



Transferring LPs to DVDs in High Resolution

Using professional-grade software and hardware to transfer LPs to DVDs in high-resolution format, the author shows you how to preserve more of the qualities of vinyl than is possible with the CD format.

[This is a follow-up to the author's "LP Transfer to CD," published in the Oct. '01 issue of *aX* (p. 30)—Eds.]

By Victor Staggs

Since 2001 new software for processing sound on the Macintosh and PC platforms has appeared, and so have new computers to use it. Both inexpensive shareware and powerful professional applications give you a range of prices to choose from. These tools, plus new hardware A/D interfaces at reasonable cost, make it feasible to extend the resolution of recording and mastering beyond the CD format of 44.1kHz and 16 bits.

My job as a computer sales technical consultant for a large reseller requires me to know how sound, video, and films are edited on the Macintosh platform. The only way to deal intelligently with our clients is to use the same tools that they do, and so I own a PowerMac G5 Dual Processor and the Apple software suite Final Cut Studio, which lets you edit video and movies and sound, add motion graphics, and author DVDs. The movie *Cold Mountain* was the first feature film to be edited using this software, by Walter Murch.

My own film project is a modest 16mm movie to DVD transfer. It is a nature film that my late father made in about 1960, and the National Park Service is interested in receiving a copy.

DISSATISFACTION IS THE FATHER OF INVENTION

Some time ago I sent a copy of one of my better LP to CD transfers to my ex-college roommate who works in a post-production house in Hollywood. He commented that it sounded like a factory CD. This irritated me, because

that is how it also sounded to me. But the LP sounded nothing like a factory CD.

When I obtained my PowerMac G5, I took advantage of its 48kHz/24-bit digitizer to transfer some LPs to its hard drive in that format. This showed considerably more faithfulness to the sound of vinyl playback. If I recorded in straight 44.1kHz/16-bit format like my old PowerMac 8600/300, I could not tell the difference between the old computer and the new one. So, the difference had to be in the improved resolution.

I also tried recording at 44.1kHz/24-bit resolution, and then requantizing to 16 bits using noise-shaped dither. This sounded better than a straight 44.1kHz/16-bit recording, which told me that you need more than 16 bits for good audio. But it still didn't sound as good as leaving the tracks at 24-bit resolution.

I was able to make improved LP to CD transfers using the G5's converter and BIAS (Berkley Integrated Audio Systems) Peak sound editing software in place of the obsolete SoundEdit 16. But how could I make a transfer at 24-bit resolution and play it on my stereo?

Roxio's Toast 5 Titanium was my faithful companion for authoring audio and data onto CDs. The new Toast 6 Titanium added the ability to record audio onto DVDs, but alas, only at 44.1kHz/16-bit resolution. This was no improvement in resolution, and it certainly did not live up to the "Versatile" part of "Digital Versatile Disk." My Pioneer DV-37 player really needed some-

thing more than CDs and DVD movies to exercise its vaunted powers.

Tomlinson Holman's book, *5.1 Surround Sound—Up and Running*, contains a trove of useful information for the desktop audio editor, including a list of what audio formats are supported by the DVD standard. A resolution of 24 bits is supported at 48kHz and at 96kHz sampling rates.

Further reading in Apple's book, *Discovering QuickTime—an Introduction for Windows and Macintosh Programmers*, provided more clues. Apple claimed that QuickTime subroutines were all-inclusive, and would do their best with whatever sound format was passed to them. So, I set out to solve the problem of how to author high-resolution audio formats onto DVDs.

The secret was to open my AIFF sound files in QuickTime Pro and save them as self-contained movies. I needed to be careful to use BIAS Peak to insert markers at the beginning of each track in a file before making them into movies (.mov files).

Because I now had movies with soundtracks but no video tracks, and Toast 6 Titanium was supposed to author DVD videos, I just told it to make a DVD video and use the movie files as content. This it did happily. Each AIFF file became a movie title, and I was able to add more than one movie title to a DVD, limited only to the free space on the DVD. The markers in a file became access points for starting the movie and for accessing individual audio tracks within the file, such as individual

tracks on one side of an LP. Apparently I became the first person to use Toast Titanium to author high-resolution audio onto DVDs.

Figure 1 shows a screenshot of the Toast user interface for producing a DVD-Video with the four sides of the 2-LP London album of *The Mikado* on

it. The black rectangles indicate that the file has no video, so that there are no keyframes to display.

Figure 2 shows the window shade that drops down when you click on the "More" button in the left-hand drawer in **Fig. 1**. This is where you select the PCM audio format of 96kHz/24 bits in

Toast 7 Titanium.

At 24-bit/48kHz resolution, the DVDs sounded better than any of my LP to CD transfers. I sent the instructions to the website "Macintouch," and you can find them in the archives at www.macintouch.com/audiorecord5.html.

I also burned a DVD with samples



FIGURE 1: Toast Titanium for authoring video DVDs with sound only.

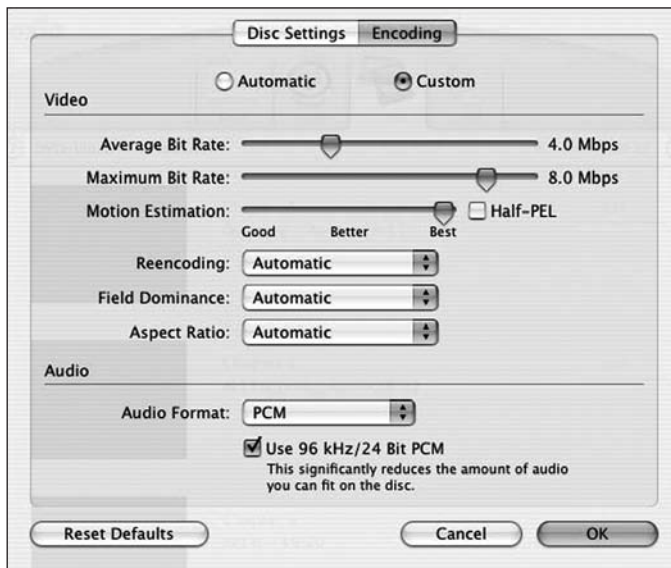
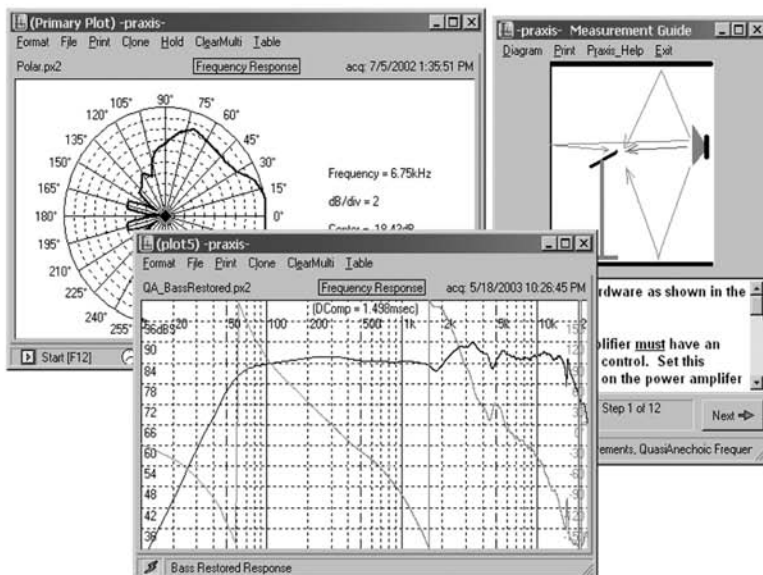


FIGURE 2: Choosing 4-bit 96kHz linear encoding (PCM) for video DVDs.

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of classical and rock music on it and sent it to Adam Fingerman, the Director of Product Development at Roxio, so that he could hear the difference between this and 16-bit recordings. Their engineering team was totally unaware that Toast could record high-resolution audio, and was not convinced initially that more bits were necessary.

But they listened to the DVD and to other users, and eventually they added the ability to author high-resolution audio onto DVDs with the release of Roxio Toast 7 Titanium. Roxio went whole hog and settled on 24-bit/96kHz resolution, calling the discs “Music DVDs.”

I burned a few more DVDs by recording at 48kHz and upsampling in software to 96kHz, but curiosity got the better of me and I purchased a Mark of the Unicorn “Traveler” recording and playback interface so that I could make true 96kHz transfers with higher-quality A/D conversion. This is not a consumer-priced product at \$849–\$899, but neither is it consumer quality—it is professional grade, and the improved quality is worth the money to a serious sound restorer.

TAKING STOCK

At this point I had the Traveler running

into the G5 via Firewire, using Apple’s SoundTrack Pro to control the hardware. The sound files now had the best quality I had obtained so far, and I needed to work out a procedure for cleaning up ticks and making the vinyl sound more presentable in the digital domain.

One day the Macintouch website announced new shareware called ClickRepair, written by Dr. Brian Davies, a mathematics professor at the Australian National University in Canberra. SoundTrack Pro has a nice click removal tool that is pretty much automated, relieving the editor of most tedious waveform repair by hand. It is good but not great software.

ClickRepair, on the other hand, can do a really deep cleaning of an LP track—or even a badly damaged shellac 78 track—so that the sound becomes truly beautiful to hear. It does so by changing only those samples that are part of a click, so that the overall fraction of samples modified is very small. Unfortunately, it only worked on sample rates up to 48kHz.

I bought ClickRepair and fed it some truly difficult files to work its magic on. It stumbled on a few by making unneeded “repairs.” I established e-mail contact with Brian Davies so that he could work

out the deficiencies and I could persuade him to make up the sample rate gap between ClickRepair and Toast 7 Titanium. At one point he had me send a CD with sample AIFF files on it to the Center for Nuclear Research and Modeling in Cedex, France, so that it could meet Brian and his colleague there to help them work on the problem of click discrimination during trumpet pieces.

Happily, ClickRepair is now a sophisticated and effective program, and it works with 96kHz files.

THE TRANSFER PROCEDURE

What follows is the workflow that I developed using my own software suite for transferring audio from vinyl LPs to DVDs. I explain my rationale for the procedure, so if your software differs from mine, you can work out a sensible workflow of your own.

CALIBRATION

Before you commit your vinyl disks to the digital medium, you should consider measuring the frequency response of your playback chain using a test LP. My collection contains an old Soundcraftsmen test LP with all pink noise on side B. I have written software for measuring pink noise, so I used the PowerMac

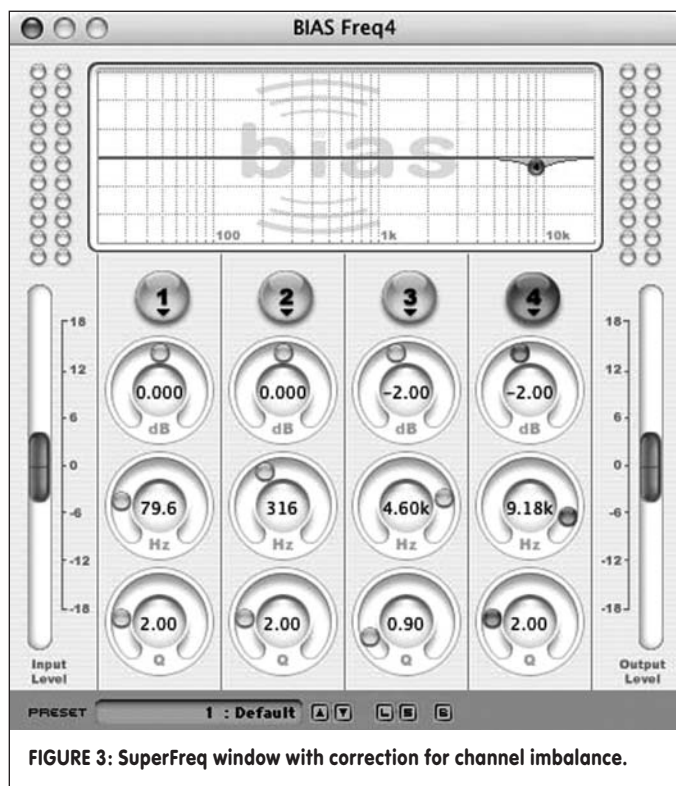


FIGURE 3: SuperFreq window with correction for channel imbalance.

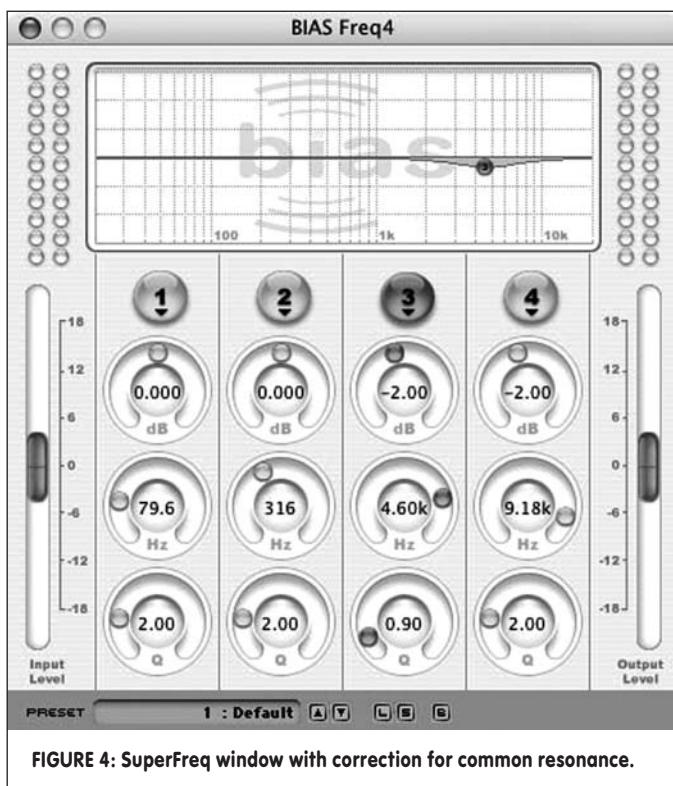


FIGURE 4: SuperFreq window with correction for common resonance.

8600 to measure the pink noise playback. This test signal is believable only between 100Hz and 10kHz because of the limitations of the General Radio pink noise generator of the time, but that is sufficient.

Figure 3 shows the frequency response of SuperFreq, a parametric equalizer in BIAS Peak, when it is set to flatten out a peak in the ratio of the right-channel response divided by the left-channel response (right minus left on a DB scale). I apply this correction only to the left channel of a file to make both channels have identical response. This solidifies the stereo image remarkably, subtle though the correction may be.

Figure 4 shows the frequency response of SuperFreq when it is set to equalize out the remaining phono cartridge response error common to both channels. It is applied to both channels in a stereo recording. The resulting sound is as neutral as a modern movie soundtrack. Note that there are no peaks or dips to be corrected at the RIAA corner frequencies of 500Hz and 2122Hz, indicating a fairly faithful RIAA pream-

plifier. Both of the frequency plots show a dip of 2dB on a scale that is ± 18 dB.

It doesn't do any good to have a perfect RIAA preamplifier if you don't also correct for the cartridge's frequency response errors, so I recommend finding some way to measure your own setup. Whenever I get a new computer or A/D converter, I check it for polarity inversion at the input with a flashlight battery, or a battery plus a 1:10 attenuator in the case of mike preamp inputs. The PowerMacs 7200, 8600, and G5 all invert polarity, so you must correct this during editing. The MOTU Traveler preserves polarity, bless its heart.

RECORDING CONNECTIONS

The Traveler connects to the PowerMac G5 via a FireWire cable, which also powers the box. I run my turntable and analog electronics from a TrippLite LC1200 AC line conditioner to remove AC hash and act as a ground isolator. I clip a ground wire between the phono preamp chassis and the PCI card opening area of the G5. This is to eliminate hum from ground loops. My old CRT

monitor needed its own isolation transformer, but my new LaCie CRT monitor doesn't.

When you set up SoundTrack Pro for recording via FireWire, you can check the recording level meter to see whether your background noise is acceptably low.

SET YOUR RECORDING LEVEL

You can find the peak levels by recording samples of the LP during the loudest parts of the music. The meters in SoundTrack Pro are not 100% infallible for this purpose, so you should stop the recording process and examine the waveform in the file to determine the headroom. After fighting to get good sound from 16 bits, I am fanatical about achieving only 1-2dB of headroom in a transfer. I prefer this to leaving more headroom and then amplifying the file in the digital domain, because this wastes resolution.

When you finish a track, you can review the waveform for clipping. SoundTrack Pro and BIAS Peak can each help you with an automated procedure for this. If I have clipping, I reset

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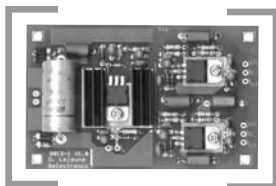
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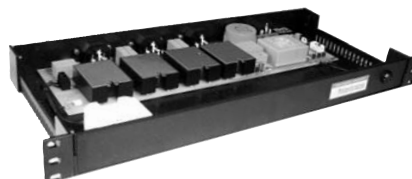
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the level and re-record. If your phono cartridge has large dips in its response requiring a peaked equalization in software, you might need to leave more headroom than I do.

SAVE YOUR FILE

Apple's OS X has a facility called "Core Audio" that programmers can tap into when producing sound editing programs. One facility that most use is the ability to save a sound file in 32-bit floating-point format. Apple considers this the native format for sound in OS X. I recommend using this format to preserve your sound quality during subsequent processing.

Because 32-bit floating-point numbers have a 24-bit fractional part and an 8-bit exponent part, you might wonder how this can be better than 24-bit integers. By a trick in how fractional parts are stored in binary form, the fractional part actually provides 25-bit precision. The extra bit, along with the scaling properties of floating point numbers, will preserve your sound quality during editing, and it will be recovered when you finally requantize back to 24-bit integer format using noise-shaped dither, for disk authoring.

EDIT YOUR FILE IN SOUNDTRACK PRO

When I use SoundTrack Pro, I always de-click the entire file in STP as a first step. Another operation is to remove the LP's lead-in groove and substitute two seconds of silence. To keep the software's

speed up while de-clicking, I make the click detection threshold about equal to the local signal amplitude; for example, a full-amplitude signal will use a 100% detection threshold. Sometimes STP makes many false positive decisions in large-amplitude sections, so I may skip de-clicking those sections.

Figure 5 shows the waveform editing window in SoundTrack Pro, where the music is the beginning of a Vivaldi mandolin concerto. You can zoom in on the time axis to resolve the waveform and enable use of the pencil editing tool. You can also zoom in on the vertical (amplitude) axis so weak signals will be much larger and easier to touch up accurately. You hope you won't need to do very much of this.

If a track seems to have a lot of infrasonic recording lathe rumble in the waveform, I run a "linear phase" high-pass filter on the file, set for 20Hz most of the time, or for 30Hz if the rumble is worrisome. This eliminates woofer cone breathing. This class of filter has a time-symmetric impulse response ripple, so you would only use it where it will be inconspicuous. It is handy to use on "thumps" as long as the music has little content at the thump frequencies and you can discriminate between them.

In some cases lathe rumble is intrusive during low-level music, even after filtering out infrasonics. STP has a broadband denoising function that is effective with background noise. You must take a noise sample where there is no signal, and then set the discrimination

threshold by listening only to the noise removed. I preserve tape/vinyl hiss with this filter so that its use will not be conspicuous.

If you listen to the many pop music selections during a feature film presentation, you will hear some that seem to be devoid of low-level detail. This is a sign that they were restored from vinyl instead of tape, and that broadband noise reduction was used too aggressively.

Be sure to process your editing actions to flatten the file occasionally, because STP is not 100% stable. When you save the file after editing, it will be ready for attention from BIAS Peak.

EDIT YOUR FILE IN BIAS PEAK

The real beauty of BIAS Peak is the SuperFreq equalizer feature pictured in **Figs. 3 and 4**. As mentioned, I use it religiously to equalize out the phono cartridge imperfections. The main editing window is shown in **Fig. 6**. Note that the headroom is 2.5dB, as stated in the lower left corner of the screen: "Max-2.5dB," where the sampling resolution is also given. I added a marker at the head of the file called "Track 01."

If you make Video DVDs as I do, the track markers provide the access points for the tracks in a title. You need at least one marker per title. If you use Roxio's Music DVD format instead, then you will use the markers to help you separate the tracks into individual files in order to produce a track list in Toast.

Next, I use the "Gain Envelope" DSP operation in Peak to produce a two- or

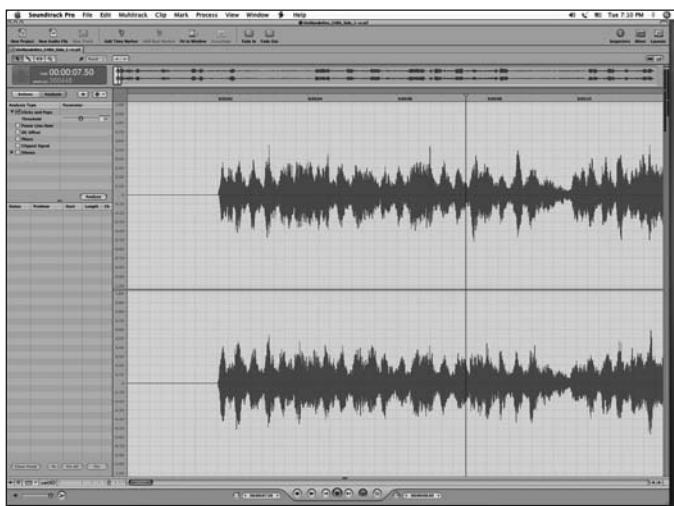


FIGURE 5: SoundTrack Pro's waveform editing window.



FIGURE 6: BIAS Peak's waveform editing window.

three-second fadeout at the end of the LP side. I use exponential decay, applied to the tail of the file where the music has just faded out by itself, and I continue the fadeout into the "silent" runout groove. This produces a natural-sounding fade to silence. I am not a fan of linear fadeouts.

You have the option of adjusting the file's amplitude, if you desire to maximize the volume. But you must check the headroom on both sides of the LP before doing this so that you can treat both sides equally. Obviously the same goes for two-LP albums or more.

Now you can save the file to preserve your 32-bit master. It takes a short wait for Peak to render the edits and write the new file.

To produce a 24-bit file for DVD authoring, choose "Save As" from the File menu, and select the 24-bit depth. Also, you need to turn on dithering at this point. I always give a saved file a suggestive name, such as "Vivaldi_Side_01_24_96." Peak will add the .aif filename extension.

DE-CLICK YOUR FILE IN CLICKREPAIR

To avoid contention for resources, quit all other sound-related programs and start up ClickRepair. You have the option of listening to just the noise, which is easier if you have an external interface such as the Traveler to boost the weak headphone signal up to audible levels in this situation. You start the click repair and then adjust the sensitivity, and check for music content being removed which you would rather keep in the file.

If you find that ClickRepair has difficulty with certain parts of your file, you can break it up into smaller files and de-click each one separately. Then you reassemble the files. This would only happen in an extreme case.

To be conservative, you can reopen the repaired file in BIAS Peak and audition it, taking care to turn the headphone volume back down first. Software is not able to detect all vinyl flaws, so this is your chance to find them by listening and correct them with the pencil tool. Peak's pencil tool acts like a "healing tool," in that logic helps blend your

correction into the rest of the waveform to avoid audible artifacts. This is much more effective than Peak's automated click repair facility.

If you now open your file in SoundTrack Pro, modify it and close it, you will lose all of your markers. STP won't even save its own markers when you close and reopen a file.

AUTHORING A DVD IN ROXIO'S TOAST 7 TITANIUM

You have your choice of authoring a Video DVD as I do, or a Music DVD as Roxio supports officially. The window for producing a Music DVD is shown in **Fig. 7**. This Playlist consists of two songs, each one an entire side of a George Wright LP. If I had broken each side into individual files corresponding to the tracks, there would be many more songs in the Playlist.

You may add artwork to take the place of the generic musical note picture in the window. You will see your artwork on the monitor when you play the DVD. In general, I don't have a screen connected to my DVD player. I only use it

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for audio. I use my computer for playing DVDs because of its superior scaling and interpolation algorithms.

Once you learn how to access tracks in Apple's DVD Player software on your computer, or in your consumer DVD

player with a screen, you needn't bother using the screen after that for your audio-only DVDs.

I always tell Toast to save the formatted DVD file as a Disk Image. This way I don't need to sacrifice any blank DVD-Rs to find out whether I

have made errors in the DVD authoring setup. Toast is not quite a What-You-See-Is-What-You-Get program yet, so you can't see how your DVD will look until it has been authored.

After Toast has finished writing a Disk Image file of your new DVD onto your hard drive, you can double-click on the file "myfilename.toast," and Toast will come to life and mount the image. Then DVD Player will start up and put your nifty interface on the screen. This is where you check that all of your track markers, titles, and artwork are in good shape.

When you are satisfied at this point, you can burn a DVD in Toast by copying the Disk Image onto a blank DVD-R. Generally, two vinyl LPs will fit onto one DVD at 24-bit/96kHz resolution. Your mileage may vary. You have the option of applying Dolby data compression to squeeze more music onto a DVD, but I always opt for linear encoding (PCM) for best sound quality.

POSTLUDE: THE FFT DISPLAY

To check your file visually for ticks, you can use SoundTrack Pro's FFT display, which presents a voiceprint of the music with the time axis running left-to-right, and frequency from bottom-to-top. Amplitude is represented by the brightness of the virtual oscilloscope display.

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FIGURE 7: Toast Titanium for authoring music DVDs.

GLOSSARY OF TERMS

AIFF: *Audio Interchange File Format*—an Apple-developed file format for audio files that are interchangeable between different editing software suites—supported by many software developers.

Disk Image: a file on a hard drive that has the same data layout as (for instance) an optical disk to be recorded.

DSP: *Digital Signal Processing*—the method of modifying digital sound data—it's all done by multiplying sample values by stored coefficients and summing them into registers.

DSP Farm: a PCI card containing many DSP integrated circuits for processing many channels rapidly.

Exponential Decay: the decay of the amplitude of a signal, where the percentage reduction in remaining amplitude is the same for each time interval. Sound in nature decays exponentially.

FFT: *Fast Fourier Transform*—a fast numerical algorithm for expressing a complex wave as a sum of its frequency components—known among mathematicians as the Tukey-Cooley algorithm.

File Flattening: when editing audio or video, this refers to the process of rendering all of the changes stored in an Edit Decision List to permanently modify the content in the audio or video file.

FireWire: a cable and transmission protocol that achieves 400 or 800Mb/sec transfer rate, also known as the IEEE 1394 standard.

Floating Point: a way of storing numbers in a word of computer memory. The number $1 = 3.1415926$ and is written as 0.3141593×10^1 in decimal notation. In a binary word, the fractional part (3141593) and the exponent (1) are expressed as binary digits, with 24 bits for the fractional part and 8 bits for the exponent. The leading non-zero binary digit after the decimal point (the "radix" in a binary word) is always 1, and is not stored. It is always replaced when moving the data to an arithmetic register for a math operation.

Keyframe: originally a single frame of animated film artwork that defined the subject's motion. It was a complete frame drawn by a senior artist. The frames in between keyframes were drawn by junior artists called "in betweeners" in an animation studio. In the language of data compression for video, a keyframe is a complete digital representation of a frame that does not rely on information from preceding or following frames.

Linear Phase: the characteristic of a filter transfer function where it acts as a pure time delay, or as no delay at all. Otherwise, the delay varies with frequency and the phase is not linear.

Marker: a piece of metadata inserted into a sound file that is not included in the sound data itself. It consists of the sample number where it is inserted, plus any text information that the sound editor wants to associate with the marker. Markers are displayed in the waveform view of a sound editing window, along with the text. The editor uses them as reminders, as beginning and end points for a selection of sound, and for telling QuickTime Pro where the chapter markers are in a movie file.

PCM: *Pulse Code Modulation*—refers to the linear encoding method of digitizing audio, where the spacing between all voltage levels is the same, and there is no data compression. Also called LPCM for Linear PCM.

Polarity: the characteristic of an electronic signal where a positive pressure pulse in a sound wave is represented as a positive voltage in an analog electronics chain, or as a positive number in a digital system. Most listeners can hear a difference when the polarity is inverted.

QuickTime: Apple's software architecture for sound, video, and movies on the Mac and PC platforms.

QuickTime Pro: an optional \$30 upgrade that adds editing and playback enhancements to QuickTime.

WYSIWYG: What You See Is What You Get.

Apple likes phosphor green, for some reason. A click will be visible as a vertical bright spike in this display because of its extended high-frequency response.

I found that music with flute soloists, or dominant flute sound, and brass showed prominent tick-like artifacts at note changes. Some looked bad enough, or occurred between notes, so that I pencil-edited them out. But it seemed as though transients were a natural part of note changes in these wind instruments.

An e-mail to Brian Davies cleared up this issue. He replied that he had spent much time with a James Galway flute recording to make the logic in ClickRepair discriminate between vinyl clicks and flute note changes. Once ClickRepair is done with a file, about all you can do is check for pops and thumps, and not for clicks. The real clicks are gone.

Figure 8 shows an FFT display of the beginning of the Vivaldi mandolin concerto, expanded in time so that individual notes are visible. I believe that frequency components much beyond 22kHz are processing arti-

facts. This file was recorded at a sample rate of 48kHz.

HIGHER-END HARDWARE AND SOFTWARE

If you have the budget of a feature film production at your disposal, you can invest in a digidesign Pro Tools setup, consisting of a PowerMac G5 or Mac Pro tower containing DSP farm cards and interface cards, plus an external interface, control surface, and the Pro Tools software itself. For LP restoration you will add Sony Oxford plug-ins for equalization and noise removal. Think about spending around \$10,000 for this setup.

If all you want to do is transfer LPs, and not make feature films, you can purchase the Apogee Digital Rosetta 200, a

very tasty two-channel A/D-D/A box. You will need to add the FireWire interface card so that you can connect it to your computer. This will run about \$2160 at street prices. You may wish to add the Big Ben clock for another \$1350 for the ultimate in low recorded

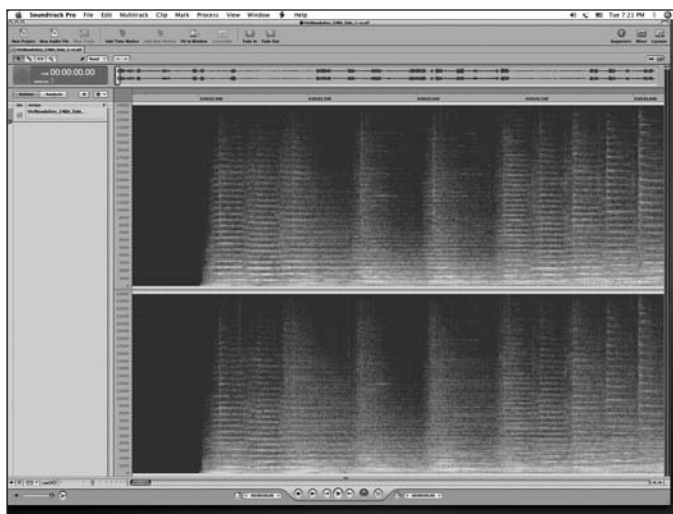


FIGURE 8: SoundTrack Pro's FFT (voiceprint) display.

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sample jitter. Other high-end mastering boxes are in this same price range.

REAL-WORLD HARDWARE AND SOFTWARE

According to Tomlinson Holman's book, no "24 bit" A/D converter actually attains full 24-bit resolution, and since he completed his book I think that this is still the case. So if you are shopping for a more mid-priced converter box, you want to read the reviews concerning sound quality rather than concentrating on the signal-to-noise number. You can find converters in the \$200-\$900 range with quality and versatility pretty much proportional to price.

Rod Paine, a stalwart Macintosh user and occasional contributor to *Macintosh*, found that the E-MU 1820 card met his requirements for recording at the 192kHz sample rate. But it only works in a PC. So he bought a cheap PC for the purpose of making LP transfers, and he uses Diskwelder Bronze to author DVD Audio disks. He sent me some AIFF files, which sound very nice. I needed to downsample them to 96kHz to play them. DiskWelder

Bronze now also runs on the Macintosh platform, and many external converters work at 192kHz.

DVD Audio disks require special players, but you can play DVDs authored with Toast Titanium, with only music on them, on any type of DVD player. If you want to go the bargain route, you can use the A/D converter built into your computer in conjunction with shareware to do the editing. Here is a list of appropriate resources that supports vinyl restoration:

SHAREWARE:

Ray-Gun, for Mac and PC:

www.arboretum.com

Amadeus II for Mac: www.hairersoft.com

SoundStudio 3 for Mac:

www.freeverse.com/soundstudio

Audacity for Mac, free:

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

ClickRepair for Mac and PC:

www.maths.anu.edu.au/~briand/sound

COMMERCIAL SOFTWARE:

BIAS Peak LE for Mac:

www.bias-inc.com

BIAS Peak for Mac: www.bias-inc.com

Roxio Toast 7 Titanium for Mac:

www.roxio.com

Roxio Easy Media Creator for PC:

www.roxio.com

Discwelder Bronze for Mac and PC:

www.minnetonkaaudio.com

Final Cut Studio for Mac:

www.apple.com/finalcutstudio/

HARDWARE:

E-MU 1820 PCI audio card for PC:

www.emu.com

Mark of the Unicorn Traveler:

www.motu.com/products/motuaudio/traveler

BOOKS:

Tomlinson Holman, *5.1 Surround Sound—Up and Running*, Focal Press, 2000.

George Towner/Apple Computer Inc., *Discovering QuickTime—An Introduction for Windows and Macintosh Programmers*, Morgan Kaufmann, 1999.

CONCLUSION

One thing I learned from experience is that the 16-bit format is unforgiving of RIAA playback equalization errors and phono cartridge response errors. Fur-

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thermore, some LPs may have an overall EQ applied by an editor. In the analog domain, you can play an LP with all of these imperfections, and it will sound wonderful due to the forgiving nature of the analog format. But when you record the LP at 16-bit resolution, all of its imperfections become starkly revealed during playback. Somehow the process of digitizing amplifies the audibility of frequency response irregularities.

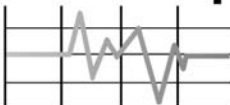
Therefore, I observe the fanaticism that you see here concerning calibrating the frequency response of my recording chain, even when using the 24-bit format. I know it will sound better when transferred to DVD, and especially if I quantize it to 16-bit/44.1kHz resolution for transfer to CD.

A reading of the Digital Millennium Copyright Act reveals that owners of analog consumer media are granted the right to transfer them to digital media "for personal use." The term "personal use" is not further defined. It states explicitly, however, that no consumers are permitted to make money from the sale of their digital transfers. This right is reserved to the original copyright owner of the analog master.

As of this writing, the HD DVD format has reached the market. Sony plans to introduce the Blu-ray format in the PlayStation 3 game player, and by next spring Blu-ray authoring drives will be commonplace for computers, if not inexpensive. This throws the future of DVD-Audio and SACD under a cloud, because very high-resolution audio is possible on the HD DVD and Blu-ray media. Even so, the new players will still play the DVD-Rs that you make now with high-resolution audio on them from vinyl LPs. *aX*

Victor Staggs has degrees in Physics, Mathematics, and Electrical Engineering, and spent the earlier part of his career in defense research. Since the Cold War ended, he has done some consulting in audio and does private research in signal processing. His full-time job is as an inside technical consultant for a computer sales company, and he concentrates on the technology for creating films and video. He is a member of the Audio Engineering Society, and enjoys jogging and 1966 Ford Mustang maintenance.

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