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Sound Processing on Your Computer

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Introduction

You can record any sound source that can be plugged into your PC's sound "line in" and achieve CD- or near-CD quality high fidelity. Popular sources include your television, stereo receiver, microphone, or "line out" from another computer system. As long as you're making personal copies of broadcasts or media you own (such as vinyl albums and tapes) you shouldn't have any problem with copyright infringement. Where folks get into trouble is when they make copies for their friends or for sale. If you have any doubt about recording copyrighted material you should obtain legal advice.

Hardware

Your first step will be to optimize your playback hardware and get your sound source wired to your computer. The quality of recording is highly dependent on the quality of your audio equipment, so tune up your turntable with a replacement needle (or cartridge) and make sure it's grounded to your receiver so you don't get 60-cycle hum. For vinyl records, purchase a record care product to clean the dust out of the grooves and reduce static. The same goes for your tape deck – clean and demagnetize the heads, install new belts, etc. Audio cables and adapters (such as RCA to 3.5 mm/1/8 inch mini) will be required to make the connection to your computer's sound card "line in". Most of today's mainstream sound cards (and motherboards equipped with on-board sound) should do a good job recording your media. Headphones are optional but sure come in handy.

Waveform Basics.

Your computer will be digitizing each of the two (stereo) channels at 44,100 samples per second. Each sample will store two bytes (16 bits) representing the voltage at that instant in time. Therefore, each sample will have a range of 2 raised to the 16th power. That is, a number that can range from 0 to 65,535. These 16 bits set the dynamic range, defined as the ratio of maximum signal level to the noise floor. For 16-bit digital audio, the root-mean-square (RMS) dynamic range is defined as $20 \times \log(65,536) + 1.76$ in dB, or 98.1 dB. (Oversampling, that is using 18-bit or higher converters, slightly improves dynamic range.)

So what's the bottom line? My friend, this is why CD audio has significantly better quality than your vinyl record, analog cassette tape, and AM/FM broadcast sources. These analog sources are limited to 60 dB of dynamic range. They may have the same peak voltage level as their digital counterparts, but their noise floors are 30 or more dB higher.

To put it simply, your digital audio systems have lower noise floors than those of your record album and tape player systems. Therefore, you will never achieve true CD quality by recording from these sources. However, with good media playback equipment and filtering software, your digitized recordings will have significantly higher quality than the analog systems they are recorded from! Digitizing your old albums and tapes is definitely cool, practical, and relatively easy to do. Once digitized, they will never pick up noise or wear out.

Digitizing and processing acoustic files requires many, many computations. Industry experts have drawn the line for an adequate computer system as a Pentium II 500 M(or equivalent). You'll also need a lot of disk space since stereo audio records at the rate of $44,100 \times 2 \times 2 = 176,400$ bytes per second. To record that 85-minute Led Zeppelin double album, you're going to need 900 MB to store the WAV file, so your computer should have lots of disk drive space available.

CD Data Format Theory

So, is 176,400 the traditional 1x CD data rate? Close, but not quite. There's a lot of error correction and track information included with the encoded data on a CD. This "overhead" takes up the majority of stored data so whether it's an audio or data CD, the electronics are transferring data at a much higher rate – 540,225 bytes per second to be exact. Audio CD overhead consumes 67.35% of this data, so the music information rate is $(1-0.6735) \times 540,225 = 176,400$ bytes per second. The data CD has more error correction so its overhead consumes 71.57%, resulting in a data rate of $(1-0.7157) \times 540,225 = 153,600$ bytes per second. This is the exact 1x data CD transfer rate. Convert to standard kilobytes by dividing 153,600 by 2 raised to the 10th power. The result is 150.000 kB/sec, the traditional 1x data read/write rate. Using this base transfer rate, CD units rated at 52x are simply $52 \times 150 = 7,800$ kB of data per second.

Here's the relationship between CD audio and CD data specifications. For a CD rated at 74 minutes of audio, the equivalent data capacity is $74 \times 60 \times 176,400 \text{ bytes} \times 0.8707$ (conversion factor for the different overheads) = 681,984,000 bytes. Likewise, for an 80-minute audio CD, the equivalent data capacity is $80 \times 60 \times 176,400 \text{ bytes} \times 0.8707 = 737,280,000$ bytes. Convert to standard megabytes by dividing these capacities by 2 raised to the 20th power. The results are 650.39 MB and 703.13 MB respectively. Sound familiar? Full-size CDR media are marketed with capacities of 650 and 700 MB.

Creating An Audio CD

Use your computer's CD-RW drive (CD burner) and application software to create a Music CD. If you need to purchase a CD burner, one feature you'll absolutely want is "burn-proof" technology. Plextor pioneered it several years ago and many competitors now offer it. This is good technology that will prevent buffer under-runs with resulting "coasters". We recommend quality CDR disks such as Verbatim Data Life because your digital copy may be with you for a long time.

A note on CD burners – yours (as ours) will probably not reach rated recording speed due to data transfer bottlenecks in your computer. IDE read/write limitations, bus traffic, background processes, etc. will slow down data transfer to your CD burner. So even if your burner is rated at 52x an actual write speed of 20-30x is more likely. This is still an excellent rate and will only take about three minutes to burn.

Software Recommendations

Microsoft's sound recorder is limited to 60 seconds so start looking for a good software package. There are a number of recording, restoration, and special effects packages available on the market in the price range of \$50.00 or less. Many are available on a free trial basis but you'll want to be careful about installing share-ware, free-ware, or trial-ware – many will install spy-ware. Use a search engine on prospective packages and look for independent product reviews.

We should point out at this point that just as we found several software packages useful for end-to-end processing of digital images, the same applies to processing audio files. We use one application for acquisition (recording), another for restoration (filtering), and a third for burning (making) the CD. We'll present the technique that works for us but there are many alternate approaches and solutions that may suit your needs better.

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For sound acquisition, we use WavePad (\$39 from NCH software, downloadable via the internet) because its features are intuitive to Windows users and it is well suited to mainstream folks like us. We found this program to be excellent for recording audio from our receiver. It is also our favorite for cutting, pasting, and parsing into individual tracks. Its most attractive feature is that the waveform window can be expanded both in time and amplitude. Other attractive features include fade-in, fade-out, inserting silence, and normalizing for maximum dynamic range. It has its glitches but overall this program is a good value for the money.

To capture the sound, we recommend that you select the industry-standard 44.1 kilosamples per second (ksp) stereo for your recording format. Record your record or tape, copy and paste side 1 with side 2. Next, filter your file to remove clicks, crackles, and hiss. Archive the file in WAV format to retain full digital accuracy. If desired, convert it to Media Player Level 3 (MP3) format for playback on personal devices. Although the MP3 format will reduce file size by 90% there will be some sacrifice in the original digital accuracy. MP3 works by compressing the file in a manner similar to JPG. For example, your 900 MB Led Zeppelin WAV file can be compressed to a 90 MB MP3 file.

For filtering, we use Pinnacle's Steinberg Clean 4.0 (\$40.00 from e-tailers such as buy.com). Although it may not ever be possible to fully restore the original audio quality, you can certainly go a long way in reducing the undesirable artifacts of age and use. We use Clean primarily for its restoration features. Despite several poor product reviews found on e-tailer web sites, we found that this software is excellent for removing clicks and crackle sounds from vinyl records. Clean's audition feature is really cool – you can turn each of the filters on and off during play and adjust their effects on the fly. Of note, you can also listen to the noise that is being filtered out. That's right, you can listen to the clicks and crackle sounds that are being removed! If you hear any of the desired audio track then decrease the filter's setting until you're left with just the noise. For albums in well-used condition we use the declicker filter set at 100%, the decrackler filter set at 70%, and all other filters turned off.

Double-click on the "Before" and "After" icons to play a 20-second clip from Blood, Sweat, and Tears 2. This is typical of how a well-used album's noise is significantly reduced by the Pinnacle Steinberg Clean software. When viewing the PDF file, to hear the sound clips, please visit this page online at: <http://www.mccordweb.com/newsletters/tech-notes/sound.php>.



Before Filtering



After Filtering

Audio editing and filtering programs may include other functions such as equalizers and special effects. Unless you have a specific listening requirement we recommend that you archive your sound files as close to their natural condition as possible and experiment with copies.

We prefer to combine the two sides of vinyl or tape sources using WavePad's cut and paste functions. Then we filter the resulting single WAV file using Clean. After filtering, we go back into WavePad to manually remove any remaining clicks, normalize the entire WAV file, then use cut and paste to parse it into individual tracks. Although a single WAV file will play fine on audio CD players, you won't be able to index from track to track. To have that functionality, open the WAV file, select (highlight) the first track, and cut the track. Open a new file and paste the track. Save the new file as Track01. Ditto for the remaining tracks.

For recording to CD we use Roxio's Easy CD 6, an application that came with our Plextor CD and DVD burners. Select the music CD tab and import the desired track(s). Enter the album title, artist name, and titles for each of the tracks. Then hit the orange button and accept the defaults to record your audio CD. Very easy! Note: Clean includes functionality to normalize, create individual tracks, and record to CD; we just like the way the other programs do it better.

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We use Avery Label Maker to create the CD label – a free application that comes with some of their label packages. I personally like to scan the album cover and select some portion of it for the CD label. Insert the album image, add a text box for the album title, artist, and year. Print the label and fix to your CD. Add a jewel case or window sleeve and you're done.

With a little practice you can get these steps down to about 60 minutes per album. Enjoy!



Finished CD, with scanned image of the Album, printed on an Avery 8692 CD label.