Choosing the Best ADC Architecture for Your Application

Part 4:

Hello, my name is Luis Chioye, Applications Engineer for the Precision the Data Converters team.

And I am Ryan Callaway; I am a Product Marketing Engineer for the Precision Delta-Sigma Converters team.

In our previous session, we provided an overview of the Delta Sigma modulator. In today’s session we will discuss the next stage in the Delta sigma converter: The Digital Filter.

The typical topology of the Delta-Sigma Converter generally consists of two blocks: a Delta-Sigma Modulator and a Digital Decimating Filter. After the modulator is a digital/decimation low pass filter which filters the modulator stream of data.

The modulator performs noise shaping and shifts the quantization noise energy to the higher frequencies while reducing the noise at the lower frequencies. The frequency response of the digital filter ultimately defines the performance of the delta-sigma converter. The bandwidth of the ADC and settling time are a function of the digital filter stage.

The digital low-pass filter eliminates the undesirable high frequency quantization noise, and reduces the output data rate of the device to the frequency of interest.

There is a strong correlation between the resolution of the ADC and the oversampling ratio.

As the bandwidth of the low pass is reduced, the in-band noise level is reduced further.

There is a strong correlation between the resolution and the Delta-Sigma output data rate. The bandwidth of the digital filter ADC is set by the sampling frequency and the decimation ratio. Therefore, as the Oversampling ratio is higher, the bandwidth of the digital filter is reduced, resulting in lower in-band noise and higher resolution in the conversions.

Understanding the role of the digital filter and its characteristics is critical for understanding the behavior of a delta sigma ADC and its suitability for a particular application. The frequency response of the digital filter plays a significant role in the performance of the delta-sigma converter. The resolution of the ADC, data rate, bandwidth and settling time of the ADC are a function of the digital decimation filter stage. Different Delta-Sigma ADCs integrate digital filters optimized for a particular application.

The most common filter types are the SINC filter and the Flat Passband Filter.

Sinc filters are generally used for applications requiring DC measurements or slow moving signals.

One advantage of the Sinc filter is that is simple and it is economical on silicon area – this leads to lower cost, and lower power consumption.

Another reason is that the settling time (or latency) is actually very low for these filters.

This filter has a frequency response with deep notches at multiples of the output data rate. These notches can be used to reject unwanted frequencies. For example, when used at a 50 or 60 SPS output data rate, this filter type will reject 50 or 60Hz line noise.

Sinc filters are not optimal for applications that require a flat AC frequency response. Since the pass band frequency response has droop, these filters are not the best choice for digitizing signals over a wide bandwidth. Also, the attenuation at certain points may not be that high.

Converters that use this type of filter generally are intended for measuring DC signals or slow moving signals such as weight scale or temperature measurement applications.

The digital filter is going to introduce a settling time or latency to the system. SINC filters offer low latency when compared to the flat passband filter.

A Sinc filter needs n cycles to settle, where n is the filter order. In the diagram above, a third order sinc filter is used, which takes 3 full conversion-cycles to settle. However, if the analog input step change occurs during one of the conversion cycles, then 4 conversion cycles are required for a settled result.

Fortunately, some Delta-Sigma devices offer digital filters that will produce a fully settled output at the first conversion. ADCs cycle latency is equal to the number of **complete** data cycles between conversion start and the availability of the corresponding output data. The unit of measure for this definition of latency is (n)-cycle latency, where "n" is an integer number.

This diagram shows a timing diagram of a zero cycle latency delta-sigma converter with an internal 5^{th} order digital filter.

(2) The "hidden conversions" are an artifact of the order of the digital filter in the delta-sigma converter. In this example the delta-sigma converter has an internal, 5^{th} order digital filter; however the user does not see the hidden conversions results. This feature is designed into many of Texas Instruments Delta-sigma ADCs.

With a zero cycle latency ADC, the 1^{st} output data is fully settled. An ADC with zero-cycle latency is also often described as having single-cycle settling or single-cycle conversion settling.

If a delta-sigma converter has zero cycle latency, the intermediate un-settled filter results are masked.

This type of filter is especially useful for multiplexed applications where the user is monitoring different channels in a sequence; and after switching the channel in the mux, the first converted data will be fully settled.

Flat Pass-Band filters find home in applications where AC performance and wide bandwidth is required. Delta-Sigma converters that use these filters often offer fast data rates with very low distortion, such as audio applications.

Unlike the Sinc filter, the Flat Passband filter frequency response behaves more like an ideal 'brick wall' filter.

Flat Pass-Band Filter provides nearly flat pass band response with very low ripple in the pass-band followed by a rapid transition to a high attenuation stop band. They offer very high attenuation in the stop band.

A disadvantage for this type of filter is the longer settling times. This type of filter takes several conversion cycles to settle.

[Luis]

The latency or settling time of the Flat Passband digital filter is dependent on the number of taps or number of delays blocks used. Flat Passband filters require many delay blocks to maintain a desired flat passband AC response and high stop-band rejection, therefore, they tend to require larger area and require higher power.

However, most modern Delta-Sigma ADC's incorporate filters with programmable settlings to optimize performance for either low latency and power consumption, or for superior AC performance and higher resolution.

Delta-Sigma ADC's are highly integrated devices, many times incorporating a complete acquisition system into one IC greatly simplifying the signal chain.

In addition to the digital filter and high resolution ADC, these devices often incorporate the analog front end driving circuitry in the form of a driving amplifier, multiplexer, programmable amplifier or PGA, voltage reference calibration and auxiliary diagnostic circuits.

In summary:

Delta-Sigma ADCs offer the highest resolution when compared to other topologies, and a highly stable conversion result.

These devices incorporate digital filter relaxing anti-aliasing requirements.

They tend to be highly integrated devices many times incorporating analog driving circuitry, and other calibration and diagnostic functions

Their performance and latency is heavily dependent on the digital filter.

On our next session we will review SAR and Delta-Sigma Analog Front Ends Circuits.

There are a number of resources available to help you evaluate and develop a system based on these ADCs. The TI Designs – Precision page features several reference designs that can help to speed the development of a system.

For more information about precision ADCs, or to order a development kit, visit the TI Precision ADC web page at ti.com/precisionadc.

I hope that you have found this overview useful. Thank you for watching.

Useful Links:

http://www.ti.com/precisonadc

http://www.ti.com/precisionadcsupport