Trevor Owen de Clercq
September 28th, 1998

Digital Audio Processing
E85.2600, Prof. K Peacock

Chapter 2 Abstract

Chapter 2 in John Watkinson's Art of Digital Audio espouses what he refers to as "some essential principles." Although these principles may be basic to digital audio, they are by no means simple. These principles include the fundamental organization of binary code in digital, as well as filters and transforms applied to this code.

The organization of binary in digital audio necessarily cannot exist in a linear fashion. Since audio signals revolve around an axis, usually a zero voltage level with both positive and negative signals (alternating current), binary has to be transformed to accommodate these positive and negative values. In order to do this, the most significant bit of a given sample word has to be changed. By flipping the MSB so that larger numbers start with a zero and smaller numbers start with a one, this "two's complement" system, as it's referred to, essentially redefines a "one" value in the MSB slot as a negative sign. Because of this redefinition, samples can be reduced/increased in gain and will thus converge/diverge on an axis instead of a baseline. By staying oriented around an axis, digital processes like mixing will affect a sample's amplitude, not its basic meaning.

Because of the logic-based nature of digital circuitry, a specific protocol needs to be developed for the treatment of adding or subtracting samples. This protocol is based on various types of logic gates, including NOT, AND, OR, etc. One of the most useful logic gates in digital applications is the exclusive OR (XOR) gate. With this gate, the output is true if the inputs are different. In a binary adder, this gate will function very well to calculate the value of the first digit place being added. Another name for the XOR gate in binary is modulo-2 arithmetic. This type of arithmetic ignores the borrow and carry functions of traditional arithmetic and just lets numbers overflow with a specified range. For example, six plus five in modulo-7 would equal four (6+5=11, 11-7=4). Because carry functions are indeed necessary for digital adders, a simple AND gate can be added to the XOR gate to determine whether a bit needs to be carried to the next position.

Skipping over filters for the time being, I would like to focus on sampling-rate conversion. Although John Watkinson did not mention it in his text, I learned that the original reason DAT players were set at a sampling rate of 48 kHz was so that they could not digitally interface with CD players which had a sampling rate of 44.1 kHz (thus stopping pirate copying). This incompatibility kind of sums up the theory behind sampling conversion. If two samples are recorded at frequencies which are an easy multiple of one another, such as 25 kHz and 50 kHz (1:2), the conversion is called integer-ratio conversion and is generally an easy process since half of the samples line up exactly. Moving up the scale of complexity, we arrive at fractional-ratio conversion which is based on sampling frequencies needing a larger number of phases to line up, such as 8:7. Finally, the hardest type of sampling frequency conversion is called variable-ratio conversion which depends on no fixed relationship between the sampling frequencies. Our DAT player at 48 kHz versus 44.1 kHz CD player is a perfect example since the ratio between these two rates is 160:147 which, as Mr. Watkinson puts it, "is indeed not simple."

In his explanation of integer-ration conversion, John Watkinson uses the term "aliasing" in his example (figure 2.43). Luckily for me, I did a little exploration into aliasing last week on my research report so this example made some sense to me. For the novice reader, however, I imagine this example would have been a bit opaque. Oddly enough, it is not that Mr. Watkinson assumes too much of his reader (which would have been one mistake) but that he has not explained concepts in a very organized manner. Just ahead, in Chapter 3 pg. 96, Mr. Watkinson finally delves into the idea of aliasing and sampling. Why, then, was aliasing brought up in Chapter 2 before it was defined? Similarly, the reader isn't given a proper "introduction to dither" until pg. 120, yet the term dither is cropping up in Watkinson's text as early as page 52. It seems to me that sometimes Watkinson is putting the cart before the horse, jumping into the application of the technology before describing the basic mechanics of that technology first.