arm Education

Embedded Systems Essentials with Arm: Getting Started

Module 5

KV3 (5): Properties of analog-to-digital conversion

There are four key properties of the analog-to-digital signal conversion process that impact the quality of the end result: resolution, range, quantization, and sampling.

The resolution of the ADC refers to the number of discrete data points that can be produced over the range of analog values, and depends on the reference voltage of the ADC.

Resolution determines the minimum magnitude of the quantization and the quantization error. The resolution can be expressed in bits, for example, an 8-bit ADC has a resolution of 256 values. Or it can be expressed in volts, called the Least Significant Bit voltage, or LSB. For example, an 8-bit ADC with range of 10 volts has a resolution of 10 over 256 volts.

Because the resolution represents discrete values, the process of analog to digital signal conversion will produce a resolution error. This is the difference between a minimum resolution step and the real value.

The resolution error can be reduced with a higher resolution. However, because no conversion principle is perfectly stable, the output value for the same input voltage may vary between conversion instances. This is resolution noise. The higher the resolution, the higher the noise, so the resolution also determines the maximum possible average signal to noise ratio.

The next property that affects conversion quality is range.

Analog-to-digital-converters have minimum and maximum permissible input values. These values determine the range of an ADC.

The range and resolution of the ADC are linked to the reference voltage and the physical principle of the ADC.

The relationship between the input and output of a flash converter and feedback converter is highlighted by this formula, where Vi is the input voltage, Vref is the reference voltage, and N is the digital resolution in bits, with D being the digital output.

The next property is quantization.

Quantization is the process of mapping continuous values to discrete values. In other words, the process of converting an analog signal to a digital one.

A quantization error is the difference between the actual analog input and the digitized value. This variation produces noise.

Finally, let's look at sampling.

The sampling rate is the rate at which the ADC collects new values. Because the analog signal is continuous in time, but the digital data is discrete, the sampling rate must be high enough to reproduce the original signal.

The sampling rate represents a combination of the total ADC system's time constants. It must be slow enough for the sample-and-hold and the multiplexer to follow, and fast enough for the sample-and-hold not to lose its values.

According to the Shannon-Nyquist sampling theorem, the sampling frequency must be at least double that of the highest frequency in the incoming signal. For example, the accepted standard range of audible frequencies is in the approximate range of 20 to 20,000 Hz, so standard audio CDs are sampled and played at 44.1kHz.

Reduced sampling frequency will result in signal aliasing. Aliasing is an effect that causes different signals to become indistinguishable when sampled. In other words, aliases of each other.

Anti-aliasing filters cut the signal above the maximum Shannon-Nyquist frequency to avoid aliasing; however, any signal above the Shannon-Nyquist frequency is lost.