Application Note

System Benefits of Ratiometric Output Isolated Amplifiers

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ABSTRACT

This application report explores the benefits of using the latest generation of isolated amplifiers with single-ended output, specifically the ratiometric configuration (AMC0330R), which automatically adjusts gain to match the reference voltage. By leveraging this functionality, systems can enhance signal integrity and optimize analog-to-digital conversion chains.

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1 Introduction

Isolated amplifiers are essential building blocks in systems that require electrical isolation of two parts of a circuit. Isolated amplifiers allow transferring analog signals across the isolation barrier. In principle, isolated amplifiers are high-end precision analog-to-digital (ADC) and digital-to-analog (DAC) converters with a digital isolator in one package. On the primary side (input) a delta-sigma modulator converts the input signal into digital data. Capacitive isolation then transfers this data across the isolation barrier. The circuitry on the secondary side (output) converts the digital data back into an analog voltage.

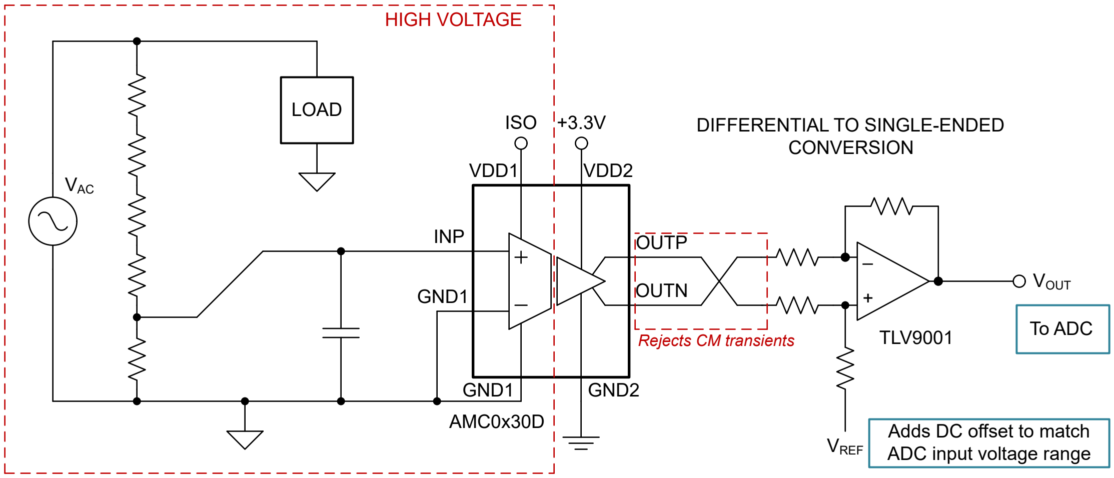

Figure 1-1. Example of the System With Differential Output

The most common versions of isolated amplifiers feature a fully differential output as shown in Figure 1-1. This configuration is beneficial in systems where the common mode (CM) noise can interfere with the signal chain between the amplifier and the analog-to-digital converter. However, in systems where the CM noise is not a concern, the single-ended output isolated amplifier (Figure 1-2) eliminates the need for a difference amplifier, typically required with the differential outputs. A good example is the AMC0330 family of voltage sensing devices that offer both output types.

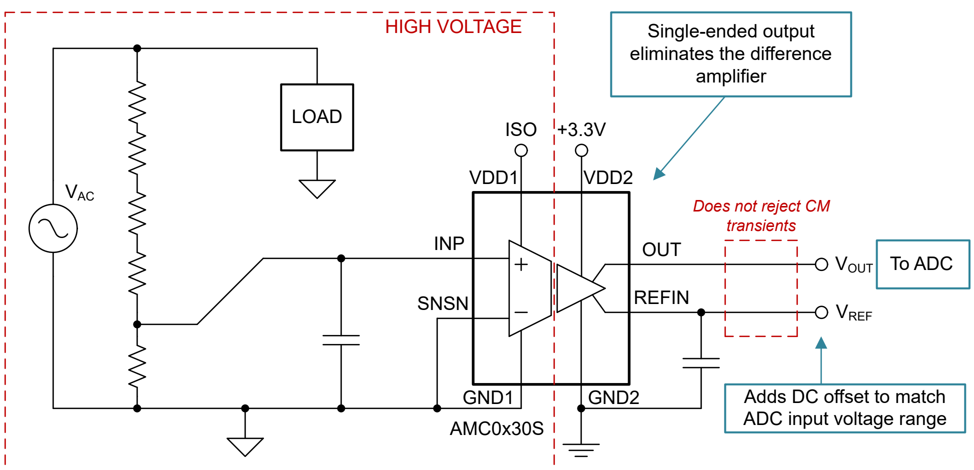

Figure 1-2. Example of the System With Single-Ended Output

2 Pairing Ratiometric Output Isolation Amplifier With ADC

Isolated amplifiers typically interface with single-ended ADCs. The ADC input range corresponds to the reference voltage (V_{REF}) that is either generated internally, or externally.

For the *ratiometric output* device, if REFIN and VREF share the same voltage, the absolute voltage is not important as both ends adjust the gain automatically and track each other. This eliminates the need for a precise voltage reference, automatically compensates for long term drift and low-frequency ripple. Of course, the effect is limited to certain voltage and frequency range. Nevertheless, this configuration effectively suppresses low frequency ripple and reference voltage deviation. Next chapters highlight in-system rejection performance of the signal chain featuring AMC0330R, paired with TMS320F28P650 microcontroller with 16b successive approximation register (SAR) ADC.

2.1 Test Setup

Figure 2-1 and Figure 2-2 show a test configuration used for measurements. An Arbitrary waveform generator (AWG) sources the reference voltage to allow for dynamically changing the reference voltage V_{REF}.

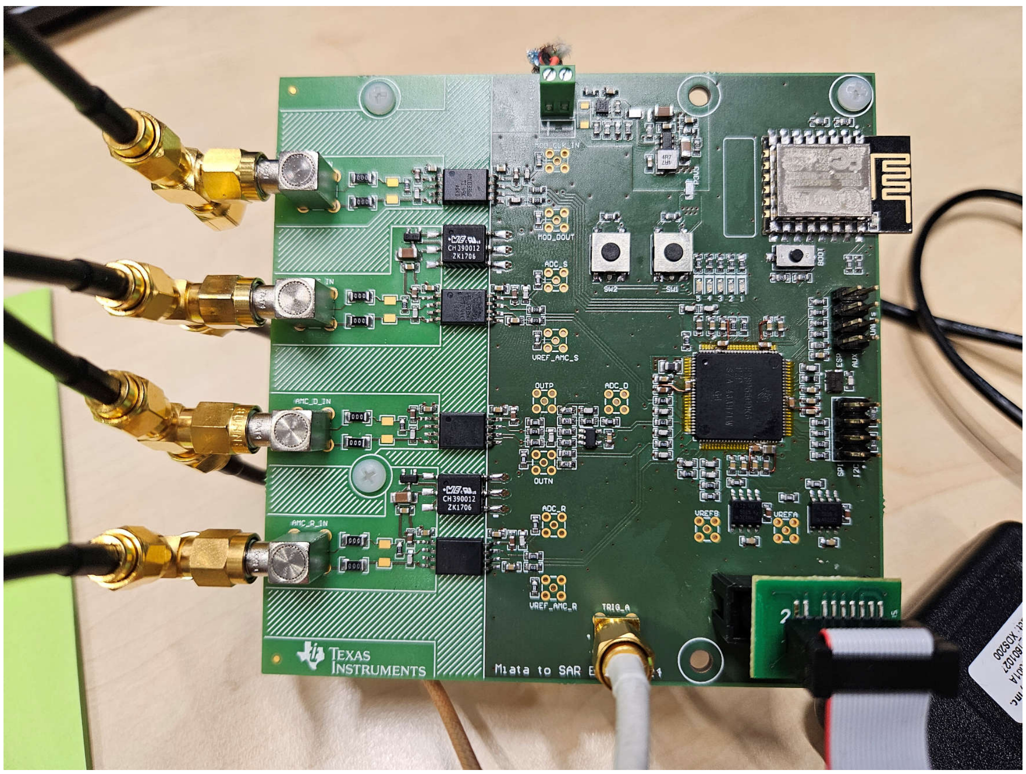

Figure 2-1. Experimental Test Setup

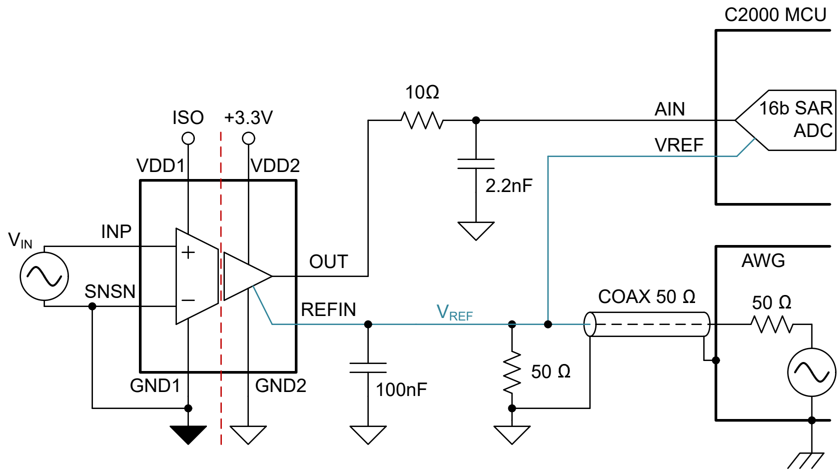

Figure 2-2. Test Configuration With AMC0330R and SAR ADC Used for Measurements

2.2 REFIN Voltage Tracking

Figure 2-3 illustrates how the output of the AMC0330R device tracks the REFIN voltage. The input signal is 10-kHz sinewave with 1V amplitude. The reference voltage applied to the REFIN pin is 1kHz triangular wave with a 3V DC offset and a 300mV peak-to-peak ripple, which corresponds to 10% of the DC offset.

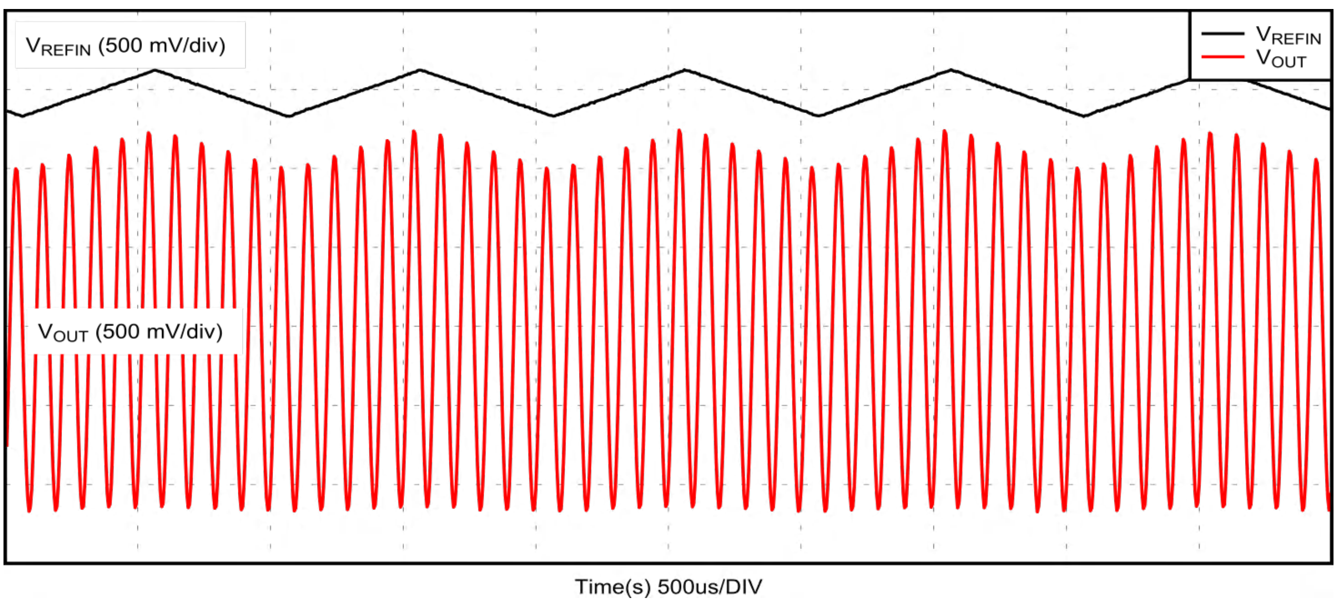

Figure 2-3. Ratiometric Output Voltage Tracking REFIN

2.3 Ratiometric Configuration Noise Rejection

For noise rejection benchmarking, the test uses the following configuration.

- The VREF is shared with 16-bit SAR ADC in TMS320F28P650 MCU and AMC0330R device as shown in Figure 2-2
- The AWG injects a modulated reference voltage, with VREF(NOM) = 3V and VREF(INJ) = 300mVpp (sinewave) (Figure 2-4)
- The input voltage is zero (VIN=0V)

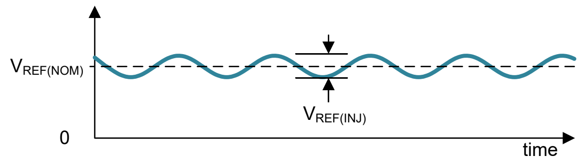

Figure 2-4. Waveform Applied to V_{REF} for the Rejection Test

Test procedure is as follows:

- The AWG sweeps V_{REF} from 500Hz to 100kHz in multiple steps
- At every step, the MCU stores 8192 ADC samples
- At every step, the software in personal computer (PC) applies Fast Fourier Transformation (FFT) at the ADC samples and reads the peak value at the frequency corresponding to the step and AWG output
- The software calculates peak amplitude $V_{ADC(OUT)}$ from the FFT peak value
- System calculates the attenuation

$$\text{Attuenation[dB]} = 20 \times \log_{10} \frac{V_{ADC(OUT)}}{V_{REF(INJ)}} \quad (1)$$

Figure 2-5 shows the plot for all steps in the range from 500Hz to 100Hz.

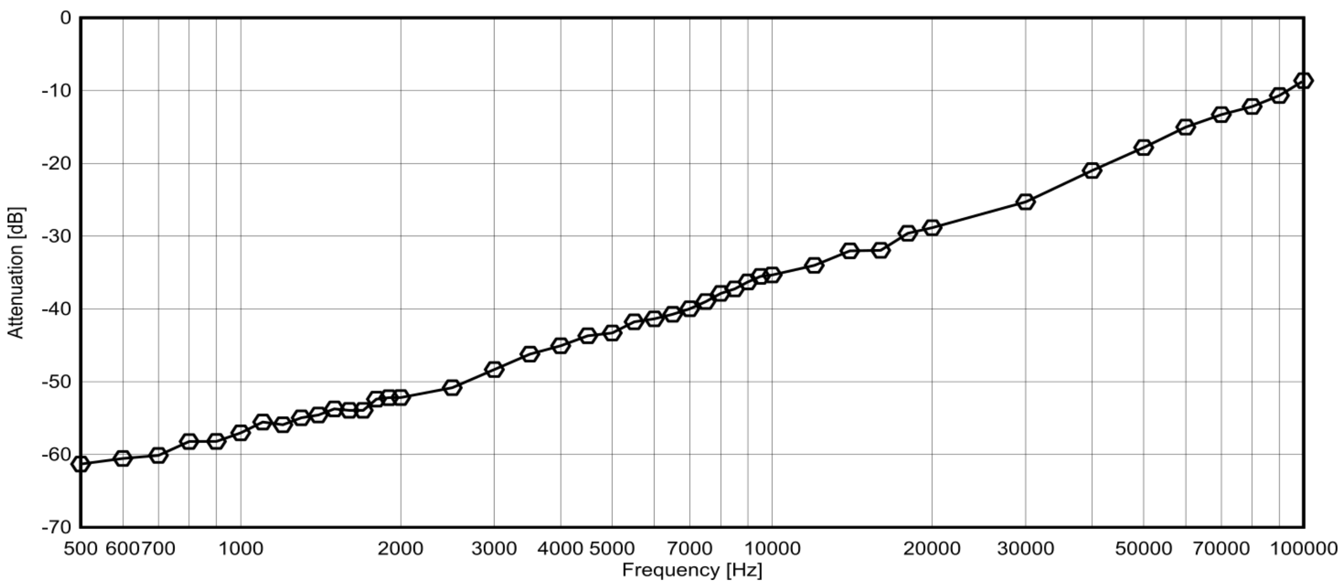

Figure 2-5. Ratiometric Configuration V_{REF} Noise Rejection

2.4 Spurious-Free Dynamic Range

The spurious-free dynamic range (SFDR) is more relevant parameter in the communication industry, but this is also a practical indicator that can be clearly seen in the frequency domain (Figure 2-6). This parameter helps in understanding how significant the injected noise is compared to the signal of the interest.

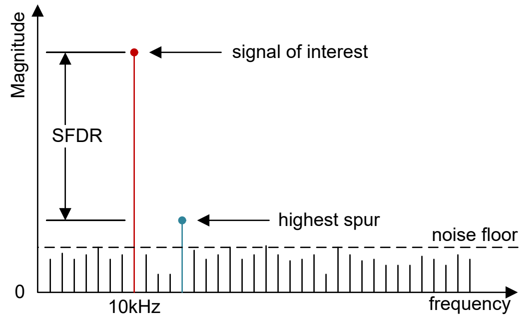

Figure 2-6. Spurious-Free Dynamic Range

The test procedure and the configuration are similar to those in the previous example, but not identical. The input voltage V_{IN} is a 10kHz sinewave with $2V_{PP}$ amplitude. This signal represents the signal of the interest. The AWG injects a modulated V_{REF}, as in the previous example.

Figure 2-7 shows SFDR performance of the ratiometric configuration compared to the non-ratiometric configuration. The default non-ratiometric configuration dynamic range, which is determined by the ratio between the injected noise and the signal of interest, remains practically constant.

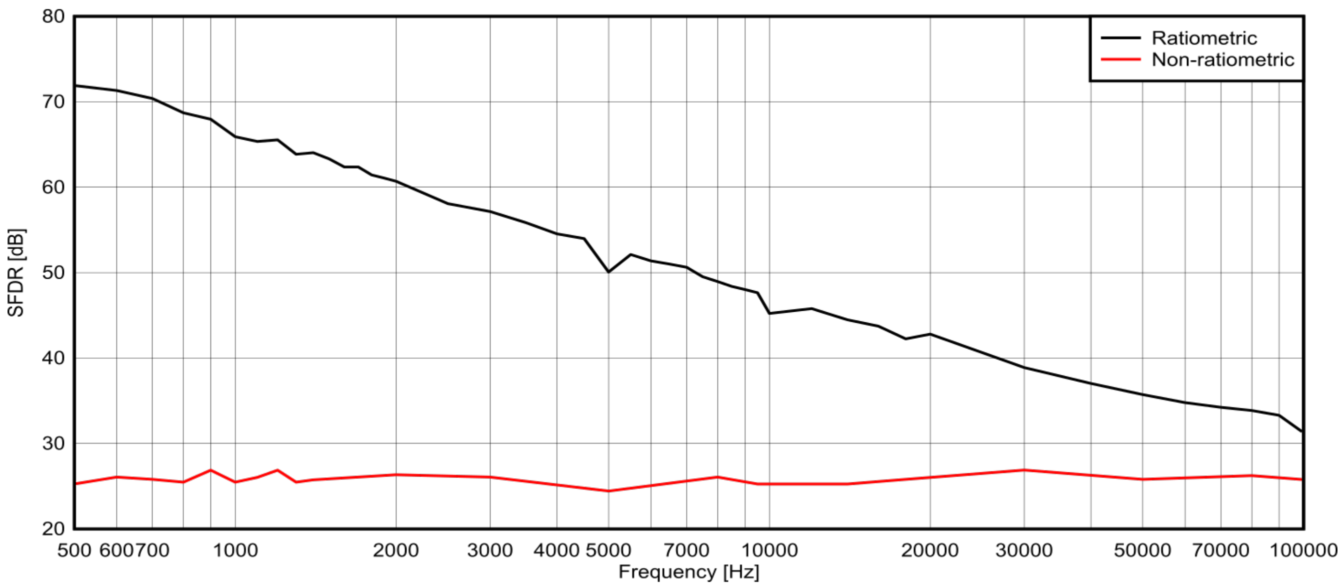

Figure 2-7. Spurious-Free Dynamic Range Comparison Between the Fixed Gain and Ratiometric Configuration

2.5 Transient Response of REFIN to VOUT

When the input voltage V_{IN} is0V, the output voltage of the AMC0330R device is V_{OUT}=V_{REFIN}/2. This test investigates how quickly the output voltage V_{OUT} responds to the changes in the reference voltage V_{REF}. Figure 2-8 illustrates the test setup. The driving impedance is 25Ω. Figure 2-9 shows the transient response with C_{REFIN} removed, Figure 2-10 shows the transient response with capacitor C_{REFIN}=68nF assembled. In both cases the V_{OUT} settling time is approximately 8μs. The configuration with the capacitor exhibits only a small overshoot.

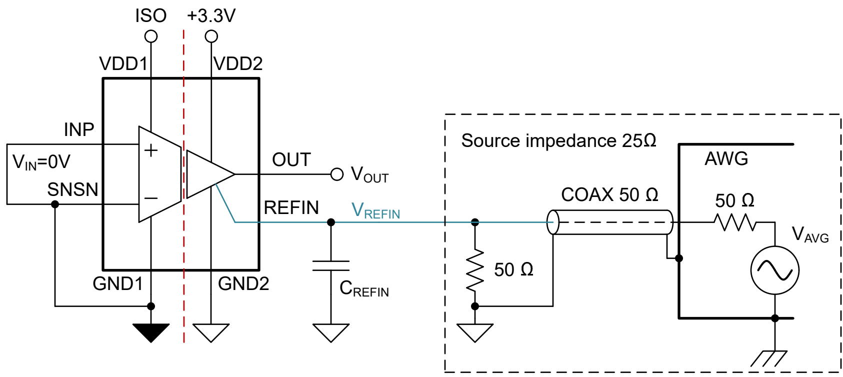

Figure 2-8. Transient and Frequency Response Test Setup

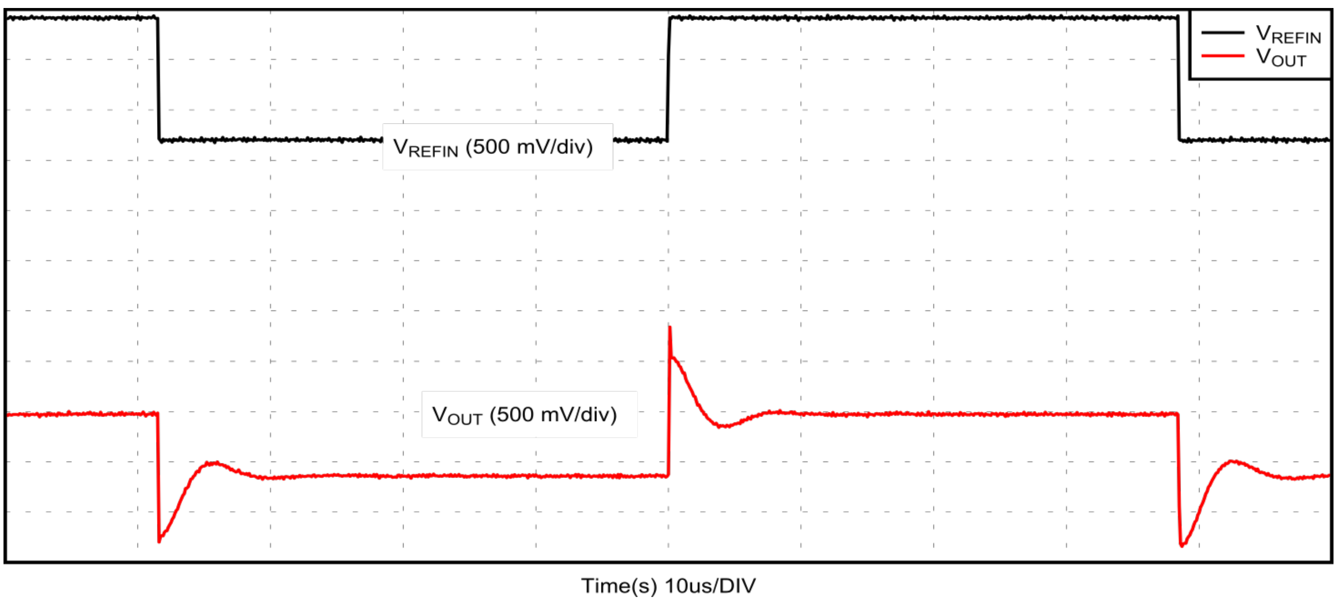

Figure 2-9. REFIN to OUT Transient Response (C_{REFIN} not Assembled)

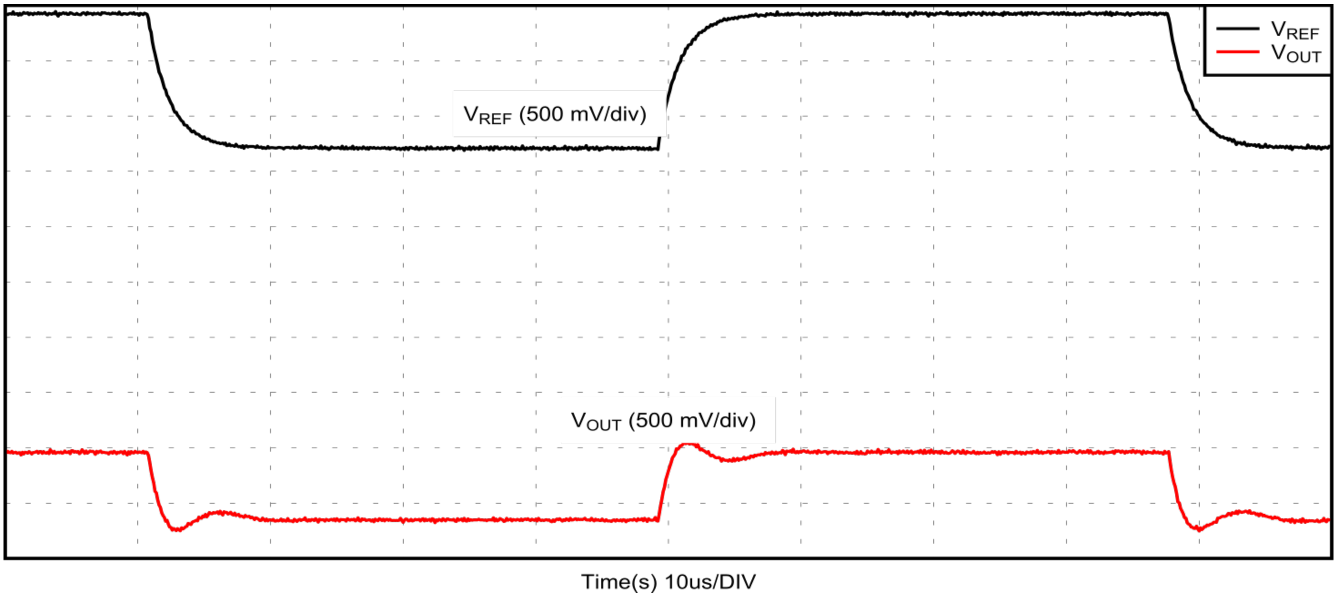

Figure 2-10. REFIN to OUT Transient Response (C_{REFIN}=68nF)

2.6 Transfer Function of REFIN to VOUT

The Figure 2-11 shows the transfer function of the REFIN signal to VOUT signal. The measurement uses the same configuration as described in Section 2.5. The plot starts with a -6dB point as the output voltage V_{OUT} is half of the reference voltage V_{REFIN}.

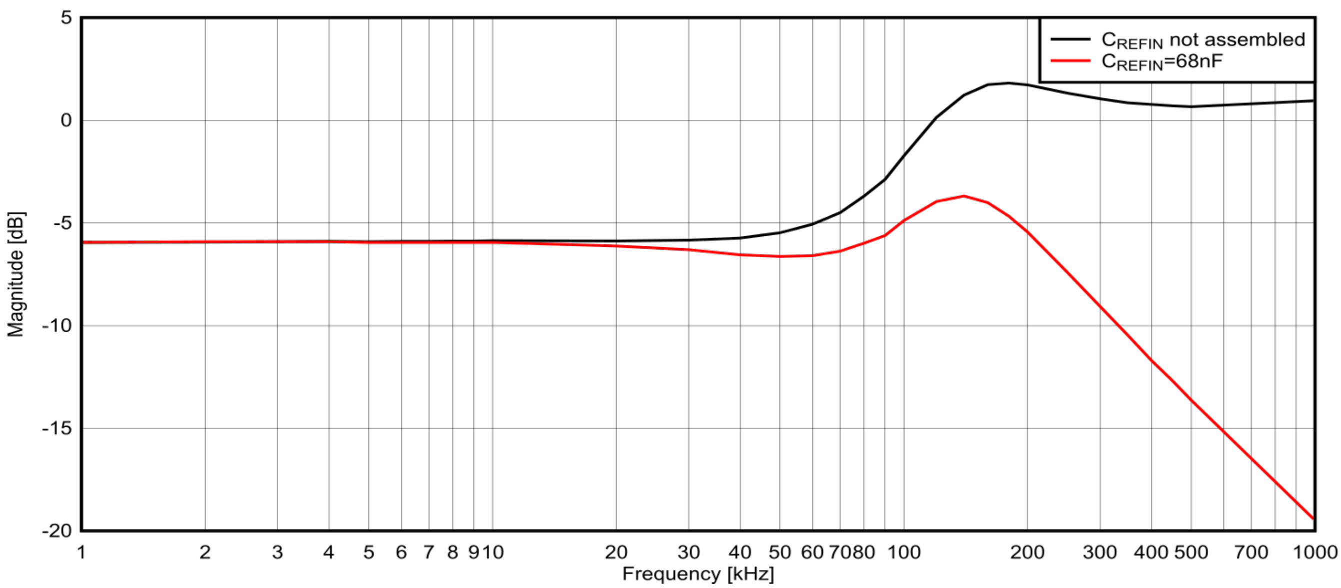

Figure 2-11. REFIN to OUT Transfer Function

3 Summary

This application report demonstrates the in-system performance of the ratiometric output isolated amplifier, highlighting the ability to reject low-frequency reference voltage variations. In many scenarios, the designer can completely remove the precise voltage reference for the ADC and instead use the integrated voltage reference or the digital power rail that supplies the microcontroller. While the ratiometric configuration offers benefits at lower frequencies, its effectiveness is limited at higher frequencies due to delays and phase-shifts in the filter stages, which prevent the output signal V_{OUT} from timely tracking the reference voltage V_{REF}. Nonetheless, assembling the C_{REFIN} capacitor is recommended in all cases, as this effectively prevents higher-frequency noise from coupling to the REFIN pin.

4 References

1. Texas Instruments, *AMC0x30R-Q1 Automotive, Precision, ±1V Input, Basic and Reinforced Isolated Amplifiers with Single-Ended, Ratiometric Output*, data sheet.