ADVANTEST®

Hideo Okawara's
Mixed Signal Lecture Series

DSP-Based Testing – Fundamentals 45
Analog Signal Generation by Digital Pin Driver II

Advantest Corporation
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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 Advantest web site at
http://www1.verigy.com/ate/news/newsletter/index.htm

Preface

Delta-sigma modulated data generation was discussed in the last Newsletter. It was about the first order noise shaping whose performance was not necessarily good enough for our daily job. In this month article, the noise shaping scheme is upgraded to the second order, and let's look at how much the performance is improved with an actual experimental result.

Second Order Noise Shaping

Figure 1 illustrates the block diagram of the second order noise shaping. With comparing to the first order block diagram[1], there are two integrators implemented in the loop so that the comparator output value is doubled. The output code is still 1s and 0s which reflect the polarity of the comparator output.

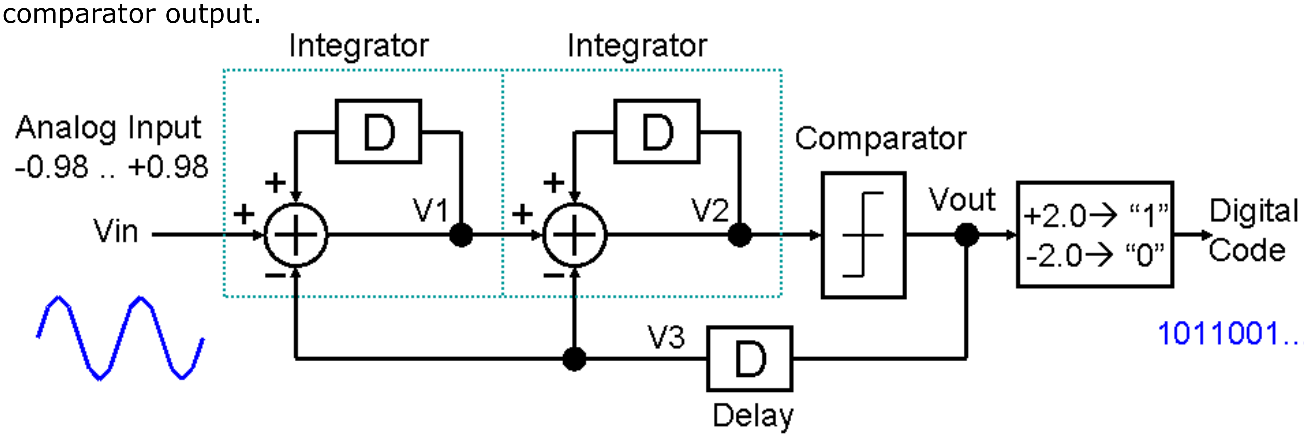

Figure 1: Second Order Noise Shaping Block Diagram

This diagram is translated into the example code as List 1. The block of Lines 15 through 20 generates the test signal containing 11 cycles of sinusoid in the stream of 16384 bits. The blocks of 24 through 30 and 33 through 40 are the noise shaping loop. The first block of Lines 22 through 30 is provided for initializing the loop. The bit stream generated in the second block is used for the analysis and the experiment. The full-scale amplitude of the signal is 1.0, but the input signal should be kept slightly less than 1.0 for successful calculation result.

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```
INT       i,N,M;
DOUBLE    dV1,dV2,dV3,dVin,dVout,dA,dP;
ARRAY_I   iCode;                                   // Digital Code Container
ARRAY_D   dWave;                                   // Original Waveform Container

N=16384;                                           // # of data
M=11;                                              // # of sinusoid cycles
dA=0.98;                                           // Relative Full-scale Amplitude
dP=2.0*M_PI*M/N;
dWave.resize(N);
for (i=0;i<N;i++) dWave[i]=dA*sin(dP*(i+0.25);// Sinusoidal Waveform

dV1=0.0;                                           // Initialize (Don't forget)
dV2=0.0;                                           // Initialize (Don't forget)
for (i=0;i<N;i++) {                                // Initialize (Don't forget)
   dVin=dWave[i];
   dV1=dVin+dV1-dV3;                               // Right V1 is 1-clock delayed.
   dV2=dV1+dV2-dV3;
   if (dV2>0.0) dVout=2.0; else dVout=-2.0;        // Comparator
   dV3=Vout;                                       // 1-clock delay
}

iCode.resize(N);
for (i=0;i<N;i++) {
   dVin=dWave[i];
   dV1=dVin+dV1-dV3;
   dV2=dV1+dV2-dV3;
   if (V2>0.0) dVout=2.0; else dVout=-2.0;
   dV3=dVout;
   if (dVout>0.0) iCode[i]=1; else iCode[i]=0;
}

```

List 1: Second Order Noise Shaping Program Code Example

The bit stream generated by this code example is depicted in Figure 2. This data stream is directly processed with the FFT (Fast Fourier Transform) and the spectrum is shown in Figure 3. In order to see how much the noise floor improved, the first order spectrum and the second order spectrum are overlaid together in Figure 4. When counting the quantization noise from the bin #1 to #50, the SNR is calculated as 99.4 dB for the second order compared to 82.6 dB for the first order. For example, when the digital bit stream runs at the rate of 400 Mbps, the sinusoidal signal frequency becomes approximately 268.6 kHz.

Let's look at an actual performance by downloading the bit stream in to a PS1600 digital pin. Figure 5 depicts the actual measurement result. The PS1600 runs at the rate of 400 Mbps with the swing of +1.5 V and -1.5 V. The output digital signal is directly measured by using the MB-AV8 VHF digitizer running at the rate of approximately 109.3 Msps, capturing 65536 points. The digitizer is set up with the input impedance of 50Ω, the input range of 2 Vpp, and the anti-aliasing filter of 50MHz. The signal level is -9 dBV so that it is approximately 0.35 Vpk.

You can find that the noise floor is lowered but the harmonics distortion appears in Figure 5. The distortion comes from the waveform itself. The imbalance of positive and negative areas of waveform and rising and falling edges can be translated to the distortion. The noise shaping is an interesting technique but you should be careful about the distortion. You need to apply an appropriate low pass filter to make the signal refined.

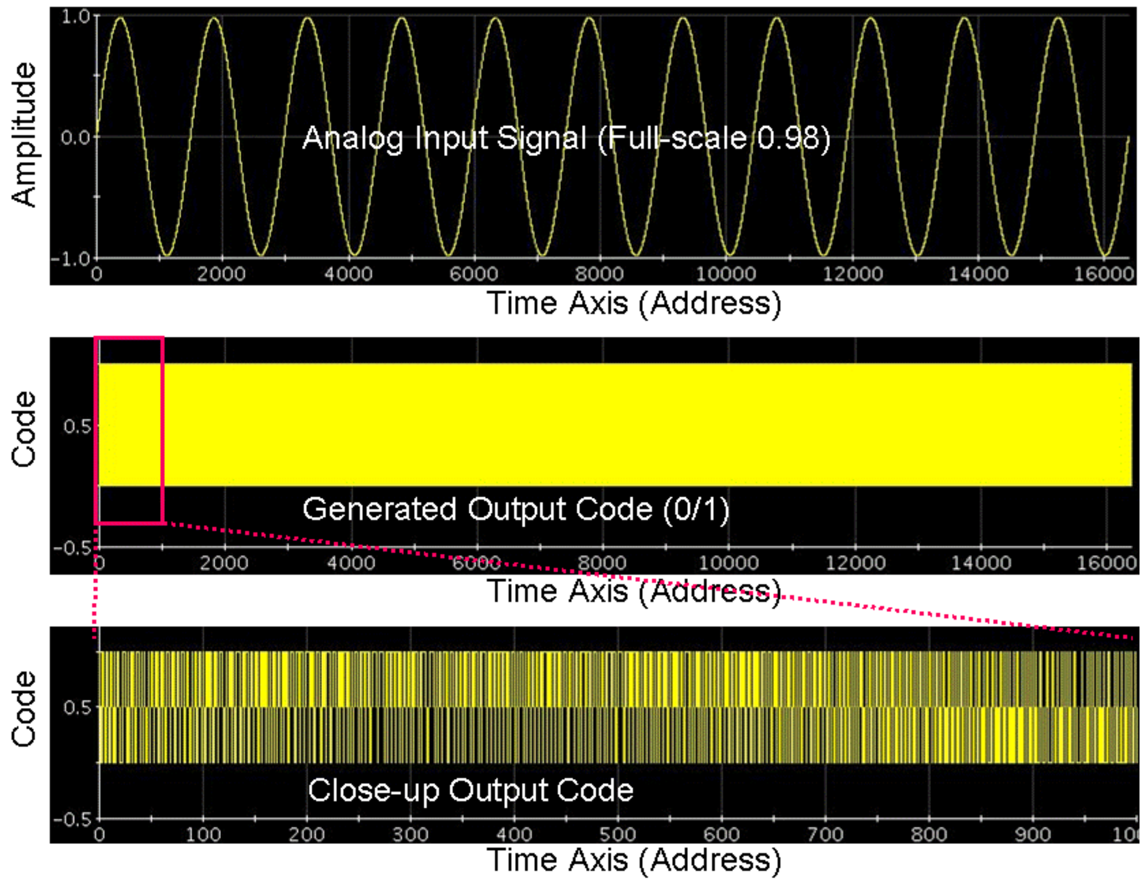

Figure 2: Sinusoidal Input Waveform and Binary Output Code

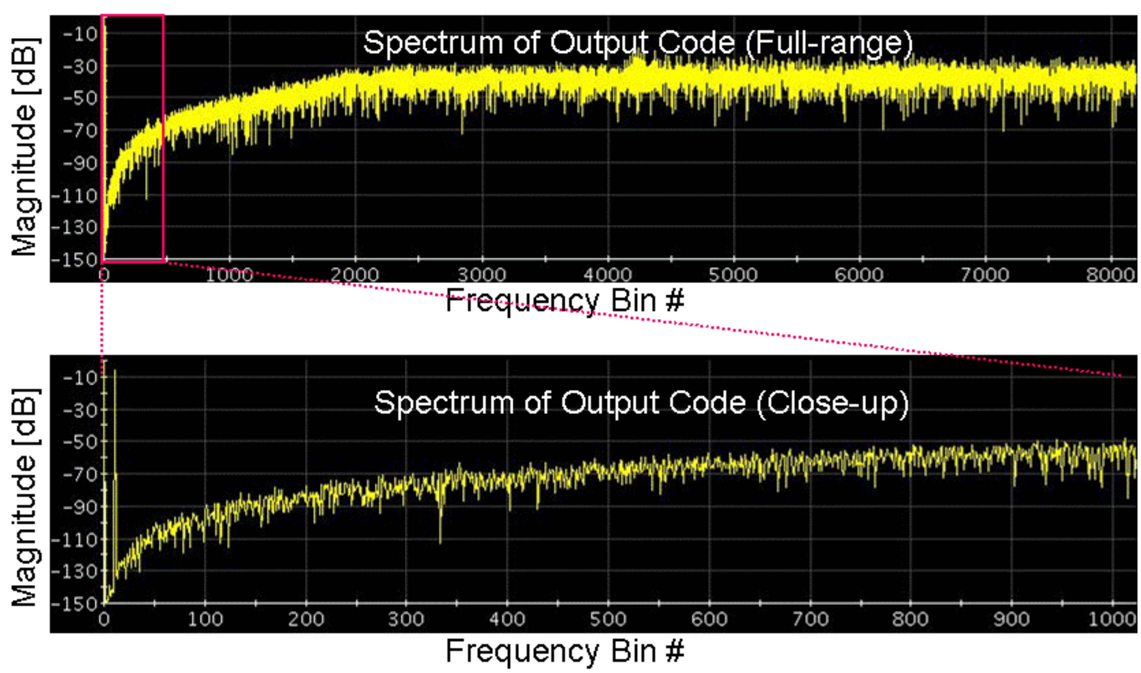

Figure 3: Spectrum of Binary Code Stream

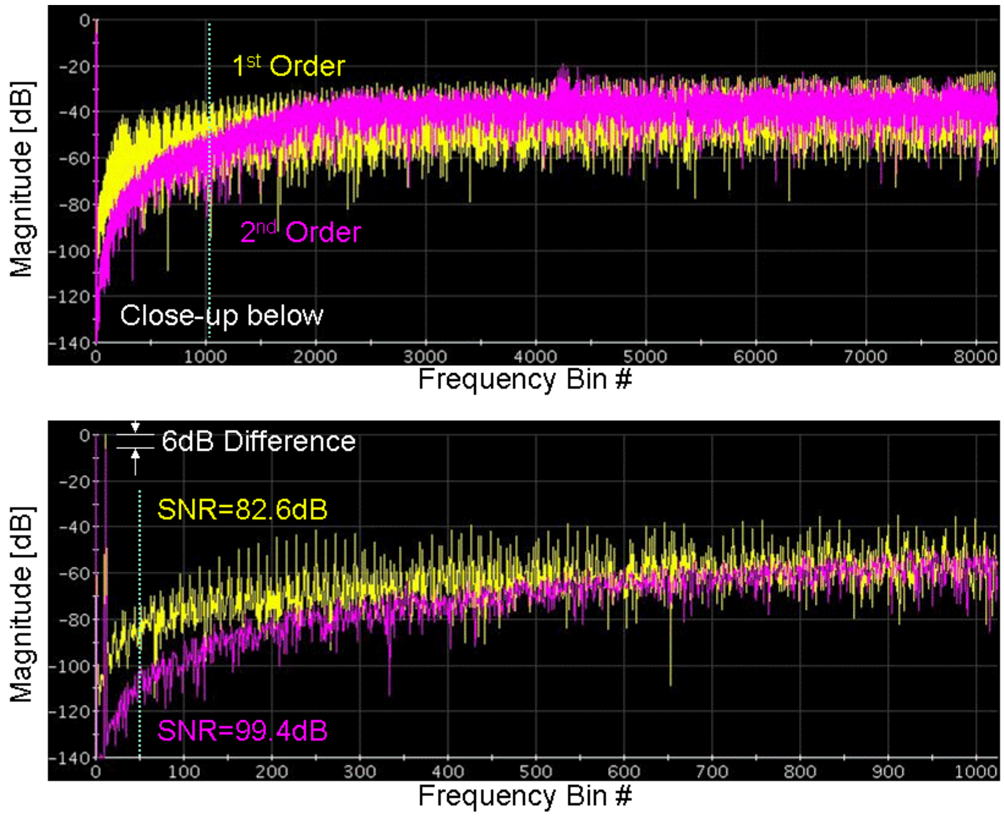

Figure 4: Spectrum Comparison between First Order and Second Order

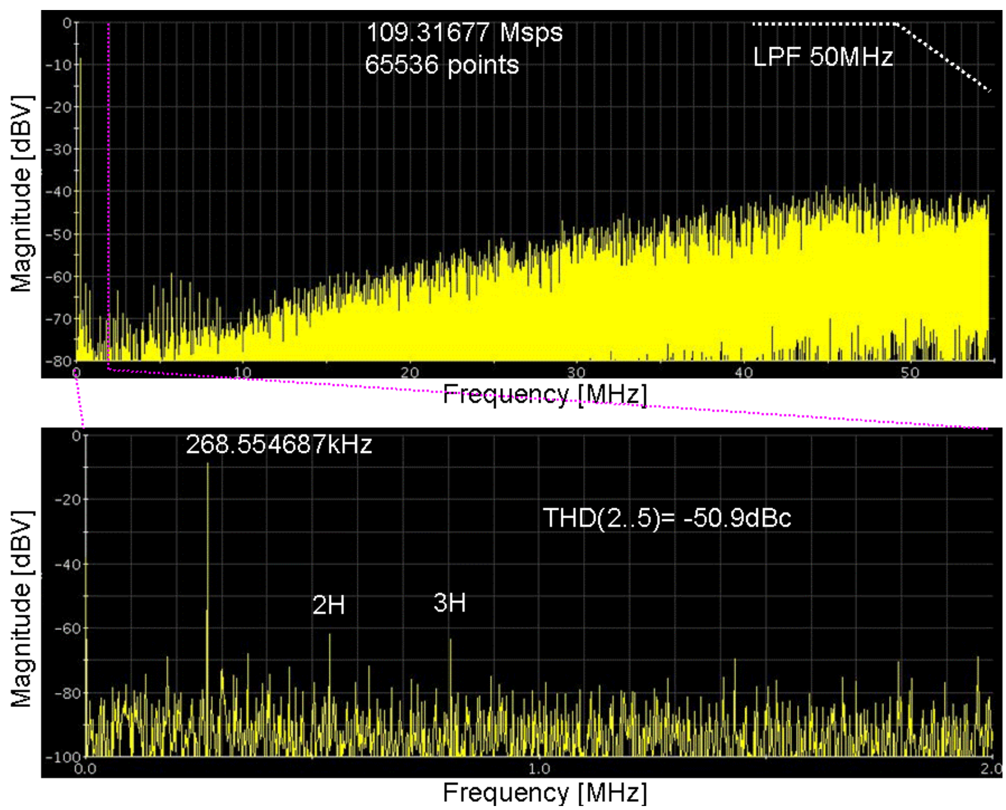

Figure 5: Actual Performance of Second Order Noise Shaping by a PS1600 Pin