In Quest of Absolute Fidelity: The Saga of the Black CD

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1 The Story

Back in mid-2002, when I was contemplating buying the assets of Genesis Technologies, one thing bothered me: I believe passionately that I had to bring something useful to the table. Despite my experience in business, I wanted to be sure that I could contribute something to the audio community (besides reviving the Genesis brand).

To find this contribution, I turned to my own frustration as an audiophile (or music-phile!) – I much preferred records over CD's, but yet a lot of material I couldn't find on LP's. CD's were taking over, but I was still dissatisfied with the quality. I wanted to make CD's sound better.

1.1 Relying on Rumours

I had already heard that group of audiophiles in Singapore found out that when they copied a CD, the copy sounded different from the original. How can that be when the copy is identical to the original? To test the theory, I made a backup copy[1] of one of my favorite pieces of music – Jazz in the Pawnshop (JatP).

Then, I listened – yep, it sounded different, but why? I did a bit-by-bit comparison using the computer. Identical.

[1] I am ***against*** music piracy, and make back-up copies of only CDs that I own. If you use this process, please respect this. Also, it is tantamount to piracy to make copies of CDs to give away or sell.

So, I took a different blank CD-R. This time, a Gold Disc, and copied JatP again. Again, a different sound. Again, identical. How can three seemingly identical copies of a piece of music sound so different?

Well, it did take the whole of my time over the next two months, but by the next time I went to visit Arnie Nudell, I had a couple of new CDs to demo to him. He was floored by how good the "Black CD" sounded. I knew then that I was on to something.

1.2 The Results

After two months of research, testing over 50 different types of CD-R media, five different CD writers, seven different software for CD-burning, we can now *consistently* make a copied CD sound spectacularly better than the original. We would like to share this discovery with you.

The CD copy is more *musical*, in particular, the high frequencies ring with trueness that I used to experience only from records and live performances. The air and the image stability are much better, and instruments and vocals sound more dynamic and true-to-life. And most importantly to me, the sense of timing and "foot-tappity-ness" of live music was there.

The benefit of this Black CD was not only evident in high-end audiophile systems, but it made the music CD obviously better on *all* playback systems that I tried it out on: in my car, a mini-compo system, a mid-fi system, and even over headphones on a Sony CD Walkman!

The acid test was the audience at the 2003 Consumer Electronics Show's High End Audio suites. A couple of "good ears" we demo'ed the Genesis CD to were stunned by how good they sounded.

Arnie with Black CD: June 30, 2002

2 The Technology

Once I found that there was a difference in sound, I delved into the technology of the music CD to try to understand why this was happening. What I found out was pretty astounding – to me anyway!

Firstly, the precision needed to write the data on to the CD is incredible! Space between tracks is 1.6μm (one millionth of a meter). That's about one-fiftieth (1/50) the width of a strand human hair! The data on these tracks is written as pits and lands, and the pits are 0.8μm to 2.8μm in length and 0.56μm wide.[2]

The tracks are written in one long spiral and read at constant *linear* velocity. This is in contrast to a record, which is also one long spiral but read at constant *angular* velocity. This means that the angular speed (rpm) of the CD has to be slowed down continuously when data is read from the inside of the disc to the outside in order to maintain constant linear velocity. To do this, all CD transports have a rotational servo to provide the correct disc speed.

However, this is almost impossible. Which means that the disc decelerates in tiny steps, so, in reading or writing the data it would go: too slow, a bit too slow, a little bit too slow, just right, a little bit too fast, a bit too fast, too fast, deccelerate, too slow, a bit too slow…… This speed difference is "smoothed" out by the read-ahead buffer on CD transports. Theoretically.

A CD writer creates discs by a process of transferring audio data to the disc's surface via laser irradiation in the form of lands and pits (digital 0's and 1's). The laser has to turn on and off within the time that it takes the disc to turn 0.8μm and still be able to make a pit of consistent depth, width and position. Unfortunately, this is also extremely difficult, so these lands and pits end up not being of a uniform length or width, and the uneven gaps between them produce a form of distortion known as jitter.

Thus, any vibration or inaccuracy in making the CD could translate to errors in encoding. What is worse is that mass-produced CDs are pressed, not burned – resulting in even more inaccuracy. Even if they are burned, they are

[2] For those of you interested in more detail, Robert Harley, in The Complete Guide to High-End Audio, gives an incredibly precise and concise treatise on the technology of digital audio.

burned at high speeds (these days up to 44x – and I tried burning a copy of JatP at 44x – it sounds *horrible* - even worse than the original).

So, why are the copies seemingly identical? Well, firstly, the copies may not be identical, they may just look identical as *data*. The computer does not care ***when*** the data is read or written, just ***what*** data is read or written. However, in music, we all know that timing is as important as playing the right note. The right note at the wrong time is the wrong note. (The wrong note at the right time is still the wrong note.)

Also, according to the Audio Red Book standard, in order to guarantee audio playback, the C-1 error rate has to be less than 220 per second. This means that if there are less than 220 error bits per second, the recording and be error-corrected to "perfect"! Since data is read at 1.4million bits per second, it supposedly "does not matter". But we all know that every bit counts in reproducing good music.

High fidelity isn't as simple as a mathematical equation telling us, "You won't hear the difference". My conclusion was that the technology was imperfect, and that jitter and other errors are already on the disc, and in the process by which CD's are written and read.

3 The Process

To minimize the deleterious effects of the limitations of the CD technology:

- use a good quality CD-RW drive, burning at the slowest speed it can,
- using a software that doesn't compress or process the music,
- burn a copy of any music CD you own on to a ***black*** CD-R blank.

The quality of the blank CD makes the most difference. Secondly, comes the CD-RW drive and speed at which you make the copy, and thirdly, the software you use.

4 The Details

4.1 The Right Media

Since my initial experiment showed up the difference between a standard silver CD-R, and a gold CD-R, the first place I explored was the media used to make the copy.

Singapore turned out to be a great place to do this experiment. On my first visit to the local IT mall, I ended up with over 30 different types of media. I was surprised at the numerous types available. Different types of gold blanks, the usual silver aluminum ones in different grades, and CD blanks of every shade of every color imaginable – blue, light blue, dark blue, orange, light green, dark green, red, pink, purple, puce, tangerine…

What I found incredible was that they all sounded different. I must have driven my wife mad playing the same piece of music over and over again for almost two months, and insisting that she help me distinguish between the various copies!

What troubled me most at this stage was that while they sounded different, there was no one disc that stood out from the rest.

Various blank CD's available

Some were truly awful, a few of them refused to play at all, and others kept skipping on music systems (but played on the computer CD-ROM). But a lot of these blanks had some quality that stood out, and were better than the original.

4.1.1 The Black CD

About a month into the process, I was told by a friend of mine – Ben Chia – about the black CD's that he and his friends had discovered. Gamers already know this one (I didn't!) – Sony issues their Playstation games on Black CDs. The theory is that games consoles tend to have to read data faster than music CD players and have weaker lasers than normal PC CD-readers, and thus have problems reading off standard CD media.

Black CDs, however, were supposed to have better reflectance than gold or standard CDs when read. The Black CD also has better absorption when writing. As the laser has to burn pits in order to write data, the better absorption enables it to burn a more consistent pit.

Eureka! I thought that I had found my solution… until I went searching for Black CD's and found 7 different brands on just one pass in the mall.

In total, over the months, I found 12 different Black CD's and more are turning up all the time. They were all also subtly different shades of black! Most were a deep reddish black, but there were also deep bluish black, and brownish black.

And yes, they all sound different. But they all sound much better than any of the silver, gold, or colored media. Again, there were the odd ones that won't play on my transport, and/or skipped when they played.

A sampling of different Black CD's

4.2 Burning Process and Software

The software must not compress or process the music in any way. Some are designed for "ripping" CD's and making compressed MP3 files out of them. Most of these sound bad – I have no idea why, even though they say that they store as uncompressed PCM. I've found that the ones with the least "bells & whistles" sound the best.

I use a freebie copy of Adaptec EasyCD that came with my CD writer. Others I've tried extensively include Ahead Nero, Roxio Platinum, VSO BlindWrite, and Real Jukebox. There are literally hundreds of different software that can be used to burn CD's.[3]

4.2.1 Have a constant source

First, make sure that the source you are going to make the copy out of is correct. The best way to do this is to take it off track by track from the CD and put on to the hard disk as different WAV files.

[3] One good place to look is at www.download.com which is a shareware/freeware download website.

Different software perform the copying and burning process differently, but this step is important as the WAV format is the simplest uncompressed PCM representation of the music that is extracted from the CD.

It seemed that the speed at which the CD's are read didn't make much of a difference. This is probably because the computer has 100% data accuracy (it thinks that it's reading data) and can read all the bits right (or error-correct along the way), and put them all on the hard-disk correctly. However, in my testing, I didn't use the maximum read speed, usually the speed just one below the maximum.

Make sure that the hard disk on which you are storing the data is clean – ie. no bad sectors, and defragment the disk first. Use a dedicated hard-disk if you have one. You have to make sure that each track or song is read as one contiguous file. Otherwise, it will be like having the notes of a song scattered around your hard-disk, and then having to collect them back together again before it can be written to the CD.

The hard-disk is a constant angular velocity drive, and it should not introduce timing errors into the music. It is unlike a CD-Reader which is a constant linear velocity drive, and needs a servo motor to constantly control the speed at which data is read off it. (Remember servo-driven direct-drive turntables?)

Most CD-RW drives have an internal memory buffer and this should theoretically fix this problem, but I've tried burning direct from a CD-ROM reader to a CD-Writer, but have had inconsistent results. Sometimes, the first couple of tracks don't sound very good, but it improves as it goes along. At other times, the timing seems to fade in and out as the music plays.

4.2.2 Don't let your computer be interrupted

This is common sense. It's like stopping a band mid-way through a song, and having them restart again!

Windows is a multi-tasking system, so even if you do not realize it, your system is doing a lot of work in the background even while idle. It could be checking email, cleaning up the swap file, doing housekeeping, etc. Hence, disable all other programs on your computer that can interrupt the music recording – virus checkers, internet, networking, system maintenance, etc.

Unplug all other devices except what is absolutely necessary. The computer will regularly poll all devices to check that they are working, gather data,

etc. This also interrupts the writing process. I have found that plugging in a USB mouse and moving it around while the disc is being written with a USB CD writer makes the sound "edgier" and gives an unnatural hardness and grain to cymbals.

Make sure that you have sufficient memory so that the soundtrack on the hard-disk is read on one pass, and then written to the CD writer. Associated to this, make sure that DMA is enabled to ensure that there is sufficient speed on the I/O bus to read the hard-disk and write to the CD writer at the same time.

The ideal would be to have a clean computer with just CD writing software, a CD writer and a hard disk installed. You will need a mouse to navigate, but if possible, put that mouse on another port, or use a serial mouse. Since you won't need a speedy computer, any old unit will do!

4.2.3 Write Slowly on One Pass

Run writing operation at the slowest setting that the writer can work at (we can hear the difference when going up to 4x and above). Many writers cannot write to 1x – the slowest being 2x.

Run the writing process "disc-at-once" so that the laser doesn't switch off in between tracks, and need to get "up to speed" again on the next track. This also ensures that the disc in the CD writer is spinning consistently.

4.3 The Right CD Writer

My first discs were written on a CD writer built into a laptop computer. Later, I tried everything I could get my hands on: a no-brand internal CD writer, units from HP and Teac, an ancient 6x Iomega Predator that was given to me as a present and I had stored away, and the latest, a newly released Yamaha that touted "Audio Master Quality" recording features.

In general, the best CD writers for this would be ones with the most powerful laser to ensure that the burns are consistent and deep (pits and lands are sufficiently differentiated). Usually the fastest writer has the strongest laser.

As it is so difficult to build a rotational servo to control the motor for constant speed acceleration, running it at the slowest speed will result in the least chance that speed oscillation caused by an imperfect servo system would introduce timing errors to the music during the writing process.

An external CD writer works best. A computer is actually a very noisy environment. There are cooling fans for the power supply, the CPU, and sometimes for the casing. The hard-disk, CD reader, floppy drives, all contribute vibration. *Just as you won't install your record player on top of a refrigerator, don't install your music CD writer in the computer.*

In addition, put your CD writer on a firm, vibration-free surface. Treat it like you would treat a hifi record player.

Iomega Predator
with Isodiscs top and bottom

I put the CD writer on four small Isodiscs[4] and damp it with another four large Isodiscs on top. To ensure a stable power supply, I plugged all the computer equipment into a PSAudio Power Plant[5] to ensure that power fluctuations will not affect the writing process.

Subjectively, the writer I liked best was the *old* Iomega Predator run at 2x – which was a surprise to me since it was so old. This was the machine with which I ended up using to make all my copies now.

I also liked the Yamaha CRW-F1 run at 1x and 2x, but the results were less consistent. However, these two units consistently beat other writers I tried.

4.4 Clean the Blank Media

This is pretty obvious; the laser can't be expected to burn consistently if there are specks of dust on the blank. Just as dust and dirt will cause pops and crackles on a record, dust on the blank media may cause bad music to be

[4] Available from www.secondbeat.com

[5] More information from www.psaudio.com

written. Again, as 220 errors are allowed per second, theoretically, this shouldn't matter – theoretically!

5 The Findings

Now, we have three variables, and theoretically millions of data points. It was a two-month process to work through all that and find the best.

Media:

- Consistently, Black CD-Rs sounded best. Different brands give subtly different sound. Unfortunately, even different batches of the same brand sounded different.
- Blanks labeled as "Digital Audio" were more expensive but sounded worse; however, some players with copy protection will not play CD-Rs on which the music royalty has not been paid so you're stuck. I haven't managed to find a Black Digital Audio CD-R
- Some brands had a premium silver blank discs labeled "Diamond" which sounded good with some material, but did not perform well when the music got too complex (orchestral or big band jazz)
- Many brands of media (even some black ones) did not play at all on my transport, and if they did, skipped
- Of all the brands I've found, I like the "Platinum Black" but Arnie preferred the "Memorex" as being more musical than the Platinum, but a touch less dynamic. (The advantage of the Memorex is that it is one of the few available in the U.S.)

Software and Process:

- The simplest software worked best for me. I preferred Adaptec with my Predator, while Arnie used Ahead Nero for his Yamaha on Audio Master Quality recording mode
- Run the software at its slowest speed, disc-at-once, taking as a source tracks pre-stored on the hard-disk in WAV format as individual songs
- Important to defragment the hard-disk first and make sure that the writing process is not interrupted by other software and hardware running on your computer

Hardware:

- Iomega Predator (the old 6x model, not the 32x model) or Yamaha CRW-F1 (USB)
- Support your CD writer as you would a turntable – it is extremely susceptible to vibration

6 The End of the Beginning

I feel that it is still too preliminary to make a conclusion. There also still a lot of mysteries[6] to be solved, and we don't believe that we have exhaustively explored every angle. We've also had slightly different results between Arnie and myself.

Just as there are so many brands of interconnects, CD transports, DACs, etc., you will have to find the combination of writer, software, and media that works best for you and the music you listen to. There are literally millions of possible combinations – and this should include different playback systems as well.

We had done all our listening tests in our own systems, and we coincidentally had the same CD transport – the Sony SACD-1. At CES, we used the Wadia 27ix and 270, and the discs sounded fabulous there too. However, you may find that with a different CD transport, or DAC, you might prefer different writers, software, and media.

However, there is one thing that we can confidently conclude – that the black CD's using this process result in a spectacular improvement to the musicality of the CD playback. I've spent many hours going back to CD's that I thought didn't sound good, and with the re-recording, have realized that they were just badly pressed. So, I now have more music to enjoy!

So, have fun. And please write and let me know how you do if you do try this process and improve on it! gary@genesisloudspeakers.com.

[6] Afternote: on a final visit to the local computer mall as I was finishing off this paper, I found a "BLACK DIAMOND" disc. Initial impressions were that this was the absolute best so far!! I was told that it was more expensive because it had a thicker, deeper coating. Isn't competition wonderful?