



In-Vehicle Sound Transmission Loss (STL) Evaluation Procedure

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. To measure the Sound Transmission Loss (STL) of a vehicle's exterior panels while in-situ. The measured STL of each exterior panel can be input into Statistical Energy Analysis (SEA) models to predict the overall noise performance for a given operating condition.

1.2 Foreword. This test is to be used for the purpose of establishing new product goals for interior trim components through the benchmarking of competitive vehicles and for the development of new product program designs to achieve the specified vehicle interior sound.

1.3 Applicability. This test procedure is applicable to the full line of passenger vehicles.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ANSI S1.11 SAE J184

2.2 GM Standards/Specifications.

GMW14172

2.3 Additional References.

B and K booklet, "Sound Intensity"

3 Resources

3.1 Facilities. The test shall be performed in a quiet acoustic environment such as a hemi anechoic room or a room in which background noise levels permit a 40 dB difference between the noise source on and off in the 1/3 octave bands from 200 Hz to 10 000 Hz.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

Note: Equipment with equivalent specifications is acceptable.

3.2.1 Multi-channel analyzer meeting SAE J184.

3.2.2 Capability to reduce data meeting class III 1/3 octave filters per ANSI S1.11 and cover the center frequencies from 200 Hz to 10 000 Hz.

3.2.3 Six (6) microphones with preamps and extension cables.

3.2.4 Transducer(s) capable of measuring sound intensity in the frequency range of 200 Hz to 10 000 Hz 1/3 octave band center frequencies.

3.2.5 Sound intensity transducer calibrator.

3.2.6 Sound level calibrator accurate to ± 0.5 dB.

3.2.7 Random noise signal generator.

3.2.8 Four (4) speakers (six required for larger vehicles). Speakers shall be able to deliver at least 90 dB in the 1/3 octave bands from 200 Hz to 10 000 Hz.

3.2.9 Graphic equalizer with minimum 24 dB dynamic range capable of sending uncorrelated noise to four/six speakers.

3.2.10 Power amplifier with minimum 75 watts/channel, meeting SAE J184.

3.2.11 Miscellaneous equipment including but not limited to: appropriate cables, microphone stands, sound barrier assembly, adhesive substances (duct tape, noise patch, perma gum), and an instrument to locate leaks.

3.3 Test Vehicle/Test Piece. Vehicle fully equipped with acoustic package. The vehicle shall be qualified to ensure that it represents design intent content. Any deviations shall either be corrected or otherwise noted on the test description sheet.

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3.4 Test Time.

Calendar time:	6 days
Test hours:	40 hours
Coordination hours:	1 to 2 hours

3.5 Test Required Information.

 Not applicable.

3.6 Personnel/Skills. To complete this test, at least one technician and/or one engineer skilled in noise data acquisition, analysis, equipment use, and test setup is required.

Actual data acquisition is made easier if one person operates the analyzer while another measures the intensity.

4 Procedure

The STL of the vehicle exterior panel will be computed using the Sound Pressure Level (L_P) measured at the six locations inside the vehicle and the transmitted Sound Intensity Level (L_I) on the vehicle's exterior panel. Calculations will be performed using this data to compute the STL as described in the appendices.

4.1 Preparation.

4.1.1 Vehicle Preparation. All of the windows, sunroof, and sunshade must be closed. The engine, climate control system, and radio must be turned off.

All free standing seats shall be removed from the vehicle. For built in seats, such as the rear bench seat of a sedan, cover with sound barrier to achieve a more reflective surface.

In order to create a more reverberant space, turn the floor mats upside down and cover any absorptive surfaces with acoustically reflective material, i.e., rubber, sound barrier, plywood, etc.

Treat all vehicle panels, other than the test panel, with sound barrier assembly material to eliminate any flanking. This includes hanging sound barrier assembly material from the vehicle's rockers to the floor of the car test room. Make sure edges around the panel under test are sealed (treated with tape and mass to avoid flanking paths).

4.1.2 Equipment Installation. Place the speakers in the four corners of the vehicle angled to face the center of the passenger compartment. For a large vehicle, such as an SUV or a vehicle without a rear window trim panel, additional speakers shall be placed in the center of the passenger compartment.

For each vehicle panel tested, the speakers may need to be moved to ensure that sound is evenly

distributed in the vehicle and to each of the microphones. Ensure that the speakers are at least 1.2 m from any potential microphone location. At no time should the speakers be pointed directly into any microphone, and avoid having a speaker in the near field of the vehicle panel being measured.

Six microphones are used for this test. They should be randomly distributed inside the vehicle over the area of the vehicle panel being tested, approximately 15 cm off the surface of the panel.

4.2 Conditions.

4.2.1 Environmental Conditions. The test shall be performed in a hemi anechoic test cell with an ambient temperature between 18 °C and 29 °C and not varying more than 6 °C. The vehicle shall soak in such an ambient environment 12 h prior to testing.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

The speaker and microphone locations shall be optimized such that the interior field is as diffuse as possible in the 1/3 octave frequencies from 200 Hz to 10 000 Hz.

4.3 Instructions.

4.3.1 Transducer Calibration. Verify the calibration of the microphones and intensity transducer per GMW14172.

4.3.2 Data Acquisition Setup. Microphone and intensity data shall be acquired with appropriate signal processing such that the end result is 1/3 octave band data for the frequency range of 200 Hz to 10 000 Hz. The microphone and intensity data shall have the same final weighting.

4.3.3 Prepare Test Panel. A window on the vehicle of a known thickness will be used as the test panel to validate the accuracy of the measurement and to develop correction factors to be applied to the data acquired on the test specimens. The thickness and type of the window glass must be known in order to compare the test result to the SEA model prediction.

4.3.4 Adjust Source Noise Levels. Activate the noise generator and adjust the equalizer and amplifiers such that the L_P is at least 90 dB in the 1/3 octave bands from 200 Hz to 10 000 Hz. The L_P measured at the six microphone positions should ideally be within 10 dB of each other. Adjust the speakers and microphone locations to achieve a uniform L_P .

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4.3.5 Data Acquisition.

4.3.5.1 Acquire Interior Microphone L_p . With the noise source on, acquire the interior sound pressure levels. Do not turn off the noise source and proceed to the intensity measurement.

4.3.5.2 Acquire Intensity L_i . Define the scan plane to be a relatively flat (approximately parallel to the panel) hypothetical surface, usually at a perpendicular distance of 0.05 m to 0.1 m from the panel to the center of probe microphones. Make sure the scan surface is far enough from the panel so it is not obstructed by door handles, under floor rails, etc.

Determine whether the entire test specimen will be measured at one time or if the test specimen will be measured in sections. Specimen approximately 0.5 m by 0.5 m or smaller is to be measured as one section. Larger specimens may be broken down into multiple sections; the non-measurement sections shall be treated with a substantial sound barrier assembly to minimize the effect of flanking from those sections on the measurement section.

Scan the exterior panel using a scan pattern as shown in Appendix B. The scan rate should be approximately 0.1 m/s to 0.3 m/s.

4.3.6 Pressure Intensity (PI) Index. This check is used to determine the effective "sound intensity noise floor" of the measurement. To check the accuracy of the sound intensity measurement, calculate the PI index for the measurement and compare it to the PI_{residual} , calculated during calibration. Use the equation in Appendix A to verify the measurement is accurate to within 1 dB.

If the PI Index criteria are not met check for problems with flanking, equipment, and source levels, then repeat the measurement.

4.3.7 Repeatability Check. Measure the STL and check for repeatability. The repeatability shall be within 1 dB.

4.3.8 Measure Exterior Panels. Adjust microphone, speaker, and sound barrier locations to prepare the next exterior panel to be tested. Repeat 4.3.4 (if necessary) and complete sections 4.3.5 through 4.3.7. Symmetry shall be assumed and only one side of the vehicle is required to be measured.

5 Data

5.1 Calculations.

5.1.1 Average Source Data. Calculate the average sound pressure level of all source microphone data. See first equation in Appendix C.

5.1.2 Calculate Sound Transmission Loss.

Calculate the sound transmission loss of the exterior panel using the averaged sound pressure level data from the source microphones and the corresponding intensity data. See 7.1 and Appendix C for equations used in the calculation of the specimen STL and the application of a correction factor from the Test Panel STL results, if necessary.

STL results shall be rounded to the nearest whole decibel.

5.2 Interpretation of Results. Verify whether Subsystem Technical Specification (SSTS) requirements are achieved, when appropriate.

5.3 Test Documentation. The STL results shall be stored in 1/3 octave bands from 400 Hz to 10 000 Hz.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Notes

7.1 Glossary.

Pressure Intensity (PI) Index: The PI index is the difference between the space-averaged sound pressure level and the normal unsigned sound intensity level when the intensity probe is placed and oriented in a sound field, expressed in decibels.

Pressure Residual Intensity (PI_{residual}) Index: The PI_{residual} is the difference between the sound pressure level and the normal sound intensity level when the intensity probe is placed and oriented in a sound field where the sound intensity is zero, expressed in decibels.

Sound Intensity Level (L_i): The time averaged rate of flow of sound energy through a unit area which is normal to the direction of propagation. Ten times the common logarithm of the average normal intensity divided by reference intensity, expressed in decibels.

$$L_i = 10 \log_{10} \left(\frac{I}{I_{\text{ref}}} \right); \text{ Where } I_{\text{ref}} = 10^{-12} \text{ W/m}^2$$

Sound Pressure Level (L_p): Ten (10) times the common logarithm of the acoustic mean squared

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