Analog-to-Digital Converters

Introduction

With the dynamic range of analog-to-digital converters (ADCs) often being the performance bottleneck in applications and technologies, companies have made drastic improvements to the performance capabilities of ADCs over the past decade [1]. ADCs have a large range of applications and are found in most technologies that we use today, such as computers, modems, televisions, and microcontrollers. This paper reviews current ADC technology and the performance capabilities of the four most common types of converters available.

Commercial Applications

There are currently four types of ADC architectures on the market: Successive Approximation (SAR), Delta-Sigma, Pipeline, and Flash. Companies that produce these ADC architectures include Maxim Integrated, Analog Devices, and Texas Instruments. All of these companies have comparable prices, which are specified below.

Successive Approximation

Most serial ADCs that are on the market are SAR or Delta-Sigma. SARs are better suited for general purpose applications, such as data loggers, temperature sensors, and bridge sensors. They have a speed range up to 5Msps, resolution up to 18 bits, and low power consumption (0.5mW). SARs can often be stand-alone or peripheral in microcontrollers and processors. On the market, SARs range from \$10-\$80 [2].

Delta-Sigma

The Delta-Sigma architecture produces higher resolutions (up to 24 bits) compared to the other three architectures. The drawback of this type of ADC is that it has slow conversion speeds that are often less than 4Msps. Delta-Sigma works by oversampling the input so that it can get high resolution. Oversampling the input leads to the conversion taking many clock cycles to compute. Delta-Sigma ADCs are comparable to SARs in cost as they range from \$20-\$100 [3].

Pipeline

The Pipeline architecture is used for high-speed applications that have frequency ranges greater than 100Mhz. Applications that would use this type of ADC include wireless communications, medical imaging, radar systems, and data acquisition. This architecture has conversion rates up to 550Msps, resolution up to 16 bits, and high power requirements. Current Pipeline ADCs have power consumptions of 290mW at 3V per integrated circuit (IC). On the market, this architecture ranges from \$150-\$250 [4].

Flash

The Flash architecture has resolution up to 8 bits, power consumption up to 5.25W, and conversion speeds up to 1Gsps. While the conversion speed is the fastest of the four architectures, it has a power consumption that is 16,000 times higher than that of a SAR [5].

Another drawback of Flash is that it takes up a large amount of area if more than 8 bits are processed. There are Flash chips available today that have power consumption values close to 875mW. Flash chips range from \$5-\$30 [6].

Underlying Technology

ADCs take in an analog signal, quantize the signal by sampling the input periodically, and then output a digital signal. The conversion from analog to digital often adds room for error since the continuous analog signal is getting sampled. The faster the sampling rate of the converter, the less error that will be present at the output. If the ADC operates at a sampling rate that is twice the bandwidth of the input signal, then it is possible to perfectly reconstruct the input signal.

ADCs are chosen to match the bandwidth and the signal-to-noise ratio (SNR) of the input signal. The resolution of a converter is often determined by the best possible SNR for a digital signal. The resolution of a converter indicates the number of discrete values that can be produced over a range of analog values. A resolution of 10 bits can produce 2^{10} discrete values for the given input signal. As the resolution of an ADC goes up, the maximum sampling rate goes down [7].

Building Blocks of Implementation

The implementation of ADCs into a system is often a fairly easy process. Once you have the converter chosen, it is just matter of connecting the converter to the appropriate nodes. In most cases, the ADC would have an input from an analog source and would be outputting to a device that could process the digital signal. The hardest part of the implementation is choosing which ADC would be best for the specified application.

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