

Guide to DVD Chapter 23 Examples: *John ffitch with Richard Dobson*

The FilterResponse Graphical Filter Utility

The program *FilterResponse* is a graphical interface for the visualization and design of biquad filters. It supports realtime audio playback through the filter (of a soundfile or a sinewave sweep) so that you can both see and hear the effect while changing coefficients. This guide should be read in conjunction with DVD Chapter 2 (Digital Filters) and its example programs which both implement various filters and print coefficients for use with *FilterResponse*.

Building

The programs depend on the **FLTK** graphical library. If your operating system or distribution does not include it, then FLTK can be downloaded from:

<http://www.fltk.org>

Any stable version should be sufficient. After extracting the archived files, change to the sources directory and type:

```
$ ./configure --enable-shared --enable-threads
```

After this configuration step, you can build with:

```
$ make
```

To install it in your system, just type (you will need the “admin” password for this):

```
$ sudo make install
```

In addition to FLTK, for the audio support, we will need *libsndfile* and *PortAudio*. Again if your distribution does not supply these, you will need to install them.

Instructions for downloading and installing *Portaudio* (v.19) are found at:

<http://portmedia.sourceforge.net/>

Libsndfile can be found at:

<http://www.mega-nerd.com/libsndfile/>

In addition to the sources, there is an installer for Windows. If Windows is your platform, it is recommended that you use one of the premade systems; building on Windows can be a little difficult. Other platforms are straightforward; just follow the instructions in the sources.

With the libraries installed, *FilterResponse* can be built in the *examples* directory by typing the command:

```
$ make
```

Linux Notes:

The *Makefile* as supplied is configured for OS X, and has alternative link options for Linux commented out. In practice, *FilterResponse* has built and run cleanly using the default makefile as supplied. Should there be a problem building on any particular system, it may be worth activating the alternative link options.

Running FilterResponse

The program can be run either from the command-line or by double-clicking (on Linux, usually single-clicking). On Linux and OS X launching via the mouse will automatically launch a terminal session that, in turn, starts the program. OS X users should note that this is not an “application bundle” (there is no *.app* extension) – it cannot, for example, be placed in the Dock.

The Main Dialog

The main window of *FilterResponse* has buttons to display the magnitude response, phase response, impulse response and the z-plane. These buttons are toggles. Clicking them first will display the associated window, and a second click will hide it. The check boxes will change the scales of the displays between linear/log frequency, and amplitude/dB. The text fields for the filter coefficients can be edited by placing the mouse within the field and typing in values, or they can be changed continuously by dragging the mouse to the right for positive values and to the left for negative values. All the displayed windows will be automatically updated. By default these text boxes are initialized with zero values except for a_0 , which is set to 1.0. This corresponds to a “do-nothing” filter that passes its input unchanged.

The “Sound” Button

This button opens the *Sound Control* dialog. This offers the choice of linear or logarithmic sine sweeps, or the playback of a soundfile. The log sweep is set as the default. To play a sweep it is not necessary to have any filter coefficient entered, other than the default. To start a sweep, click the button “Play Audio” and the sweep will perform over the range specified in the options dialog (see below). At the end of this range it will automatically reset and repeat. To stop the sweep at any time click the “Play Audio” button again. This will reset the sweep ready for another run.

Use the options dialog to change the range of the sweep and the interval of time over which to sweep. The audio facilities enable you to experiment with filter settings and both see and hear the results.

Note that the log sweep starts at a very low (sub-audio) frequency, and it may be a few seconds before you hear the sound.

Sound Control: Playing Soundfiles

The program does not provide a file selector dialog box; rather, the full path to a soundfile needs to be entered. Windows users will type a drive letter and path in the usual way. Users on Linux and OS X will need to type the appropriate full Unix path (the shorthand “home” character “~” is not supported at present):

Linux:

```
/home/jpff/sounds/wonderful.wav
```

OS X:

```
/Users/jpff/sounds/wonderful.wav
```

Note, there is a very useful shortcut on OS X. In the finder, you can click and drag the soundfile from it’s folder to the text field in *FilterResponse* and the complete path will be typed into the field for you!

Click the “Play Audio” button to start playback. The process fails silently if an incorrect path is entered – you will simply not hear anything. Note that as the internal sample rate is fixed at 44100Hz, it is best if soundfiles at that rate are used. The file will loop indefinitely until the “Play Audio” button is clicked again.

The “Options” Button

This button launches the Options dialog. It offers five settings, all with reasonable default values. All the controls are bi-modal “spin controls”. The inner arrow buttons make fine changes, the outer double-arrow buttons make larger-scale changes.

- *resolution* – Sets the number of points over which the various displays are computed and drawn. You will generally not need to change this. Very low values will reduce the smooth curves to breakpoint-like shapes, with a consequent loss of accuracy. The default setting is 1000.
- *min dB* – Sets the low limit of the dB scale for the magnitude display. The default is -60dB. This can be extended down to -150dB, which is below the minimum dynamic range of 24bit audio. Outer buttons change in steps of ± 6 dB. For the full 16bit range, a minimum value around -96dB is appropriate. Note that the display attempts to adjust the upper limit automatically in those cases where the filter response exceeds 0dB.

- *min freq, max freq* – These set the lower and upper frequency boundaries for the sine sweeps. The upper limit default is 18000Hz, which, for all but the youngest users, will be beyond the hearing limit. As the fixed internal sample rate is 44100Hz (so Nyquist is 22050 Hz), a value of 11025Hz will stop the sweep exactly at the top of the unit circle – hopefully still audible!
- *interval* – Sets the sweep duration in seconds. The default is 30, which is slow enough to hear the effects of a resonant peak very clearly for example. The range lies between 5 and 120 seconds. The shortest interval takes the sweep into “chirp signal” territory.

The Displays

See DVD Chapter 2 for a full discussion of the significance of the various displays for the study and exploration of filters. They should be quite self-explanatory. In the z-plane, the zeros of the transfer function are marked with a small circle, and the poles with a cross. The unit circle is always shown. If the zeros move far outside the unit circle scaling will be applied – the unit circle may become quite small! If poles move beyond the unit circle they are drawn in a different color. An important aspect to discover and observe when changing coefficients with the mouse is how to move poles and zeros off the real (x) axis to create a conjugate pair of poles on the z-plane.

It is recommended that you switch regularly between the linear and log frequency scales, in order to get a proper sense of the extent to which the frequencies of interest to musicians are relatively low.

Command-line Flags

FilterResponse can be made to start with some of the windows already open. From the command-line, the letters *f*, *p*, *z* and *i* (in either uppercase or lowercase) will open the frequency (magnitude) response, phase response, z-plane and impulse response windows. The letter *d* enables a dB scale, and the letters *l* starts in log scale.

Following any flags it is possible to give up to five floating point numbers as the initial values of the filter parameters a_0 , a_1 , a_2 , b_1 and b_2 . If these are not given the program starts with the values 1, 0, 0, 0 and 0.

For example:

```
$ ./FilterResponse f i d 0.15 0.25 0.1 0.0 0.0
```

will start the program with a lowpass filter, displaying the impulse response and the magnitude response in decibels.

Quitting the Program

To exit the program cleanly, use the yellow “Quit” button.

OS X

If, out of long habit, you close the main dialog window using the usual button in the title bar, the window will be closed, but the program will still be running. Activate (if necessary) the associated terminal window, and type Ctrl-C to terminate the program. Linux usually manages to kill such a “zombie” programs automatically. The solution to this particular “quirk” of the *FilterResponse* program is left as a simple C++ exercise for the reader.