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What Is Multi-Sub Optimizer?

Multi-Sub Optimizer Introduction

Multi-Sub Optimizer (MSO) is a freeware (software gratis) Windows-based program for optimizing the bass response of audio systems using multiple subwoofers. It optimizes the flatness of the combined frequency responses of main loudspeakers and multiple subwoofers at multiple listening positions simultaneously. It is not simply a global EQ program, but allows individual EQ, gain and delay parameters to be optimized for each subwoofer such that the variation of the overall bass responses from seat to seat is reduced, in addition to being flattened at multiple listening positions.

A multi-channel DSP device such as a Behringer DCX2496 or a miniDSP device or equivalent is assumed to be present in your system. MSO processes data you supply, including measurement data in FRD format (text files containing frequency response magnitude and phase), and information about collections of filters, gains and delays you wish to use, and uses global optimization technology to determine the best values for the filter, gain and delay parameters. MSO generates a filter report, allowing you to enter the calculated filter information into your DSP device.

System Requirements

MSO runs only on Windows. MSO requires Windows XP Service Pack 3 or a later version of Windows.

Important: Measurement System Requirements

Your measurement system must be capable of using a loopback timing reference or the equivalent acoustic timing reference to achieve time-synchronized measurements. This means that **USB microphones can only be used with Room EQ Wizard version 5.15 or later in conjunction with the acoustic timing reference feature. If you are measuring a two-channel system using a USB microphone, REW 5.15 versions prior to beta 6 had the restriction that the speaker used for the acoustic timing reference could not also be measured without some special workarounds. You**

must use REW 5.15 beta 6 or later when measuring a two-channel system with a USB microphone. For more information, see the measurements section.

Download Links

- **Program:** The software can be downloaded here. Unzipping **mso.zip** gives you **install_mso.exe**, which is the new installer
  Most recent update: Version 1.07, uploaded 15 May, 2016. See the revision history.
- **Tutorial Files, Samples and Help:** A tutorial is now available as a zipped PDF file for download. You'll also need to download the tutorial's sample files and projects. For detailed help information, see the Help Contents.

Online Forum Discussion

A discussion thread about MSO can be found at AVS Forum. There is also some MSO discussion on reddit. The AVS Forum thread is the best place to go for discussion of MSO.

Before You Post to the AVS Forum MSO Thread

The AVS Forum MSO discussion thread is for discussion of MSO usage, feature requests, bug reports and so on. It's not an REW or miniDSP support thread. Before posting, you should ensure that you are completely familiar with your hardware and its features, that you have the hardware configured correctly. You should also have a strong familiarity with your measurement software, be able to get good measurements, and be fully confident in the validity of the measurements. The thread is not intended as a measurement or hardware configuration discussion thread, except in cases for which those subjects pertain specifically to MSO.

License

Multi-Sub Optimizer is freeware (software gratis) **for non-commercial use only. Commercial use is a violation of the license agreement.**

Acknowledgments

The optimization algorithm used is from the following article:
J. Zhang and A. C. Sanderson, *JADE: Adaptive Differential Evolution with Optional External Archive*, IEEE Transactions on Evolutionary Computation, 13(5): 945 - 958, October 2009.

Thanks to Earl Geddes, whose video about multiple subwoofers and its associated PowerPoint presentation inspired the creation of this software.

Thanks to Cédric Moonen for the High-speed Charting Control used for MSO's graphs.

Thanks to Nemanja Trifunovic for the UTF-8 CPP library used for UTF-8 text conversion.

Thanks to Jag768 from AVSForum and DIYAudio for beta testing, providing data and many helpful suggestions for program features.

Thanks to markus767 and AV_mike from AVSForum for finding and reporting bugs.

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Revision History

Version 1.07

- Added optimization mode that gives the best match of non-MLP frequency responses to the MLP
- Requires specifying which listening position is the MLP
- Specified in the new **Method** property page of the **Optimization Options** property sheet
- Use this mode for best performance when a later global EQ step will be applied to the MLP

Version 1.06

- Properly scale sub data when left and right main speakers are energized and measured individually instead of together
- Needed when using REW acoustic timing reference for two-channel systems or MCH when main speakers are left and right (not center)
- Situation is detected automatically with no user intervention required

Multi-Sub Optimizer Tutorial

Introduction

Multi-Sub Optimizer (MSO) is free software that optimizes the low-frequency response of an audio system having multiple subwoofers. It optimizes the integration of the subwoofers with one another and with the main speakers. It is able to perform this optimization at multiple listening positions simultaneously. It does this by using individual gain, delay, and equalization (EQ) adjustments for each sub. Because of this individual sub adjustments, it can:

- Control the interaction between the subs.
- Control the interaction between the subs and main speakers.

The technique used by MSO is different than the conventional approach of tackling room mode effects by using shared EQ for all subs.

Conventional Equalization for Room Mode Effects

When you place subwoofers and main speakers in a room and the measure their frequency response, room modes in the modal region (typically 200 Hz and below, depending on room dimensions) cause large peaks and dips in the measured frequency response. A typical way to tackle this problem is to use a digital signal processing (DSP) device that provides parametric EQ for the subwoofers. You might apply the same EQ to all subwoofers in order to flatten the measured response at the main listening position (MLP). In a home theater application, you'd typically adjust the subwoofer distance and level settings in the AVR or preamp/processor for best integration of the subs and main speakers. After each such sub distance and level adjustment, you'd make a new measurement to determine if the result is good enough. In a more sophisticated approach using a DSP device, you might set individual delays for each subwoofer. You might then calculate these delays based on the relative distances of each sub from the main listening position and keep them at their calculated value. This step alone can make a significant improvement.

Problems with the Conventional Approach

At the specific frequencies of the room modes, the frequency response may have peaks at some listening positions and dips at others. Unless you're very lucky, flattening the response at the main listening position can make it worse at others. Also, when integrating the main speakers and subs, each new adjustment of subwoofer distance and level requires a corresponding measurement to determine if the integration of main speakers and subs is good enough. That can become very time consuming.

The Advantage of Using Individual Subwoofer EQ

The earliest known effective attempt to simultaneously fix frequency response errors at multiple listening positions can be found in the 1995 Master's thesis of Bruno Korst-Fagundes. He assumed multiple speakers with a mono source signal and didn't specifically mention subwoofers, but his concept applies equally well to subs. He split the mono signal into separate EQ for each speaker and found that if the number of speakers is equal to the number of listening positions at which their frequency response is measured, it's possible in theory to get perfectly flat response of the combined speaker outputs at multiple listening positions simultaneously. His approach works by solving a set of simultaneous linear equations at each frequency, based on measurements from each speaker to each listening position. The solution to each system of equations at a given frequency yields the required gain and phase of each sub's DSP filter at that frequency. A high-order finite-impulse-response (FIR) filter having the calculated gain and phase response at each frequency is then designed for each speaker. This approach requires special-purpose FIR filter hardware and has some practical problems related to the need for impractically high filter gains at some frequencies. The practical need to limit these gains places a limit on how flat the combined subwoofer responses can be in practice. JBL used a variation of this approach on a product called the BassQ.

Earl Geddes has some proprietary software designed under the assumption that a commonly-available type of DSP device having infinite-impulse-response (IIR) filters will be used. These IIR filters are simple compared to the FIR filters used in products like the BassQ. They emulate the behavior of analog filters. An approach that determines the best possible result with hardware that's commonly available and low in cost, like that used by Dr. Geddes, makes a lot of practical sense. Not much is known about his proprietary software, but his video about multiple subwoofers suggests it's doing something similar to what MSO is doing: trying to get the flattest combined response of subs and main speakers at multiple seating positions. The idea for MSO was inspired by that video.

Harman also has a patented system called Sound Field Management (SFM). Its theory of operation is described in the article "Low-Frequency Optimization Using Multiple Subwoofers". It works by minimizing a metric called the *mean spatial variance* (MSV).

The goal of SFM is to first minimize the *variation with listening position* of the combined sub frequency responses (the MSV) *without regard to the flatness of the response*. A single separate PEQ, gain and delay per subwoofer are adjusted to minimize the MSV. After this step, EQ that's common to all subs is performed to flatten response. Finally, integration with the mains is performed in a third step. MSO does not work in this way.

MSO bases its calculations on the response *flatness* at multiple listening positions, so its reduction of seat-to-seat frequency response variation is an indirect (but significant) result of its approach. The optimization of response flatness at multiple seating positions and integration of subs and main speakers are all done in one step in order to maximize the usage of the limited EQ resources available in low-cost DSP units.

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Multi-Sub Optimizer Tutorial

Tutorial: Creating An Example Project

To perform the tutorial, download tutorial_files.zip to the folder of your choice and unzip it, ensuring that the unzip operation preserves the folders within the zip file. The tutorial contains the folders **Data**, **Project** and **Sample Projects**. The **Data** folder contains the measurement text files you'll be importing, and the **Project** folder is empty. The **Project** folder is where you'll save the MSO project file (.msop file), which is a binary file containing all the information about your project. The **Sample Projects** folder contains projects that have progressed in various stages and whose data on such items as optimized filter parameters matches up with the illustrations in this tutorial. Before looking at the example, we'll have a brief look at the main window of MSO as shown below.

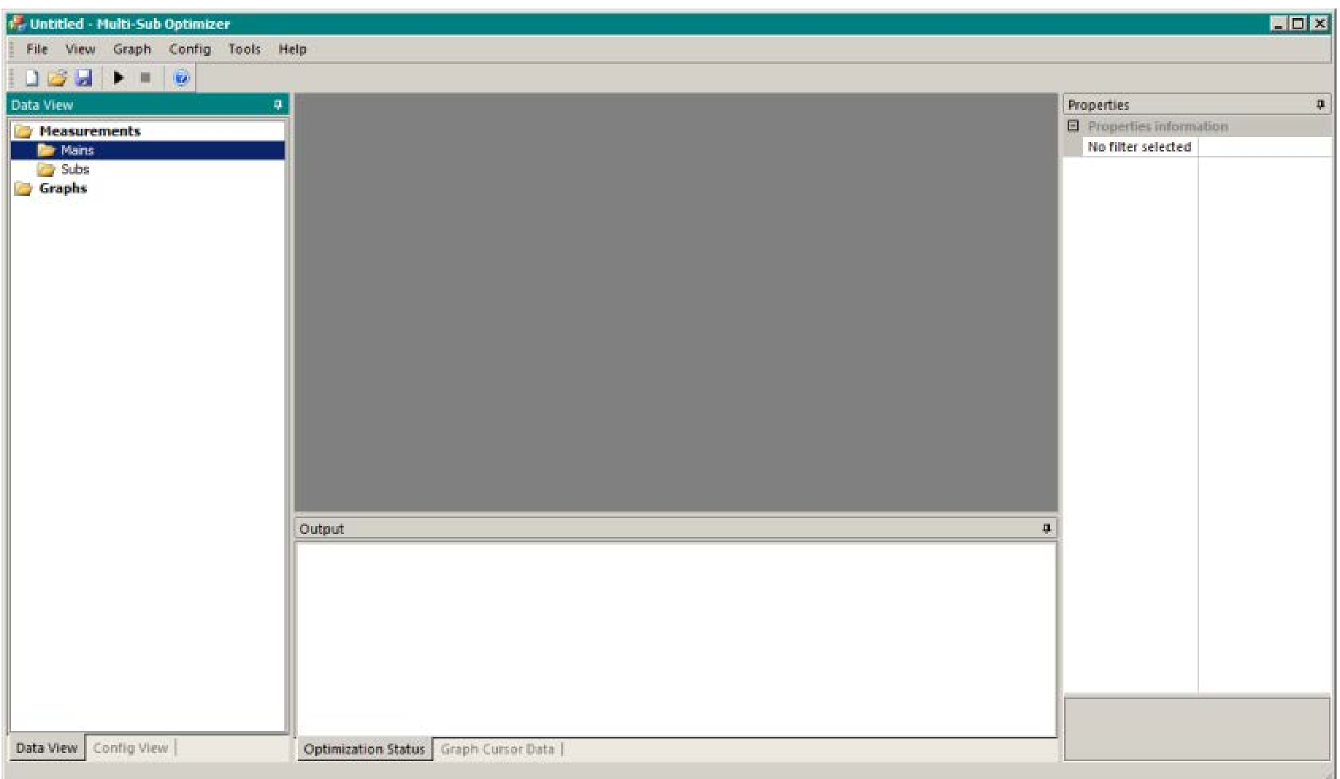

Figure 1. MSO Main Window

You'll see a typical menu and a small toolbar. The left window pane contains two tabs labeled **Data View** and **Config View**. The **Data View** is for displaying which text files you've imported, and allows you to create and manipulate graphs and their traces. In the **Config View,** you can define filter channels, add filters to them, associate measurements with them and other activities. Both **Data View** and **Config View** are tree views whose nodes, if shown as a folder icon, represent categories of data, and if shown as a document-like icon, represent data added explicitly or implicitly by you. At the bottom in the center is the **Output** window. It displays various status items such as optimization status if an optimization is being run, or cursor data values if you are tracing a curve on a graph. At the top in the center is an empty area where graphs and text windows will be shown after you create them. On the right side of the main window is the **Properties** window, also called the **Properties** grid. When you define filters to be used for EQ, their parameter values and upper and lower limits will be shown there, where you can modify them if needed.

Click on the **Data View** tab at the lower left of the main window and try hovering the mouse over the text labeled **Mains** (under **Measurements**), or its icon. You'll see a yellow “tool tip” pop up. The tool tip provides a hint that you can obtain a context menu when you right-click on this node. It also gives a list of some of the menu options. Right-click on this node and you'll see a context menu with only one choice: **Import Mains Measurements**. Using this menu, you can import some data. One good way to explore the user interface of MSO is to hover the mouse over various nodes in the **Data View** and **Config View** trees. If a tool tip appears, there is a context menu associated with that node. By right-clicking a node that shows a tool tip, you can see what menu options are associated with that node. For the tool tip to appear, the mouse must be on the text or icon of the corresponding node. If the mouse is hovered to the right of the node's text, no tool tip will be shown.

A Note About The Project

This project, whose data was provided by Jag768, uses the multi-sub technique recommended by Earl Geddes. In the Geddes arrangement, the main speakers have no high-pass filter. In addition, the sub measurements were performed without a low-pass filter. For this project, individual low-pass filters will be added for each separate subwoofer filter channel using an external DSP, and these low-pass filters will in general have different cutoff frequencies. This is different from a typical home theater application in which the measurements are performed with the chosen crossover already in place and bass management enables. In such a case, no low-pass filter would be added via an external EQ, and typically only PEQ, delay and gain would be used in MSO for each subwoofer filter channel.

Multi-Sub Optimizer Tutorial

Importing Data

After choosing the **Import Mains Measurements** menu selection, you'll get a standard Windows **File Open** dialog with the default extension set to **.frd**. Navigate to the folder where you downloaded the tutorial and select the **Data** sub-folder. There you'll see the **.frd** files for the tutorial. Resize the dialog if necessary to see all of the files. You'll notice that the provider of these files, Jag768, has helpfully given them names that allow identification of which sub or main speaker is being measured, and what the listening position is. There are four files of mains measurements to import: **Pos1_mains.frd**, **Pos2_mains.frd**, **Pos3_mains.frd** and **Pos4_mains.frd**, corresponding to four listening positions. Select all four by pressing **Ctrl** and left-clicking to select each one in turn. Click the **Open** button of the dialog to import the files. There is a short delay while the software checks the text files for errors and converts the text to numeric data. You will then see four icons under **Mains**, displaying the names of the four imported main speaker measurement files as shown below.

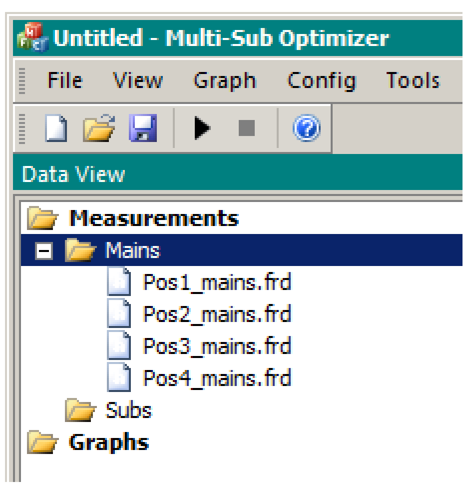

Figure 2. Data View after importing mains measurements

If you hover over one of these file names, you'll see a tool tip indicating that there is a context menu associated with the imported data. Right-click on one of the file names and choose **Show Imported Text**. This will create a tabbed window showing the text you imported. This is illustrated below.

Pos1_mains.frd

11.804	86.0129	-53.4869
11.929	85.9570	-89.1449
12.056	85.8581	-89.8347
12.184	85.7535	-90.5236
12.314	85.6488	-91.2105
12.445	85.5439	-91.8945
12.578	85.4389	-92.5750
12.711	85.3338	-93.2512
12.847	85.2286	-93.9225
12.983	85.1233	-94.5878
13.122	85.0181	-95.2464
13.261	84.9128	-95.8974
13.402	84.8075	-96.5398
13.545	84.7023	-97.1725
13.689	84.5972	-97.7946
13.835	84.4921	-98.4050
13.982	84.3871	-99.0024
14.131	84.2823	-99.5857
14.281	84.1777	-100.1536
14.433	84.0733	-100.7048
14.587	83.9691	-101.2379
14.742	83.8652	-101.7514
14.899	83.7616	-102.2438
15.057	83.6584	-102.7135
15.217	83.5555	-103.1590
15.379	83.4530	-103.5783
15.543	83.3510	-103.9697
15.708	83.2494	-104.3314
15.875	83.1484	-104.6613
16.044	83.0479	-104.9574
16.215	82.9481	-105.2176
16.388	82.8489	-105.4395
16.562	82.7504	-105.6208
16.738	82.6526	-105.7591
16.916	82.5556	-105.8519
17.096	82.4594	-105.8965

Figure 3. Imported measurement in text form

The **.frd** format is very simple. The first column contains the frequency in Hz, the second the SPL in dB, and the third the phase in degrees. The columns can be separated by spaces or tabs. Not present in this example are comment lines, which are recommended. Comment lines can help by reminding you of information such as which speaker and listening position you measured. The description of this format on the FRD

Consortium web page specifies that comment lines begin with the “*” character. MSO allows comment lines to begin with many different characters, so it's not critical that they begin with the “*” character. If MSO determines the line is not data, it treats the line as a comment and preserves it. However, you should avoid beginning comment lines with characters such as “+”, “-”, “.”, “,” or the digits 0 through 9 to prevent them from being mistaken as numeric data. If you are using Room EQ Wizard (REW), you can create the **.frd** files by using REW's **File**, **Export**, **Measurement as Text** menu sequence. If you have comments in REW's comment field for the measurement, which is recommended, these will be imported by MSO as-is without error. There is no need to edit these files in any way prior to importing them if REW is used to generate them, provided you use the REW menu selection mentioned above to generate the **.frd** files. If you are using REW in a country that uses the comma as the decimal separator, REW will export the text in that format. MSO will sense the decimal separator when importing and will import the data accordingly. The need to interpret commas as decimal separators in countries using this convention means that commas must not be used to separate data columns – only spaces or tabs.

Now you can import the sub measurements. A second way to import measurements uses the main menu. Choose **File**, **Import Sub Measurements** from the main menu. This will show the same **File Open** dialog that we used to import the mains data, but it will now open in the same folder (directory) used before. The easiest way to select the sub measurement files is to select the first file by clicking on it, then press **Shift** and click the last file. This will select all of the files. Then press **Ctrl** and left-click on the four mains measurement files (**Pos1_mains.frd**, **Pos2_mains.frd**, **Pos3_mains.frd** and **Pos4_mains.frd**) to deselect them so that only sub measurement files are selected. Click the **Open** button on the dialog to import the files. There is a delay while the software performs error checking and converts the text of the files to numeric data. Each file name will appear as an icon under the **Subs** category in the **Data View**.

If you again right-click on the name of one of the imported files, you can look at the other options on the context menu as shown below.

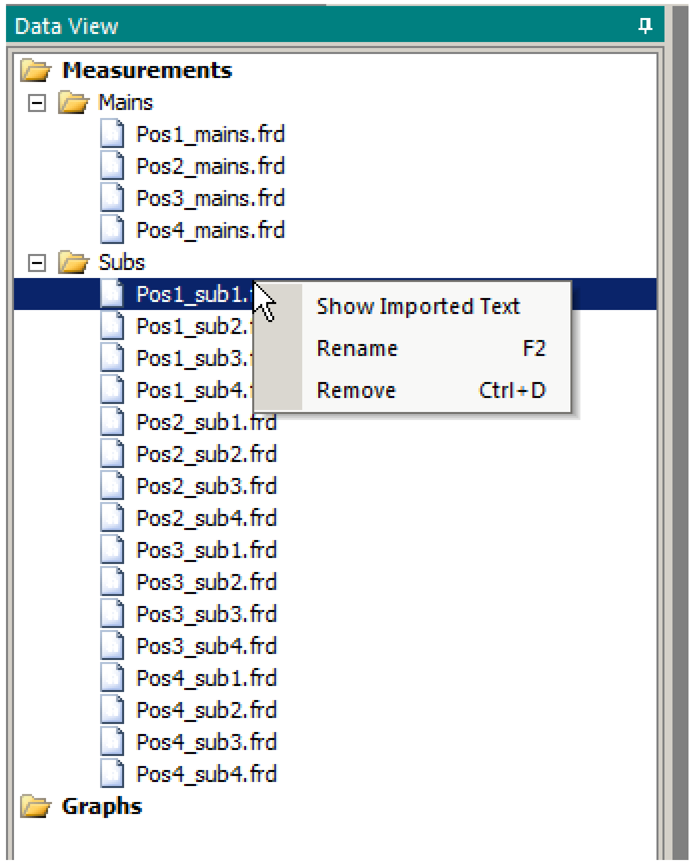

Figure 4. Context menu for imported measurements

Show Imported Text has already been illustrated. You can rename the measurement from this context menu by choosing **Rename** or by pressing **F2**. You can give measurements any name, but the name should be short, yet contain information about which speaker or sub was being measured and what the listening position was. If you chose file names carefully, you probably won't need to rename them. You might want to remove the "**.frd**" at the end of the measurement name for clarity. Also, once you import the measurements, they become part of the project and are saved with it when you choose **File**, **Save** from the main menu. These files need not be present on disk after they are imported. The other option on this context menu is **Remove**. If you accidentally import **Mains** data into the **Subs** category or vice versa, you can use **Remove** to remove the problem measurement from the project. **Ctrl+D** and **Delete** also cause the selected measurement to be removed from the project. This operation doesn't affect the original text files on disk. You can then re-import the data to the correct data category as needed in the event of an error.

Multi-Sub Optimizer Tutorial

Trying Out Graphs

Since you now have imported data, you're in a position to take a preliminary look at graphs. You won't see all the possibilities with graphs just yet, but you can get a good first idea of how to use them by creating some simple ones with the data you now have available. You can create Graphs in two ways:

- From the main menu, choose **Graph**, **New Graph**.
- In the **Data View** tab, right-click on the tree node named **Graphs** and choose **New Graph** from the context menu.

This will cause the **Graph Properties** dialog to be launched as shown below.

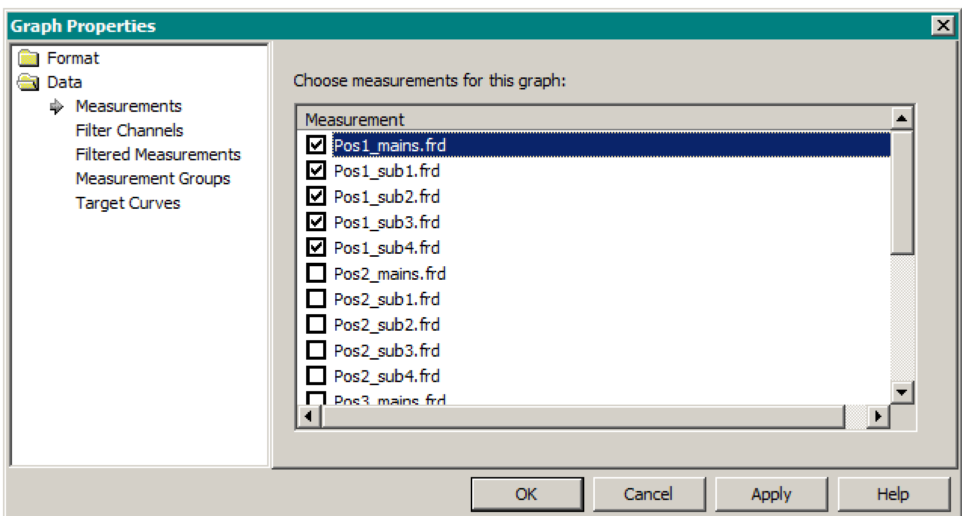

Figure 5. Graph Properties dialog – Measurements page

You use this dialog both for creating new graphs as well as modifying existing ones. The dialog has a tree view on the left, which allows you to select different categories of options to change. Initially, the **Data** category is active, and the item underneath that, **Measurements**, is shown. You can plot four other types of data, but since you only have imported measurements at this point, only those are available. You'll see the other data types when you create them later in this tutorial. When you select **Measurements**, the pane on the right of the dialog shows all the measurements you previously imported. For this graph, choose the first five measurements (**Pos1_mains.frd**, **Pos1_sub1.frd**, **Pos1_sub2.frd**, **Pos1_sub3.frd** and **Pos1_sub4.frd**) as shown above by clicking on the checkboxes in the measurement list. These are all the measurements at position 1, which is the main listening position. After selecting them, do not press the **OK** button at this time. Instead, press **Apply**. The graph will immediately display the changes you've made, while still keeping the dialog box open if further changes are required. If you accidentally press **OK**, this will close the dialog box. To get the dialog box back, simply right-click the graph and choose **Graph Properties** from the context menu. In the tree view on the left side of the **Graph Properties** dialog, click **Format**. This will display the format options. Click **Axes**. The dialog box will be as shown below.

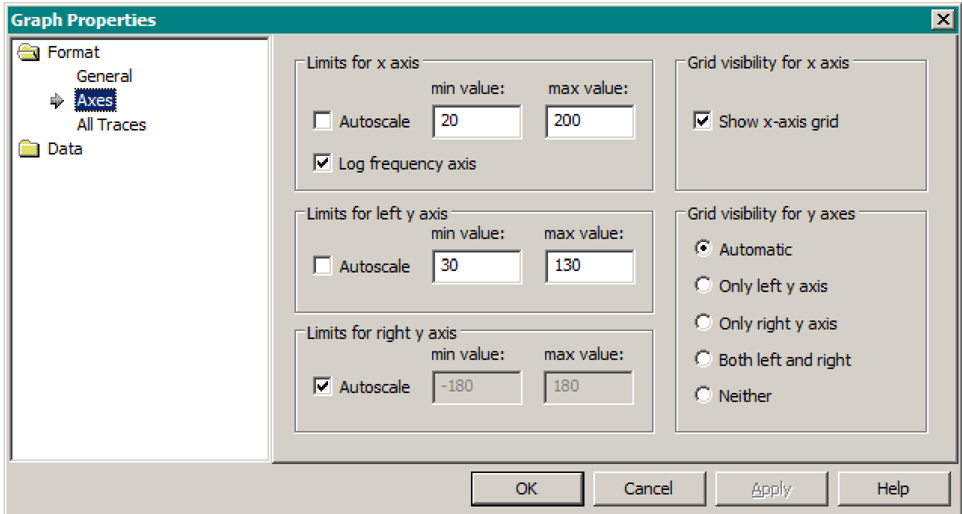

Figure 6. Graph Properties dialog – Axes page

Notice that the default x-axis scaling is manual and the default y-axis scaling is automatic. You can change the y axis scaling to manual by unchecking **Autoscale** under **Limits for left y axis**,. Type in **30** to the **min value** edit box, and **130** to the **max value** edit box as shown above. Press **Apply** to see your changes. After you click the **Apply** button, it will be grayed out as shown above.

One useful feature of graphs is the data cursor. First, close the **Graph Properties** dialog by clicking on **OK** if you haven't yet done so. Next, right-click on the graph to show its context menu. Choose **Show Data Cursor**. This will cause the data cursor to appear as a vertical line, with the mouse cursor, now in the shape of a double-ended arrow, positioned on the data cursor as shown below.

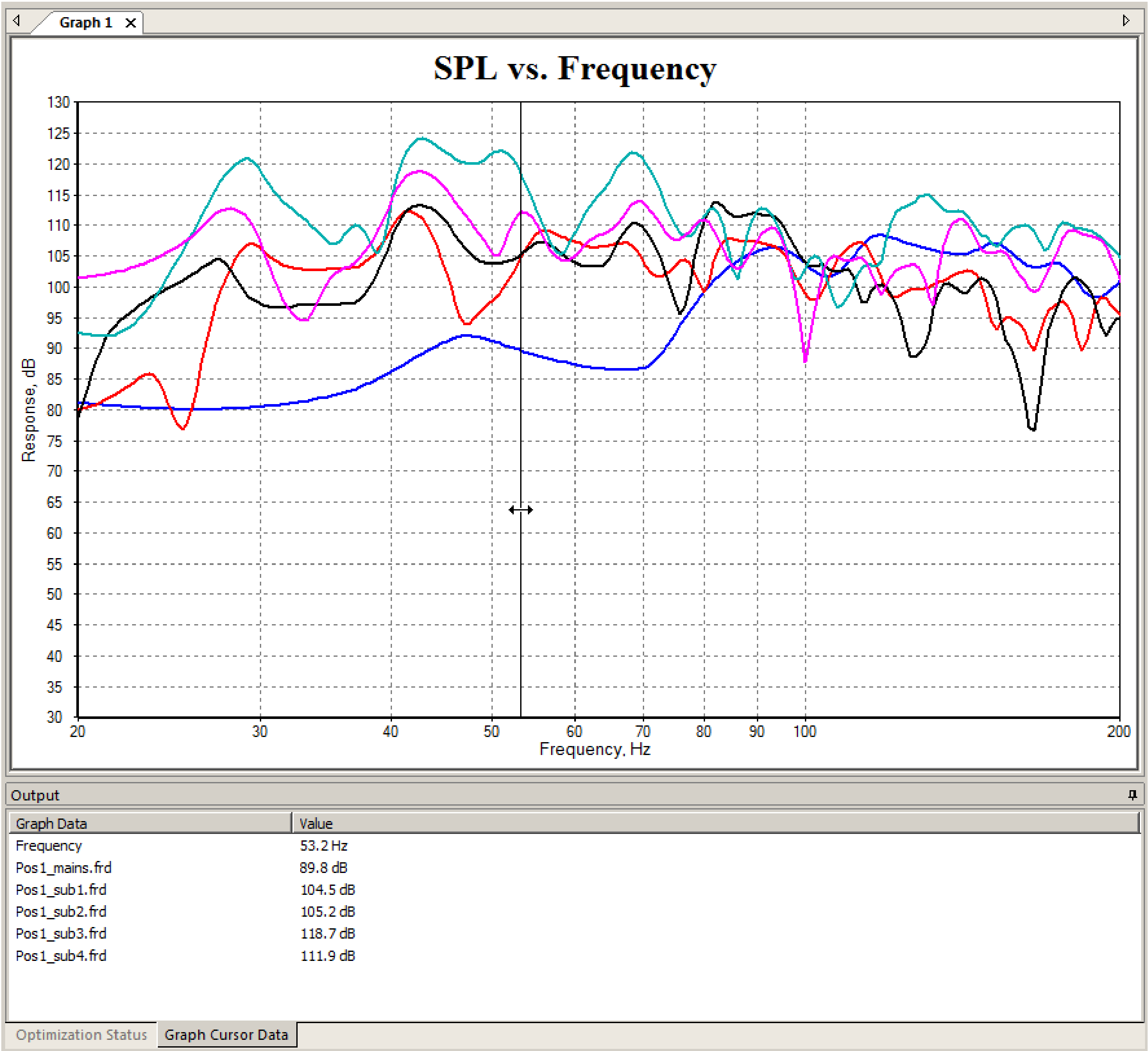

Figure 7. Tracing graph data with the data cursor

This special mouse cursor indicates that you can use the left mouse button to drag the data cursor to the desired frequency and examine the trace data values. In the **Output** window, the **Graph Cursor Data** tab has been automatically activated, and the frequency at the cursor position, along with the SPL values of all of the traces at that frequency are shown. These values automatically update as you drag the data cursor. If you release the left mouse button and move it away from the data cursor, the mouse cursor goes back to its original shape. If you move the mouse cursor close enough to the data cursor, it will turn into a double-ended arrow and you can drag the data cursor again. To hide the data cursor, right-click on the graph and choose **Hide Data Cursor** from the context menu.

Multi-Sub Optimizer Tutorial

Adding Filter Channels

MSO does not have preconfigured setups for specific DSP hardware. Instead, you tell MSO how many filter channels your hardware has by adding filter channels in the **Config View**. To add filter channels, click the **Config View** tab at the lower left of the main window and locate the **Subwoofer Channels** folder icon. Right-click on it and choose **Add Filter Channel** from the context menu. This will create a new filter channel called **Sub Channel 1**. Repeat this process three more times to create the filter channels **Sub Channel 2**, **Sub Channel 3** and **Sub Channel 4**. You have just created four subwoofer channels, one for each of four subwoofers. You set up the filters you want by adding filters to each of these channels. Before you do that though, you need to add a channel for the main speakers, even though you may not be using MSO to EQ the mains. The reason for this will be explained shortly. Right-click the **Mains Channels** node and choose **Add Filter Channel** from the context menu. This will create a new filter channel for the main speakers called **Mains Channel 1**. When done, the results should appear as below.

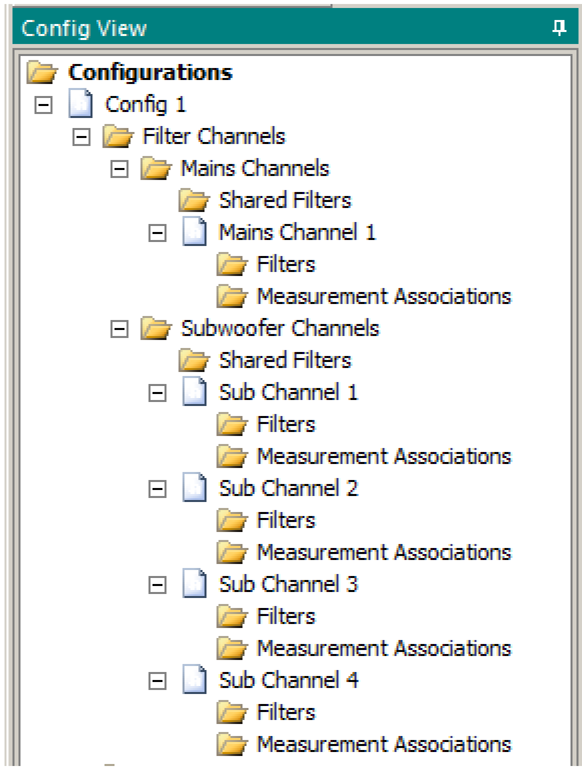

Figure 8. Filter channels added

Adding Filters to Filter Channels

Now you'll add a parametric EQ to **Sub Channel 1**. Click the **Filters** folder icon under **Sub Channel 1**. Right-click and choose **Add Parametric EQ**. You'll see a new icon labeled **FL1:Parametric EQ** under **Filters**, which is under **Sub Channel 1**. Click on **FL1: Parametric EQ** to select it.

When a filter is selected in this way, the **Properties** window on the right side of the main window will show information about the filter, its parameter values, and the upper and lower limits of permissible values of each parameter. This is illustrated below.

Properties	
Filter Information	
Filter type	Parametric EQ
Reference designator	FL1
Configuration name	Config 1
Channel name	Sub Channel 1
Center freq (Hz)	
Value	80.0
Minimum value	40.0
Maximum value	150.0
Optimization allowed	True
Boost (dB)	
Value	0.00
Minimum value	-15.00
Maximum value	0.00
Optimization allowed	True
Q	
Value	2.000
Minimum value	1.000
Maximum value	25.000
Optimization allowed	True

Figure 9. Properties Window

The first group of properties is **Filter Information**. You can't alter any of the **Filter Information** values as their purpose is just to identify the filter, its type, and other information about it. Below **Filter Information** are the parameters, their names, values, and the upper and lower limits of those values. Only the information in the right column can be changed. You can change the values themselves in the right column by editing them as you would in a spreadsheet. In addition, when you click in the right column of the **Value** field, a spin control with up and down arrows appears, allowing you to tune the value by pressing either of these two arrows.

The **Optimization allowed** field controls whether the optimizer is permitted to alter the value of the parameter. If set to **False**, the parameter will retain the value set in the **Properties** window and won't be changed by the optimizer.

Notice the **Maximum value** field of the **Boost (dB)** parameter has a value of 0 dB to disallow boosting. This is only an initial maximum value as a safety feature for some DSP hardware that might have dynamic range problems when boosting is done. You can manually edit the maximum value of the boost to be up to 15 dB, which is likely to be much more than you'd ever want to use. You can also set the default minimum and maximum values of newly-created filters of all types. You'll look at that next.

Multi-Sub Optimizer Tutorial

Setting Default Filter Parameter Limits

MSO is initially set up with default values for the minimum and maximum parameter limits. These limits prevent the optimizer from adjusting parameters to values that are either impractical or beyond the capability of your DSP hardware. You can change these limits using the Application Options dialog. From the main menu, choose Tools, Application Options. The Application Options dialog will be shown as below.

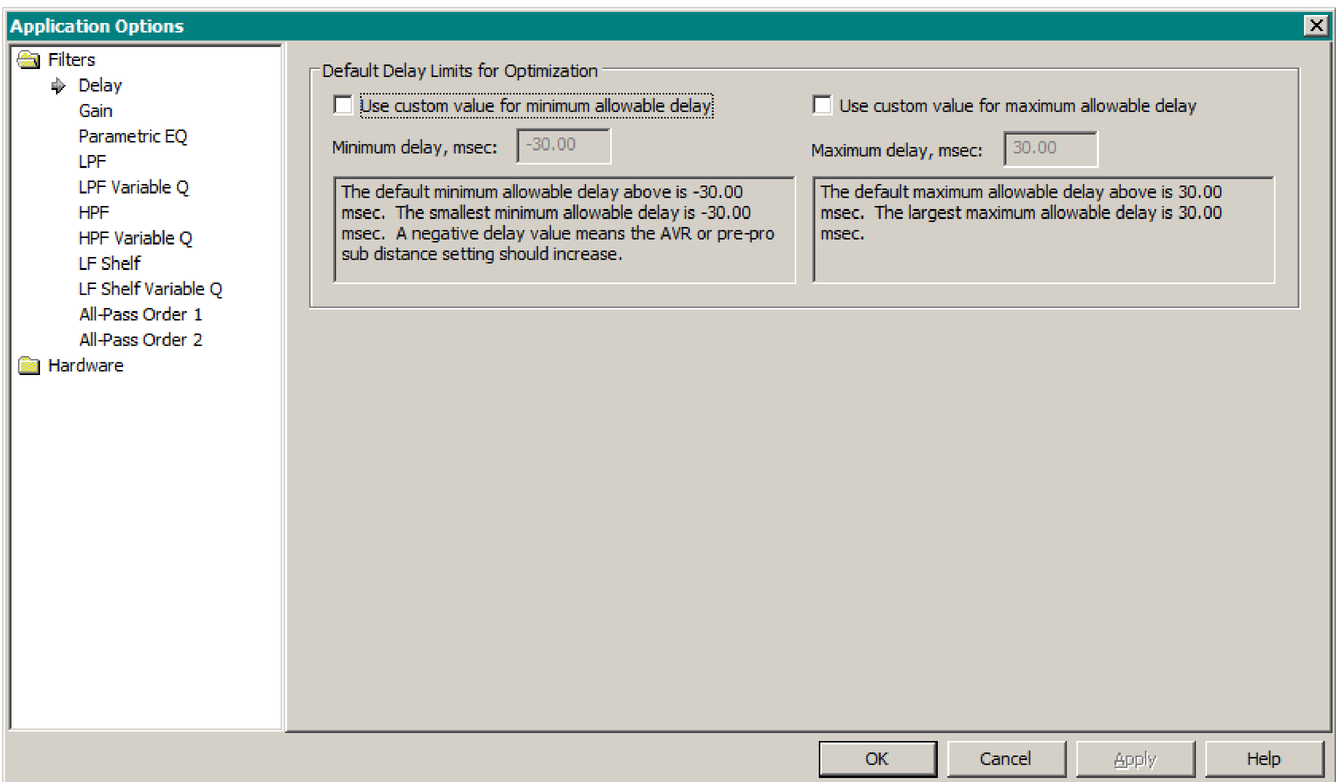

Figure 10. Application Options dialog

Assume the DSP being used has a maximum delay of 15 milliseconds. Check the **Use custom value for minimum allowable delay** checkbox and enter **0** into the **Minimum delay, msec** edit control. Check the **Use custom value for maximum allowable delay** checkbox and enter **15** into the **Maximum delay, msec** edit control. Now all newly-created delay blocks will have these limits for the delay. You can override the limits manually after the delay block is added, by using values as low as -30 milliseconds for the lower limit and as high as 30 milliseconds for the upper limit. A negative delay means that the delay should be reduced relative to the as-measured condition, which means increasing the sub distance in your AVR from what it was when the measurement was performed.

You can configure custom minimum and maximum values for each of the parameters of other filter types too, but for this tutorial you'll keep all of them at the default values except the minimum and maximum delays. These values will stay in effect for all projects, not just the current one. Changes you made to the default minimum and maximum delays affects only newly-created delay blocks.

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Multi-Sub Optimizer Tutorial

A Second Look at Graphs

You can demonstrate the tuning feature by making another graph. From the main menu, choose **Graph, New Graph**. Under the **Data** category, choose **Filter Channels**. The five filter channels you defined now appear in the list. However, only one of them, **Sub Channel 1**, has any filters in it. Check the checkbox of only **Sub Channel 1** from the list as shown below.

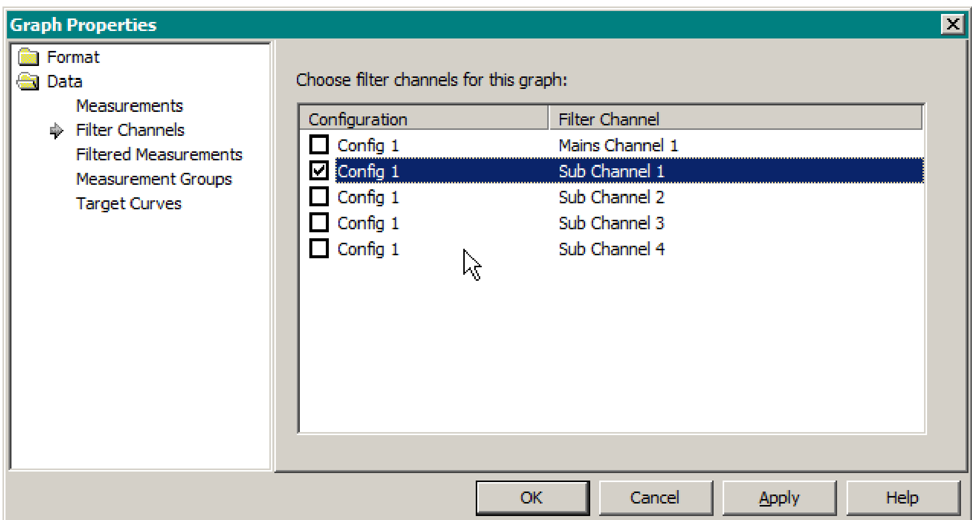


Figure 11. Choosing filter channels to plot

Press **Apply**. Under **Format**, **General**, change the graph title from **SPL vs. Frequency** to **Sub Channel 1 Response vs. Frequency**. Under **Format**, **Axes**, disable autoscaling of the left y axis and enter **-20** for its lower limit and **20** for its upper limit. Press **Apply**. The frequency response of **Sub Channel 1** is shown, but it's just a flat line because the PEQ boost is set to its initial value of 0 dB. If the properties of the parametric EQ **FL1** are not shown in the properties window, go to the **Config View** and select **FL1:Parametric EQ**. In the **Properties** window, locate the **Boost (dB)** parameter and click the mouse on the right column of the **Value** field. The spin control should appear as in Figure 9 above. Press and hold the left mouse button down with the mouse cursor over the down arrow of the spin control while observing the graph. You might have to wait a few seconds because the initial changes happen slowly, but you should see the filter response of the graph change as you tune the **Boost (dB)** parameter. When it has reached its minimum value of -15 dB, the graph should look as below. This assumes the center frequency and Q of **FL1** are set to their default values of 80 Hz and 2.0 respectively.

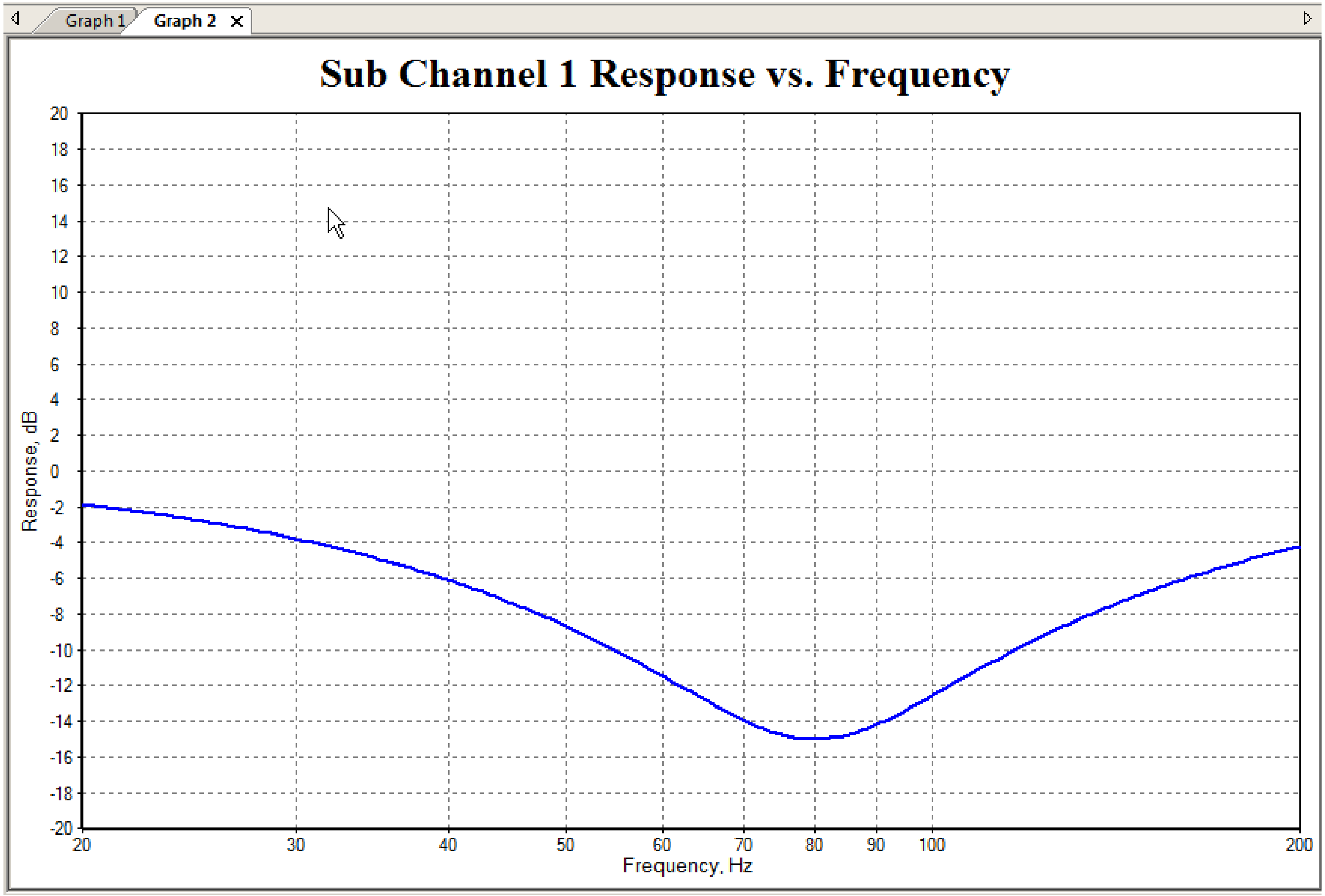


Figure 12. Parametric EQ response vs. frequency with 15 dB cut

For now, set **FL1** back to 0 dB boost. To do this, just enter the text into the right column of the **Value** field of the **Boost (dB)** parameter. You must press **Enter** for the change to be finalized. When the change takes effect, the text display of the value turns to bold. The graph of the response of **Sub Channel 1** should once again be a flat line at 0 dB.

Assume that each of the four sub channels will contain the following filters:

- Four PEQ filters
- One 24 dB/oct Linkwitz-Riley low-pass filter
- One delay block
- One gain block

The channel for the main speakers will have no filters, delays or gain blocks of any kind.

Add filters to each of the four sub channels you've defined so its configuration matches that above. For each sub channel, add the PEQs first, then the low-pass filter, then the delay, then the gain block, beginning with **Sub Channel 1**. Then move on to the next sub channel. Performing the steps in that order will ensure that the reference designators (e.g. FL1, FL2 etc.) match up with the illustrations in this document. The 24 dB/oct Linkwitz-Riley low-pass filter is added using the **Advanced** sub-menu of the context menu for adding filters and is named “LPF Linkwitz-Riley 24 dB/oct” . If you accidentally add the wrong type of filter, just select it and press the **Delete** key to remove it.

Saving Your Work

Now would be a good time to save what you've done. Choose **File**, **Save** from the main menu or press **Ctrl+S**.

Navigate to the tutorial's Project folder and save your file as **tutorial_1**. MSO will automatically add a **.msop** extension to the file. A file with a **.msop** extension is an MSO project.

Multi-Sub Optimizer Tutorial

Associating Measurements With Filter Channels

To perform an optimization, MSO needs information about which imported measurements are associated with which sub or main speaker. Since each independent Sub or main speaker is associated with an individual filter channel, you accomplish this by associating measurements with filter channels. The following assumptions apply:

- All main speaker measurements are associated with **Mains Channel 1**
- All Sub 1 measurements are associated with **Sub Channel 1**
- All Sub 2 measurements are associated with **Sub Channel 2**
- All Sub 3 measurements are associated with **Sub Channel 3**
- All Sub 4 measurements are associated with **Sub Channel 4**

To associate the main speaker measurements with **Mains Channel 1**, select the **Measurement Associations** icon under **Mains Channel 1**. Right-click and choose **Associate Measurements** from the context menu. All the main speaker measurements are shown in the dialog. Check all of them and click **OK**. You will now see four icons corresponding to the four main speaker measurements (that is, the main speakers at four listening positions) under **Measurement Associations**, which in turn is under **Mains Channel 1**. This is illustrated below.

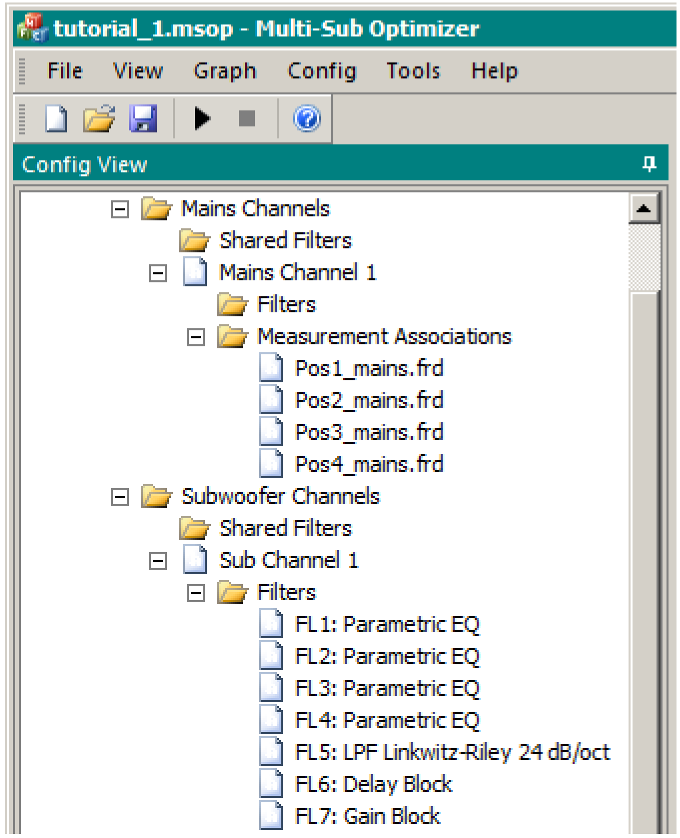


Figure 13. Associating main speaker measurements with their filter channel

Next, associate the Sub 1 measurements with **Sub Channel 1**. Right-clicking on **Measurement Associations** under **Sub Channel 1** and choosing **Associate Measurements** gives the following dialog box:

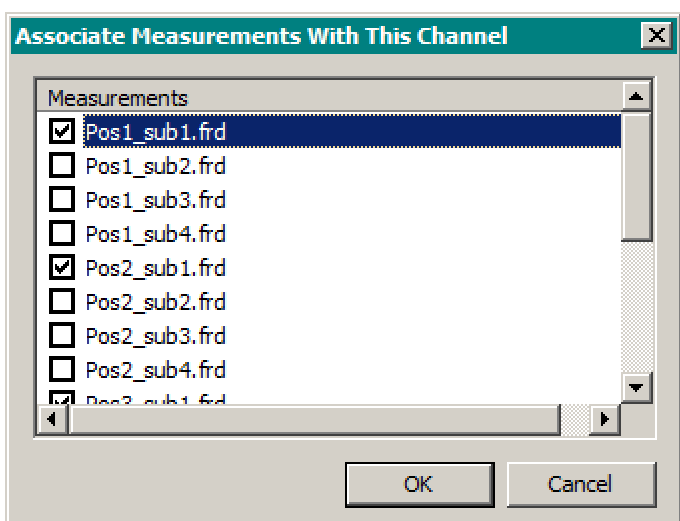


Figure 14. Measurement association for subs

There should be a total of four measurements involving Sub 1, showing up as every fifth measurement. Select the four measurements ending in **_sub1.frd** and press **OK**. Repeat this process for each of the three remaining sub channels. Each time you invoke the **Associate Measurements** dialog for a sub channel, the measurements you previously associated with a channel will have been removed from the list. A measurement cannot be associated with more than one channel. When done, the **Config View** should look something like this (**Filters** nodes have been collapsed for clarity):

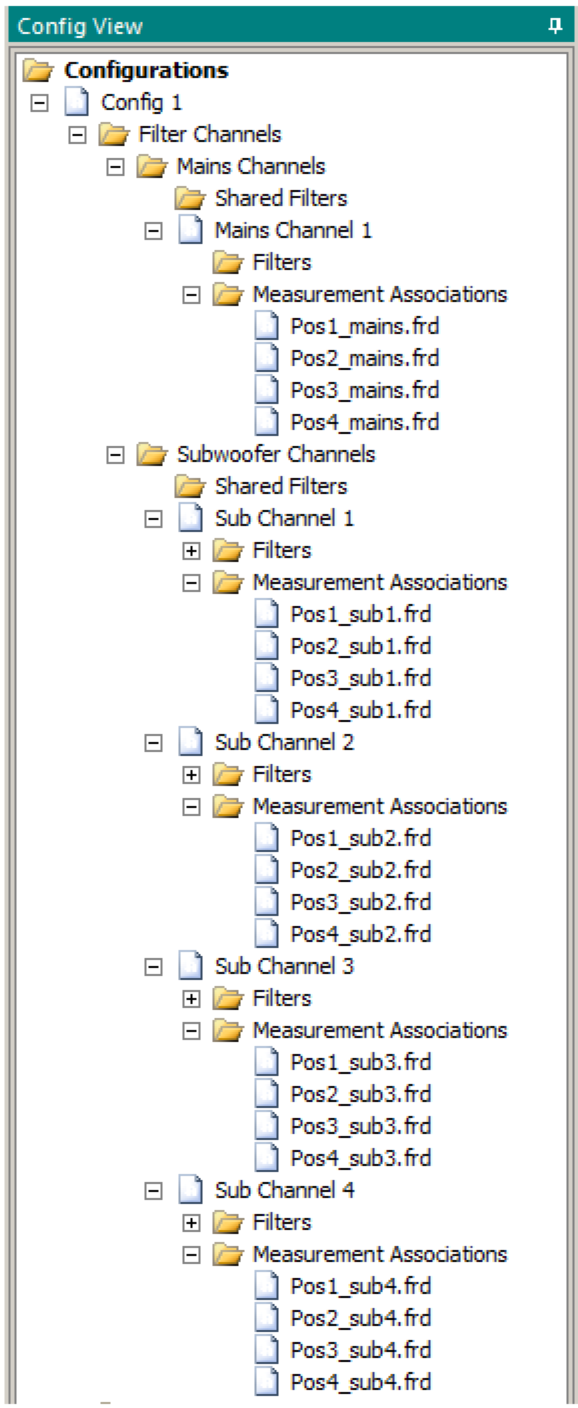


Figure 15. All measurement associations complete

Multi-Sub Optimizer Tutorial

A Third Look at Graphs

Now that you've associated measurements with filter channels, you can look at another type of graph trace.

From the main menu, choose Graph, New Graph. This launches the Graph Properties dialog. The property page for Data, under Measurements, is the default when the dialog launches. On this page, check the checkbox for the measurement named Pos1_sub1.frd as shown below.

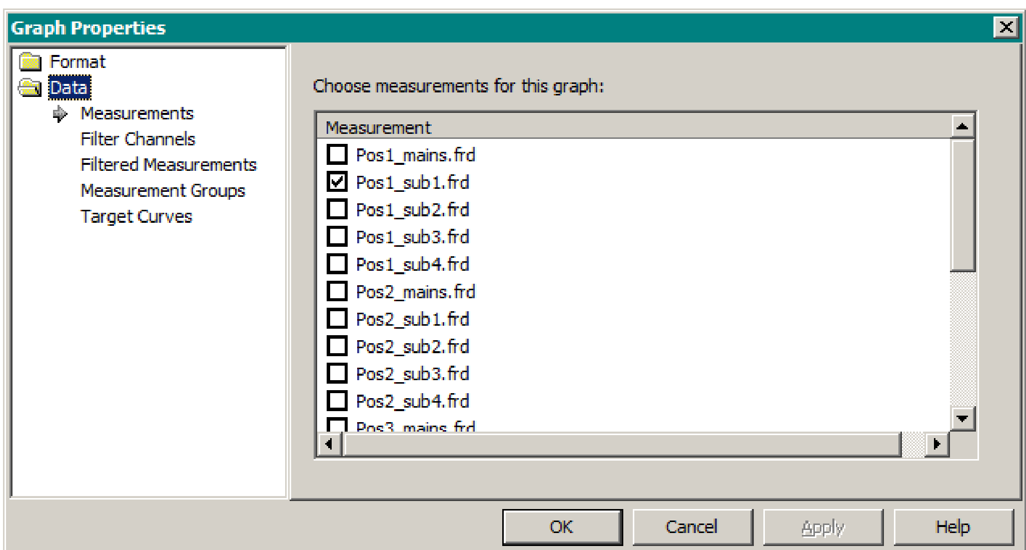


Figure 16. Plotting an unfiltered measurement

Next, choose **Filtered Measurements** as shown below.

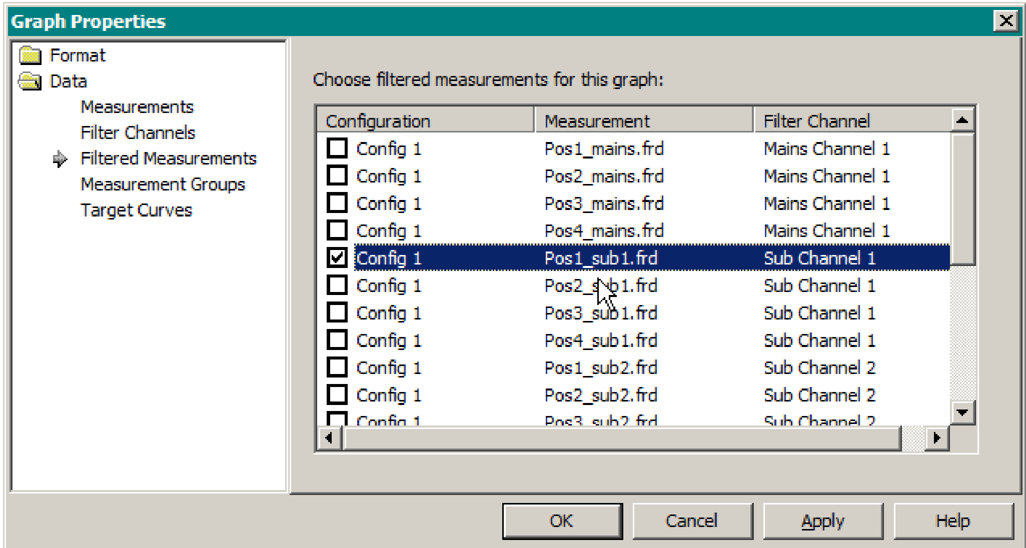
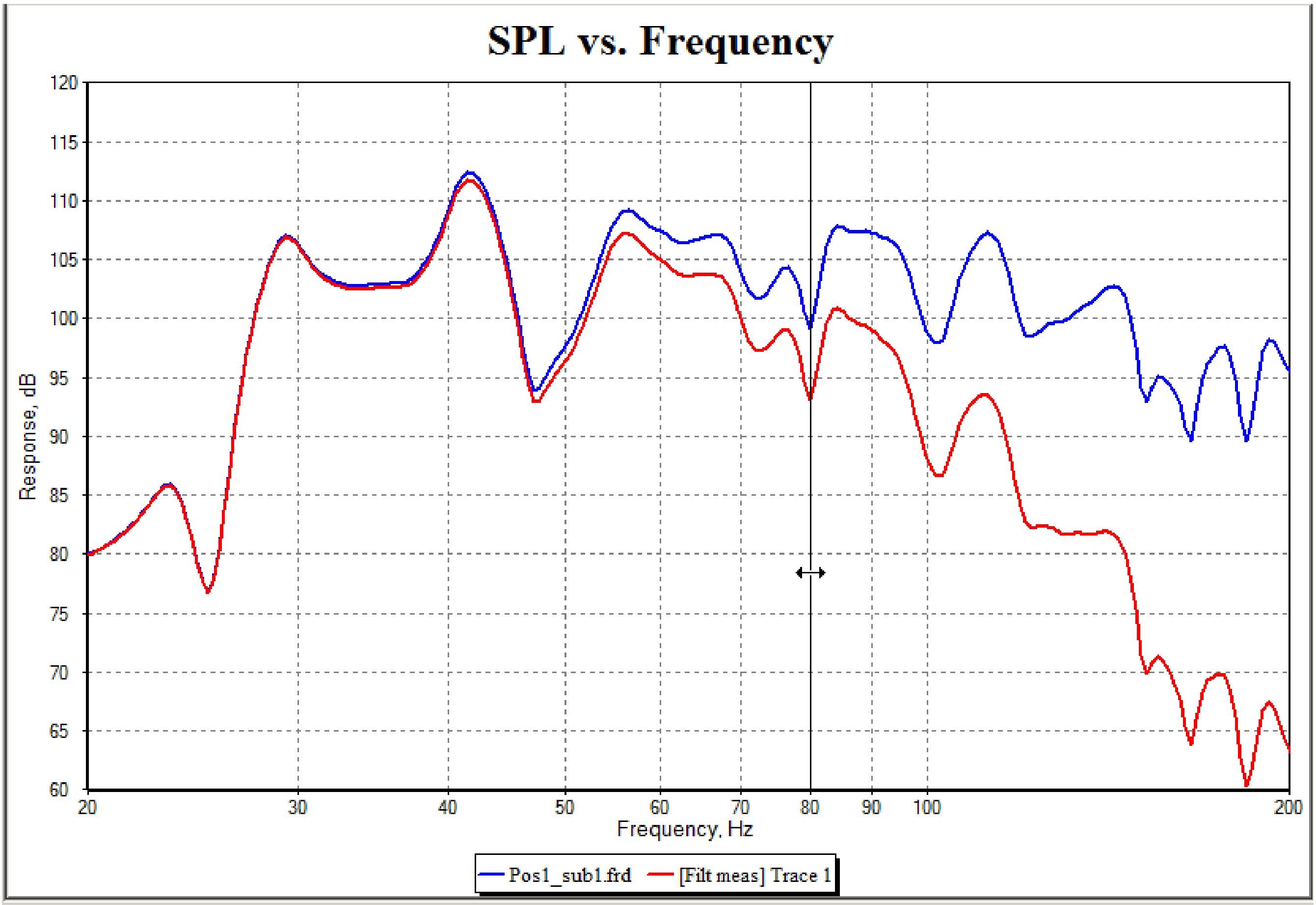


Figure 17. Plotting a filtered measurement

Check the checkbox for the measurement named **Pos1_sub1.frd** as shown above. Press **Apply**. This shows two traces, the unfiltered and filtered **Pos1_sub1.frd** measurement of Sub 1 at the main listening position (position 1). The dialog shows that **Sub Channel 1** performs the filtering. Choose **Format**, **General**, and on the resulting property page, check the **Show legend** checkbox. Choose **Axes** under **Format**, disable autoscale for the left y axis, and set its lower and upper limits to **60** and **120** respectively. Click **OK**. The filtered measurement shows the effect of the 24 dB/oct Linkwitz-Riley low-pass filter in **Sub Channel 1** on the **Pos1_sub1.frd** measurement. The default cutoff frequency of newly-created low-pass filters is 80 Hz, so activating the data cursor and setting it as close as possible to 80 Hz should show a 6 dB difference between the filtered and unfiltered **Pos1_sub1.frd** measurement as shown below.



Output

Graph Data	Value
Frequency	79.9 Hz
Pos1_sub1.frd	99.3 dB
[Filt meas] Trace 1	93.3 dB

Figure 18. A plot of filtered and unfiltered measurements

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Multi-Sub Optimizer Tutorial

Measurement Groups

So far, you've seen how to plot measurements, filter channel frequency responses and filtered measurements. But one piece of the puzzle is still missing: how do you plot the combined output of multiple subs and main speakers at a given listening position? This is done using *measurement groups*. A measurement group is a collection of filtered measurements that are added together (properly taking phase into account) to form a single combined response. To plot the combined outputs of **Sub 1**, **Sub 2**, **Sub 3**, **Sub 4** and main speakers at each of the four listening positions, you'll need to define four measurement groups, one for each listening position. Measurement groups are also used by the automatic optimizer. If you define these four measurement groups, the optimizer will adjust the filter parameters to simultaneously make the frequency response of each group as flat as possible.

To define a measurement group, activate the **Config View** tab at the lower left of the main window. Scroll down to the bottom, where you'll see a folder icon named **Measurement Groups**. Right-click on this icon and choose **Add Measurement Group** from the context menu. For the first group, you'll choose all the measurements from position 1 as shown below.

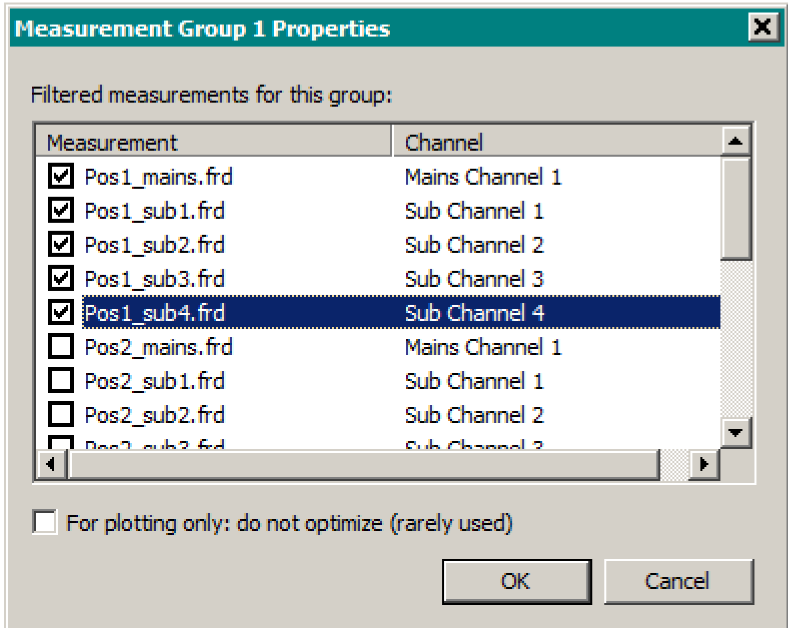

Figure 19. Defining a measurement group

Click **OK**. In the **Config View**, a new icon is created under **Measurement Groups** called **Measurement Group 1**. This name isn't very descriptive, but you can easily change it. Select **Measurement Group 1** and press **F2**. This allows editing the name in place. Since position 1 is the main listening position, call it **MLP** as shown below.

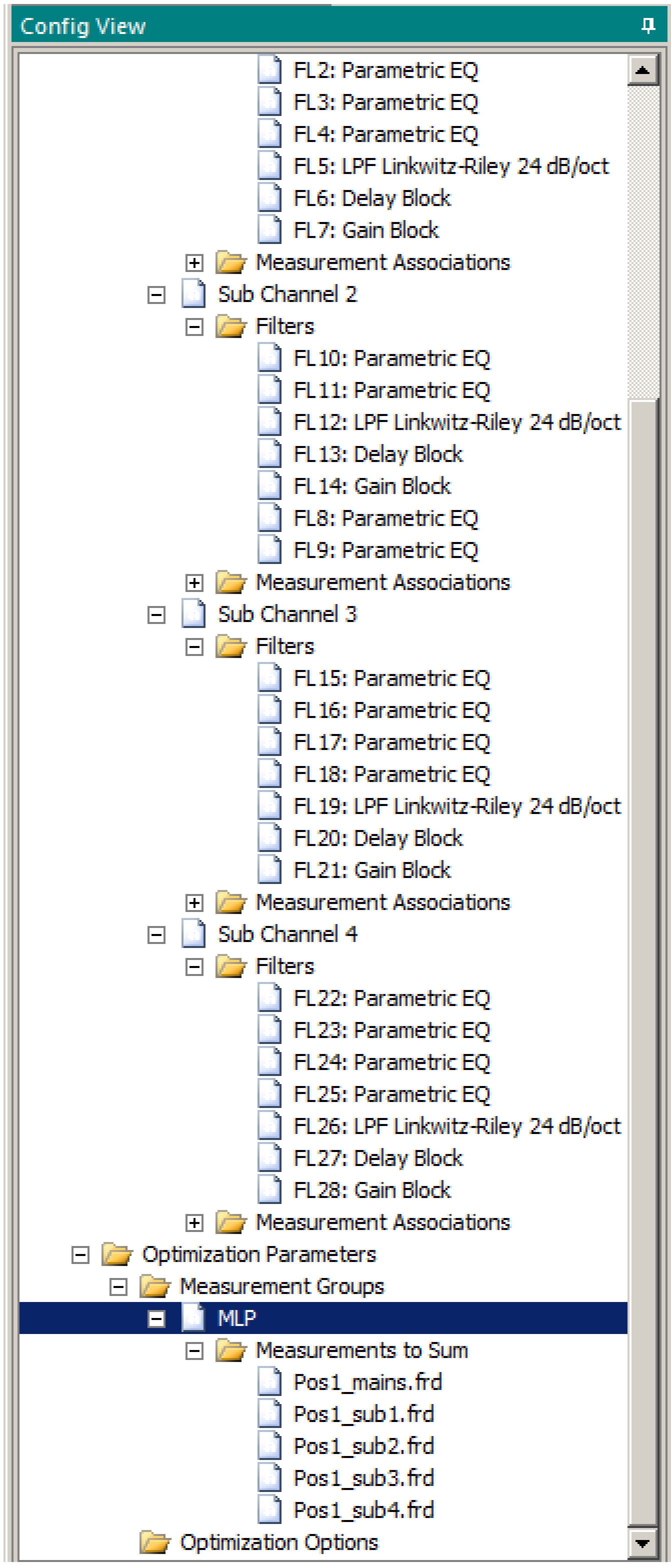

Figure 20. First measurement group defined

Create three more measurement groups, choosing all measurements in position 2 for the first, position 3 for the second and position 4 for the third. Rename these groups **Pos 2**, **Pos 3** and **Pos 4** respectively. The result should look as below.

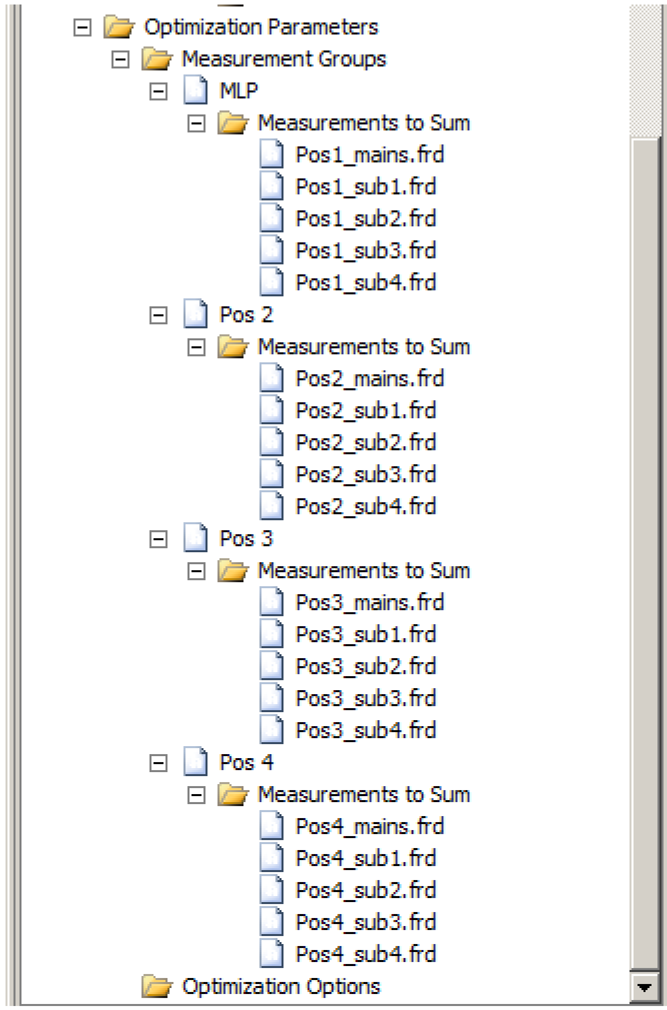

Figure 21. All measurement groups defined

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Multi-Sub Optimizer Tutorial

A Fourth Look at Graphs

Now that all the measurement groups are defined, you can plot them on a graph. Select the **Data View** tab at the lower left of the main window. You created several graphs earlier in the tutorial, but these were only for demonstration purposes, so they can be deleted. To delete a graph, select its icon (named e.g. **Graph 1**, **Graph 2** etc.) in the Data View and press the **Delete** key. Repeat this action for all existing graphs unless you're sure you want to keep them.

Create a new graph, and under **Data** in the **Graph Properties** dialog, select **Measurement Groups**. The four measurement groups you created are shown in the dialog as below.

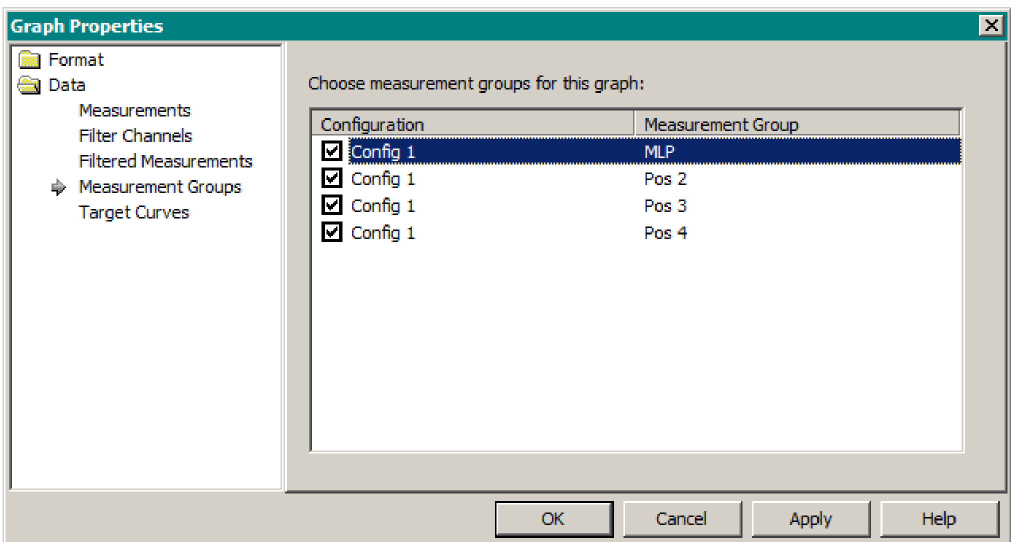

Figure 22. Plotting measurement groups

Check the checkboxes of all four of them and click **Apply**. Under **Format**, select **General**. Change the graph title from **SPL vs. Frequency** to **Combined Response SPL vs. Frequency**. Check the **Show legend** checkbox. Under **Format**, select **Axes** and disable autoscaling for the left y axis. Set the lower limit of the left y axis to **50** and its upper limit to **125**. Click OK.

You'll notice the trace names are automatically generated, but these names aren't descriptive of their actual meaning. In the **Data View**, you can expand the tree nodes of each trace to see its constituent parts. Both the names of graphs and their traces can be changed. When you change a trace name, the new name will show up in the graph's legend. When you change a graph name, the new name will show up in the tab of the graph window. Before renaming, the trace display in the Data View looks as below.

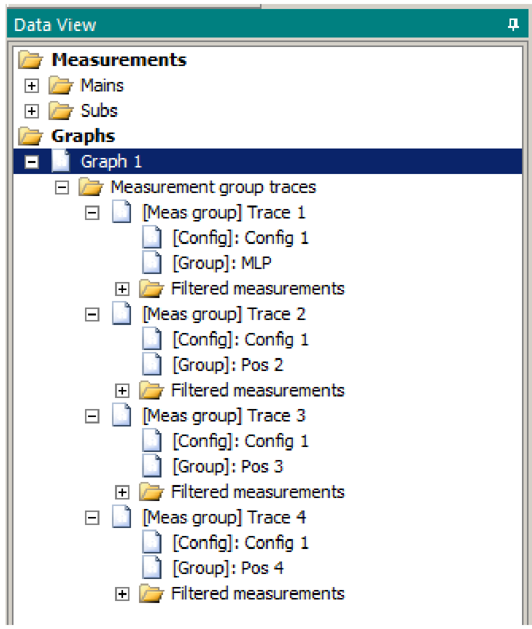

Figure 23. Graph and trace names before renaming

You rename graphs and their traces by selecting their associated node in the tree, pressing **F2**, and entering new text into the edit control that appears. Rename the graph from **Graph 1** to **Combined Responses**. Rename each trace to the name of the measurement group that it displays (that is, **[Meas group] Trace 1** will be renamed to **MLP** and so on for the other traces). When this is done, the **Data View** will look as below.

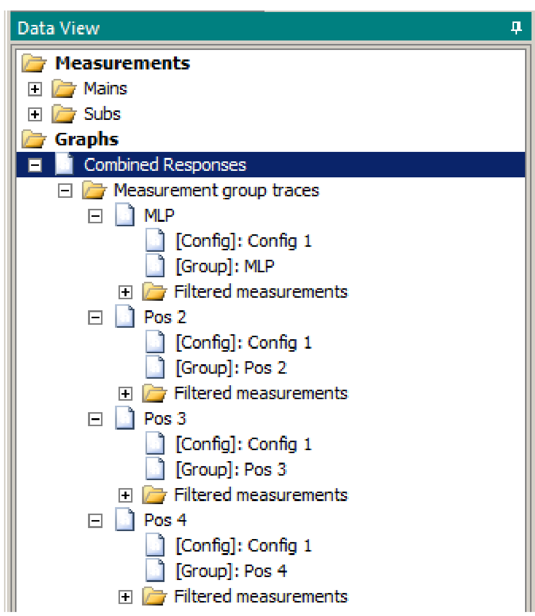

Figure 24. Graph and trace names after renaming

The graph legend now shows the new trace names, which are more descriptive of what's being plotted. The tab at the top of the graph window now reads **Combined Responses** and the legend entries now match the trace names.

Another problem is that the traces are all on top of one another. It would be better to separate them to make them easier to see. To do this, you'll add display offsets to three of the four traces. Right-click the graph and choose **Trace Properties**. This opens up the Trace Properties dialog as shown below.

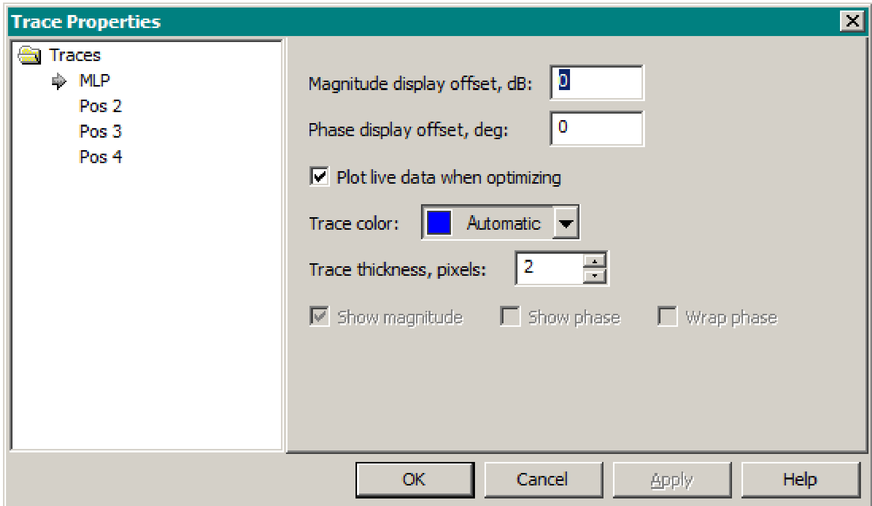

Figure 25. Trace properties dialog

The new trace names you chose also show up here. The edit control labeled **Magnitude display offset, dB** is used to enter the desired offset. For **MLP**, leave the display offset at **0**. Set the **Pos 2**, **Pos 3** and **Pos 4** offsets to **-15**, **-30** and **-45** dB respectively and click **Apply**. Before closing this dialog box, notice the **Plot live data when optimizing** option. When this option is checked and an optimization is running, the trace will be animated, updating continuously with the best solution currently found. It is strongly suggested to leave this option in the default checked state.

After making these changes, the Combined Responses graph should look as below.

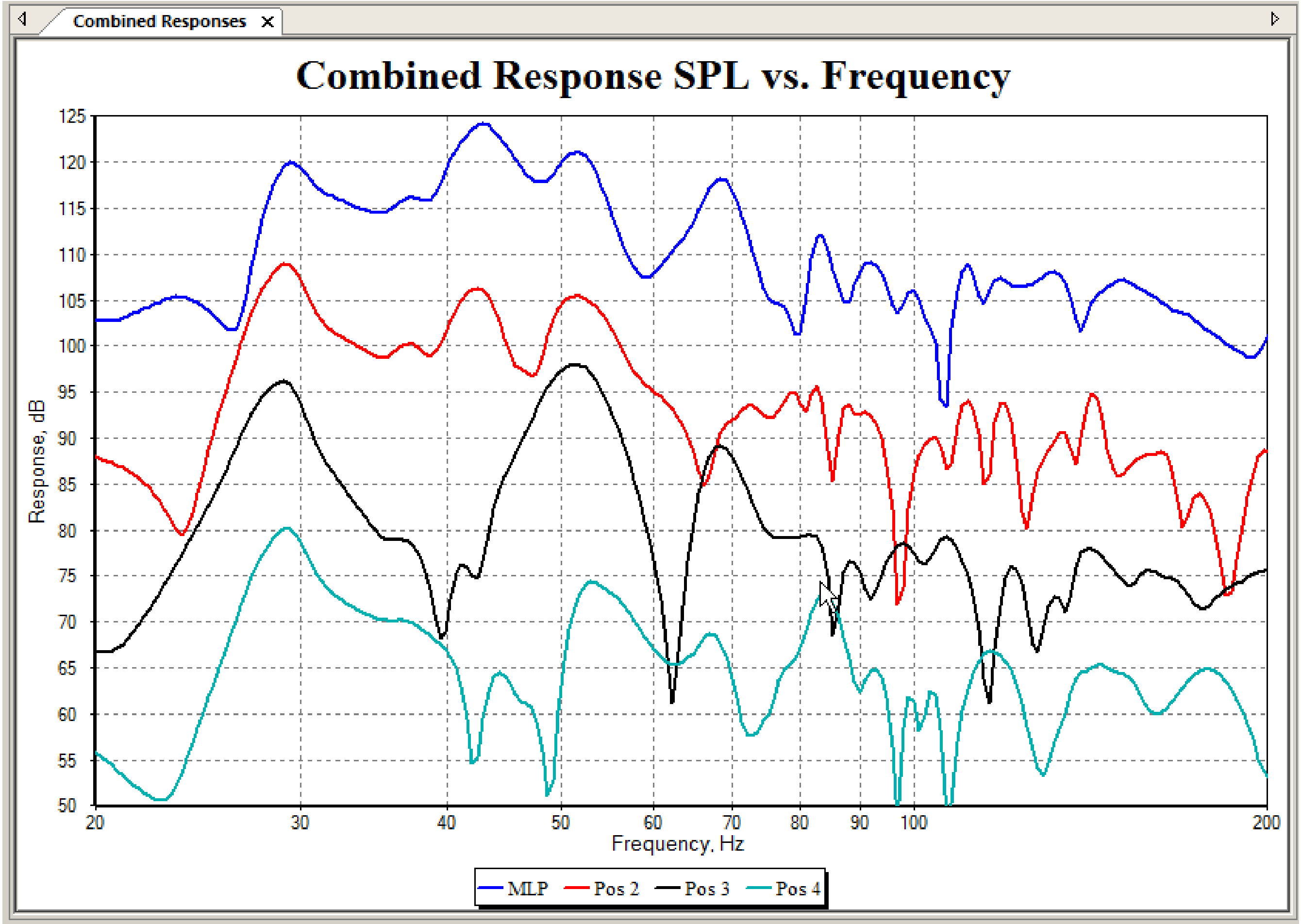

Figure 26. Combined responses after entry of display offsets

Many problems exist in the data of Figure 26, especially in position 3, which has a big peak at about 51 Hz, followed by a suckout at about 62 Hz. Simply applying EQ to make the response flat at the main listening position would still leave many problems at the other positions. This is the kind of problem that MSO's optimization was designed to solve.

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Multi-Sub Optimizer Tutorial

Setting Up the Optimization

Before running an optimization, some setup is required. You must consider the upper and lower limits of filter parameter values and set the optimization options.

Filter Parameter Limits

For this tutorial, you'll use the default parameter limits for all filters. For other applications, some experimentation may be needed.

Optimization Options

You set the optimization options by choosing **Tools, Optimization Options** from the main menu. A folder representing the configuration name is shown on the left of the **Optimization Options** dialog, with **Criteria** selected. Set the options as shown below.

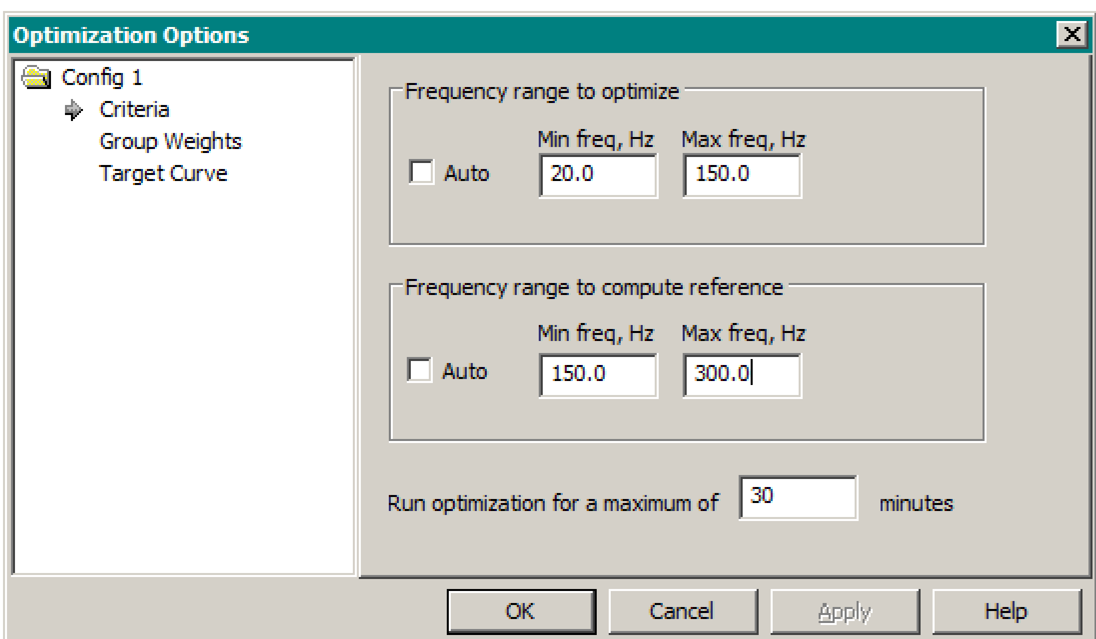

Figure 27. Optimization Options Criteria page

MSO only optimizes the flatness of the combined sub and main speaker responses over the frequency range specified in **Frequency range to optimize**. Uncheck the **Auto** checkbox and enter **20** and **150** for the minimum and maximum frequencies respectively. **Frequency range to compute reference** needs some explanation. MSO optimizes response flatness by minimizing the sum of the squares of the differences in dB between the response value at each frequency and a reference value. For each listening position, the reference value is computed by taking the average over frequency of its frequency response values in dB over the **Frequency range to compute reference** above. This reference frequency range should be at the high end of the frequency band, where the response is nominally constant with frequency and not affected much by the filters being used. Using a reference frequency range of 150-300 Hz is a good rule of thumb. You could think of the optimization as "lining up" the response at each listening position from 20 Hz to 150 Hz with its corresponding average response from 150 Hz to 300 Hz while also trying to make the response from 20 Hz to 150 Hz as flat as possible.

Set **Run optimization for a maximum of...** to 30 minutes. This seems like a long time, but the optimizer has a lot of work to do, and the problem solved by MSO has no closed-form mathematical solution. Each sub channel has fifteen adjustable parameters (four PEQs with three parameters each, one delay, one gain and one LPF). Considering all four channels, that's a total of sixty adjustable parameters. When running an optimization, the status is shown and you can stop it at any time. The running status and the appearance of the graph gives an idea about the best solution the optimizer has found thus far, and you can stop early if need be. When the optimization stops, either automatically or manually, you are prompted for whether you want to keep or discard the modifications made.

Next, select **Group Weights** in the left-hand portion of the Optimization Options dialog. Weighting allows you to "score" errors higher for, say, the MLP than the other listening positions. On the Group Weights property page, set the weights for positions 2, 3 and 4 to 0.75 as shown below.

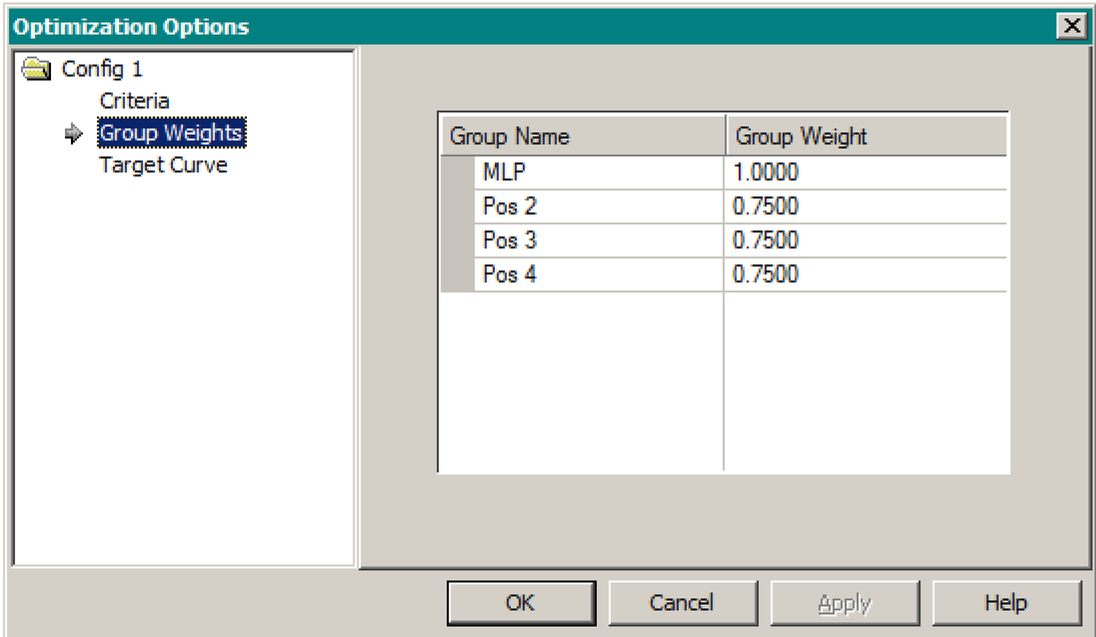

Figure 28. Assigning error weights to different listening positions

For this weighting, an error of (1 / 0.75) dB = 1.33 dB in positions 2, 3 and 4 counts the same toward the total error as a 1 dB error at the MLP. This will tend to make the frequency response at the MLP slightly flatter than the other positions.

For now, you won't use the **Target Curve** option, so the project is ready for optimization.

Multi-Sub Optimizer Tutorial

Running the Optimization

Before running the optimization, save the project using **Ctrl+S**. Then using **File**, **Save As**, save it again under the new name **tutorial_2.msop**. By performing the optimization on **tutorial_2.msop** and keeping **tutorial_1.msop** in its non-optimized state, you'll be able to do a “before and after” comparison between the two. Later in the tutorial, you'll see a better way to do such comparisons. Also, make sure the **Combined Responses** graph is currently displayed. If it is not, select the **Data View** tab, right-click on the **Combined Responses** graph icon and choose **Show Graph**.

To run the optimization, press the **Start Optimization** button on the toolbar or choose **Config**, **Optimize** from the main menu. As the optimization runs, you'll see the **Combined Responses** graph continuously update with the newest solution found. It may appear to get stuck on a solution that isn't as good as what you'd like, but often giving it 20 minutes or so to explore the space of possible solutions can show surprising improvements in the result, even late into the process. Your results may vary because of MSO's use of a random number generator within the optimizer, but you should expect to see something like the results shown below, given that you've run the optimizer long enough.

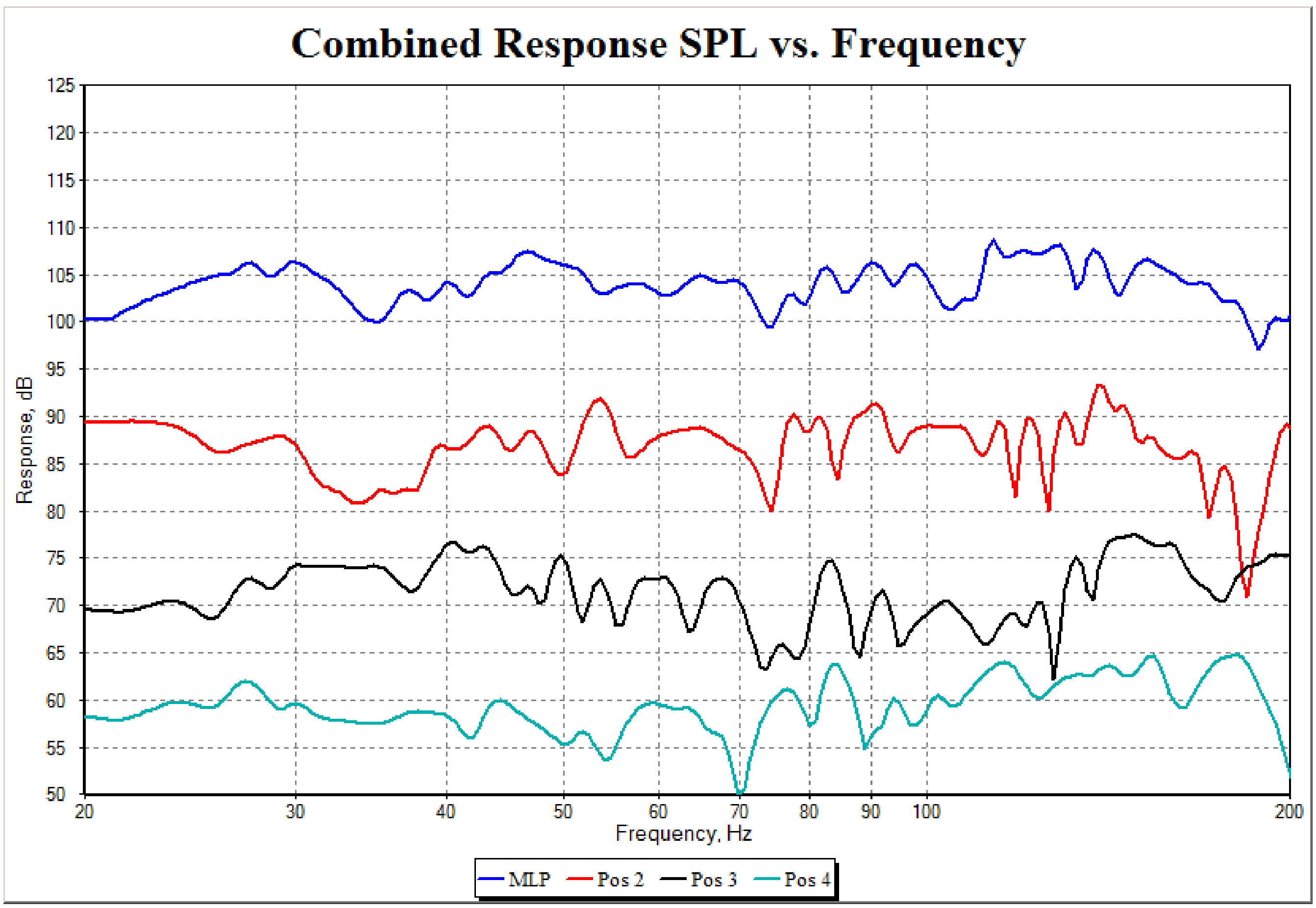

Figure 29. Combined responses after optimization

Compare this with the combined responses before optimization, repeated for clarity below.

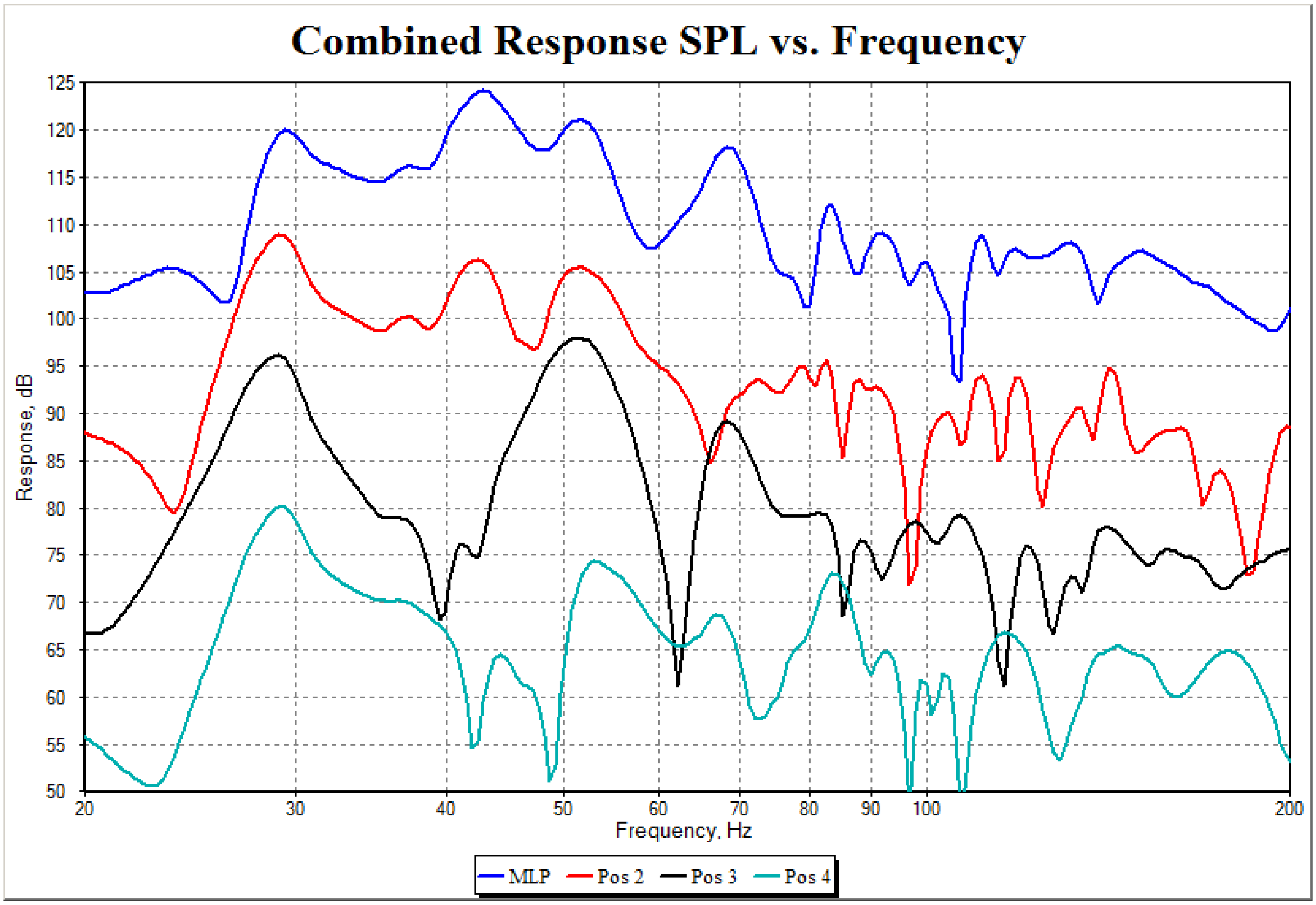

Figure 30. Combined responses before optimization

Running the optimization has provided a substantial improvement, both to flatness and seat-to-seat consistency of responses.

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Multi-Sub Optimizer Tutorial

Getting Information About the DSP Filters

To find out what the filter responses look like, you'll create a graph to plot them. Since your results may be different from the results above, open the **tutorial_2_prefab.msop** in the **Sample Projects** sub-folder of the tutorial to ensure your results match the tutorial. Then, use **File**, **Save As** to save it as **tutorial_2.msop**, overwriting the **tutorial_2.msop** you created earlier.

Create a new graph, then in **Data**, **Filter Channels** in the **Graph Properties** dialog, check the checkboxes for all four subwoofer channels (but not the mains channel, which has no filters). Press **Apply**. In **Format**, **General**, change the graph title to **Filter Responses vs. Frequency**. Check the **Show legend** checkbox. In **Format**, **Axes**, disable autoscale for the left y axis and set its lower and upper limits to **-65** and **5** respectively. Press **Apply** to make sure the axis values are correct, then press **OK** to close the dialog. Rename the graph from **Graph 2** to **Filter Responses**. Rename the **[Filt chan] Trace 1**, **[Filt chan] Trace 2**, **[Filt chan] Trace 3**, and [**Filt chan] Trace 4** traces to **Sub Chan 1**, **Sub Chan 2**, **Sub Chan 3**, and **Sub Chan 4** respectively. The new graph should look as below.

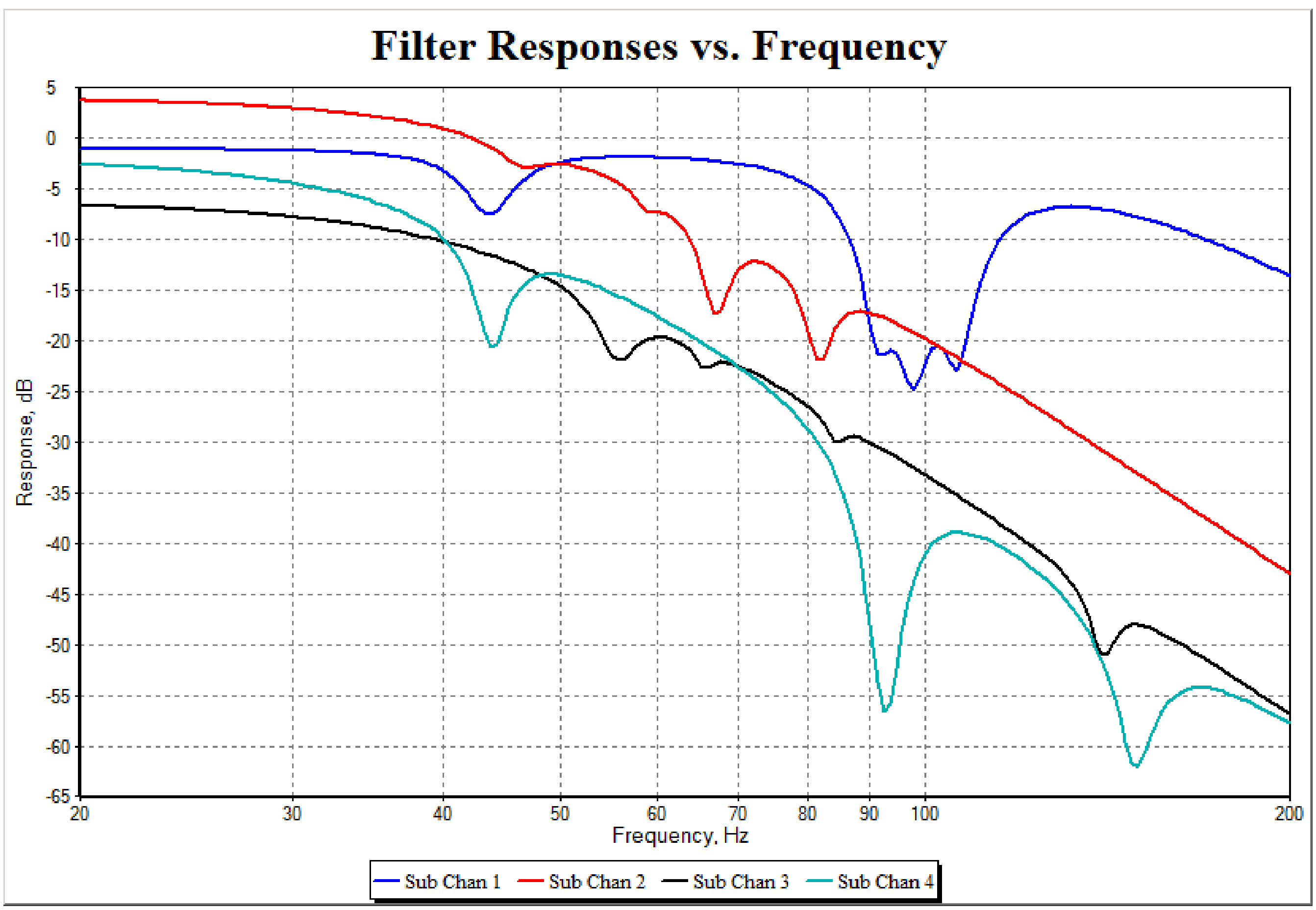

Figure 31. Filter channel responses after optimization

Filter Reports

You could determine the filter parameter values by selecting each one and looking in the **Properties** window, but using the filter report feature is easier and quicker. To see the filter report, activate the **Config View** and right-click on the **Config 1** icon just underneath the topmost **Configurations** icon. Select **Show Filter Report** from the context window. This will open up a tabbed text window with the information you'll need to enter into the software of your DSP. If there are many filters, such as in this project, this could get tedious.

Biquad Information

Some DSP vendors, such as miniDSP, support a special text format which allows you to copy and paste all the parameter values for an entire filter channel into the software to configure all the filters in that channel at once. MSO supports the miniDSP format, but you'll need to enable it in the application options. Select **Tools**, **Application Options** from the main menu. On the left side of the **Application Options** dialog, select **Hardware** and **Filter Reports**. Check the checkbox labeled **Include biquad information in filter reports**. This activates the **Sample rate** selection radio buttons. Be sure to choose the sample rate used by the actual hardware. For the purposes of the tutorial, choose 48 kHz. In the Config 1 filters text view containing the filter report, right-click and choose Refresh from the context menu. This will cause the filter report to be updated with the biquad information. Pressing Page Down a few times will take you to the part of the filter report containing the information about the biquads and other related information. The portion for Sub Channel 1 should look as below.

```
Sub Channel 1:
FL1: Parametric EQ (biquad1)
FL2: Parametric EQ (biquad2)
FL3: Parametric EQ (biquad3)
FL4: Parametric EQ (biquad4)
FL5: LPF Linkwitz-Riley 24 dB/oct (biquad5, biquad6)
biquad1,
b0=0.999289245870467,
b1=-1.997957246800862,
b2=0.998811046390038,
a1=1.997957246800862,
a2=-0.998100292260505,
biquad2,
b0=0.998818991406365,
b1=-1.996962910604257,
b2=0.998307607188862,
a1=1.996962910604257,
a2=-0.997126598595227,
biquad3,
b0=0.998746233369988,
b1=-1.996741429491683,
b2=0.998189334211126,
a1=1.996741429491683,
a2=-0.996935567581113,
biquad4,
```

```
b0=0.999748065657730,
b1=-1.998989646925358,
b2=0.999274155844187,
a1=1.998989646925358,
a2=-0.999022221501918,
biquad5,
b0=0.000095059903807,
b1=0.000190119807613,
b2=0.000095059903807,
a1=1.972233747669657,
a2=-0.972613987284884,
biquad6,
b0=0.000095059903807,
b1=0.000190119807613,
b2=0.000095059903807,
a1=1.972233747669657,
a2=-0.972613987284884
```

You can highlight the text of a channel (biquad1-biquad6) and press **Ctrl+C** to copy it to the clipboard. You can then paste it into the miniDSP software to configure the appropriate channel. See the miniDSP documentation for more information.

Multi-Sub Optimizer Tutorial

Additional Topics

Earlier in the tutorial, in order to compare the results before and after optimization, you saved the project as **tutorial_1.msop** before optimizing, and obtained the graph of Figure 30. After optimization, you saved the project as **tutorial_2.msop** and obtained the graph of Figure 29. This kind of comparison can be done within a single project using the **Configurations** feature.

Configurations

The **Configurations** feature allows for optimizing using different types of filters, different filter parameters and so on. Save the current project and open up the **tutorial_1.msop**. Save it as **tutorial_3.msop** so you can still go back to the original if you make a mistake. Select the name of the configuration, **Config 1**, and press **F2**. Rename the configuration to **Original**. Right-click on **Original** and choose **Clone Configuration**. This will create an exact copy of the configuration named **Config 2**. Rename **Config 2** to **Optimized**. After collapsing the tree structure of both **Original** and **Optimized**, the result should look as below.

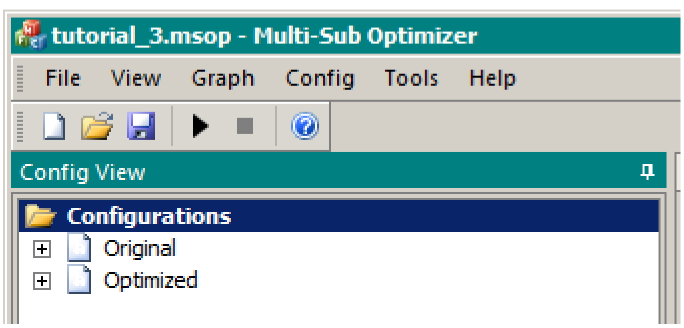

Figure 32. Cloning a configuration

The **Original** configuration should be kept as-is to enable performance comparison before and after optimization. To protect it, you can lock all the parameters of all the filters in the configuration. Select the topmost node of the **Original** configuration as shown above in Figure 32. Right-click and choose **Lock All Filter Parameters of this Configuration** from the context menu. This will set the **Optimization allowed** property of all parameters of all filters in **Original** to **False**. Verify that this is the case by expanding the **Original** node. The icons for all the filters in the **Original** configuration will now be a dark gray color, indicating that the optimizer will not adjust any of their parameters.

Press the **Start optimization** button on the toolbar. A dialog box pops up, asking you to specify which configuration you want to optimize. This dialog only pops up when there is more than one configuration present. Select **Original** and click **OK**. You should get the message **The configuration named "Original" has no optimizable parameters**. Since this project originated with the **tutorial_1.msop** that was saved prior to running the optimization, you'll need to run the optimization again to optimize the filter parameters for the **Optimized** configuration. However, since you just created the **Optimized** configuration by cloning the **Original** configuration, there are not yet any graphs associated with the new **Optimized** configuration. You'll do that next.

Activate the **Data View** by clicking on the **Data View** tab at the lower left of the main window. Rename the **Combined Responses** graph by clicking on the **Combined Responses** text under **Graphs** and pressing **F2**. Rename it to **Combined Responses (Original)**. Right-click on **Graphs** and choose **New Graph…** to create a new graph. Under **Data** in the **Graph Properties** dialog, select **Measurement Groups**. On the right side of this dialog, check the checkboxes of the four measurement groups associated with the configuration named **Optimized**. The **Graph Properties** dialog should appear as below.

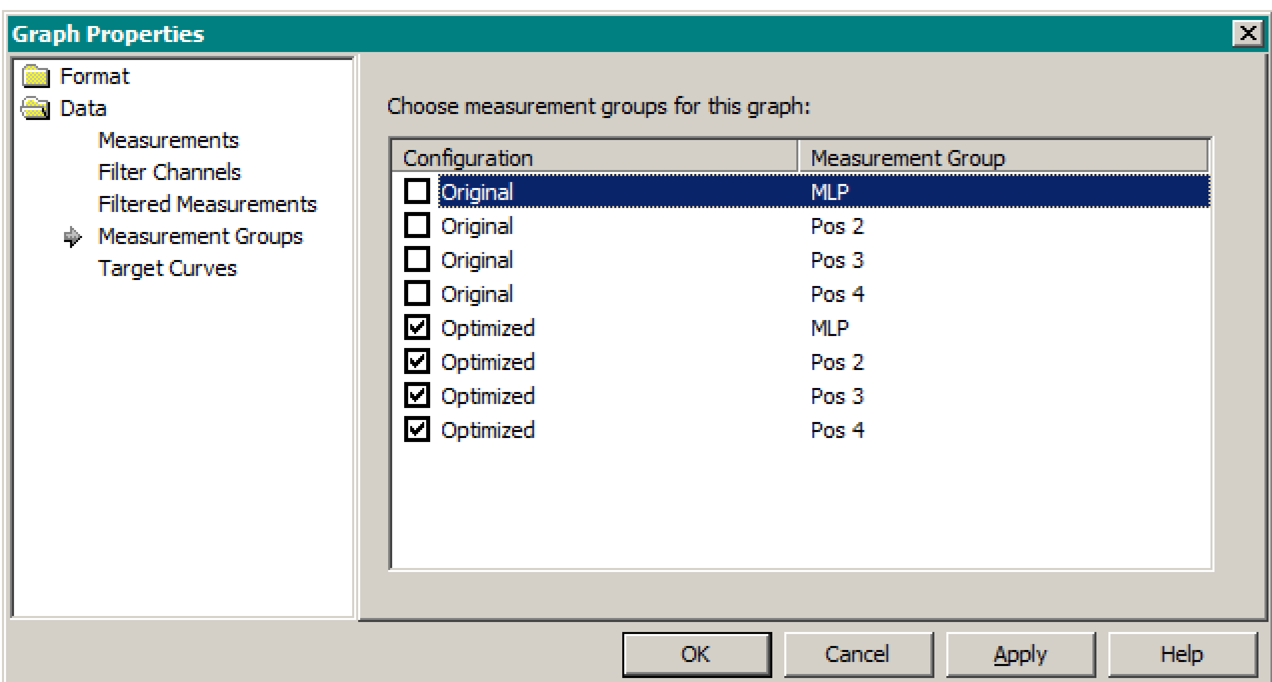

Figure 33. Choosing data to plot for the new configuration

Under **Format**, choose **General**. Change the graph title to **Optimized Combined Response SPL vs. Frequency** and check the **Show legend** checkbox. Under **Format**, choose **Axes**. Uncheck the **Autoscale** checkbox for the left y axis and set the **min value** and **max value** to **50** and **125** respectively. Click **OK**. In the **Data View**, rename the newly-created **Graph 2** to **Combined Responses (Optimized)**.

The graph names now properly reflect their content, but you should still rename the graph traces. Before doing that, expand the nodes in the tree that contain the trace names so they look as below.

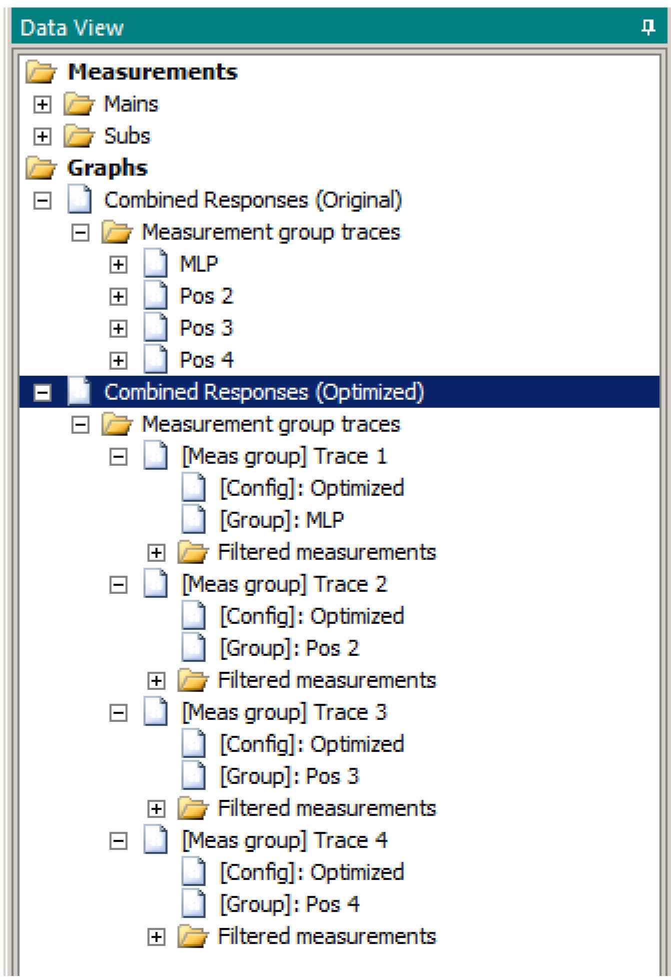

Figure 34. Trace names before renaming

For consistency with the previous graph, name each trace the same as its group name. This means **[Meas group] Trace 1**, **[Meas group] Trace 2**, **[Meas group] Trace 3** and **[Meas group] Trace 4** get renamed to **MLP**, **Pos 2**, **Pos 3** and **Pos 4** respectively.

After renaming, the **Data View** should look as below.

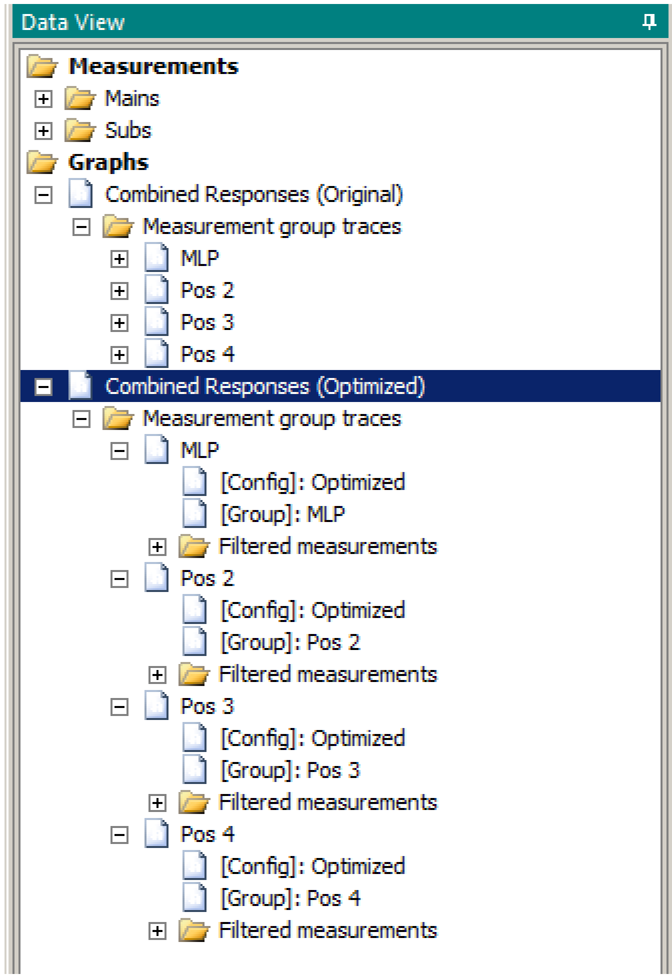

Figure 35. Trace names after renaming

You'll also notice that the trace names in the graph's legend have changed, and match up with what you entered in the **Data View**.

You'll need to add display offsets to the traces to make them more easily distinguishable. Right click on the graph and choose **Trace Properties…** from the context menu. Set the **Magnitude display offset, dB** of the **MLP**, **Pos 2**, **Pos 3** and **Pos 4** traces to **0**, **-15**, **-30** and **-45** respectively. Click **OK**. The graphs named **Combined Responses (Original)** and **Combined Responses (Optimized)** should now look the same. To avoid confusion, close the **Combined Responses (Original)** graph window if it is open, so that only the **Combined Responses (Optimized)** graph is shown.

Now is a good time to save your work, so press **Ctrl+S** to save or choose **File**, **Save** from the main menu to save the project.

Press the **Start optimization** button on the toolbar again, but this time choose **Optimized** as the configuration. In the dialog, you can either click **OK** or double-click the configuration name to start the optimization. This is a complex optimization, so let it run for the full 30 minutes to ensure the best results.

Since the optimizer uses a random number generator in its optimization algorithm, the results vary somewhat from one equally long optimization run to another. Because of this, , open the **tutorial_3_prefab.msop** in the **Sample Projects** sub-folder of the tutorial to ensure your results match the tutorial. Then, use **File**, **Save As** to save it as **tutorial_3.msop**, overwriting the **tutorial_3.msop** you created earlier.

As an exercise on your own, try out what you learned earlier in **Getting Information About the DSP Filters** to create a graph named **Optimized Filter Responses** showing the frequency responses of the **Sub 1**, **Sub 2**, **Sub 3** and **Sub 4** channels of the **Optimized** configuration. Choose manual scaling for the y axis and name the traces **Sub 1**, **Sub 2**, **Sub 3** and **Sub 4**. You can also try the step of doing a filter report for the **Optimized** configuration. That exercise has been worked out and can be found in the **tutorial_4_prefab.msop** in the **Sample Projects** sub-folder of the tutorial.

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Multi-Sub Optimizer Tutorial

Supplying Information About Your AVR

MSO allows you to enter information about your AVR or preamp/processor, which enables MSO to incorporate the AVR's distance and gain adjustment capability into the overall calculation of gain and delay parameters. For instance, if the optimum delay of some sub channel is negative, this is unrealizable in DSP circuitry, but can easily be accommodated in the AVR by increasing its distance setting relative to the as-measured condition and adjusting the other sub delays accordingly.

To enter your AVR information, choose **Tools**, **Application Options** from the main menu, then select **Hardware** in the **Application Options** dialog. Check the **System uses AVR or pre/pro with sub out** checkbox. The dialog will appear as below.

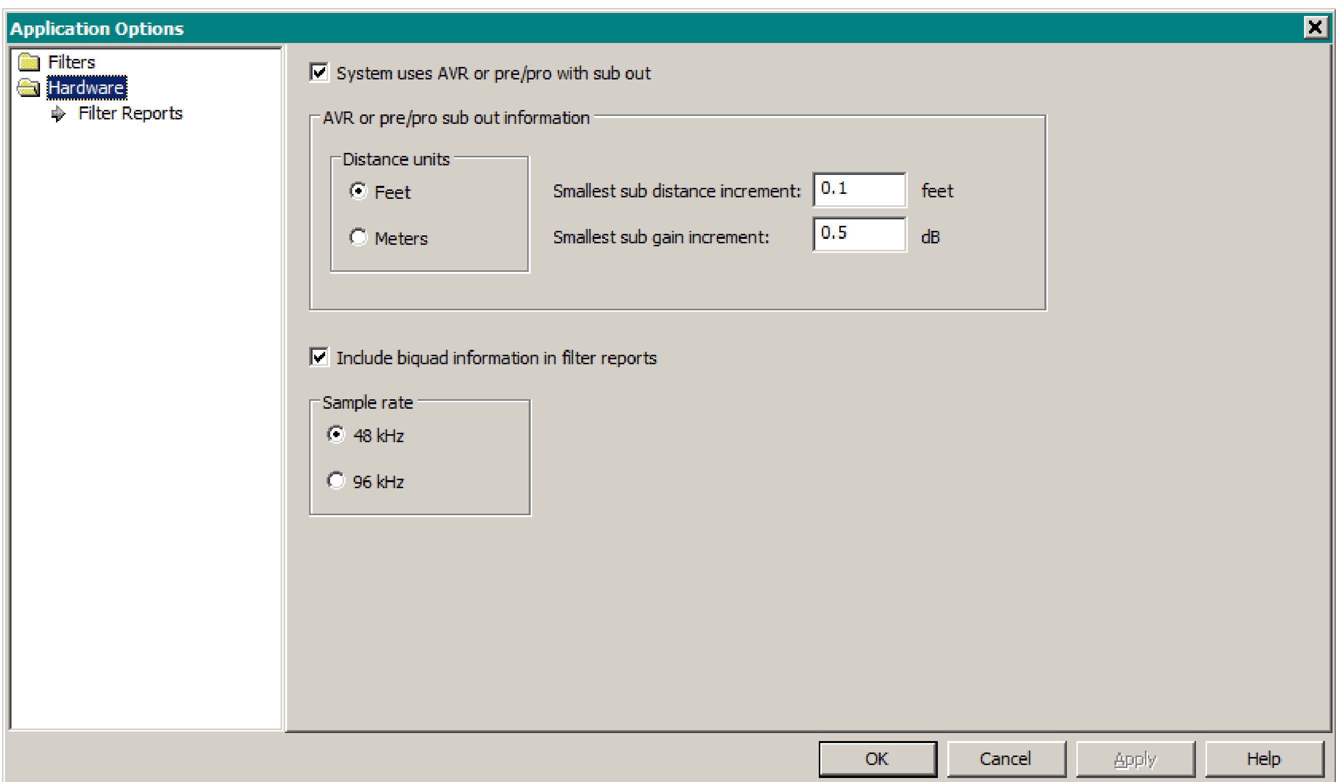

Figure 36. Configuring the AVR settings

Enter the appropriate distance units and increment, along with the sub out gain step in dB (usually 0.5 dB). The actual distance settings of the AVR usually depend on both its make and model as well as its setup options. For this reason, it makes sense to double-check the AVR's setup before entering the data here.

Getting Additional AVR Settings From the Filter Report

Entering AVR information into the Application Options enables an additional feature in the filter reports. To see this, open up **tutorial_4_prefab.msop** and save it as **tutorial_4.msop**. Select the top-most node of the **Optimized** configuration and choose **Show Filter Report**. Scrolling down to the bottom of the report reveals additional information as follows.

```
Final gain and delay/distance settings:
Increase AVR sub out trim gain by 1.5 dB
Sub Channel 1 gain: -5.6301 dB
Sub Channel 2 gain: -0.0673176 dB
Sub Channel 3 gain: -14.0948 dB
Sub Channel 4 gain: -4.23466 dB
Decrease AVR sub out distance by 3 feet
Sub Channel 1 delay: 12.346 msec
Sub Channel 2 delay: 4.53837 msec
Sub Channel 3 delay: 4.46217 msec
Sub Channel 4 delay: 0.0462191 msec
```

MSO configures the gain of each DSP channel to be 0.0 dB or less, to prevent the possibility of internal digital overload. In addition, the imprecision of the 0.5 dB gain step of the AVR is made up for by adjusting the individual channel gains, which are assumed to have a finer gain step size than that of the AVR. A similar situation holds for the delay. If negative delays are present in the delay blocks, they will be absorbed into the AVR setting by means of an increase in the sub distance. In this case, no negative delays are present, so the sub distance undergoes a net decrease.

Multi-Sub Optimizer Tutorial

Improving Response Flatness at the Main Listening Position

The corrected responses of Figure 29 show improved frequency response flatness for all listening positions compared to the uncorrected responses of Figure 30. Yet the response at the main listening position may not be as flat as you would like it to be. Since one side effect of adjusting the individual channel EQs is to reduce the seat-to-seat variation in frequency response, altering these individual EQ settings is not a good way to flatten the response at the main listening position any further. Instead, a better idea is to keep the existing individual channel EQs and add shared filters that affect the responses of all subs simultaneously so that the seat-to-seat variation of the frequency response is not affected. Keep in mind that in doing so, the flatness of the frequency response at positions other than the main listening position may be degraded relative to Figure 29, as was mentioned earlier in the tutorial when discussing the pitfalls of shared EQ. However, should you choose to use this technique, MSO gives you the needed tools.

To perform this task, you'll clone the **Optimized** configuration of **tutorial_4.msop**. Open up **tutorial_4.msop** and in the **Config View**, select the root node of the **Optimized** configuration (the node labeled “Optimized” just underneath **Configurations**. Right-click and choose **Clone Configuration** from the context menu. This will create a new configuration called **Config 3**. Rename it to **MLP Cleanup**. Right-click on **MLP Cleanup** and choose **Lock All Filter Parameters of this Configuration**. This will prevent the optimizer from changing the individual subwoofer EQ settings. You'll see that the icons for all the filters in this channel are dark gray in color. You'll want to add some shared sub filters and run a new optimization on **MLP Cleanup** so that only the parameters of these shared filters are adjusted.

Using Plot-Only Measurement Groups

Before adding shared sub filters, the optimization parameters must be changed so that only the **MLP** response is optimized for flatness, and not any of the other listening positions. One way to do this would be to remove all the measurement groups except **MLP**. However, this would have the undesired side effect of disallowing the ability to graph the frequency responses of the other three listening positions, at least while the optimization is being run. To solve this problem, you can instead make all the measurement groups not associated with the **MLP** into plot-only measurement groups. Such measurement groups can be plotted, but are not used as optimization criteria.

Locate the measurement groups of the **MLP Cleanup** configuration. Select the **Pos 2** measurement group, right-click on it and choose **Properties** from the context menu. In the resulting dialog box, check the checkbox labeled **For plotting only: do not optimize**. Click **OK**. The icon for the **Pos 2** measurement group will turn gray, indicating it is a plot-only group. Repeat the process for the **Pos 3** and **Pos 4** measurement groups. The measurement groups for **MLP Cleanup** should look as below.

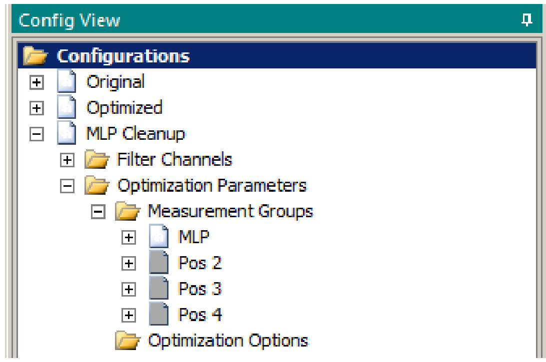

Figure 37. After making non-MLP measurement groups plot-only

Using the Rearrange Gains and Rearrange Delays Features

In the next section, you'll be adding some PEQ filters to the **Shared Filters** of the **Subwoofer Channels**. These filters will only affect the subs, not the main speakers. In addition to altering the frequency response magnitude of the combined sub outputs, they will also change the phase of this frequency response. Since the main speakers aren't affected by this change, it follows that the shared PEQs will change the relative phase between mains and subs from the previously-optimized condition. To fix this, you'll need a shared delay. Likewise, the PEQs you'll use will be limited to response cuts, not boost. It's reasonable to expect that because of these response cuts, a shared gain boost will be needed for the subs to get the best flatness of the combined response of subs and main speakers. Taking delay as an example, you can see that the configuration of delays in the four sub channels of the **MLP Cleanup** configuration looks conceptually as below.

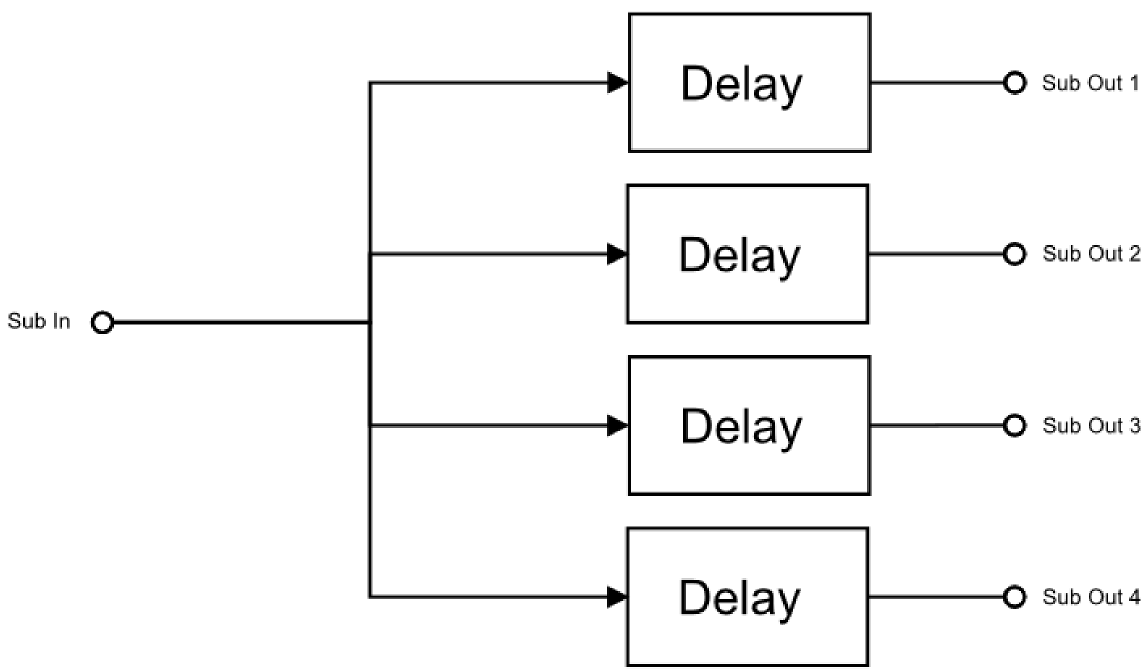

Figure 38. Delay configuration before rearrange

We'd like to add a shared delay, making the new configuration as below.

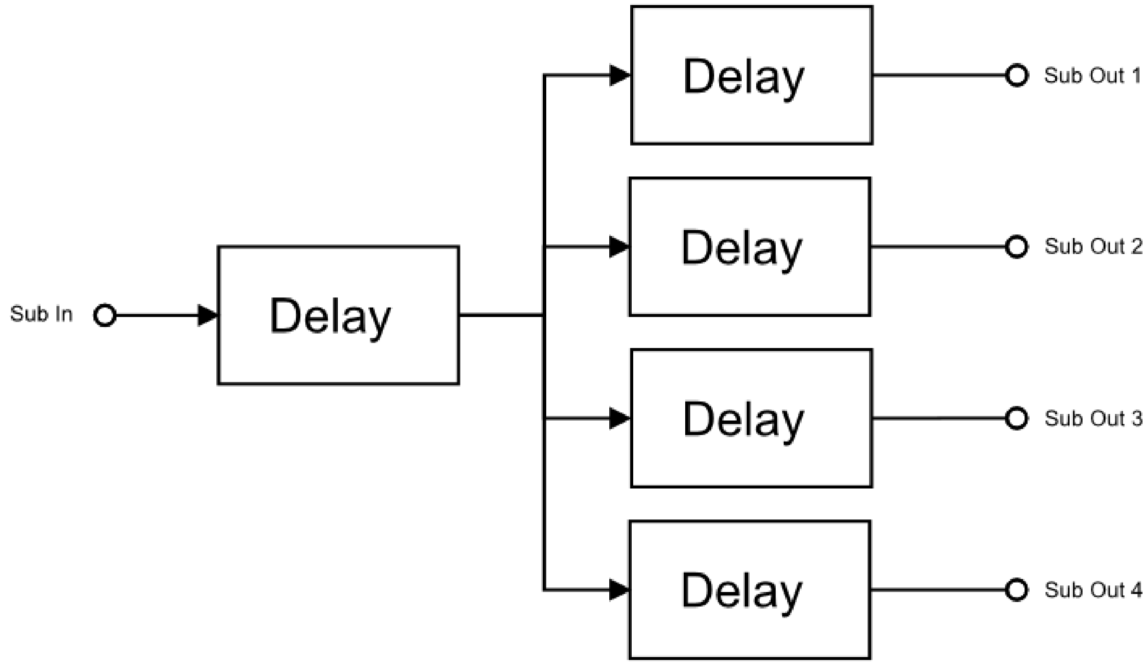

Figure 39. Disallowed delay configuration

The delay configuration of Figure 39 is conceptually correct, but disallowed in MSO. This is discussed in the MSO Reference. Briefly, if the configuration of Figure 39 were allowed, it would be possible to set the **Optimization allowed** property of all five delays to **True**. This would have the effect of causing the optimizer to explore an infinite space of redundant solutions when an optimization is run. The optimizer would “chase its tail” so to speak. To prevent this, a delay configuration similar to the figure below must be used.

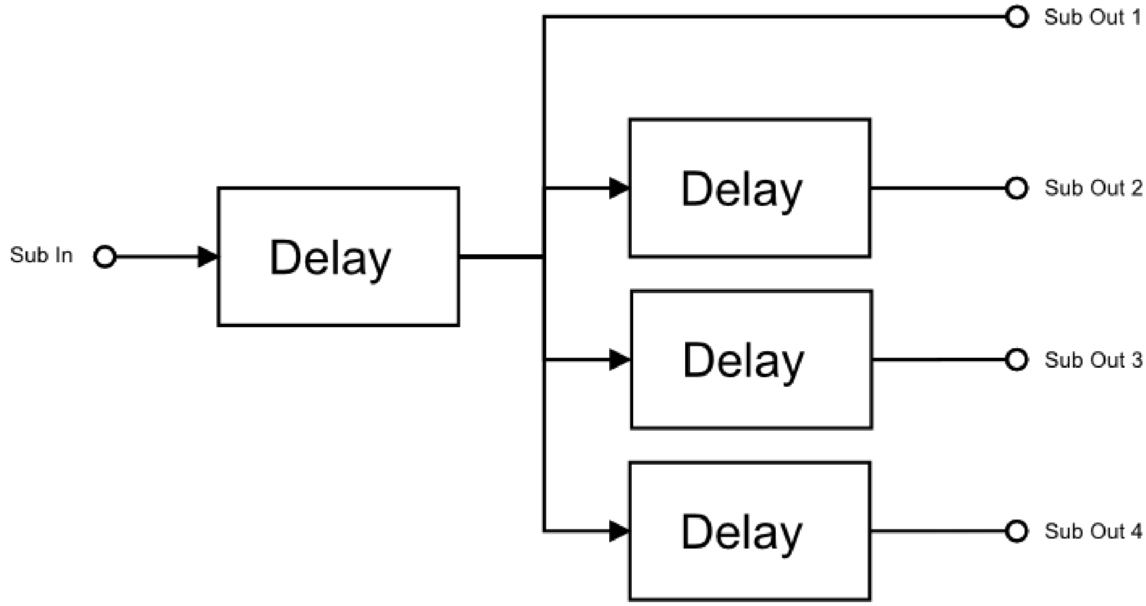

Figure 40. An allowed delay configuration using a shared delay

In practice, it's not necessary for the channel without delay to be the first one as in the figure above. The individual channel with the smallest delay in Figure 38 ends up with no delay in the configuration of Figure 40. It should be clear that in going from the configuration of Figure 38 to that of Figure 40 to set up the project to optimize the **MLP** response flatness would involve some tedious calculations and shuffling of the delay blocks. An exactly analogous procedure would have to be done with the gain blocks too. MSO can do this in one step for each of the gain and delay configurations via the **Rearrange Delays** and **Rearrange Gains** commands respectively.

Locate the **Subwoofer Channels** node under the **MLP Cleanup** configuration. Observe that there are initially no shared filters of any kind. Right-click this node and select **Rearrange Delays** from the context menu. You'll notice that there is now a delay block under **Shared Filters**, and the delay block of **Sub Channel 4** is now gone. All the delays have been recalculated to give a net delay for each sub channel that is exactly equivalent to the previous condition.

Right-click on the **Subwoofer Channels** node and choose **Rearrange Gains** from the context menu. A gain block appears under **Shared Filters**, and the gain block of **Sub Channel 2** is now gone.

These shared gain and delay blocks were not newly created, but are existing blocks that have been relocated to the **Shared Filters** and had their **Value** parameters suitably altered. Since all filter parameters were previously locked (that is, the **Optimization allowed** properties of all their parameters were set to **False**), the shared gain and delay blocks retain this setting and will need to be unlocked. This can be seen via the gray color of the icons for FL14 and FL27. The fastest way to unlock the shared gain and delay blocks is to right-click on the **Shared Filters** node and choose **Unlock Shared Sub Filter Parameters** from the context menu. You can verify that the change took place by observing that the color of the corresponding filter icons is now white. The **MLP Cleanup** configuration should now look as below. The individual sub channel nodes have been collapsed for clarity.

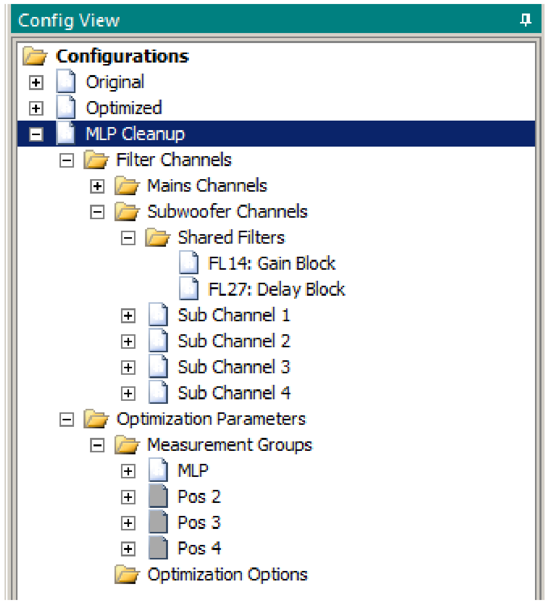

Figure 41. After rearranging delays and gains

Successive applications of the **Rearrange Delays** command just toggle between the delay configurations of Figure 38 and Figure 40. **Rearrange Gains** behaves similarly.

Using Shared Sub Filters, Delays and Gains

Now that you have shared gain and delay blocks, you can add the shared PEQ filters. In the **MLP Cleanup** configuration, right-click the **Shared Filters** node under **Subwoofer Channels**. Choose **Add Parametric EQ** from the context menu. Repeat this operation until six shared PEQs have been added.

Tweaking the Optimization Options

Since the previous optimization has flattened the frequency response well, it can be beneficial to alter the frequency range over which the level reference is computed for the next optimization. You'll change those options next.

From the main menu, choose **Tools**, **Optimization Options**, then choose **MLP Cleanup**. In **Criteria**, change **Frequency range to compute reference**, specifying a minimum frequency of 25 Hz and a maximum frequency of 200 Hz. Click OK.

Making a Graph for the New Configuration

Using what you learned before about making graphs, create a new graph whose traces are the four measurement groups of the **MLP Cleanup** configuration. Set the graph title to "MLP Cleanup Combined Response SPL vs. Frequency" and enable the legend. Set the y-axis to manual scaling with minimum and maximum values of 45 dB and 120 dB respectively. Set the graph name in the **Data View** to "MLP Cleanup Combined Responses" and make each trace name the same as its corresponding measurement group name. The graph information should show up in the **Data View** as below.

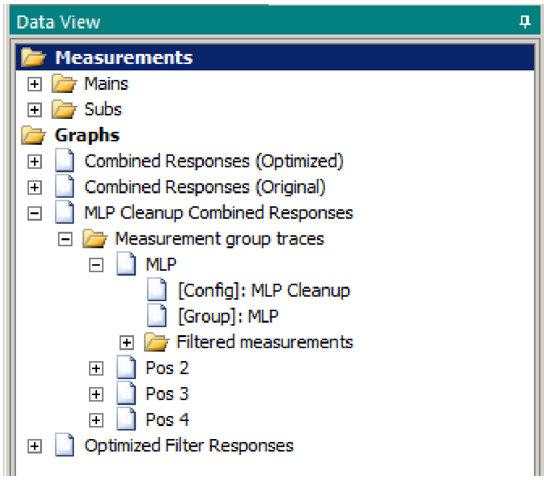

Figure 42. Graph settings for final MLP cleanup

Save your results as **tutorial_5.msop**, then run the optimization, saving the results again afterward. The results of the optimization are shown below, and can be found in the MSO project **tutorial_5_prefab.msop**.

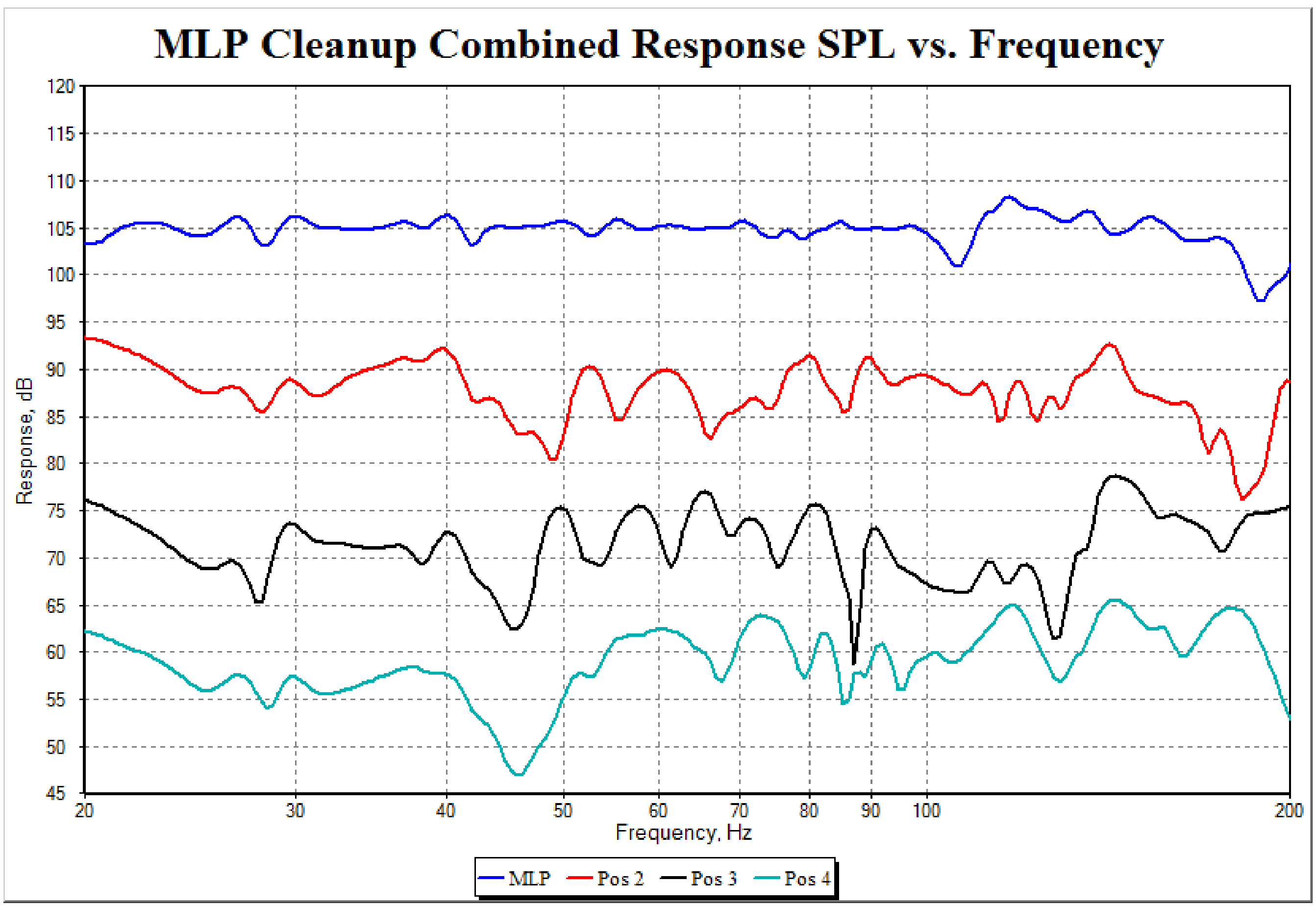

Figure 43. Optimization results of MLP cleanup

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Multi-Sub Optimizer Tutorial

Summary of Results

A graph of the frequency response data before any optimization is repeated below, showing large deviations from flat response and large seat-to-seat variation.

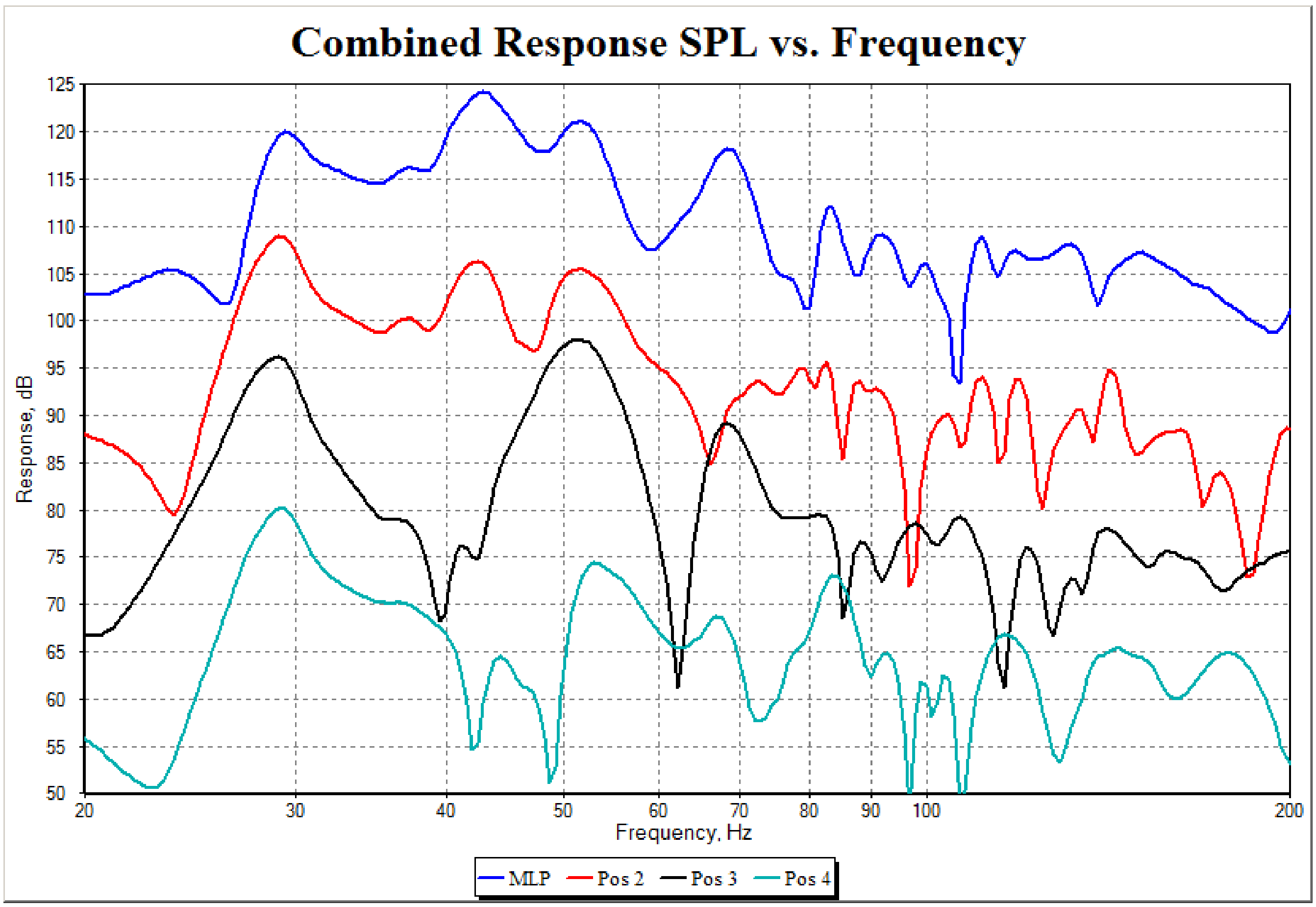

Figure 44. Combined responses before optimization

The results after the first optimization as performed in the **tutorial_4_prefab.msop** in the **Sample Projects** sub-folder of the tutorial are shown below.

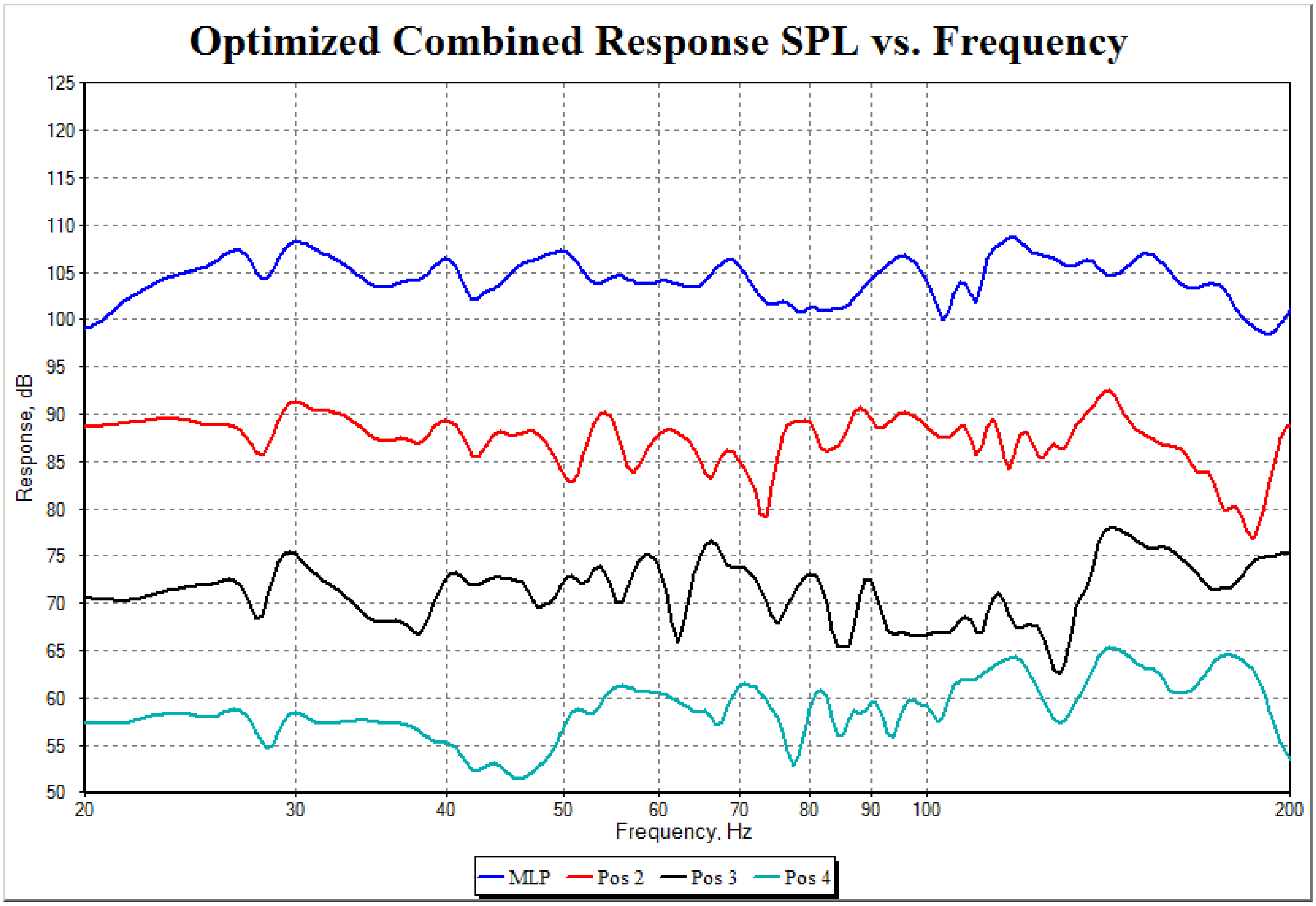

Figure 45. Combined responses after first optimization

You can see clear improvements in both overall flatness and response variation from seat to seat.

The final filter responses are shown below.

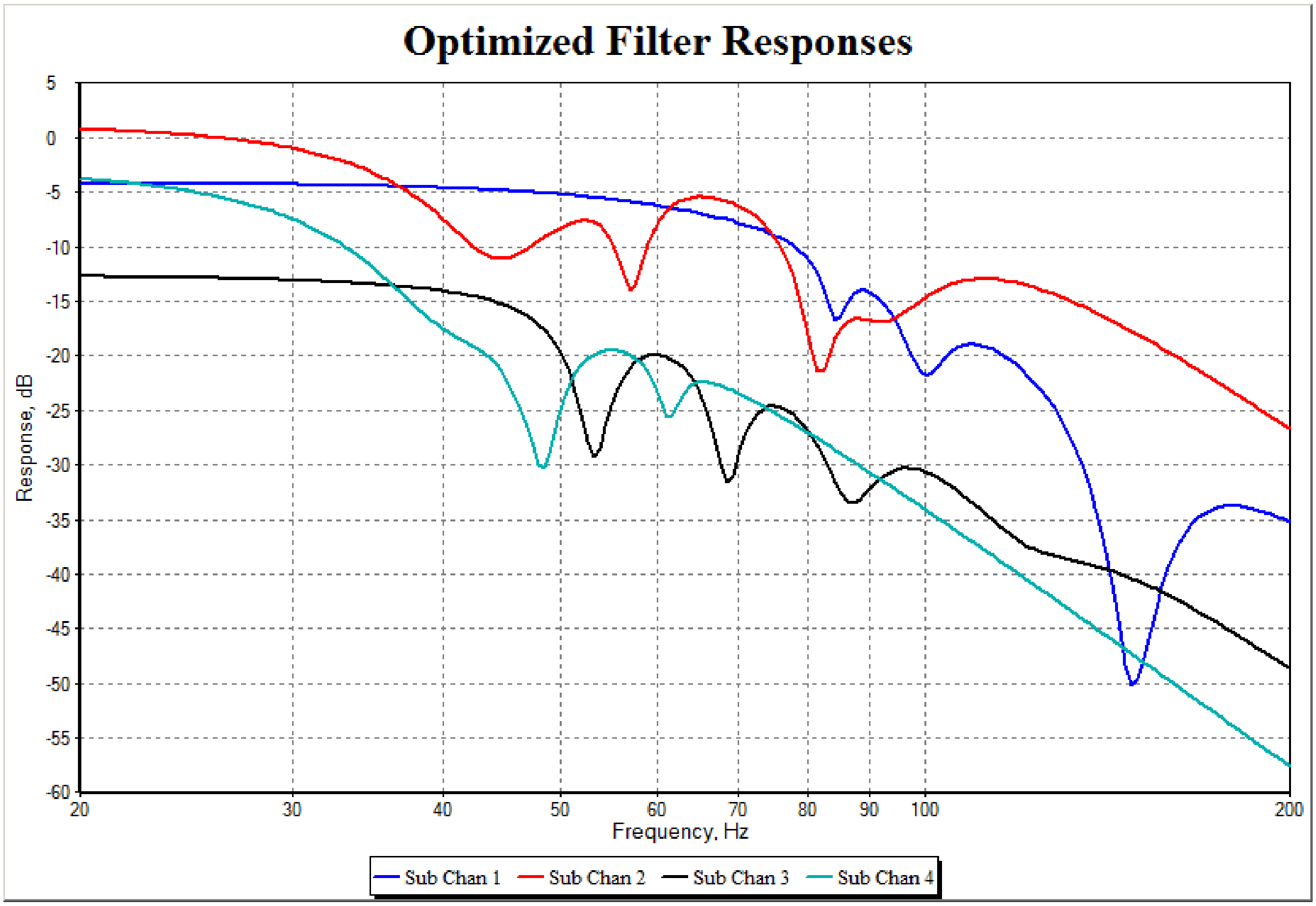

Figure 46. Filter responses after optimization

No boosting is done in any of the PEQ filters.

Next, the MLP response was made as flat as possible using the following steps.

- Clone the **Optimized** configuration, renaming it **MLP Cleanup**.
- Lock all the filter parameters of the **MLP Cleanup** configuration.
- Use **Rearrange Gains** and **Rearrange Delays** to make a shared delay block and gain block available in the **MLP Cleanup** configuration.
- Unlock the parameters of just the shared gain and delay blocks.
- Add six PEQ filters to the **Shared Filters** of the **Subwoofer Channels** of **MLP Cleanup**.
- Make all measurement groups except the MLP plot-only in **MLP Cleanup**.
- Re-run the optimization.

This gives the results shown below.

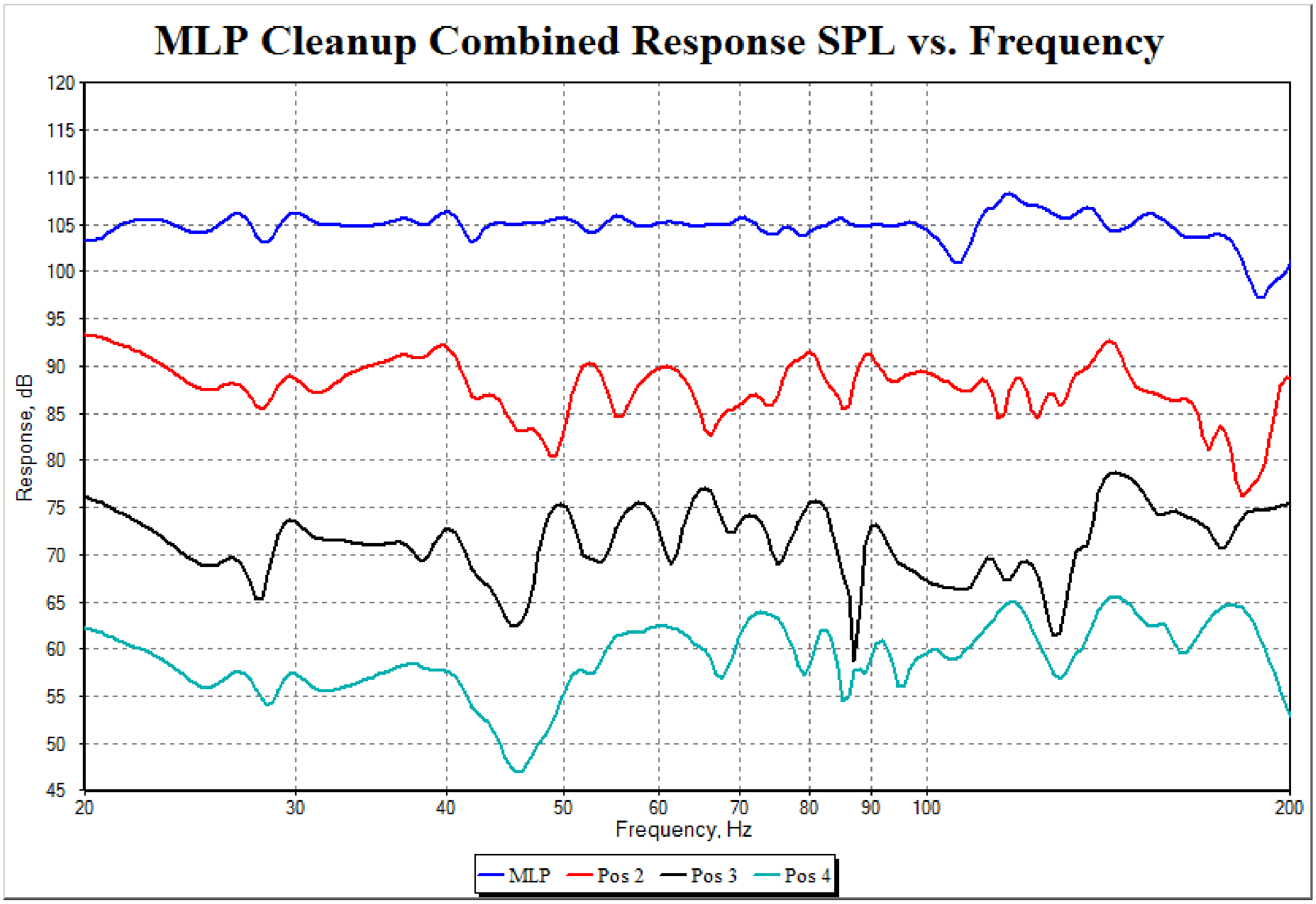

Figure 47. Optimization results of MLP cleanup

It is interesting to compare the final gain and delay settings of the first optimization and the final one. After the first optimization, the following results were obtained.

```
Final gain and delay/distance settings:
Increase AVR sub out trim gain by 1.5 dB
Sub Channel 1 gain: -5.6301 dB
Sub Channel 2 gain: -0.0673176 dB
Sub Channel 3 gain: -14.0948 dB
Sub Channel 4 gain: -4.23466 dB
Decrease AVR sub out distance by 3 feet
Sub Channel 1 delay: 12.346 msec
Sub Channel 2 delay: 4.53837 msec
Sub Channel 3 delay: 4.46217 msec
Sub Channel 4 delay: 0.0462191 msec
```

Here are the results after the final optimization.

```
Final gain and delay/distance settings:
Increase AVR sub out trim gain by 9.5 dB
Sub Channel 1 gain: -5.89511 dB
Sub Channel 2 gain: -0.332327 dB
Sub Channel 3 gain: -14.3598 dB
Sub Channel 4 gain: -4.49967 dB
Increase AVR sub out distance by 12.4 feet
```

```
Sub Channel 1 delay: 12.3516 msec
Sub Channel 2 delay: 4.54393 msec
Sub Channel 3 delay: 4.46773 msec
Sub Channel 4 delay: 0.0517806 msec
```

The AVR sub out gain of the final optimization is 8 dB higher than the first one. The AVR sub distance of the final optimization is a surprising 15.4 feet greater than the first optimization. This is probably due to the added phase shift of the shared PEQ filters used in the final optimization.

It's not completely clear whether the final effort to flatten the MLP was worth the side effects. Though the final MLP response is much flatter than in the first optimization, the listening positions other than the MLP have been made slightly worse.

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Multi-Sub Optimizer Reference

Overview of Use

To use Multi-Sub Optimizer (MSO), you perform the following steps:

- Determine how you will configure your AVR and DSP devices before making measurements. This will depend on whether you want to use MSO to help find the optimum crossover frequency, and if your subs are identical or not. (Details)
- Measure the frequency response of your mains and subs at one or more listening positions using separate measurement software. (Details)
- Export a text file from your measurement software in FRD format for each measurement. (Details)
- Import the text files into MSO. (Details)
- Define filter channels for your subs and mains. (Details)
- Add filters, delays and gains to these channels as desired. (Details)
- Examine and alter gain, delay, and filter parameter values manually at any time as desired. (Details)
- Associate measurements with the filter channels you've defined. (Details)
- Assign measurements to measurement groups, with one group per listening position. (Details)
- Graph various types of data. (Details)
- Specify optimization options. (Details)
- Run automatic optimization. (Details)
- List all filter parameters in a filter report. (Details)
- Enter the calculated filter parameters into your DSP device.

These steps are explained in more detail in the following pages.

Multi-Sub Optimizer Reference

Optimization Strategies

MSO allows for a number of approaches for optimizing the integration of subwoofers with main speakers and with one another. It is assumed that if you're using an AVR or pre-pro, you also have some sort of DSP device connected to its subwoofer output that allows individual EQ, gain and delay to be applied to each subwoofer. The alternatives can be generally categorized as follows.

- Use an AVR or pre-pro with crossover frequency decided in advance
- Use an AVR or pre-pro and use MSO to help determine an optimum crossover frequency
- Use an AVR or pre-pro without a conventional crossover using the configuration recommended by Earl Geddes
- Use an HTPC or other general-purpose device capable of applying DSP to each subwoofer individually and optionally the mains

Fixed Crossover Frequency

This is the simplest strategy. Set your AVR's crossover frequency to the desired value, then perform the measurements with the crossover in place. When adding filters to subwoofer channels in MSO, do not add low-pass or high-pass filters, as these will already be present in the measured data. Any filters added within MSO represent changes from the as-measured condition.

Using MSO to Help Find the Optimum Crossover Frequency

Using this strategy, you'll need to set your main speakers to Large before making measurements, while still allowing the subwoofer to play. Ideally, the sub should have no low-pass filter in effect at all, but this is generally not possible. The solution is to enable the mode sometimes called "LFE + Main", "double bass" or "plus mode" depending on the AVR manufacturer. Then set the crossover frequency as high as possible, preferably 250 Hz. When this is done, the mains will be full-range, and the subs will have a low-pass filter of e.g. 250 Hz applied. This low-pass filter will not be present when the final crossover frequency is chosen, so MSO has a facility for correcting the measured subwoofer data to remove its effect. This feature is described below.

After importing the data into MSO, the following steps must be performed (see "adding filters") in MSO's Config View.

- Under the **Mains Channels** node of the desired configuration, right-click the **Shared Filters** node and select **Add Standard AVR Crossover HPF**.
- Under the **Subwoofer Channels** node of the desired configuration, right-click the **Shared Filters** node and select **Add Standard AVR Crossover LPF**.
- In the Main Menu, choose **Tools**, then **Project Options**. Check the check box labeled "Correct sub measurements to remove sub LPF response". Then enter the frequency in Hz that you chose for the crossover frequency for measurements. Since this correction boosts the amplitude of the measured subwoofer data above the cutoff frequency, to prevent excessive correction from being applied, the value entered into this field of the dialog box must be no less than 200 Hz.

The latter step ensures that the subwoofer low-pass filter effect modeled by MSO will be only the crossover low-pass filter without the added effect of the undesired low-pass filter present in the measurements. Though I'm not aware of any AVR that supports running the sub completely "wide open" with now low-pass filter at all when "LFE + Main", "double bass", "plus mode" or the equivalent is chosen, if you use such an AVR, correcting for the low-pass filter is unnecessary.

After adding the crossover filters per the above, the cutoff frequency of each one will be set to the default value of 80 Hz, and the "Optimization allowed" parameter will be set to **False**. Change the cutoff frequency of both the low-pass and high-pass filters to the desired value if that value is different from the default 80 Hz, but keep "Optimization allowed" set to **False** for each one. See Changing Filter Parameter Values and Constraints for how to edit filter parameters. Unfortunately, if you set "Optimization allowed" to **True** for the crossover low-pass and high-pass filters, MSO will adjust each cutoff frequency individually, resulting in cutoff frequencies for the crossover low-pass and high-pass filters that are different from one another. Such a configuration is incompatible with the capabilities of AVRs. To evaluate different crossover frequencies, use the Configurations feature. From the main menu, choose **Config**, **Clone**. Then, in the newly created configuration, change the cutoff frequency parameter of the low-pass and high-pass filters to the desired value. For a detailed explanation of the **Configurations** feature, see the Configurations topic.

Using an AVR or Pre-Pro Without a Conventional Crossover

This is the strategy recommended by Earl Geddes for use with his speakers. In this approach, the AVR or pre-pro is set to the "LFE + Main", "double bass", "plus" or similarly-named mode, depending on its manufacturer. The main speakers are run full range, and the AVR crossover is set to as high a frequency as possible, say 250 Hz. A separate low-pass filter for each sub is configured in the DSP device connected to the AVR's sub out. These low-pass filters could in general have a different cutoff frequency for each sub, and the cutoff frequency is chosen so the frequency ranges of subs and mains overlap. It should be noted that the Geddes loudspeakers are of closed-box type, with high power handling and an anechoic low-frequency cutoff of 80 - 90 Hz. If your mains are of the vented-box type, you'll still need to high-pass filter them, which for this configuration would require your DSP device to filter the main speakers, requiring more DSP channels and potentially another A/D→D/A conversion for the main channels.

In the past, Earl Geddes has recommended that dissimilar subwoofers be used, with one high-output "super sub", and two or three additional subs having lesser output. MSO assumes linear operation, so running an optimization without taking maximum output into consideration could lead to a solution that is sub-optimal in that regard. Since this potential problem is not limited to the Geddes-style configuration, it is discussed separately on the Working With Dissimilar Subwoofers page.

Using an HTPC With Filters Implemented in Playback Software

Modern pro audio multi-channel audio interfaces, along with playback software having DSP capability such as JRiver Media Center, provide interesting opportunities for multiple-subwoofer systems without the constraints of AVRs. Because they are so flexible, it's hard to make specific recommendations with regard to their operation with MSO. However, there are a couple of suggestions that are generally applicable.

- Prior to measuring, configure signal routing software for mains, subs and others so the desired signals are getting to the correct loudspeakers.
- When measuring, run both main loudspeakers and subwoofers "wide open", with no high-pass for the mains, and no low-pass for the subs.
- From the main menu of MSO, choose **Tools**, **Project Options**, and ensure that "Correct sub measurements to remove sub LPF response" is **unchecked**.

Some playback software has the ability to incorporate FIR filters, but MSO only supports IIR filters of the type normally used to emulate their corresponding analog filters (Butterworth, Linkwitz-Riley, Bessel and so on).

Multi-Sub Optimizer Reference

Taking Measurements With Your Measurement Software

Imported Measurements Must Be Time-Synchronized

MSO requires that the measurements you import into it be time-synchronized with one another. This means that the relative delays between all loudspeakers measured at a given listening position, including mains and subs, must be preserved. While it might appear that this would not be a problem and would be accomplished automatically by measurement software, this feature is *not* automatic and special attention is required in order to ensure time synchronization. In fact, *certain measurement configurations guarantee that obtaining time-synchronized measurements is impossible*, so it's very important to avoid such configurations. The method for ensuring that relative delays are preserved usually involves the use of a so-called "loopback timing reference" or an "acoustic timing reference" in the case of Room EQ Wizard. Accomplishing time synchronization of measurements is described in detail in connection with specific software in the sections below.

Caution: Measurements Taken With USB Microphones Require An Acoustic Timing Reference

Time-synchronized measurements with a USB microphone can only be done using Room EQ Wizard version 5.15 or greater, with its "acoustic timing reference" feature. For all other known measurement software, time-synchronized measurements with a USB microphone are not possible. Those familiar with HolmImpulse might be tempted to try HolmImpulse's "time locking" feature to work around this problem, but that workaround fails. The reason is described in the HolmImpulse section below.

Caution: Making Time-Synchronized Measurements With HDMI Requires Special Precautions

Special care must be taken when making time-synchronized measurements using HDMI. This is described further in the HDMI measurement section below.

Room EQ Wizard (REW) Considerations

REW is a popular choice for measurement software, and is recommended for use with MSO on all platforms.

To obtain time-synchronized measurements with REW and an XLR microphone such as the Parts Express EMM-6, you must use a separate sound device. In addition, measurements must be performed using a loopback timing reference. To enable the loopback timing reference in REW, go to the **Analysis** tab of the REW **Preferences** dialog, and in the section labeled **Impulse Response Calculation**, make sure the **Use Loopback as Timing Reference** checkbox is checked *before* making measurements.

Time-synchronized measurements can be performed with a USB microphone using REW's "acoustic timing reference" feature. To enable it, go to the **Analysis** tab of the REW **Preferences** dialog, and in the section labeled **Impulse Response Calculation**, make sure the **Use Acoustic Timing Reference** option is chosen *before* making measurements. This requires REW version 5.15 or later. If you are using REW to measure a two-channel system with a USB microphone, you must use 5.15 beta 6 or later so that the speaker used for the acoustic timing reference can also be measured.

See the REW documentation for measuring with a timing reference for more details.

Using HolmImpulse With The Time-Locking Feature (Windows Only)

Another option for measurements using Windows-based systems is the HolmImpulse freeware. Unfortunately, the HolmImpulse documentation tends to be theoretical in nature and doesn't include much information about how to actually use the software. A worthwhile source of information for learning HolmImpulse is the HolmImpulse tutorial at the Parts Express forum.

HolmImpulse uses a single-input, single-output approach that nonetheless can achieve time-synchronized measurements using the so-called "time locking" feature. The diysubwoofers.org site has a very good step-by-step procedure for using the time-locking feature. A word of caution is in order regarding HolmImpulse and time-locking. When used with sound cards having clocks that are not locked to one another on the record and play sides, the timing reference will shift from one measurement to the next, causing them to be non-time-synchronized and thus unusable with MSO. To find out more about how time-locking can fail in HolmImpulse, see the "Holm Impulse - Timelock, creeping offset?" thread at the Parts Express forum. That thread contains a description of a test that can be run to determine if your sound device is compatible with time-locking. It also contains an explanation by Bill Waslo, author of the Dayton OmniMic measurement software, of the clocking issue as it relates to the failure of time-locking in HolmImpulse.

If the clocks on the record-side and playback-side sound devices are not locked to one another, then as Bill Waslo states in the "creeping offset" thread, the time locking cannot work. With that information, it can be seen why using a USB microphone will cause HolmImpulse time-locking to fail. The USB microphone contains an internal A/D converter, so the converter's clock must be contained within the microphone itself. An analog or digital signal from the computer's sound device supplies the input signal to the device under test in this configuration. This signal's clock is internal to the computer itself or in an attached external sound device, so the record and playback clocks are physically different and can't possibly be locked to one another. This will cause time-locking to fail. A similar situation will occur if one attempts to use HolmImpulse time-locking with HDMI supplying the measurement source signal.

It should also be pointed out that these failures of time-locking won't be flagged by the software. In order to find them, you'll need to look for them by performing multiple measurements and checking for consistency.

FuzzMeasure (Mac Only)

FuzzMeasure has a loopback timing reference capability and is therefore recommended for use with MSO, provided a USB microphone is not used. For more information about using loopback with FuzzMeasure, see this Youtube FuzzMeasure tutorial video.

Dayton OmniMic

Dayton OmniMic cannot be used with MSO, as it has no timing reference capability.

General Considerations

When performing subwoofer measurements for use with MSO, it's essential that only one subwoofer be energized at a time for a given subwoofer measurement. Assuming you have a DSP device for performing individual EQ of each sub, this means muting all outputs of the DSP device except the one associated with the sub being measured. If you have more than one sub connected to a given DSP channel, these count as a single "logical sub" for the purposes of MSO, so there is no need to individually energize the physical subs. It's probably a good idea that multiple subs assigned to a single DSP channel be physically close to one another.

When performing mains measurements, you have more than one choice. You can choose to integrate center channel plus subs, or left and right plus subs, but not both. Suppose you have a four-channel DSP, a total of four subwoofers, and each DSP channel individually drives a single subwoofer via its associated power amp channel. If you choose to integrate center channel plus subs, each listening position would consist of five measurements as follows.

- Center channel only, with all subs muted
- Sub 1 only, with all other subs and center channel muted
- Sub 2 only, with all other subs and center channel muted
- Sub 3 only, with all other subs and center channel muted
- Sub 4 only, with all other subs and center channel muted

If you choose to integrate left and right fromt channels plus subs, each listening position would consist of the following five measurements.

- Left and right front channels energized together in mono, with all subs muted
- Sub 1 only, with all other subs muted, and left and right front channels muted
- Sub 2 only, with all other subs muted, and left and right front channels muted
- Sub 3 only, with all other subs muted, and left and right front channels muted
- Sub 4 only, with all other subs muted, and left and right front channels muted

The recommended frequency range for the measurements is 10 Hz to 300 Hz. The reason for the high upper limit is to ensure that any filter applied to the mains does not affect the response in the frequency range outside that which is being optimized. This will be explained in more detail in the optimization options section. Measurements should be *unsmoothed*, or, in the case of newer versions of Room EQ Wizard, variable smoothing. Currently, MSO requires that the frequency resolution of the exported data be at least 300 points per decade (about 90 points per octave - I might relax this?). Measurements of mains and subs should be performed over the same frequency range, since MSO determines the frequency range to perform the optimization by finding the highest start frequency and the lowest stop frequency in all imported measurements.

Combined frequency response of mains and subs can be optimized at multiple listening positions.

How Many Positions Should Be Measured?

It is recommended that the number of listening positions measured be the same as or a little greater than the number of logical filter channels defined in MSO which contain tunable filters. For example, if you have a miniDSP 8x8 and four subwoofers, each controlled by a separate channel of the miniDSP, and four correspondingly-defined MSO filter channels having tunable filters in each of them, and no EQ of the mains, then you should measure at four or more listening positions. If you wish to EQ the main speakers as well, energize both left and right speakers together in mono and measure them together with one measurement. This measurement should be assigned to a single logical mains filter channel in MSO, and the tunable filters for the mains should be used identically in the physical left and right main speaker channels of the DSP device. In this case, the number of positions measured should be five or more, as there would be five channels defined in MSO having tunable filters. Your DSP should be set to a flat response and zero delay for the measurements. All filters, delays and gains that you add in MSO represent *changes from the as-measured condition*, so confusion could result later if measurements were performed with some DSP filters or delays already in place. However, it's a good idea to adjust your AVR's sub distance setting to get decent integration of mains and subs before committing to a full set of measurements at multiple listening positions. Be sure to record your AVR's sub distance and sub gain trim settings for the as-measured condition, as you'll probably need them later. You'll also need to record which DSP channel each sub was connected to when the measurement was performed.

Some Experiences With Time-Synchronized Measurements Using HDMI and Loopback

Below is a report of some experiences I had using HDMI with loopback for time-synchronized measurements, performed prior to the introduction of the acoustic timing reference in REW. With the acoustic timing reference feature, loopback is no longer required for time-synchronized acoustic measurements using HDMI or any other type of digital or analog input. Since the measurements performed below were purely of an electrical nature and not acoustical, loopback would still be requred even with the latest REW version. I first encountered these issues when measuring the bass management functions of an Emotiva UMC-200 pre-pro. These were line-level electrical measurements only, and did not involve any microphone. Equipment and software used were as follows:

- Computer: ASUS laptop with AMD CPU and HDMI sound device
- Operating System: Windows 7 x64
- Measurement software: Room EQ Wizard
- Support Software: ASIO4ALL
- External sound device: Tascam US-144MKII

My first measurement attempt used the following configuration: In the **Analysis** tab of the REW **Preferences** dialog, **Use Loopback as Timing Reference** was checked. The options in the **Soundcard** tab of the **Preferences** dialog and the electrical connections were as listed below.

- Drivers: ASIO
- ASIO Device: ASIO4ALL v2
- Output: HDMI left front channel
- HDMI cable to UMC-200 HDMI input
- Input: Tascam US-144MKII channel 1 analog in
- Tascam US-144MKII channel 1 analog in connected to UMC-200 left front channel output
- Timing Reference Output: Tascam US-144MKII channel 2 analog out (loopback)
- Timing Reference Input: Tascam US-144MKII channel 2 analog in (loopback)
- RCA cable connecting Tascam US-144MKII channel 2 analog out to Tascam channel 2 analog in (loopback)
- Main speakers set to **Small** in the UMC-200

This setup gave frequency response data whose phase was completely wrong and inconsistent from one measurement to the next. So I thought I'd try using HDMI for the timing reference output as well. This involved the loopback path going through the UMC-200 itself. In this situation, the loopback path is the D/A system of the pre-pro. The analog output of the pre-pro can be taken from a spare output if available, or from a Y splitter at the output of a channel in use. In the latter case, the other output of the Y cable would connect to an RCA cable leading to the input of the power amp used for that channel. To use this approach for acoustical measurements, you'd need to be using a pre-pro or an AVR with preamp outputs to provide the loopback. The revised configuration is listed below.

- Drivers: ASIO
- ASIO Device: ASIO4ALL v2
- Output: HDMI left front channel
- HDMI cable to UMC-200 HDMI input
- Input: Tascam US-144MKII channel 1 analog in
- Tascam US-144MKII channel 1 analog in connected to UMC-200 left front channel output
- Timing Reference Output: HDMI center channel (loopback)
- Timing Reference Input: Tascam US-144MKII channel 2 analog in (loopback)
- RCA cable connecting UMC-200 center channel output to Tascam US-144MKII channel 2 analog in (loopback)
- Center channel speaker distance set to match the most distant other speaker in

the UMC-200 setup

This configuration gave the correct phase and delay data and was consistent... when it worked. The problem was that quite often, I would get some strange-looking frequency response with 10 dB of ripple or more. Since this is completely unexpected when measuring electronics, it was easy to see from the data itself when the error occurred. The workaround was to temporarily set the output to a different channel in the **Soundcard** tab of the REW **Preferences** dialog, then set it back to the desired channel again. But the problem kept coming back. When making acoustical measurements, users have observed that an easily-recognizable sound results when this error occurs. When this happens, one can then discard the measurement and perform the workaround above before re-measuring. One user observed that the problem went away entirely when setting the sample rate to 48 kHz. The problem may be related to ASIO4ALL or to defective motherboard HDMI audio drivers. Many users have never experienced the problem, so it's not universal. Newer ASIO4ALL versions have been released since the time these measurements were taken.

Multi-Sub Optimizer Reference

Exporting Measurements From Your Measurement Software

Measurements should be exported in FRD format, as described at the FRD Consortium web page. This loosely-defined format consists first of optional comments, which begin with the "*" character in the first position of each row of text. The comment lines are followed by rows of data, each consisting of three columns of text separated by spaces or tabs. Each row of data contains frequency, SPL in dB, and phase in degrees in that order. It's helpful if your measurement software allows exporting user comments to the file. If possible, information regarding listening position and which main speaker or sub was measured should be included in each exported file. If you're unable to do that, try to name your exported files so this information can be obtained from the file name.

Multi-Sub Optimizer Reference

Importing Measurement Text Files

Measurements can be imported into MSO in two ways:

- From the **File** menu, choose **Import Sub Measurements** or **Import Mains Measurements**
- Select the Data View tab. In the Data View, right click on the **Subs** node (under the **Measurements** node) and choose **Import Sub Measurements** from the context menu. Repeat for the **Mains** node.

In either case, you'll be presented with a **File Open** dialog that allows selection of multiple files at once to speed the import process. When each measurement is first imported, it is given the same name as the file that originally contained its data. You can (and should) rename each one by selecting it in the Data View and pressing **F2** to edit its name in place. You can also right-click the measurement and choose **Rename** from the context menu, or select it, then click a second time (same as in Windows Explorer). You can examine a copy of the imported text file by right-clicking on the measurement name and choosing **Show Imported Text**. This information is a copy of the original file on disk and is always stored internally in the project file itself for viewing at any time. The original files need not be present on disk to view the imported text. I'd suggest that you choose a short but descriptive names for the measurements, with text referring to both the listening position and the loudspeaker that was measured such as below.

MLP:Sub 1

Later tasks will be easier if the text referring to the listening position is placed at the beginning of the measurement name. The reason for this will become clear later when creating measurement groups. You can use any characters you like in a measurement name as long as the name doesn't clash with that of another measurement.

If you accidentally import a sub measurement as a mains measurement or vice versa, just select the out-of-place measurement in the Data View and press the **Delete** key or press **Ctrl+D**, then re-import the measurement in the correct category. Deleting the measurement in this way doen't affect the original on disk, but only removes a copy of it from the project.

MSO does not require strict conformance to the format described at the FRD Consortium web page. The following guidelines apply.

- Any line of text that MSO determines to not be data is treated as a comment and ignored.
- The leading "*" character required of comment lines in the FRD format is not strictly necessary to import them into MSO successfully.
- Lines of text containing frequency response data can use the "dot" character or the comma for the decimal separator, as long as all lines of data are consistent in this regard.
- Allowing the use of the comma as a decimal separator is to accommodate Room EQ Wizard and other software that respects cultural conventions when exporting measurements as text.

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Multi-Sub Optimizer Reference

Defining Filter Channels

MSO does not currently maintain a database of the various DSPs available and their capabilities. Instead, it assumes the DSP has a simple structure analogous to that of the miniDSP 2x4 with the four-way advanced plugin. The DSP structure is assumed to consist of a single bank of filters whose response affects all channels at once (called the "Shared Filters"), together with an arbitrary number of independent filter channels added by the user.

To add subwoofer channels, select the Config View tab. You'll see an initially empty configuration defined. Right-click the **Subwoofer Channels** node and choose **Add Filter Channel** from the context menu. This will create a new channel initially named "Sub Channel 1". You can rename it in the same way you renamed the measurements in the earlier step. Repeat this operation for as many independent DSP channels as you actually have in use for your subs. Also, even if you're not doing any DSP on the mains, you must still create a single mains channel so that mains measurements can be associated with it. To do so, repeat this procedure by right-clicking on the **Mains Channels** node.

Multi-Sub Optimizer Reference

Adding Filters, Delays and Gains

Once you add filter channels, you can add filters, delays and gains to them. To do so, right-click on the **Filters** category node under the newly-created channel. This presents a context menu allowing the addition of various filter types (delays, gains and polarity inversions are considered "filters" for this purpose).

Restrictions on Filters, Delays and Gains

The available filters depend on whether the chosen channel is a mains or sub channel, as well as what filters have already been added to that channel in certain specific cases. For instance, once a delay has been added to an individual subwoofer channel, another cannot be added to that same channel, as this would cause the optimizer to explore a potentially infinite number of redundant solutions when performing the optimization. If a delay or gain cannot be added, MSO shows the menu item as grayed out. For example, attempting to create the configuration of delays shown below in Figure 1 is disallowed.

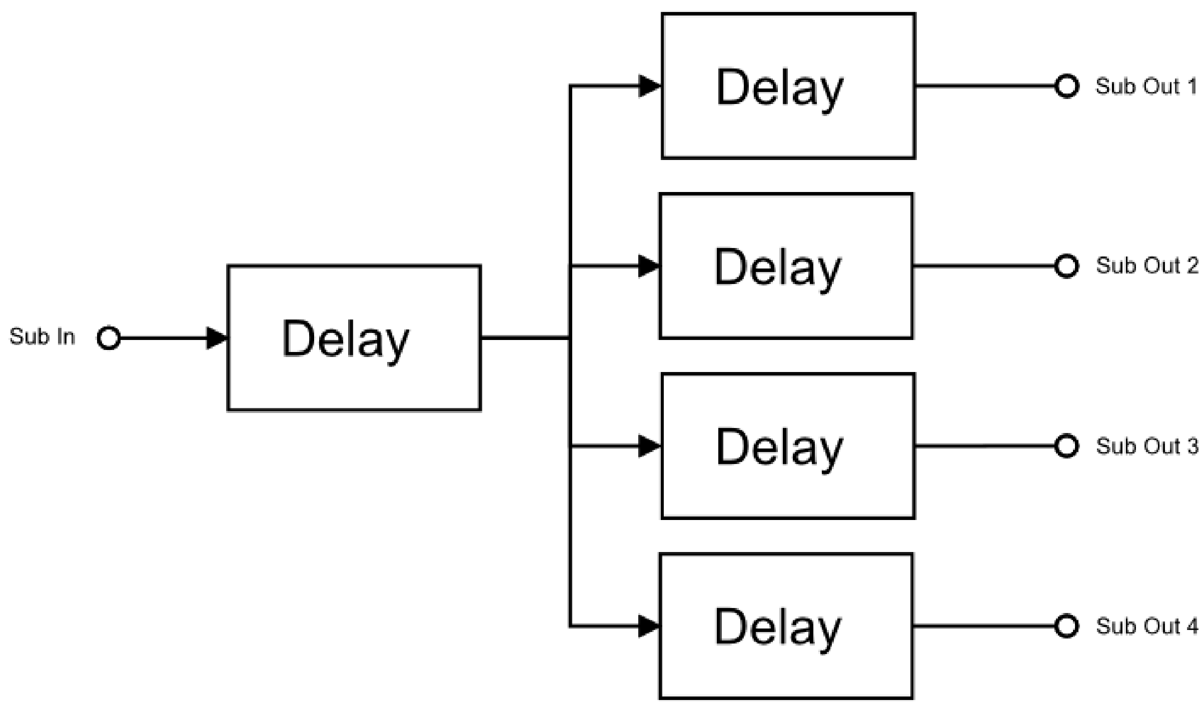

Figure 1. Example of Disallowed Delay Configuration

This can be remedied in several ways. One way is shown in Figure 2 below.

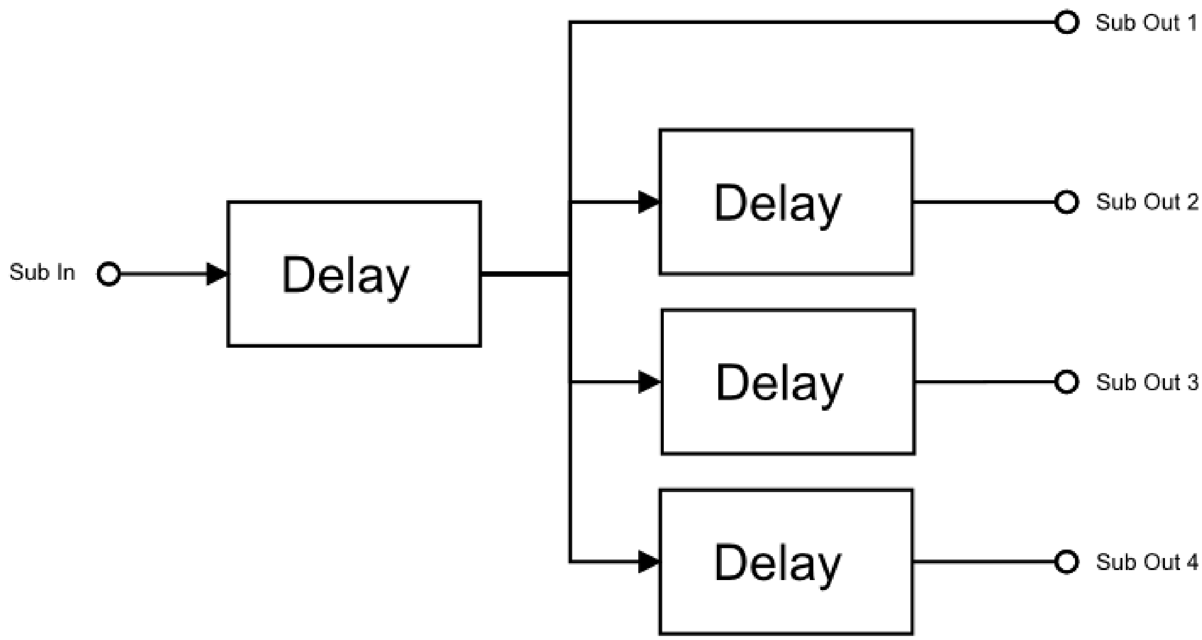

Figure 2. An Alternative to the Configuration of Figure 1

The leftmost delays in each of figures 1 and 2 above represent delays added to the **Shared Filters** node under **Subwoofer Channels** in the Config View. If you try to add a fifth delay to the configuration of Figure 2 in an attempt to obtain the configuration of Figure 1, MSO will disable the menu option to add the delay. Of course, any of the four channels in Figure 2 can be chosen as the one without a delay block.

Another permitted delay configuration is shown in Figure 3 below.

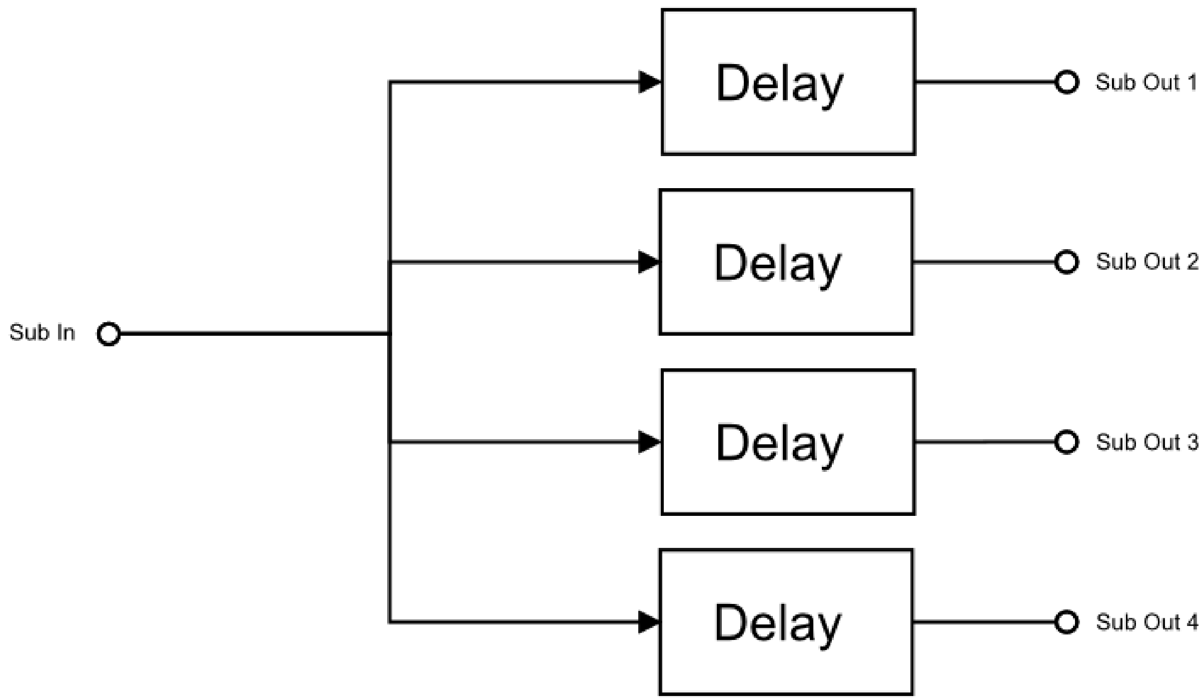

Figure 3. Another Alternative to the Configuration of Figure 1

This configuration has no delay block under the **Shared Filters** node of **Subwoofer Channels** in the Config View. Allowing the delays to take on negative values is permitted, and can be a useful technique if the delay implied by the AVR subwoofer distance setting in the as-measured condition is larger than the optimum value.

An exactly analogous situation exists with gains as well. MSO prevents configurations that will cause the optimizer trouble, and the preferred configurations for sub gains are analogous to the delay configurations of figures 2 and 3 above.

Delays and Gains Not Allowed in Mains Channels

Delays and gains cannot be added to mains channels. It's assumed that mains distance and level trims have been set correctly prior to performing measurements. Relative gain and delay are accomplished using adjustments to subwoofer channels only. Reductions in delay of the sub channels relative to the as-measured condition are accomplished by allowing negative delay values. A negative delay means that the delay should be reduced relative to the as-measured condition, which corresponds to increasing the subwoofer distance setting in your AVR.

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Multi-Sub Optimizer Reference

Changing Filter Parameter Values and Constraints

MSO allows you to manually adjust filter parameters and also use the optimizer to find the optimum parameter values. For any parameter, you can specify whether or not the optimizer is allowed to alter it. If you permit the optimizer to modify it, you can specify the range of permissable values (the constraints) for the parameter. If not, the parameter will retain its user-chosen value at all times. You perform these operations using the **Properties** window.

Using the Properties Window

Try adding a Parametric EQ to the **Filters** category of a channel. After doing so, select the filter node in the Config View on the left, and you'll see its properties displayed in the **Properties** window on the right. The **Properties** window is where you can examine and alter filter parameter values and their constraints. The first group of properties shown in the **Properties** window is "Filter Information", which is just a description of the type of filter, its reference designator, and the configuration and filter channel to which it belongs. You cannot change this information. The second and subsequent groups are the filter parameters, which can be changed. In the case of the Parametric EQ, the parameters are Center frequency in Hz, boost in dB, and Q. Each parameter has four properties: its value, minimum and maximum allowed values, and whether or not the optimizer is allowed to adjust the parameter's value. You can alter the properties of any parameter by clicking in the field containing the value and editing it directly. After doing so, press **Enter** to finalize the change. The text of the value will then change to bold. In addition, when clicking on the **Value** property, a spin-button control will appear, allowing you to adjust the value by pressing and holding the left mouse button down on a spin button arrow as well. This can be useful (or gimmicky, depending on your perspective) if a graph is currently being displayed having traces that depend on the value of the parameter. In this case, pressing and holding the spin button causes a "tuning" effect and the graph updates continually in real time to show the effect. The Windows spin-button control takes a while before its action speeds up enough for this to be easily visible.

Here's another example. Select the Parametric EQ you've added. Then right-click on it in the Config View, and while glancing at the Properties Window, choose **Lock Filter Parameters** from the context menu. You'll see the **Optimization allowed** property of all three parameters change from **True** to **False**. Then right-click on the filter again and choose **Unlock Filter Parameters** to change the **Optimization allowed** property back to **True** for all the filter's parameters. "Lock" in this context means "require the optimizer to respect the user's value for the filter parameters". The user can still modify any parameter value or other editable properties using the Properties Window. To lock a single parameter, it's necessary to do so using the Properties Window. If you need to alter many filters at once, locking and unlocking can be used at different levels of the tree hierarchy in the Config View (such as all filters in a channel, all subwoofer filters, all the way up to locking all filters in the configuration). We'll look at that more later.

The Importance of Constraints

Constraints are the means by which you prevent MSO from using parameter values that are unrealizable or impractical. The optimizer used by MSO is a general-purpose one, so it does not *automatically* constrain itself to avoid, say, boosting a null in a frequency response. You impart this information to MSO by applying constraints to filter parameters. This can be done on an individual filter basis using the **Properties** window as described above, or you can define constraints for different parameters of newly-created filters of various types choosing **Tools**, **Application Options** from the main menu. The **Application Options** property sheet has a tree view on its left, allowing different filter types to be chosen. Choosing a filter type will cause a property page for the selected filter type to be displayed on the right.

Example: Maximum Boost for Parametric EQ

Suppose you want to make the default maximum value for the boost of a parametric EQ filter equal to 3 dB. Select **PEQ** under the **Filters** category of the **Application Options** property sheet. At the upper right of the associated property sheet, check the checkbox labeled **Use custom value for maximum allowable gain**, and enter the number 3 in the **Custom maximum gain, dB** edit field. Click **OK** to close the **Application Options** property sheet. This change will only affect newly-created parametric EQ filters, not existing ones. If you wish to alter the maximum allowable boost of existing PEQ filters, you'll need to do so using the main **Properties** window.

Another Example of Constraints for Parametric EQ

Suppose your filter configuration has two parametric EQ filters per subwoofer channel, and you have configured all your parametric EQ filters to have a maximum boost of 3 dB. If one of your subwoofer responses had, say, a 6 dB dip at some frequency f_{dip}, MSO might find that the optimum solution put the center frequency of both parametric EQ filters for that channel at f_{dip} as well, giving a total boost of 6 dB at that frequency. This probably violates your intent of having a maximum boost of 3 dB at any frequency from parametric EQ. One way to fix this is to conceptually divide the frequency range of optimization into multiple ranges. You might set the minimum and maximum allowable center frequency values of the first parametric EQ to 20 Hz and 80 Hz respectively, and for the second parametric EQ, 80 Hz and 160 Hz respectively. Since these changes are for individual filters, the changes must be made using the **Properties** window. Splitting up the optimization frequency range into multiple bands, with one parametric EQ per band per subwoofer channel can help MSO converge on a solution more quickly, and help avoid situations you didn't intend.

Advanced Example: Ensuring High Output With Dissimilar Subwoofers

When using dissimilar subwoofers, ensuring high output is more difficult than it appears. Although MSO only deals with frequency responses and does not optimize large signal parameters, by using constraints and other techniques, you can steer the solutions of MSO toward those that are favorable to high output. This is discussed in the separate Dealing With Dissimilar Subwoofers topic.

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Multi-Sub Optimizer Reference

Associating Measurements With Filter Channels

After adding filter channels, measurements can be associated with each channel. Suppose you have four subs, and the mains were measured together as one, with both mains and subs measured at four listening positions. You might have measurements named as follows:

MLP:Mains
MLP:Sub 1
MLP:Sub 2
MLP:Sub 3
MLP:Sub 4
Pos 2:Mains
Pos 2:Sub 1
Pos 2:Sub 2
Pos 2:Sub 3
Pos 2:Sub 4
Pos 3:Mains
Pos 3:Sub 1
Pos 3:Sub 2
Pos 3:Sub 3
Pos 3:Sub 4
Pos 4:Mains
Pos 4:Sub 1
Pos 4:Sub 2
Pos 4:Sub 3
Pos 4:Sub 4

For each channel defined in the Config View, right-click its **Measurement Associations** category node and choose **Associate Measurements** from the context menu. This will open up a dialog box showing the measurements available for association. Using the example of the measurement names above, since each measurement name contains the name of its corresponding sub (or mains speaker as applicable), this association of measurement to channel is straightforward. For instance, all "Sub 1" measurements above could be associated with the "Sub Channel 1" channel, all "Sub 2" measurements could be associated with the "Sub Channel 2" channel, and so on. Only the measurements that are currently available for association will be shown in the dialog box. For example, mains measurements cannot be associated with sub channels and vice versa. Also, once a measurement is associated with a channel, it is considered "used up" for this particular purpose and cannot be associated with any other channel. Assuming no extraneous measurements were imported, after doing your measurement associations, all imported measurements should be associated with either a mains or sub channel.

Multi-Sub Optimizer Reference

Adding Measurements to Measurement Groups

Once a measurement has been associated with a filter channel, it can be added to one or more *measurement groups*. A measurement group is a collection of measurements whose complex summation should ideally have a flat magnitude response vs. frequency (or conform to a house curve) as a goal for optimization. MSO can optimize the frequency response of multiple measurement groups simultaneously. If the measurement groups correspond to listening positions, this improves response flattens at all positions at once.

Assume we're using the example list of measurement names from the previous section, and repeated below.

MLP:Mains
MLP:Sub 1
MLP:Sub 2
MLP:Sub 3
MLP:Sub 4
Pos 2:Mains
Pos 2:Sub 1
Pos 2:Sub 2
Pos 2:Sub 3
Pos 2:Sub 4
Pos 3:Mains
Pos 3:Sub 1
Pos 3:Sub 2
Pos 3:Sub 3
Pos 3:Sub 4
Pos 4:Mains
Pos 4:Sub 1
Pos 4:Sub 2
Pos 4:Sub 3
Pos 4:Sub 4

The complex summation of all MLP measurements should ideally have a flat frequency response, and the same holds true for Pos 2, Pos 3 and Pos 4. Thus all the MLP measurements should be in the same group, all the Pos 2 measurements in another group, and so on. Why not call measurement groups "listening positions" or something similar? The reason is that most of the time, measurement groups do correspond exactly with listening positions, but not always. Consider a two-channel system with two mains and two subs used in stereo mode. In this scenario, one measurement group might contain left main and left sub data at the MLP. Another measurement group might contain right main and right sub data, also at the MLP. A third group might contain left main, left sub, right main and right sub data taken at the MLP. Thus you'd want the frequency response of the left channel alone, the right channel alone, and both channels playing together in mono to each be as flat as possible vs. frequency after optimization. This is admittedly an unusual case.

Using the list of measurement names above, we'd create four measurement groups, one for each listening position (MLP, Pos 2, Pos 3 and Pos 4). To do so, in the Config View, right-click on the **Measurement Groups to Optimize** category node under **Optimization Parameters** and choose and choose **Add Measurement Group** from the context menu. This will add a measurement group and automatically pop up a dialog box allowing the measurements for the group to be chosen. Check all the measurement names beginning in "MLP", then press the **OK** button to apply the selections. Select the tree node with the measurement group name, which was automatically generated as "Measurement Group 1" and rename it using the usual method (**F2** key) to MLP. Repeat the procedure for the three other listening positions. When you're done, you'll have four measurement groups, one for each listening position, each containing five measurements.

With measurement groups defined as above, MSO is ready to perform an optimization. If we were to run the optimization, MSO would try to optimize the frequency responses at the MLP, Pos 2, Pos 3 and Pos 4 to be as flat as possible. But before doing so, let's take a look at how we can display some data using graphs.

Multi-Sub Optimizer Reference

Displaying Data With Graphs

Graphs can display the following types of frequency response data in any combination for a given graph.

- A raw measurement as imported from disk
- A measurement filtered by the response of the filter channel to which it is associated
- The frequency response of a filter channel
- The frequency response of a measurement group. This is computed from the complex summation of the measurements in the group.
- The target curve (house curve), if any, assigned to a configuration.

To add a new graph, you can do either of the following:

- From the **Graph** menu, choose **New Graph...**
- In the Data View tab, right-click on the **Graphs** category node and choose **New Graph...** from the context menu.

This will launch a property sheet dialog having a tree display on its left side. The tree display contains category nodes which, when clicked, expand to show a list of property pages that can be activated to control various options for the new graph.

The **Data** category expands to show the four types of frequency response data sets you can add (Measurements, Filter Channels, Filtered Measurements and Measurement Groups). Selecting one of these subitems in the tree will cause an arrow icon to appear to its left, and the available data for that category will be shown in a property page on the right, with a checkbox for each one allowing persistend selection. Select the data you want to display. Pressing the Apply button will apply the changes without closing the property sheet, allowing experimentation with various settings.

The **Format** category allows for controlling various aspects affecting graph appearance (General, Axes and All Traces). The **General** property page allows for specifying the graph title and an option to hide it, whether or not a legend will be displayed, and the legend's location if visible. The **Axes** property page allows the properties of the x axis and left and right y axes to be set. This includes whether or not the axis is autoscaled, and the limits if manual scaling is used. It is suggested to start out with autoscaling of the y axis, then pressing the **Apply** button to see the results. Then switch to manual scaling if needed and adjust axis limits as desired, pressing **Apply** to test the changes each time. Grid visibility should be set to **Automatic** except for unusual cases. The **All Traces** property sheet controls how traces as a whole for this graph are displayed. You can display magnitude only, phase only, both, or elect to specify this individually for each trace. You can enable or disable phase unwrapping for the phase traces. Phase unwrapping presents the phase vs. frequency as a continuous curve without discontinuities near ±180°. When done modifying the graph properties, click the **OK** button to close the graph property sheet.

Appearance and behavior of individual traces of a graph are controlled via the **Trace Properties** property sheet. It can be launched in two ways.

- Right-click on the graph itself and choose **Trace Properties...** from the context menu.
- In the Meas View, locate the node of the graph, right-click on it and choose **Trace Properties...** from the context menu.

This property sheet allows selection of any trace by name and setting its magnitude and phase display offsets, whether or not you want the trace to update in real time as an optimization is running, and the trace color and line thickness.

A similar property sheet can be launched from the main menu by choosing **Trace Properties...** from the **Graph** menu. This property sheet differs from the one just discussed by allowing you to edit the traces of all defined graphs rather than just the selected one. This makes the **Apply** button less useful, as the desired graph may not be visible.

Saving Graphs as PNG Files

A graph can be saved to disk as a PNG file without needing to use a screen capture program. To do so, ensure that the graph you want to save in this way is visible. The two ways to save a graph as PNG are:

- Right-click on the graph itself and choose **Save as PNG File...** from the context menu.
- From the main menu, choose **Graph, Save as PNG File...**

This will launch a standard **Save As** dialog. Navigate to the desired directory, choose a file name, and press **OK** to save the file.

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Multi-Sub Optimizer Reference

Specifying Optimization Options

Before running an automated optimization, the optimization options should be set. On the main menu, choose **Tools**, then **Optimization Options...**. This will launch a property sheet with three property pages. The first page, called **Criteria** allows for specifying the frequency range for optimization, the frequency range over which the reference value is computed, and the maximum time the optimizer is allowed to run.

For each measurement group, the RMS value of the deviation of the response of that group from the reference level is computed over frequency. The frequency range over which this computation is performed is specified in the **Frequency range to optimize** field. The reference level is not specified directly as a numeric value, but indirectly using a range of frequencies. This range is the **Frequency range to compute reference**. The average value of the combined response of mains and subs at a given listening position is computed over the frequency range specified in the **Frequency range to compute reference** fields. This is the reference level. The reference level may therefore shift during the process of the optimization, especially if some EQ is being applied to the mains. This is one reason for the recommendation of a rather high 300 Hz upper limit to the exported measurement data. If the frequency range over which the reference level is computed were, say, 150 Hz to 300 Hz, and the optimization frequency range only extended to 175 Hz, then as long as filter constraints are not specified improperly, much of the response in the reference level frequency range will be unaffected by the EQ at the lower frequencies. Stated differently, to get the lowest possible frequency response error, the reference level needs to shift a little, but not too much. If it shifts too much, an undesired baseline shift between subs and mains can occur. To prevent the reference level from shifting too much, the reference level frequency range needs to include some higher frequencies unaffected by the optimization to act as a kind of "anchor".

The final option on the **Criteria** page is the time duration the optimizer is allowed to run. The optimizer is always searching for a better solution as long as it's running. The maximum allowed duration can be specified here, and may require a bit of experimentation to get right. If too long a duration is specified, the optimization is easily stopped via the **Stop Optimization** button on the toolbar.

The second property page is the **Group Weights** page. For each measurement group, the RMS amplitude deviation from the reference in dB is computed over frequency. Then these RMS errors are again combined in an RMS fashion over all measurement groups to get a single number whose value would be 0 dB for perfectly flat response at all listening positions. This second stage of RMS error computations can be weighted, for example to prefer a slightly flatter response at the main listening position. This is done by giving the MLP a weight of 1.0 and the other listening positions a weight of less than 1.0, maybe something like 0.75 for all non-MLP positions.

Finally, a house curve can be imported in the **House Curve** page. It is *not* recommended to establish a house curve via individual EQ of each sub. Rather, individual EQ should be used to establish a flat response, and EQ applied at a later stage via a shared filter DSP channel EQ with the individual filters locked. This will be discussed later.

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Running Automatic Optimization

To run an optimization, press the **Start Optimization** button on the toolbar or choose **Config**, then **Optimize** from the main menu. This will activate the Optimization Status tab of the Output Window and show running status of the results. If you have a graph open with traces having the **Plot live data when optimizing** property checked, these traces will update each time the optimizer reaches an improved solution. You can either wait for the optimization to complete, or press the **Stop Optimization** button on the toolbar. In either case, MSO will ask you whether you want to keep the results the optimizer computed or revert to the original state. Click the appropriate button on the dialog box to proceed.

Multi-Sub Optimizer Reference

Listing Filter Parameters in a Filter Report

When the optimization is complete, you can see a summary of the parameter values of all filters by choosing **Config**, then **Show Filter Report** from the main menu. This will list all parameter values for all filters in a text display.

Gettiong Optional Biquad Parameters

Support for biquad parameters in miniDSP-compatible text format can be enabled. From the main Menu, choose **Tools**, then **Application Options**. Click the **Hardware** folder in the property sheet's left pane. This will give you the option to include biquad information in the filter reports, and allow you to choose the sample rate used by the device. Refresh or regenerate the filter report to show the coefficients.

Special Topics

Understanding Configurations

MSO works by evaluating many different combinations of filter parameter values and finding combinations that give the flattest combined response of mains and subwoofers at multiple listening positions. However, it cannot determine automatically what types of filters are necessary or how many of them are needed. Parametric EQ (PEQ) is the primary tool for manipulating each sub's response. To determine how many PEQs are needed per subwoofer channel, some experimentation is necessary. For each experiment, you'll probably want to keep the results to compare with other experiments. This is one problem that *configurations* were designed to solve. Instead of having a separate project for each experiment, you create multiple configurations within a given project. This allows for comparing the results of multiple configurations on a graph.

MSO treats each filter as a completely independent entity. This has an unfortunate side effect when working with crossovers. If you were to set the **Optimization allowed** property to **True** for the cutoff frequency parameter of each of the low-pass and high-pass filters filters that make up the crossover, MSO would adjust each one independently to optimize the system. But this would generally result in different cutoff frequencies for the high-pass and low-pass filters. AVRs and pre-pros force the cutoff frequencies of the high-pass and low-pass sections of the crossover to identical values. In this case, MSO's optimized result would be incompatible with your hardware. The solution is to set the **Optimization allowed** property to **False** for these cutoff frequency parameters, then set the cutoff frequencies to the same value manually. To try out different crossover frequencies, use a separate configuration for each one.

The Initial Configuration

When starting from scratch with an empty project, MSO creates a single, empty configuration called "Config 1". You can rename this configuration by clicking on its node in the Config View and pressing **F2**. After importing your measurements, you flesh out the configuration by performing the following steps.

- Define your filter channels

- Add filters, delays and gains to these channels
- Associate measurements with your filter channels
- Add measurements to measurement groups to define your optimization goals

To evaluate an alternative set of filters and compare the results with the initial or subsequent configuration, you can *clone* a configuration. This means you'll only have to perform the above steps once for a given project.

Cloning a Configuration

To evaluate the performance of different crossover frequencies or different numbers of PEQ filers per subwoofer channel, you'll need to create a new configuration for each alternative you want to evaluate. You could create a new configuration using **Config**, **New** from the main menu. But that would create a new empty configuration, which requires that the four steps in the list above be performed all over again. This is unnecessary work. To save this effort, *clone* an existing configuration instead. This can be done in two different ways.

- Choose **Config**, **Clone** from the main menu, or;
- In the Config View, right-click on the node of the configuration you wish to clone, and select **Clone Configuration**

If you choose **Config**, **Clone** from the main menu and there is only one existing configuration, it will be cloned immediately. If there is more than one, a dialog box will pop up, asking which configuration you wish to clone. Choose the desired configuration and click **OK**. The cloned configuration initially takes on all the elements of the original, but it is completely independent of the original in all other respects. To rename the newly-cloned configuration, click its name in the Config View and press **F2**.

Evaluating Different Crossover Frequencies

Once you have cloned a configuration, you can change the cutoff frequency parameter of the crossover low-pass and high-pass filters of the clone to the desired value. Always make the cutoff frequencies of the low-pass and high-pass halves of the crossover equal to one another, and always ensure that the "Optimization allowed" property of each low-pass and high-pass cutoff frequency parameter is set to **False**.

Evaluating Different Parametric EQ Combinations

The configuration feature is also a good way to explore the effects of having different numbers of PEQ filters per subwoofer. It's a good idea to start simple with the initial configuration, possibly using only gains and delays to flatten the overall response. Then clone the configuration to add one PEQ at a time. If your configuration has more than one PEQ per subwoofer, it may be advantageous to split the optimization frequency band into multiple mutually exclusive sub-bands, and change the constraints (the minimum and maximum allowable values) of each PEQ center frequency value to give one PEQ per sub-band.

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Special Topics

Working With Dissimilar Subwoofers

When the subwoofers you're using aren't identical, extra steps are needed to ensure that the optimization performed by MSO does not degrade maximum output substantially. This might occur if you follow some recommendations to have one large, high-output sub, called the "super sub", along with several other smaller, lower output subs called "helper subs". Unless you take extra steps, MSO might apply too much gain to a helper sub that's not capable of the corresponding output. These steps consist of the following.

1. When setting up subwoofer gains before measurement, set them so the helper subs are at the highest permissible level relative to the "super sub" and no higher.
2. Apply the appropriate constraints to the gains on the helper subs to prevent these gains from increasing relative to the "super sub" gain in the as-measured condition.

These guidelines are based on the assumption that maximum output should be limited only by the "super sub", not the helper subs.

The first step of setting up the relative gains of the subs before measurement is straightforward only if you've designed the subs and can produce a plot of the cone excursion vs. frequency for a given voltage amplitude. If you have this information, you can set the gains of the helper subs relative to the "super sub" such that for a sine wave sweep, all subs have the same ratio of maximum peak cone excursion over frequency to maximum allowable cone excursion x_{max}. Without such information, some approximation must be made to determine the relative gains.

The second step of applying constraints to sub gains should be done as below in Figure 4.

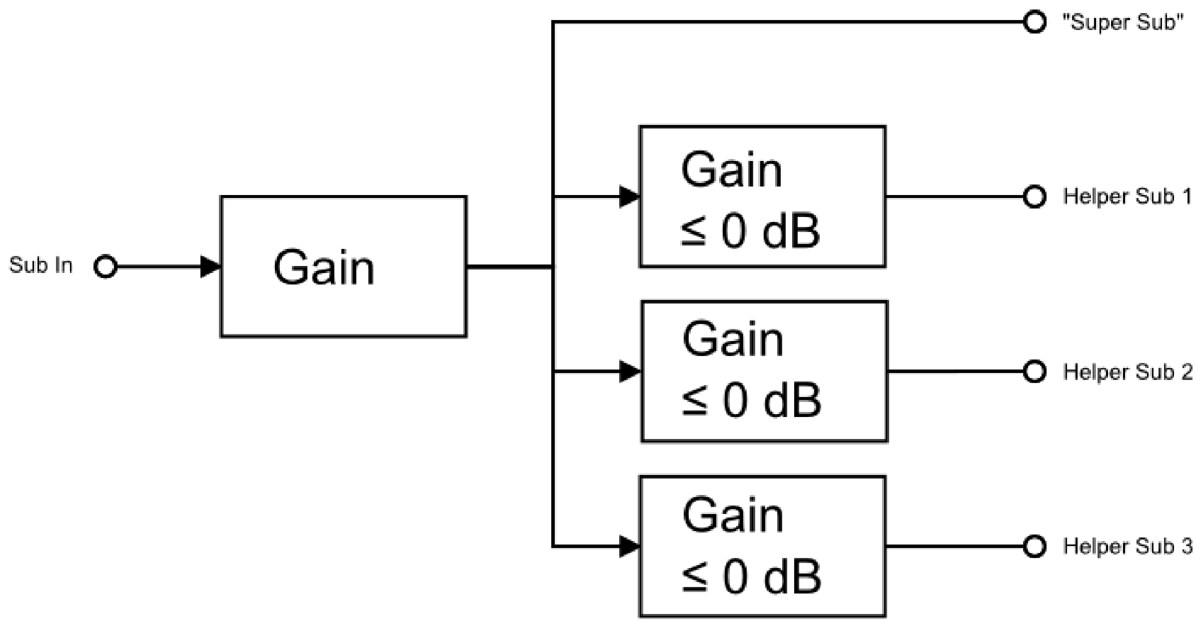

Figure 4. Gain Constraints for Dissimilar Subs

The "super sub" channel has no gain block, so its gain value is forced to 0 dB. The leftmost gain block adjusts the level of all subs relative to the mains simultaneously. The maximum allowable gain for the helper subs is set to 0 dB using the Properties Window. Since step 1 of the recommendations above sets the as-measured condition such that the helper subs are at their maximum permissible level relative to the "super sub", all helper subs are now constrained to be below this level after frequency response optimization.

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