ANALOG DEVICES

AN-615 APPLICATION NOTE

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Peak-to-Peak Resolution Versus Effective Resolution

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INTRODUCTION

The low bandwidth, high resolution ADCs have a resolution of 16 bits or 24 bits. However, the effective number of bits of a device is limited by noise. This varies depending on the output word rate and the gain setting used. This parameter is specified by some companies as effective resolution. Analog Devices specifies peak-to-peak resolution, which is the number of flicker-free bits and is calculated differently from effective resolution. This application note distinguishes between peak-to-peak resolution and effective resolution.

Noise

Figure 1 shows a typical histogram obtained from a sigma-delta ADC when the analog input is grounded. Ideally, for this fixed dc analog input, the output code should be zero. However, due to noise, there will be a spread of codes for a constant analog input. This noise is due to thermal noise within the ADC and quantization noise due to the analog-to-digital conversion process. The code spread is generally Gaussian in nature. The rms noise is calculated using the curve that results from the histogram, the width of the curve determining the rms noise. A Gaussian curve goes from –infinity to +infinity. However, 99.99% of the codes occur within 6.6 × rms noise. Therefore, the peak noise is 6.6 × rms noise.

Data sheets normally specify the rms noise. The noise is dependent on the filter frequency used and the gain setting used. Normally, the rms noise gets smaller as the analog input range decreases. However, since the full-scale analog input signal is also being reduced, the effective number of bits degrades.

Peak-to-Peak Resolution Versus Effective Resolution

Most applications do not want to see code flicker on the system output. For example, in a weigh-scale application, the number of flicker-free bits is important. The digital word from the ADC can then be truncated so that the flickering bits are not seen on the weigh-scale monitor.

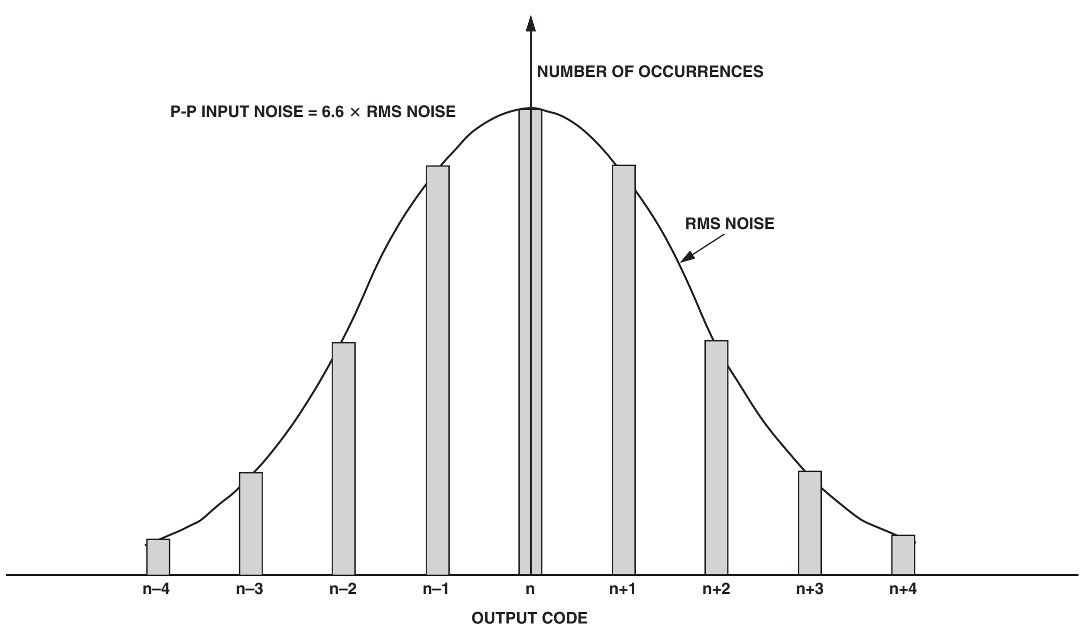

Figure 1. Histogram for a Grounded Analog Input

The noise-free resolution or peak-to-peak resolution is determined from the noise values given in a data sheet. First, let's calculate the signal-to-noise ratio. The signal-to-noise ratio equals

$$SNR = 20\log(noise/full\text{-}scale\ input)$$

Analog Devices normally specifies the peak-to-peak resolution or noise-free code resolution. This is achieved by calculating the SNR using the peak noise that equals 6.6 × rms noise. From the signal-to-noise calculation, the accuracy can be determined.

$$SNR = 6.02N + 1.76 = 20\log(peak\ noise/full\text{-}scale\ input)$$

From the AD7719 data sheet, the rms noise equals 1.25 μV when the analog input range is ±2.56 V and the data update rate equals 5.35 Hz. From this data, the signal-to-noise ratio equals

$$(20\log((6.6 \times 1.25E\text{–}6)/(2.56 \times 2)) = –115.85\ dB$$

From this data, the peak-to-peak resolution is

$$115.85 = 6.02N + 1.76 \Rightarrow N = (115.85 – 1.76)/6.02 = 19\ Bits$$

Therefore, under the above conditions, there will be no flicker in the 19 MSBs.

Some companies specify effective resolution rather than peak-to-peak resolution. The effective resolution is calculated using the rms noise rather than the peak noise. Using the rms noise leads to a signal-to-noise ratio of

$$(20\log((1.25E\text{–}6)/(2.56 \times 2)) = – 132.25\ dB$$

This leads to an effective resolution of

$$132.25 = 6.02N + 1.76 \Rightarrow$$
$$N = (132.25 – 1.76)/6.02 = 21.7\ Bits$$

Therefore, the effective resolution equals the peak-to-peak resolution + 2.7 bits.

It is important when evaluating ADCs to know that the effective resolution and peak-to-peak resolution are calculated differently, the effective resolution giving a value that is greater than the peak-to-peak resolution by 2.7 bits. Also, the effective resolution does not highlight the amount of bits that flicker. The peak-to-peak resolution gives a better indication of performance since it indicates the number of bits that will not flicker.

Summary

The method in which the effective number of bits of low bandwidth, high resolution ADCs is calculated differs from company to company. Therefore, when comparing devices from different companies for an application, it is not valid to compare numbers directly because parts that are specified using peak-to-peak resolution appear worse than parts that are specified using effective resolution. For an ADC, its effective resolution will be better than its peak-to-peak resolution by 2.7 bits. Therefore, a device that has an effective resolution of 22 bits has a flicker-free resolution of 22 – 2.7 = 19.3 bits. It is important to determine whether the peak-to-peak resolution or effective resolution is being specified so that one knows the true performance of a device for an application.

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