Resolution-Boosting ADS7138 Using Programmable Averaging Filter

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In supervisory circuits, small changes in signals can be buried in random noise. To measure small changes in signal in the presence of considerable random noise, a higher effective number of bits (ENOB) is required. The ENOB of a measurement can be limited from the noise performance of the measurement system (amplifiers, resistors, ADC resolution, and so forth) or the random noise content in the signal source (temperature sensor, resistive voltage divider, and so forth).

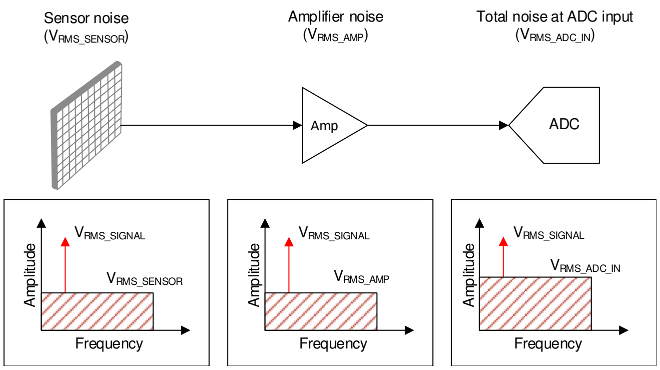

Figure 1. Noise in a Measurement System

As illustrated in Figure 1, there is considerable noise at the ADC input. Hence using a higher resolution ADC does not necessarily improve the measurement resolution that is, ENOB. The noise at the input of the ADC can be reduced by either using analog filtering techniques or using lower noise components which can result in an increase in system power, solution size, or overall cost of the system. Another approach to achieve higher measurement resolution is to use digital filtering techniques. One of the simplest forms of digital filtering is to compute the average of various ADC output samples. This article discusses various aspects in achieving higher ENOB using the ADS7138 and ADS7038.

Data Averaging to Improve Measurement Resolution

The quantization noise of two different ADC samples is uncorrelated, that is white noise. In other words, the noise is predominantly uncorrelated from one sample to another. The primary benefit of calculating the average of various ADC output samples is to average this white random noise. When two uncorrelated signals (such as white noise) are summed together, they combine mathematically as a square root of the sum of the squares (RSS). This results in a magnitude increase by a factor of 1.414 for two equal amplitudes. Consequently, the result of combining two samples of the same signal is that the signal power doubles (2x addition of the same signal). Since the random noise increases by only a factor of 1.414, or half the power of the signal, averaging two ADC samples yields an increase in +3 dB signal power of the overall averaged SNR. The increase in SNR by averaging N samples is given by Equation 1.

$$\text{Increase in SNR} = 10\log_{10} N\ dB \tag{1}$$

The effective number of bits (ENOB) of a data converter is given by Equation 2.

$$ENOB = \frac{SINAD - 1.76}{6.02} dB \tag{2}$$

SINAD can be expressed in terms of SNR and THD as shown in Equation 3.

$$SINAD = -10\log\left(10^{(SNR+10\log N)/10} + 10^{THD/10}\right) dB \tag{3}$$

Averaging N samples reduces the impact of uncorrelated white noise, however, the total harmonic distortion (THD) remains unaffected. Hence, the maximum achievable SINAD is limited by the THD of the ADC. When the input signal to the ADC is a DC signal, such as temperature or DC voltage input, SNR can be used for computing ENOB as given by Equation 4.

$$ENOB = \frac{SNR - 1.76}{6.02} dB \tag{4}$$

Programmable Averaging Filters in ADS7138 and ADS7038

The ADS7138 (I^2C) and ADS7038 (SPI) are 8-channel, multiplexed, 12-bit, successive approximation register analog-to-digital converters (SAR ADC). The eight channels can be independently configured as either analog inputs, digital inputs, or digital outputs. The ADS7138 features a built-in programmable averaging filter that can be used to average several samples. The averaging filter can be enabled by programming the OSR[2:0] bits in the OSR_CFG register. The averaging filter configuration is common to all analog input channels. Figure 2 shows that the averaging filter module output is 16 bits long.

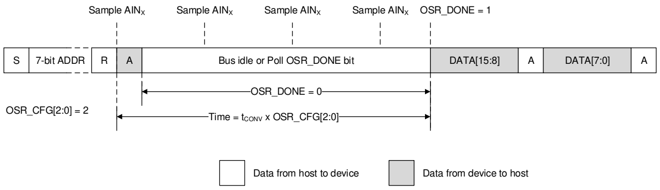

Figure 2. Output Data Format of ADS7138

ADS7138 Performance Test Results

Table 1 shows SNR, SINAD, and DC/AC ENOB for various averaging filter configurations. The DC ENOB is measured when ADC input is 1 V DC while the AC ENOB is measured with 1 V_{PP}, 2 kHz sine signal. By averaging N samples, SNR increase is given by Equation 1. However, when THD (-85 dB typical) is taken into consideration, SINAD is limited to 84 dB. As a result, the SNR of ADS7138 can reach 15-bit by sampling 128 times, an increase of 3.5 bit resolution for DC signals while SINAD can reach 13.7 bits by over-sampling 128 times, an increase of 2.2-bit resolution for AC signals.

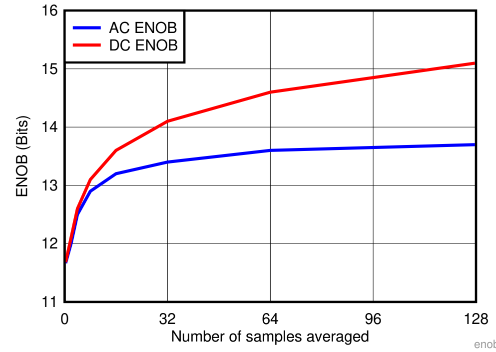

Figure 3. ENOB with ADS7x38 Programmable Averaging Filters

Conclusion

Supervisory function is used broadly in the industry to monitor critical system parameters. As the key part to realize supervisory function, data converters with programmable averaging filters add the flexibility of choosing between precision and speed.

Table 1. Increase in Resolution with Averaging

NUMBER OF SAMPLES AVERAGED	INCREASE IN SNR (dB) (Equation 1)	EFFECTIVE SNR (dB)	EFFECTIVE SINAD (dB) (Equation 3)	AC ENOB (BITS) (Equation 2)	DC ENOB (BITS) (Equation 4)
0	0	71.5	71.3	11.6	11.6
2	3.01	74.5	74.1	12.0	12.1
4	6.02	77.5	76.8	12.5	12.6
8	9.03	80.5	79.2	12.9	13.1
16	12.04	83.5	81.2	13.2	13.6
32	15.05	86.6	82.7	13.4	14.1
64	18.06	89.6	83.7	13.6	14.6
128	21.07	92.6	84.3	13.7	15.1

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