

# Wadia Resolution Enhancement Technology

Wadia Digital

Guide to Wadia Technology

Number 5



# Wadia's Resolution Enhancement Technology

Wadia's Resolution Enhancement System improves performance, raising the capability of Compact Disc playback another significant step. Wadia's Resolution Enhancement Systems uses carefully constructed dither, or random noise, to improve digital-to-analog converter resolution, reduce correlated jitter, and increase the "self-similar" nature of the signal, more closely matching the character of live music.

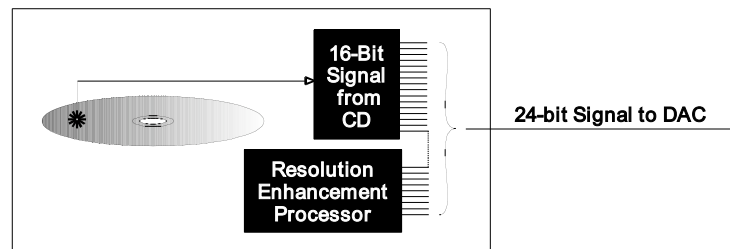
This discussion will cover the following information:

1. What is Resolution Enhancement?
2. How does the Wadia Resolution Enhancement System generate the enhanced signal?
3. Why does Wadia's Resolution Enhancement improve sound quality?

## What is Resolution Enhancement?

Resolution Enhancement is the process of adding carefully constructed, un-correlated signals to the least-significant bits in a CD playback system. While it is not possible to exceed the 16-bit resolution of the Compact Disc system, resolution enhancement allows CD playback to share many of the characteristics of higher resolution systems.

The drawing at right shows the operation of the Wadia Resolution Enhancement system. First, a 16-bit signal is retrieved from the Compact Disc. Then, the Wadia Resolution Enhancement System adds a 9-bit signal which is calculated by the Resolution Enhancement Processor. These two signals are combined, resulting in a 24-bit output from the CD transport. This can be decoded by 24-bit equipped Decoding Computers, such as the Wadia 15*i*, 25, upgraded 2000, 9, and 27, or CD players with 24-bit inputs, such as the Wadia 16, 16*i*, 850, and 860.



Resolution Enhancement adds a 9-bit signal to the 16-bit signal from the CD.

## How does the Wadia system generate the Resolution Enhanced signal?

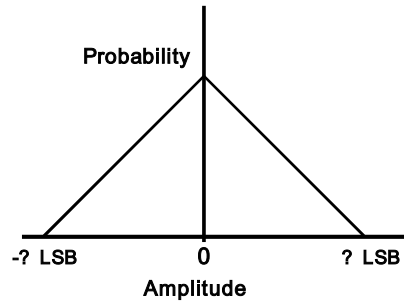
The Resolution Enhancement signal is calculated using a carefully designed Resolution Enhancement Algorithm. Strictly speaking, the 9-bit signal added by the Wadia Resolution Enhancement system is random noise. However, there are many types of random noise and some types produce better results than others. Through research and experimentation, Wadia engineers created the Resolution Enhancement Algorithm to produce the most effective type of noise signal.

For example, to achieve the full potential of Resolution Enhancement, the added noise signal must not be correlated with the digital music signal. This type of noise is known as *un-correlated* noise. Un-correlated noise has no relationship, or correlation, to the music signal. For example, harmonic distortion *is* correlated with the music signal; that is, the distortion gets louder as the music gets louder. Correlated noise and distortions are particularly sonically objectionable. To create completely un-correlated signal, the Wadia Resolution Enhancement Algorithm uses a sophisticated random number generator. One measure of the quality of random number generation is the length of time before the system repeats itself. Wadia's Resolution Enhancement Algorithm repeats after 14 days of continuous play. This shows a high degree of un-correlation.

Beyond the un-correlated nature of the system, the Wadia Resolution Enhancement Algorithm controls two parameters when generating the random noise -- the amplitude distribution and the frequency distribution.

### Amplitude Distribution

The amplitude distribution of Wadia's Resolution Enhancement signal is called Triangular Probability Amplitude Function (TPDF). This means that there is greater probability that the noise signal will have an amplitude of zero, and decreasing probability that it will be higher amplitude. In other words, most of the Resolution Enhancement Signal will be very small signals, but occasionally, they will be larger.

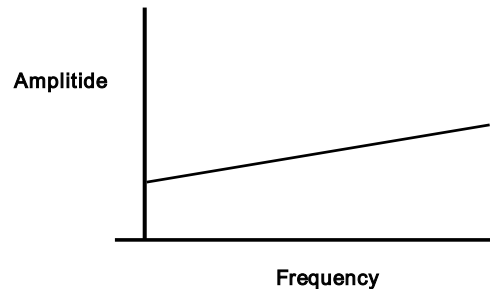


Triangular Amplitude Probability Distribution

Extensive research and listening test have shown that TPDF produces the best sonic results compared with other amplitude distributions.

### Frequency Distribution

The Wadia Resolution Enhancement Algorithm gives two choices for frequency distribution, high pass and low pass. These two options have different sonic qualities. The Wadia system allows the user to chose, via the remote control, the frequency distribution that best matches the rest of their audio system. Shown at right is high-pass frequency distribution.



High-Pass Frequency Distribution

## Why does Wadia's Resolution Enhancement improve sound quality?

Based on our studies, there are three mechanisms by which Resolution Enhancement improves sonic performance, each of which is described on the following pages:

1. Increases linearity of DACs by averaging-out DAC errors
2. Reduces digital signal- correlated jitter
3. Re-creates the Self-Similar nature of music

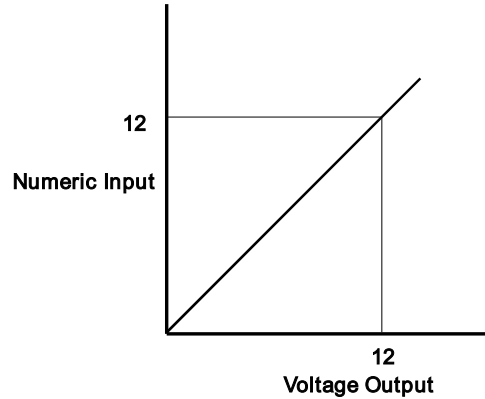
## Resolution Enhancement Linearizes the DAC

The most widely understood function of resolution enhancement is the improvement in DAC linearity. By providing randomly varying samples to the digital-to-analog converter, errors are averaged out.

(Although DACs use binary numbers, it is often easier to think in terms of decimal numbers, as we will for this example.)

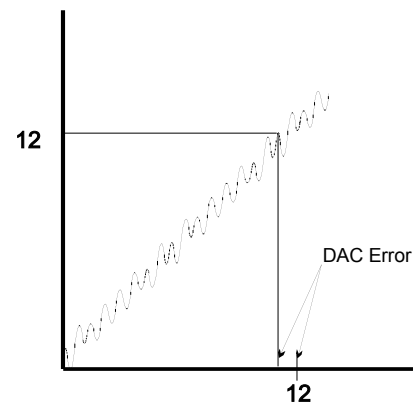
An ideal digital-to-analog converter has an output that looks like the drawing at right. On the vertical axis are the numbers fed to the DAC, the actual digital samples. On the horizontal is the DAC output signal. Ideally, the DAC converts each numeric value to a corresponding electrical signal.

In this picture, the DAC is fed the number “12”, and it produces an electrical signal with a voltage of 12.



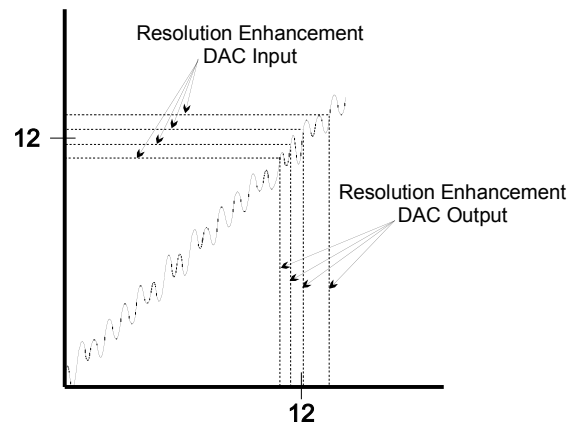
Ideal DAC Response -- put in a number, and a corresponding voltage is produced.

In real life, the DAC does not respond ideally. Instead the response looks like the picture at right. When fed a numeric value of 12, the voltage produced is not exactly 12. This type of error is called DAC non-linearity and it is typical for all DAC architectures.



Actual DAC response

Wadia's Resolution Enhancement system adds a random element to the signal, producing sample values that are randomly slightly higher or lower than the original value. When fed to the DAC, these samples produce outputs that are, in turn, slightly higher or lower. When these output values are averaged by the DAC's low-pass filter, the result is much closer to the ideal response than would be the case without Resolution Enhancement.



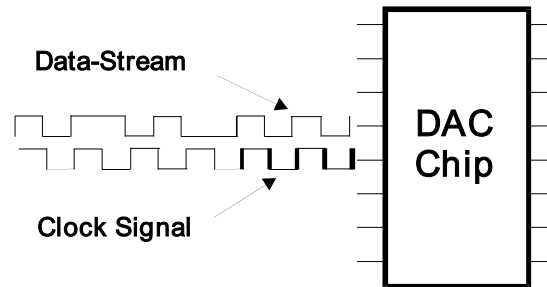
The effect of Resolution Enhancement on DAC performance

### Resolution enhancement reduces correlated jitter.

Another advantage of Wadia's Resolution Enhancement system is reduction of signal-correlated clock jitter. By adding a random, non-correlated component to the digital data stream, signal-correlated jitter is reduced.

Noise created by digital data stream is one of the most insidious and little known methods for jitter to infect the clock signal. The digital data stream is a sequence of electrical pulses which, as the stream travels through the circuitry, radiates noise. This noise is correlated to the data that is encoded in the stream. For example, a stream of all "zeros" with produce a certain kind of noise. All "ones" will create different noise, and alternating "zeros" and "ones", different noise still. What ever the digital signal, there will be a related type of noise that is created by it.

This signal stream is fed to the DAC chips on input pins that are physically very close to the DAC's clock input. Noise radiated by the digital stream infects the clock with jitter whose characteristics are related to the digital stream. This is correlated jitter, a prime enemy of good sound.



Wadia's Resolution Enhancement system adds un-correlated component to the digital stream being fed to the DAC. This means that the noise generated by the data stream is less correlated to the signal. Therefore, correlated jitter is reduced and the sound improved.

Noise from the data stream contaminates the Clock, resulting in correlated jitter

### Resolution Enhancement recreates the Self-Similar quality of music.

Sounds, such as the sounds of acoustical musical instruments, have a characteristic that chaos theoreticians would describe as *self-similarity*. Wadia's Resolution Enhancement retains the self-similar nature of music to a greater degree than a conventional 16-bit systems, resulting in a more natural sonic character.

Self-similarity, which is a characteristic of fractal objects, means that large scale features of an object have the same structure as small scale features. A common example of an object with self-similarity is a coast-line. Viewed from a distance, a coast line has jagged edges, peninsulas, and inlets. Zooming in reveals that there are smaller features that were not visible from a distance. These smaller features are still the same kinds -- peninsulas, jagged edges, and inlets. Moving in closer reveals more of the same type of details, but smaller still. Looking at the coast line on one's hands and knees reveals more of the same type of structure, but on a tiny scale. Thus, a coastline has this self-similar character where small and large scale features are of the same form.

Music occurring in live space is also self-similar in character. If the music signal were observed on an oscilloscope, it would look like a combination of high and low frequency sine waves of varying amplitude. If the magnification is increased, the structure would look the same; it would still appear as a combination of sine waves. No matter how closely you look, the structure would remain the same. As magnification increases, eventually, these sine waves would not represent musical information. They would represent random background noise, or random motion of air particles. But even at this tiny level, the structure would appear the same as the large scale features. Thus, music, too, has self-similarity.

Digital audio systems are not self-similar in nature. Imagine examining a digital audio signal on an oscilloscope. For large scale features it will have the same structure as live music - a combination of sine waves. As the magnification is increased, the structure would stay the same -- *until* you reach the resolution floor of the digital system, 16-bits in the CD format. There, the structure changes abruptly because the

system is not capable of reproducing any smaller than allowed by 16-bits of resolution. A 16-bit digital system can not even produce random sinusoidal noise, like the kind contained in live music, below the resolution threshold.

Wadia's Resolution Enhancement system adds 9 additional bits below the 16-bit resolution threshold of a CD system. These bits allow the system to produce sine waves that are much lower in amplitude than those from a 16-bit system. Although these small signals are not related to the music signal, they allow the system to retain the self-similar nature down to a much lower signal level than a standard CD system. The result is sound quality that more closely matches the character of music occurring in live space.

## **Hearing is believing**

As with most Wadia innovation, the Resolution Enhancement System resulted from applying advanced digital theory to the pursuit of musical quality. Through experimentation and listening, the Resolution Enhancement System evolved from an engineering concept into a breakthrough in sonic performance. Although similar ideas have been attempted by other manufacturers, the Wadia Resolution Enhancement Systems is distinguished by the quality of the implementation and the degree of sonic improvement.