FuzzMeasure Pro 3.2

User Guide

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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.

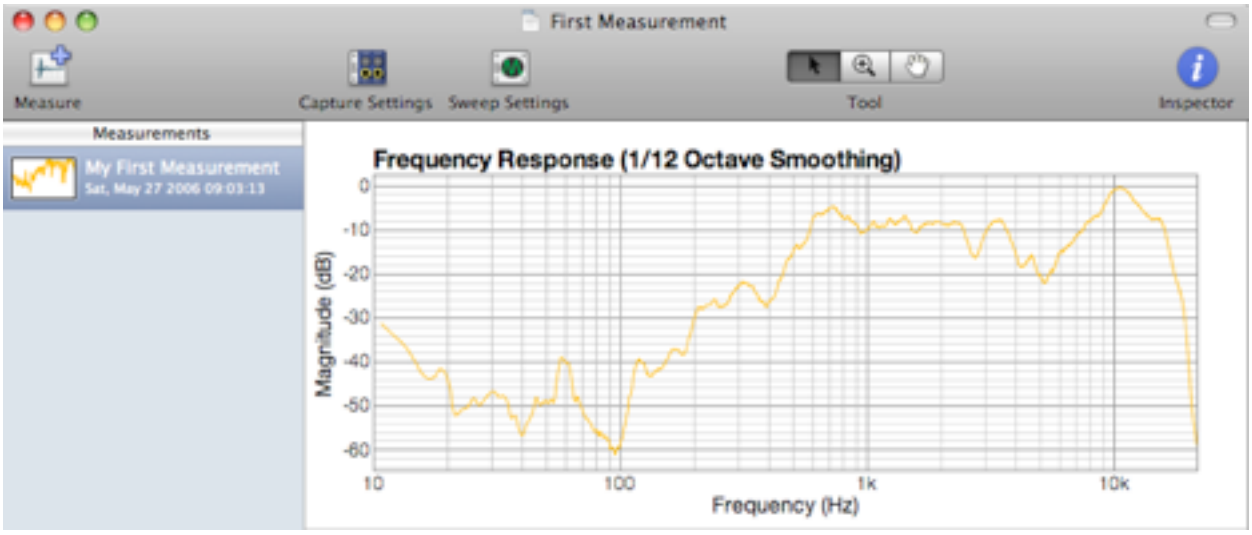
FuzzMeasure makes it easy to capture and analyze your measurements on your computer. Using FuzzMeasure's tools, you can easily gather measurements of a home theater system, recording studio, stage, auditorium, raw loudspeaker components, and more.

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.

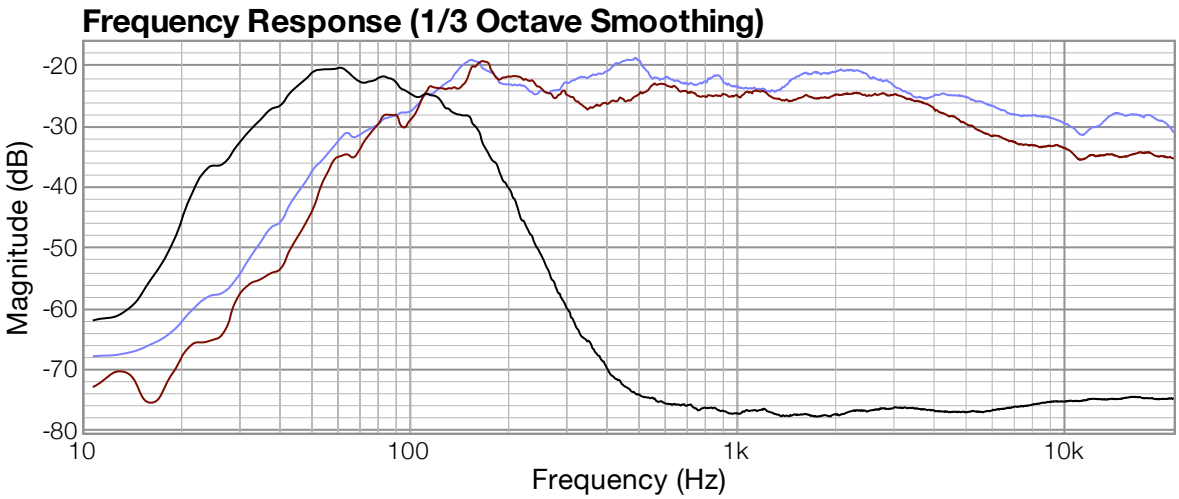
Powerful Audio Settings

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.

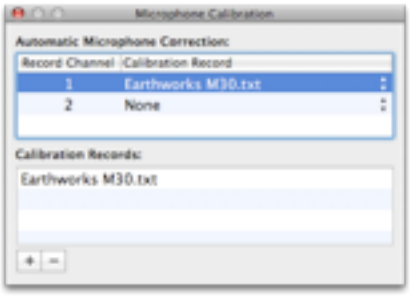
Print Quality Graphs

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.



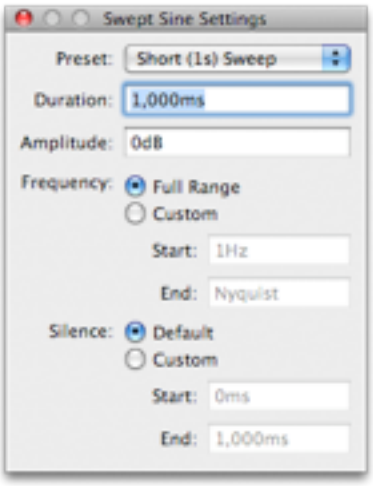
Synchronous Averaging

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

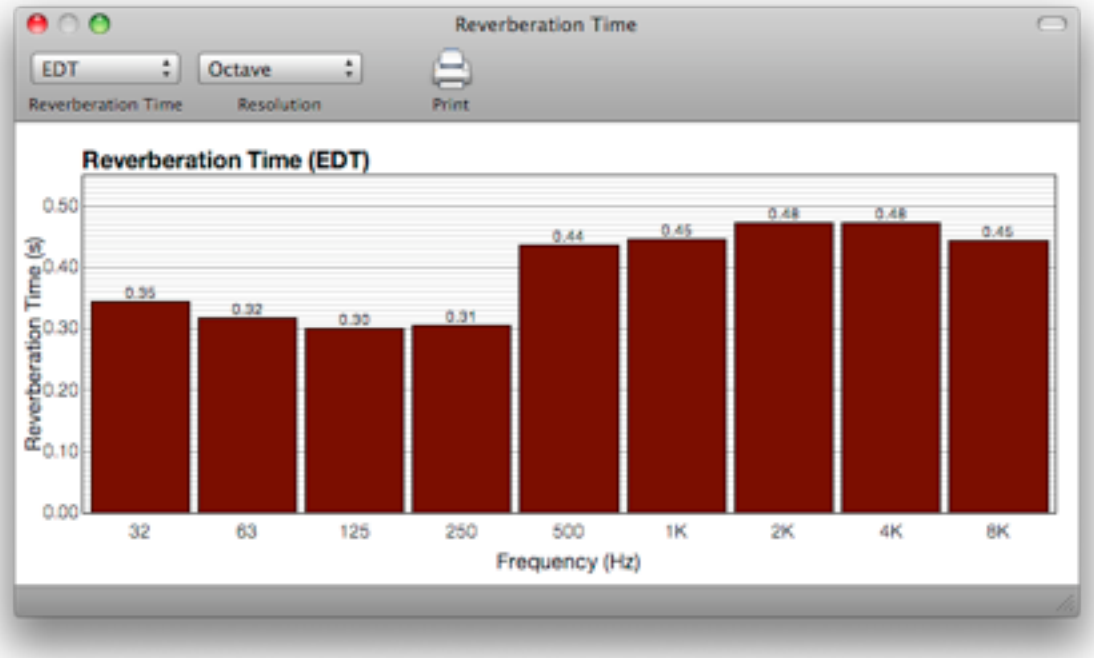
You can easily control the various aspects of the swept sine signal that's used as FuzzMeasure's measurement stimulus, and save them as presets for repeated use. Setting longer sweep times

will result in improved SNR, and adding delay to the stimulus can help to cope with slower audio devices.



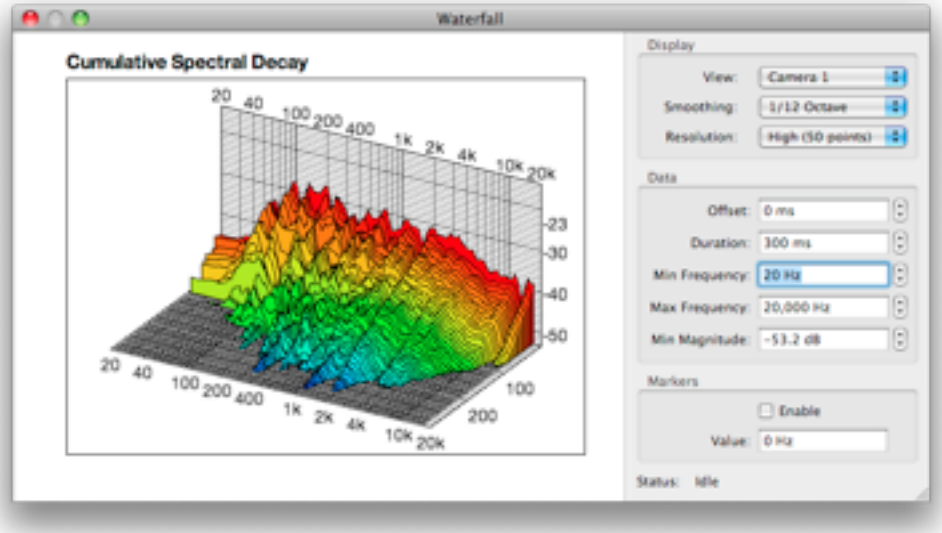
Reverberation Time Calculations

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



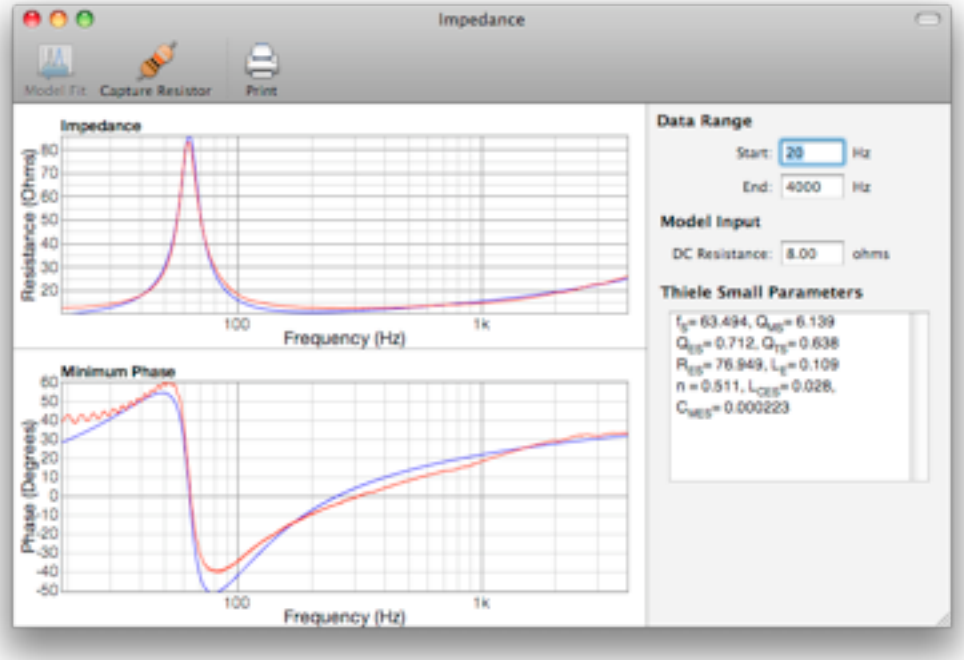
Waterfall Plots

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 is located at Get Satisfaction. It is read and posted to by both the FuzzMeasure community, and the developer. Most questions about usage should be posted here, but make sure to search the group's history to make sure your question isn't already answered!

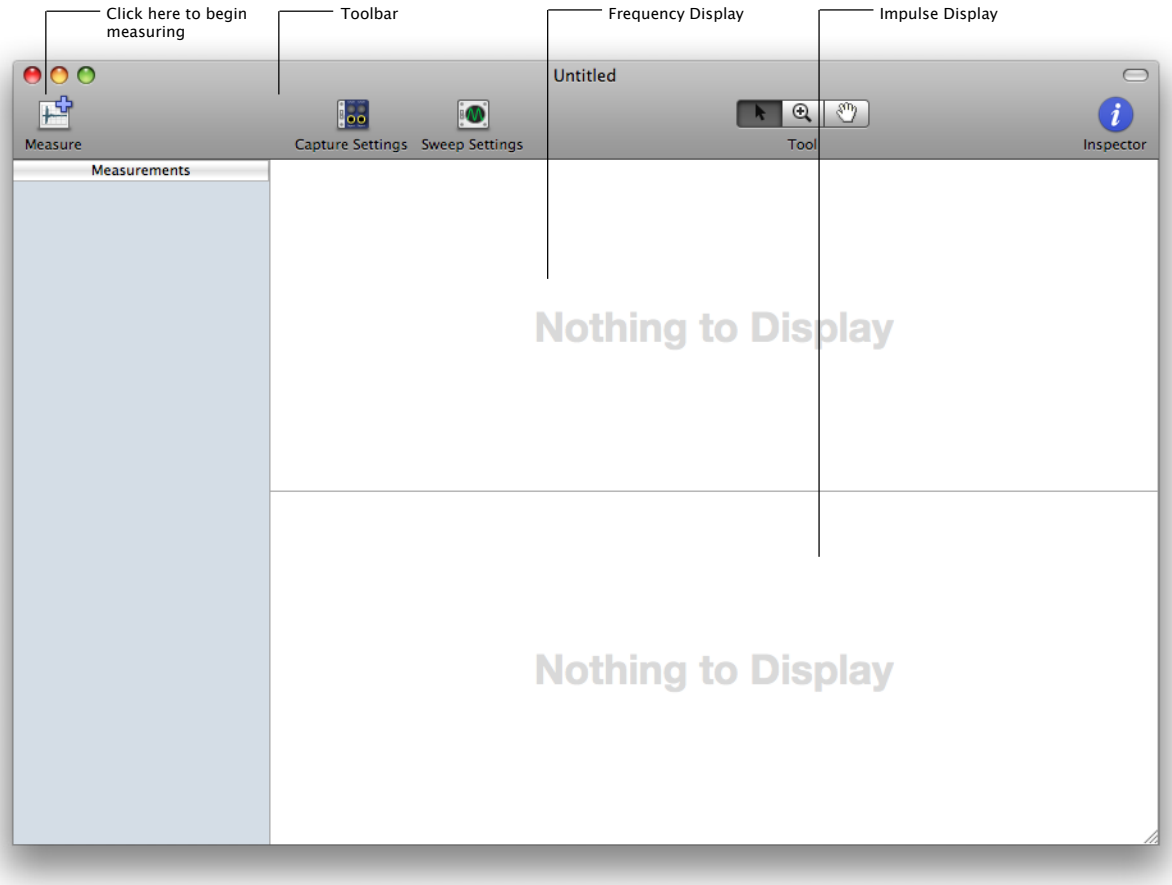
Email

You can always send email to fuzzmeasure@supermegaultragroovy.com if you encounter an urgent issue, or have trouble with licensing or purchasing.

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, the optional inspector, and 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, such as calibration data.

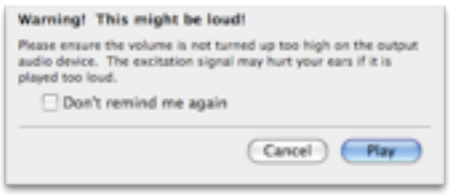


Capturing Measurements

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, do one of the following:

- 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.
- With the measurement record highlighted in the measurement list, hit return, and type a new name. Hit return again when you are done to save the change.

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

- 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:

- Select the measurement record you wish to delete, and hit the delete key
- Choose Measurement > Delete
- Control-click the measurement record you wish to delete, and choose Delete

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 or TIM (MLSSA) format.

To import an impulse response:

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

Note: MLSSA .TIM files are captured at non-standard sample rates, and hence imported impulses may not work with certain functions, such as Octave-Band Decomposition.

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 save it.

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.

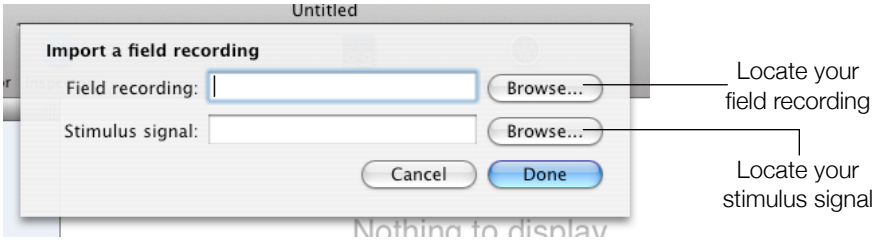
Note: You must save the exported stimulus signal for later, because you'll need it again to import the field recording.

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.
- Once you have both files selected, press the Done button to import the field recording.



Operating on Measurements

FuzzMeasure lets you perform various mathematical operations on measurements in both the time and frequency domain. Operations which are considered 'lossy' will create new records containing the modified signal data inside them. Non-lossy operations, such as normalization and inversion, will leave the record intact.

To normalize a record, select the record and do one of the following:

- Choose Measurement > Normalize
- Press option-N on your keyboard

To invert a record:

- Select the record
- Choose Measurement > Invert Impulse

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.

For some of the math operations on signals (add, subtract, average, etc), it's a good idea to make minimum phase copies first to get the best results.

To create a minimum phase copy:

- Choose Measurement > Create Copy > Minimum Phase

A- and C-Weighted Copies

For certain acoustic tests, an A-Weighted or C-Weighted measurement is important information to gather. FuzzMeasure lets you create A- and C-Weighted copies of your measurements so you can analyze them with different weightings while keeping the original measurement intact.

To create an A-Weighted copy:

- Choose Measurement > Create Copy > A-Weighted

To create a C-Weighted copy:

- Choose Measurement > Create Copy > C-Weighted

Octave and Third-Octave Band Decompositions

When analyzing a complex space's reverberation performance, it is sometimes useful to isolate specific bands of a signal to analyze an impulse's behavior in greater detail. FuzzMeasure lets you split a signal into octave or third-octave bands to analyze portions of an impulse response's spectrum.

When doing in-depth reverberation time analysis, splitting a signal into its octave-band components and then viewing each impulse in Energy Decay Curve mode will give you greater insight into the reverberation of each octave band. It may also help you identify troublesome behavior such as unwanted room resonances.

To create an Octave Band decomposition:

- Choose Measurement > Create Decomposition > Octave Band

To create a Third-Octave Band decomposition:

- Choose Measurement > Create Decomposition > Third-Octave Band

Time Domain Combinations

FuzzMeasure lets you combine multiple signals together in the time domain, so you can experiment with various combinations of your measurements.

For example, you can see how adding a subwoofer and full-range speaker's acoustical measurements will affect the resulting sound of the two components when listened to together.

To average multiple signals:

- While holding the Shift key, click the records you wish to average
- Choose Measurement > Time Domain Combine > Average

To add multiple signals:

- While holding the Shift key, click the records you wish to add
- Choose Measurement > Time Domain Combine > Add

To subtract multiple signals:

- While holding the Shift key, click the records you wish to subtract
- Choose Measurement > Time Domain Combine > Subtract

Frequency Domain Combinations

More complicated situations can be modeled by combining records in the frequency domain. If you've measured the response of a crossover, you can see the effect that crossover will have on a loudspeaker using convolution.

Correlation is just the opposite. To match the example above, if you measured a speaker with the crossover enabled, and then measured it again without the crossover enabled, you could correlate the two responses to find the response of the crossover.

To convolve two signals:

- While holding the Shift key, click the two records you wish to convolve
- Choose Measurement > Frequency Domain Combine > Convolve

To correlate two signals:

- While holding the Shift key, click the records you wish to correlate
- Choose Measurement > Frequency Domain Combine > Correlate

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.

If you absolutely must record on multiple channels, you can purchase a Y adapter cable that splits the output of a single channel to multiple channels.

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
- Click on the individual record channels you wish to enable or disable

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:

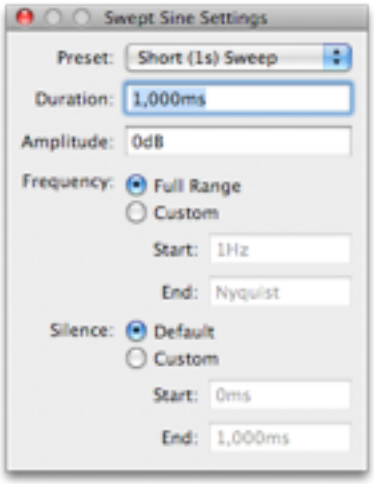
- Check the Enable correction checkbox
- Select an available playback channel from the Playback popup button
- Select an available record channel from the Record popup button
- Make sure there is a loopback cable connected between the correction playback and record channels

Swept Sine Settings

FuzzMeasure lets you modify the parameters used to generate the log sweep signal for testing. For most users, the built-in default 1s and 10s sweep presets will perform most jobs perfectly. For advanced users, new presets may be created and modified to suit your needs.

To show the Swept Sine Settings panel, do one of the following:

- Choose Window > Swept Sine Settings
- Click the Sweep Settings icon in the toolbar



To select a preset:

- Click on the Preset popup button, and select your desired preset

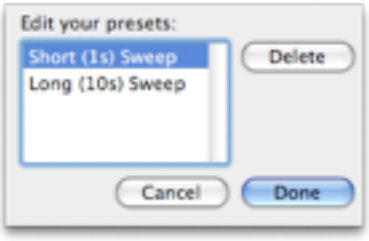
To create a new preset:

- Click on the Preset popup button, and choose Add New Preset…
- Enter the name of the new preset, and press OK

To rearrange or delete presets:

- Click on the Preset popup button, and choose Manage Presets…
- Rearrange or delete presets as you please

When rearranging presets, you will be presented with the following sheet.



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. It is advised that you try this first, before using averaging.

To enable synchronous averaging:

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

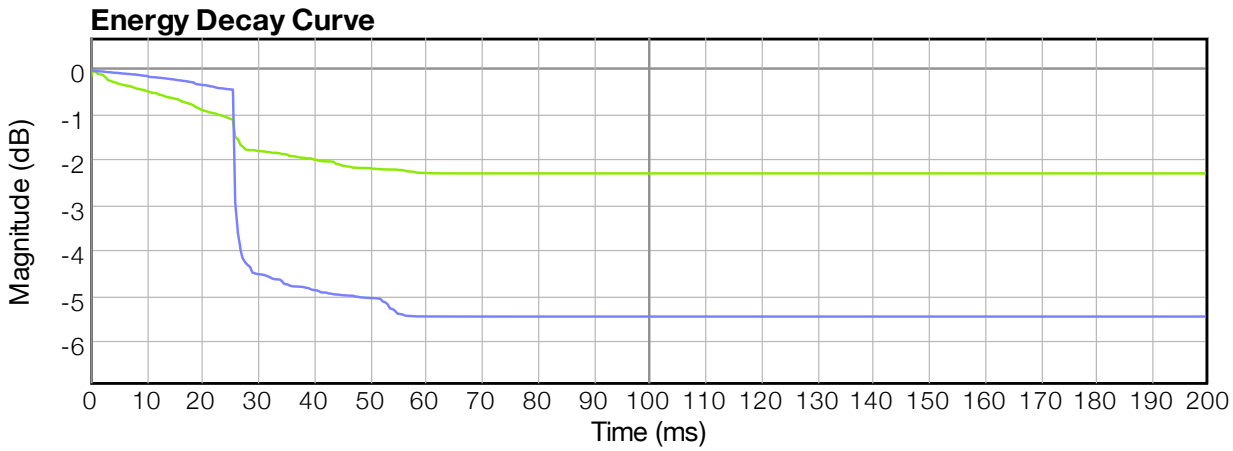
As you change the number of averages, FuzzMeasure will immediately inform you of the SNR improvement that you can expect. Each doubling of averages will gain you approximately 3dB of SNR. So, 2 averages buys you a 3dB improvement, 4 buys you 6dB, and so on.

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 arbitrarily high 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.

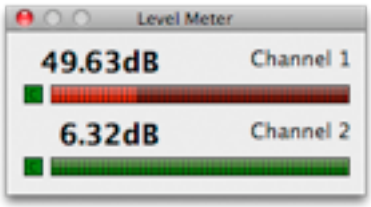
In general, averaging 4 or 8 times will suffice if you're having trouble with a high noise floor in a single measurement. Consider increasing the log sweep's duration before going this route, as it has a higher payoff.



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.

Level Meter

The level meter allows you to monitor the selected record channels, and calibrate your microphone for accurate SPL measurements. It also turns red to indicate when a channel has clipped.



To show the level meter:

- Select Window > Level Meter

To reset the clipping indicator on a meter:

- Click on the meter that has clipped

There is one meter present for each channel that's enabled for recording. By default, the SPL level is calibrated to 94dB at full-scale, which is not usable for true SPL measurements. You must calibrate the level meter in order to report reliable SPL values.

In order to calibrate your level meter, you must attach an SPL calibrator to your measurement microphone. FuzzMeasure works with any calibrator that can produce 94dB @ 1kHz.

To calibrate the level meter:

- Turn on your SPL calibrator while attached to the microphone on the channel you wish to calibrate
- Modify the input volume on your input device, if you have access to such a control, so that the 94dB point rests at an acceptable level

- Once the level meter displays a constant value, hit the button labeled with the letter ‘C’ on the left of the meter

Depending on the kind of measurement you’re capturing, you’ll want the 94dB point to rest at an appropriate level. For measurements where you expect to be exceeding 94dB, you’ll want to have a little bit of headroom without allowing recording to clip.

If you accidentally hit the calibration button while no calibrator is hooked up, or you simply wish to re-calibrate the system, you can easily reset the level meter’s SPL calibration value.

To reset the calibration on the level meter:

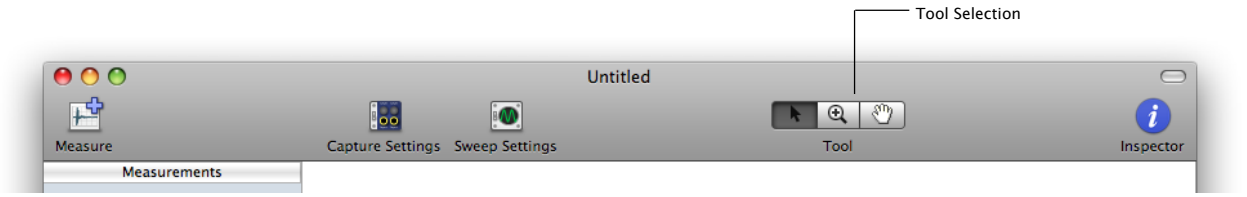
- Hit the button labeled with the letter ‘C’ on the left of the meter

After calibrating, you must take care not to modify the input level or make any other changes on the recording device. FuzzMeasure resets the calibration value on every launch, to ensure you are calibrating often. Calibration is advised before taking any new measurements that you wish to report accurate SPL values for.

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.

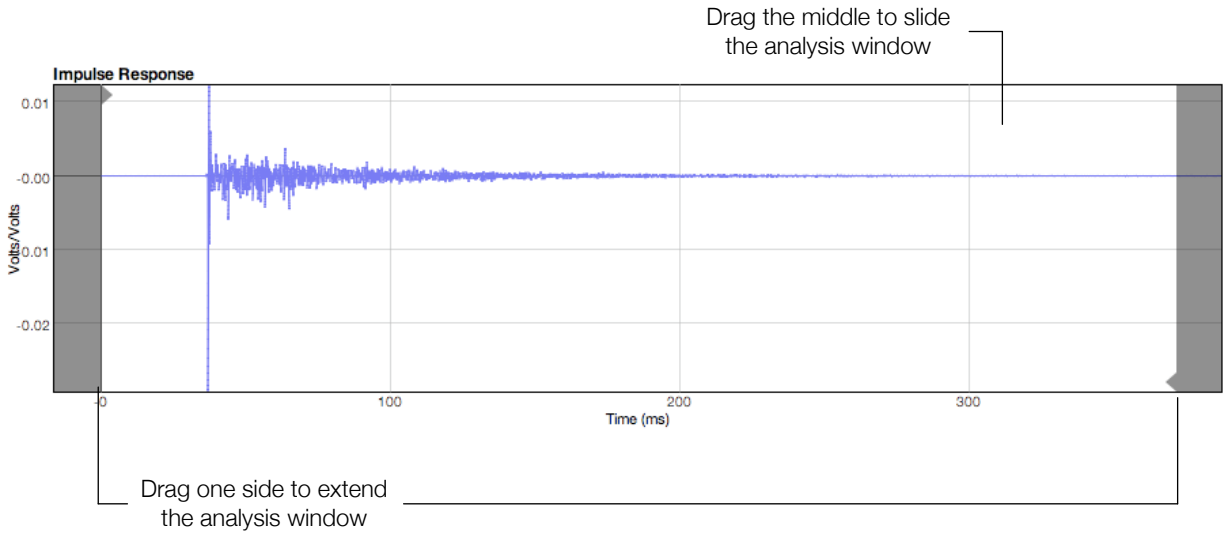


To select the current graph tool, do one of the following:

- 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.

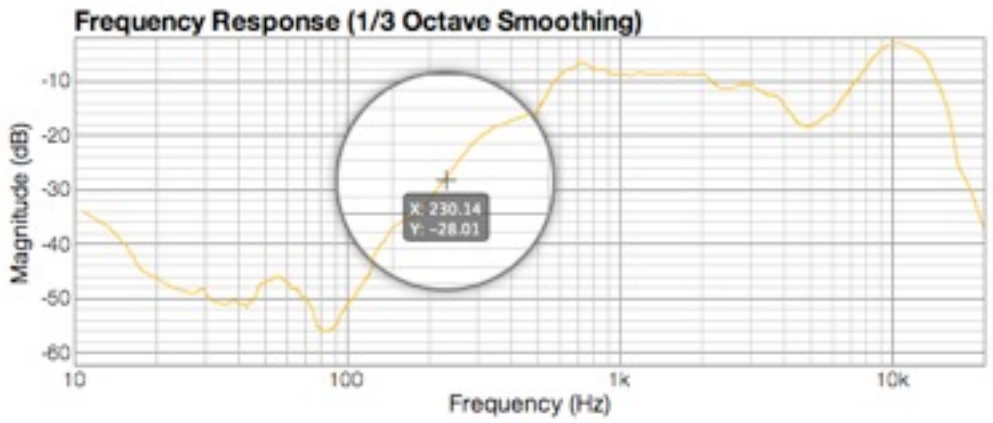
To move an existing marker around the graph:

- 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, then hold the command key and click to remove the marker.

If you would like to get detailed information about points on the graph, you can activate the loupe and see exactly which values you're looking at.



To enable the loupe:

- Place your mouse over the graph you wish to inspect
- Press and hold the option key
- Move your mouse around the graph to get information about the points on the graph

To zoom the loupe:

- While using the loupe, use the scroll wheel on your mouse, or two-finger trackpad scrolling to change the zoom level

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.

With the scroll wheel, you can also zoom in/out by scrolling up/down respectively. This option scrolls both axes by default. Hold down the Option to key to zoom the X axis, and the Command key to zoom the Y axis.

To access further zooming options:

- Choose Frequency > Zoom
- Choose Impulse > Zoom

You can also get a look at a specific region in the graph by zooming to the interior of a rectangle defined using your mouse.

To zoom in to a rectangle:

- Click the graph at the top-left of the rectangle you wish to zoom in to
- While holding the mouse button down, drag the mouse to the lower-right of the rectangle you wish to zoom in to
- Release the mouse to zoom in

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.

You can also get around the graph quickly using your scroll wheel or two-finger scrolling on a portable computer when using the move tool.

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 a Graph Image File

You can save a graph from FuzzMeasure to a PNG file, for easy attachment to an email or forum post.

To export the impulse display:

- Choose Impulse > Export Image File…
- Hold down the command key, and click the impulse display. Then, choose Export Image File…

To print the contents of the frequency display:

- Choose Frequency > Export Image File…
- Hold down the command key, and click the frequency display. Then, choose Export Image File…

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). You can also choose to display using no smoothing.

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>

In the phase display modes, you may choose to unwrap the phase data to get a better look at certain phase behaviors.

To enable or disable phase unwrapping, do one of the following:

- Choose Frequency > Unwrap Phase Response
- Hold down the command key, and click the frequency display. Then, choose Unwrap Phase Response

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>

Frequency Domain Graphs

FuzzMeasure ships with many graph displays which can provide a rich set of information. This section aims to list, and explain, what they show.

Sound Pressure Level

The Sound Pressure Level (SPL) graph allows you to plot frequency response in dB SPL, using a calibrated microphone. It is the same underlying data as the Magnitude Response graph, only shifted using the SPL calibration data.

See the Level Meter section for more information on calibrating your microphone to use with SPL measurements.

Magnitude Response

The Magnitude Response graph displays the result of a Fourier transform contained within the analysis window for the selected impulse response(s). The window's shape (i.e. Hamming, Half-Hamming, etc.) is taken into account for this calculation.

Harmonic Distortion

This plot shows the fundamental Magnitude Response (as above), combined with the magnitude responses of the 2nd and 3rd order distortion peaks.

The distortion peaks are located in "negative time" in relation to the impulse response. In the context of FuzzMeasure, that corresponds to small impulse peaks that appear near the end of the impulse data. For example, in an impulse that is 35000ms long, the impulse peak may appear at 10ms, while the first and second distortion peaks may appear at 34900ms and 34800ms, respectively.

The fundamental Magnitude Response is shown in the bold line style, the 2nd harmonic in the solid line style, and the 3rd is a dashed line.

Harmonic Distortion Percentage

This plot is similar to the Harmonic distortion plot, except that the 2nd and 3rd harmonic distortion components are compared to the fundamental, and their percentages are plotted. The line styles are the same as above (solid line for 2nd harmonic, dashed line for 3rd), except that now there is no fundamental component shown.

Group Delay

Group delay illustrates the transit time of a signal through the device under test, for each frequency. It is useful for detecting phase distortion.

Mixed Phase Response

This plot simply shows the phase component of the Magnitude Response measurement, as described above.

Minimum Phase Response

This plot depicts the minimum phase component (calculated via a Hilbert transform), which effectively minimizes delay in the calculation of the phase response.

Excess Phase Response

The excess phase plot displays the same data as the Mixed Phase response, after subtracting the minimum phase.

Time Domain Graphs

Similar to the Frequency Domain Graphs, there are plenty of time domain visualizations available in FuzzMeasure.

Impulse Response

The impulse response is the output of the deconvolution step that FuzzMeasure performs when you capture a measurement. It's a time-domain representation of the system you are measuring.

Step Response

The step response is derived from the impulse response by a simple integration. It's showing the response of your system to the application of a step function.

The step response is useful for evaluating loudspeaker performance—specifically the time-alignment of loudspeaker drivers.

Envelope Time Curve

The Envelope Time Curve (ETC), originally developed by Richard Heyser, is the magnitude of the analytic signal description of the impulse response.

ETC is similar to a smoothed version of the log squared impulse response, except it shows a much clearer view of individual reflections over time.

Log Squared Impulse Response

This plot is similar to the Envelope Time Curve, except that only the magnitude of the original (real-valued) impulse response is calculated.

This plot isn't as useful, in practice, for acoustics work, and its continued presence in FuzzMeasure is mostly for completeness, and comparison with the ETC values.

Energy Decay Curve

This plot is also known as the Schroeder Curve. It is the magnitude of a reverse-integrated, and normalized, version of the impulse response. It's the method set out by ISO 3382 to determine the reverberation time for each octave band.

Viewing the Energy Decay Curve for the full-band signal gives an overall view of the impulse's energy decay.

Overview of PlugIns

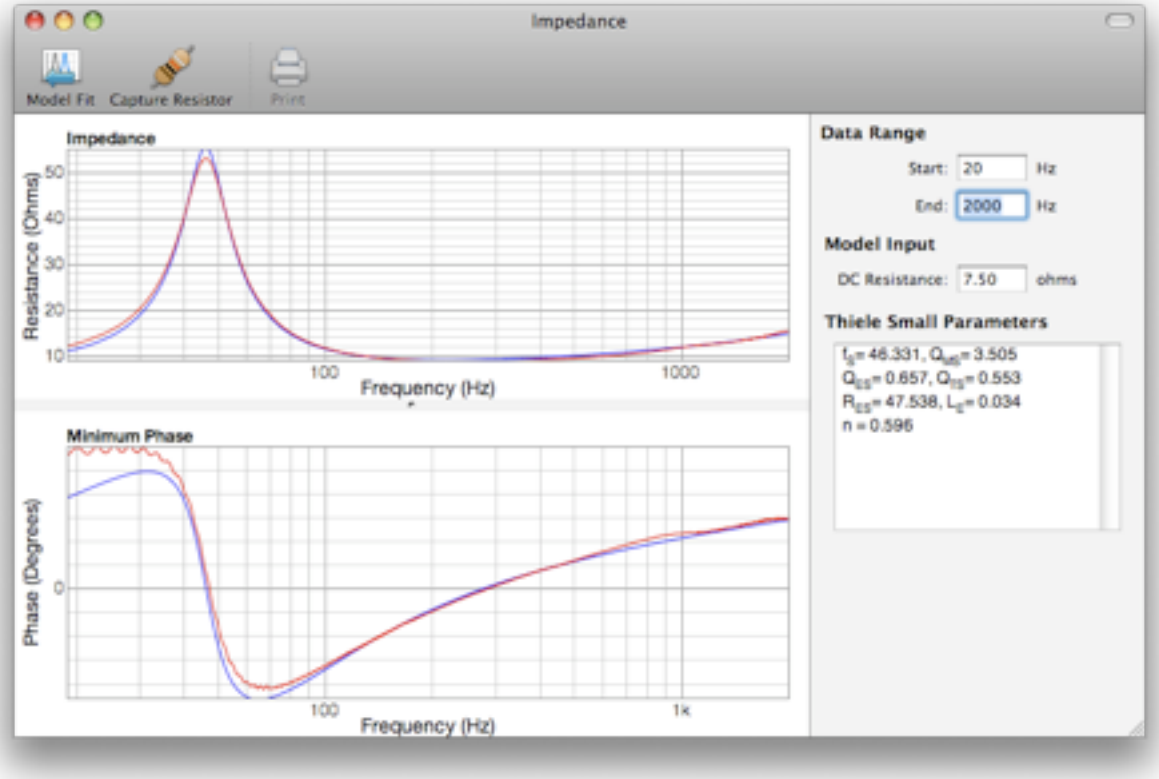
FuzzMeasure Pro contains some powerful PlugIns that extend its base functionality beyond the standard set of impulse and frequency analysis techniques.

The Impedance, Reverberation Time, and Waterfall PlugIns come included with FuzzMeasure, for special analysis that's not possible in the main UI. There are also more plugins you can build and install yourself, stored at http://code.google.com/p/smug.

Installing a PlugIn is as simple as double-clicking the .fumeplug bundle in the Finder. FuzzMeasure launches and installs the PlugIn for you automatically!

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.



Using the Impedance PlugIn involves a few steps. A resistor record is captured from the main document, you measure and set the DC resistance for your loudspeakers, and then perform a model fitting operation to your measured data to estimate the Thiele Small parameters.

Before you 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.

Once you have a resistor and a speaker measured with the jig, you're ready to use the Impedance PlugIn.

Capturing a resistor record

- In the document window containing the resistor and speaker measurement, select the resistor measurement
- Press the Capture Resistor button in the Impedance PlugIn window
- Enter the value of the resistor, and click OK

Setting the DC resistance

- In the document window containing the resistor and speaker measurement, select the speaker measurement
- Set the DC Resistance value for the selected speaker

When measuring the DC resistance value of your raw speaker in free air, make sure it is 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.

Performing the model fit

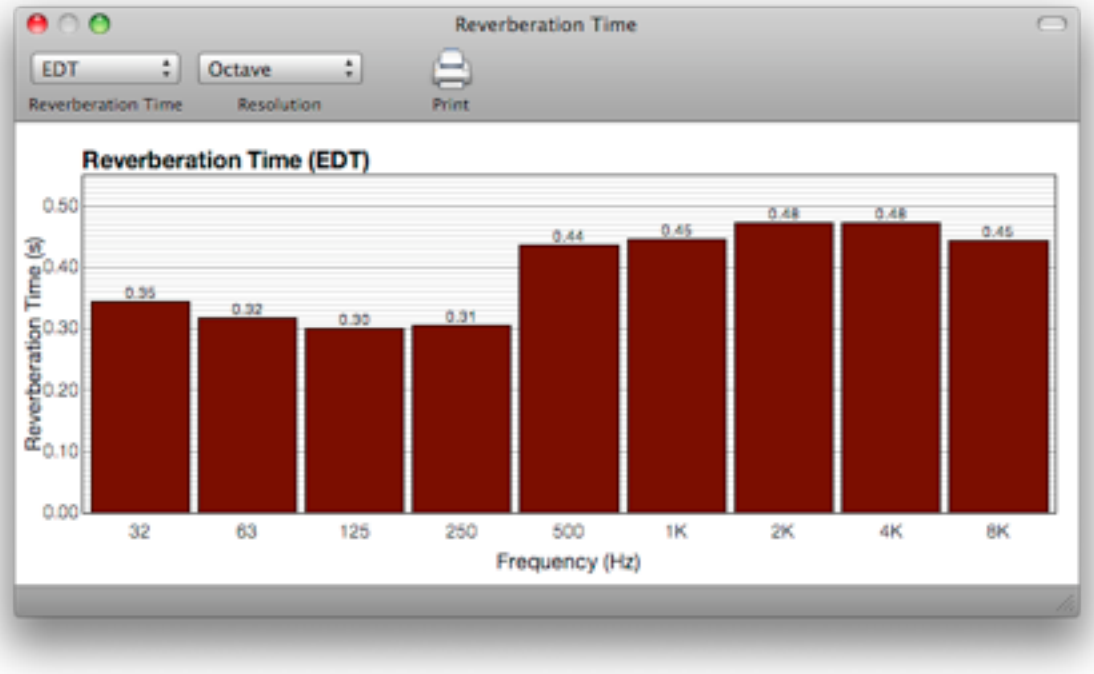
- In the document window containing the resistor and speaker measurement, select the speaker measurement
- In the Impedance PlugIn window, set the DC Resistance field to match the DC resistance of your speaker (measured with a multimeter across the terminals, set to DC resistance mode)
- Press the Perform Model Fit button in the Impedance PlugIn window

You can also limit the frequency range in which the model fitting is performed. The lossy voice coil model used in FuzzMeasure doesn't accurately capture the effects of very high frequencies in a woofer, where you'd often see a drop-off in impedance and phase.

Choose an end frequency that comes well before that drop-off, and feel free to modify and re-fit the curve until you see a good fit. The quality of the Thiele Small parameter estimation is only as good as the fit to the measured curve.

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 get valid 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 get valid 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.

Invalid values appear on the graph as 0.0.

To import a record into the Reverberation Time PlugIn:

- With the Reverberation Time PlugIn running, select a single record from your measurement list which satisfies the criteria above.

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.

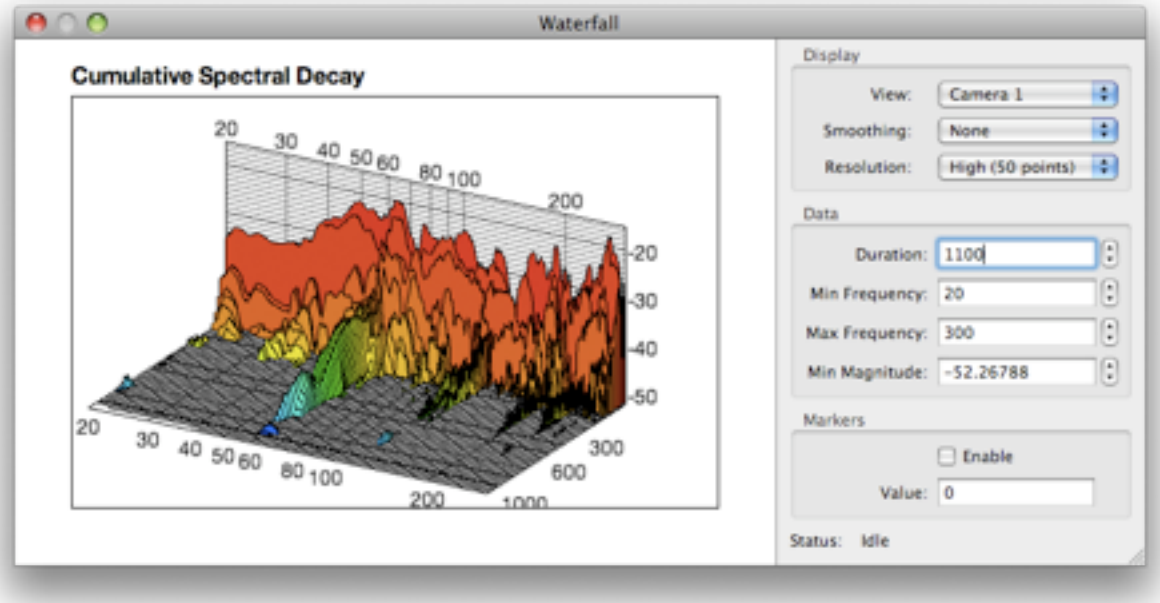
When you export reverberation time data, it produces a CSV (Comma-Separated Values) text file with EDT, T20, and T30 values.

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.

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. Alternatively, make a minimum phase copy of your measurement record before importing it into the waterfall plugin.

To import a record into the Waterfall PlugIn:

- With the Waterfall PlugIn running, select a single record from your measurement list which satisfies the criteria above.

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. You can also use your mouse to rotate the graph around.

Moving your mouse along the X axis will affect the graph's rotation about the Y axis, and moving along the Y axis will affect rotation about the X axis. You may slide the graph along the

X axis by holding the shift key while clicking and dragging the mouse in the waterfall view. If you wish to reset the camera, you can choose one of the camera presets.

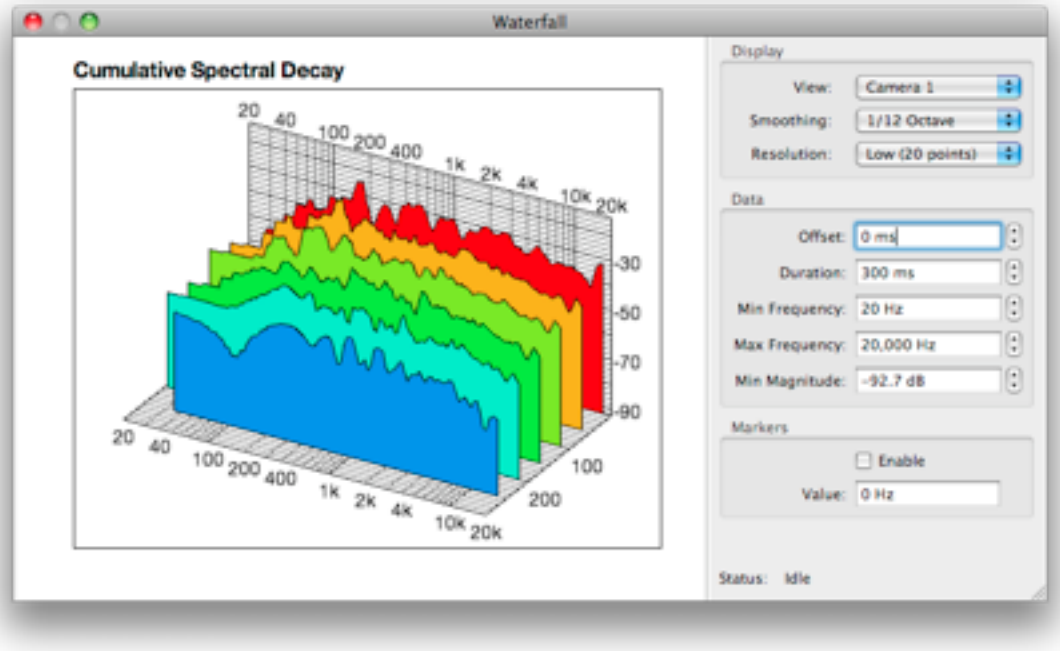
For room acoustics measurements, it is best to work with a duration of 1000ms or more. The waterfall plugin uses the data within the analysis window for a given record, so make sure the analysis window's duration is longer than 1000ms to ensure you capture all the data you need for the waterfall.

Some notes on waterfall calculations

If you are evaluating a loudspeaker's performance and wish to window out the reflections in a room, you would typically retain the quasi-anechoic window in the main FuzzMeasure document, and analyze the frequency response within that period. However, in the Waterfall PlugIn, this is not ideal.

Individual waterfall slices are calculated using an FFT window as determined (automatically) by the main document. A longer analysis window length will yield higher-precision FFTs. Thus, if you require highly detailed measurements of only the first few ms of a loudspeaker's response, you should set the impulse window much longer in the main document, and set the duration in the Waterfall PlugIn accordingly.

The duration setting in the Waterfall PlugIn is used to calculate within the windowed impulse response as determined in the main document window. Thus, with a 300ms window, only 300ms of the impulse data can be viewed in the waterfall. Setting values larger than the duration of the impulse's window will cause waterfall slices to be dropped.



An example of a waterfall with missing slices.

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. The discussion group is a good place to discuss these options.

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.

If you decide to get your microphone calibrated using a service, please be sure to post your experiences on the discussion group. This will go a long way towards helping future users find reputable services in the future.

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.

Once you do purchase a professional microphone, you might also want to purchase an SPL calibrator to go along with it for accurate SPL measurements.

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:

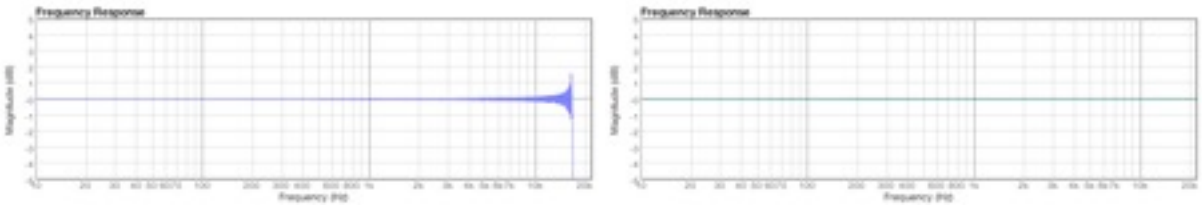
- Purchase an audio interface that has built-in preamplifiers and phantom power for its microphone inputs.
- Purchase a preamplifier with phantom power that can be plugged into the line-in on your built-in or external audio device.

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.

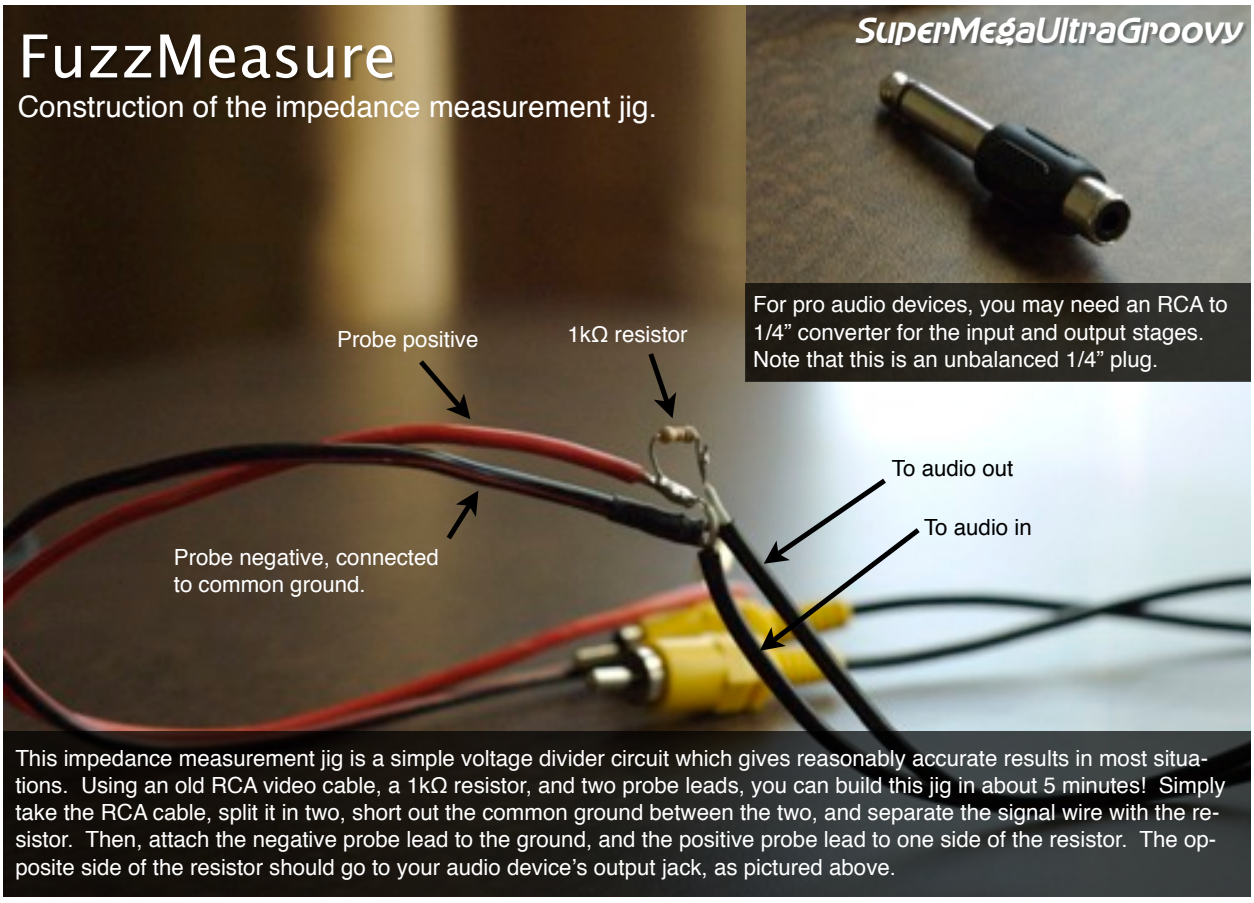
Some audio systems (especially home theater receivers with optical digital inputs) have a little bit of a delay before they play audio that's coming in on their inputs. As a result, some of the swept sine signal won't be played through the speakers, and thus not captured by FuzzMeasure.

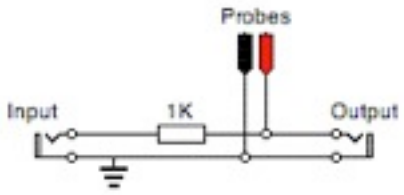
To add delay to the start of your swept sine signal:

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

Some home theater receivers might also go even further and not turn on until the signal contains actual audio. In this case, your only real course of action is to choose a longer log sweep time to try and mitigate the problem. Synchronous averaging might also help you get around this.

Appendix A: Impedance Jig





Impedance Jig Schematic