

# Application Brief

## Using TI ADCs for Noise, Vibration, and Harshness Measurements

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### Introduction

Data acquisition systems (DAQs) are an important component in testing setups, as these systems translate measured data from the physical world to a computer where that data can be analyzed. Changes and advancements in technology are quickly followed by improvements in testing as standard testing procedures can possibly not be sufficient or practical. The automotive landscape has changed rapidly in recent years, as more and more automotive manufacturers introduce electric vehicles and hybrids. This article discusses noise, vibration, and harshness (NVH) data acquisition related to automotive testing. NVH measurements are crucial in maintaining that a vehicle runs smoothly on the road and is comfortable for passengers. This application brief covers key challenges to consider when designing an NVH data acquisition system.

### Noise, Vibration, and Harshness (NVH)

Noise, vibration, and harshness (NVH) analysis in automotive testing is one use case for data acquisition systems (DAQs). Noise and vibration are quantitative measurements, measuring the oscillations which are heard and felt, while harshness is a qualitative measurement, describing passenger discomfort due to the physical motion and ambient noise. NVH analysis is used to identify sources of noise and vibrations to reduce the effects of these noises and vibrations. Excess noise and vibration fatigues drivers more quickly, and adds unnecessary stress on the vehicle's mechanical structure, posing a safety risk.

Electric and hybrid-electric vehicles changes the requirements for NVH testing, as electric engines are quieter than internal combustion engines (ICEs). There are many NVH sources throughout a vehicle, both internal and external. Sources include sound from the engine, the brakes, external wind. ICEs drown out some ambient noise, so there are more noticeable noise sources to consider with an electric. Additionally, electric engines have a different acoustic profile than ICEs. For example, the noise and vibrations from an EV engine tend to produce higher frequency noise than an ICE. The dampening and absorption structures used to reduce the noise from an ICE are not designed to reduce the noise from an electric motor. Additionally, different structural materials have different noise generation and absorption properties, which affects how noise propagates and is amplified throughout the vehicle.

### NVH Measurements

A variety of transducers are used for NVH measurements, such as microphones, accelerometers, and vibrometers. The frequency range for NVH measurements is from around 10Hz to about 100kHz. For example, vibrations from the road are measured in hertz, while interior rattling and squeaking are measured in the tens of kilohertz. Depending on the transducer, the output voltage can range from hundreds of millivolts to volts.

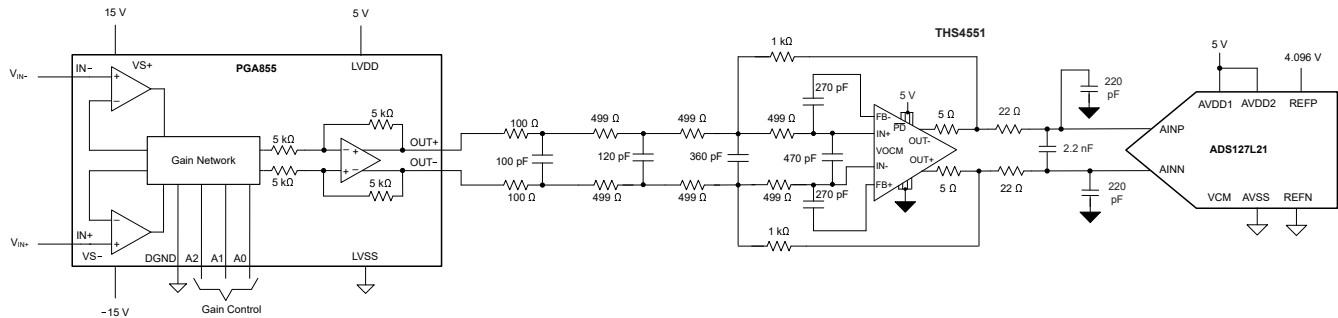
Many NVH tests require multiple channels, such as microphones placed in various locations around a vehicle or three accelerometers for 3-axis vibration. For useful data collection, the different measurement channels need to be synchronized with one another. Sometimes, there is channel-to-channel isolation to prevent interference between channels.

NVH testing is performed at various stages of the design and prototyping process, as data collected early in the process can be used to tune software for subsystem simulations and inform design decisions later on. Design engineers use the collected data to build and improve noise simulation models, which allow them to analyze

interactions between different noise sources. Ultimately, designers want to reduce the amount of noise and vibrations present, and identifying noisy sources early allows designers to more easily reduce the overall impact. Unwanted noise and vibrations can be reduced through absorption, source reduction, barrier, and isolation techniques.

### Example Noise and Vibration Signal Chain

Figure 1 is an example analog signal chain for noise and vibration measurements.



**Figure 1. Example Signal Chain With PGA855, THS4551, and ADS127L21**

The required system input voltage range and bandwidth depend on the transducer. To accommodate multiple kinds of transducers, the system needs a flexible input voltage range and a wide bandwidth. For example, a microphone can have a dynamic range of 20dB to 135dB (0.2mPa to 112Pa), a frequency range of 10Hz to 20kHz, and a sensitivity of 50mV/Pa. This means that the bandwidth must be able to measure a 20kHz signal and have an input range of 5.6V (112pA × 50mV/Pa). A strain gauge can have a measurement range of ±100mV/με, a frequency range of 1Hz to 100kHz, and a sensitivity of 50mV/με. The required bandwidth is larger, and the required input voltage range is 10V.

The PGA855 is a good choice for the input amplifier due to the wide-bandwidth, low input bias current (1nA) and input-referred noise (7.8nV/rtHz at Gain 16V/V), and configurable gain settings (1/8 through 16V/V). The PGA855 flat passband of 10MHz at all gains maintains that the input signal has less distortion in the measurement path. Low input-referred noise is key because the input amplifier can limit the performance of the entire system, since the noise propagates through the signal chain. The configurable gain options allow the PGA855 to scale the input signal to the ADCs full-scale range, allowing for one signal chain path to be used for a variety of sensors.

The ADS127L21 ADC is an appropriate choice in this application due to the 24-bit resolution and high dynamic range (111.5dB) at 200kSPS. The 24-bit resolution allows the ADC to measure μV signals from very sensitive transducers. The high sampling rate is enough to meet the Nyquist sample rate criteria (at least twice the largest sampled frequency) and can be used to oversample the signal to increase the dynamic range of the signal chain. Additionally, the ADS127L21 has programmable IIR and FIR filters, which allow the designer to tune the signal chain based on the bandwidth requirements. An anti-aliasing filter with a bandwidth of 100kHz is used on the input of the ADC to maintain that unwanted high-frequency signals from the transducer do not interfere with the signal of interest.

To see more detailed design information and test data, please see [Anti-alias filter design for a 100kHz bandwidth data acquisition signal chain](#).

### Conclusion

NVH testing and analysis is a crucial component when designing and building a safe and comfortable vehicle. As the automotive market shifts and evolves, automotive testing must shift and evolve with the market. NVH is a specific application of sound and vibration data acquisition, and is not unique to the automotive industry. Sound and vibration analysis is used in aerospace testing, and consumer appliance designs. The need for NVH measurements continues to grow with the increased push for vehicle electrification. TI offers devices and signal chain designs which are an excellent choice for NVH measurements. For more information on TI resources for designing DAQ systems, [click here](#).

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