Application Brief

1MHz Signal-Chain for Wide Bandwidth Data Acquisition

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Precision ADC

Introduction

A wide-bandwidth precision data acquisition circuit (DAQ) is required to measure analog signals with rapid changes in signal amplitude in a short period of time. Even circuits for measuring low-frequency or DC signals need a wide-bandwidth precision data acquisition circuit as the signal multiplexer changes from one input channel to another causing a step change at the output as Figure 1 illustrates.

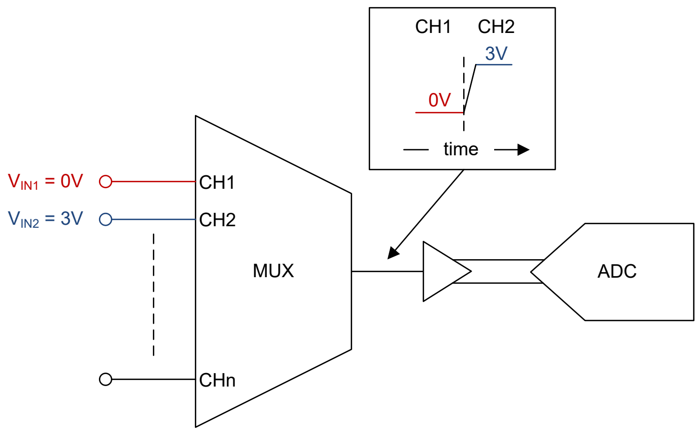


Figure 1. Multiplexed Wide-Bandwidth DAQ Circuit

In some applications, the analog input signal has high-frequency content and hence the data acquisition circuit needs to have wide bandwidth. Applications that require wide-bandwidth precision data acquisition circuits include electric vehicle traction inverter power analysis and near-field pyroshock testing.

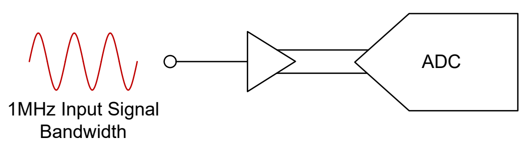


Figure 2. DAQ Circuit for Wide-Bandwidth Analog Signals

1MHz DAQ Circuit

The circuit in Figure 3 includes an ADC (ADS9219), and an ADC driver (THS4541). This ADC driver and ADC circuit are optimized for low distortion and low noise for signals with 1MHz bandwidth making this circuit an excellent choice for use in wide bandwidth data acquisition systems.

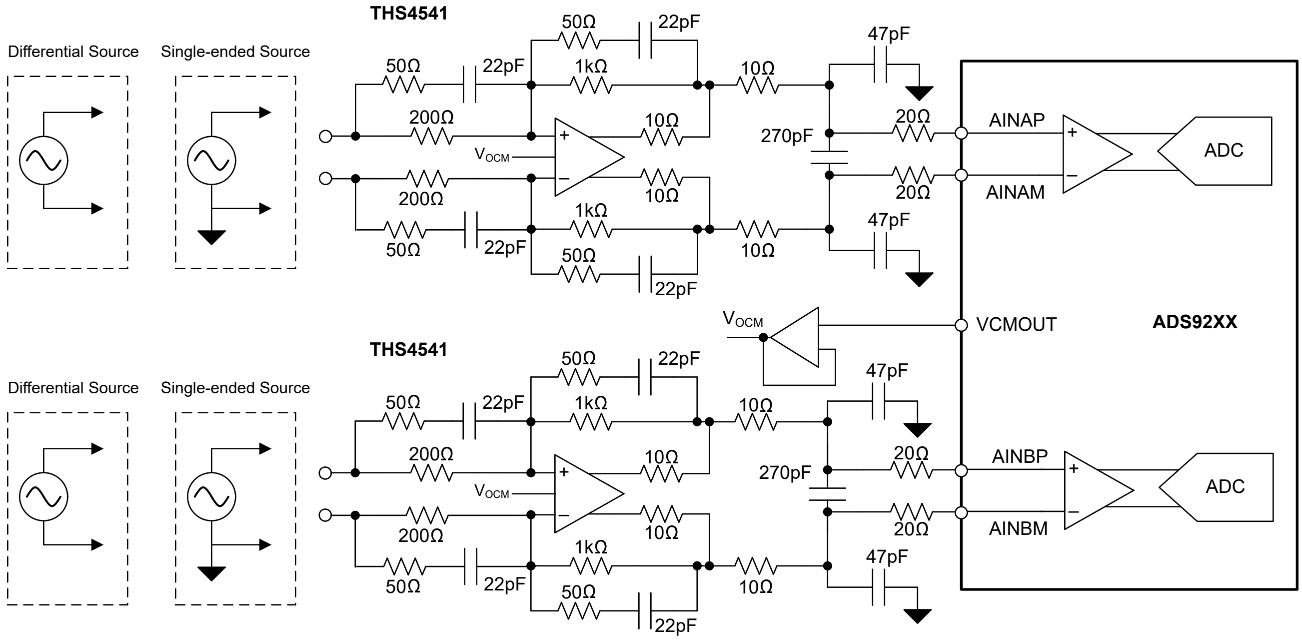


Figure 3. Circuit for Measuring an Input Signal With 1MHz Bandwidth

Component Selection

The circuit for driving the analog inputs of an analog-to-digital converter (ADC) needs to have sufficient bandwidth, usually much more than the signal-bandwidth, to handle the kickback from the switched capacitor input of the ADC. However, amplifiers have wide-band voltage noise, usually specified as voltage noise density in the amplifier data sheet, that causes the signal-to-noise ratio (SNR) to degrade as the circuit bandwidth is increased. Hence, there can be a trade-off between low-noise (lower bandwidth) and low-distortion (wider bandwidth) when driving the analog inputs of an ADC. The tradeoff is more pronounced when the analog input signal is high-frequency, which inherently requires a wide-bandwidth circuit.

The Figure 4 and Figure 5 graphs show a comparison of total harmonic distortion (THD) versus frequency for two fully differential amplifiers: THS4551 and THS4541, respectively. The THS4541 has a lower harmonic distortion of –120dB at 1MHz. Therefore, this amplifier is a good choice for designing a low-distortion, wide-bandwidth signal-chain.

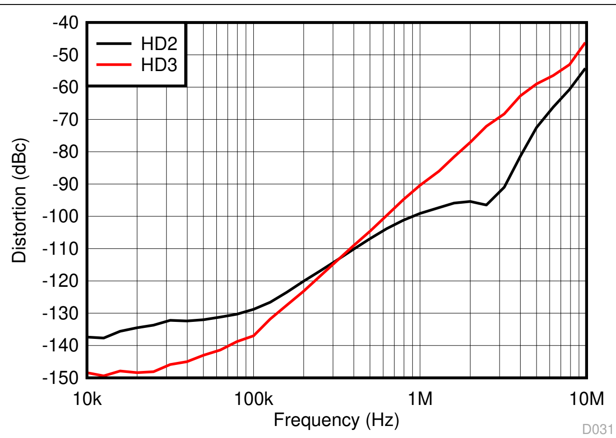


Figure 4. THS4551 Harmonic Distortion vs Frequency

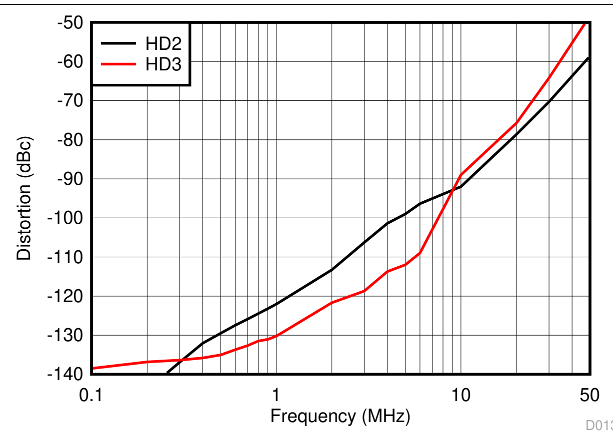


Figure 5. THS4541 Harmonic Distortion vs Frequency

When selecting the ADC, the sampling rate and analog input bandwidth needs to be sufficient enough to digitize a wide-bandwidth signal or a fast-changing signal that can be seen at the output of a multiplexer. Based on the

Nyquist theorem, the sampling rate of the ADC needs to be twice the analog input signal bandwidth. Practically however, the ADC sampling rate needs to be much more than the signal bandwidth to get a sufficient number of data points for post-processing. Additionally, the analog input bandwidth of the ADC needs to be large enough to reliably sample a fast changing or high-frequency analog input signal.

The challenge with using a much faster ADC compared to the analog input signal bandwidth at 1MHz is that the ADC driver design becomes quite complicated to balance low-distortion and low-noise. This is because the ADC input driver must have high bandwidth to fully charge the sampling capacitor of the ADC between two consecutive samples to maintain low distortion. The ADS9219 has an integrated ADC driver with > 45MHz analog input bandwidth, which means the external circuit does not have to charge the sampling capacitor of the ADC and the ADC has enough analog input bandwidth to reliably digitize a 1MHz analog input signal.

As the ADS9219 has an integrated ADC driver, the THS4541 circuit needs to have just enough bandwidth for a 1MHz analog input with low-distortion. The circuit described in Circuit Optimization shows an example of a wide-bandwidth data acquisition circuit optimized for low-noise and low-distortion for analog input signals up to 1MHz.

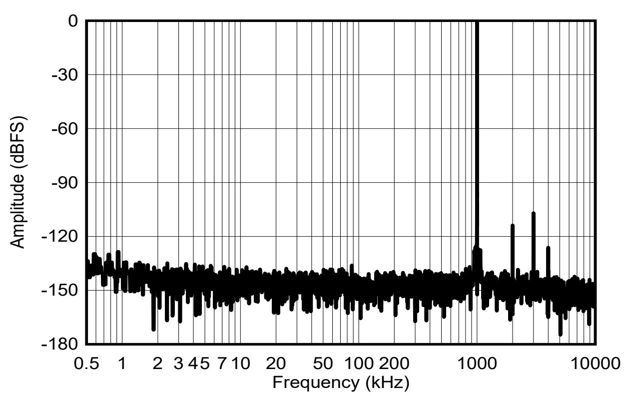
Circuit Optimization

To improve the performance of the circuit shown in Figure 3, the following design optimizations were made:

1. **THD Optimization** – To improve the THD of the circuit, R_{LOAD} was increased by setting the feedback resistors to 1kΩ and Z_{LOAD} to 270pF.
2. **SNR Optimization** – The feedback network of the THS4541 circuit generates white noise, so the 270pF differential capacitor and 22pF feedback capacitor are added to limit the signal-chain noise bandwidth.
3. **Amplifier Stability** – To improve phase margin and stability, 50Ω resistors were added in series with the feedback capacitors.

Measurement Results

The THS4541 and ADS9219 circuit was tested with a 1MHz analog input signal. This circuit achieves an SNR of 94.9dBFS and a THD of –104.2dB, as shown in Figure 6. This combination of low noise and low distortion makes the THS4541 and ADS9219 circuits good choices for applications requiring high-fidelity signal processing such as wide bandwidth data acquisition systems.



f_{IN} = 1MHz, SNR = 94.9dBFS, THD = –104.2dB

Figure 6. Typical FFT for f_{IN} = 1MHz

Summary

Designing a wide-bandwidth precision circuit is crucial for measuring analog signals with rapid changes in signal amplitude in a short period of time. To achieve this, engineers must balance low-noise and low-distortion requirements, which can be challenging, especially when dealing with high-frequency signals. The THS4541 fully differential amplifier and the ADS9219 ADC, which features an integrated ADC driver with high analog input bandwidth is an excellent choice for this application. By optimizing the THS4541 circuit for low-distortion and low-noise, as described in Circuit Optimization, the circuit achieves an SNR of 94.9dBFS and a THD of –104.2dB when driven by a 1MHz input signal. By implementing optimizations for SNR, THD, and amplifier stability, the circuit provides excellent performance making the circuit an exemplary choice for applications needing high-fidelity signal processing, such as power analysis and pyroshock testing.

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