

Measurement Dynamic Range Considerations for Sound Transmission Loss Testing

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ABSTRACT

Highly effective double-wall systems for automotive applications can often have over a 90 dB span in sound transmission loss values between low frequencies, where they are usually least effective and upper frequencies, where they are typically most effective. Particularly for 16-bit measurement systems, but even for 24-bit systems, this can represent a very difficult scenario for measurements in either the source and/or receiving chamber(s). A methodology to balance the observed dynamic ranges in both source and receiving chambers is presented and discussed in this paper. An improved sound transmission loss measurement system can therefore be implemented which reduces the potential of overload or noise floor contamination occurring in measurements within either chamber. Low frequency SPL requirements for the source chamber speaker system and flanking noise issues with adjacent test chambers can also be typically reduced. Although this paper focuses on the case of SAE J1400 [1] sound transmission loss testing, the methodology described could also benefit other test standards, such as ASTM E-90 [2] and ISO 10140-2 [3].

INTRODUCTION

As shown in Fig. 1, it has been clearly evident that some test labs can have difficulty making reliable sound transmission loss measurements of highly effective double-wall (sandwich) sound insulator constructions. The fall off in measured transmission loss at higher frequencies by Lab 2 is indicative of severe noise leakage due to inadequate sample sealing in the test window, flanking noise through adjacent walls or the receiving chamber floor and/or measurement system dynamic range problems. Although the last SAE J1400 round robin was performed many years ago by the Acoustical Materials Committee, it is evident that even today

some nationally certified testing labs continue to have similar problems. As a result SAE J1400 has undergone a major revision to address most of these issues.

The following key changes have been incorporated into the Aug 2010 release of SAE J1400:

- Methodologies have been incorporated to assess the maximum transmission loss measurement capability versus frequency of the transmission loss (TL) suite as limited by the combination of flanking noise, measurement system noise and background noise. Labs are now required to indicate their maximum TL measurement capability on all test results. TL results within 10 dB of the maximum measurement capability of a given lab should be provided for reference only. The hope is that laboratories now have a method to identify deficiencies in the measurement facility and/or instrumentation and they will strive to make improvements if deficient.
- Background noise levels are to be measured at the same measurement system gain settings as when measuring test samples. In this manner, measurement system noise levels will be captured at the proper relationship to other background noise levels.
- The design and construction of a Control Sample using readily available materials has been defined. The target sound transmission loss values of the Control Sample have been listed in order for labs to check their results and take corrective action if necessary. Note that the target TL of the Control Sample is 86 dB at 10 kHz.

Changes in the new release of J1400 should go a long way toward improving inter-laboratory reproducibility. However, the intent of this paper is to propose a further method to balance dynamic range requirements in the source and receiving chambers so that noise floors and overloads are

hopefully avoided in both chambers. Although this paper makes a number of simplifying assumptions, the general approach should be applicable to a wide range of test installations and specific data acquisition / measurement systems.

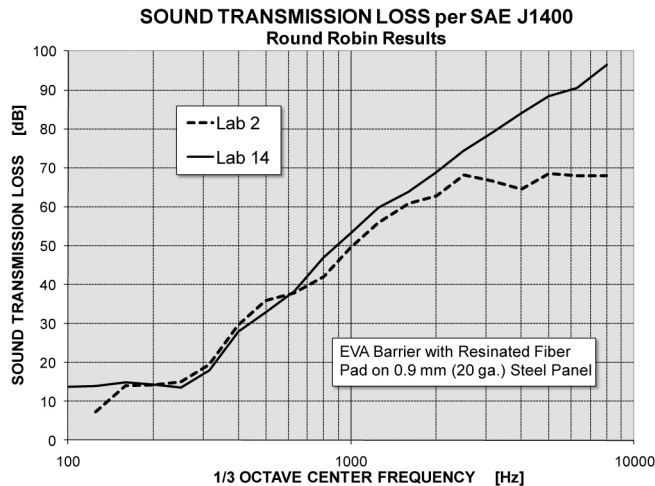


Figure 1. Results from a previous SAE Acoustical Materials Committee J1400 Round Robin

DATA ACQUISITION SYSTEMS

The dynamic range of a data acquisition system is easily defined as the difference in dB between the maximum signal level the system can accurately measure (before clipping and distortion occur) and the lowest signal level it can accurately measure (before residual noise in the transducer and electronics obscure the signal) [4]. With the advent of digital data acquisition systems, most commonly discussed are the theoretical dynamic ranges of analog-to-digital converters (ADC). There is however an understanding, even with modern analog and digital electronics, that actual dynamic range can be reduced [4] due to:

- Harmonic distortion
- Cross-talk
- Spurious circuit noise
- ADC quantization noise
- ADC non-linearity
- Aliasing
- DSP imperfections

Moreover, as shown in Fig. 2, the “useful” or “usable” dynamic range is actually the result of measurement signals cascading through a number of processing stages. Particularly if clipping levels and noise floors are not aligned via gains / sensitivities of each stage, then the clipping level of one stage and the noise floor of another when combined can limit the overall useful range.

For the purposes of this paper, it is assumed that the overall data acquisition system, including transducers and electronics, have a usable dynamic range of 80 dB. Each lab with its own acquisition system will have to determine their particular overall dynamic range capabilities. They should not rely on published numbers of individual measurement stages.

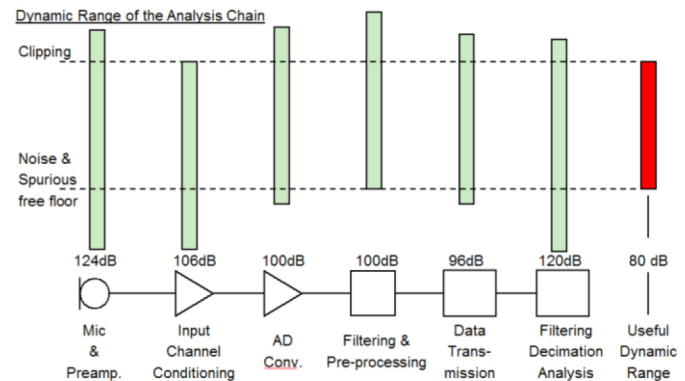


Figure 2*. Useful dynamic range of a typical laboratory-grade 24-bit data acquisition system [4] * Graphic used with the kind permission of Brüel & Kjær

THE PROBLEM

The most common practice among laboratories testing per SAE J1400 is to aim for constant SPL versus frequency in the source chamber. While not usually achieved at the frequency extremes, most labs will have SPLs equalized to within a ± 5 dB band.

In the worst case with highly effective sound insulators, the resulting SPL in the receiving chamber decreases dramatically as frequencies increase. Unfortunately, as Fig. 3 illustrates, a poorly implemented system will reach the noise floor of the receiving chamber at higher frequencies and not be able to measure correctly the target signal level. Note that this example looks like it could have been the case as shown in Fig. 1.

For the purposes of this paper, Fig. 4 illustrates the assumed background noise levels in the receiving chamber with a “maximum TL treatment in the test window and the source chamber speakers turned on. A well design TL suite should be able to achieve NC15 noise levels [5] in the receiving chamber.