

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

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Preface

In the two months following the first publication of this article, I've had an astonishing amount of feedback. Mostly from readers who have had great success and surprised themselves by how good these black CDs sounded. More importantly, there were a number of readers who had great inputs and contributions as they had been doing something like this for sometime now. So, this update includes all I've learnt from these, the true music-philes who have been experimenting for years.

I also want to thank the real computer experts who think that I am a "complete idiot" because digital bits are digital bits. I am always reminded of the quote from F.A. Clark, "We find comfort among those who agree with us - growth among those who don't". From those experts, I have also learnt a thing or two, and this paper is all the better for it.

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 to 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 CD's that sound better. I bought an SACD player, and lots of SACDs, but the result was still musically unsatisfying.

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 copy¹ of one of my favorite pieces of music from 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.

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 full months² of research, testing over 50 different types of



Arnie with Black CD: June 30, 2002

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.

² By the second version of this paper, I had over 9 months of experience. Way less than one reader who first tried this process of re-recording CDs in 1995!

CD-R media, five different CD writers, and eight 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"³ of live music was there.

The benefit of this Black CD was evident not only 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 Black CD to were stunned by how much better they sounded than the original.

2 The Technology

Once I found that there was a difference in sound, I researched some of 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.⁴

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. Theoretically, this means that the distortion on

³ Some readers have told me that this is called PRaT - Pace, Rhythm and Timing. Well, it makes my foot tap in time to music!

⁴ For those of you interested in more detail, Robert Harley, in *The Complete Guide to High-End Audio*, gives a precise and concise treatise on the technology of digital audio. On the web, <http://www.howstuffworks.com/cd-burner.htm> gives a great description too!

the whole CD should be the same, whereas the distortion on an LP increases as the stylus reads the inner grooves of a record.

In order to achieve CLV, 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, it is almost impossible to control speed steplessly. 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, decelerate, too slow, a bit too slow..... This speed difference is theoretically "smoothed" out by the read-ahead buffer and digital clock on all CD transports.

A CD writer creates discs by a process of transferring audio data to the disc's surface via laser irradiation creating "lands" and "pits" (digital 0's and 1's) on a layer of organic dye. 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 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 second⁵. This means that if there are less than 220 errors per second, the recording can be error-corrected to "perfect"! After error correction, the data is supposedly perfect, but it still sounds different.

High fidelity isn't as simple as a mathematical equation telling us, "You won't hear the difference". My simplistic conclusion was that the technology was still imperfect, and that jitter and other errors are created 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 can⁶,
- 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.

After the first publication of this paper, many readers have directed me to a piece of software for music extraction that makes a huge difference. This is Exact Audio Copy (EAC) - more later.

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.

⁵ See <http://www.msscience.com/faq.html> for more explanations about error rates and correction.

⁶ One exception is the Yamaha CRW-F1UX in Audio Master Mode. The best speed using the majority of media is 4X.

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...



Various blank CD's available

What I found incredible was that they mostly 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. 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.⁷

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.

⁷ It seems that CD-Rs are made of a layer of aluminum coated with an organic dye that turns changes when "burned" with a laser. In general, there are only 3 types of dyes used in CD-R's cyanine (long strategy), phthalocynine (short strategy), and metal azo (long strategy). One reader told me that he thought that the metal azo gave the best sound, but I have not been able to find a black metal azo. It also made sense when some readers suggested that the thickness of the aluminum substrate, and also the thickness of the dye layer had some effect on the sound quality of these discs.

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 dye layer has to absorb the laser and turn opaque 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.



A sampling of different Black CD's

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 ones that won't play on my transport, and/or skipped when they played.

In order to determine what the media actually is, readers have suggested various software that read the ATIP on the CD-R media. Here's an article on what ATIP is:

<http://knowhow.cdfreaks.com/article.php?ID=122>

And here are two software that read the ATIP.

http://w510.tm.odessa.ua/soft/cdr_atip/

.....and

<http://www.gum.de/cdrid/>

However, despite what the skeptics say about the color of the disk making no difference, the black CDs still sound best to me.

4.2 Burning Process and Software

The software used for this process 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.⁸

The most important piece of advice I got from readers is that there are also different audio *extraction* software that take the music off the CD, and they sound different. I had only been using disk burning software as I had thought that the extraction process was the same.

By far the best software for music extraction is Exact Audio Copy (EAC) - from www.exactaudiocopy.de - which will make many passes to extract the track in the most accurate way, resulting in error-free digital extraction⁹. Run on its "secure" mode, EAC made the most astonishing sonic improvement to the process!

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. This is what EAC does best. Read the log when EAC finishes. Sometimes, it says that the copy is OK, but you only had 96% accuracy. In this case, re-extract that track.

Also, 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

⁸ One good place to look is at www.download.com which is a shareware/freeware download website.

⁹ Many thanks to Eric Fantone, Warren Parker, Adrian Wang (they were the first three!) and many others who suggested this.

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.

This may be caused by the slightly different speeds between the CD reader and CD writer, and which is not totally compensated for by the read buffer in the reader and the write buffer in the writer.

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.¹⁰

Run the writing process "disc-at-once" so that the laser doesn't switch off and on 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 spins 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 4x 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.

¹⁰ One exception is the Yamaha CRW-F1. Using its proprietary Audio Master Mode, the lowest jitter is actually at 4x when using medium and high speed media

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

I put the CD writer on four small Isodiscs¹¹ 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 Plant¹² to ensure that power fluctuations will not affect the writing process.



Iomega Predator
with Isodiscs top and bottom

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.¹³

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.

A new piece of information from some readers is that there is an optimum pairing of CD-burner and media, and that

each burner and media pairing has an optimum write speed!

<http://www.cdrinfo.com/Sections/Articles/Specific.asp?ArticleHeadline=Jitter%20Tests&Series=0>

The article also showed how using a different media resulted in different levels of jitter. The surprising conclusion was that using the Yamaha on its Audio Master Mode produced the least jitter at 4x, while using it in normal

¹¹ Available from www.secondbeat.com

¹² More information from www.psaudio.com

¹³ A couple of readers suggested that I liked the Predator because it was a top-loading machine with a clamp. I also damped down the clamp and cover with the Isodisc. Other readers have also suggested the Plextor with its proprietary VariRec jitter-reduction burning process as a good alternative to the Yamaha.

mode gave the least jitter at 1x! (with Audio Master Mode at 4x producing less jitter than normal mode at 1x).

It also showed how using a long strategy cyanine or metal azo dye gave reduced jitter as compared to a short strategy dye when burning at 4x on the Yamaha Audio Master Mode. In general though, the lower the recording speed, the lower the jitter.

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 written.

5 The Findings

Now, we have three variables, and theoretically millions of data points. It was initially a two-month process to work through all that and find the best. Over the past couple of months, I've also learnt a lot more, and especially with the feedback from helpful (and some insulting) readers.

Media:

- Consistently, Black CD-Rs sounded best. Different brands give subtly different sound. Unfortunately, even different batches of the same brand sounded different. The later batch of my early favourite - the Platinum - did not sound as good as the first batch.
- 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, even though they read well on the computer's CD-reader.
- 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.)

- Just before the publication of version 1 of article, I discovered a "Melody Black Diamond". Now that I've had a chance to test it much more extensively, I've found this to be the bestso far anyway. And this is something that both Arnie and I agree on - this has the advantages of both the Platinum and Memorex, and then some!

Software and Process:

- The best software for music extraction is EAC - Exact Audio Copy.
- The simplest software for burning worked best for me. I preferred Adaptec with my Predator, while Arnie used Ahead Nero for his Yamaha on Audio Master Quality recording mode.
- Subsequent information leads me to believe that the Yamaha recording at 4x on Audio Master Mode would result in lowest jitter, and best quality. However, I haven't done extensive testing on this yet to compare the results between this and the Predator.
- 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:

- External CD burners work best: the Iomega Predator (the old 4x/4x/6x top-loading model, not the newer 32x model) or Yamaha CRW-F1 (USB). Many readers have asked about using a stand-alone hifi CD recorder - I have not tried these, so I don't know.
- Support your CD writer as you would a turntable - it is extremely susceptible to vibration
- Use a dedicated recording computer, which is not doing anything else. One reader has suggested that making copies with a laptop computer running on batteries result in better copies.

Despite all the feedback, and now so many doing experiments on this process, it is still too preliminary to make a conclusion. There are still a lot of mysteries to be solved, and we don't believe that we have exhaustively explored every angle. Since publication of the first version of this paper I've had plenty of feedback, some of which I've incorporated in this paper.

Both Arnie and I did all our listening tests in our own systems, and we coincidentally had the same CD transport - the Sony SCD-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.

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.

The Music

Lady be Good: Jazz at the Pawnshop XRCD2, First Impressions Music

Could You Believe: Antonio Forcione & Sabina Sciubba, Naim

Hotel California: Eagles, Hell Freezes Over, XRCD, Victor

Vivaldi Largo: Arne Domnerus & Gustaf Sjökvist, Antiphone Blues, Proprius

Associated Equipment (System 1 - Singapore)

Analogue: Roksan Xerxes X,
Naim Aro, Virus

Phono amp: FM Acoustics Resolution Series FM-122
with FM 102 Power Supply

Transports: Sony SCD-1, Rega Planet

DACs: Sony SCD-1 (built-in) on "custom" mode, filter 1
Classe DAC-1 (with Rega Planet)

Pre-amp: FM Acoustics Resolution Series FM 266

Power Amp: Classe CA-401

Speakers: Magneplanar MG3.5/R (this was before I bought Genesis! ☺)

Cables: FM Acoustics Forcelines, Audioquest and XLO Signature

Associated Equipment (System 2 - Seattle)

Transport: Sony SCD-777EX

DACs: Sony SCD-777EX (built-in) on "custom" mode, filter 1
Classe DAC-1
Monarchy Audio Digital Interface Processor 24/96

Pre-amp: Musical Fidelity Nu-Vista M3 (used as pre-amp)

Power Amp: Anthem PVA-7 (used as two-channel)

Speakers: Genesis 6.1

Cables: Genesis proprietary