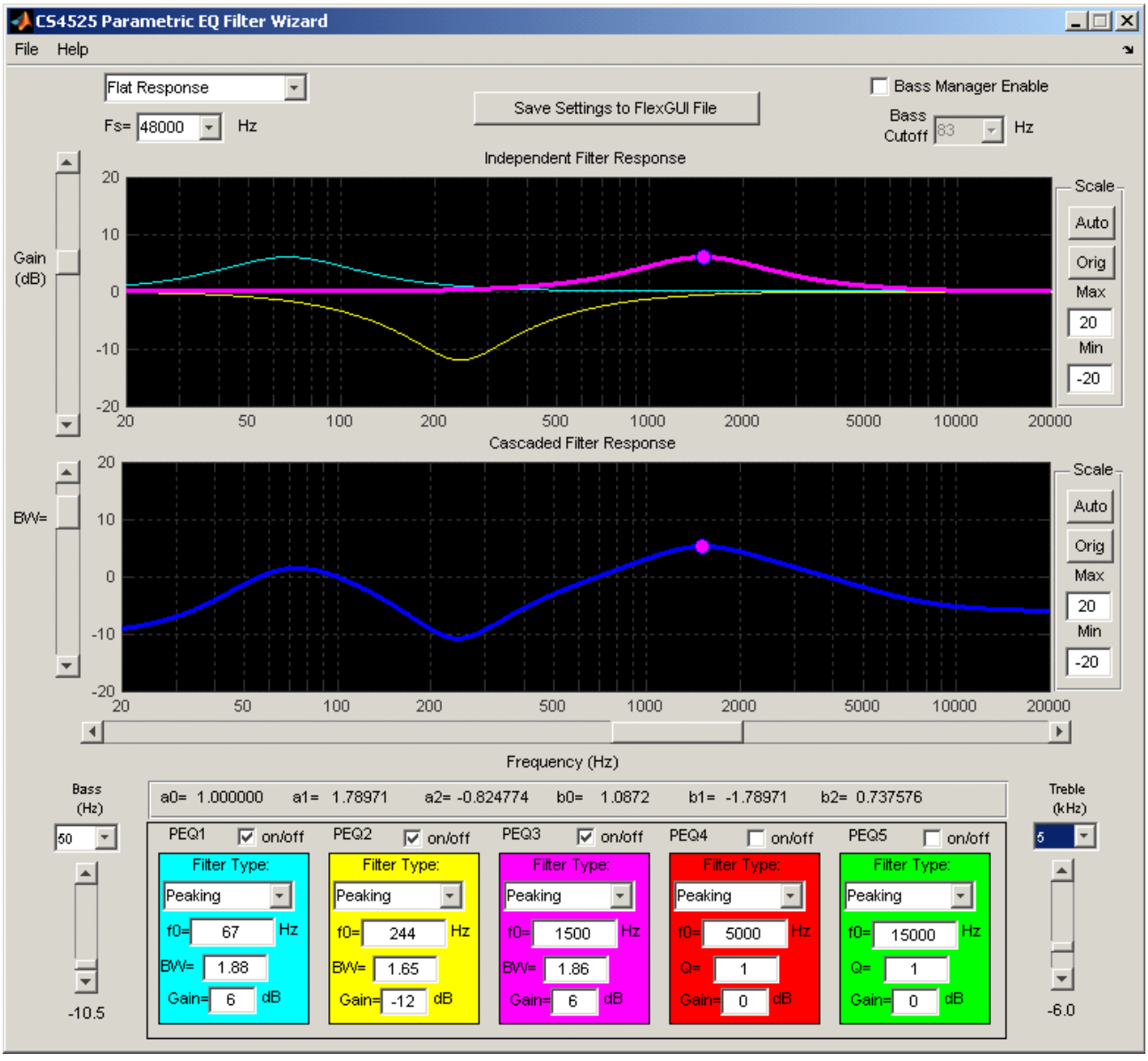
CS4525 Parametric EQ Filter Wizard

1. OVERVIEW

The CS4525 Parametric EQ Filter Wizard provides a graphical interface to the Parametric Equalization, Bass Manager, and Tone Control features of the CS4525. The user can graphically configure any or all of the five on-chip biquad filters, the Bass Manager crossover frequency, and the bass/treble shelving filters available in the CS4525 via the application's Graphical User Interface (GUI). The desired filter settings are downloaded to the CS4525 chip via the FlexGUI interface using a configuration file that is generated by the Filter Wizard application.



2. TERMS

The following section defines terms frequently used throughout this document.

Filter Wizard Application

The CS4525 Parametric EQ Filter Wizard application and graphical user interface components.

Active Filter

A filter is active when its filter state box “on/off” is checked in the filter panel. When a filter is active, its response is visible in the amplitude response windows, and the generated FlexGUI file contains the filter and configures its biquad coefficients. When a filter is not active, its response is masked in the amplitude response windows, and the generated FlexGUI file contains a unity-gain, pass-through biquad in place of the filter.

Selected Filter

When one or more filters are active, the Filter Wizard application recognizes one filter as the currently selected filter. When a filter is enabled or when one of its parameters is changed, it becomes the selected filter. Clicking on a filter response curve within the independent filter response window also selects the filter. Subsequently, clicking and dragging within the independent filter response window changes the shape of the selected filter response curve. The significant frequency of the selected filter is highlighted by a solid circle in the Independent and Cascaded Filter Response windows.

3. GETTING STARTED

3.1 System Requirements

The Filter Wizard application requires a PC with the Windows XP® operating system.

3.2 Files

The following files are required to run the Filter Wizard application: MCRInstaller.exe - Matlab® Component Runtime Installer, filtergui.exe - CS4525 Parametric EQ Filter Wizard application, filtergui.ctf - Component Technology File archive.

3.3 Installation

Before running the Filter Wizard application for the first time: 1.) Run the self-extracting MCR library utility, MCRInstaller.exe, from a directory. 2.) Copy filtergui.exe and filtergui.ctf into your desired application directory.

3.4 Running the Application

Double-click on the application "filtergui.exe" icon.

3.5 Interfacing with CS4525 via the FlexGUI

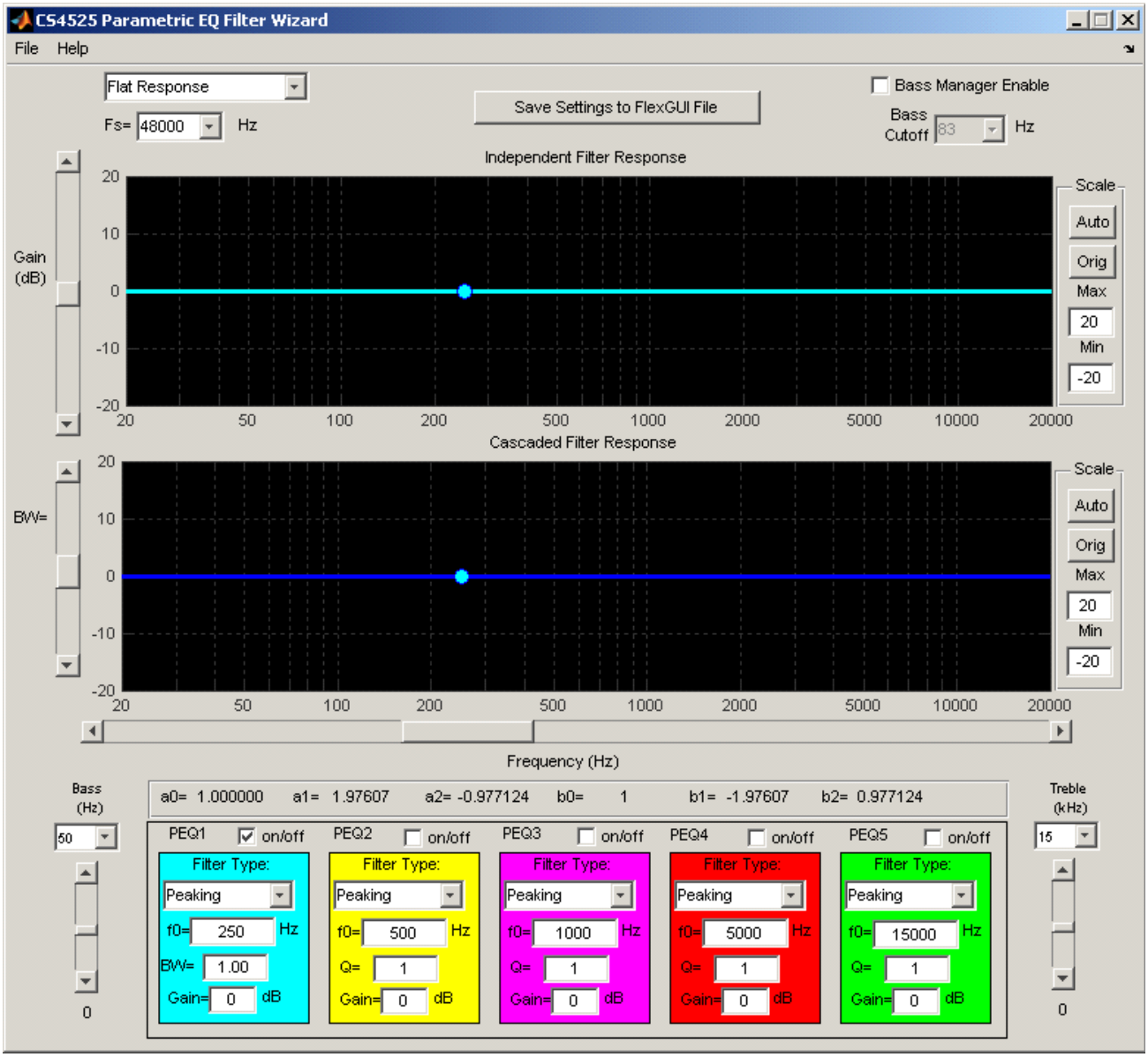
Interfacing with the CS4525 via the FlexGUI requires the following:

- CRD4525 reference design board
- Current version of Cirrus Logic FlexGUI software installed on machine
- USB interface established between CRD4525 board and PC

For more information, consult the Cirrus Logic FlexGUI documentation at www.cirrus.com.

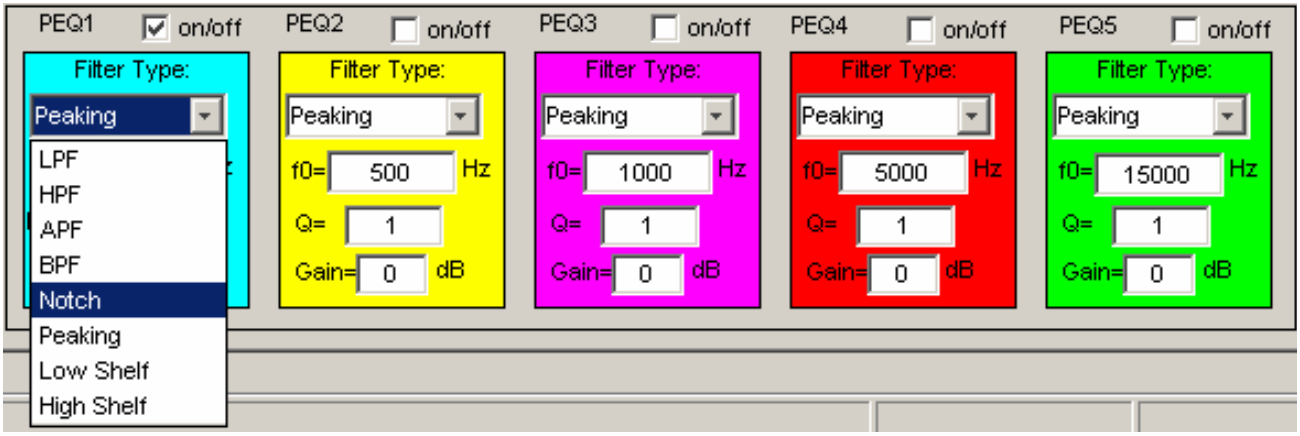
4. QUICK START: CREATING A NOTCH FILTER

This section describes how to create a Notch Filter and download the settings onto the CS4525 chip. To begin, launch the Filter Wizard Application. The default settings and window are shown below.



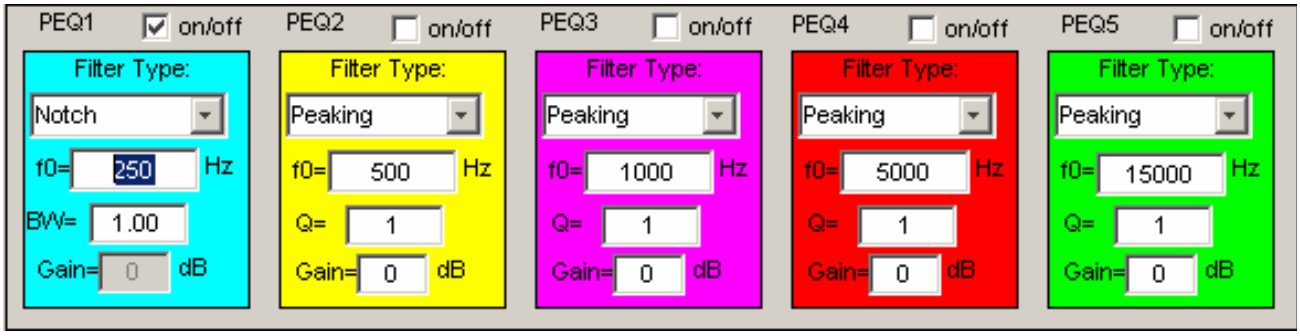
Notice PEQ1 is automatically enabled.

To configure PEQ1 as a Notch Filter, first change the Filter Type in the filter panel by selecting "Notch" from the drop-down menu labeled "Filter Type".

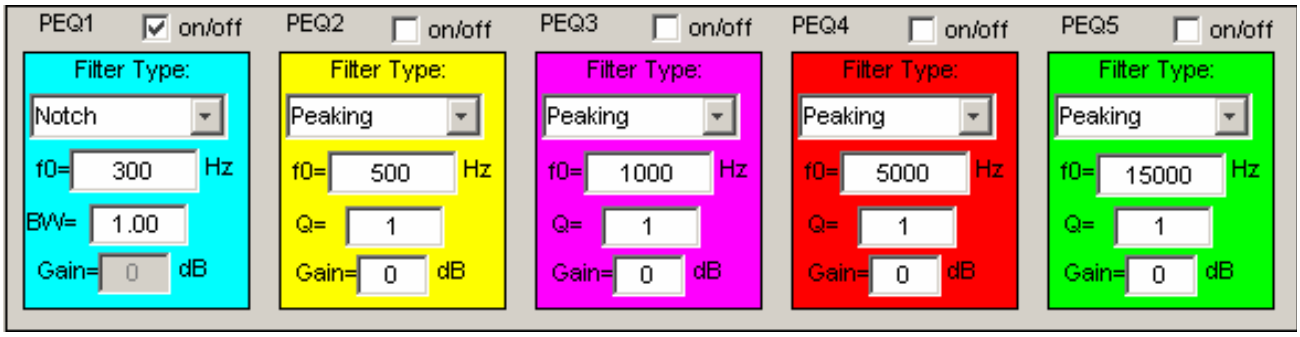


Notice that the "Gain" parameter is now grayed-out in PEQ1. That's because the Notch Filter does not have a Gain parameter (see PEQ Filter Parameter chart in Section 5 on page 7).

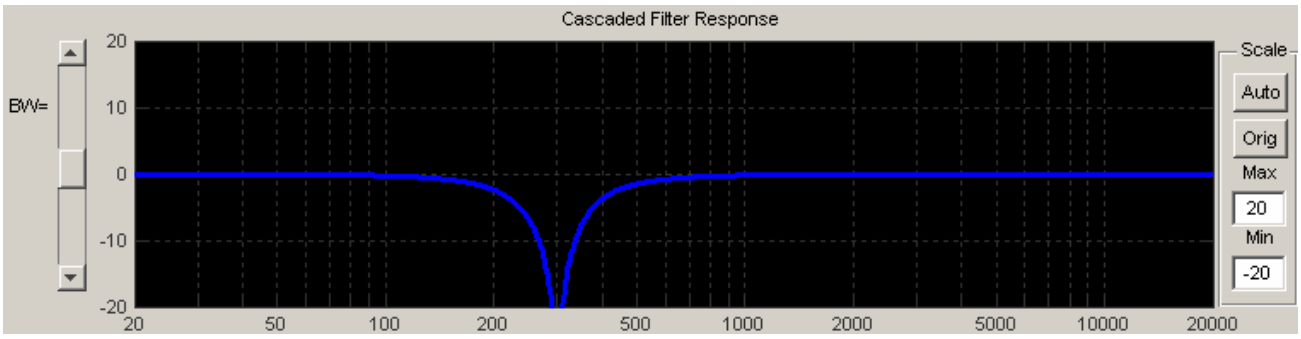
Next, change the value of f0 by selecting the text in the editable text box and typing the desired center frequency for the Notch Filter.



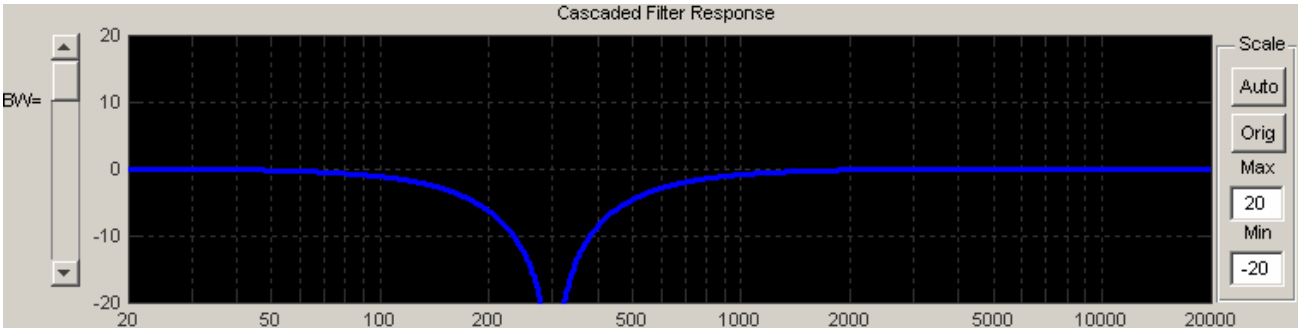
In this example, replace "250" with "300" to create a Notch Filter centered around 300 Hz.



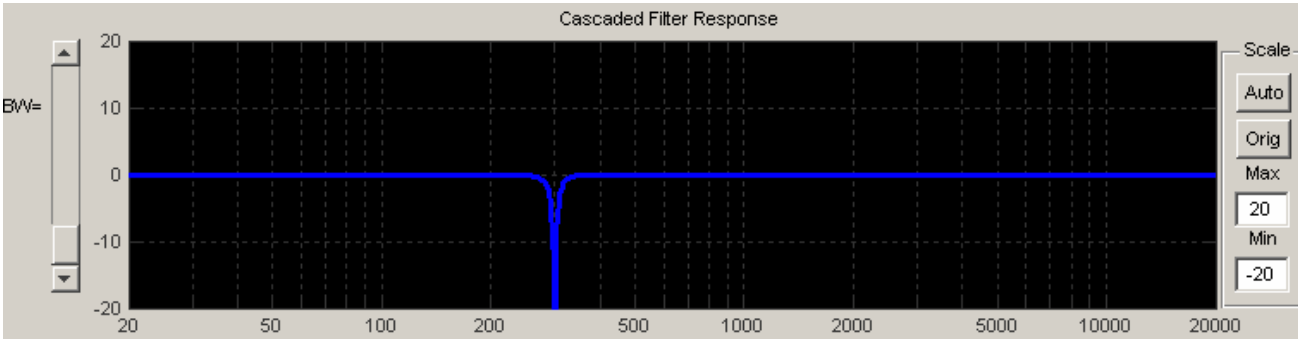
The Cascaded Filter Response now looks like this:



To widen the attenuation band, increase the Bandwidth parameter using the slider on the left side of the Cascaded Filter Response.

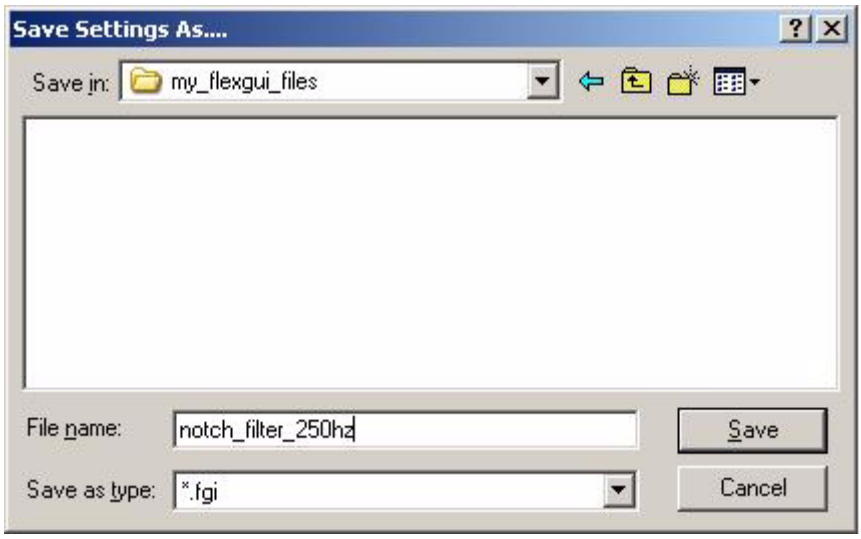


To make the attenuation band more narrow, decrease the Bandwidth parameter using the same slider.



Once you are satisfied with the shape of your filter, you will need to create a FlexGUI file for downloading the filter settings onto the CS4525 chip via the FlexGUI interface to the CRD4525 board. To do this, simply click on the "Save Settings to FlexGUI File" button at the top of the Filter Wizard GUI.

You will be prompted to save the file. Choose a name and destination for your file; then click "Save".



Establish a connection to your CRD4525 board via the FlexGUI USB interface. From the FlexGUI, select "File –> Restore Board Registers…" to load your newly created FlexGUI configuration file onto the CS4525 chip.

5. PEQ FILTERS

The following table describes the available Parametric EQ filters and filter parameters:

Filter Type	f0	Q/BW/S	Gain
Low Pass (2^{nd} order)	Corner Frequency (Hz)	Q factor of the filter, defined by the following equation, $Q = \frac{1}{2\zeta}$ where ζ is the damping factor. As Q increases, the filter is amplified at the resonant frequency and falls off more quickly just past the resonant frequency. As the frequency moves further away from f_0, the filter reaches a steady slope of -12 dB/octave.	N/A
High Pass (2^{nd} order)	Corner Frequency (Hz)	Q factor of the filter, defined by the following equation, $Q = \frac{1}{2\zeta}$ where ζ is the damping factor. As Q increases, the filter is amplified at the resonant frequency and falls off more quickly just past the resonant frequency. As the frequency moves further away from f_0, the filter reaches a steady slope of -12 dB/octave.	N/A
All Pass	Corner Frequency (Hz)	Q factor of the filter. Since an all pass filter has a flat amplitude response, the Q factor only affects the slope of the phase.	N/A
Band Pass	Center Frequency (Hz)	BW – Bandwidth, in octaves, described by the following equation: $BW = \log_2\left(\frac{fh}{fL}\right)$ where f_h and f_L are the frequencies at which -3 dB attenuation occurs.	N/A
Notch	Center Frequency (Hz)	BW – Bandwidth, in octaves, described by the following equation: $BW = \log_2\left(\frac{fh}{fL}\right)$ where f_h and f_L are the frequencies at which -3 dB attenuation occurs.	N/A
Peaking	Center Frequency (Hz)	BW – Bandwidth, in octaves, described by the following equation: $BW = \log_2\left(\frac{fh}{fL}\right)$ where f_h and f_L are the frequencies at which midpoint gain (dB) occurs.	Filter Gain (dB)
Low Shelf	Center Frequency (Hz) at which gain/attenuation in dB is one half the total filter gain/attenuation.	*S* - Shelving Slope in dB per octave described by the following equation: $S = (filtergain(dB))/\log_2\left(\frac{fh}{fL}\right)$ where f_h is where gain/attenuation begins, and f_L is where the filter has reached its desired level.	Filter Gain (dB)
High Shelf	Center Frequency (Hz) at which gain/attenuation in dB is one half the total filter gain/attenuation.	*S* - Shelving Slope in dB per octave described by the following equation: $S = (filtergain(dB))/\log_2\left(\frac{fh}{fL}\right)$ where f_L is where gain/attenuation begins, and f_h is where the filter has reached its desired level.	Filter Gain (dB)

6. TONE CONTROL

The CS4525 implements bass and treble shelving filters for added tone control that is adjustable from the Filter Wizard application. The adjustable parameters are cutoff frequency and gain. The gain provides a cut or boost from -10.5 dB and +12.0 dB in 1.5 dB increments. The nominal treble cutoff frequencies are 5 kHz, 7 kHz, 10 kHz, and 15 kHz. The nominal bass cutoff frequencies are 50 Hz, 100 Hz, 200 Hz, and 250 Hz. The actual cutoff frequencies vary slightly with different sampling rates. Refer to the CS4525 data sheet.

7. BASS MANAGER

The Bass Manager engages a 24 dB per octave Linkwitz-Riley crossover filter that separates the high and low frequencies at the specified crossover frequency. When the Bass Manager is enabled, Channels 1 and 2 are high-pass and low-pass filtered at the crossover frequency. The low-pass filtered frequencies from Channels 1 and 2 are each attenuated by 6 dB and summed together to provide the Sub. Channels 1 and 2 will contain the high frequencies from the original incoming Channels 1 and 2, as specified by the crossover frequency. When the Bass Manager is disabled, the crossover filter is not engaged, and there the Sub channel is muted.

8. GRAPHICAL USER INTERFACE (GUI)

Refer to the GUI Component Map (Figure 1) throughout this section for detailed GUI component descriptions.

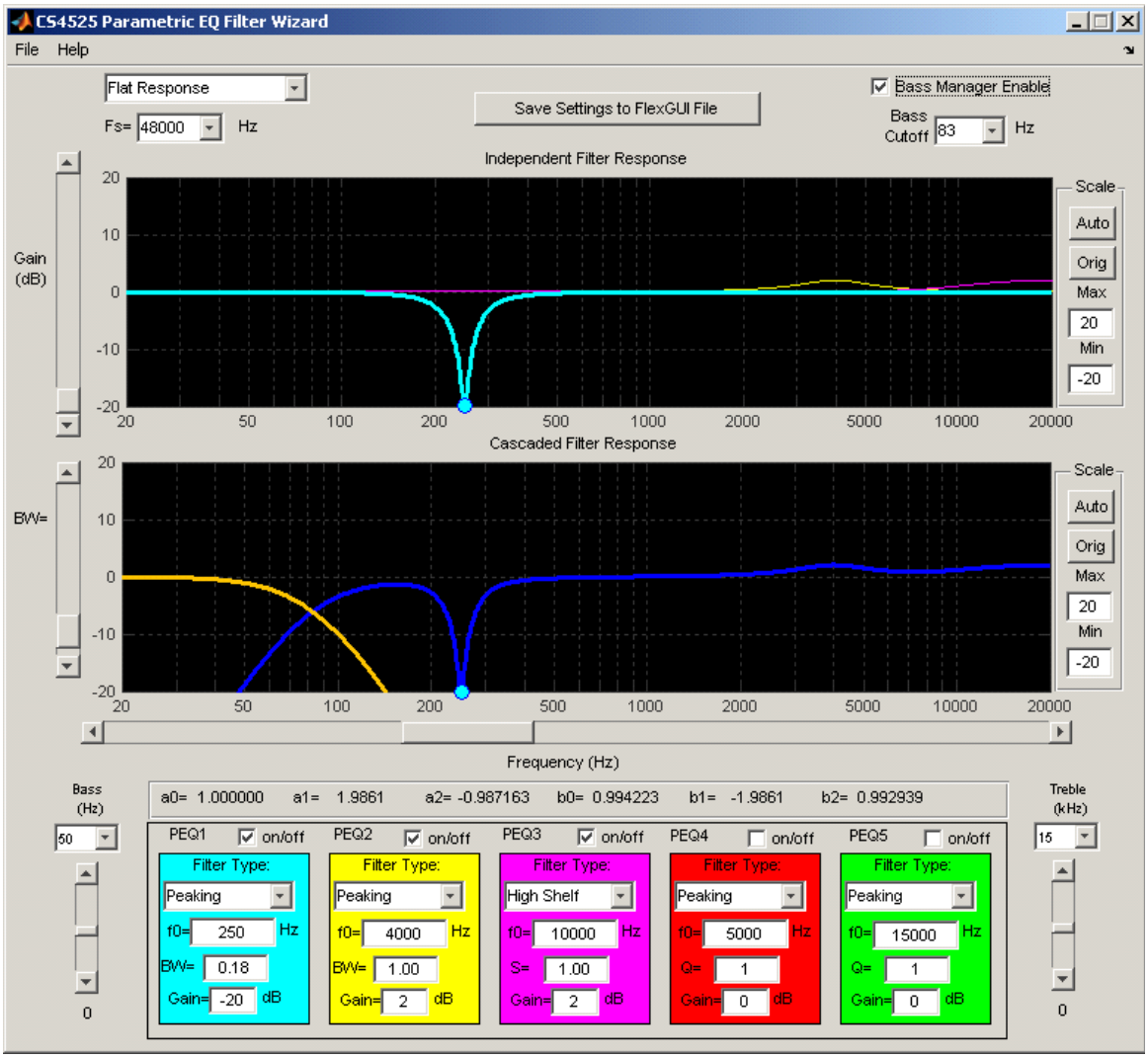


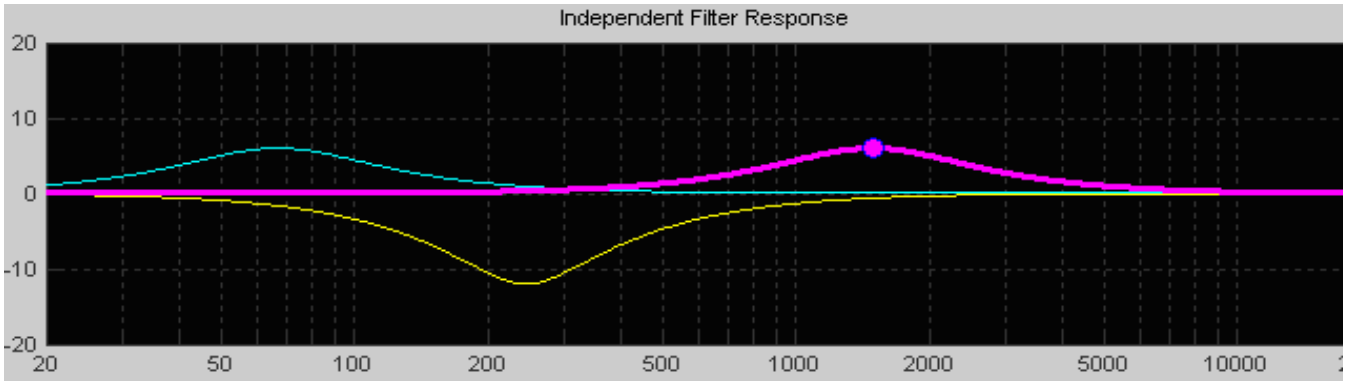
Figure 1. Graphical User Interface Component Map

8.1 Amplitude Response Curves

The Filter Wizard application GUI displays two amplitude response windows – Independent and Cascaded.

8.1.1 Independent Filter Response

The Independent Filter Response window displays the amplitude response curves for all active filters.



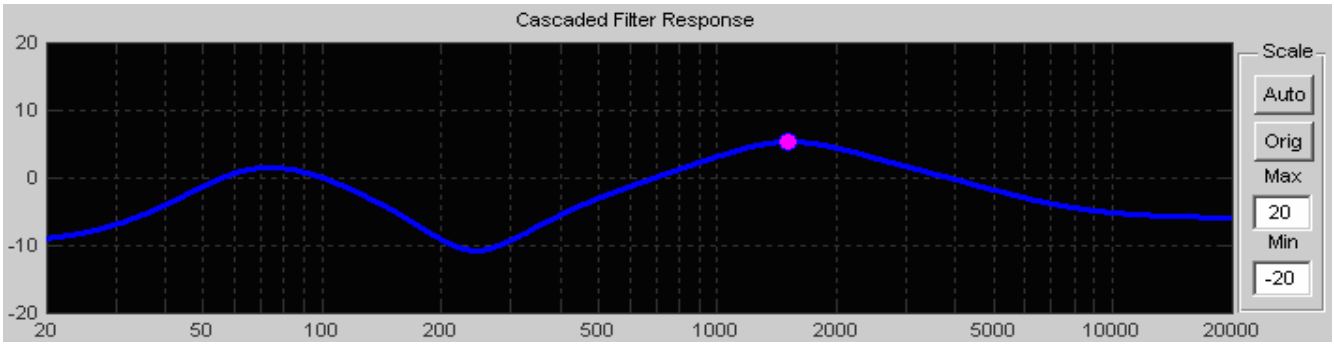
The color of each response curve corresponds to the color of the filter represented as shown in the filter panel. The response shown in bold is the response of the currently selected filter. The solid circle on the selected filter highlights the significant frequency of the selected filter.

Click and drag the mouse anywhere inside the Independent Filter Response window to change the shape of the selected filter. Use the sliders or the filter panel to adjust one parameter at a time.

To adjust the scale of the y-axis (dB), use the scale panel to the right of the response window. Use "Auto" to auto-scale the axis, "Orig" to return to +/- 20 dB scale, or manually adjust the upper and lower limit by editing the values in the Max and Min text boxes.

8.1.2 Cascaded Filter Response

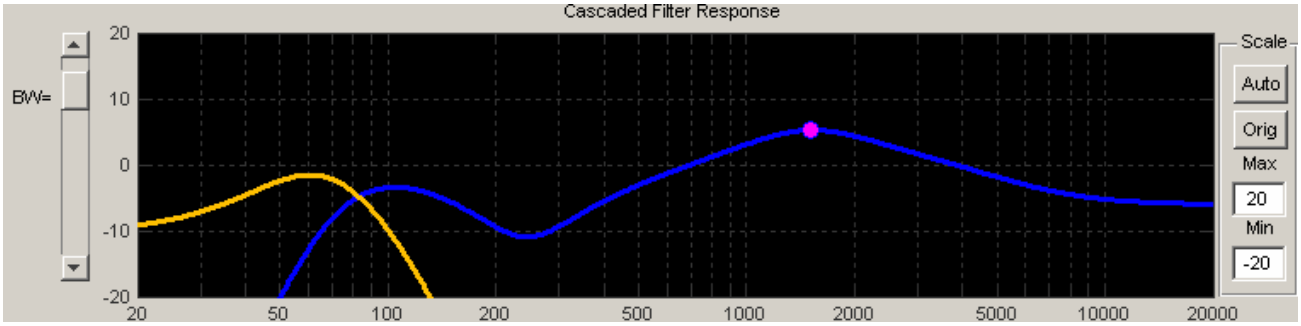
The Cascaded Filter Response window displays the cumulative amplitude response curve for all active filters in series.



The solid circle on the cascaded response curve highlights the significant frequency of the selected filter.

Click and drag anywhere on the response curve to display the gain at that frequency.

When the Bass Manager is enabled, the response of the LFE channel is displayed in orange.



To adjust the scale of the y-axis (dB), use the scale panel to the right of the response window. Use "Auto" to auto-scale the axis, "Orig" to return to +/- 20 dB scale, or manually adjust the upper and lower limit by editing the values in the Max and Min text boxes.

8.2 Bass Manager Enable/Disable

Click in the checkbox labeled "Bass Manager Enable" to enable/disable the Bass Manager. When the Bass Manager is enabled, adjust the crossover frequency using the drop-down box labeled "Bass Cutoff".

8.3 Sliders

Slider Name	Function
Gain Slider	Adjusts the gain of the selected filter
Frequency Slider	Adjusts the significant frequency of the selected filter
Q/BW/S Slider	Adjusts the Q, Bandwidth, or Shelf Slope (filter-dependent) of the selected filter

8.4 Tone Controls

Select the corner frequency and gain settings for the bass/treble tone controls.

8.5 Filter Panel

The filter panel shows the status and parameter settings for each of the CS4525 on-chip parametric EQ filters. The color of each filter panel corresponds to the color of the filter's amplitude response curve in the Independent Filter Response window.

8.5.1 On/Off

Toggle this checkbox to enable/disable the filter. Enable each filter to view the response in the response windows. To hide a filter's response, disable the filter. All settings for each disabled filter will be maintained in the GUI when disabled. The generated FlexGUI file will configure disabled filters in their default pass-through state.

8.5.2 Filter Parameters

Selectable filter parameters are Filter Type, f0, Bandwidth/Q-Factor/Shelf Slope (filter-dependent), and Gain. For detailed descriptions of filters and their corresponding parameters, please refer to the filter table in Section 5 on page 7.

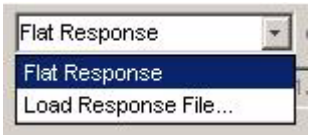
8.6 File Menu

Select "Save Settings" or "Load Settings" from the File menu to save current filter parameter settings or to load previously saved settings.

8.7 Initial Response

Select "Load Response File…" to load a tab delimited, comma separated value, or Audio Precision .ADX file as your initial frequency response. The file should contain frequency data in column 1 and corresponding dB level data in column 2. See Section 10 on page 15 for an example Initial Response file.

Select "Flat Response" for a flat initial frequency response. The default value for Initial Response is "Flat Response".



8.8 Fs

Specifies the sampling frequency used to calculate the frequency response and biquad coefficients.

8.9 Biquad Coefficients

The biquad coefficients panel shows the decimal value coefficients for the selected filter.

8.10 Save Settings to FlexGUI File Button

To create a FlexGUI script file that configures the Parametric EQ Filters on the CS4525, click on the "Save Settings to FlexGUI File" button. The generated FlexGUI configuration script configures and enables all active filters and adds gain compensation to avoid saturation in the signal path by adjusting the prescale gain and channel volume controls in the CS4525.

9. EXAMPLE FLEXGUI FILE

The following is an example of a FlexGUI compatible text file that downloads the parametric EQ filters into the CS4525. The hex value to the left of the "=" is the CS4525 register address, and the hex value to the right of the "=" is the register data value.

```
[FlexGUIBoardState]
Board=CRD4525
[CS4525]
09=80 ;Set Freeze Bit & disable PEQ filters
0A=3F
0B=B8
0C=9B
0D=E0
0E=46
0F=C4
10=20
11=23
12=36
13=C0
14=47
15=65
16=1F
17=96
18=05
19=3D
1A=99
1B=21
1C=E2
1D=5E
1E=D3
1F=1F
20=1C
21=CD
22=C2
23=66
24=DF
25=1E
26=84
27=60
28=39
29=45
2A=50
2B=E5
2C=9B
2D=74
2E=22
2F=CA
30=53
31=C6
32=BA
33=B0
34=17
35=9A
```

```
36=39
37=00
38=00
39=00
3A=00
3B=00
3C=00
3D=20
3E=00
3F=00
40=00
41=00
42=00
43=00
44=00
45=00
46=00
47=00
48=00
49=00
4A=00
4B=00
4C=20
4D=00
4E=00
4F=00
50=00
51=00
52=00
53=00
54=00
08=88; bass/treble gain
07=19; bass/treble corner freq & tone control enable
; Signal gain added from PEQ & tone control: 6.00dB
06=60; Set Prescale value to -6
; Add 6dB gain to compensate for prescale attenuation:
58=24; ch1
59=24; ch2
5A=24; ch3
09=03; Clear Freeze bit, configure Bass Manager, and enable PEQ
```

10.EXAMPLE INITIAL RESPONSE FILE

The following is an example of an Initial Response file that can be loaded into the Parametric EQ Wizard as described in Section 8.7 “Initial Response” on page 12.

```
20000,          -88.8238076994,
15887.5,        -87.6352154899,
12620,          -88.6235308932,
10022.5,        -80.6163611345,
7962.5,         -82.5085820427,
6325,           -82.6950389842,
5025,           -83.9168042204,
3990,           -83.9266870062,
3170,           -83.9899328504,
2517.5,         -83.8095388041,
2000,           -84.713806231,
1588.75,        -84.9283352102,
1262,           -85.5750791713,
1002.25,        -85.5566230331,
796.25,         -85.1880168929,
632.5,          -86.1347190375,
502.5,          -86.2841347545,
399,            -85.9362412612,
317,            -85.9910219309,
251.75,         -85.9227695852,
200,            -82.904345755,
158.875,        -83.8380551665,
126.2,          -84.0289575699,
100.225,        -84.583397485,
79.625,         -85.2018524856,
63.25,          -85.4221072116,
50.25,          -85.9925042133,
39.9,           -84.6651258633,
31.7,           -84.633668311,
25.175,         -84.3403702132,
20,             -82.8966775054,
```

11.GUIDE TO CUSTOM SPEAKER EQUALIZATION USING THE CRD4525

11.1 Necessary Equipment

- One PC with the following hardware and software installed:
  - Windows XP®
  - USB interface
  - Microphone input (recommended: the M-Audio USB audio device)
  - Audio output (recommended: S/PDIF output through the M-Audio USB audio device)
  - Audio analysis software (recommended: TrueRTA™)
  - FlexGUI
  - CS4525 Parametric EQ Filter Wizard
- One microphone with relatively linear frequency response (recommended: Behringer ECM8000)
- One CRD4525 Reference Design kit (including power supply and USB cable)
- The speakers to be calibrated (preferably enclosed the same as the final application)

Notes:

1. The M-Audio Transit is a high-resolution mobile audio device that interfaces to a PC through USB. It is available for purchase through M-Audio's website (www.m-audio.com) as well as in many consumer electronic retail stores.
2. The Behringer ECM8000 is a low-cost condenser microphone with a linear frequency response and omnidirectional polar pattern optimized for audio measurements. A list of local dealers is available on Berhinger's website (www.behringer.com).
3. TrueRTA is a powerful and cost-effective audio analyzer program that can be used to both generate and record frequency response. Cirrus Logic recommends using its "Level 3" version (1/6 octave resolution) for speaker equalization. However, the Level 1 version is available free for download through True Audio's website (www.trueaudio.com). The Level 3 version can also be purchased through the same website.

11.2 Installation

- Install the CS4525 Parametric EQ Filter Wizard per the instructions in Section 3.3 “Installation” on page 2.
- Download the latest version of FlexGUI from Cirrus's website, http://www.cirrus.com/msasoftware, and install it according to the directions on the website. Make all required cable connections and attach a pair of speakers to the CRD4525. Launch the FlexGUI application and playback audio from either an Analog or S/PDIF source and verify proper operation.
- If using the TrueRTA audio analyzer program, install the software according to the directions. Read the corresponding Users Guide for proper operation.
- If the M-Audio device is being employed, install the corresponding software per the manufacture's directions. Read the corresponding Users Guide for proper operation.

11.3 Instructions

1. Connect the speakers to the CRD4525, and position the two speakers apart to the approximate distance used in the final system.
2. Apply power to the CRD4525 through its provided power supply. Connect the PC to the CRD4525 with a USB cable. Launch the FlexGUI program. Load the corresponding input script ("Analog In", "Coaxial SPDIF In", or "Optical SPDIF In").
3. The following steps apply to using an M-Audio Transit to input and output sound from the PC. If a different method is being used for input and/or output, try to replicate these instructions as closely as possible with the appropriate modifications:
   – Connect the PC to the M-Audio Transit with the USB cable.
   – Connect a S/PDIF cable from the M-Audio optical output jack to the CRD4525.
   – Make sure the CRD4525 input source is configured for optical S/PDIF input. Play an audio file from the PC and verify audio is heard from the speakers.
   – Connect the microphone into the Line-In Jack (white connector) on the M-Audio device. Open the M-Audio control panel, and set the Mic Boost to +20 dB.

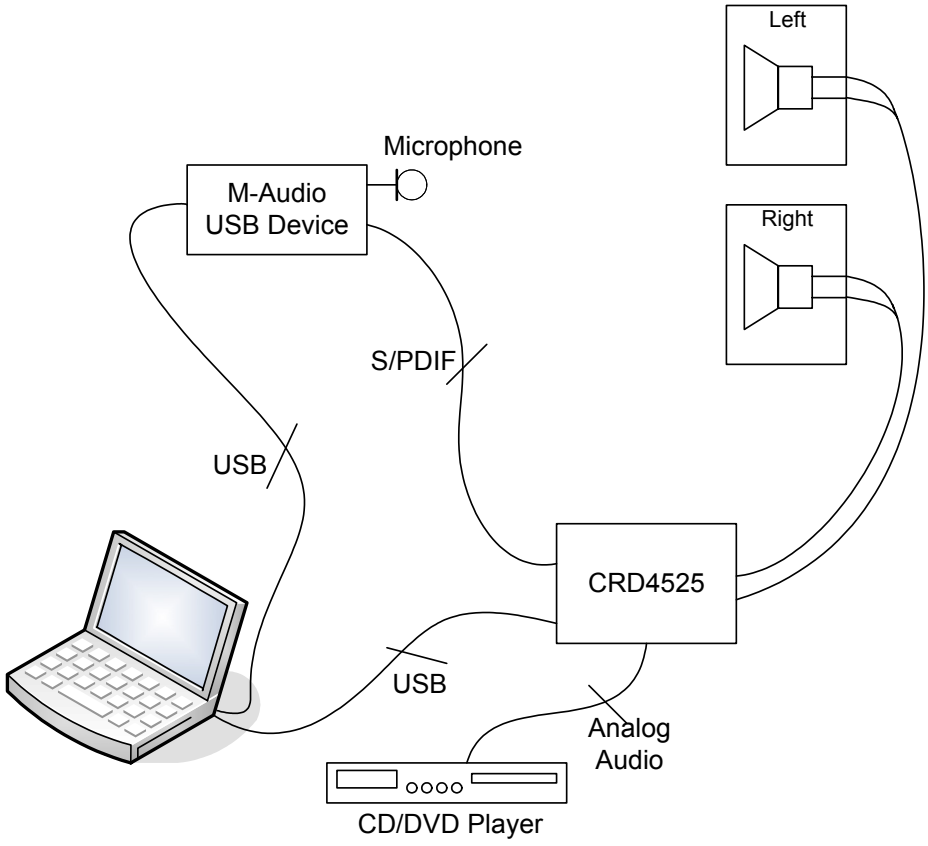


Figure 2. Speaker EQ System Setup

4. Align the microphone horizontally as shown in Figure 3 so that it is along the same horizontal axis as the midpoint between the speakers and approximately two meters away from the midpoint. Then, raise the microphone so that it is even with midpoint of the speakers on the vertical axis as well. Both the speakers and the microphone should be positioned above the floor, which should be carpeted to reduce reflections.

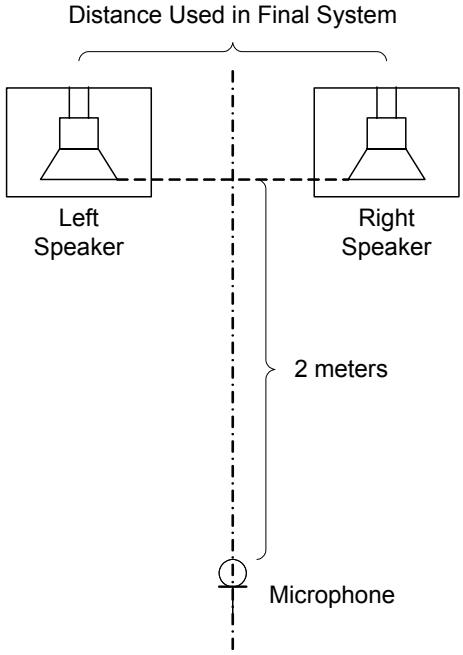


Figure 3. Horizontal Alignment of Microphone and Speakers

5. The following steps apply to using the TrueRTA analyzer program to characterize the speakers' frequency response. If a different method is being used for input and/or output, try to replicate these instructions as closely as possible with the appropriate modifications:
   - Use FlexGUI to verify that all CS4525 sound processing has been disabled, (i.e., bass, treble, Parametric EQ, Bass Manager, etc.).
   - To test the setup, use the audio generator in the TrueRTA application and set the audio type to sine wave, frequency to 1 kHz, and the amplitude to 0 dBu. Select the On/Off button and verify that a sine wave is playing from the speakers attached to the CRD4525. Increase the Master Volume setting in the CRD4525 FlexGUI to -6 dB. Turn off the TrueRTA audio generator.
   - Set TrueRTA to Oscilloscope mode. Turn on the audio generator. With the 1 kHz tone playing from the speakers, select the "Go" button. A 1 kHz sine wave should now be displayed on the graph. Press the "Stop" button to pause Oscilloscope mode.
   - To check the frequency response of the speakers, set TrueRTA to Spectrum Analyzer mode. Set the "Wave" type to Pink N and turn on the audio generator. With the pink noise playing from the speakers, select the "Go" button. A rough representation of the speakers' frequency response should now be displayed on the graph. Take note of what the response looks like.
   - To generate a "baseline" frequency response plot for the speaker, use the "Quick Sweep" button. A short burst of frequency sweep noise will be played and captured. This chirp method reduces the effects of reflections. The speakers' frequency response will be displayed on the screen and should look much like the previous pink noise plot. If the graph does not look like the pink noise plot, press the "Quick Sweep" button again. If this does not produce a valid frequency response, trying adjusting the Windows Mixer Record Volume setting for the microphone input.
   - Pull down the "File" menu and select "Export Data". Save this into a text file to be loaded into the CRD4525 Parametric EQ Filter Wizard

6. Launch the CS4525 Parametric EQ Filter Wizard program.
7. Drop down the "Flat Response" box at the top and select "Load Response File". Find and select the baseline frequency response file characterizing the speakers. This plot will be shown in the bottom window labeled "Cascaded Filter Response".
8. You can now enable the EQ filters and adjust the response as you wish. The parameters of each filter can be adjusted by either clicking the "dot" on the frequency response curve in the top window (Independent Filter Response) and dragging or by using the sliders to the left and bottom of the filter windows. You can select each filter response in the upper window and move/resize, or use the Gain/BW sliders to the left. The cascaded filter response will be shown in the lower window.
9. Once satisfied with the frequency response of the "Cascaded Filter Response" window, select the "Save Settings to FlexGUI File" button to save the parametric EQ coefficients to an .FGS file.
10. Connect a musical audio source to the CRD4525 analog input jacks. Use the CRD4525 FlexGUI to select “Internal ADC” as the audio source (Note: the M-Audio Transit can serve this function if the PC can operate as a music source). Listen to the default frequency response with no EQ registers set. Using the FlexGUI program, dowload the .FGS file containing the saved parametric EQ coefficients and listen to the frequency response with the custom EQ and verify the improvement in sound quality.
11. Use the CRD4525 FlexGUI and select “Serial Audio Input Port” as the audio source. Again use the “Quick Sweep” function of TrueRTA to analyze the new equalized frequency response.
12. Repeat steps 8 through 11 until optimal speaker frequency response is attained.

Contacting Cirrus Logic Support

For all product questions and inquiries, contact a Cirrus Logic Sales Representative.
To find the one nearest you, go to www.cirrus.com.