Application Brief

Isolated Amplifiers and Modulator System Level Noise Comparison

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Introduction

Isolated amplifiers and modulators for voltage and current sensing are an essential building block for circuits with galvanic isolation. THe isolated amplifiers and modulators electrically isolate two parts of the circuit but allow for the transfer of analog information.

Both amplifier and modulator devices utilize a sigma-delta modulator to digitize the analog input signal. The resulting digital information is then transmitted across a capacitive isolation barrier to the other side of the device. On the receiving end, an amplifier converts the digital signal back into an analog voltage. In a typical system, this analog voltage is subsequently converted back into a digital signal by a successive approximation register (SAR) analog-to-digital converter (ADC), which is often integrated into a microcontroller (MCU).

Amplifiers are available with differential output, single-ended fixed-gain output and single-ended radiometric outputs:

- **Differential output** (AMC0330D) is a preferred choice for systems where the physical distance between the isolated amplifier and the ADC is long or passes through connectors. The information carried to the controller is the voltage difference between two complementary outputs, not the absolute value with regard to the common ground. For this reason, this output effectively suppresses common-mode noise that can be intruding the circuit between the ADC and the isolated amplifier. The drawback is that many ADCs cannot work directly with the differential signaling. In this case there is a differential-to-single-ended conversion in close proximity to the ADC. The difference amplifier converts the signal for the ADC but introduces additional measurement errors and increases the system complexity.
- **Fixed-gain single-ended output** (AMC0330S) interface directly with the ADC and does not require a difference amplifier. This is easier to implement but cannot reject the common-mode noise. For this reason, this type of output is a preferred design for situations where the distance between the ADC and the isolated amplifier is relatively short (<10cm), or performance degradation due to the common mode noise is acceptable.
- **Ratiometric single-ended output** (AMC0330R) is a version of the single-ended variant but the gain adjusts automatically based on the voltage applied to the REFIN pin. Refer to the *System Benefits of Ratiometric Output Isolated Amplifiers*, application note for a detailed discussion on system-level benefits of single-ended amplifiers with ratiometric output.

A modulator device passes the digital information directly to the MCU where this is processed by a digital low-pass filter.

This application brief shows how different voltage-sensing variants perform in a system from a noise perspective.

Measurement results come from the test setup that uses a TMS320F28P650 MCU with an integrated 16-b single-ended SAR ADC. The sampling frequency is 312.5kHz. The differential output amplifier AMC0330D connects to an OPA365-based difference amplifier to match the ADC input voltage range. The ADC uses an external 3V voltage reference REF5030. The modulator configuration uses an oversampling rate (OSR) of 32 together with a 10MHz clock. In this case, new data are available at the same rate as from the ADC.

The noise level of the system is very low. Arbitrary waveform generators (AWGs) or source-measure-units (SMUs) unfortunately have higher noise levels compromising the test. For this reason, measurements use only

the condition with the input voltage V_{IN}=0V made sure by applying a 50Ω termination across the inputs. Each test run uses 8192 samples for a histogram.

The best performing device is the modulator. This is because of the single analog-to-digital conversion. Because of the low noise level, modulators are the devices of choice for high-resolution measurements, such as in-phase current sensing in high-performance servo drives.

Systems with isolated amplifiers typically perform two analog-to-digital conversions each decreasing the signal fidelity. The first conversion happens in the isolated amplifier. The second conversion occurs in the MCU. Differential output and single-ended ratiometric output devices perform about the same. Devices with differential output are preferred in systems where the physical distance between the isolated amplifier and the ADC is long, as explained above.

On a system-level, the single-ended ratiometric output device performs slightly better compared to the single-ended fixed-gain output device. This is related to the ability to reject low-frequency noise on a system level as demonstrated in the *System Benefits of Ratiometric Output Isolated Amplifiers*, application note. Refer to Figure 11 for comparative study.

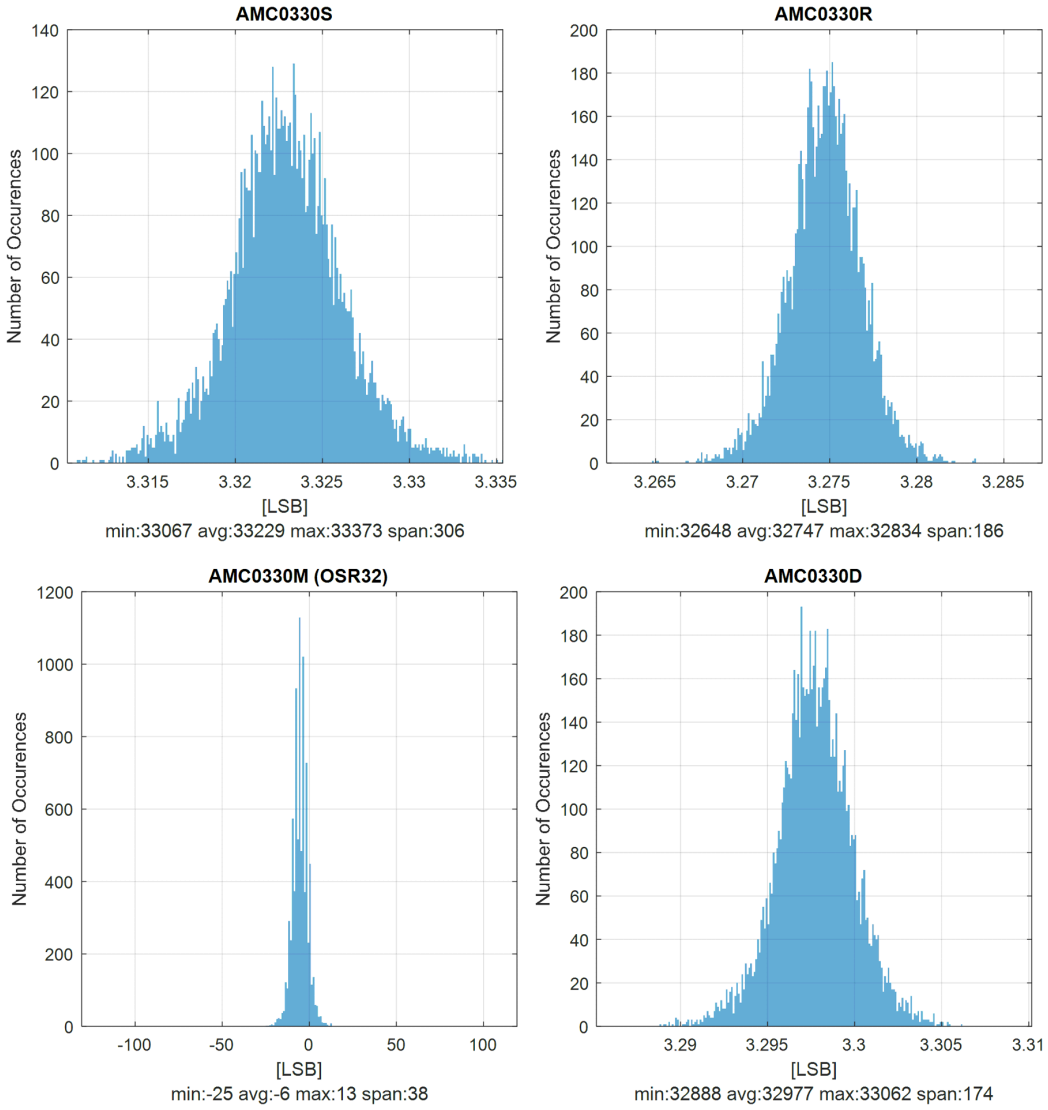

Figure 1. Isolation Devices Output Code Histogram Comparison (V_{IN}=0V)

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