SMUG Software

FuzzMeasure Pro 2.0

User Guide

Last updated: June 15, 2006

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Welcome to FuzzMeasure Pro

FuzzMeasure Pro is an audio and acoustical measurement application you use to perform, analyze, and produce visually stunning graphs of your measurements. This chapter provides an overview of the features of FuzzMeasure, and some information about where you can learn more about using it.

FuzzMeasure makes it easy to capture and analyze your measurements on your computer. Using FuzzMeasure's tools, you can easily gather measurements of a home theater system, recording studio, stage, auditorium, raw loudspeaker components, and more.

When you're ready to share your measurements, you can print your graphs, save them as PDFs, or copy and paste them into other applications.

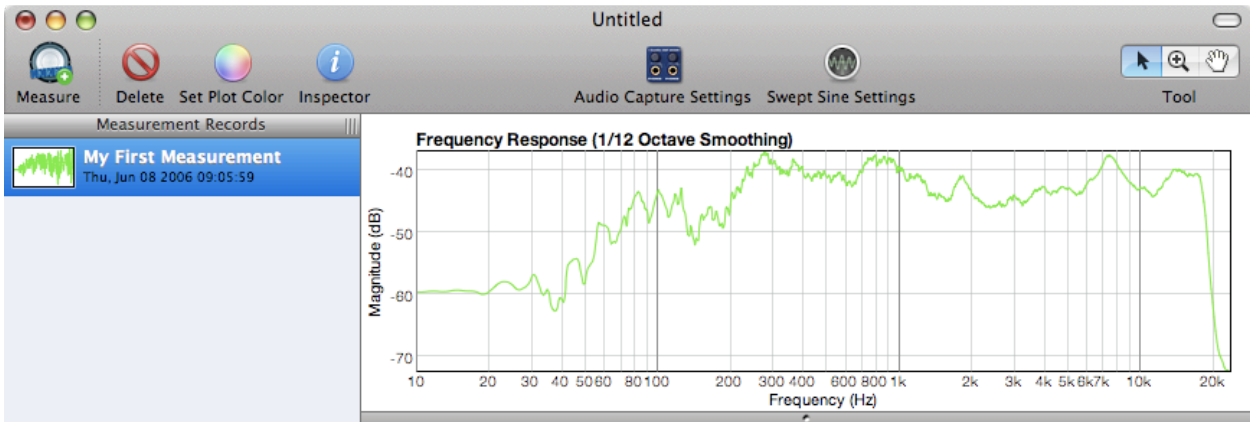
If you wish to perform further processing on your captured measurements, you can export your FuzzMeasure measurements to Comma Separated Values (CSV) files, for use with GNU Octave, Excel, or Matlab.

FuzzMeasure Features at a Glance

Use FuzzMeasure's powerful measurement and analysis capabilities to visualize and understand your measurements.

One Step Measurements

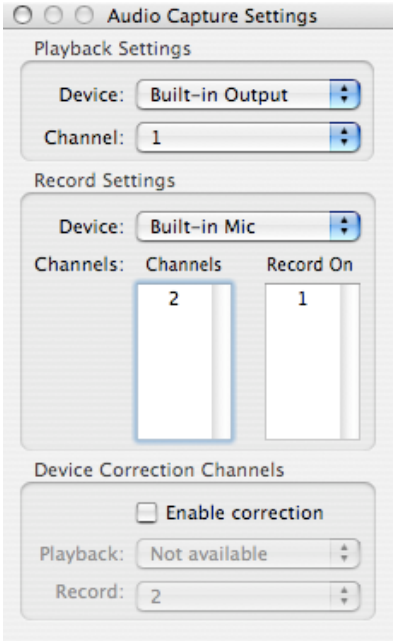
Measuring in FuzzMeasure is as easy as clicking the mouse. Press the Measure button on the toolbar to capture your first measurement.



Powerful Audio Settings

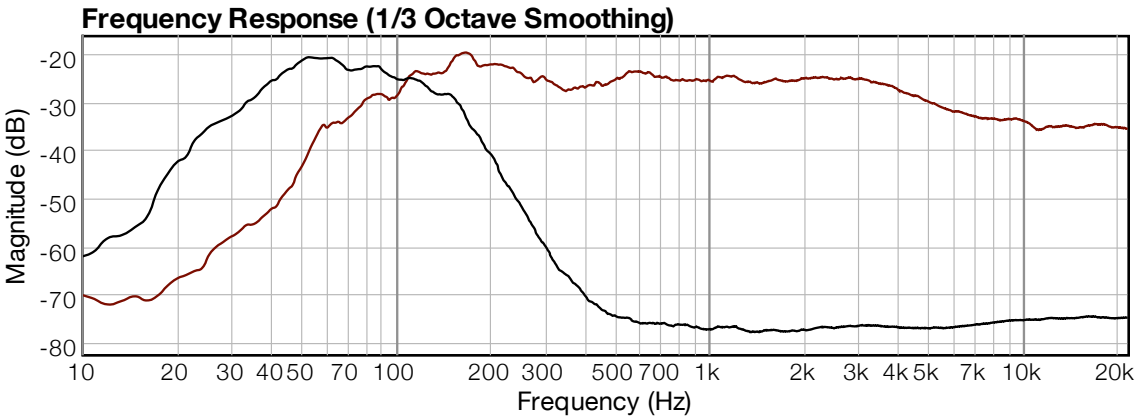
FuzzMeasure's audio capture settings panel makes selecting and configuring your audio devices easy. For example, you can simply drag and drop your available record channels to the list of selected channels to choose which channels FuzzMeasure should record on.

For advanced users, FuzzMeasure also allows you to apply automatic device correction to eliminate the effects of the audio device used to capture the audio signal. This ensures the highest accuracy measurements with your professional audio hardware.



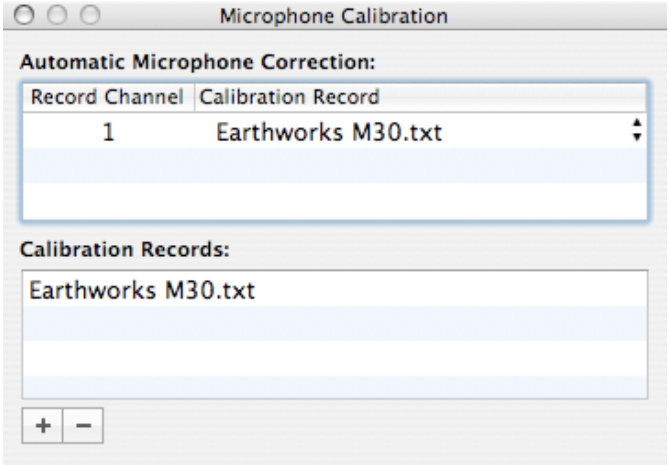
Print Quality Graphs

Both on screen and on your printer, FuzzMeasure's graphs look great! Simply control-clicking either graph gives you access to copy, print, or export the graph's contents.



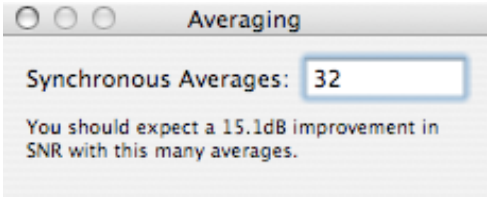
Microphone Calibration

If you have calibration data for your microphones, you can attach your calibration records to different record channels for correction to be applied automatically. You can even apply different calibration records to different record channels if you are recording on multiple channels simultaneously.



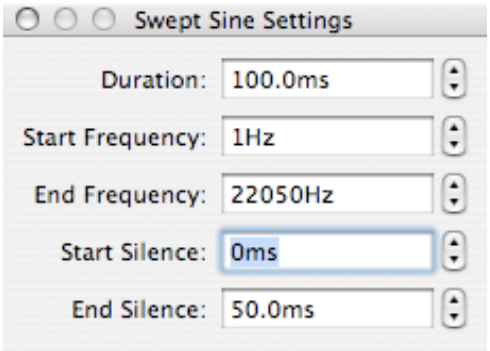
Synchronous Averaging

In noisy environments, you can increase the signal-to-noise ratio (SNR) of your measurements by averaging the results of synchronous measurements. FuzzMeasure can automatically perform this measuring for you.



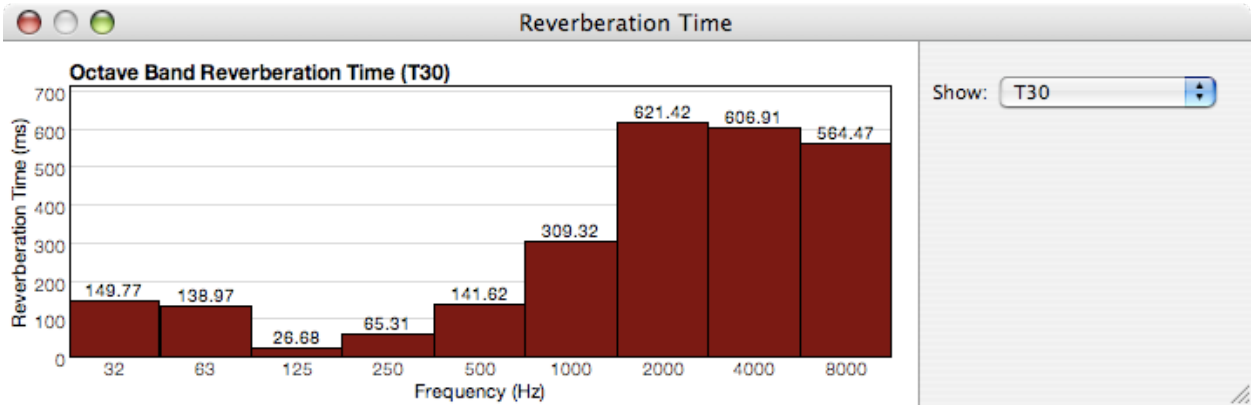
Swept Sine Settings

You can easily control the various aspects of the swept sine signal that's used as FuzzMeasure's measurement stimulus. Setting longer sweep times will result in improved SNR, and adding delay to the stimulus can help to cope with slower audio devices.



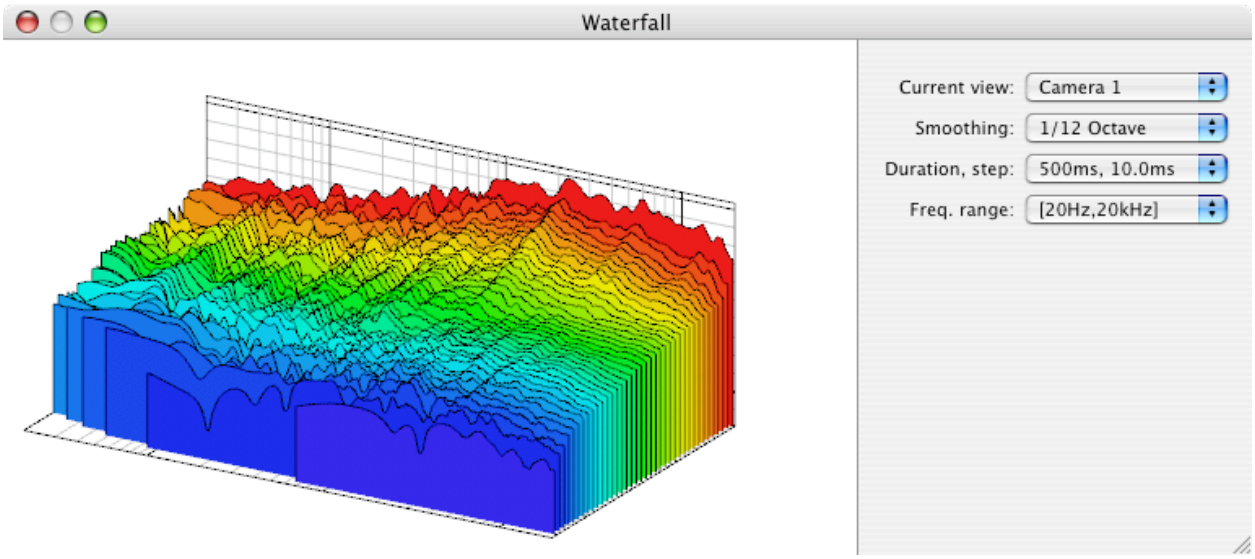
Reverberation Time Calculations

Capture ISO 3382 standard reverberation time (also called RT60) EDT, T30, and T20 values on an octave band basis.



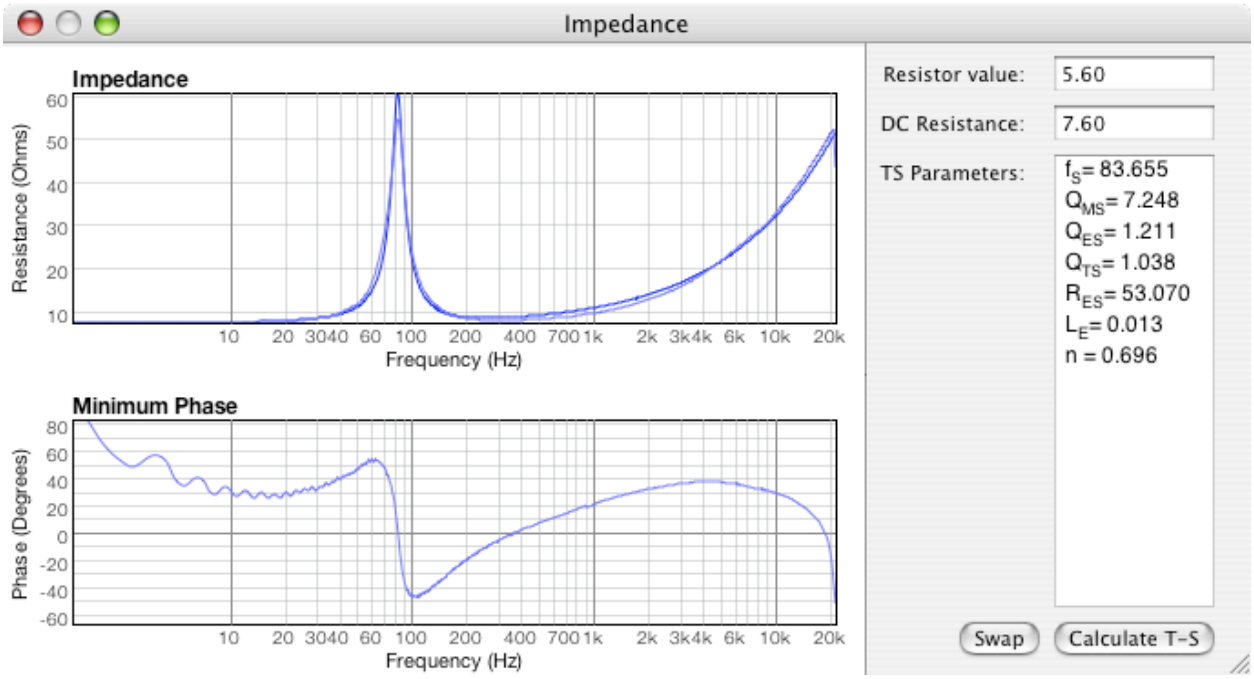
Waterfall Plots

Analyze the Cumulative Spectral Decay (CSD) of your impulse responses with ease.



Impedance Measurements

Measure the impedance of loudspeakers, and estimate Thiele Small parameters for your raw loudspeaker components.



Field Recordings

You can take the measurement step away from your computer with FuzzMeasure's field recording feature, which removes the requirement to have your computer on-site for your measurements.

For example, you could use a CD player and DAT recorder to perform the measurement step while away from your computer, and import it into FuzzMeasure later when you return to your office.

Obtaining Support

FuzzMeasure is easy to use, for an acoustical measurement tool. Of course, you may encounter issues along the way, and you have a few options to obtain support. In most cases, you'll get a response in a day or less.

Discussion Group

The FuzzMeasure discussion group, located at http://support.supermegaultragroovy.com/default.php?fm, which is read and posted to by both the FuzzMeasure community, and the developer.

The FuzzMeasure Wiki

There is a lot of rapidly changing information that relates to FuzzMeasure, and stuff that just doesn't belong in this manual (such as device and microphone recommendations, and links to some online stores where you can buy them). You will find that at http://support.supermegaultragroovy.com/wiki/index.php/FuzzMeasure. The best part about the wiki is that if you find any errors, or have anything new to add, you can just go ahead and add it!

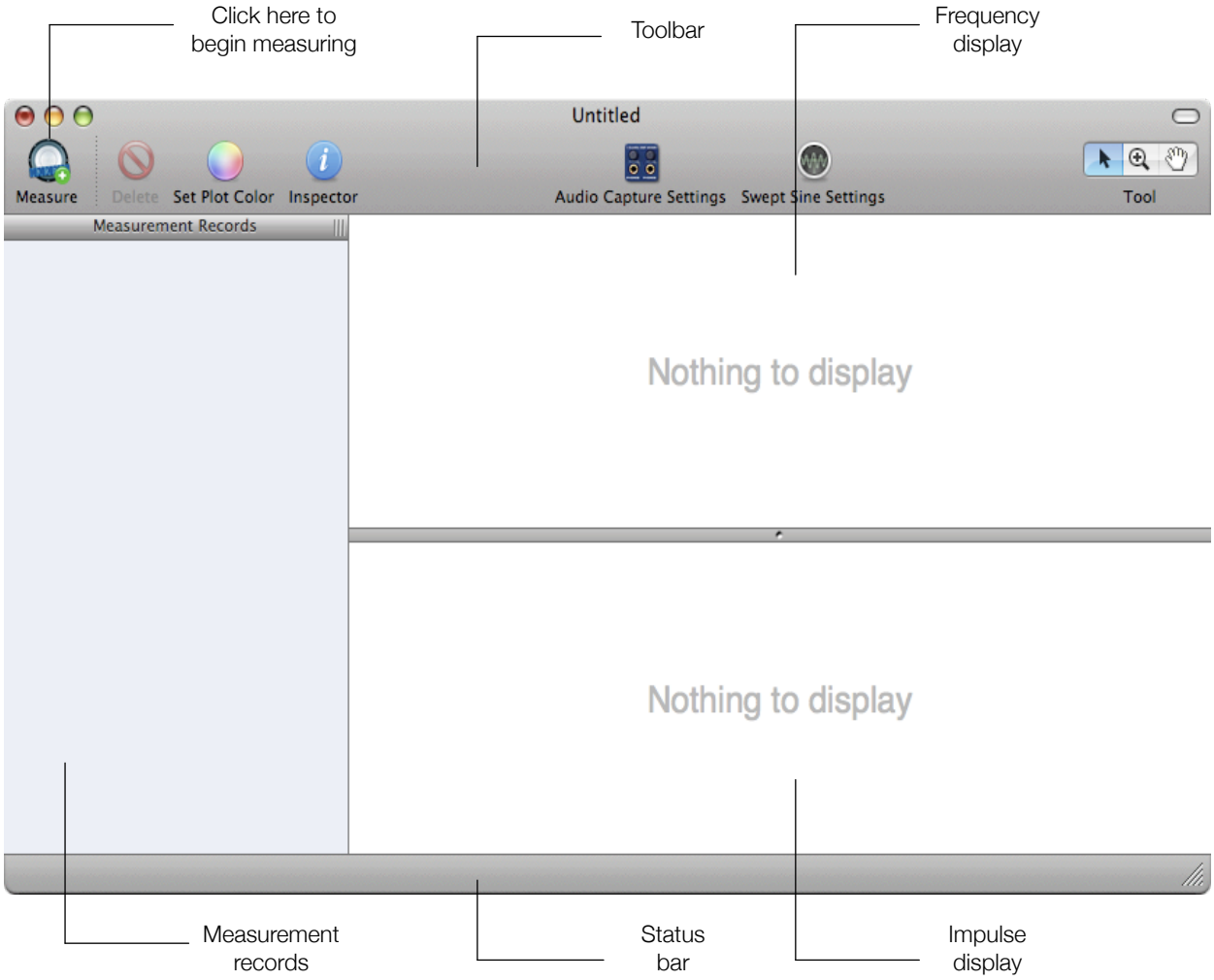
Email

If you encounter any problems that you don't think are better solved by any of the avenues mentioned above, you can always send email to fuzzmeasure@supermegaultragroovy.com.

Overview of FuzzMeasure

This chapter introduces you to the various windows and tools you'll use in FuzzMeasure.

When you first launch FuzzMeasure, you are greeted by the main window, which shows an empty FuzzMeasure document. FuzzMeasure documents contain collections of measurement records, as well as some details about the two main graphs. Each measurement record contains a title, the captured impulse response, the date of the capture, and more information specific to a single impulse response measurement.



Capturing Measurements

To capture a new measurement, do one of the following:

- Choose Measurement > Measure
- Click Measure in the toolbar

When you measure for the first time, a sheet will show up, warning you about the volume of the test signal.

Please ensure that you check your volume level before the first measurement, because you may be in for a surprise if you don't.

Once your measurement is complete, it will show up as a new entry in the list of measurement records.

Managing Measurements

Once you've built up a list of measurement records, it's a good idea to keep them organized. You can easily rename, rearrange, delete, duplicate, and otherwise change the measurement records in your collection.

Modifying Measurement Records

To set the title of a measurement record:

- Double-click the measurement record you wish to set the title for in the Measurement records, and type a new name. Hit return when you are done to save the change, or click outside the text entry field.

To change the plot color of a measurement record, do one of the following:

- Click Color in the toolbar
- Choose Measurement > Set color > <*desired color*>
- Control-click the measurement record you wish to change the color of, and choose Set color > <*desired color*>

To duplicate a measurement record, do one of the following:

- Choose Measurement > Duplicate
- Control-click the measurement record you wish to duplicate, and choose Duplicate

To delete a measurement record, do one of the following:

- Click Delete in the toolbar
- Choose Measurement > Delete
- Control-click the measurement record you wish to delete, and choose Delete

Shrinking FuzzMeasure Pro Documents

Measurement records can get large due to the extra space required to store the impulse after the deconvolution step, especially when using really long sweep lengths. Much of the extra space is silence, and you can reduce the size of your measurement records considerably by cropping out this extra space.

To crop a measurement record:

- First, ensure that you are done setting the impulse response analysis window, and you do not wish to keep any data outside the analysis window.
- Choose Measurement > Crop to window

Note: If you ever accidentally crop the window, you can always restore the previous state of the record by using the undo feature.

Minimum Phase Copies

If you plan to export the impulse response for use in convolution reverb plugins, or room correction software, a minimum phase copy of your measurement record might give you better results. It will minimize the phase components, and remove the delay to the peak of the impulse response.

Minimum phase copies are also a good idea before running the Waterfall PlugIn, since you no longer have to find the start of the impulse response after some delay.

To create a minimum phase copy:

- Choose Measurement > Create minimum phase copy

Importing Impulse Responses

You can create new measurement records in FuzzMeasure by importing impulse responses captured using a traditional method (such as a spark gap, or pistol shot) or created in other applications, provided they're in AIFF format.

To import an impulse response:

- Choose Measurement > Impulse Impulse Response...
- Select the file you wish to import

Exporting Impulse Responses

You can export FuzzMeasure's captured impulse responses for use in convolution reverb or room correction software.

To export an impulse response:

- Choose Measurement > Export Impulse Response...
- Enter the name you wish to give the exported impulse response, and select where you wish to put the impulse response on your computer.

Exporting FRD Files

You can also export a record's frequency analysis for use in some loudspeaker design software packages using the FRD file format. The FRD file format simply consists of frequency, magnitude, and phase information data in a text format.

To export a measurement as an FRD file:

- Choose Measurement > Export FRD File...
- Enter the name you wish to give the exported FRD file, and select where you wish to put the impulse response on your computer.

Working With Field Recordings

If you are working in a situation where you cannot connect your computer to the sound source you are measuring, you may need to use FuzzMeasure's field recording features. One common scenario is when measuring the response of an automobile's passenger cabin. Many car audio systems do not have line-in ports that you can utilize for FuzzMeasure's purposes, and often have only a CD player installed.

To get around this, FuzzMeasure allows you to capture field recordings by exporting the stimulus signal as defined by the parameters in the Swept Sine Settings panel, and importing a recording of the system's response to that stimulus.

To export FuzzMeasure's swept sine stimulus signal:

- Choose Measurement > Export Stimulus Signal...
- Select your desired sampling rate for the generated file. If you plan to burn a CD of the results, leave the setting at 44100.
- Enter the name you wish to give the exported stimulus signal, and select where you wish to put the stimulus signal on your computer.

Note: For most situations, a longer sweep is better, and setting some delay before and after the sweep is recommended. After exporting the signal from FuzzMeasure, you can burn it to an audio CD using iTunes or Toast. Do not burn the CD as an MP3 CD, or allow the AIFF file to be compressed in any way.

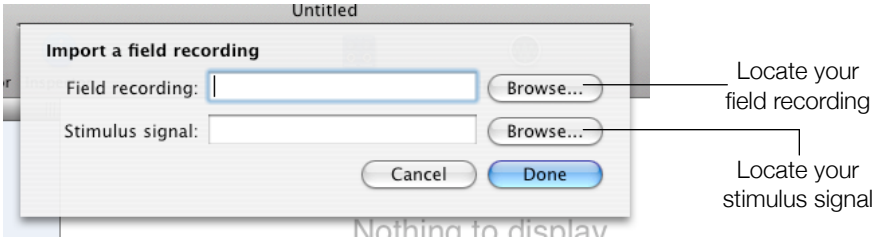
Note: You must save the exported stimulus signal in a safe spot for later, because you'll need it again to import the field recording.

You can now record the response to the stimulus using your method of choice. However, the recording must be done at the same sampling rate that you chose for the stimulus that you exported. Otherwise, importing the field recording will not work. So, for example, if recording with a DAT deck, make sure that the deck is set to record at 44100Hz if you set a 44100Hz sampling rate for your stimulus signal.

Once you've captured and saved your recording as an AIFF file, you can import it into FuzzMeasure as a field recording.

To import a field recording:

- Select Measurement > Import Field Recording...
- Press the first Browse... button to search for the field recording AIFF file on your computer.
- Press the second Browse... button to search for the stimulus signal you exported for the field recording earlier.



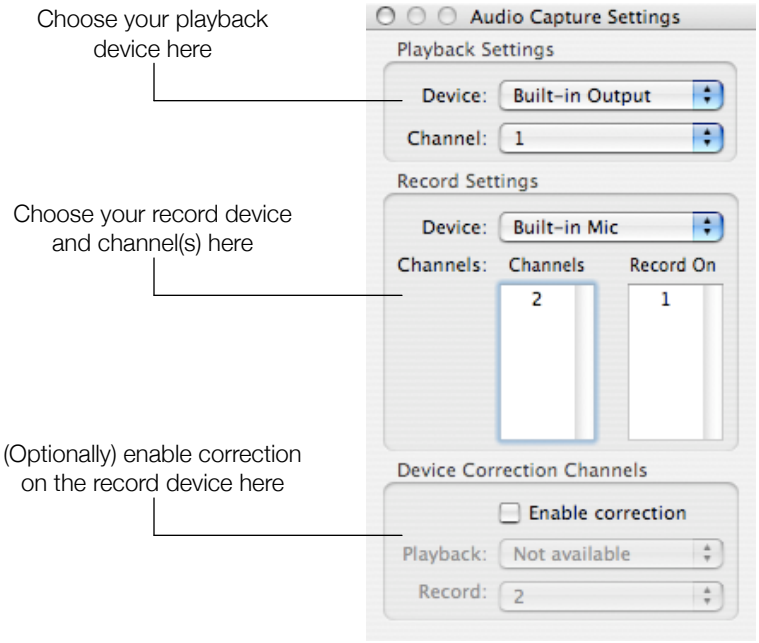
Audio Capture Settings

FuzzMeasure facilitates many complex measurement scenarios by providing comprehensive support for multi-channel audio devices.

In addition to supporting capture on multiple channels, FuzzMeasure also allows you to automatically correct for the device's own frequency response using a loopback channel.

To show the audio capture settings panel, do one of the following:

- Choose Window > Audio Capture Settings item in the Window menu. This menu item will toggle the audio capture settings panel's visibility.
- Click the Audio Capture Settings item in the toolbar



Playback Settings

FuzzMeasure plays the log sweep stimulus signal through a single output channel on a single device. When measuring multiple channel audio systems (such as a home theater), it is a requirement that you individually measure each speaker. You can combine the graphs later, and analyze each speaker on their own more effectively than if you tried to play the stimulus through all the channels at once.

To set up your playback device:

- Select a device from the Device popup button
- Select a channel from the Channel popup button

Record Settings

Unlike playback, FuzzMeasure can record the stimulus signal on multiple channels simultaneously. This allows for complex setups with multiple microphone positions in auditorium or home theater environments. When you have multiple channels selected for recording, a new record is added for each channel that you've selected.

To set up your record device:

- Select a device from the Device popup button
- Drag record channels from the Channels table to the Record On table

Device Correction

You can automatically correct a device's response when you're playing back and recording on the same audio device. This will remove any nonlinearity in the response of the audio device you're working with.

To set up device correction:

- Check the Enable correction checkbox
- Select an available playback channel from the Playback popup button
- Select an available record channel from the Record popup button
- Make sure there is a loopback cable connected between the correction playback and record channels

Synchronous Averaging

To achieve a higher Signal-Noise Ratio (SNR) in your acoustical measurements, FuzzMeasure can calculate synchronous averages of the recorded log sweep signal. FuzzMeasure calculates the synchronous averages by capturing the log sweep stimulus multiple times, and averaging the resulting impulse responses on each record channel.

Note: You can also increase SNR by increasing the duration of your swept sine stimulus signal.

To enable synchronous averaging:

- Choose Window > Synchronous Averaging
- Set a value greater than 1 to get an increase in SNR

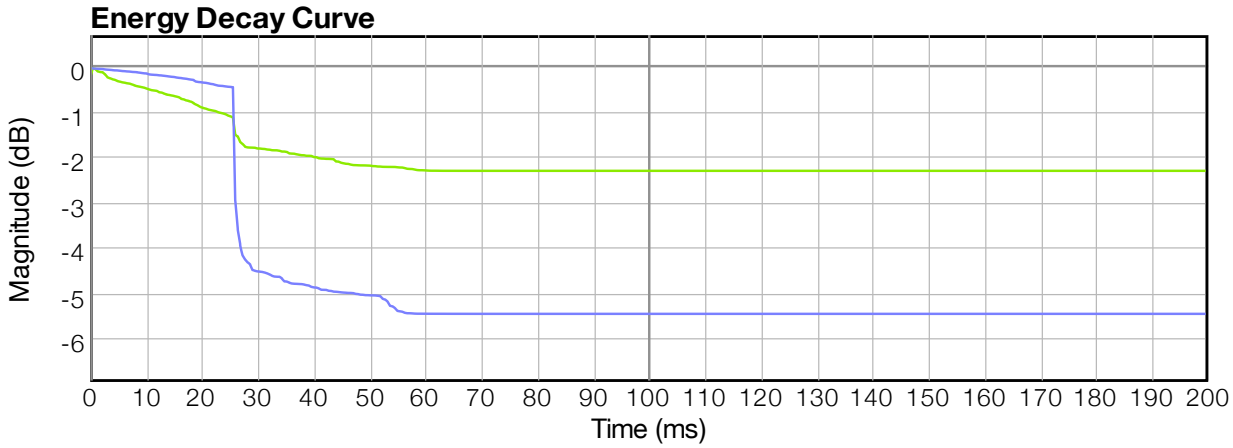
As you change the number of averages, FuzzMeasure will immediately inform you of the SNR improvement that you can expect. Each doubling of averages will gain you approximately 3dB of SNR. So, 2 averages buys you a 3dB improvement, 4 buys you 6dB, and so on.

When to use Synchronous Averaging

You should experiment with the averaging option if you are capturing acoustical measurements in a noisy environment. Averaging is not at all useful if you're performing loopback or electrical measurements with FuzzMeasure, and should be avoided in these cases.

Setting the averaging value to an arbitrarily high value will not always guarantee that increase in SNR, as the law of diminishing returns applies here. To see this in action, run a few measurements at a lower volume, increasing averages with each step. This effect is seen most clearly in the log sweep impulse response and energy decay curve views.

In general, averaging 4 or 8 times will suffice if you're having trouble with a high noise floor in a single measurement.

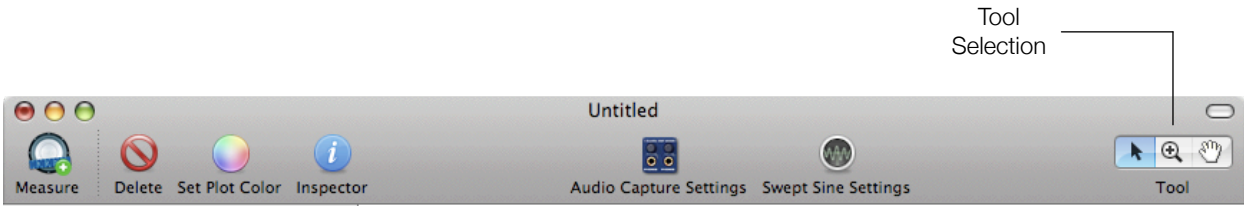


In the graph above, the green curve represents a measurement done at a low volume with 1 synchronous average. The blue curve represents the exact same settings, except with 16 synchronous averages. Note how the theoretical increase of 12dB was not achieved.

Working with Graphs

Much of FuzzMeasure's analysis strength comes from its powerful graphing facilities. FuzzMeasure's graphing features allow you to explore the measurements you performed in great detail.

You can use the select, zoom, and move tools to work with the Frequency and Impulse graphs in FuzzMeasure.

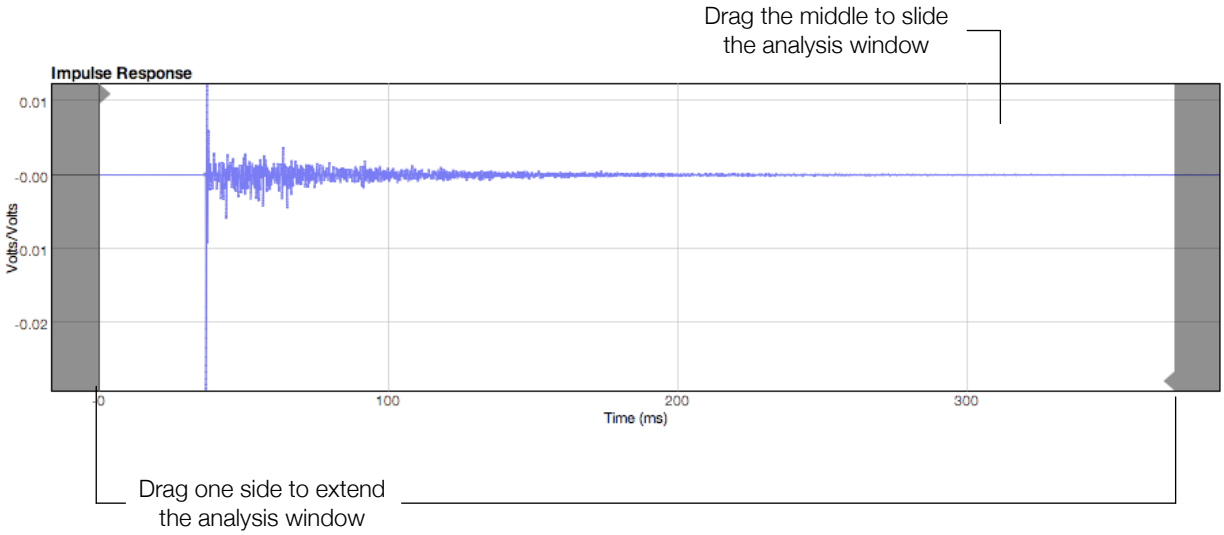


To select the current graph tool, do one of the following:

- Press the s, z, or v key to select the selection, zoom, or move tool, respectively
- Click either the selection, zoom, or move item in the Tool button in the toolbar

Using the Selection Tool

The selection tool allows you to modify the impulse response analysis window (used to calculate what's shown in the Frequency graph above it) by clicking and dragging in the impulse display.



To slide the impulse response analysis window:

- Place your cursor inside the impulse analysis window, then click and drag the impulse analysis window to the desired position.

To extend the length of the impulse response analysis window:

- Place your cursor near either end of the impulse analysis window, then click and drag the impulse analysis window to the desired length.

You can also use the selection tool to place markers in either the impulse display or the frequency display.

To add a marker to either of the graphs:

- Hold down the command key, and then click on the desired point where you wish to place the marker.

To move an existing marker around the graph:

- Place your mouse over the marker you wish to move, then click and drag it to a new point.

To delete an existing marker from the graph:

- Place your mouse over the marker you wish to delete, hold the option key, and then click on it to remove it.

Using the Zoom Tool

Both the frequency and impulse displays allow you to zoom in and out of their respective graphs. Zooming is done one axis at a time.

To zoom into the X axis:

- Click the graph at the point where you wish to zoom in.

To zoom out of the X axis:

- Hold down the option key, and click the graph at the point where you wish to zoom out.

To zoom into the Y axis:

- Hold down the command key, and click the graph at the point where you wish to zoom in.

To zoom out of the Y axis:

- Hold down the option and command keys, and click the graph at the point where you wish to zoom out.

You can also zoom to fit the full extents of either axis, or both. In the impulse display, you have the added option to zoom to fit just the extents of the impulse analysis window.

To access further zooming options:

- Choose Frequency > Zoom
- Choose Impulse > Zoom

Using the Move Tool

You can use the move tool to shift around the contents of the impulse and frequency displays using your mouse. Simply click and drag the graph around to the desired position, in either the impulse or frequency display.

Setting Extents Manually

If you wish to display specific regions of the graph, you may set the graph extents manually.

To set the Frequency graph extents manually:

- Choose Frequency > Set Graph Extents...
- Hold down the Command key, and click the frequency display. Then, choose Set Graph Extents...

To set the Impulse graph extents manually:

- Choose Impulse > Set Graph Extents...
- Hold down the Command key, and click the impulse display. Then, choose Set Graph Extents...

Locking Graph Extents

Normally, the impulse and frequency displays will always try to resize to fit the data contained within as their data changes. Locking the graph extents allows you to hold the current extents of either graph, so that further selections and measurements will stay within those extents.

To lock the Frequency display's extents, do one of the following:

- Choose Frequency > Lock Graph Extents
- Hold down the command key, and click the frequency display. Then, select Lock Graph Extents.

To lock the Impulse display's extents, do one of the following:

- Choose Impulse > Lock Graph Extents
- Hold down the command key, and click the impulse display. Then, select Lock Graph Extents.

Copying Graphs

You can copy and paste your graphs into other applications, such as Mail, or Pages.

To copy the contents of the impulse display:

- Choose Impulse > Copy Impulse Graph
- Hold down the command key, and click the impulse display. Then, choose Copy Impulse Graph

To copy the contents of the frequency display:

- Choose Frequency > Copy Frequency Graph
- Hold down the command key, and click the frequency display. Then, choose Copy Frequency Graph

Printing a Graph

You can also print either graph from FuzzMeasure directly, if you wish.

To print the contents of the impulse display:

- Choose Impulse > Print Impulse Graph
- Hold down the command key, and click the impulse display. Then, choose Print Impulse Graph

To print the contents of the frequency display:

- Choose Frequency > Print Frequency Graph
- Hold down the command key, and click the frequency display. Then, choose Print Frequency Graph

Exporting Graph Data

If you wish to use the graph's data in other applications, such as GNU Octave, or Matlab, you can export the contents of the graph as a CSV (Comma-Separated Values) file, which is used by many other analysis and graphing applications.

Note: The exported graph data will contain all the values stored in the graph, even beyond your current graph extents.

To export the impulse display's graph data:

- Choose Impulse > Export Impulse Graph Data...

- Enter the name you wish to give the exported impulse data, and select where you wish to put the impulse data on your computer.

To export the frequency display's graph data:

- Choose Impulse > Export Frequency Graph Data...
- Enter the name you wish to give the exported frequency data, and select where you wish to put the frequency data on your computer.

Frequency Display Specific Features

The frequency display has specific features that allow you to explore your measurements in the frequency domain. These features include the display type, smoothing, and multiple selection modes.

The display types correspond to different frequency domain analysis methods. Currently, these include Magnitude Response, Mixed Phase Response, Minimum Phase Response, and Excess Phase Response.

To select the current frequency display type, do one of the following:

- Choose Frequency > Display Type > <desired display type>
- Hold down the command key, and click the frequency display. Then, choose Display Type > <desired display type>

You can apply smoothing to the frequency domain data in terms of fractional octaves. The smoothing options range from 1/48 Octave (Least) to 1/3 Octave (Most).

To select the current smoothing amount, do one of the following:

- Choose Frequency > Smoothing > <desired smoothing amount>
- Hold down the command key, and click the frequency display. Then, choose Smoothing > <desired smoothing amount>

When you select multiple measurements in the list of measurement records on the left side of the main window, the default behavior is to show you all the records overlaid on top of one another for comparison purposes. However, you can alter this behavior to also show you the Average, Difference, or Sum of the records.

To select the current multiple selection mode, do one of the following:

- Choose Frequency > Multiple Selection > <desired selection mode>
- Hold down the command key, and click the frequency display. Then, choose Multiple Selection > <desired selection mode>

Impulse Display Specific Features

Just like the frequency display, the impulse display also has some specific features that help you analyze the impulse response in the time domain. These features include the display type, and normalization.

The display types correspond to different time domain analysis methods. Currently, these include Impulse Response, Step Response, Log Squared Impulse Response, and Energy Decay Curve.

To select the current impulse display type, do one of the following:

- Choose Impulse > Display Type > <desired display type>
- Hold down the command key, and click the impulse display. Then, choose Display Type > <desired display type>

You can also choose to normalize the values in the impulse display in case they turn up real small. Normalization will boost (or shrink) the values in the display so that they fall between the range 0 and 1. When using the log squared impulse response display, this means the values will peak at 0dB, and fall from there.

To normalize the values in the impulse display, do one of the following:

- Choose Impulse > Normalize
- Hold down the command key, and click the impulse display. Then, choose Normalize.

Overview of PlugIns

FuzzMeasure Pro contains some powerful PlugIns that extend its base functionality beyond the standard set of impulse and frequency analysis techniques.

By adopting a PlugIn system, FuzzMeasure allows for further features to be added easily in the future, without convoluting the main interface.

The Impedance, Reverberation Time, and Waterfall PlugIns come included with FuzzMeasure, to help analyze your measurements even further than with the main UI.

Impedance

The Impedance PlugIn allows you to show resistance and phase information for impedance measurements captured in the main FuzzMeasure window, and then estimate Thiele Small parameters for use in loudspeaker construction.

To get started, you must first build the impedance measuring jig as shown in Appendix A. Then, measure a calibration resistor that's close to the value of the speaker you wish to capture. Finally, measure a raw driver to be used for Thiele Small parameter calculation.

Note: In general, woofers are best suited to this estimation method.

To import records into the impedance plugin:

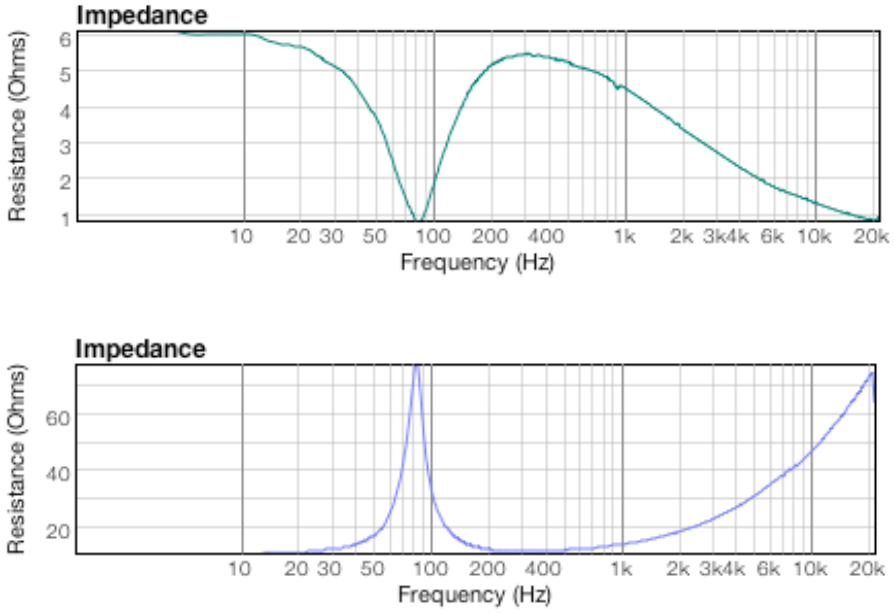
- Select two records from your measurement record list — the resistor record, and the impedance record.
- Choose PlugIns > Impedance...

Set the resistor value to the value of the calibration resistor you measured above. This will update the display to show you the actual resistance value of your speaker.

Because FuzzMeasure relies on the ordering that you selected your measurements in the main window, it often gets the resistor and impedance records mixed up.

If the impedance graph appears upside-down:

- Press the Swap button



The graph on the top demonstrates an upside-down impedance measurement, while the graph on the bottom shows one that's correctly oriented.

Now, set the DC resistance value to the resistance value of your raw speaker in free air, not connected to anything else. The quieter the environment, the less these values will swing.

Note: A speaker is a very sensitive microphone, too! Make your measurements in a quiet area, with few reflecting surfaces near your speaker.

To run the Thiele Small estimation procedure:

- Press the Calculate T-S button

A blue graph should now be sitting alongside your original graph — it represents the best-fit curve to the loudspeaker voice coil inductance model. If the fitted curve does not agree with your measurements at all, then the automatically calculated values should not be used.

Reverberation Time

The Reverberation Time PlugIn calculates ISO 3382 reverberation time values on an octave band basis. In order to use the reverberation time measurements, your measurements must have some prerequisites.

To use the EDT values, your measurement should be at least 20dB above the noise floor. You can verify this by using the Energy Decay Curve or Log Squared Impulse Response impulse display modes.

To use the T20 and T30 values, your measurement should be at least 40dB and 60dB above the noise floor, respectively. Longer sweep times or synchronous averaging can be used to improve your measurement's SNR (Signal to Noise Ratio) for reverberation time measurements.

To import a record into the Reverberation Time PlugIn:

- Select a single record from your measurement list which satisfies the criteria above.

- Choose PlugIns > Reverberation Time...

The reverberation time PlugIn will now show you the reverberation time estimates for each octave band, based on a linear least squares fit of each octave band's energy decay curve. If any values seem too far off, double-check your source measurement to ensure it has a sufficient SNR.

You can copy, print, and export the reverberation time graph, just like you can in the main graphs.

To copy the reverberation time graph to the pasteboard:

- Hold down the command key, and click the reverberation time graph.
- Choose Copy Reverberation Time Graph.

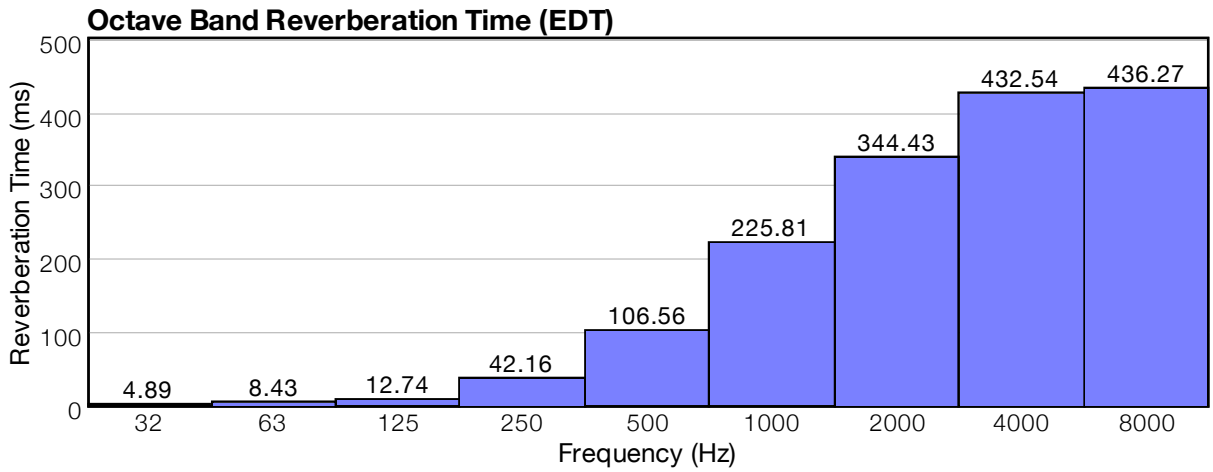
To print the reverberation time graph:

- Hold down the command key, and click the reverberation time graph.
- Choose Print Reverberation Time Graph.

When you export reverberation time data, it produces a CSV (Comma-Separated Values) text file with EDT, T20, and T30 values.

To export the reverberation time graph data:

- Hold down the command key, and click the reverberation time graph.
- Choose Export Reverberation Time Data.
- Enter a name for your exported data, and find a location on your computer to place the data file.



This is an example graph demonstrating the Early Decay Time measurement of a home theater bookshelf speaker, as captured in the listening area.

Waterfall

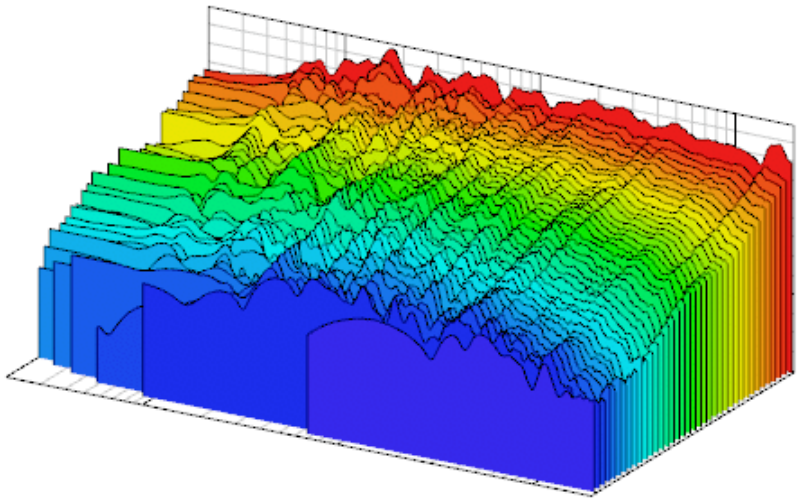
The 2D plots in FuzzMeasure are great for visualizing the frequency response for a given analysis window, but there's more to be gained in analyzing cumulative spectral decay of an impulse response when trying to identify resonant behavior in speakers. A resonance will show up as a long decaying ridge along the time axis.

The conditions in which the waterfall plot is produced has an effect on each slice of the overall waterfall plot, and hence each individual trace is not very useful on its own. However, it is the overall display of the plot which provides such valuable information about the behavior of a speaker.

To prepare a record for use in the Waterfall PlugIn, set up the impulse response analysis window so that its peak (or slightly before it) is at the beginning of the window. A simpler approach to this is just making a minimum phase copy of your measurement record before importing it into the waterfall plugin.

To import a record into the Waterfall PlugIn:

- Select a single record from your measurement list which satisfies the criteria above.
- Choose PlugIns > Waterfall...



This is a waterfall plot obtained from a bookshelf speaker in a home-theater system, with a 500ms analysis duration, across the [20Hz,20kHz] range.

You can modify the parameters used in calculating the waterfall display on the right side of the waterfall plot itself, and select a different camera to get an alternate view of your waterfall.

Troubleshooting/FAQ

FuzzMeasure employs sophisticated algorithms, and interacts with various audio hardware configurations —there are a lot of places where your measurements could go wrong. Don't fear! The solutions are often simpler than you think.

Of course, a solid background in the theory of acoustical measurements can go a long way to understanding the source of many issues in FuzzMeasure. However, not everyone has a post-graduate degree in acoustics or electrical engineering, and you certainly don't need one to find your way around FuzzMeasure!

The majority of problems in FuzzMeasure have very straightforward solutions and explanations. However, some issues may fall through the cracks. If this is the case, you can always exercise your support options, as outlined in the first chapter of this guide.

Audio Hardware

The audio hardware is the most crucial part of the measurement chain. Your measurements are only as accurate on the devices they're captured on. Also, your measurements are affected by volume settings, sample rate selections, and other factors.

I don't have an audio input on my computer! What do I do?

If your computer does not come with a line-in port, then you have no choice but to buy yourself a microphone and audio interface with phantom power. There are many great audio devices on the market at various price points. You can find some suggestions on the wiki at this link: http://support.supermegaultragroovy.com/wiki/index.php/Hardware_Suggestions

I have an audio input, and a built-in speaker/microphone. Is that good enough?

The built-in microphone is great for toying around with FuzzMeasure, but you really should avoid relying on it for measurements. For starters, its response is not very linear, and it's often not located in an ideal position (near other electrical components, for instance).

Measurement microphones can be obtained for well under $100, and shoot right up to $1500 and beyond. You get what you pay for, but many folks don't really need the extra precision. A $500 microphone may have 1dB-2dB less error across the frequency range compared to a $100 microphone, and often get you access to a factory-certified calibration record which you can use with FuzzMeasure.

Purchasing a low-cost microphone

- Choose one that's clearly marked by the manufacturer as a measurement microphone.
- Make sure it is omni-directional.
- Look into microphone calibration services, and ask your calibration facility for advice about your microphone selection. Some technicians have been impressed with the performance of deceivingly low-cost microphones.

Purchasing a professional measurement microphone

- Choose one with a good reputation — read reviews, online, or in magazines if you can.
- Ideally, try to find one with calibration data included, or easily obtainable afterwards.
- Earthworks measurement microphones are priced very competitively to other manufacturers, and you can obtain calibration data directly from Earthworks at any time after your purchase.

My microphone requires phantom power. What do ghosts have to do with microphones?

Many professional microphones require preamplification to raise their signal up to the level of a standard line-in audio interface. These microphones also tend to require a fixed voltage (+48v) in order to operate properly. This fixed voltage power supply is often referred to as "phantom power".

You can get phantom power for your microphone by doing one of the following:

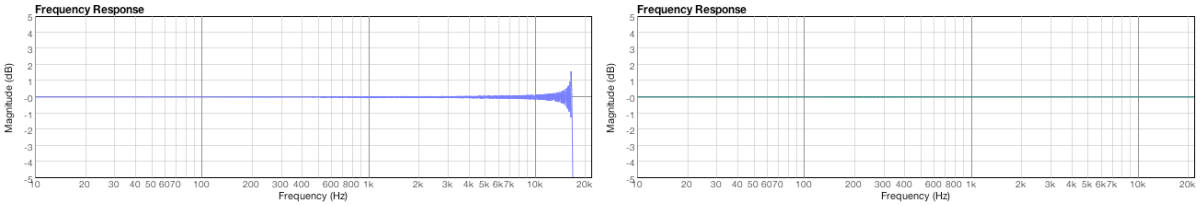
- Purchase an audio interface that has built-in preamplifiers and phantom power for its microphone inputs.
- Purchase a preamplifier with phantom power that can be plugged into the line-in on your built-in or external audio device.

I tried performing a measurement, but the result was not what I expected.

Sometimes FuzzMeasure does not catch the entire stimulus signal when it records. This problem will lead to a garbled graph in the high-frequency range.

If your loopback frequency response appears garbled in the high-frequency range:

- Try setting a larger value for End Silence in the sweep settings



The graph on the left shows the result of a digital loopback measurement done with 0ms of end silence. The graph on the right shows the same loopback, but with 50ms of end silence.

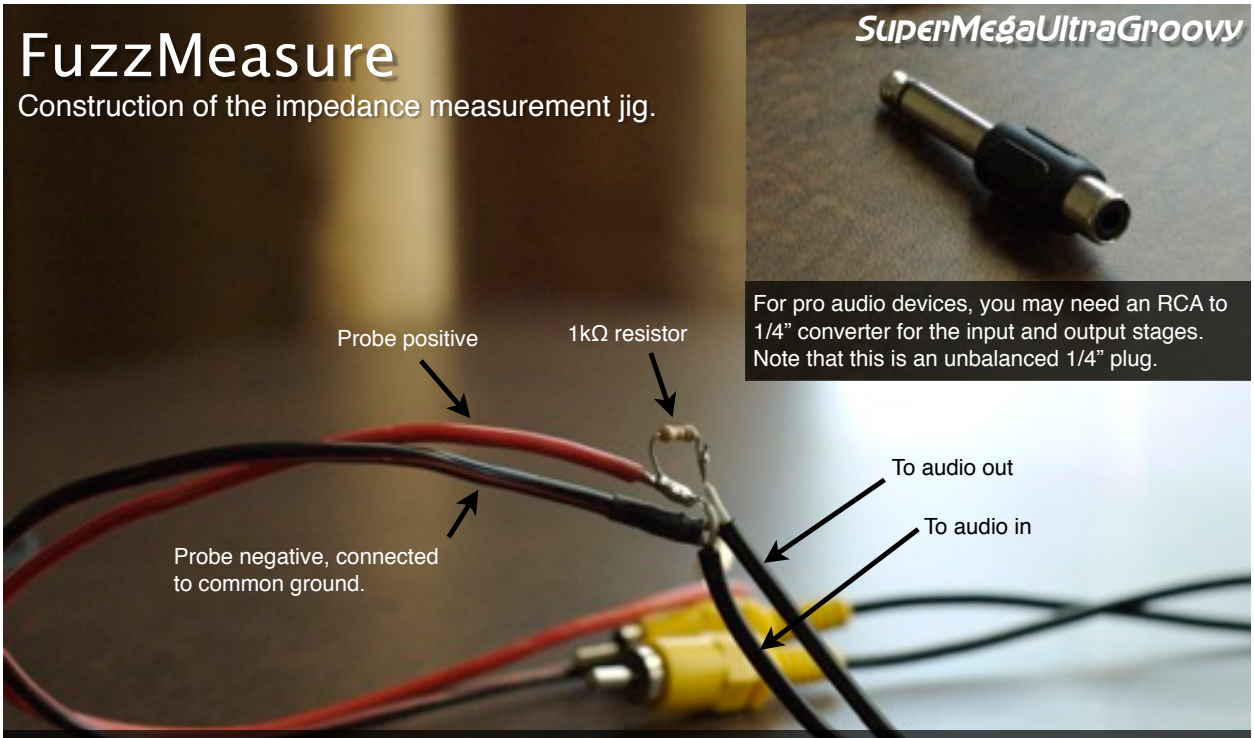
There is a delay in my audio system, and the sweep is getting cut off at the start.

Some audio systems (especially home theater receivers with optical digital inputs) have a little bit of a delay before they play audio that's coming in on their inputs. As a result, some of the swept sine signal won't be played through the speakers, and thus not captured by FuzzMeasure.

To add delay to the start of your swept sine signal:

- Open the swept sine settings panel, and set the start silence value to match the delay you're hearing.

Appendix A: Impedance Jig



This impedance measurement jig is a simple voltage divider circuit which gives reasonably accurate results in most situations. Using an old RCA video cable, a 1kΩ resistor, and two probe leads, you can build this jig in about 5 minutes! Simply take the RCA cable, split it in two, short out the common ground between the two, and separate the signal wire with the resistor. Then, attach the negative probe lead to the ground, and the positive probe lead to one side of the resistor. The opposite side of the resistor should go to your audio device’s output jack, as pictured above.