Fusion CD64 CD Player Digital Engine in Depth

Tube Technology Compton House Drefach Carmarthenshire SA14 7BA
T +44 (0) 1269 844771 F +44 (0)1269 833538
e info@tubetechnology.co.uk www.tubetechnology.co.uk
Contact Mr. Zia Faruqi

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Introduction

Our decision to enter the art of digital reply was taken with some very careful consideration. The development of 'yet-another' CD product featuring a tube output stage and 'off-the-shelf' DAC ICs such as Analog Devices or Burr Brown etc. was not preferable, because we had auditioned many fine products using conventional D/A conversion methods and were not 'musically-moved'.

If we were to enter this complex arena of digital engineering it should be with a product that really pushed the boundaries of D/A conversion, making a worthwhile contribution to musical reproduction.

In 1999 we introduced the Fusion CD Player. It utilised revolutionary new technology using FPGA devices running at 96kHz with 24 Bit operation and DSD capability, all designed using the Pulse Array engine. We now introduce the new Fusion CD64 Platinum featuring a new and improved 64 Bit 96kHz Pulse Array engine.

Most of the world's audio companies, including some of the very exotic and costly brands have only a handful of D/A chip manufacturers to choose from. There are varying degrees of finesse and tonal balance between these products, but the overall limitations of 'bitstream' or 'multibit' technology can make it difficult for digital designers to create products that do not sound sterile and clinical in presentation. Our quest for accurate digital replay has led us to co-develop a completely new concept for D/A conversion, known as Pulse Array. The research and development involved in this project span a period of over 20 years, since the early inception of digital audio itself. It allows us to offer an impressive 64 bit 96 kHz custom digital engine with an amazing 1024 tap digital filter - more than four times greater than any commercial device i.e. HDCD filter has approx. 256 taps. All this is achievable because custom software is written to operate FPGA (Field Programmable Gate Array) devices allowing flexible solutions to be developed and implemented for Hi-End Audio use.

The Fusion CD64 is a very versatile player offering tri-mode operation, a CD player, a Transport with clock lock facility and DAC mode with two inputs.

'Clock Lock' of either 256 x Fs with TT Transports or 1 x Fs for other manufacturers transports is standard. This system transmits the sync-lock from

the DAC to the CD Player allowing both the DAC and Transport to be 'locked together' at the same clock frequency reducing jitter to a minimum. With this system in use, better sonic results are achieved with an optical connection because an optical cable does not introduce any RF noise.

Digital versus Analogue or Vinyl has been a long running debate. The Fusion CD64 has reduced the gap considerably between a natural analogue sound and one that is digital. The maximum dynamic range of even a standard 16 bit CD is in the order of 120dB and vinyl in the order of 65dB. In order to take advantage of this increased dynamic range it is important that the increased high frequency energy is 'palatable', without losing any resolution. Red-Book CD still has many virtues and even with the recent introduction of new formats such as DVD-A and SACD, we feel outstanding results can be achieved with the Fusion CD64, from Tube Technology.

The Fusion CD64 is a formidable machine combining State-of-the-Art digital electronics with classic analogue principles. This document defines the different stages within the products architecture. (Refrences to the previous version 24 Bit CD64 where applicable.)

1. Hardware Improvements
2. Overall Digital Topology
3. Digital Receiver
4. D/A Converter
5. Digital Filter
6. CD Mechanism
7. Analogue Stage

1. Hardware Improvements

The previous (MKII) digital engine utilized the HDCD 24 bit 48 kHz digital filter, and three FPGAs, one per channel as the 24 bit 64xFs DAC and one as the 16 bit RECEIVER. These FPGA devices utilize 16,000 gates each and are program once only, with fusible links. Clock speed of the Pulse Array DAC was 40 MHz utilizing a ceramic resonator and a crystal resonator for the CD clock. The complete circuit inclusive of Class A vacuum tube output stage is housed on a two layer pcb.

The new digital engine for the Fusion CD64 uses three FPGAs, one as a 64 bit 2048 x oversampling DAC, one as a 24 bit (32-96 kHz input rate) all digital RECEIVER and one as the WTA 64 bit 64xFs,1024 tap digital filter. These new FPGA devices utilize 200,000 gates each, and have memory which is programmable, uploading software from EPROM. This ensures absolute future proofing as new changes in digital formats, i.e. SACD, DVD-A, DVD-V (DAC mode) can always be accommodated by simply changing the EPROM memory chip. The engine also utilizes an FPGA for clock distribution, software protection and host controller. Clock speed of the Pulse Array DAC is 98 MHz utilizing a 10ppm clock oscillator module for

2. Overall Digital Topology

The Fusion CD64 uses 3 FPGA devices featuring over 200,000 gates in each unit. One is used as an Input receiver, one for D/A Conversion and one for the Digital Filter. The whole system is governed by a Host Controller which allows the use of proprietary software with software protection.

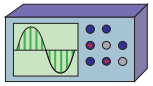
What makes pulse array different to multi-bit and bitstream DACs (the norm' in almost every other CD player) is its ability to reveal more of the music without sounding aggressive or tiring. All DACs are sensitive to jitter on their master clock; this makes a product sound more 'digital'. The advantage of this system over bitstream

and multibit is reduced jitter sensitivity one thousand times less than bitstream DACs and ten times less than multibit DACs. For example one nanosecond of random jitter on a bitstream DAC will have an output with S/N Ratio of approx. 67dB, a perfect multibit would be in the order of 94 dB, but pulse array is astonishingly low at 114dB.

A Pulse Array DAC utilises a low bit pulse array modulation system. This device is custom programmed with a sophisticated set of instructions so it behaves like a discrete DAC. The Fusion CD64 uses 24 elements in its design. Each element produces a stream of pulses; each stream is slightly different from each other. These small differences include information such as ambience and low level detail, which are usually lost in standard DACs. The 24 streams of pulses are added together and produce the final array. The resulting sound is natural, smooth, full-bodied and extremely engaging.

3. Digital Receiver

The receiver chip takes the SPDIF or AES/EBU data and generates clocks and the data in a form that the filter can accept. The new chip has a major benefit of all digital data extraction and a RAM buffer. The all digital extraction is error tolerant it can accept multiple edges, which often happens in noisy environments, without generating errors.



4. D/A Converter

This fourth generation builds on the success of the 24 bit system; it employs 64 bit 7th order noise shaping, 2048 times oversampling rates and improved pulse width modulated elements. These refinements give much better measured performance, better detail resolution with a smoother more focussed sound quality. Why use 64 bits? All digital filters generate higher output bit data widths for example 16-bit input multiplied by 16-bit coefficient generates a 32-bit output. All conventional filters truncate the output by discarding bits however this discarding may lose information. By using a 64-bit filter and DAC architecture, there is no possibility of degrading the sound quality. 64-bit architecture becomes a very big advantage when digital volume controls are used as no loss of detail or degradation is possible.

The output on all DACs require at least one audio amplifier in their circuit to convert its current output into voltage, so it can drive a pre-amp in your system. This is another area where unwanted out of band noise is created, sounding coarse and hard. This noise on a multibit DAC is in the order of 30dB and a bitstream DAC 20 dB, The Fusion CD64 uses extensive filtering and its correlated RF noise output is below 100 dB across the spectrum! Because the conversion process is based on discrete logic with 24 DAC elements running at 192 X oversampling, the final DAC array oversampling ratio is equivalent to 4608X.

5. Digital Filter

Digital filters play a very important role in all D/A converters, as they are responsible for accurately reconstructing the audio signal. Sophisticated algorithms and very long tap lengths coupled with 64 bit performance give the Fusion CD64 a much better measured performance, with better detail resolution and a smoother more focused quality.

The WTA filter algorithm has taken twenty years of research to develop. It solves the question as to why higher sampling rates sound better. It is well known that 96 kHz (DVD Audio) recordings sound better than 44.1 kHz (CD) recordings. Most people believe that this is due to the presence of ultrasonic information being audible. What is not well known is that 768 kHz recordings sound better than 384 kHz and that the sound quality limit for sampling lies in the MHz region. 768 kHz recordings cannot sound better because of information above 200 kHz being important simply because musical instruments, microphones, amplifiers and loudspeakers do not work at these frequencies. So if it is not the extra bandwidth that is important, why do higher sampling rates sound better?

The answer is not being able to hear inaudible supersonic information, but the timing of transients. It has long been known that the ear/brain can detect differences in the phase of sound between the ears to the order of microseconds. This timing difference between the ears is used for localising high frequency sound. Since transients can be detected down to microseconds, then the recording system needs to resolve timing of one microsecond implying sampling of 1 MHz.

However, 44.1 kHz sampling is capable of accurately resolving transients *if the FIR filters have infinite long tap lengths.* Sampling theory is proved by having brick wall filters that span from the birth to the end of the universe not practical in a real world filter. All reconstruction filters have relatively short tap lengths the largest commercial device is only about 256 taps. It is due to this short tap length and the filter algorithm employed that generates the transient timing errors. These errors turned out to be very audible. Going from 256 taps to 2048 taps gave a massive improvement in sound quality much smoother, more focussed sound quality, with an incredibly deep and precise sound stage.

Initial experiments used variations on existing filter algorithms. Unfortunately, going from 1024 taps to 2048 taps gave a very big improvement in sound quality, and it was implying that almost infinite tap length filters were needed for the ultimate sound quality. At this stage, a new type of algorithm was developed the WTA filter. This was designed to minimise transient timing errors from the outset, thereby reducing the need for extremely long tap lengths. The WTA algorithm was a success a 256 tap WTA filter sounds better than all other conventional filters, even with 2048 taps. WTA filters still benefit from long tap lengths; there is a large difference going from 256 taps to 1024 taps, so the Fusion CD64 features a WTA Digital Filter with 1024 taps.

6. CD Mechanism

The Fusion CD64 utilizes a high stability CD mechanism. The drive has been designed to offer very low jitter and high quality error correction. It utilizes the new Sony KSS213B dual beam optical block ensuring optimum performance and reliability. The CD64 also features CD TEXT which displays the album title and track title using a Vacuum Fluorescent Display, which may be switched off for minimum interference.

7. Analogue Stage

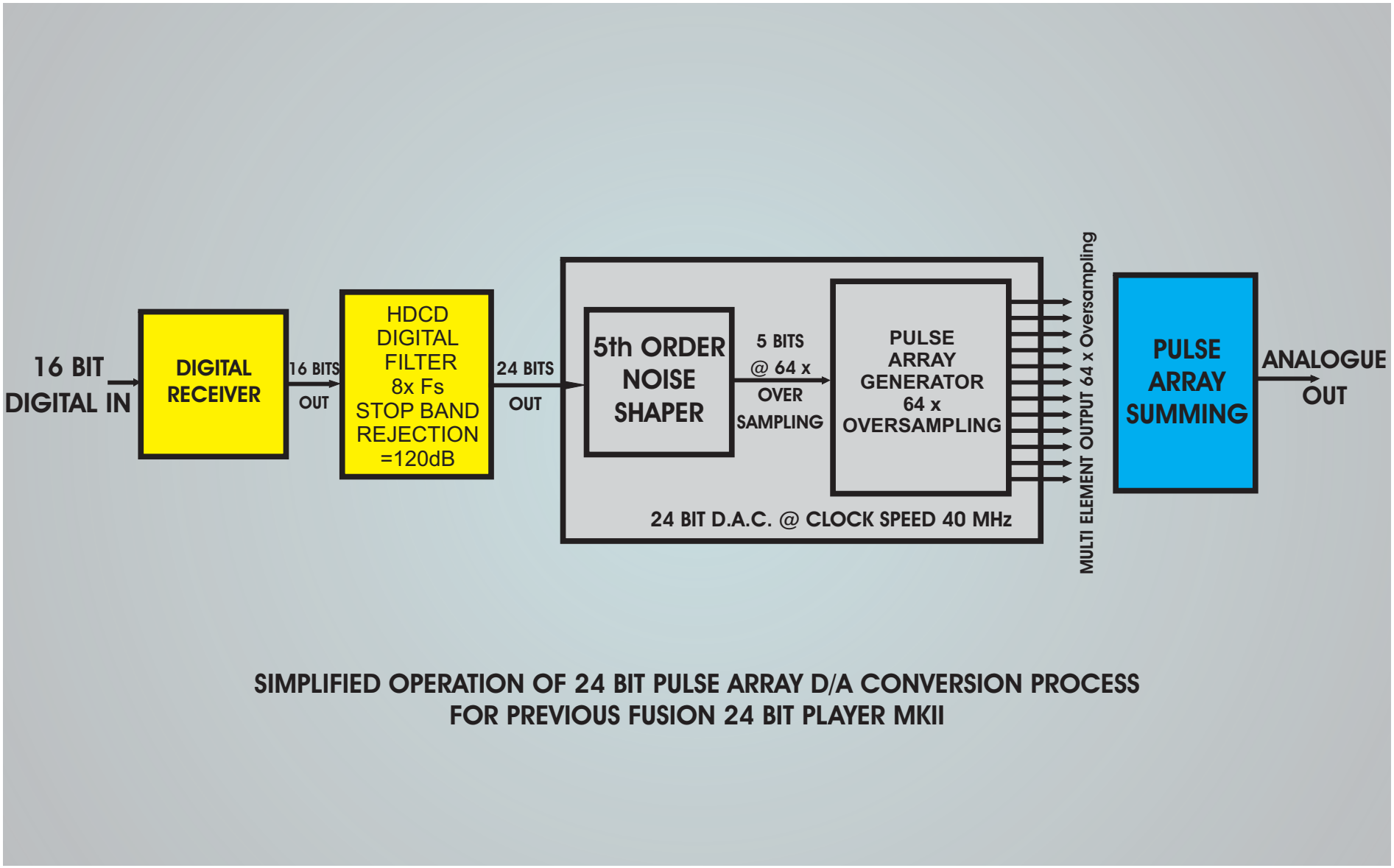
The output from the DAC array is a balanced voltage, implementing a simple first order low pass filter, which is fed into a balanced high linearity hybrid output stage, featuring a Milspec 6922 vacuum tube per channel and operational amplifier. Independent regulated power supplies are used to supply all the individual, stages. All digital and Analogue supplies are from independent transformers.

It was not an automatic response to fit a tube analogue stage because we are Tube equipment manufacturers! The need for an excellent analogue stage is paramount when designing a very critical D/A converter otherwise the whole shooting match is over when the signal passes through this stage. Firstly high grade solid state op-amp and discrete circuits were designed and tested, results were not as impressive as to the final tube stage fitted. Increased depth and realism coupled with real drive to the inter-connects made the use of tubes paramount.

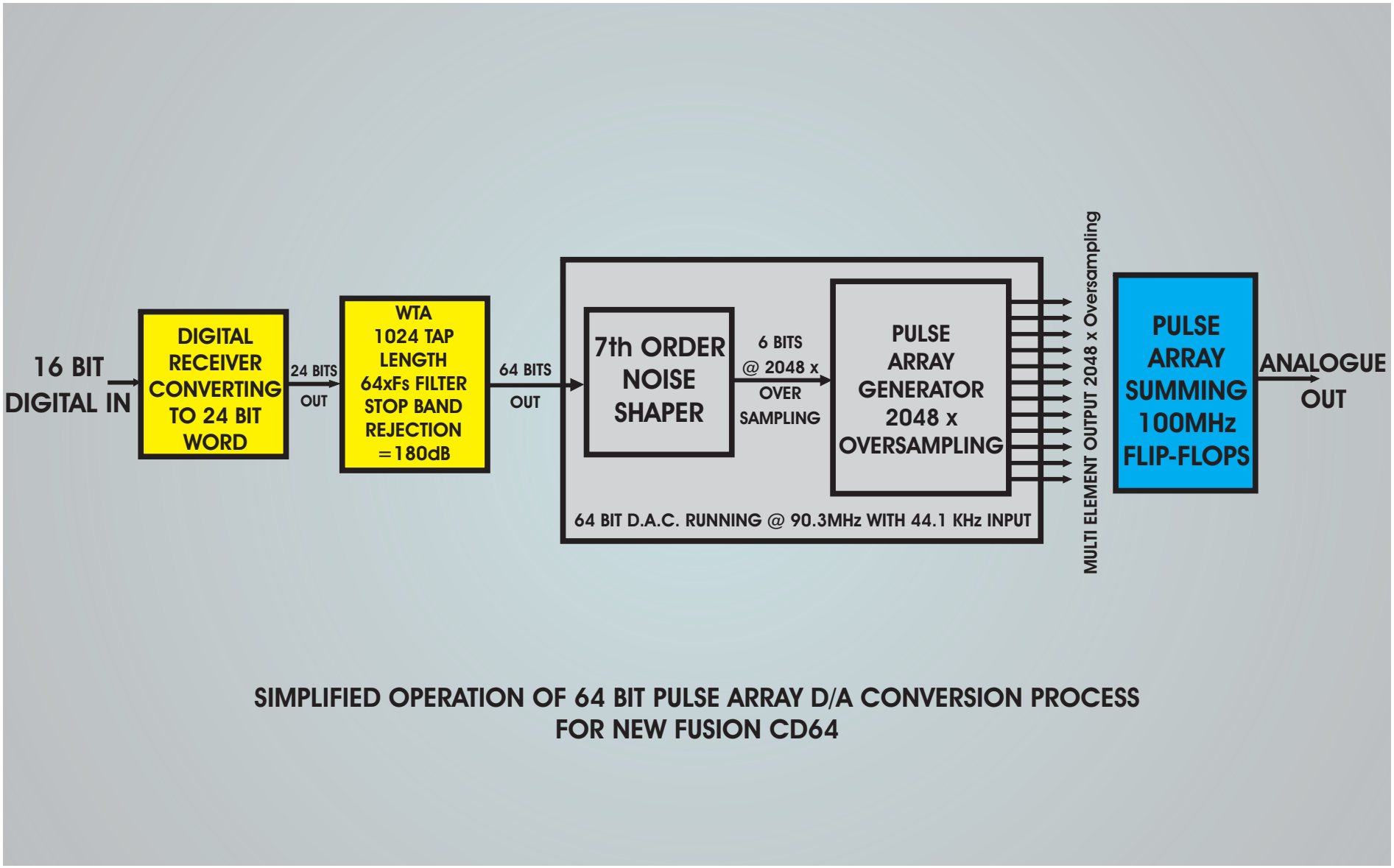
Specifications

96 kHz 64 BIT CUSTOM PULSE ARRAY DAC
WTA Custom Digital Filter
Gold Plated 4 Layer DAC PCB
1 x Auto Sensing 44.1-96 kHz Optical Input
1 x Auto Sensing 44.1-96 kHz Digital Coax. Input
1 x 44.1 kHz Optical Output
1 x Optical Clock Lock Input (128 x Fs)
1 x BNC Digital Clock Lock Output (1 x Fs)
4608 times oversampling
Surface Mount Technology
High Quality Transport Mechanism, Sony Dual Beam Laser
"Ever-Warm" Standby for DAC & Tube Stage
Universal Remote Control Handset (operates TT amplifiers)
Class A Vacuum Tube Output Stage 6922 V.T.
1 pair RCA outputs 2.7 V RMS
Vacuum Flourescent Display (Disable Function)
Supports CD Text

Available in Black or Silver
or with optional Rostrum support system
Dimensions 410 x 310 x 95 mm (W,D,H)
Weight = 10 Kg



SIMPLIFIED OPERATION OF 24 BIT PULSE ARRAY D/A CONVERSION PROCESS FOR PREVIOUS FUSION 24 BIT PLAYER MKII



SIMPLIFIED OPERATION OF 64 BIT PULSE ARRAY D/A CONVERSION PROCESS
FOR NEW FUSION CD64