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A De-Emphasis Test CD

By Gary Galo, Regular Contributor

You'll find this test CD more useful than the existing published versions.

When the compact disc was under development, Sony and Philips built an optional treble pre-emphasis curve into the Red Book specifications for the format. Initially the CD was intended to be a 14-bit medium, which pushed the limits of storage and signal processing at that time. By the time the CD was actually introduced to the public in 1982, the resolution had been increased to 16 bits. Recordings made with a resolution of 14 bits had very poor linearity at low signal levels, particularly in the high frequencies, and even the 16-bit converters in the 1980s had shortcomings in this regard.

The Red Book *pre-emphasis* specification applied a high-frequency boost ahead of the analog-to-digital converters, which ensured that low-level, high frequencies would be recorded in a more linear fashion. This high-frequency boost was applied with an analog equalization circuit, because it needed to be applied *prior* to A-to-D conversion in order to overcome the limitations of the converters. A complementary *de-emphasis* equalization curve was applied in playback, usually with an analog filter *after* digital-to-analog conversion. Because low level, high frequencies remained boosted during the D-to-A conversion process, linearity problems in those converters were also reduced.

By the early 1990s many manufacturers of digital conversion chips were implementing de-emphasis in the digital domain, usually in the playback digital filters. At that point, low-level linearity of D-to-A converter chips had improved to the point where it really was not necessary to keep the signal pre-emphasized during the conversion process.

The Red Book pre-emphasis/de-emphasis standard has often been referred to as a noise-reduction system, but this is a simplistic and incomplete explanation. True, the high-frequency boost in record and complementary cut in playback does reduce quantization noise, but this was probably not the greatest sonic benefit. The greatest benefit was the improved high-frequency linearity at low signal levels. By the early 1990s, the entire process had become a moot point due to improved linearity of both A/D and D/A converters.

Very few CD manufacturers actually implemented the Red Book pre-emphasis standard. Nearly all of the CDs I own with pre-emphasis are discs manufactured in Japan by Denon in the 1980s, either for their own label (the entire Eliahu Inbal/Frankfurt Radio Symphony Mahler cycle, for example), or discs they made for other labels (Music and Arts Programs of America had many of their early CDs manufactured in Japan by Denon). In recent years, many manufacturers of CD players and outboard D/A converters have stopped implementing playback de-emphasis—the Monarchy M24 I reviewed in the Oct. 2007 *aX* is a case in point. This is a problem for those of us who have been collecting CDs since the 1980s. I believe that all CD playback hardware should be backwards compatible.

RED BOOK STANDARD

The Red Book pre-emphasis curve is shown in **Fig. 1**. Time constants are specified as 50µS and 15µS, corresponding

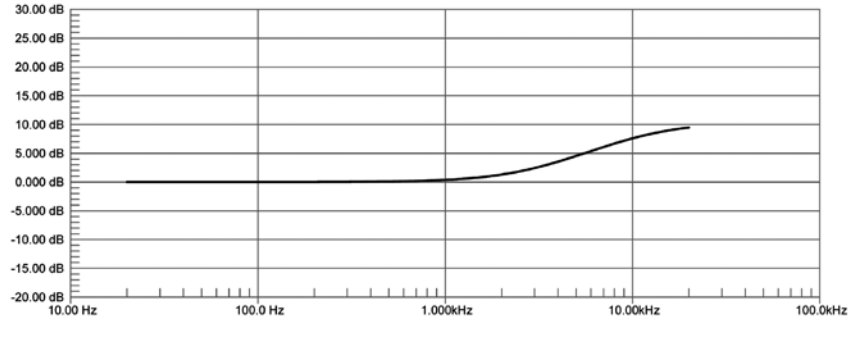

FIGURE 1: The Red Book pre-emphasis curve specifies time constants of 50µS and 15µs. The +3dB point for the high-frequency boost is 3183Hz, shelving at 10610Hz. Maximum boost is +9.49dB at 20kHz.

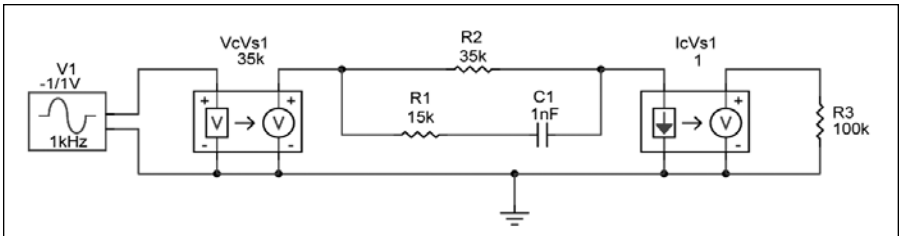

FIGURE 2: Simulation model for generating the Red Book pre-emphasis curve. The 50μS time constant is the product of (R1 + R2) * C1; 15μs is equal to R1 * C1.

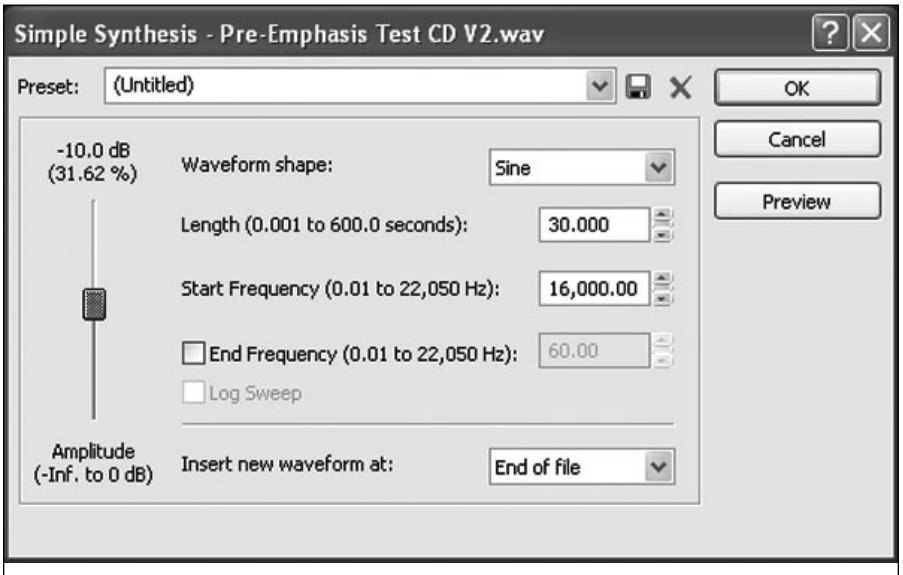

FIGURE 3: The Simple Synthesis module in Sony's Sound Forge will generate a sine wave at any frequency, for any duration, at any level.

to frequencies of 3183Hz and 10610Hz. Relative to the low end of the spectrum, the +3dB point for the boost is 3183Hz, with the boost shelving at 10610Hz.

Only a handful of test CDs have been made with tracks for checking de-emphasis in playback. I have used *Hi-Fi News and Record Review Test CD II* (HFN15), which has pre-emphasis tones at 1kHz, 4kHz, and 16kHz. Chuck Hansen has used the *CBS Test Disc* (CBS-1), which has tones at 125Hz, 1kHz, 4kHz, 10kHz, and 16kHz. These discs are adequate for determining whether de-emphasis has been implemented, but they don't have enough tones to give meaningful data about the *accuracy* of the de-emphasis. Some discs, such as the *Pierre Verany Digital Test* (DV 788031-32) and the *Denon Audio Technical CD* (38C39-7147), have sweeps with pre-emphasis from 20Hz to 20kHz, but these are only useful if you have measurement equipment that can be synchronized with a sweep generator.

ROLLING YOUR OWN

I have always been frustrated with my inability to measure the accuracy of playback de-emphasis, so I decided to take matters into my own hands and make my own test CD. To do so, I needed a precise model of the Red Book pre-emphasis curve, which I produced using CircuitMaker 2000. **Figure 2** shows the simulation model. T = RC, so the 50μS time constant is produced by (R1 + R2) * C1, and the 15μs time constant is produced by R1 * C1. Scaling for VcVs1 is set to the value of R2, and IcVs1 is set to unity. R3 is a load resistor for IcVs1, arbitrarily set to 100k (this value is unimportant).

I used this simulation model to generate the curve shown in **Fig. 1**. CircuitMaker 2000, like most schematic capture programs with simulation, will allow you to put cursors on the generated graph and measure one level relative to another. **Table 1** shows the measurements I made on the simulation in **Fig. 1**. The "FREQ." column lists the frequencies I decided were appropriate for a truly useful de-emphasis test CD.

I set the first cursor at exactly 20Hz, then moved the second cursor to the remaining frequencies and noted the difference relative to 20Hz. Those results are plotted in the second column. The maximum Red Book high-frequency boost in record is about 9.5dB. To avoid clipping, the 20Hz reference should be recorded at a level of -10dB, which is why that column is labeled "LEVEL REF TO -10dB."

The third column gives those levels relative to 0dB, in which case 20Hz is now at -10dB. Finally, the fourth column lists the track numbers for each test tone. The CD I made actually has two sets of tracks: 1 through 28 are recorded without pre-emphasis—in other words, flat—at -10dB. Tracks 29 through 56 duplicate the previous tones, but with pre-emphasis applied according to the levels indicated in **Table 1**.

I produced the test CD with Sony Creative Software's Sound Forge version 9.0, the digital audio editor I use on an almost daily basis (www.sonycreativesoftware.com). Sound Forge has a Simple Synthesis function that allows you to generate sine waves at any frequency, for any duration you specify (**Fig. 3**). I used Simple Synthesis to generate each tone in **Table 1** for a length of 30 seconds, at a level of exactly -10.0dB, for a total of 28 tracks. I put 4 seconds of silence at the end of each tone, plus 1 minute of silence at the end of the

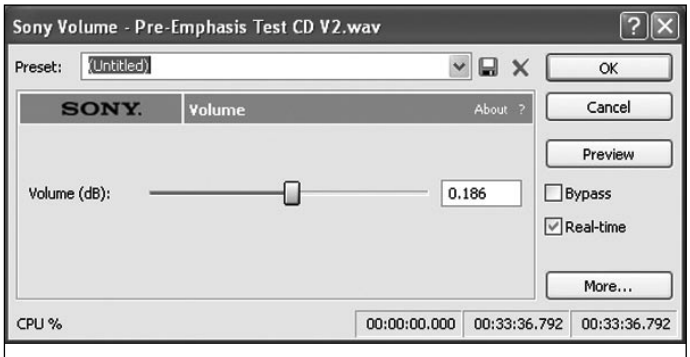

FIGURE 4: The FX "Volume" plug-in supplied with Sound Forge allows level adjustments with resolution to 0.001dB.

last track. Then, I marked the entire file and performed a simple copy and paste, duplicating all 28 tracks again. These duplicated tracks—29 through 56—are the ones that will have pre-emphasis added.

Sound Forge has two different "Volume" functions that can boost or cut volume by any level you choose. The one under the "Process" menu allows adjustments in 0.01dB increments, which is a bit too coarse for the lowest frequencies. There's another "Volume" plug-in, under the "FX Favorites" menu, that allows adjustments in increments of 0.001dB, which is the one I used (**Fig. 4**). You'll need to highlight each tone from track 29 through track 56 and boost that tone by the amount indicated in the "LEVEL REF TO -10dB" column. When you finish, if you zoom all the way out, your Sound Forge screen will look like **Fig. 5**.

You can then use Sound Forge's "Statistics" function (under the "Tools" menu) to check the level of each tone relative to 0dB (**Fig. 6**). Highlight nearly all of the tone in each track, one at a time, but don't highlight the silence on either side. Then click on "Statistics" and look at either "Maximum sample value" or "Minimum sample value." They should be the same and should also match the level given in column 3 of **Table 1** for that particular tone.

Occasionally, I found that the tones were not at the level they should be. In this case, I highlighted the entire tone and normalized it to a level of -10.0dB, then repeated the above procedures. It always worked on the second attempt.

Sound Forge 9.0 comes with a Mastering Equalizer plug-in made by iZotope, which includes pre-emphasis and de-emphasis curves. However, the algorithms don't seem to have the precision I get from manually adjusting each tone according to the simulation. As an example, **Table 1**, column 3 says that 11kHz should be at -2.05dB; if I pre-emphasize all 28 tracks using iZotope's plug-in, 11kHz is at -1.65dB.

CD AUTHORING

With Sound Forge, you first produce tracks by putting markers in the file where you want them. You also need a marker at the end of the file. When you're all done, right-click on the Regions List and change the markers to regions. Sound Forge comes bundled with CD Architect 5.2, a professional "disc at once" CD authoring program that provides full Red Book PQ encoding and editing. CD Architect makes tracks from the regions you've already produced.

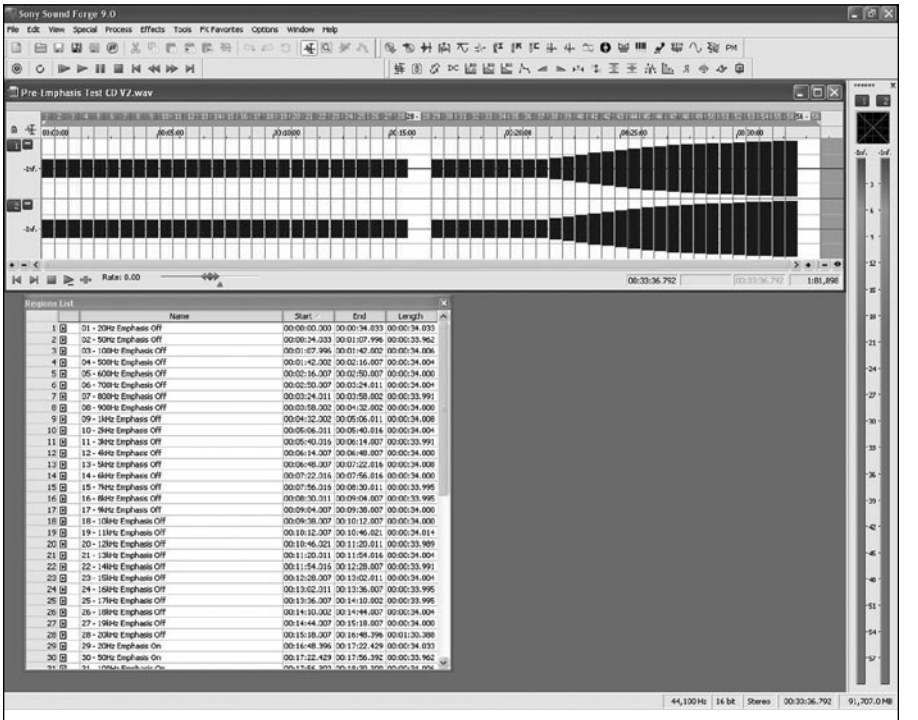

FIGURE 5: The Sound Forge screen with the completed test CD. Tracks 1–28 are recorded flat; tracks 29-56 have been adjusted in level to correspond to the Red Book pre-emphasis standard.

Table 1 Pre-Emphasis Simulation Levels

FREQ.	LEVEL REF TO -10dB	LEVEL REF TO 0dB	Tracks
20Hz	0	-10.000	1, 29
50Hz	0.001	-9.999	2, 30
100Hz	0.004	-9.996	3, 31
500Hz	0.096	-9.904	4, 32
600Hz	0.138	-9.862	5, 33
700Hz	0.186	-9.814	6, 34
800Hz	0.241	-9.759	7, 35
900Hz	0.303	-9.697	8, 36
1kHz	0.37	-9.630	9, 37
2kHz	1.29	-8.710	10, 38
3kHz	2.43	-7.570	11, 39
4kHz	3.54	-6.460	12, 40
5kHz	4.53	-5.470	13, 41
6kHz	5.38	-4.620	14, 42
7kHz	6.1	-3.900	15, 43
8kHz	6.69	-3.310	16, 44
9kHz	7.19	-2.810	17, 45
10kHz	7.61	-2.390	18, 46
11kHz	7.95	-2.050	19, 47
12kHz	8.25	-1.750	20, 48
13kHz	8.49	-1.510	21, 49
14kHz	8.71	-1.290	22, 50
15kHz	8.89	-1.110	23, 51
16kHz	9.05	-0.950	24, 52
17kHz	9.18	-0.820	25, 53
18kHz	9.3	-0.700	26, 54
19kHz	9.4	-0.600	27, 55
20kHz	9.49	-0.510	28, 56

Pre-emphasis levels based on the circuit simulation of **Figs. 1** and **2**. The test CD has 28 tracks recorded flat at -10dB, and 28 more recorded with the 50µS/15µs Red Book pre-emphasis curve.

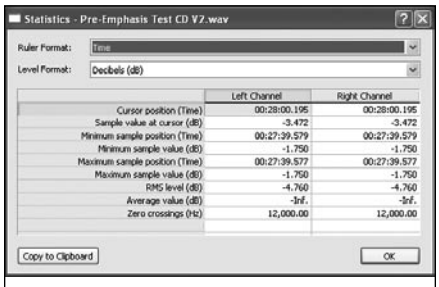

FIGURE 6: The Sound Forge Statistics module allows verification of the level of each tone relative to 0dB. Use the minimum or maximum sample values, which should be the same.

Open the .WAV file with CD Architect's "Open Media" function, and save the file as a CD Architect (.CDP) project. Click on "Track List" in the lower window (**Fig. 7**).

You should see all 56 tracks you've produced in Sound Forge. On the right, you'll see a column called "Emph."—there's a box for each track, all unchecked. Check each box from track 29 through track 56. This will tell CD Architect to write the pre-emphasis flag for each of those tracks. This flag tells your CD player or outboard DAC to turn on the de-emphasis circuit.

It's important to understand that there are two processes involved in producing a CD, or individual CD tracks, with pre-emphasis. The first step is to apply the correct high-frequency boost to your .WAV file. I did this with Sound Forge, one track at a time, adjusting the level of each tone according to my circuit simulation.

But, altering the frequency response according to the Red Book 50µS/15µS time constants won't tell your CD player to apply the correct de-emphasis. The pre-emphasis flag must be recorded on the disc by your CD authoring program. CD Architect allows you to add a pre-emphasis flag to each track, individually.

FINISHED TEST CD

Once you've finished adding the emphasis flag to tracks 29 through 56, save your changes in the .CDP file and burn the CD. You'll now have a de-emphasis test CD that is far more useful than any published test discs that I've seen. To check your CD player or outboard DAC, first play tracks 1 through 28, monitoring the player or DAC output on an AC voltmeter with a dB scale. These tracks should show a flat frequency response from 20Hz to 20kHz. Now do the same with tracks 29 through 56.

If your player or DAC supports the Red Book de-emphasis specification, you should also get the same flat frequency response you got with tracks 1 through 28. If you get a response that rises with frequency, with 20kHz at about +9.5dB relative to 20Hz, your player or DAC doesn't support de-emphasis. For the most accurate measurements, I use a digital AC voltmeter with resolution to 1mV. After making the voltage measurements, I convert them to dB in a spreadsheet using the formula dB = 20 Log E1/E2.

De-emphasis errors are similar to RIAA equalization errors in phono preamps. Because errors are sometimes spread across an octave or more, even errors of a few tenths of a dB can be audible, if they occur between 1 and 5kHz, where the ear is especially sensitive. The de-emphasis graph Chuck Hansen prepared for the Benchmark DAC1 USB review (Fig. 2 in his review, published in Jan. '09 issue, p. 32), was produced from data I measured with this test CD, and shows excellent accuracy, ±0.09dB, 20Hz to 20kHz.

The worst errors are at the top of the spectrum, where they are unlikely to be audible. I also measured the DAC1 USB using the *Hi-Fi News and Record Review* test disc mentioned previously. The *HFNRR* disc showed 16kHz to be at +0.399dB (left) and +0.451dB (right), relative to 1kHz. The measurements with my test CD showed 16kHz to be at +0.002dB (left) and 0.058dB (right), relative to 1kHz.

The nearly half a dB error shown by the *HFNRR* test CD is suspicious. In the datasheet for the AD1853—the DAC chip used in the Benchmark DAC1 USB—Analog Devices specifies the de-emphasis error as ±0.1dB. The measurements made with my test CD show the Benchmark DAC to be well within Analog Devices' tolerance. After sending Chuck Hansen a copy of my test CD, he said he would use it for his de-emphasis measurements. I thank him for his feedback and words of encouragement during the preparation of the test CD and this article. I hope other readers will find this disc as useful as we have.

The De-Emphasis Test CD can be purchased from the author for $20 each including Media Mail shipping in the US. Send a check or money order payable to Gary Galo, 211 May Road, Potsdam, NY 13676. *aX*

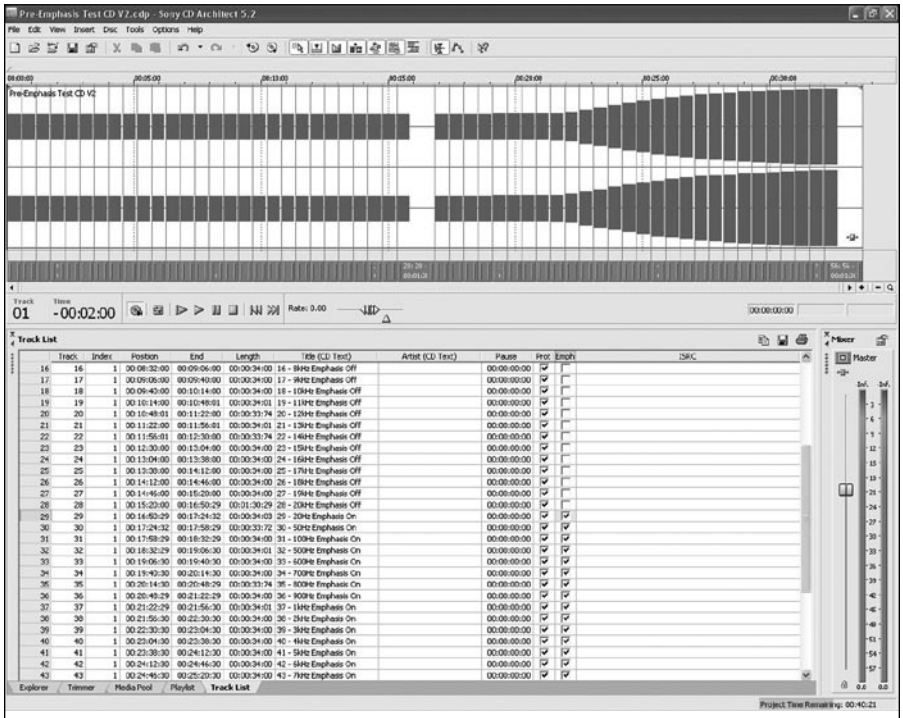

FIGURE 7: Sony's CD Architect 5.2 allows full Red Book PQ encoding and editing, including the addition of a pre-emphasis flag to any track.