *Install*.



Please wait until the installer is finished.



The installation is finished. Optionally, you can choose to directly launch the Sonocat Software by checking *Launch Sonocat Software*. Please click *Finish* to exit the installation.

Congratulations, you have successfully installed the Sonocat Software!

4.3 Sonocat license

To run the Sonocat Software a license key is required, specific for the PC used to run the application. During start-up of the Sonocat Software the availability of a license key is verified. If there is no license key available one needs to be generated and installed on the PC. To generate a key, two items are needed:

- a Firm Code, which is specific to your company

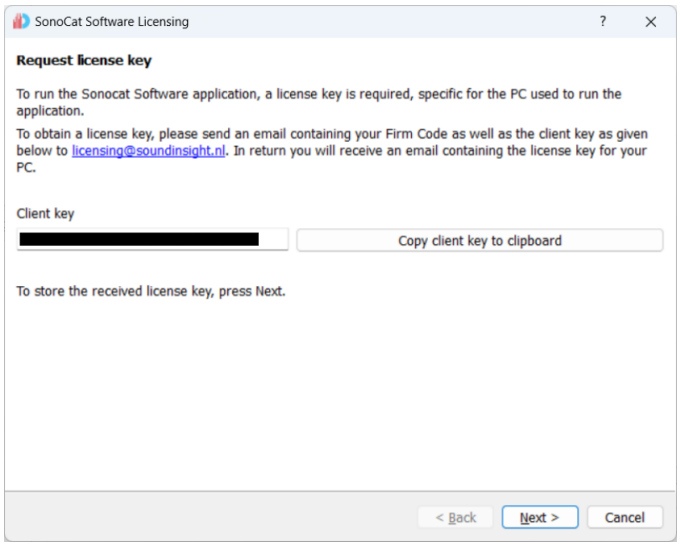
  The Firm Code can be found on the USB stick and on the Welcome! sheet both found in the Sonocat case on delivery.

- a client key, which is specific to your PC and will be generated by the Sonocat Software

  The client key is generated and displayed by Sonocat Software when no license key is found.

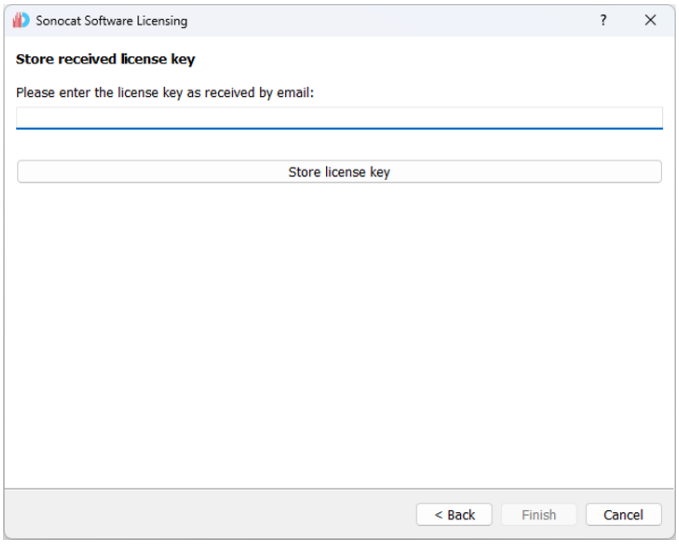
Note: license keys are bound to a specific PC. There are five license keys available for each Sonocat and Firm Code. Additional license keys are available for purchase from support@soundinsight.nl.

The following dialog will appear at startup of the Sonocat Software if no license key is found:



To obtain a license key, please send an email containing your Sonocat Software Firm Code *as well as* the client key as given below to licensing@soundinsight.nl In return you will receive an email containing the license key for your PC. The client key can be copied to the clipboard by clicking *Copy client key to clipboard*.

To store the received license key, please click *Next*.



Enter the license key as received by email in the indicated text box. The license key can be stored by clicking *Store license key*. Thereafter click *Finish* to finish the licensing. The Sonocat Software starts after finishing the licensing successfully.

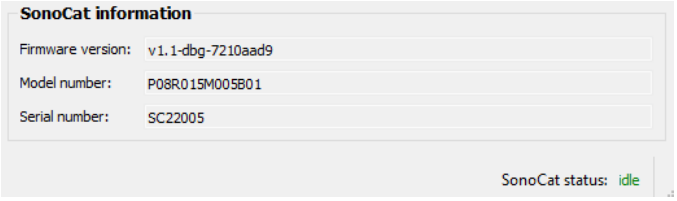
You have successfully licensed the Sonocat Software! Note that this procedure is needed only once. After storing the license key, the Sonocat Software does start without interruptions on the licensed PC.

5 Connecting Sonocat

To use Sonocat, you have to connect Sonocat to a workstation (laptop/PC) with the installed Sonocat Software and device drivers. Sonocat cannot be connected earlier than when the operating system has been fully booted. Once the operating system is running, please **first connect the USB cable to Sonocat and then to the workstation**.

Once Sonocat is connected to the workstation, ***DO NOT*** *touch the sphere of Sonocat as it will negatively affect your measurements or even damage Sonocat. See also Section 1.*

→ Section 1



The state of Sonocat is shown in the status bar of the Sonocat Software, see figure above, and knows four states:

- idle
  The Sonocat is connected to the workstation and is in its idle state.
- streaming
  The Sonocat is connected to the workstation and is streaming data.
- error
  An error occurred. Please restart software and replug Sonocat.
- disconnected
  Sonocat is not connected to the workstation.

Furthermore, the firmware version, model number and serial number are displayed in the Sonocat information box. If no Sonocat is connected, no information is displayed here.

Note: The time to start up a Sonocat connection may last up to about ten seconds when plugging into a workstation.

6 Sonocat Software

The Sonocat Software is dedicated to Sonocat measurements and its interface allows the user to monitor, record and analyse the data collected by Sonocat.
The Sonocat Software can be used with or without plugging in Sonocat; however, Sonocat cannot be used without the Sonocat Software.

The Sonocat Software comprises a graphical user interface with its functionalities provided in four panels (outlined vertically on the left side of the main window; see figure below):

- Project
- Monitor

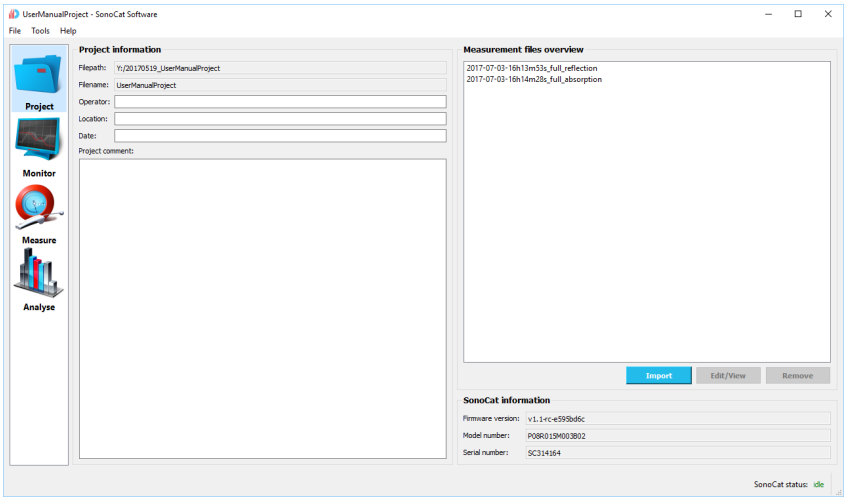
- Measure
- Analyse

Switching between the different panels is possible in any order.
Moreover, a menu bar has two main menus called *File* and *Tools*. The *File* menu allows to create, load and save your project. The *Tools* menu provides access to the *Waveform generator* and the *Sensor inspector*. The functionality of these tools is explained in Section 6.5 and 6.6.

→ Section 6.5 and 6.6

Furthermore, a status bar provides the Sonocat status, which can be either idle, streaming, error or disconnected as explained in Section 5.

→ Section 5



All Sonocat measurements are grouped into projects. A project is created, loaded or saved by clicking on the *File* menu and selecting *New project*, *Load project* or *Save project* respectively.

Note: A Sonocat project file (`*.sip`) can directly be opened by the Sonocat Software by double-clicking on the file in the operating system's file manager.

6.1 Project panel

The *Project* panel displays an overview of the *Project information*, but also provides the *Measurement files overview* together with the *Sonocat information*.

6.1.1 Project information

In the *Project information* box most fields are editable, some are read-only:

Filepath: (read-only) indicates the filepath of the folder in which the project is stored. The filepath will indicate **temp* in case the project has not yet been saved yet.

Filename: (read-only) shows the filename of the project. The filename will indicate **unsaved_project* in case the project has not yet been saved. The filename and filepath are defined when the project is created or loaded under *Menu > File*

Operator: (editable) where you can specify the measurement operator(s).

Location: (editable) where you can enter the location where the measurements have

been done.

Date: (editable) where you can fill in the date at which the measurements have been performed.

Project comment: (editable) Any noteworthy comments and other user-defined metadata can be conveniently stored here.

6.1.2 Measurement files overview

The measurements that belong to the current project are listed in the *Measurement files overview* box, as displayed in the right side of the window.

When a measurement is saved, a folder `Measurements` is created at the same location of the project file (`*.sip`) and the measurement (`*.sim`) is stored in it. Besides the above mentioned metadata, a project file (`*.sip`), stores a "weak link" (i.e. relative file location path) to each measurement (`*.sim`) belonging to the project. This allows the user to copy and move measurements using the file manager of the operating system.

Once a project has been loaded, a check will be done to see if all measurement files are still in place. If not, the user can relocate the files by clicking on the *Import* button, or optionally, remove the files from the project by clicking on the *Remove* button.
The *Remove* button withdraws measurement files from the project by removing the 'weak link' of the selected measurement from the project file. In this case the measurement file is still on the hard disc drive. However, you can optionally choose to also remove the measurement file from the hard disc drive. The measurement file will then be moved to the operating system's trash bin.

→ Section 6.4.1

The *Edit/View* button allows to change options for a measurement file in a new dialog. More information will be provided in Section 6.4.1

6.1.3 Sonocat information

The *Sonocat information* box provides information about the connected Sonocat. If no Sonocat is connected, the (read-only) fields show 'N/A'.

Firmware version: This is the version number of the embedded software which runs on a digital signal processor inside the connected Sonocat.

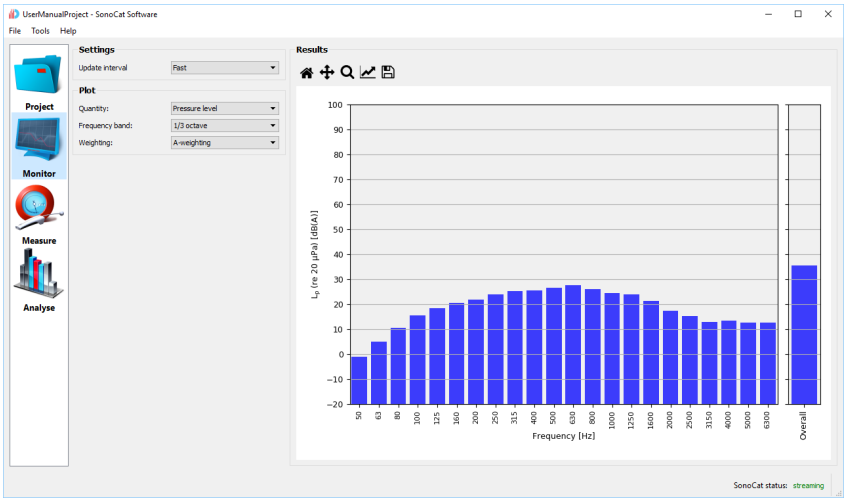
Model number: This number indicates the model and configuration of the connected Sonocat.

Serial number: This number is a unique identifier of the connected Sonocat.

Note: Besides this information, Sonocat Software obtains probe configuration including microphone positions, sensitivities, calibration data, sample resolution and available sample rates from Sonocat. A copy of all this information is stored in each measurement, such that measurement files are exchangeable between different users of Sonocat Software for postprocessing. This also allows for combining measurements from different Sonocat's. See Section 6.4.2 for more information.

6.2 Monitor panel

In the *Monitor* panel, the different quantities of the sound field measurable by Sonocat (e.g. Sound Absorption Coefficient) can be monitored in real time. Measurement results are shown in the frequency domain using spectral averaging over short time blocks, where the *Update interval* of these blocks can be configurated in *Settings*. After a time block has been processed, the figure is updated automatically. The frequency spectrum of complex quantities, like Impedance, is presented in the form of a Bode plot. So, besides the magnitude of the frequency spectrum also the phase of the spectrum is shown.



Note: the Monitor *panel is intended to give a quick view of the measured quantity. For an actual measurement of the quantity of interest, it is recommended to perform a measurement using the* Measure *panel.*

6.2.1 Settings

Update interval: For monitoring the sound field, you can choose three *Update frequencies*:

Interval	FFT length	Number of averages	Update frequency
Fast	512	5	8 Hz
Medium	512	20	3 Hz
Slow	1024	30	1 Hz

Switching the update frequency can be done while monitoring. The changes you make will affect the results instantly. If performance issues arise due to the Sonocat Software not being able to perform all of its calculations within the allotted time frame as determined by the update frequency, resampling is performed on the signal. This can result in the temporary loss of one or more of the higher frequency bands (this only happens during real-time monitoring, not when performing a measurement from the *Measure* panel). For more information about the *FFT length* and *Number of averages* settings, please refer to Section 6.3.1.

→ Section 6.3.1

6.2.2 Plot

Quantity: The monitoring quantity can be selected here. The options show the same

→ Section 6.4.2

list as in the *Analyse* panel and are explained in Section 6.4.2.

Frequency band: We provide the options to display the data in octave bands, $^1/_3$ octave bands, $^1/_6$ octave bands, $^1/_{12}$ octave bands, and narrow band (PS - power spectra and PSD - power spectral density).

Weighting: The frequency weighting can be to set A-, C- and, a so-called, Z-weighting (please check Section 9 for explanation about weighting).

→ Section 9

Changes made to these settings will affect the next update of the figure in the *Results* box.

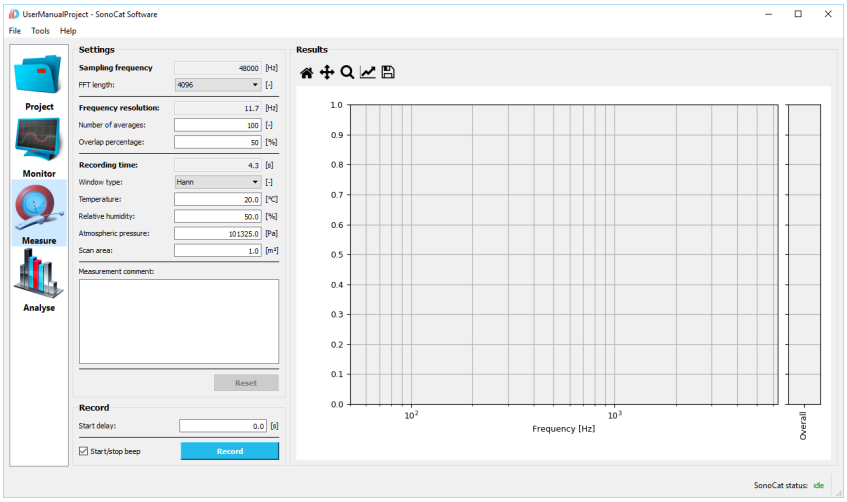
6.2.3 Results

The *Results* box shows the current result of the *Monitor* panel settings. The buttons and configuration of the *Results* box are the same as in the *Measure* and *Analyse* panels and are described in Section 6.4.3.

→ Section 6.4.3

6.3 Measure panel

Clicking on the *Measure* tab, the following panel is shown:



On the left side, settings for the measurement can be set in the *Settings* box. Next, a recording can be initiated in the *Record* box. On the right side, the *Results* box will display the result after the measurement is finished.

6.3.1 Settings

Although Sonocat records eight temporal signals, all the analyses of the measurements are performed in the frequency domain. The temporal signals are cut in blocks of defined length, windowed and transposed to frequency bins via FFT. This process is repeated for the length of the temporal signals. The length of the temporal signals, and therefore, the duration of the measurement are influenced by the settings. Most fields are editable, some are read-only and are given as a 'result' based on the given settings.

Sample frequency: (read-only) The sampling frequency of Sonocat is 48 kHz, i.e. 48,000 samples

per second are recorded for each microphone. This setting is fixed and cannot be changed.

FFT length: The temporal signals are cut in blocks of length defined by this setting. For the number of samples in a window, you can choose the following FFT lengths: 512, 1024, 2048, 4096 and 8192 samples. The bigger the number of samples, the more detailed the measurement. A default value of 4096 is set.

Frequency resolution: (read-only) As a result, you will find the frequency resolution = sample rate/FFT length. The frequency resolution determines the narrow-band resolution of the power spectrum. A narrower frequency resolution results in more accurate low frequency result at the price of longer measurement times according to the bandwidth×time principle.

Number of averages: The number of windows that will be averaged in the spectral estimator can be specified with a value between 1 and 10000. The Sonocat Software has a default value of 100 averages. The higher the value, the more data is recorded.

Overlap percentage: Specify the overlap percentage of two windows in the range of 0-90%. With a Hanning window with 50% overlap the entire signal is analysed (no signal loss).

Recording time: (read-only) As a result, you will find the recording time = ((1 - overlap percentage/100) × number of averages + overlap percentage/100) × FFT length / sampling frequency.

Window type: Choose the window type you want to apply to each time block: Hann, Hamming, Rectangular, Bartlett or Blackman. The energy loss due to windowing is compensated for in the spectra estimation.

Temperature: The temperature has to be specified in degrees Celsius. The temperature will be used to calculate the speed of sound.

Relative humidity: Specify the relative humidity in this field. The relative humidity will be used to calculate the speed of sound.

Atmospheric pressure: Enter the atmospheric pressure in Pascal here. The atmospheric pressure will be used to calculate the speed of sound.

Scan area: The scan area will be used to either calculate the sound power or the area-averaged sound absorption, intensity or pressure.

Measurement comment: Any text commented here will be stored as part of the measurement and can be retrieved in the *Edit/View* dialog, see also Section 6.4.1.

→ Section 6.4.1

The *Reset* button can be used to restore the latest saved measurement settings.

Note: The implemented model used to compute the speed of sound in air and the air density is as described by Cramer [1].

6.3.2 Record

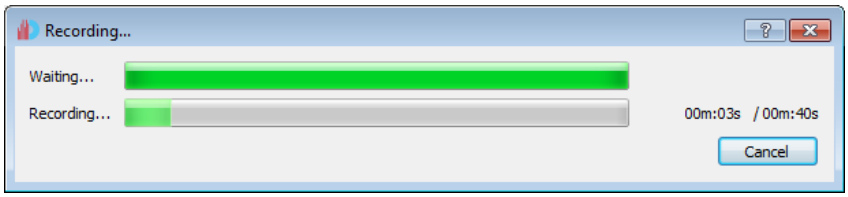
In the *Record* box you can start the recording by pressing the *Record* button. In the *Start delay* field one can specify a time delay; the actual recording starts after this time delay. Three beep signals will be played after pressing the record button to indicate that:

1. The start delay is initiated.

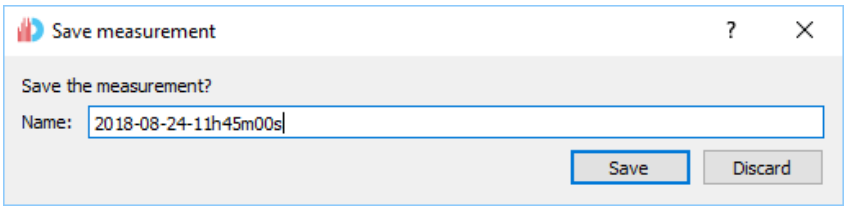
2. The start delay has ended and the actual recording has started.

3. The recording has ended.

The beep itself is not recorded in the measurement. However, the user can enable/disable the beeps by (un)checking the *Start/stop beep* box. Once the record button is pressed, provided that Sonocat is connected, the following dialog will be shown:



This dialog indicates the progress of the start delay and the recording. Press the *Cancel* button if you wish to cancel the current recording before the recording has ended. When the recording finishes, the following dialog will appear:



Here, you can either choose to *Save* the measurement, or *Discard* it. When you press save, the measurement is saved as part of the project, with the name as entered in the field. When the project has not been saved yet, you will be asked to save the project first. After the project has been saved, the measurement will be saved as well.

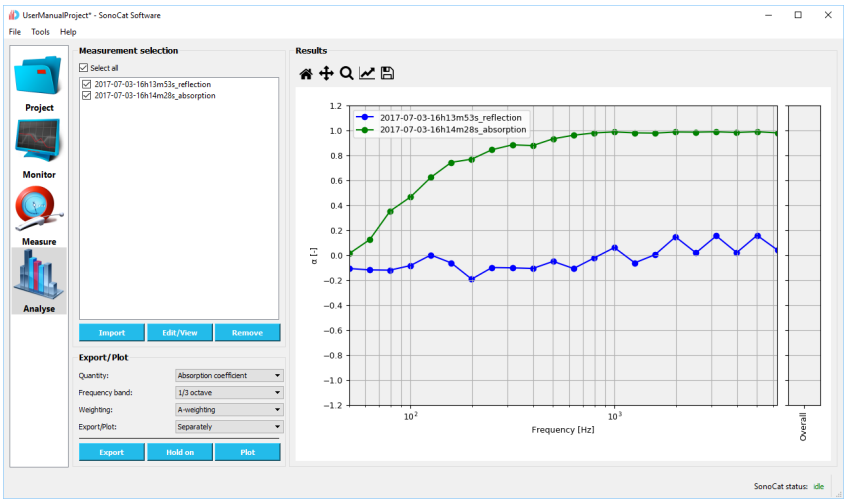
Note: As the measurement is part of the project, the project needs to be saved first in order to store the link between the measurement file and project. To save the project after a measurement, press CTRL-S*, or use* File > Save project.

6.3.3 Results

After a measurement is finished, the result is shown in the graph of the *Results* box, where the quantity as chosen in the *Monitor* panel is plotted.
If you are interested in showing a different quantity of the same sound field, you can select a different quantity in the *Analyse* panel. You can interact with the results graph in the *Results* box. The buttons are the same as in the *Analyse* panel and will be discussed in Section 6.4.3.

→ Section 6.4.3

6.4 Analyse panel

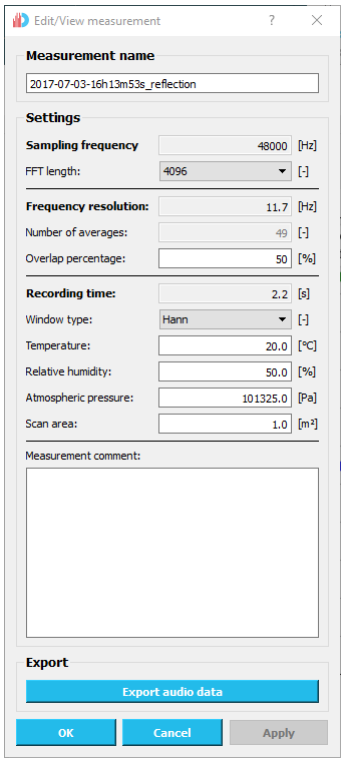


The *Analyse* panel is used to compute, analyse, compare and combine measurement results. The analysis is performed in the frequency domain on the selected measurement file(s) for the desired quantity with the chosen frequency band resolution and weighting. The selected measurements can be analysed separately or combined.
The measurement analysis can be performed straight after a measurement or remotely without plugged in Sonocat .

6.4.1 Measurement selection

The *Measurement selection* box shows an overview of the measurements in the project. If no measurements are available, the *Measurement selection* box shows *No measurement files in this project*.
The *Import*, *Edit/View* and *Remove* buttons have the same functionality as in the *Project* panel. However, in contrast to the *Project* panel, multiple measurements can be selected in the Analyse panel and the buttons operate on *all* selected measurements. This way, operations can easily be executed on multiple measurements.

The *Import* button will help to localise the measurement file you want to import and the *Remove* button will withdraw the measurement from the project. Pressing the *Edit/View* button opens the *Edit/View measurement* dialog (see figure below) where the measurement settings can be adjusted.



Measurement name: The measurement name can be edited. The measurement name is the file name without its file extension (`*.sim`). When the measurement name is changed, also the filename will be changed.

Settings: The measurement settings can be viewed and/or changed. As explained in Section 6.3.1, the recording time is a result of the FFT length, number of averages and overlap percentage. It is therefore only possible to adjust the FFT length and overlap percentage. The number of averages corresponding to the recording time is then changed accordingly.

→ Section 6.3.1

Export: In this box you can press the *Export audio data* button to export the uncalibrated audio data of the microphone signals as wave files (*.wav), FLAC (*.flac) or ASCII data (*.dat).

6.4.2 Export/Plot

The options for the analysis of the measurements are set in the *Export/Plot* box.

Quantity: With this drop-down list you can select the quantity to export/plot. The theoretical principles behind these quantities are developed in the glossary in Section 9. The current version of the software offers:

→ Section 9

- Sound absorption coefficient α. The range of α goes from -1 to 1; where -1 reflects a fully emitting surface, 0 a fully reflective surface and 1 a fully absorbing surface.
- Impedance in $Pa\,s/m$ (in the x-, y- and z-direction in a Cartesian coordinate system). The impedance spectrum will be presented as a Bode

plot. The impedance is only available for the narrow band (PS/PSD, which makes no difference for an impedance) and Z-weighting.

→ Section 7.1

- Sound intensity direction (θ and ϕ coordinate of the intensity vector in a spherical coordinate system displayed in degree). See Section 7.1 for a graphical representation of the coordinate system.

→ Section 7.1

- Sound intensity level, in dBSIL (x-, y- and z-coordinate of the intensity vector in a Cartesian coordinate system, and its vector magnitude). See Section Section 7.1 for a graphical representation of the coordinate system. The sound intensity in a certain frequency band can have either a positive or negative value indicating the direction of the net sound energy flow per unit area. In the former case (i.e. for positive values) the bar colors are uniform, in the latter case the bars are hatched and the color is more transparent. The $(-)$ sign in front of the overall value, which is shown on top of the overall bar, indicates energy flow in the negative direction.

- Power emitted/reflected in dBSWL. This is the sound power of a scan area in the positive direction of the z-plane of the Sonocat. Scanning a surface with the Sonocat (with the z-direction of the Sonocatperpendicular to the surface) it represents the sound energy, integrated over the area, coming from that surface, either because that surface reflects incident sound and/or that surface radiates sound. The mathematical difference of the emitted/reflected power and the immitted/incident power is the (net) power in the z-direction. The scan area, in square meter, is a setting in the Measure panel and can be changed for a saved and loaded measurement with the Edit/View button in the Analyse panel.
  Note: when monitoring, the scan area is set to 1 m^2, which means that the sound power is identical to the sound intensity.

- Power immitted/incident in dBSWL. This is the sound power of a scan area in the negative direction of the z-plane of the Sonocat.Scanning a surface with the Sonocat (with the z-direction of the Sonocat perpendicular to the surface) it represents the sound energy, integrated over the area, towards that surface. The mathematical difference of the emitted/reflected power and the immitted/incident power is the (net) power in the z-direction. The scan area, in square meter, is a setting in the Measure panel and can be changed for a saved and loaded measuremen with the Edit/View button in the Analyse panel.
  Note: when monitoring, the scan area is set to 1 m^2, which means that the sound power is identical to the sound intensity.

- Partical velocity level in dBPVL (in the x-, y- and z-direction in a Cartesian coordinate system).

- Sound power level, in dBSWL (relative to 1pW). The sound power in a certain frequency band can have either a positive or negative value indicating the direction of the net sound energy flow. In the former case (i.e. for positive values) the bar colors are uniform, in the latter case the bars are hatched and the color is more transparent. The $(-)$ sign in front of the overall value, which is shown on top of the overall bar, indicates energy flow in the negative direction. The user is able to measure the Sound Power Level in the z-direction of a Cartesian coordinate system only.

- Sound pressure level, in dBSPL.
- Sound pressure-intensity index in dB (for the x-, y- and z-component of the sound intensity vector in a Cartesian coordinate system, and for the magnitude of the sound intensity vector)

Frequency band: We provide the option to bin the data in octave bands, $1/3$ octave bands, $1/6$ octave bands, $1/12$ octave bands, and narrow band. The latter option can be plotted either as power spectra or power spectral density.

Weighting: The frequency weighting can be set to A-, C- and, a so-called, Z-weighting according to [2]. The latter actually means no frequency weighting.

Note: For relative quantities, such as the absorption coefficient and pressure-intensity index, the weighting value has no effect on the output. See also Section 8.

→ Section 8

Export/Plot: This drop down list determines how the results are plotted or exported. Two options are available:

- Separately:
  When *Separately* is selected, the exported/plotted results will be shown as a comparison. For each selected measurement, the selected *Quantity* will be exported/plotted. This options is used to compare different measurements.
- Combined:
  When *Combined* is selected, the selected measurements are energetically combined to an over-all result. Selecting *Combined* always results in a single data set. For theoretical explanations please consult Section 9.6

→ Section 9.6

When you have selected the options from the above choices, you have the following options:

Export: Pressing this button will open an export dialog. The data set(s) can be saved in one of the following file types:

- Text file (`*.txt`):
  A text-file stores the data as ASCII-data.
- Comma-separated values (`*.csv`):
  Comma-separated values stores the data as ASCII-data in a format better understood by programs.
- Excel Workbook (`*.xlsx`):
  Excel Workbook stores the file in Office Open XML format, which can be read by Spreadsheet programs.

Plot: Clicking this button will plot the results in the *Results* box. The way the data is presented can further be adjusted in this box, see Section 6.4.3. Note that clicking the *Plot* button will normally overwrite the already plotted result object, unless the *Hold on* button is switched on.

→ Section 6.4.3

Hold on: This button acts like a switch for the *Results* box. When the button is pressed down, any additional graph is added to the current plot, without deleting the previous graph. This way, multiple quantities for the same measurement selection can easily be plotted alongside of each other. For example, when you

want to plot the sound pressure level alongside of the sound intensity level, you first plot the *Sound Pressure Level*, next you click *Hold on*, then you select *Sound Intensity Level* from the list and finally you click the *Plot* button.

Note: you cannot combine the Hold on *and* Export *functionalities. If you for example want to export both sound pressure and sound intensity data, you have to export them to two separate files.*

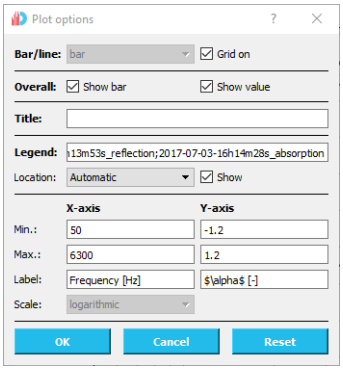
6.4.3 Results

When the measurement result is plotted in the figure of the *Results* box you can interact with the figure using the following buttons:

From left to right, the buttons have the following functions:

1. Reset to original view
2. Pan axes (left mouse button) and zoom (right mouse button)
3. Zoom to rectangle
4. Edit curves, lines and axes parameters
5. Save the figure

With the first 3 buttons from the left, you can interact directly with the figure. Clicking on the *Edit curves, lines and axes parameters* icon results in opening the following dialog:



Here you can specify detailed parameters of the figure, such as the range of the axes, labels and the figure title. Moreover, if applicable, the figure plot can be changed from lines to bars and visa versa. Text between $-signs is interpreted as a LaTeX equation.

Note: By default, all quantities except the absorption coefficient are plotted as bars; the absorption coefficient is plotted as a line. It is possible to plot the others as lines as well. However, it is not possible to plot the absorption coefficient in bars. Furthermore, only lines can be plotted on both a linear and logarith-

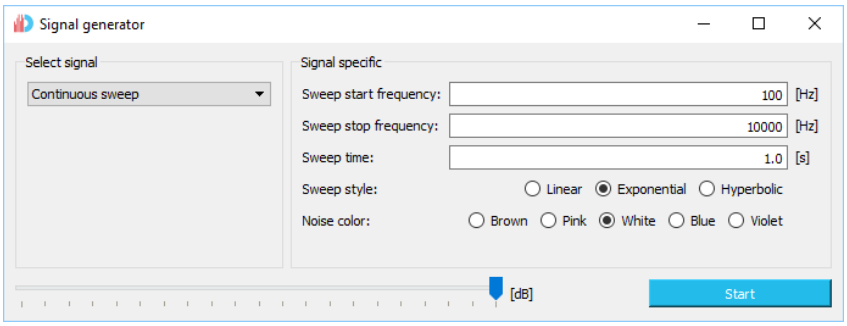
mic x-scale. Hence, the X-scale *box is only activated when selecting 'line' in the* Bar/line *box.*

Exporting the results figure can be done by clicking the last button, i.e. *Save the figure* icon. The following figure formats are provided to generate publication-quality figures:

- Encapsulated Postscript (`*.eps`)
- PGF code for LaTeX (`*.pgf`)
- Portable Document Format (`*.pdf`)
- Portable Netwok Graphics (`*.png`)
- Postscript (`*.ps`)
- Raw RGBA bitmap (`*.raw`,`*.rgba`)
- Scalable Vector Graphics (`*.svg`,`*.svgz`)

6.5 Waveform generator

The Sonocat Software also provides a *Waveform generator* that can be used to aid you in making measurements. The *Waveform generator* can be found under *Tools* > *Waveform generator*, or via the applications menu of your operating system. The signal from the generator is sent to the selected output of the workstation's sound card. The user should provide a speaker to output the waveform if that is desired.



6.5.1 Select waveform

Four waveforms can be selected from the following options:

- Continuous sweep, where the signal is continuous from the *Sweep start frequency* to the *Sweep stop frequency* and back during the defined *Sweep time*.
- Forward sweep, where the signal goes from the *Sweep start frequency* to the *Sweep stop frequency* in the defined *Sweep time*.
- Gaussian noise.
- Sine wave. The wave frequency is set in the *Sweep start frequency* box.

6.5.2 Signal specific

Sweep start frequency: For a *Continuous sweep* and a *Forward sweep*, the start frequency can be set. For a *Sine wave* the frequency of the sine can be set here.

Sweep stop frequency: For a *Continuous sweep* and a *Forward sweep*, the stop frequency can be set.

Note: No signal will be outputted when a lower stop frequency than the start frequency is set for a sine sweep.

Sweep time: For a *Continuous sweep* and a *Forward sweep*, the time length of the sweep can be set.

Sweep style: For a *Continuous sweep* and a *Forward sweep*, the sweep style can be set. You can choose to output a linear, exponential or hyperbolic sweep.

Noise color: For *Gaussian Noise*, the color can be set. You can choose for Brown, Pink, White, Blue and Violet noise.

6.5.3 Start

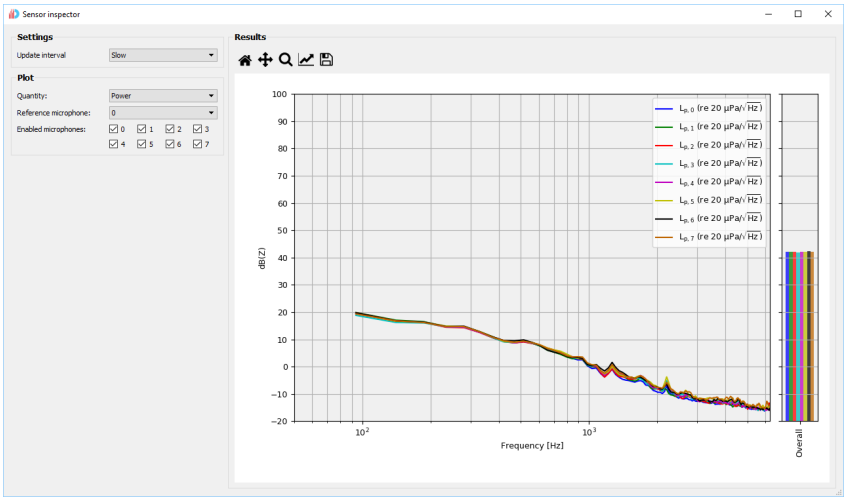
When the button *Start* is pressed, the generator will output the waveform signal based on the settings. Note that the settings can be changed while running. The signal will play until the button *Start* is pressed back.

6.5.4 Volume control

The volume can be controlled using the slider on the bottom left.

6.6 Sensor inspector

The *Sensor inspector* can be found under *Tools* > *Sensor inspector* and can be used to assure proper functioning of the microphones. The sensor inspector shows the estimated power spectral densities of the raw uncalibrated microphone signals. The figure is updated in real time based on what is currently measured.



6.6.1 Settings

Update interval: The update interval uses the same settings as in the *Monitor* panel, see Section 6.2.

6.6.2 Plot

Quantity: You can choose to plot either the (auto) power spectral densities on a decibel scale of the microphones, or the phase angle relative to a reference microphone.

Reference microphone: When the *Quantity* is changed from *Power* to *Phase*, the phase angle is plotted for each microphone relative to the *Reference microphone* as chosen in this drop-down list.

Enabled microphones: Optionally, the user can enable/disable microphones from plotting using the checkboxes under *Enabled microphones*.

Healthy microphones always output power levels in the same range. When one or more microphones is/are out of this range, it could indicate (a) malfunctioning microphone(s). In that event, please contact Soundinsight BV.

Note: In case the figure updates slowly, the current panel in the main window should be switched away from the Monitor *panel prior to starting the sensor inspector. If the* Monitor *panel is running alongside of the Sensor inspector, this may overload the CPU, resulting in missing figure frames.*

7 Sonocat measurement procedures

Sonocat uses eight MEMS microphones embedded in a sphere to record the sound field. Using the recorded signals, the Sonocat Software calculates *the sound pressure level*, *the intensity level* and *direction*, *the sound power level*, and *the sound absorption coefficient*. To get these quantities as desired, information and guidelines on how to use Sonocat at its best are presented below.

7.1 Coordinate system

The coordinate system of Sonocat is defined such that the z-axis points upwards when Sonocat lies on a horizontal table, see figure below. The x-axis lies in the symmetry plane of Sonocat and is perpendicular to the z-axis, which also lies in that plane. The y direction is chosen such that a right-handed Cartesian coordinate system arises. The polar angle θ and azimuthal angle ϕ are defined according to the figure.

7.2 Use of the tripod stand

Sonocat can be mounted on the tripod stand for point measurements. A screw hole is available on the Sonocat which fits on the thread of the tripod. This way, less intrusive measurements can be performed, as the body of the operator is not in the vicinity of the sphere of Sonocat. Hence, unwanted disturbances of the sound field can be minimized.

7.3 Measurement procedure

To perform measurements, Sonocat should be plugged to a computer or tablet where the Sonocat Software is installed. An external sound source can be used but it is not compulsory. For the absorption coefficient measurements we, however, advice to have enough sound energy in the desired frequency band(s) to be able to have correct results. If needed, the *Signal generator* under *Tools* > *Waveform generator* (see Section 6.5) will provide some sound options.

→ Section 6.5

In the Sonocat Software all Sonocat measurements are grouped into projects. If you want to perform a series of measurements, we advice you to first create a project by clicking in the menu *File* > *New project*. If you want to add measurements to an existing project, please, first load the project by selecting *Load project* in the menu *File* before starting the measurements. The project can be saved at the start of the procedure (*File* > *Save project*) or when the

first measurement is saved (the Sonocat Software will ask you to save the project prior to saving the measurement).
In the *Project* panel, you can fill in the information related to the measurement.
The *Monitor* panel will visualise in real time the selected quantity of the soundfield Sonocat captures.
To perform an adequate recording, appropriate options should be chosen in the *Measure* panel (see Section 6.3) and a proper start delay should be applied as desired.
Please, remember that the *FFT length* will affect the frequency resolution; the *Frequency resolution*, *Number of averages* and *Overlap percentage* will determine the *Recording time*.

→ Section 6.3

Next, Sonocat can be set for a measurement. Two measuring procedures can be followed: a point or a scan measurement (see 7.3.1 and 7.3.2).
If you are using a sound source, please, set the generator before the start of the measurement. The measurement starts by pressing *Record* in the *Measure panel*.
Please take care to move your body away from the Sonocat sphere to minimize unwanted body reflections and use appropriate ear protection in case of loud noise. Please remember not to touch the sphere when Sonocat is plugged in.
The analysis can be performed straight after the measurement in the *Analyse* panel or later on (see Section 6.4).

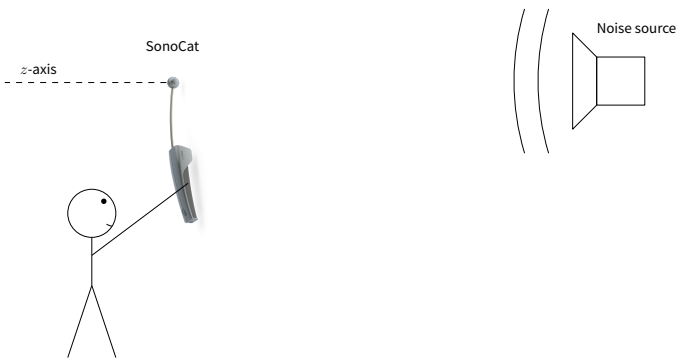
→ Section 6.4

Please note that all results are only valid in the range as given in the specifications, see Section 10.2.

7.3.1 Point measurement

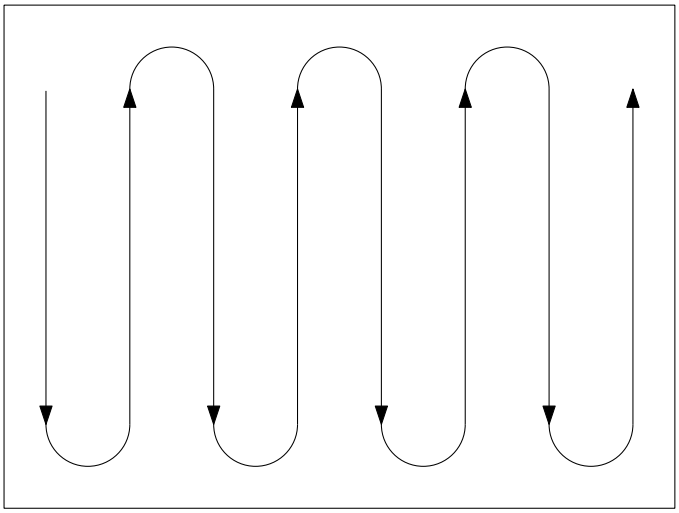
A point measurement records the sound field in one point in space. While performing point measurements, Sonocat should not move during the measurement. It can either be mounted on the tripod stand or rest on the surface under test for stability. Point measurements are used to measure sound pressure level, intensity level and direction. The level is determined at the position of the centre of the Sonocat's sphere. It can also be used to measure the sound power and sound absorption coefficient. For these last two options, we, however, advice to combine several point measurements.

An example of measuring the Sound Intensity Level in the z-direction is shown in the figure below:



7.3.2 Scan measurement

Scan measurements can be conducted with Sonocat. The scan measurement provides a surface-average of the squared pressure or sound intensity [3]. When doing a scan measurement, scan movements of the Sonocat sphere should be as smooth as possible with an in-plane **constant speed** of maximally *5* $^{cm}/_{s}$, while holding the z-axis perpendicular to the surface (see figure below). The scanning technique can be used to measure the time-averaged pressure or intensity level, the sound power level and the absorption coefficient.



7.3.3 Measuring sound pressure

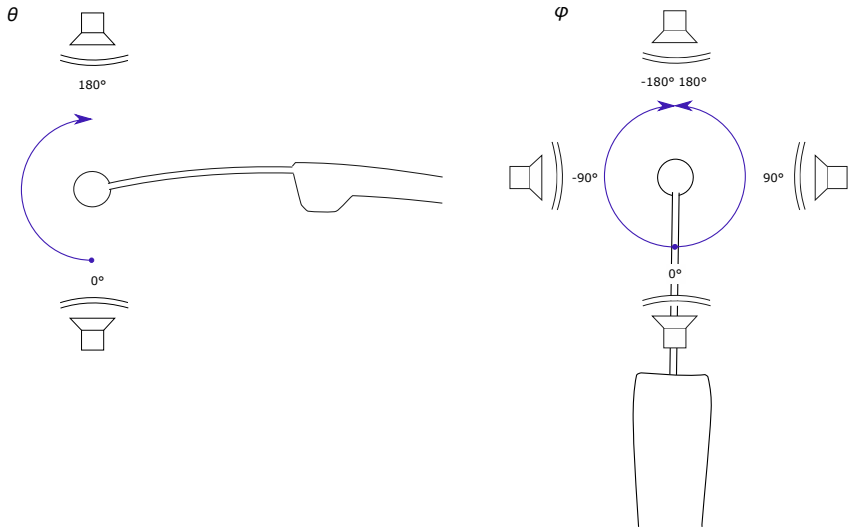
The Sound Pressure Level (SPL) can be measured as explained at the beginning of the Section 7.3 by point measurement(s)(see 7.3.1). To know the sound pressure in an area, an average sound pressure can also be measured using a scan measurement (see 7.3.2) or combined point measurements (see Section 9.6 for theoretical details about energetically combined quantities). The overall level is shown in a separate bar plot. In accordance with IEC-61672-1[2], the overall level result depends on the chosen frequency bands and weighting. You will see that the result in the overall bar is changed when selecting different bands and frequency weightings. The lower and upper frequency band limits of the overall SPL are obtained from the range showed in the *Results* box. Adjusting these limits will result in a different overall value.

7.3.4 Measuring sound intensity

The Sound Intensity Level (SIL) can be measured as explained at the beginning of the Section 7.3 by point or scan measurement(s) (see 7.3.1 or 7.3.2). The sound intensity in a certain frequency band can have either a positive or negative value indicating the direction of sound energy flow. The user is able to measure the Sound Intensity Level in the x-, y- and z-direction of a Cartesian coordinate system as well as in the direction of the intensity vector itself.

7.3.5 Measuring sound intensity direction

The polar angles θ and ϕ of the intensity vector (see Section 7.1) can be determined and measured as explained at the beginning of the Section 7.3 by a point measurement (see 7.3.1). The figure below displays a schematic representation of the value of θ and ϕ according to the position of the source.



The angle θ displays the elevation angle in degrees over frequency. It goes from 0° to 180° in the *vertical plane*. The 0° indicates an intensity vector pointing in the same direction as the *z-axis* (the sound energy is coming from "below" Sonocat). 90° indicates an intensity vector pointing in the *xy-plane*, showing a sound energy coming from the same horizontal plane. 180° indicates an intensity vector pointing to the *-z-direction*, meaning that the sound energy is coming from "above" Sonocat.
The angle ϕ displays the azimuth angle in degrees over frequency. It goes from - 180° to 180° in the *xy-plane*. The 0° indicates an intensity vector pointing in the same direction as the *x-direction*, the sound energy is then coming from the "back" of Sonocat. When the source is coming from the "right" of Sonocat its intensity vector is pointing in the same direction as the *y-axis*, ϕ is therefore positive (see Section 7.1). When the source is coming from the "left" of Sonocat its intensity vector is pointing in the opposite direction of the *y-axis*, ϕ is therefore negative. In "front" of Sonocat ϕ angle indicates 180° or - 180°.

7.3.6 Measuring sound power

For sound power measurements, a point or scan measurement is associated with a surface area such that the sound power can be calculated. For a scan measurement, the surface averaged sound intensity is calculated first. Multiplication with the surface area will then result in the sound power. For a point measurement, that point is considered to be representative for the specified surface area. Hence, do not forget to set the scan area in the *Measurement Settings*, see also Section 6.3.1.

→ Section 6.3.1

As for the intensity level, the sound power in a certain frequency band can

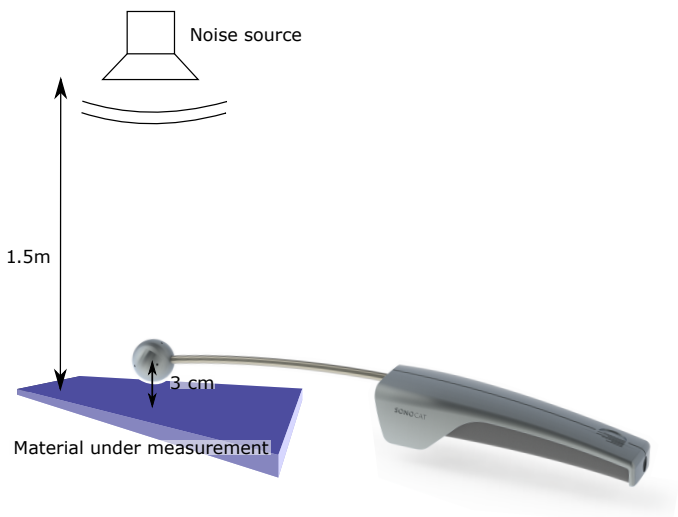
have either a positive or negative value indicating the direction of sound energy flow. The user is able to measure the Sound Power Level in the z-direction of a Cartesian coordinate system only. It is therefore important to hold the z-axis of Sonocat aligned with the normal of the (scan) surface, i.e. $\mathbf{I} \cdot \mathbf{n} = I_z$.

Please take into account the considerations for power measurements as stated in the ISO-9641-1 [4] and ISO-9641-2 [3] standards throughout the measurement procedure.

7.3.7 Measuring sound absorption

An acoustic material can be characterized by the amount of sound energy which is absorbed by the material under an acoustic load. Sonocat is able to measure the (effective) in situ Sound Absorption Coefficient α of a material in stationary sound fields following the procedure as explained at the beginning of Section 7.3 either with point or scan measurement(s) (see 7.3.1 or 7.3.2). In case of point measurement, we advice to do several points and combined them using the combine option in the *Analyse* panel (see Section 9.6 for theoretical details about energetically combined quantities).
Sonocat should be oriented such that the z-axis points away from the surface of interest. Keep a distance of approximately 3 cm between the centre of the sphere and the surface. Sonocat uses the z-axis to measure the sound absorption coefficient. It is therefore important to hold the z-direction of Sonocat aligned with the normal of the surface.

If you are using an external source, we advice to place it at least at 1.5 meter from the sample surface under test to have a wave as plane as possible in the low frequency range.



The *Results* box shows the sound absorption coefficient α as a function of frequency on a scale from -1 to +1. Hence, negative values are possible. For a negative value of α, the model assumes emission from the surface. Due to the theoretical model, the result for α is always in the range from -1 to +1. See also Section 9.5.

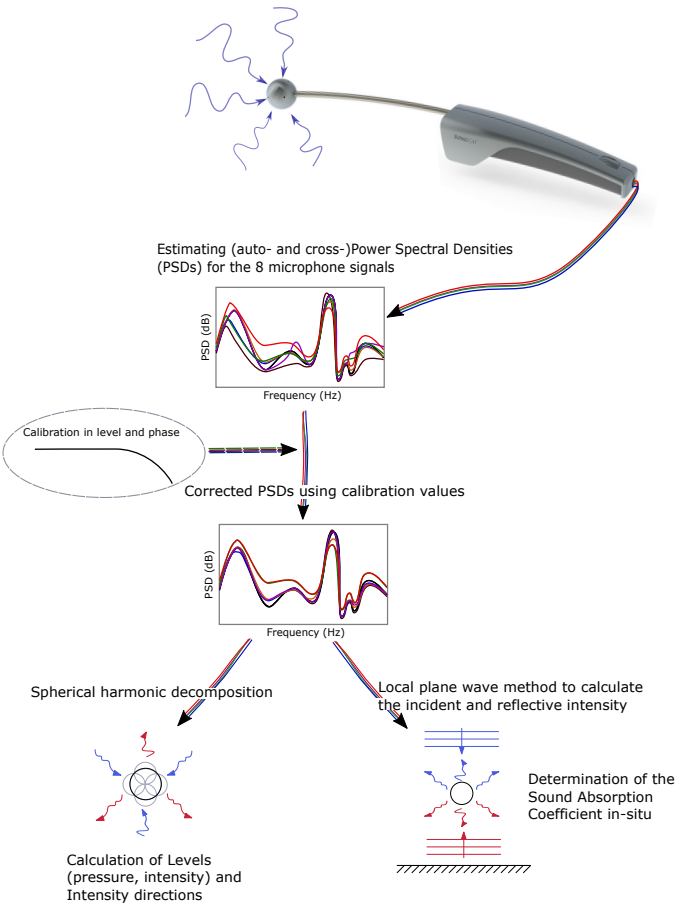
→ Section 9.5

→ Section 6.2

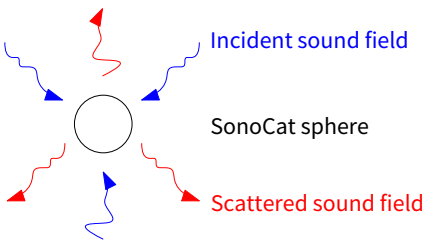
Note: You can also measure sound absorption real time using the Monitor *panel Section 6.2. Note that in that case the results are generally less accurate since shorter measurement times are used. However, the* Monitor *panel is especially useful to locate 'defect spots' in an absorbing surface, which are visible by abrupt changes in the indicated sound absorption coefficient.*

8 Theoretical principles

This section provides some background information about the theoretical principles behind Sonocat's measurement algorithms. In order to calculate the different quantities using the recorded signals of the eight MEMS microphones located in the Sonocat's sphere, two models are implemented. The different steps are schematized below:



8.1 Spherical Harmonics decomposition



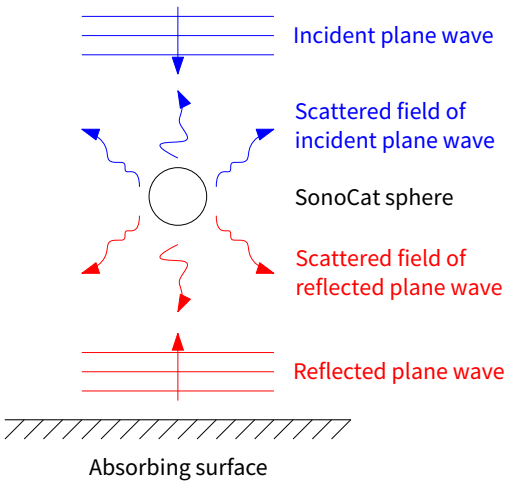
The algorithms for the Spherical Harmonics decomposition used in the Sonocat Software follow more or less the same procedure as proposed in [5]. The sound field is written as a linear combination of an incident and a scattered

sound field, see figure above. Both fields are expanded in terms of spherical harmonics. Applying the boundary condition on the rigid sphere (that is, the pressure gradient in normal direction is zero) yields an expression for the total sound field. An approximation of this total sound field can be found by truncation of the spherical harmonics terms up to fourth term (i.e. only the zero'th and first order modes are considered). Mapping this model onto the measured microphone signals yields now the contribution of each mode.

The coefficients of the four modes can now be used to determine the sound pressure and particle velocity of the incident sound field. Hence, we can calculate the quantity of interest (e.g. sound pressure level and sound intensity level) in the middle point of the sphere as if Sonocat would not be in the field.

Note: The model does not account for other acoustically hard objects nearby other than the sphere of Sonocat. Therefore, to accurately measure quantities other than the sound absorption coefficient, it is imperative to hold Sonocat at sufficient distance from other acoustically hard objects.

8.2 Local Plane Wave-method



Using the Local Plane Wave-method, the local acoustic field is modelled as two plane waves travelling in opposite direction. [6, 7, 8, 9, 10] The presence of Sonocat in the acoustic field introduces scattering of the plane waves on the sphere of Sonocat, see figure above. This scattering is accounted for in the model, in such a way that the amplitudes of the plane waves are computed as if the sphere would not be present. [11]

The amplitude of the incoming plane wave is used to determine the incident intensity; the amplitude of the reflecting plane wave to determine the reflected intensity. The active intensity is equal to the difference between the incident and the reflected intensity. The incident, reflected and active power are now found by multiplying the associated intensities by the surface. Hence, the sound absorption coefficient is obtained by dividing the active power by the incident power.

Note: For each frequency, Sonocat Software checks whether the incident power is larger than the reflected power. In the event that this is not the case, the

active power is divided by the reflected power and the Absorption coefficient *is called an* Emission coefficient. *As the active power has a negative sign in that case, the emission coefficient is plotted as a negative number (distinguishing from the absorption coefficient).*

9 Glossary

9.1 Sound Pressure Level

The Sound Pressure Levels are calculated according to the following definition [12, p. 52]:

$$L_p = 10 \log_{10} \left(\frac{p_{\mathrm{rms}}^2}{p_{\mathrm{ref}}^2} \right), \tag{1}$$

where p_{rms} is the root-mean-squared sound pressure and $p_{\mathrm{ref}} = 2 \cdot 10^{-5}\ Pa$ the reference sound pressure. The root-mean-squared sound pressure is defined as:

$$p_{\mathrm{rms}} = \sqrt{\lim_{T \to \infty} \frac{1}{T} \int_{t=0}^{T} p^2(t)\, \mathrm{d}t}, \tag{2}$$

where p is the sound pressure at time t.

The SPL is computed per frequency bin. From there on, the frequency weighted SPL in a certain frequency band b is computed as:

$$L_{p,b} = 10 \log_{10} \left(\sum_{i=i_l}^{i_u} \frac{p_{\mathrm{rms},i}^2}{p_{\mathrm{ref}}^2} \right) + L_{A/C/Z}, \tag{3}$$

where i_l denotes the lower frequency bin index of band b, i_u the upper frequency bin index of band b, $p_{\mathrm{rms},i}$ the root-mean-squared sound pressure of frequency bin i and $L_{A/C/Z}$ the frequency weighting of band b in dB.

The number of frequency bins in a frequency band depends on the chosen frequency resolution. Frequency bins crossing a band edge are proportionally divided between these two bands.

The overall Sound Pressure Level is computed according to the IEC-61672-1 standard [2], that is:

$$L_p = 10 \log_{10} \left(\sum_{b=b_l}^{b_u} 10^{\left(\frac{1}{10} L_{p,b}\right)} \right), \tag{4}$$

where b_l and b_u denote the lowest and highest frequency band of interest, respectively. In accordance with IEC-61672-1[2], the overall level result depends on the chosen frequency bands and weighting.

For the (average) sound pressure a formulation is defined:

$$p_{\mathrm{rms},b,\mathrm{tot}}^2 = \frac{\sum_{i=1}^{N} p_{\mathrm{rms},b,i}^2 S_i}{\sum_{i=1}^{N} S_i}, \tag{5}$$

where $p_{\mathrm{rms},b,i}$ is the root-mean-squared sound pressure in band b of measurement i and S_i again the corresponding surface area.

9.2 Sound Intensity Level

The Sound Intensity Levels (SIL) in stationary sound fields is measured according to the following definition [12, p. 52]:

$$L_I = 10 \log_{10} \left(\frac{|\mathbf{I} \cdot \mathbf{n}|}{I_{\mathrm{ref}}} \right), \tag{6}$$

where $\mathbf{I}$ is the sound intensity vector, $\mathbf{n}$ the normal vector pointing in the direction of interest and $I_{\text{ref}} = 10^{-12}\ Pa$ the reference sound intensity. The sound intensity is known as the time average of the instantaneous acoustic energy flow per unit area ($\mathbf{i}(t) = p(t)\mathbf{u}(t)$), that is:

$$\mathbf{I} = \lim_{T\to\infty} \frac{1}{T} \int_{t=0}^{T} p(t)\mathbf{u}(t)\,\mathrm{d}t, \tag{7}$$

where p and $\mathbf{u}$ are the sound pressure and particle velocity vector at time t, respectively.

The Sonocat Software computes the SIL per frequency bin. The frequency weighted SIL in a certain frequency band b is computed similar to the SPL as:

$$L_{I,b} = 10\log_{10}\left(\left|\sum_{i=i_l}^{i_u} \frac{I_i}{I_{\text{ref}}}\right|\right) + L_{A/C/Z}, \tag{8}$$

where i_l denotes the lower frequency bin index of band b, i_u the upper frequency bin index of band b, I_i the sound intensity (in the direction of interest) of frequency bin i and $L_{A/C/Z}$ the frequency weighting of band b in dB.

The overall Sound Intensity Level in a certain direction is computed as:

$$L_I = 10\log_{10}\left(\sum_{b=b_l}^{b_u} \pm 10^{\left(\frac{1}{10}L_{I,b}\right)}\right), \tag{9}$$

where b_l and b_u denote the lowest and highest frequency band of interest, respectively. The $\pm$ character is either positive or negative depending on the the energy flow sign per unit area in a certain band.

The sound intensity in a certain frequency band can have either a positive or negative value indicating the direction of sound energy flow.

9.3 Pressure-residual intensity index

The pressure-residual intensity index provides a measure for the 'reactivity' of the acoustic field and is defined as [4]:

$$\delta_{p,I} = L_p - L_I. \tag{10}$$

This quantity is also provided for all directions of the sound intensity.

9.4 Sound Power Level

The Sound Power Levels (SWL) in stationary sound fields is measured according to the following definition [12, p. 53]:

$$L_W = 10\log_{10}\left(\frac{|W|}{W_{\text{ref}}}\right), \tag{11}$$

where W is the sound power through a certain surface and $W_{\text{ref}} = 10^{-12}\ Pa$ the reference sound power. The sound power can be determined by integrating the normal component of the sound intensity vector $\mathbf{I}\cdot\mathbf{n}$ over the surface S:

$$W = \int_S \mathbf{I}\cdot\mathbf{n}\,\mathrm{d}S. \tag{12}$$

The SWL is calculated per frequency bin. To obtain this result, the (surface average) intensity per bin has to be determined (equation 7). Next, this sound intensity has to be multiplied with the associated surface area to obtain the sound power per bin. From there on, the frequency weighted SWL in a certain frequency band b is computed similar to the SIL as:

$$L_{W,b} = 10\log_{10}\left(\left|\sum_{i=i_l}^{i_u}\frac{W_i}{W_{\mathrm{ref}}}\right|\right) + L_{A/C/Z}, \tag{13}$$

where i_l denotes the lower frequency bin index of band b, i_u the upper frequency bin index of band b, W_i the sound power of frequency bin i and $L_{A/C/Z}$ the frequency weighting of band b in dB.

The overall Sound Power Level is computed as:

$$L_I = 10\log_{10}\left(\sum_{b=b_l}^{b_u}\pm 10^{\left(\frac{1}{10}L_{W,b}\right)}\right), \tag{14}$$

where b_l and b_u denote the lowest and highest frequency band of interest, respectively. The $\pm$ character is either positive or negative depending on which direction the energy through the surface in a certain band flows to.

9.5 Sound Absorption Coefficient

An acoustic material can be characterized by the amount of sound energy which is absorbed by the material under an acoustic load. Sonocat is able to measure the (effective) in situ Sound Absorption Coefficient of a material in stationary sound fields according to the following definition:

$$\alpha = \frac{W_{\mathrm{ac}}}{W_{\mathrm{in}}}, \tag{15}$$

where W_{ac} is the (time-averaged or, so-called, active) sound power through a certain (material) surface and W_{in} the incident sound power through the same surface. Determination of the active sound power and the incident sound power are computed similarly:

$$W_{\mathrm{ac}} = \int_S I_{\mathrm{ac}}\,\mathrm{d}S, \tag{16}$$

$$W_{\mathrm{in}} = \int_S I_{\mathrm{in}}\,\mathrm{d}S, \tag{17}$$

with I_{ac} the active sound intensity and I_{in} the incident sound intensity.

The Sound Absorption Coefficient is calculated per frequency bin. The active and incident sound intensity per bin are calculated. Then, the active and incident sound power per band can be determined and thus the sound absorption coefficient per frequency band b, that is:

$$\alpha_b = \frac{W_{\mathrm{ac},b}}{W_{\mathrm{in},b}}. \tag{18}$$

The sound absorption coefficient measurements can be combined to obtain an average coefficient, the total incident and active power has to be determined and hence the (average) sound absorption is:

$$\alpha_{b,\mathrm{tot}} = \frac{W_{\mathrm{ac},b,\mathrm{tot}}}{W_{\mathrm{in},b,\mathrm{tot}}}. \tag{19}$$

9.6 Energetically combined quantities

For measuring the sound power level of an object, multiple point and/or scan measurements are typically combined to form a closed surface area around the object under investigation. The level of the total sound power can be obtained by selecting each measurement belonging to the set. The SWL of the selected measurements are effectively combined as:

$$W_{b,\mathrm{tot}} = \sum_{i=1}^{N} W_{b,i}, \tag{20}$$

with N the number of measurements and i the measurement index.

The sound intensity level, Sound pressure level and absorption coefficient can also be combined. In that case, the (average) sound intensity is defined as:

$$I_{b,\mathrm{tot}} = \frac{\sum_{i=1}^{N} I_{b,i} S_i}{\sum_{i=1}^{N} S_i} = \frac{W_{b,\mathrm{tot}}}{\sum_{i=1}^{N} S_i}, \tag{21}$$

where $S_{b,i}$ is the sound intensity in band b of measurement i and S_i is the corresponding surface area. For the (average) sound pressure a similar formulation is defined:

$$p^2_{\mathrm{rms},b,\mathrm{tot}} = \frac{\sum_{i=1}^{N} p^2_{\mathrm{rms},b,i} S_i}{\sum_{i=1}^{N} S_i}, \tag{22}$$

where $p_{\mathrm{rms},b,i}$ is the root-mean-squared sound pressure in band b of measurement i and S_i again the corresponding surface area. For the sound absorption coefficient, the total incident and active power has to be determined and hence the (average) sound absorption is:

$$\alpha_{b,\mathrm{tot}} = \frac{W_{\mathrm{ac},b,\mathrm{tot}}}{W_{\mathrm{in},b,\mathrm{tot}}}. \tag{23}$$

9.7 Frequency binning

Binning is a technique to reduce a large number of data to a smaller number of "bins". In the case of Sonocat we provide the option to bin the data in different octave bands, as shown in equations 3, 8, 13, for the pressure, intensity and power level respectively. If the frequency band choice is set to anything other than narrow band, the narrow band results are energetically summed up in frequency bands prior to exporting/plotting the result. For the *Absorption coefficient*, the incident and active intensities per bin are first summed up in bands, and afterwards the absorption coefficient is computed from the intensity values in each frequency band. In this case the abscissa will show the nominal midband frequencies of the chosen frequency band.

9.8 Weighting

Three common types of frequency weighting are provided:

A-weighting : Frequency weighting based on the relative loudness perceived by the human ear at a sound loudness level of 40 phon.

C-weighting : Frequency weighting that is more appropriate for higher loudness levels.

Z-weighting : Frequency weighting at an equal level (0 dB) for all frequency bands (i.e. no frequency weighting).

10 Data sheet

10.1 Sonocat dimensions

Size:	Sonocat:	365x65x45 mm (LxWxH)
	USB Cable:	2.5 m
	Case:	405x330x170 mm
Weight:	Probe:	212 g

10.2 Specifications

Acoustic:	Frequency range:	12 - 24000 Hz
	Calibrated frequency range:	50 - 6300 Hz
	Acoustic dynamic range:	29 - 116 dB(A)-SPL
Digital:	Sampling rate:	48 kHz
	Bit depth:	24 Bits

10.3 System requirements

Operating system:	Windows 7 SP1, 8, 8.1 or 10. x64 (x86_64) instruction set.
Processor:	Clock speed of at least 2 GHz. At least a dual core system.
RAM Memory:	4GB or more.
Disk space:	At least 150MB of free space.
USB Controller:	High-speed (2.0) or newer.

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