Hideo Okawara's

Mixed Signal Lecture Series

DSP-Based Testing – Fundamentals 3

DAC Output Waveform

Verigy Japan

July 2008

Preface to the Series

ADC and DAC are the most typical mixed signal devices. In mixed signal testing, analog stimulus signal is generated by an arbitrary waveform generator (AWG) which employs a D/A converter inside, and analog signal is measured by a digitizer or a sampler which employs an A/D converter inside. The stimulus signal is created with mathematical method, and the measured signal is processed with mathematical method, extracting various parameters. It is based on digital signal processing (DSP) so that our test methodologies are often called DSP-based testing.

Test/application engineers in the mixed signal field should have thorough knowledge about DSP-based testing. FFT (Fast Fourier Transform) is the most powerful tool here. This corner will deliver a series of fundamental knowledge of DSP-based testing, especially FFT and its related topics. It will help test/application engineers comprehend what the DSP-based testing is and assorted techniques.

Editor's Note

For other articles in this series, please visit the Verigy web site at www.verigy.com/go/gosemi.

DAC Output Waveform

When a DA converter (DAC) is stimulated by a certain code, the DAC generates a DC voltage specified and holds its level until the next code is fed in the DAC. Therefore the waveform out of a DAC theoretically looks like a staircase. In this issue we look at the DAC output waveform.

Zero-order Hold Waveform

The waveform out of a DAC theoretically looks like staircase as shown in Figure 1. This type of waveform is called zero-order hold waveform.

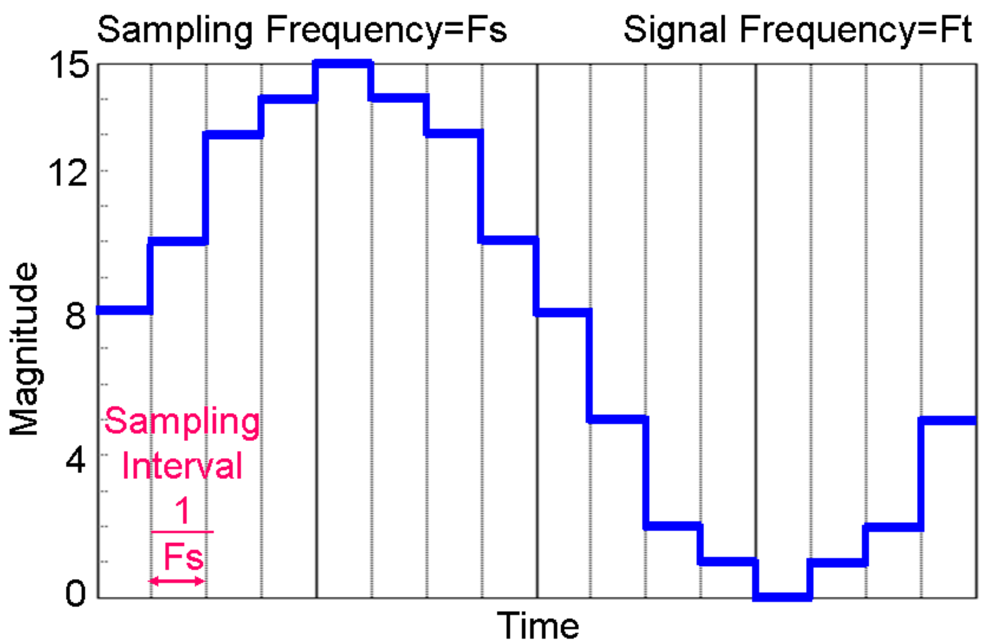

Figure 1. Zero-order Hold Waveform.

When a digitizer tests a DAC, this zero-order hold waveform is useful. If the digitizer can run synchronously to the DAC, and exactly sample each one of the stairs at the stable level as shown in Figure 2, the test can be performed quite effectively. This technique can be applied to relatively slow-speed DACs. The digitizer used for this measurement must have excellent DC performance compared to the DUT.

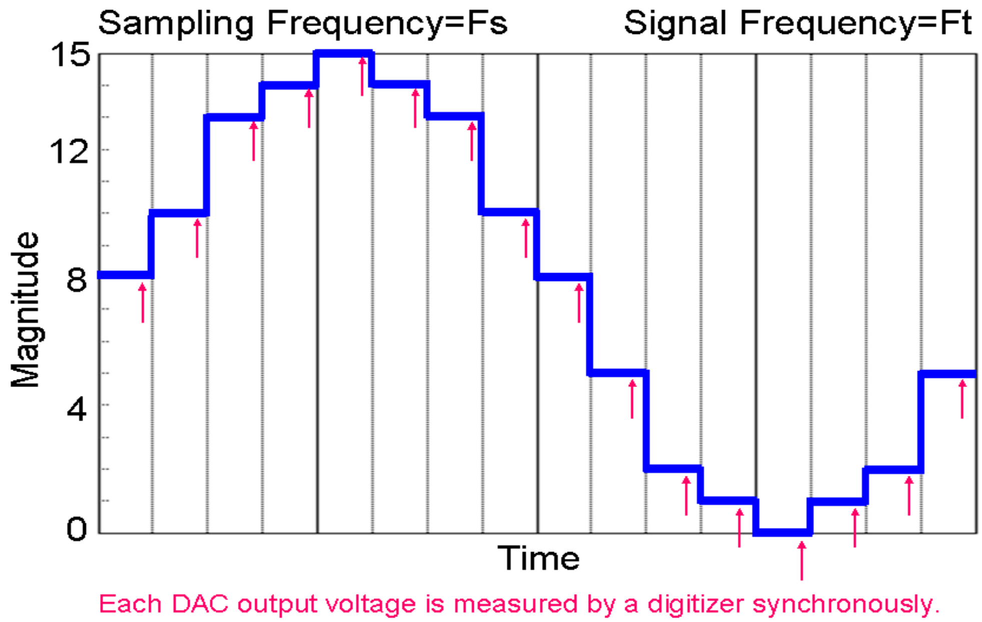

Figure 2. Synchronous Digitizing.

Figure 3 shows the spectrum of a zero-order hold waveform of a sine wave. It contains not only the fundamental spectrum whose frequency is *Ft* but also lots of image spectra besides the sampling frequency *Fs* and its multiples *k*Fs*. (*k*=1, 2, 3, 4, …) The image spectra locate at the frequencies of *k*Fs-Ft* and *k*Fs+Ft*. The magnitude of the fundamental and the image spectra are weighted by the curve of *sinX/X* which is often called SINC function.

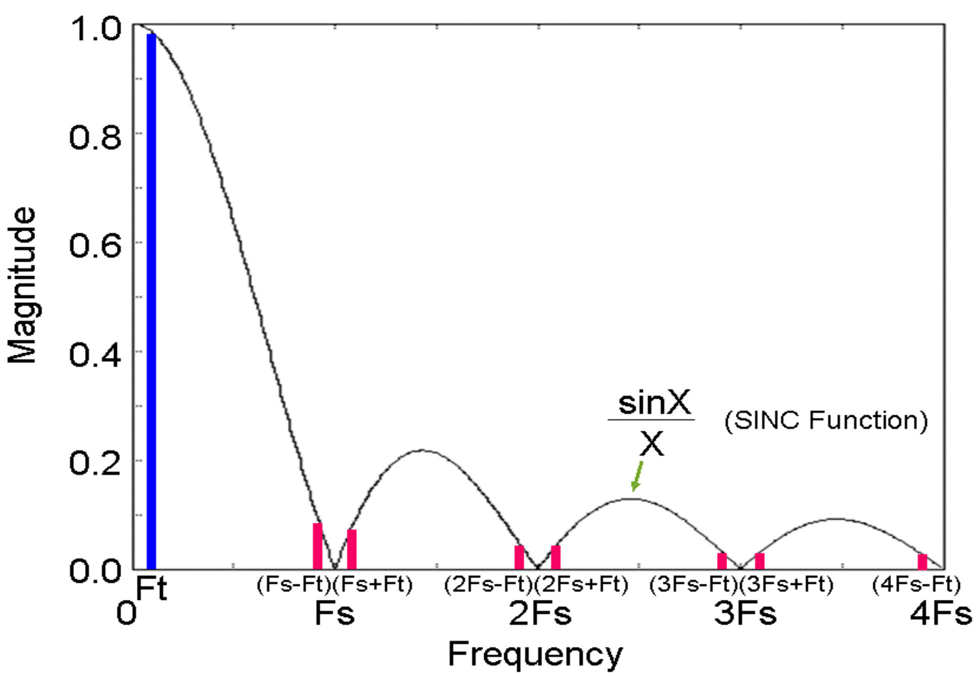

Figure 3. Spectrum of Zero-order Hold Waveform.

Smoothing Filter

In the mission mode of the DAC, the staircase waveform should be smoothed with a low pass filter (LPF). See Figure 4. The LPF suppresses the unwanted image spectra, and then the DAC output waveform becomes clean and smooth as shown in Figure 5. (Compare to Figure 2.) Therefore the LPF is called a smoothing filter.

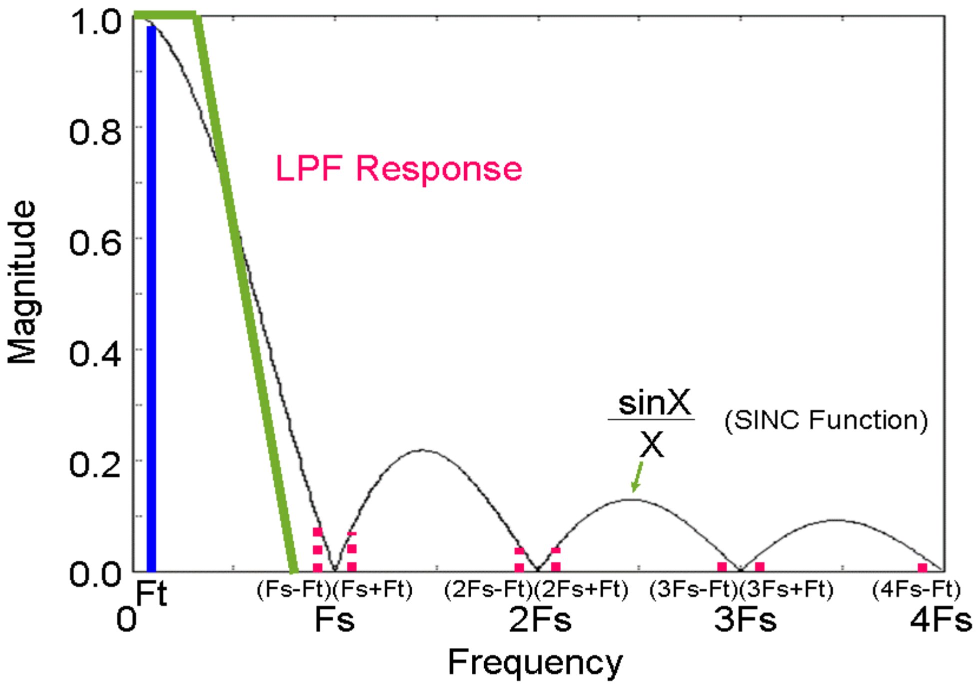

Figure 4. Smoothing Filter.

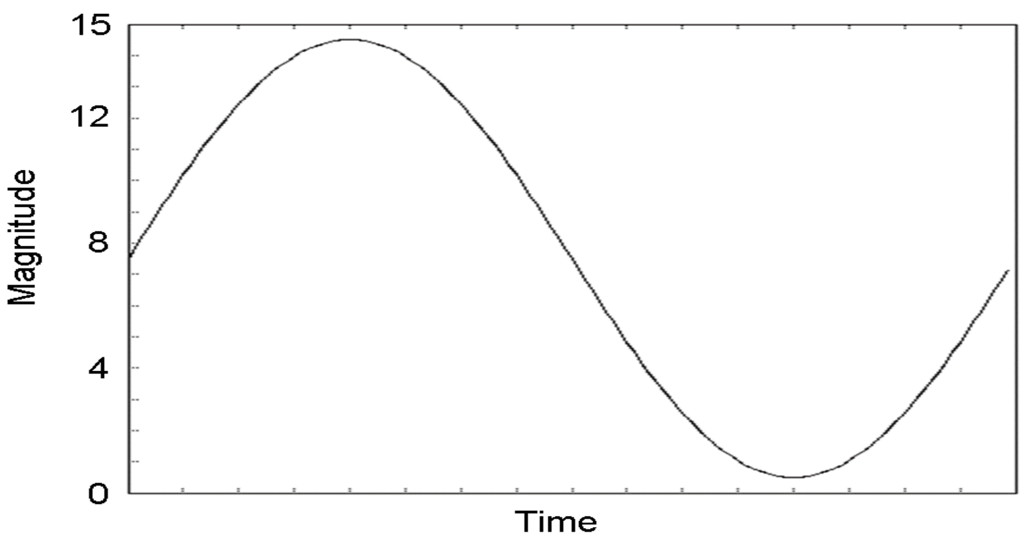

Figure 5. Filtered DAC Output Waveform.

AWG: Arbitrary Waveform Generator

In a modern DSP-based mixed signal tester, analog stimulus signals are generated by using arbitrary waveform generators (AWG). Figure 6 shows a typical block diagram of an AWG. Usually there are several smoothing filters integrated in the AWG. Each filter has different cut-off frequency, and you can select the most suitable LPF according to the sampling rate and the test signal frequency. If no appropriate smoothing filter is available in the AWG for the test signal frequency, you may need to employ a filter on your DUT board.

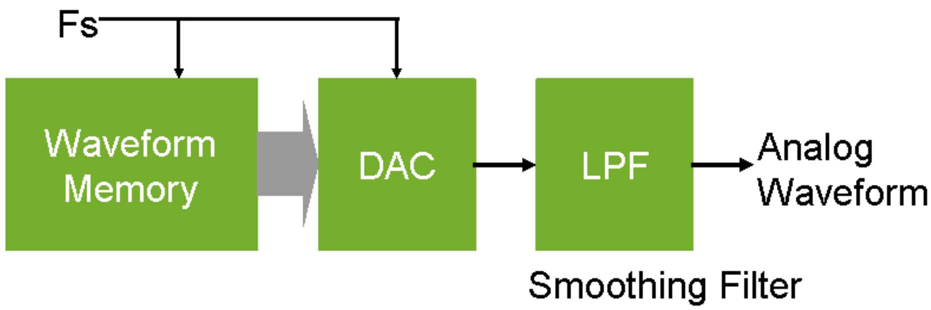

Figure 6. AWG Block Diagram.

Multi-tone Signal

A multi-tone signal is a very useful stimulus for testing frequency responses. It is often applied in filter tests. For example, when four equal-magnitude tones *Fa*, *Fb*, *Fc* and *Fd* are programmed in a DAC, the primitive waveform is zero-order hold waveform right at the DAC output so that the image spectra *Fd'*, *Fc'*, *Fb'* and *Fa'* symmetrically sit in the range from *Fs*/2 to *Fs.* This is shown in Figure 7.

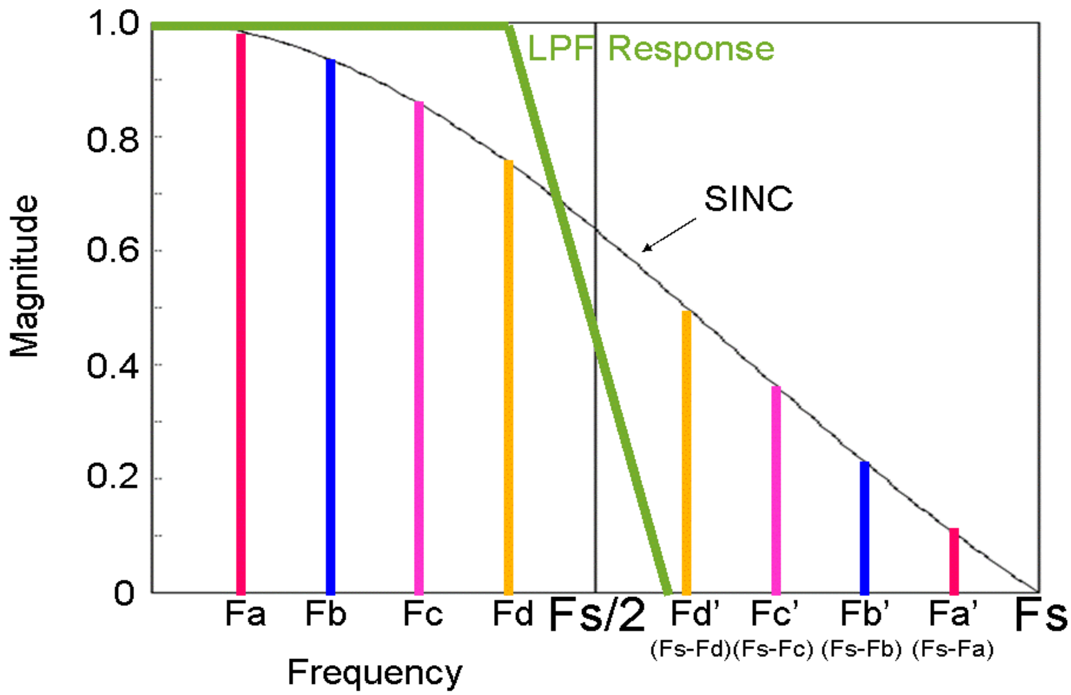

Figure 7. Multi-tone Spectrum.

The smoothing filter suppresses the image components, and makes it a smooth multi-tone waveform. Even if you create equal-magnitude multi-tone *Fa*, *Fb*, *Fc* and *Fd*, the magnitude of all spectral lines from *Fa* to *Fa'* is weighted with SINC function. If you are not happy with the SINC shaping of levels, you could program your primitive waveform with reverse SINC response for compensation. The SINC weighting at *Fs*/2 is *sin*(π/2)/(π/2)=0.6366. (-3.92[dB])