

Digital Mapping to the Analog Domain

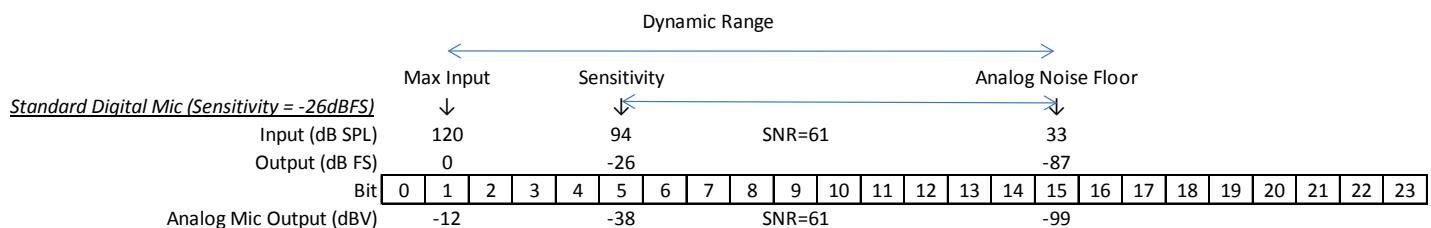


Analog audio signals are very easy to conceptualize. For example, an audio tone looks like a simple sine wave and can be observed by looking at the output of a microphone on an oscilloscope. A louder tone generates a larger sine wave. But what does this look like in the digital domain? This application note describes the utilities in “Digital Mapping to the Analog Domain.xlsx”, a utility for visualizing and understanding the output of digital microphones, encoded in PDM or PCM format.

Analog to Digital Mapping

The first sheet in the Excel file, “Analog to Digital Mapping”, shows the relationship between dynamic range, sensitivity, and SNR for both analog voltage and digital PCM sample values. The difficulty many people have with the digital paradigm is that of representing a time-varying digital signal. An analog voltage is easy to envision; for a digital signal, bits will be changing much too rapidly to be able to visualize the signal. Additionally, since the PCM samples are in 2's complement format, the top bits will be changing with the sign of the signal (positive or negative).

Below are representations of standard sensitivity microphones (digital mics = -26dBFS and analog mics = -38dBV/Pa), and a mic with sensitivity lowered by 20dBFS to allow additional headroom for louder signals.



Note that the noise floor levels may not reflect an actual Knowles microphone and are shown to demonstrate the relationship between SNR, sensitivity, and dynamic range.



Signal Conversion Utilities

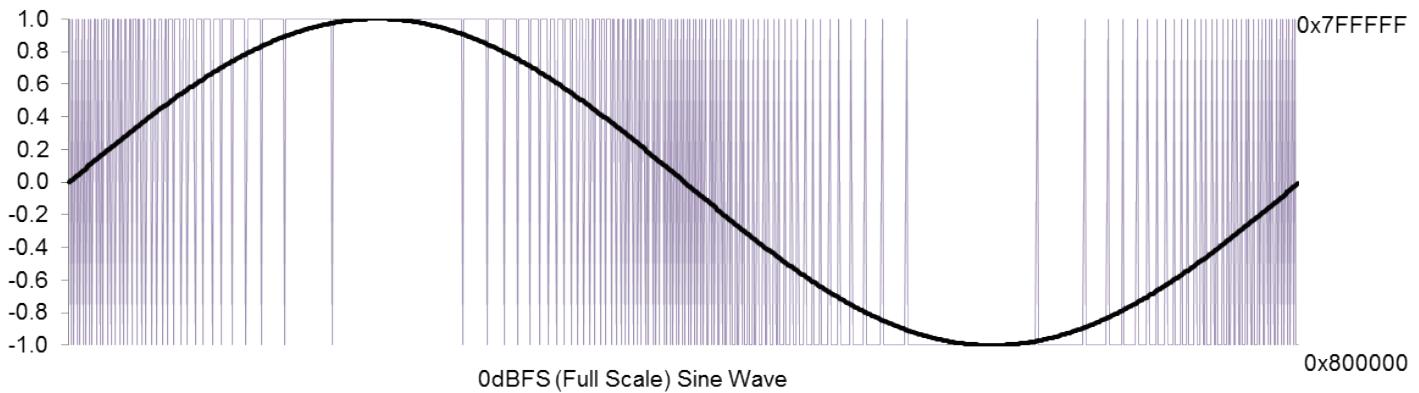
The next sheet in the Excel file allows users to input a number in hexadecimal or dBFS format. This input will then be converted, with the largest positive and negative hexadecimal numbers shown along with the top signal bit used (ignoring sign extension). Users enter values in “blue” columns and the spreadsheet generates the associated values in “green” columns. Note that the user configures the number of bits of resolution they want to use.

Enter The Number of Bits Here	Top Used Bit	Enter a Valid Positive Hex Number Here	Negative Hex Number	Decimal Value	Decibel (FS) Value
32	1	7fffffff	FF8000001	0.999999995343	0.00
8	1	40	FFFFFFFC0	0.5000000000000000	-6.02
32	15	15110	FFFFFEAEF0	0.0000401809812	-87.92

Enter The Number of Bits Here	Top Used Bit	Largest Positive Hex Number	Largest Negative Hex Number	Decimal Value	Enter a dBFS Number Here
24	1	7FFFFF	FFFF800001	0.999998807907	0.00
24	8	00A439	FFFFF5BC7	0.0050117531270	-46.00
24	5	066A49	FFFF995B6	0.0501186041534	-26.00

Waveforms

The remaining sheets in the Excel file generate demonstrative plots showing varying signal levels in the digital paradigm. A PDM encoder is also implemented to show the relationship of analog signals to PDM encoded digital signals. The 1-bit PDM stream will appear differently depending on the ratio of audio frequency to sampling frequency. Lower frequency signals will appear with a higher resolution, but the same increasing or decreasing density of 1's and 0's is observed in the output PDM stream.



The preceding waveform shows a full scale sine wave. Here, the maximum signal level reaches the top bit (excluding the sign bit). Rarely will an actual audio signal reach this level. Below are graphs included in the “Digital Mapping to the Analog Domain.xlsx” utility that show the relationship of very loud and very soft waveforms in mics with the standard -26dBFS sensitivity and a microphone with 20dB of additional headroom to accommodate louder signals better. The 140dBSPL sound is clearly lost in the standard microphone (sensitivity = -26dBFS).



