Rarely Asked Questions

Strange but true stories from the call logs of Analog Devices

It may be Greek to you, but sigma delta converters are not really hard to understand.

Q. *Can you please explain, simply, as to a Bear of Little Brain[1], how sigma-delta converters work?*
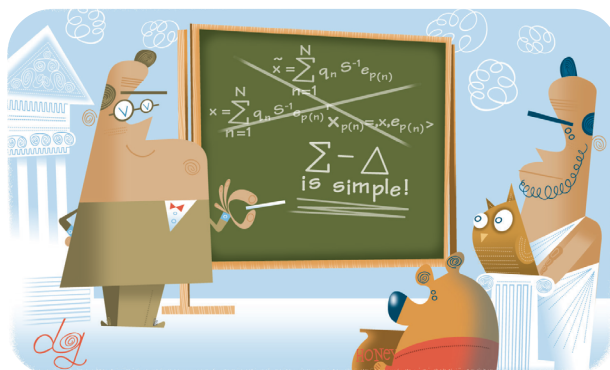
A. By over-sampling, noise shaping and digital filtering.

Athens is a beautiful city, with the ambiance of many millennia of history. I was walking round the Acropolis with Spiros, one of our Greek distributors, when he asked me how sigma-delta (Σ–Δ) converters work. "Sigma and delta are letters of our Greek alphabet," he exclaimed, "but every article I have seen about their operation is double dutch[2] to me. They all start with several pages of partial differential equations and then go downhill from there."

If a voltage is measured many times, the average of the measurements will be more accurate than most individual measurements. This is "over-sampling." (Dither[3] may be necessary to randomize the errors in the individual measurements.)

There is a definite theoretical minimum limit to the possible noise of an analog-to-digital converter (ADC). When an ADC samples a signal at a frequency of f_S the digital output contains the signal and this "quantization noise" is usually spread evenly from dc to $f_S/2$. By sampling at a higher rate of Kf_S, the noise is spread over the wider band from dc to $Kf_S/2$. If we then remove all the noise above $f_S/2$ with a digital filter the signal-to-noise ratio (SNR) of the digital output is improved — effectively improving the ADC resolution.

Normally the SNR increases with the square root of K, so very high sampling rates are necessary for useful increases in SNR. But a Σ–Δ modulator does not produce uniformly distributed quantization noise. Although the total noise is unaltered in a Σ–Δ system, most of it is at high fre-

quencies (HF). This is known as noise shaping and permits much lower values of K.

If the digital output from the Σ–Δ modulator is filtered to remove HF, leaving the frequencies from dc to $f_S/2$ (where the wanted signals are) then the SNR and resolution of the digital output are improved. A Σ–Δ ADC simply consists of a Σ–Δ modulator and a digital low-pass filter, both of which are easily made with modern high-density digital technology. The principle of Σ–Δ ADCs has been known for more than 40 years, but the ability to build one on a chip is relatively recent.

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[1] *"When you are a Bear of Very Little Brain and you think of Things, you find sometimes that a Thing which seemed very Thingish inside you is quite different when it gets out into the open and has other people looking at it."* — AA Milne, *"The House at Pooh Corner"*
[2] *Double dutch means gobbledygook*
[3] *Dither — the addition of noise or some other AC signal in order to randomize errors.*

To learn more about sigma delta converters,
Go to: http://rbi.ims.ca/5696-112

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Have a question involving a perplexing or unusual analog problem? Submit your question to:

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