



world class sound...

Naim HDX Hard Disk Player

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Abstract

Getting data from hard drive to music is no easy task. To join the two different worlds of audio and computing and produce audiophile sound quality was the challenge. The diverse skills required to achieve this level of quality and ease of use was enormous. Experience gained through eighteen years of CD player development has stood Naim in good stead to develop a world class hard disk player. This paper describes the technical features incorporated in the design of the HDX Hard Disk player.

1. Introduction

Naim launched their first CD player in 1991: the CDS. This player set new audio standards of what could be achieved from the 16 bit 44.1kHz CD format. Since then Naim have continued to develop and improve the technology and techniques necessary to turn the data on the silver disks into great sounding music.

All of this knowledge gained has been utilised to create the HDX. The HDX is not limited to 16 bit 44.1kHz, the internal architecture is 24 bit 192kHz. Although music ripped from CD is 16 bit the HDX has been designed with future formats in mind. Hi-Res audio is becoming available ironically as it appears that SACD and DVD-A are dying. The source of hi-res audio of the future is the web. There are now a significant number of sites selling 24 bit 96kHz and 88kHz music downloads. The Naim Label will be releasing the majority of its catalogue in hi-res audio format over the next two years.

The HDX is not only a hard disk player it is also an audio server, using technology developed for sister products, the NS01, NS02 and NS03. The HDX can serve six streams simultaneously and well as the highest quality audio output for local listening.

2. CD Loader

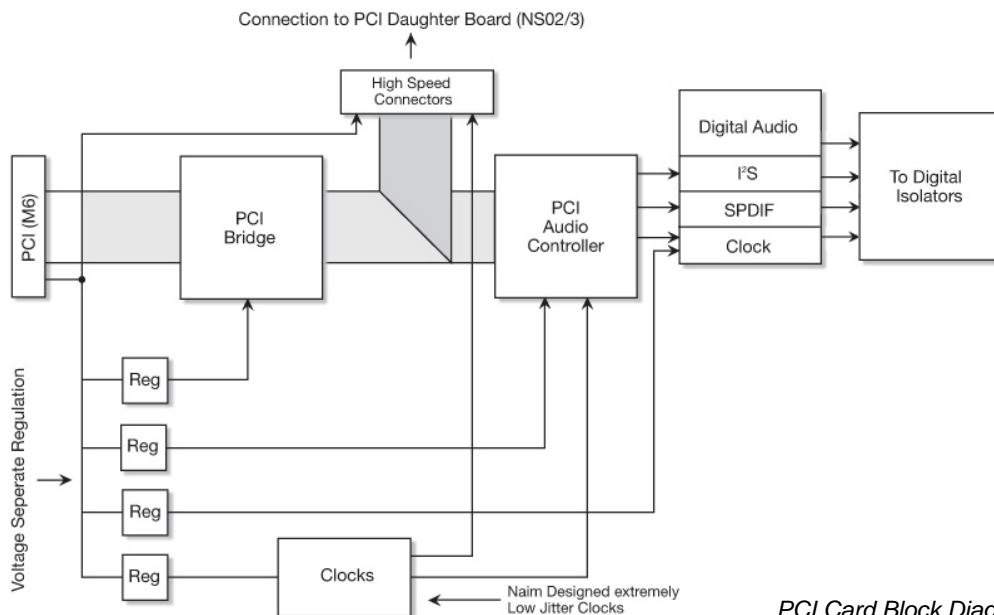
A hard disk player follows the obvious computer maxim of Garbage in Garbage out. (GIGO). The quality of the CD Rip is critical in getting the best performance.

The CD loader has been selected for quality of rip and audible noise during ripping. Bespoke firmware had to be developed to ensure bit for bit ripping.

See the Naim White Paper 'Naim CD Ripping Machine' about ripping.

3. PCI card

The Naim designed PCI card is the starting point of the audio master clock and digital data to be converted into analogue on the Analogue board described later. There are various methods of extracting data from a computer based system to convert the audio, such as PCI, USB and Firewire. Each method has its merit but the fast parallel PCI bus was preferred. To make this happen Naim have developed a custom PCI audio driver to ensure correct bit for bit data is transferred to the audio environment. The PCI card is actually two six layer PCBs. Each PCB has been designed for high speed signal paths using the latest ECAD systems. Careful tracking design techniques are required to ensure the data in the parallel bus arrives at each PCI Audio controller without corruption. As with all high speed design the route of the tracks must ensure no overshoot or undershoot on the fast edges of digital signals. Ground planes are also utilized to reduce electromagnetic radiation. The PCI card utilizes a PCI bridge connecting four PCI audio controllers. The main PCI has the PCI bridge, PCI audio controller and two master clocks. The daughter PCI card has three PCI audio controllers.



PCI Card Block Diagram

As with all Naim's design ethos, good sound quality starts with good stable power supplies. The PCI card has separate regulation for each stage in the PCI card, there are four low noise regulated power supplies on the main PCI card; there are a further three on the PCI daughter. Only the PCI main is used in the HDX design. There are two Naim designed extremely low jitter auto switched master clocks on the PCI main board: 49.152MHz and 22.5702MHz. These clocks are separately buffered to each PCI Audio controller.

4. Naim Audio Driver

To ensure the data on the hard disk gets transferred accurately to the PCI audio controllers, a custom sound driver was written.

The driver runs as a Ring 0 Kernel driver (known as Kernel Sound) and handles the following tasks:

4.1 DMA transfer from Sound subsystem to PCI audio controller on Naim Sound card. Using DMA means that the system CPU usage of the driver is held to the bare minimum. There is only one CPU driven copy & data translate function getting done.

4.2 Appearing as a single input 'hardware mixer' that ensures we do the handling of audio data, rather than the operating system.

4.3 Driving four PCI audio controller ICs via a PCI bridge seamlessly.

4.4 Communicating through IOCTL to a custom Ring 3 Services library, which communicates to our ARM powered 'System Services' board, which in-turn routes VCXO messages to the sleeping PIC Microcontroller. This wakes up and reconfigures the analogue board when needed.

4.5 Mapping fixed and float data formats to the 24bit fixed point internal format of the PCI audio controllers.

4.6 Keeping consistent physical output of unit, mapped to the relevant audio controller on the PCI sound card. An output ID EEPROM on each PCI controller allows this mapping to occur.

4.7 Generating a parallel stream for the SPDIF output.

The sound driver handles 8bit fixed, 16bit fixed, 24bit fixed (packed), 24bit float, 32bit fixed and 32bit float sample formats. This ensures good compatibility with consumer and studio grade audio files.

Low resolution 'internet media' formats are converted to 44.1kHz / 16bit to give compatibility with external DAC's and AV processors connected via the S/PDIF output.

5. Analogue Board

Audio PCB design in the HDX comprises one four layer main PCB which includes:

- Digital outputs
- Digital Isolation
- De-jittering circuits
- DAC
- First and second stage analogue filtering
- Microcontroller

- Analogue and Digital Power supply
- Relay Drivers
- Relay switching

The second sub PCB is a two layer design containing:

- Third stage analogue filtering
- Output Relays

6. Digital Output – SPDIF

Both Coaxial and Optical SPDIF (IEC958) digital outputs are provided on the rear panel of the HDX. The coax output is transformer coupled.

7. Digital to Analogue Isolation

To ensure ground isolation and therefore no interaction, the analogue stages of the HDX have an independent toroidal transformer to power the analogue and digital circuits. The ground system is separate for the computer and analogue circuits in the HDX. Where the data is transferred from the PCI card to the Analogue Board electrical isolation is required. The high speed clocks and digital data are isolated using monolithic air core transformer technology. The slower speed control lines are opto coupled.

8. Clock

As discovered many years ago developing Naim's CD players; the quality of the clocks is paramount to the resultant sound quality. The already low jitter clocks arriving at the Analogue board are then conditioned by de-jittering circuits. The de-jittering circuits incorporate three independent Voltage Controlled Oscillators (VCXO's). These are switched in depending on the sample rate of the incoming audio data.

9. DAC

The HDX employs the Burr Brown PCM1791A for the digital to analogue conversion. This part has been selected by Naim by hours of bench testing and listening tests for best sound quality. Careful attention to the PCB layout around the DAC stage ensures best performance is achieved.

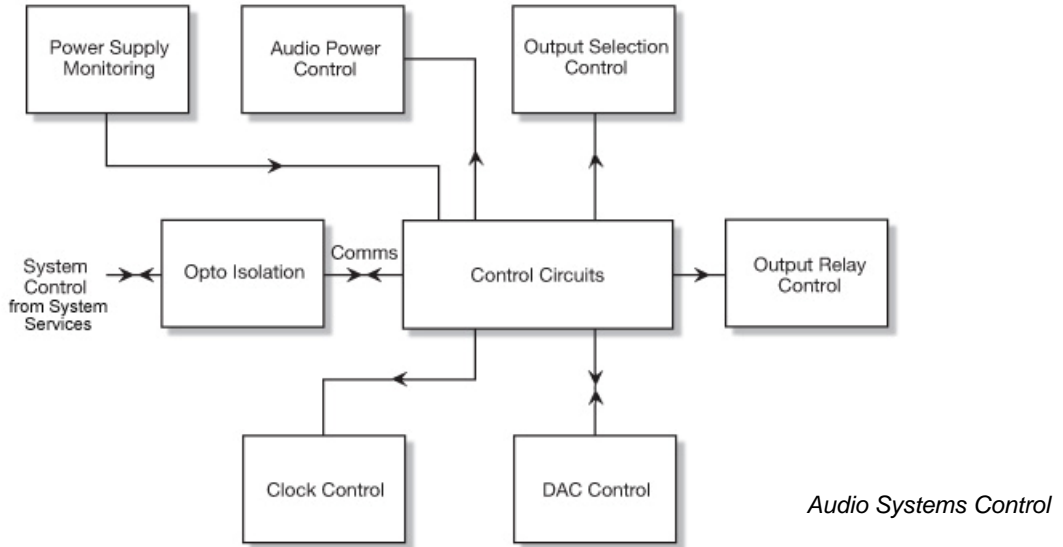
10. Analogue Filters

The analogue output filter is multi-stage seven pole filter. The design uses Burr Brown OPA604 opamps to perform the filtering; these are single chip opamps so a total of six are required. These OPA604s have been chosen by Naim for best performance. There is a plethora of audio opamps available but after many hours of listening tests this one was chosen as having the finest sound quality. A combination of Sallen-Key and multiple feedback lowpass filters are used to implement the seven pole filter.

The highest quality through-hole components are used in the signal path.

These components are also tested and matched in to tight tolerance groups to ensure correct frequency response.

11. Microcontroller



The Microcontroller (PIC) is in sleep mode during audio playback. The Microcontroller is woken by communications from the System Services Board to control the de-jittering circuits and DAC.

The system controller sends information to the Microcontroller about the sample rate of the audio data, the Microcontroller then configures the de-jittering circuits and DAC to accommodate this audio data.

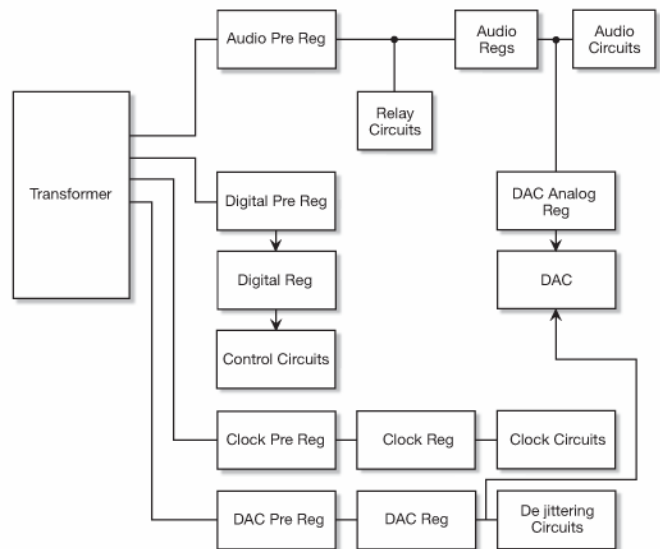
The Microcontroller also controls the outputs relays and feeds this information back to the System Services Board to display on the GUI. To maintain isolation between the digital Microcontroller and the analogue DAC the control lines are electrically isolated. The Microcontroller also monitors the power supply checking for mains brown outs.

12. Audio Power Supplies

A split rail power supply is utilised in the HDX audio circuits. This is double regulated to ensure good clean power is supplied to the opamps, DAC and relays. Finest quality 4700µF capacitors are used for bulk storage then the voltage is regulated to +/-14V. This is then re-regulated to +/-12V.

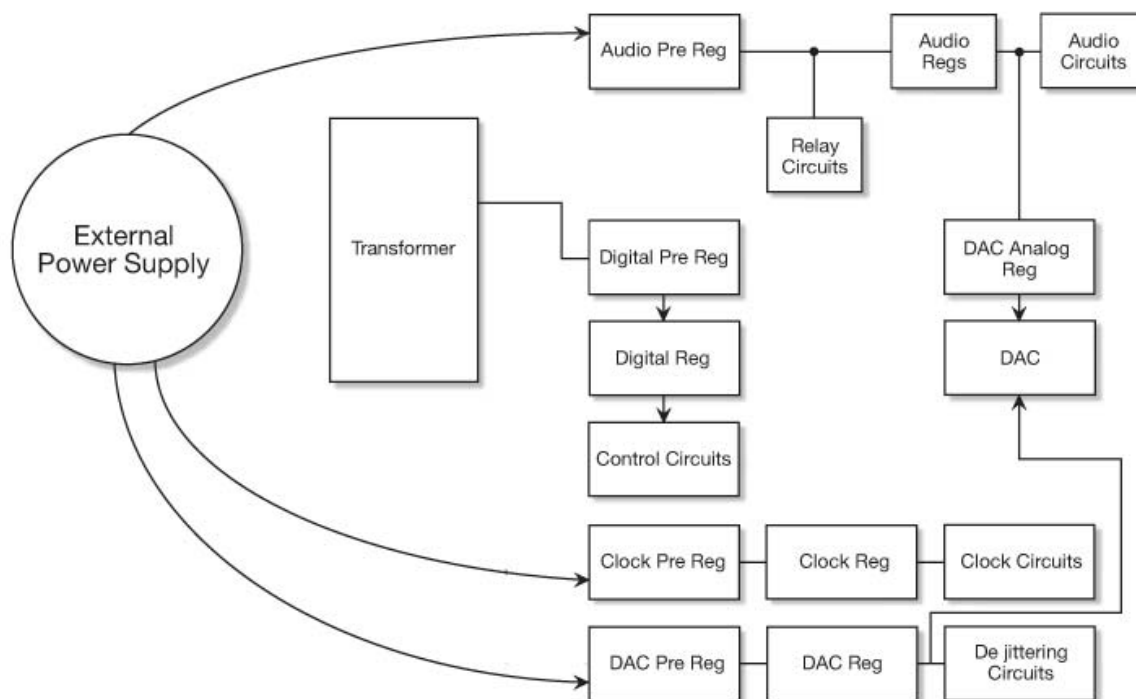
This ensures a very low power supply noise floor for the audio circuits to work from.

The power supplies for the digital sections use a 15,000µF bulk storage capacitor. Each section on the digital circuits: De-jittering, DAC and Microcontroller have dedicated double regulation.



Internal Power Supply Topology

13. External Power Supplies



External Power Supply Topology

External power supply upgrade can be achieved by removing the link plug and adding a Naim XPS or CD555PS, connecting the two products using the SXPS Burndy lead. Both the XPS and CD555PS supply very low noise regulated voltages. When this upgrade is applied the analogue bulk capacitors are bypassed so the +/-14V regulators are fed from the voltage coming up the SXPS Burndy lead; This means the analogue supplies are triple regulated in this mode pushing the noise floor even lower. The analogue side of the DAC also has a dedicated voltage rail.

With the HDX connected to an external supply the microcontroller continues to be powered by the internal toroidal transformer. This is done so that all the external supplies are best utilised for powering the various digital circuits. In this mode the pre-regulators for the DAC digital and the de-jittering circuits are fed by the external supply and therefore triple regulated.

14. Muting Circuits

Output muting is achieved by the use of the highest quality reed relays. To get the best audio quality signal through a relay is not a trivial task. As with all electro mechanical devices these are affected by acoustic energy and so are mounted to the PCB to minimise this effect. Reed relays are also susceptible to power supply noise. To counter this Naim uses constant current mirror drive circuits to achieve the best audio quality. The audio outputs are available via the DIN and RCA sockets; these outputs are separately switched.

15. Conclusion

Joining the two vastly different worlds of audio and computing wasn't easy. The development process of Naim's servers and Hard Disk player has been long and arduous. The amount learnt in the process has been huge. The result, we believe, is products we can be proud of. Products that are Naim through and through and products that we think we set a new standard in the market.

It's not customary in a white paper to thank the team but everyone worked so hard and had so much good input that I just have to. Thanks, you all know who you are.



Naim's HDX is powered by the DigiFi™ platform; leading edge software technology licensed from DigiFi Ltd of London