Wadia Digital

Wadia 121Decoding Computer Overview

A Definition

What is a 121Decoding Computer?

The Wadia 121Decoding Computer is a small form factor digital-to-analog converter with digital pre-amplifier capabilities. It is designed to function as the control center for playback of digital audio sources.

At Wadia we refer to our digital-to-analog converters (DAC's) as Decoding Computers. This is because in function our DAC's work in much the same way as a personal computer (PC). We write software programs for our DAC's that run on powerful multi-purpose processors to accomplish a task (in this case decoding and perfecting digital audio waveforms). Digital audio data received from a source, is buffered in memory, and then processed via our software and circuit designs, much in much the same way as a conventional computer.

The 121Decoding Computer

Although diminutive in form, the 121 Decoding Computer was developed using the same design principles and philosophy that has shaped our reference level products. Remarkably for its size and cost, the 121 features several core Wadia technologies including: DigiMaster upsampling algorithm, SwiftCurrent current to voltage conversion, ClockLink and ClockLock jitter reduction, and DirectConnect with 32-bit Digital Volume Control.

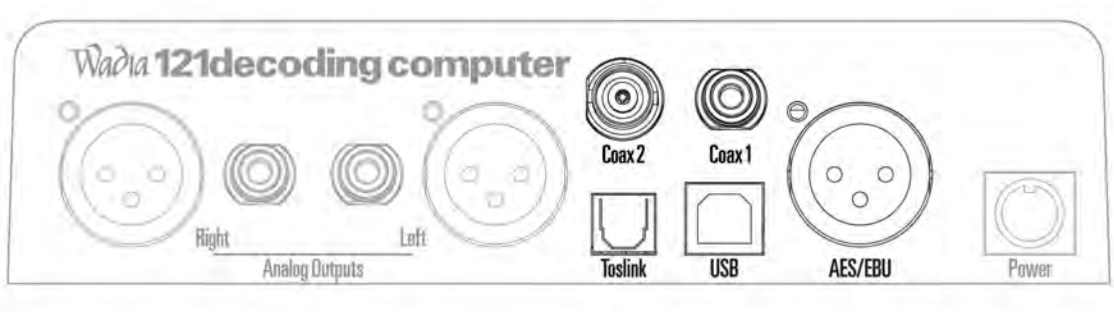
The 121 is comprised of 8 main sections – Digital Input's, Clocking, Digital Processing, Digital-to-Analog conversion, Current-to-Voltage conversion, Variable Output stages, Power supply, and User Interface. The following document will provide you with a brief overview of how each of these sections works and integrates together to create a true Wadia DAC.

Digital Inputs

The 121Decoding Computer has five digital inputs each capable of receiving and decoding data rates of up to 24-bits and 192 kHz sample rate in AES/EBU, S/PDIF, and USB formats.

Inputs include:

- AES/EBU (XLR)
- S/PDIF Coax (BNC and RCA)
- Toslink
- USB (B)

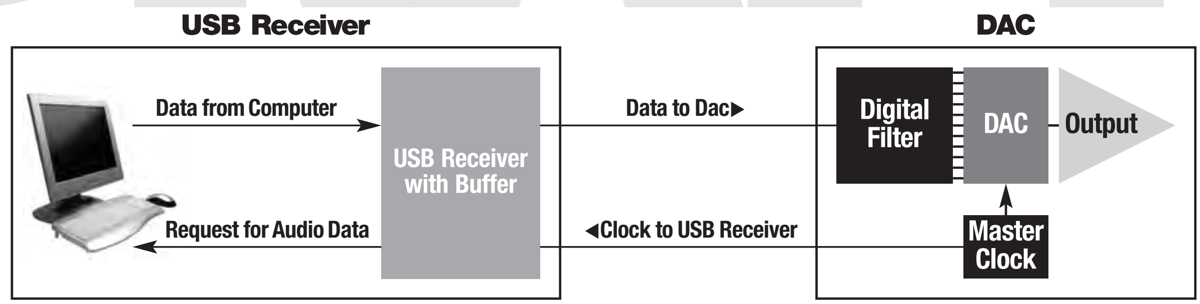


The 121 inputs employ one of two Wadia jitter-reduction technologies: ClockLink for USB and ClockLock.

ClockLink for USB

The Wadia 121 features a new implementation of Wadia's traditional jitter reduction technology in the form of a USB input featuring dedicated internal ClockLink.

As in previous versions, the function of ClockLink is to position a master oscillator as near as possible to the D>A converter chip to reduce transmission-induced jitter. All upstream sources are then synchronized to the DAC's oscillator clock signal. With USB Internal ClockLink, instead of using a clock embedded in the incoming data stream (isochronous audio), a high performance fixed frequency oscillator located at the point of conversion to analog is used. In the case of the 121 USB input, the receiver is Asynchronous in function. This means that the 121 is controlling requests for audio data from your computer. The 121 is managing a buffer and requesting data from the connected PC as needed to keep the buffer at an optimal level. Our fixed oscillator located at the DAC is controlling the rate that data is depleted from this buffer and in effect initiating the requests for additional audio data from the PC. The net result is that the jitter laden source clock can be ignored and the high performance 121 DAC oscillator is the only clock used in the conversion to analog process eliminating time related distortions.



ClockLock

ClockLock is a Wadia proprietary circuit implemented in a Field Programmable Gate Array that virtually eliminates jitter from any standard digital source. ClockLock is utilized on all inputs on the 121 other than USB. It works by monitoring the incoming clock frequency and then adjusting its DAC oscillator clock to match the incoming rate. Once the two clocks are aligned the DAC clock is locked into a fixed jitter free mode. The incoming clocking information is then monitored but not used. A large buffer prior to the DAC oscillator ensures that no data is lost due to small changes in the incoming rate. The benefit again is that the jitter laden source clock can be bypassed and the high performance 121 DAC oscillator can be locked into a fixed position and be the only clock used in the conversion to analog process.

Digital Processing

Field Programmable Gate Array (FPGA)

All inputs and outputs in the 121 Decoding Computer are routed to a large field-programmable gate array (FPGA) on the main control board. With 8256 logic cells, or gates, this gate array provides tremendous flexibility for digital signal processing and routing. The gate array performs several operations on the data, including DSP functions.

Some of the functional blocks programed into the FPGA include:

- Input source signal selection and multiplexing
- USB master clock provisioning (logic, dividers and distribution)
- Digital Audio Receiver (DAR) I2S connection
- Clocking Control
- DAC I2S connection, DAC clocking

DSP Capability

The FPGA is configured so that a dedicated DSP block is created that performs all data processing including execution of the DigiMaster interpolation upsampling algorithm.

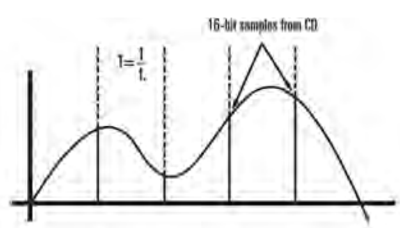
DigiMaster 4 Interpolation Filter

The Wadia 121 features a new generation of Wadia's proprietary interpolating digital filtering system known as DigiMaster. The DigiMaster 4 Waveform Algorithm for the 121 has been optimized for a wide range of performance parameters. Incoming data samples are reconstructed with special emphasis placed on time and phase accuracy so that it is able to recreate the subtle musical presence and details.

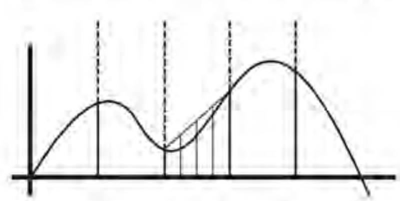
The DigiMaster 4 interpolator uses a curve fitting spline interpolation algorithm to precisely reconstruct the original analog waveform. Using digital signal processing (DSP), a curve is fitted that conforms to the current sample plus future and prior samples.

DigiMaster 4 operates at the rate of 4-times re-sampling of 44.1 kHz, that is, 4 interpolated values are calculated for each original sample from the source. Although DigiMaster 4 calculates the interpolated samples using 64-bit calculations to 32-bit precision, the original data samples from the source are not altered in any way (as shown in the illustration below).

Original waveform and 16-bit 44.1 kHz samples



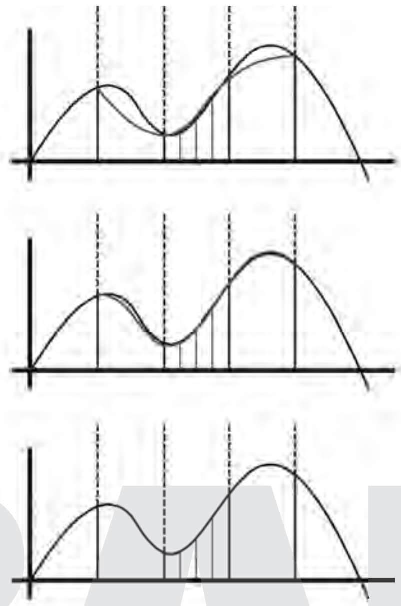
First-order curve fitting



Third-order curve fitting

Sixth-order curve fitting

12th-order curve fitting



DigiMaster curve fitting and interpolation.
Only 4 times re-sampling is shown for clarity.

Digital to Analog Conversion

The 121 D>A section utilizes a unique implementation of a state of the art multi-channel, 32-bit DAC integrated circuit (IC) to convert the signal with a theoretical resolution of 32-bit. The D>A section also provides the final stage of upsampling of the data to a rate of over 1.4 million samples per second, prior to converting the digital audio data into an analog signal.

Multiple channels in the DAC IC were configured in such a way as to create a truly balanced output design topology. A positive and inverted halve of the signal is assigned to each channel of output. The output of the DAC was designed to connect it in a virtual ground current mode (inverting amplifier) configuration to allow the highest level of performance in terms of Total Harmonic Distortion (THD).

Careful PCB design and layout was required to ensure that maximum performance could be achieved. The four-layer PCB layout allows the DAC to be fed with clean supply voltage and to ensure excellent high frequency bypassing.

Dedicated analog regulators were utilized to ensure a precise output reference supply voltage was achieved.

Additionally high stability, low phase noise oscillators were selected to provide extremely low jitter conversion.

Current to Voltage Conversion

The rapidly switching current output of a DAC contains the fastest transients of any point in the audio signal path. It is therefore especially critical to transform these current waveforms into an analog voltage with the least possible dynamic distortion. Using a feedback amplifier in a conventional manner results in transient inter-modulation distortion (TIM), slew induced distortion (SID), settling time errors.

The 121 utilizes a streamlined version of our proprietary current-to-voltage conversion technology known as SwiftCurrent. SC-5 current conveyor circuit in the 121 performs the critical current-to-voltage conversion at the output of the digital to analog converter. The Current Conveyor function does not utilize any global feedback, providing a significant improvement over conventional I/V amplifier circuits. Additional circuitry was implemented to optimize transient response, which stabilizes output impedance. The net result is a constant impedance response regardless of frequency output from the DAC section. Maintaining constant impedance from the DAC section results in linear output response that will not vary or degrade with dynamic changes in the frequency of the output signal. The SC-5 is then able to generate voltage output with drastically reduced distortion by driving a single, high-quality 0.1% metal film resistor directly, again resulting in linear response regardless of the frequency applied to the resistor while also drastically simplifying the signal path by connecting directly to a high current output stage.

Hence, the Current Conveyor allows the 121 to realize the goal of transforming the DAC output current into a pure analog voltage while avoiding the dynamic distortions common in many other products.

Variable Level Outputs

The line-level output stage on the 121 is a new design capable of driving the input section of any amplifier directly; even through extremely long interconnect cables. We call this ability DirectConnect with Digital Volume Control, and it allows the user the benefit of bypassing additional interconnects and analog circuits used of a traditional configuration with separate pre-amplifier.

The output stage can be adjusted (via the remote control) to match the overall sensitivity of the installation. Each of the 3 reference voltage settings, 4Vrms, 2Vrms, 1Vrms, will actuate a relay that routes the audio signal through a single high-quality, 0.1% metal film resistor to attenuate the full-scale output. This is in comparison to resistor networks, where the audio signal is routed through different combinations of multiple resistor arrays in order to attenuate the maximum audio output of the circuit.

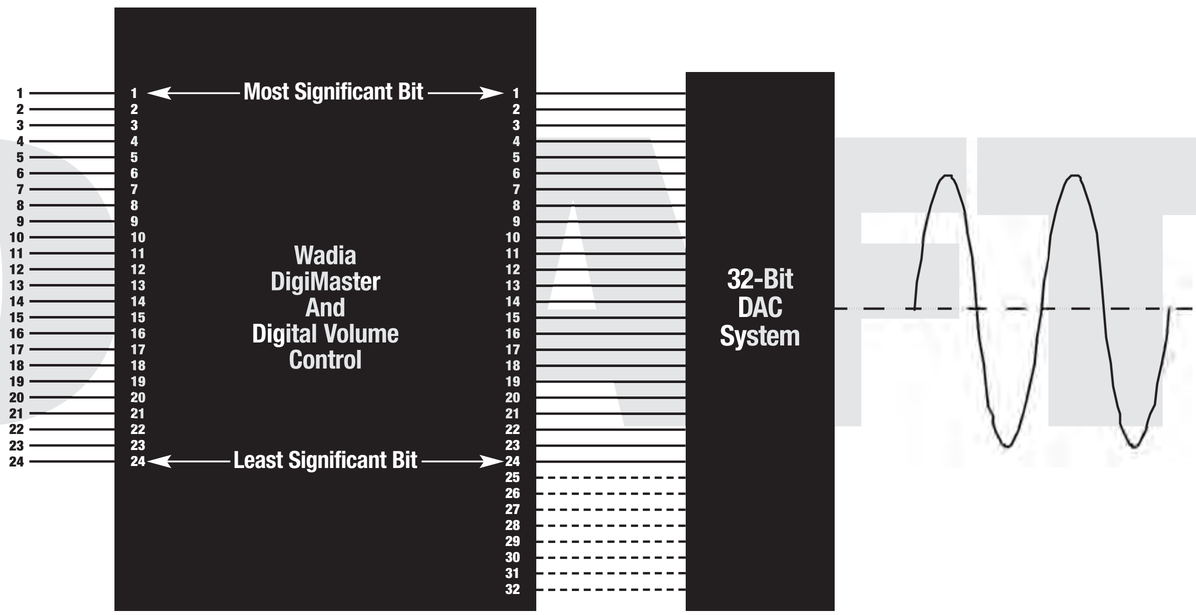
The benefits of utilizing a single resistor in place of a resistor network (traditional volume control) are two-fold:

- First, the 0.1% tolerance of a single resistor is much tighter and accurate than the combined tolerances of multiple resistors.
- Second, the use of a single resistor avoids the complex signal path required in the implementation of a resistor network, which would direct the delicate audio signal through an additional number of separate components, solder joints, and circuit board traces.

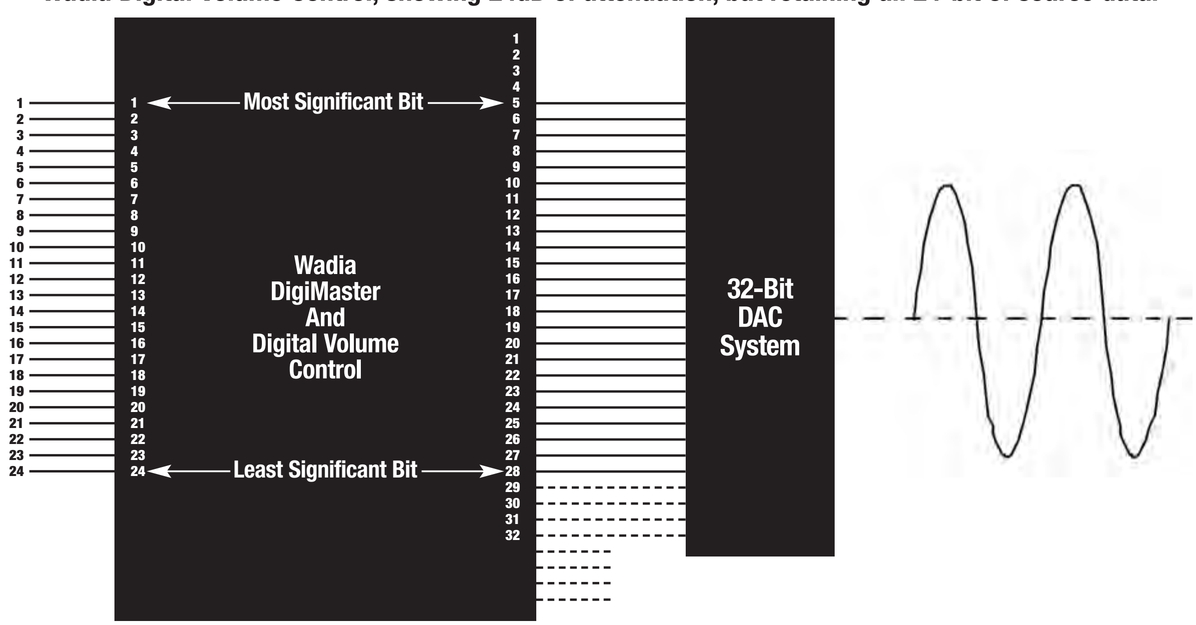
Once the optimal output voltage is identified, further volume adjustments are made via a digital volume calculation based on a 32-bit scale. The key to high performance Digital Volume Control is overall system resolution. The Wadia 121 has 64-bit processing and DAC resolution of 32-bit. As a result, a 24-bit signal from a digital source can be attenuated as much as 48db without loss of the original information.

When this system is attenuated, the original 24-bit data is shifted towards the least significant bit. In the second drawing below, the system is attenuated by 24dB. Notice that four least significant bits from the DigiMaster Interpolation are lost, but the original 24-bit information from the source is fully preserved.

Wadia's Decoding System, showing the 24-bit input from digital source, and 32-bit output from the DigiMaster Filter fed into a 32-bit DAC.



Wadia Digital Volume Control, showing 24dB of attenuation, but retaining all 24-bit of source data.



Headphone Amplifier Output
The 121 features a high performance headphone output state terminated to a ¼ inch jack located on the front panel. The headphone jack has an auto detection feature that provides automatic smooth mute/unmute transitions for the XLR, RCA and Headphone outputs.

The headphone amplifier is a differential circuit based on the National Semiconductors LME49600 audio buffer placed inside the feedback loop of the precision wide bandwidth operational amplifier. The buffer is very low noise and distortion (0.0005% THD+N (-106 dB) ensuring optimum performance.

This output stage further features a wide output power range (1 mW up to 0.7 W), a wide output voltage range and can be set to either a High or Low sensitivity mode via remote impedance switching feature. This allows the 121 be used with almost any headphone model available on the market.

Power Supply
As power supply noise is the most common source digital and analog distortions, a great deal of attention was placed on the design of a robust and well-isolated power supply.

For example:

- The main switching power supply was located physically outside of the 121 in order to afford a compact design and to eliminate radiated EMI and RFI interference that would adversely affect both and digital and especially the analog output stage.
- Input filters provide additional RFI suppression as well as EMC improvement inside of the 121.
- Synchronous converters that feature a high operational switching frequency are used in conjunction with inductors to create ultra-fast transient response and stable output digital supply voltages (3.3V and 1.2V).
- Multiple stages of regulation were designed into the main circuit board to ensure quiet, stable DC power is available for all sensitive circuits.
- A dedicated voltage regulator for the master oscillators is used to provide clean pure DC power for maximum clock stability.
- Analog post regulators and a dedicated filter network ensure that only clean and quiet supply voltages are fed to the DAC.
- Every power supply in the 121 has additional capacitive filtering, and large values are bypassed by higher-speed capacitors in parallel.
- The main filter capacitors for the line-level output stage were selected based on listening tests involving numerous filter capacitor configurations.
- Each channel is provided with its own return ground signal path delivering minimal a distortion.

User Interface

The 121Decoding Computer performs all user interface functions initiated via the remote using a powerful control microprocessor. The microprocessor in the 121 acts as the brain of the unit. Given commands to be executed, such as “Mute” or a volume level change, are initiated and routed via microprocessor to the appropriate device such as a relay or the FPGA.

Any necessary status and command information is displayed within the LED display area on the front of the 121. The display can also be turned to a low light output setting to accommodate darkened listing areas.

The Final Word

We hope your understanding of some of the design principles and unique component selections utilized in the Wadia 121Decoding Computer as well as your own sonic evaluation results in a level of appreciation similar to our own.

Although many manufacturers claim to invest painstaking hours in the development of their products, the 121Decoding Computer can truthfully be represented as the result of nearly 25 years of continuous research. In fact, we are continuing to develop this technology as we build for the future.