
NOISE DIODES

RANDOMIZE

QUANTIZATION

ERRORS IN

A/D CONVERTERS

An A/D converter's finite resolution produces quantization errors as the analog input is partitioned into 2^n discrete ranges during an n-bit conversion. All analog values within a given range are represented by the same digital code, which is assigned the midrange value. This produces an inherent quantization uncertainty of $\pm 1/2$ LSB in addition to the actual conversion errors.

When converting periodic waveforms, the quantization error waveform becomes periodic and appears as harmonic distortion (spurious). These harmonics, regardless of frequency, all appear within the Nyquist bandwidth due to aliasing produced by the sampling process. The spurious responses are undesirable in receiver and spectrum analysis applications, where they limit the Spurious Free Dynamic Range (SFDR).

The harmonics present in the error waveform are coherently related to the analog input, which complicates the task of processing the signal spectrum. The power of the quantization error is better spread over the Nyquist bandwidth rather than concentrated in a discrete set of spectral lines.

Inserting a white Gaussian noise source in front of the converter randomizes the threshold crossovers, which decorrelates the quantization error waveform and the input signal. This procedure is known as dithering. The resulting error waveform is no longer periodic and appears as a small increase of about 3 dB in the noise floor, rather than as discrete spurious responses.

The noise necessary to obtain the decorrelation must have a flat spectrum over the Nyquist bandwidth and an RMS noise voltage of at least $q/\sqrt{12}$. The noise power thereby exceeds the RMS power of the quantization error, which can accurately be calculated to be $q^2/12$, where q is the voltage equivalent to 1 LSB.

The noise source is easily incorporated into the circuit, as shown in Figure 1. Noise diodes such as the NC101 through NC302 can be coupled directly to the A/D converter input, assuming that the converter's input circuitry represents a resistive load to ground. The value of the load can be adjusted to obtain the best performance. A larger load impedance will usually result in a high RMS noise voltage from the diode. The bias resistor and the coupling capacitor can be selected by use of the following equations for low-frequency circuits.

$$R = \frac{V_{DC} - V_b}{I_{op}}$$

$$C \geq \frac{1}{2\pi R_L (f_c)}$$

f_c = low frequency cut-off

When using the NC2000 Series or the NC511, which include the bias network and coupling capacitors, the load impedance must be 2,200, 1,000 or 50 ohms, as specified on the data sheet for the noise source. Adjustable noise voltage is then obtained by inserting an attenuation circuit or matching pad. Recommended noise sources for 6- to 16-bit A/D converters are shown in Table 1 below. Contact Noise Com for full input ranges different from $10 V_{pp}$.

MAXIMUM NYQUIST FREQUENCY	6-, 8-, OR 10-BIT	12-BIT	16-BIT
0.5 - 100 kHz	NC2102	NC2102	NC101
100 - 500 kHz	NC2104	NC102	NC102
0.5 - 3 MHz	NC2105	NC104	NC201
3 - 20 MHz	NC2106	NC2106	NC202
20 - 100 MHz	NC2201	NC511	NC203
0.1 - 1 GHz	NC2501	NC302	NC302

Table 1. Recommended noise sources for 6- to 16-bit A/D converters at full input range of $10 V_{pp}$.

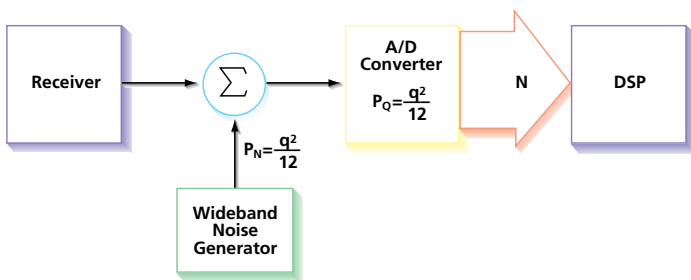


Figure 1. Noise sources reduce spurious caused by quantization errors of A/D conversions.

For more information on the NC101 through NC302, see pages 30-31; on the NC2000 Series, see pages 26-27; and on the NC511, see pages 28-29.