Naim CD Ripping Engine

Steve Harris
Naim Audio
Southampton Road, Salisbury, SP1 2LN, England

1. Introduction

This paper describes the issues of making quality copies of audio from a CD onto a hard drive. During the development of the Naim Audio Server and Hard Disk Player range, it became very apparent that there was a large variation in systems for extracting audio data from CDs.

From analysis the issues came down to:

- Secure Mode ripping and techniques to get the audio samples off the disc
- Copy protected and non compliant CDs
- Offset Correction
- Capturing track lead-in and lead-out
- The CD mechanism and the firmware running inside it.

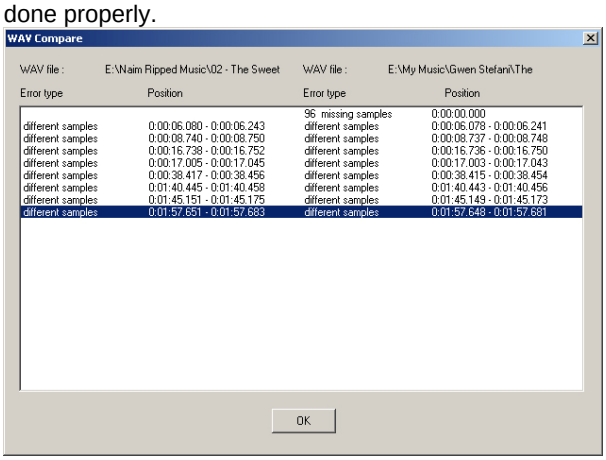
2. Burst Mode vs. Secure Mode Ripping

PCs have shown that a CD can be copied to hard drive within a couple of minutes. Unfortunately, due to the weak error correction system implemented on audio CDs, the resultant audio files can be not bit perfect. The issues can range from subtle but audible unnecessary interpolation, to random clicks and pops when copying used CDs. This type of ripping is known as “Burst mode” and assumes that the sectors being read from the disc are perfect; hence a fast copy can be achieved. Some mechanisms provide hardware-assisted correction in this mode, but typically it results in unnecessary interpolation of the audio, rather than trying techniques to get the real audio samples from the disc.

The Naim audio servers use a superior technique called Secure Mode Ripping on a specially selected audio grade CD mechanism. Secure mode works by using a CD mechanism that does not cache data and reads the sectors multiple times. It also uses the un-correctable C2 error feedback information supported by the CD mechanism, so known problematic areas can be re-read and handled accordingly.

The Naim engine typically spins discs at peak speeds of 16x, but when problematic areas of the disc are reached, the disc rotation speed is reduced, as this can help on reading the data off the disc.

Given the peak speed of x16, the way the ripping works where at bare minimum the data is read twice, this reduces the ripping speed to x 8. Tracks at the start of disc actually rip slower then ones on the outer edge, as the physical spin speed needs to be inherently faster nearer the centre and mechanical speed limits are reached. Also there is overhead locking into the start of each track. So the real world speed is around x7.5.
Copy protected discs that have purposely corrupted error correction information are detected and the interpolation algorithm as used by a traditional CD player to play such a CD is used, hence the resultant audio data is reconstructed. Typically the Naim server will rip a CD in about 8 minutes, which is approx 3 times slower than burst mode, but gives a far higher level of confidence that the extraction of data off the disc was done properly.



Comparison of ripped track using Naim Rip versus Rip using a common media player

3. Copy Protected CDs

One of the key requirements of a CD ripping engine is to ensure that it can handle a wide range of real world CDs. Nowadays there are plenty of non standard CDs due to copy protections schemes implemented that break compliance with the original Philips Red book (audio) and Orange Book (audio + data) CD specification.
Copy protection schemes fall under four techniques:

3.1 Corrupt Table Of Contents (TOC).

Orange and yellow books CD’s can have multiple sessions on them. This scheme assumes that an audio CD player will only look at the first TOC entry, while on a computer drive it will read the other TOC entries which are purposely corrupted.

3.2 Corrupt data layer on Orange Book CDs.

These CDs are a hybrid of traditional audio tracks and also an optional computer data section. This opens the opportunity for audio CDs to contain multimedia content. Some copy protection schemes use the quirk that if a PC CDROM drive attempts to read a data layer that has unreadable sections on it, then it will give up mounting the disc, so the audio section part of the disc is inaccessible to the computer.

3.3 Corrupt C1 & C2 Reed-Solomon Information in the audio information.

The copy protection scheme purposes breaks the error correction information embedded in the audio and forces the player to interpolate. Many ripping systems cannot handle this situation, so they decide that the disc is faulty and abort on ripping the disc. This type of schemes is bad as it makes discs vulnerable to wear and tear and it also affects sound quality.

3.4 Auto-run computer software supplied on data layer of Orange Book Disc that blocks access to audio tracks.

This is a very sinister scheme as it works by automatically installing software on the user's computer that blocks access to the audio tracks on the CD. Some of these small software applications were hidden deep in the operating system of the computer and very difficult to remove. This is known as a Root Kit. Luckily these schemes were short-lived as the system is 'virus like' in the way it achieves its protection method.

The Naim ripping engine has a high level of compatibility with the various non-compliant discs in the market. The audio mechanism runs custom firmware that the data part of orange book CDs appear invisible, hence giving ultimate protection against data layer corruption tricks.

4. Offset Correction

Most computer CD-ROM mechanisms suffer from a symptom where there is a small positional error when playing audio CDs. This is because the calculated position vs. the actual position the laser moves to on the disc is slightly different. The consequence of this is that either the start or end of the track is not captured correctly.

Schemes like AccurateRip have been created which allows users to calibrate their 'data grade' mechanism via their ripping application, by inserting a CD that is known by the AccurateRip database on the Internet. A positive or negative offset can be then calculated to adjust for the offset error. Few ripping applications actually support this and it's hit and miss if the CD mechanism supports this either (i.e. each mechanism manufactured is consistent), as the finer details of the firmware in CD drives are rarely advertised. The Naim ripping system uses a drive designed for reading audio CDs and is factory calibrated to have no offset error. This ensures that the start and end of tracks are accurately captured.

5. Capturing Track Lead-in and Lead-out times

CDs have a concept of time between tracks that can be defined by the artist. This can range from nothing (one track merges on to the next), to several seconds.

MP3s and WAV files have no concept of this inter-track album spacing, which means ripped albums typically lose this information. It is up to the player to add a predefined gap between tracks. On gapless albums, like live concerts, this can ruin the flow of the recording. If this information is not captured at rip time, then it is impossible to add this information at a later stage. The Naim ripping engine captures the lead-in and lead-out times and records this as silence (PCM0) into the WAV audio files. When the player application is playing an album, it seamlessly joins each WAV file together, resulting with the album on the hard disc playing back the way the artist wanted it to be heard.

6. CD Mechanism Requirements

A computer CD-ROM drive typically connects via the IDE, SATA or USB interfaces and uses ATAPI protocol. This means that much of the code for actually getting the data off the disc runs on an embedded micro on the CDROM mechanism, rather than in the ripping program running on the computer.

The requirements for the CD-ROM mechanism used in the Naim Servers:

- Ability to handle C1 & C2 error correction + report back non-correctable C2 errors to the PC.
- Good compliance with copy protected CDs when reading corrupt TOCs and purposely corrupted error correction information.
- Mechanically quiet. Many drives sound like a jet engine when spinning a CD at high speeds.
- No data caching. Caching causes havoc; as a one-off bad read of audio from the disc, will keep on returning the same bad data when asked to read the disc again.
- Hiding of data layer from Orange Layer CDs, which can then cause various compatibility issues for the drive and computer operating system if strategically corrupted.
- Calibrated offset tracking. Start and end of tracks can be captured accurately X
- Good compliance of tracking warped, off-centre and discs with poor reflectivity (CDR, CDRW and well worn CDs)
- Clamping mechanism that can cope with dual layer discs that are out of specification thickness wise.

7. Conclusion

Although it is possible to create an equivalent ripping system using a PC, CD-ROM drive and ripping software, it is fraught with technical issues to ensure the correct combination of software and hardware is used. Spending weeks ripping your CD collection, only to find that the copies are sub-standard is a very disheartening experience.

The Naim Audio Server solves this problem by providing a solution that works out of the box and doesn't need any computer knowledge to make it work. Simply open the door, insert a CD and about 8 minutes later the CD has been ripped and categorised into the database.

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