

SOUNDSCAPE

**A PROGRAM FOR DEMONSTRATING
ACOUSTIC PROPERTIES OF SPACES**

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1 INTRODUCTION

SoundScape is designed to be used by architects, interior designers, and anyone interested in understanding the acoustic properties of interior spaces. The program allows you to hear sounds, coming from both outside and inside the space, as the occupants would hear them. In doing so it takes account of the building materials in the surrounding partitions, and the reverberation properties of the room.

SoundScape is not a replacement for sophisticated acoustic modelling programs, and should not be used for the design of concert halls or other spaces where quality of acoustics is critical for the performance of the space. Rather, it is intended as an aid in designing acoustics for more general spaces such as restaurants, offices and public buildings, where the use of detailed modelling programs would not be cost-justified.

SoundScape also does not remove the need to obtain advice from a qualified acoustic consultant on the practical implementation of acoustic treatments, and on acoustic issues not covered in SoundScape such as structure-borne noise. Rather, the program is intended to make the designer, as well as their client, aware of potential acoustic issues and how they can affect occupants' experience of the space.

This section provides an introduction to the use of the program, including system requirements, basic concepts, and some performance issues that may affect the program's operation. Other sections deal in more detail with the way sound sources, sound paths and rooms are represented, and, for those interested, tools to add additional sounds, partition types and wall finishes to the program's library.

SoundScape Version 1.3 is freely distributed and can be installed on any number of machines.

However, no warranty is given or implied as to fitness for any purpose, and no liability is accepted for any damage or loss caused by use of the program.

1.1 Requirements

To install and run SoundScape, the following is required.

- Windows PC. SoundScape has been tested on Windows 2000 Professional, XP and Vista. It should run on other operating systems, but no guarantees are given.
- At least 490 MB of free disk space. This is mostly used to save sound samples.
- To perform audio simulation, the processor speed should be at least 2.4 GHz. However, faster speeds allow more sounds to be replayed simultaneously, and more accurate reproduction of reverberation, as described in "System Performance Issues".

To listen to sounds, of course you need a sound card and either headphones or speakers. Headphones are often better because the sound you hear is not influenced by the room you are listening in. However, with headphones you can only make an approximate setting of the loudness of the sound. For the best quality reproduction, listen using good quality speakers in a very "dead" room and adjust the sound level as described under "Calibration".

1.2 Basic Program Concepts

In SoundScape, sound from one or more **sound sources** reaches a listener in a **room** through one or more **sound paths**. The level (loudness) and quality of the sound depend on properties of the sound source(s), the sound paths(s) and the room, all of which you can change. The program shows you the level of sound arriving from each source and each sound path, and, assuming you have a fast enough computer, you can hear the sound as it would be heard in the room. The sound sources, sound paths and room properties can all be saved in a project file and re-loaded later.

1.2.1 Sound Sources

In SoundScape, sound sources are of two types. Background sound sources are sources that don't change much over time and would generally not be noticed consciously. They are treated separately from foreground sources that do change with time and would be noticed if they are loud enough. For background sources, the program shows the L_{Aeq} sound level (representing the average A-weighted sound level), while for foreground sources the program shows the L_{Amax} sound level (representing the maximum A-weighted sound level in the sound file). For mixtures of sounds the program shows the L_{Aeq} level.

Both background and foreground sound sources can be located:

- outside the room (in an adjacent room or in the external environment), in which case the sound will enter the room via a partition;
- inside the room at a specific point, in which case the listener will be at a certain distance from the source; or
- as diffuse sound in the room (e.g. air-conditioning, a crowd of people, or "masking" noise), in which case the sound level is the same throughout the room.

1.2.2 Sound Paths

To be heard by the listener, each sound source needs to be connected to the listener via a sound path of the right type. For sources outside the room, the sound path specifies what type of partition the sound travels through (e.g. glazing, brick wall, opening, etc.) and how far the listener is from the partition. For a point source in the room, the path just specifies the distance from the source, and for a diffuse source the path doesn't need to specify anything - the sound is the same everywhere.

In SoundScape you create sound paths, then connect sources to them by clicking and dragging. You can only connect a source to the appropriate type of sound path for that source. Several sources can be connected to the same path - for example, several types of sound may enter the room through the same partition. In addition, the same source can be connected to several paths - for example, the same sound may enter the room through both a window and a wall.

1.2.3 The Room

The room itself has properties that affect the sound level and quality of all sound heard in the room. The most important of these properties is the reverberation time, which can be specified by octave band between 125 Hz and 4 KHz. You can enter these values by hand, and the sound levels and audible simulation will change accordingly.

A calculator is also provided that allows you to calculate the reverberation time of a room from the room volume and absorption properties of the surface finishes. The calculated reverberation time is then written to the main screen.

1.2.4 Project File

This saves details of all the sound sources, sound paths and connections between them, as well as the room properties. It also saves details of the latest reverberation calculation performed - the room volume used and the type and area of each surface.

1.3 A Simple Project

To create a first project in SoundScape, follow these steps.

1. Start SoundScape and select File > New Project. You should see empty boxes labelled "Background Sound Sources", "Foreground Sound Sources" and "Sound Paths", and a box labelled "Room" with some default properties.
2. Click the label "Background Sound Sources", and the menu item "Add Source". Select an item under "Use Sound from this Library File" - say, section "Traffic" and item "Medium Traffic". Select "Source Location" as "External Environment" and change "SPL outside room" to 75 dBA (fairly loud traffic). Click "OK". This should show the new source in the "Background Sound Sources" box.
3. Click the label "Sound Paths" and the menu item "Add Sound Path". Leave "Path Type" as "Through a Partition", and don't change the default distance and size of the partition, but under "Use Transmission Loss from this Library File", select section "Glazing - Single Fixed", item "6mm - Al frame". (This is a fully glazed wall, 3 m x 10 m.) Click OK. This should show the new sound path in the "Sound Paths" box.

4. Now click in the square at the right of the sound source, and drag to the square to the left of the sound path. The source is now connected to the path. You can see the sound level in the room from that source is 49.4 dBA, L_{Aeq} . If you click the green "Play" button you should hear the traffic through the glazing. Click the "Pause" button to stop.
5. Now create a new foreground source by clicking the label "Foreground Sound Sources". Use the library file "Speech" / "Male - Maths", and make the source location "Point in Room", with SPL at 1m being 67 dBA (typical normal male speaking level). Click "OK". You now have a foreground source with a sound level of 67 dBA L_{Amax} .
6. Create a new sound path for this source. Make the Path Type "In Room, at a Distance", and make the distance 5m. (Keep "Include Direct Sound" checked.)
7. Connect the second source to the second path. The L_{Amax} sound level due to this source is 61.1 dBA, or about 12 dBA above the level of the traffic. Click "Play" to hear the combined sound.
8. Save the project by selecting menu item File > Save (give it any name).

You can now introduce other sound sources and sound paths, change the type of wall construction, and change the room properties to see (and hear) what effect it has on the sound. The section "Sound Sources, Sound Paths and Rooms" gives more detail on what the various options mean and how to use them.

1.4 Files and System Performance Issues

Files associated with the project are installed in folder "SoundScape", in the location you selected during installation. This has sub-folders "Library" (for noise source files, partition types and wall finishes), "Program" (for program files) and "Project" (the default location for project files) and "Help". You can choose to install or move the files to another folder, but it's best if you keep the same sub-folders within the main folder. Also, when a project refers to a sound file it uses the full file path, so if you move the "Library" folder, any saved projects won't work because the project won't know where to find the sound files.

Producing sound in real time is fairly computing-intensive, and slower computers may show signs of overloading if you use too many sound sources. Very slow computers may not handle even a single source and path. The symptom of this is that the sound will break up, with gaps between sections of sound. If this is an issue, you can keep track of how your system is doing using Windows Task Manager (accessed by Ctrl-Alt-Delete). When the CPU usage approaches 100%, you're in trouble.

You can ease the computing burden a little by using a less accurate simulation of reverberation. A control in the "Room" box allows five levels of accuracy for simulating reverberation. The default is 5, which gives the best simulation. If your sound is breaking up, try lower levels, which use fewer resources but don't sound as good, particularly for long reverberation times.

Something to note if you're running low on resources is that selecting "Mute" or "Play Alone" for a source doesn't speed the system up - the output of unused sources just becomes a string of 0's. A better way is to remove the connection from the source to its sound path(s) - this does free up some system resources.

2 SOUND SOURCES, SOUND PATHS AND ROOMS

This section provides more details on how to define and use sound sources, sound paths and room properties.

2.1 Sound Sources

To create a new sound source, click on the label "Background Sound Sources" or "Foreground Sound Sources" and then "Add Source". The "Add New Sound Source" dialog appears.

The **source name** (top box) can be anything you use to identify the source. If you don't change it from "New Sound Source", it will default to the name of the sound file you select. However, if you later edit the source and change the sound file, the source name will not change with it - you need to change it yourself.

The **sound file** represents one of the files that are saved in the Sound File Library. These files are identified as either "background" or "foreground" - if you're adding a new background sound, only the "background" sound files will be shown. Select a library section in the left-hand box, and select the actual file from the right-hand box.

Source Location can be one of four options. The Sound Pressure Level (SPL) specified underneath has a different meaning depending on the source location selected.

- **Point in Room** - the sound source is at a specific, single point in the room. The SPL is the SPL that would be measured at 1m from this source, with no reverberation. Note that this is not the same as the Sound Power Level (SWL) of the source, which is often used to specify source strength. In fact, for the sources considered here, the SWL is the SPL at 1m plus 8 dB. Sources are assumed to be omnidirectional - their sound level does not depend on the angle to the listener.
- **Diffuse Source in Room** - the source is heard at the same level throughout the room, generally because the sound is created by a large number of actual sources (e.g. small loudspeakers, or people in a crowd). Here the SPL specifies the sound level at which the source is heard.
- **In An Adjacent Room** - sound from the source enters the room from an adjacent room through a partition (or a gap in a partition), and the sound path will need to specify the area and type of partition involved. Here the SPL specifies the sound level that would be recorded in the adjacent room, close to the partition.
- **External Environment** - similar to "In An Adjacent Room", but the sound entering the room comes from a non-reverberant environment outside, rather than from another reverberant space. (This affects the amount of sound that is transmitted.)

Once a sound source is created, it can be edited or removed by clicking on the box at the right of the source. Selecting "Edit" brings up the same dialog box used to create the source. If the source is not connected to a sound path, the "Edit" and "Remove" options are available. If the source is connected to a sound path, you can't change the Source Location to a type that would be incompatible with the connected path - for example, you can't change to location "Point in Room" if the source is connected to a path that is "Through Partition".

The "Remove" option is not available for sources that are connected to sound paths.

If the source is connected to a path, the additional options "Mute" (set this source to zero output) and "Play Alone" (set all other sources to zero output) are available.

2.2 Sound Paths

To create a new sound path, click on the label "Sound Paths" and then "Add Sound Path". The "Add New Sound Path" dialog appears.

The **path name** (top box) can be anything you use to identify the path. However, it is recommended that you use the default name unless you've got a good reason not to. The default name is the name of the partition you select (for "Through a Partition" paths), "Source at x m" for "In a Room, at a Distance" paths and "Diffuse Source" for "Diffuse Sound Through the Room" paths. If you later edit the path and change the type, the path name will change to the default - if you want to give it a different name, you need to edit the name immediately before closing the dialog.

If the **path type** is "Through a Partition", you need to specify the following:

- Distance to the partition, m. This is the distance from the listener to the closest point on the partition.
- Include Direct Sound. This should normally be checked. Uncheck the box if the listener will be in a position where there is a solid barrier between them and the partition (e.g. they are around a corner in the room).
- Partition Size - approximate if the partition is not rectangular, but try to ensure that the area will be correct.
- Library file for Transmission Loss. This is selected as for sound sources, and represents the construction of the partition. If there is more than one construction type, treat them as two partitions with smaller size.

If the **path type** is "In Room, at a Distance", the only things to set are the distance and "Include Direct Sound".

If the **path type** is "Diffuse Sound Through Room", no other parameters need to be set.

Once a sound path is created, it can be edited or removed by clicking on the box at the left of the path. Selecting "Edit" brings up the same dialog box used to create the path. The "Remove" option is not available for paths that are connected to sound sources, and in this case you can't change the Path Type.

The "Show Spectrum" option is available if the path type is "Through a Partition". This shows a graph of the Transmission Loss values for the selected partition (as red squares) – or more accurately the opposite of the Transmission Loss values, because they are plotted as negative numbers. It also shows the performance of the audio filter that the program has used to simulate the partition (as a blue line). Soundscape's audio filters are optimised to produce a reasonable simulation with low resource usage – this graph gives an idea of how close the simulated sound will be to the actual sound.

2.3 Connecting Sources and Paths

To connect a sound source to a path, click and drag from the box at the right of the source to the box at the left of the path. Only the following connections are allowed:

- Source location "Point in Room" to path type "In Room, at a Distance"
- Source location "Diffuse Source in Room" to path type "Diffuse Sound through the Room"
- Source location "In an Adjacent Room" or "External Environment" to path type "Through a Partition".

You can connect more than one source to the same path, and the same source to more than one path.

The sound path will show the SPL heard by the listener from all sources using that path. If there is only one source connected and that is a foreground source, then the path shows the L_{Amax} sound level - otherwise it shows the L_{Aeq} level.

A connection can be removed by clicking on the connecting line and selecting "Remove Connection".

2.4 Room Properties

The room's reverberation time (RT) can be set for each octave band between 125 Hz and 4 KHz. When you click in one of the boxes used to set the RT, the value shows in magenta, indicating that it is being edited, but no changes have been made to the program's reverberation processor yet. When you leave the box, the value you have entered is checked. If the entered value is OK then the reverberation processor is re-configured and the value returns to black.

The same is true for the boxes showing the room's length, width and height, which are used to set more subtle properties of the program's reverberation processor. These values don't need to be exact, and the implied room volume doesn't need to match the volume used to calculate reverberation time.

While changing these boxes (or the "Simulation Accuracy" setting), it is best to pause the audio playback - otherwise more strain is put on the machine's computing resources.

2.5 Calculating the Reverberation Time

SoundScape includes a tool to help you calculate the reverberation time of a room using the Sabine formula

$$RT(f) = 0.16 V / A(f)$$

where $RT(f)$ is the reverberation time in seconds as a function of frequency f , V is the room volume in cubic metres, and $A(f)$ is the total absorption in the room, in metric sabines (also a function of frequency). $A(f)$ is defined as

$$A(f) = \sum \alpha_i(f) a_i$$

where $\alpha_i(f)$ is the sound absorption co-efficient of room surface i , and a_i is its area.

Clicking "Calculate Reverb. Time" in the Room box brings up a calculation screen. Initially the room volume is just the value implied by the three room dimensions in the Room box, but change this if it's not accurate. Then you can add surfaces of various types, with their areas, and the reverberation time is calculated in octave bands between 125 Hz and 4 KHz.

If you click OK, the reverberation time you've calculated is transferred to the Room box in the main form, and the reverberation processor is re-configured.

It's best if you pause the audio playback before doing this calculation, once again to save the machine's resources.

2.6 Calibrating the Sound Level

The simulated sound gives a better indication of what it would actually sound like in the space if the sound pressure level you're hearing matches the SPL shown on the screen. You can do this using the Calibration procedure.

If you click "Calibrate" on the main screen (top right), you can produce a constant "whooshing" sound (high-pass filtered pink noise if you want the technical description). If the SPL from this sound is 70 dBA* at your listening position, then the SPL from all the other sounds produced by the program will be correct at that position.

The only way to make the calibration accurate is to use loudspeakers, in a very "dead" room, and use a sound level meter to measure the level of the "calibration" sound. Then adjust the level being produced by the speakers until it measures 70 dBA*. (You can adjust it by using the computer's "Volume Control" setting.)

If you're using headphones or you don't have a sound level meter, you can get it approximately right by adjusting the calibration sound until it would be difficult to understand (not difficult to hear) a normal male voice at 2 m.

Instructions are given on the screen that appears when you push "Calibrate".

2.7 The Peak Level Meter

The "Peak Level" meter next to the "Play" button monitors the total audio signal being produced by SoundScape. If you ask for a sound level that is too high, the program can produce a signal that will overload the computer's sound card, producing a distorted output. This is a particular issue for low-frequency sound, which may produce a high peak level even though the A-weighted SPL is moderate.

Distortion is indicated when the peak level exceeds the highest mark on the scale, and the bar turns red. The other marks are at intervals of 10 dB below the distortion level.

By default, the maximum peak sound level before distortion is 90 dB. (Note this is a "linear" sound level – it doesn't relate directly to the A-weighted SPL.) If you need to produce higher sound levels than this, you can increase the maximum level through the "Settings ..." menu item. If you do this, you will need to re-calibrate if you want the actual sound level to be accurate. Increasing the "maximum peak sound level before distortion" means quiet sound will not be reproduced quite as well. Change it back down to 90 if you don't need it to be higher.

One point to note is that the maximum peak sound level is stored with the **program settings**, **not** with the **project**. If you change this value it will be changed for all projects, and will stay changed if you close and re-open the program.

* 70 dBA is the default SPL for calibration, and is suitable for most cases. You can alter the SPL used for calibration through the "Settings ..." menu item (see Section 2.8). If you change this value, calibration can only be performed by measurement with a sound level meter.

2.8 Changing Program Settings

Several settings can be changed using the "Tools" > "Settings ..." menu item.

- "Maximum Peak Sound Level Before Distortion": this is described in Section 2.7.
- "SPL for Calibration": Sets the SPL that you should measure when calibrating the output sound level. I can't think of a good reason for wanting to change this from the default of 70 dBA, unless the environment is very noisy (in which case your simulations won't be very useful) or your sound system can't generate 70 dBA at the measurement position (in which case you won't be able to generate most sounds that you'd normally be interested in). However the option to change it is there.
- Location of library files: The "Audio Files", "Partition Types" and "Wall Finishes" libraries are stored by default in a "Libraries" folder within the general "SoundScape" folder, which was saved on installation of the program. You can change the location of these files using the appropriate "Browse ..." button. This allows you, for example, to maintain several separate libraries for different purposes (see Section 3). The "Default" button will reset the library to the default location.

Note that the "Audio Files" library doesn't contain the actual audio files – just the name and path of each file and information about the spectrum.

3 EDITING THE SOUNDSCAPE LIBRARIES

SoundScape is installed with libraries of audio files, partition types and wall finishes that you can select. You can add to, remove or edit the items in these libraries using the procedures described in this section.

Please note that if you add to or alter the supplied libraries, SoundScience takes no responsibility for any problems that may arise, either within the program or because the material you enter may be incorrect.

Also, if you add audio files containing material that is subject to copyright or other restrictions, you are solely responsible for any consequences.

3.1 Common Procedures for All Libraries

Open one of the libraries using one of the items under the "Tools" menu on the main screen – an "Edit Library" dialog appears. Each library is divided into Sections, which just serve to group similar items together. You can create a new Section using the "Add Section" button at the bottom of the library dialog. "Remove Section" removes the section AND ALL ITEMS IN IT – be careful.

When a Section is selected in the left-hand box, you can add an Item to the Section, or view or remove the item selected in the right-hand box, using the appropriate buttons. Details for adding and editing items in each library are in the following sections.

3.2 Adding Audio Files

Audio files to be added to SoundScape MUST be in WAV format, 16-bit, stereo, and sampled at 44,100 samples per second. If you don't know what this means, you shouldn't be adding audio files to SoundScape.

The files should be reasonably short – 2 minutes would be the maximum required and often 30 seconds is fine. Use an audio editor such as Audacity to select the section of audio you need, and save it as a separate file.

When you add a sound file to the library, what is saved is the location of the file – the file itself can be anywhere on your computer. However, it is recommended that you keep SoundScape audio files in the "AudioFiles" sub-folder of SoundScape's "Library" folder – that way they don't get lost.

When you click "Add Item" to add a new audio file, the first thing you should do is select the file location. The program will then analyse the file to find the level and spectrum of the sound it contains. It calculates the spectrum corresponding to the L_{Aeq} , L_{Amax} and L_{Amin} levels in the file, relative to 0 dB being the highest sound level that could be stored without distortion. This process may take several minutes, depending on the length of the file and the speed of your machine.

When the file is analysed, supply a display name for the new sound, and make sure you select whether this is a background or foreground sound. You can then use this sound in simulations.

You can view an existing audio file, and see all three spectra, but you can't change any of the properties once it has been saved.

3.3 Adding and Editing Partition Types

To add a new partition type, just give the material a name and add its Sound Transmission Loss (STL) values at third-octave band centre frequencies. Ideally the STL should be specified for all frequencies between 100 Hz and 10 KHz, but often it's only known between 125 Hz and 5 KHz and this is OK – just leave the others blank.

When viewing partition types, you can change the transmission loss values, but not the names.

When adding or viewing a partition type, R_w value is calculated and shown. You can use this to find the R_w values of the partitions you use in your design.

3.4 Adding and Editing Wall Finishes

To add a new wall finish, just give it a name and add its sound absorption co-efficients at octave band centre frequencies between 63 Hz and 8 KHz. Please fill in all the frequencies, even if you're guessing – blanks may lead to strange results when calculating reverberation times.

When viewing wall finishes, you can change the absorption co-efficients, but not the names.

When adding or viewing a wall finishes, the NRC (Noise Reduction Co-Efficient) is calculated and shown. You can use this to find the NRC values of the partitions you use in your design.