



Transmission Level Allocable Test (TLAT)

1 Introduction

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. The purpose of the Transmission Level Allocable Test (TLAT) is to measure the transmission portion of powertrain noise and vibration emissions as measured by the Powertrain Level Allocable Test (PLAT) procedures GMW14008 and GMW14238. The measurements are used to assess conformance to requirements for transmission noise and vibration.

1.2 Applicability. All Battery Electric Vehicle (BEV) drive units, and hybrid, manual, and automatic transmissions.

1.3 Remarks. The noise and vibration emissions are measured at PLAT operating conditions, as they pertain to the transmission. They are measured in terms of radiated sound power and vibration acceleration at the transmission mount bracket locations. The TLAT is to be consistent with the PLAT so that sound and vibration data can be compared between the two. In addition to the PLAT operating conditions, additional tests are included to emphasize the rotating components of the transmission.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14008 GMW14238

2.3 Additional References.

- GM Sound Power Procedure spreadsheet. Contact the Lead Noise and Vibration (N&V) Engineer for details.
- Greenwood, D.D., "Critical Bandwidth and the Frequency Coordinates of the Basilar Membrane", Journal of the Acoustical Society of America, Volume 33, Number 10, 1961, pages 1344 to 1356.
- Siemens LMS Test.Lab, available at www.plm.automation.siemens.com/en_us/products/lms/testing/test-lab/desktop.
- Siemens LMS Test.Lab Template Settings workbook. Contact the Lead N&V Engineer for details.
- TLAT Load Calculator workbook. Contact the Lead N&V Engineer for details.

3 Resources

3.1 Facilities. Tests are to be performed in a transmission dynamometer facility with a hemi-anechoic measuring environment, and with ambient sound and vibration levels that do not influence the sound and vibration measurements of the transmission. The ambient sound level of the room, with operating dynamometer and air/fluid handling systems, should be at least 5 dB less than that of the test object in each 1/3 Octave band from 50 Hz to 200 Hz, and at least 10 dB less than for each band from 250 Hz to 10 000 Hz, at all microphone locations. The reflectivity and size of the room must be adequate to allow far-field sound pressure measurements greater than 200 Hz, at a distance of 1 m from the transmission.

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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.

3.1.3 Additional Details for Electrified Drive Units. The appropriate electronics, power supply and control system hardware and software are required for operation of any active traction motor testing.

3.2 Equipment.

3.2.1 Microphones. Pressure response microphones with associated signal conditioning and mounting stands are required to measure sound power. Sensitivity and frequency response of the transducer must be suitable for test transmission sound pressure measurements from 20 Hz to 12.8 kHz. Noise due to hybrid power electronics may require flat microphone response out to 16 kHz, to be specified by test engineer.

3.2.2 Accelerometer(s). Triaxial accelerometers should be used to quantify mount boss vibration and shifter cable bracket vibration. Also, a single-axis accelerometer should be located at the manufacturing end-of-line test measurement location. Sensitivity and frequency response of the transducer must be suitable for acceleration measurements from 3 Hz to 6400 Hz.

3.2.2.1 Additional Details for Electrified Drive Units. Accelerometers are required to be electrically isolated from the Drive Unit (DU).

3.2.3 Tachometer. Dynamometer speed sensors are adequate.

3.2.3.1 Derived Tachometers (optional). To improve data reduction it is recommended to implement a calculated or 'derived' tachometer that represents the rotation of various components when their rotation is a function of more than one (1) measureable tachometer. For example, this occurs in electrically variable Continuously Variable Transmission (CVT)-like mode of some hybrids. A traction motor's speed is definable by the linear sum of output speed and input speed. The exact formula for these calculated tachometers is a product of the specifics of a given powerflow and not definable here.

3.2.4 Pressure Transducer. With a gauge range of 3500 kPa (or higher, if needed).

3.2.5 Laser Vibrometer. Not part of standard TLAT, but this may be needed for development testing for Front Wheel Drive (FWD) final drive axle noise.

3.2.6 Thermocouple. One (1) K-type is required for transmission oil sump temperature.

3.2.7 Wingplate Mounting. Use GM 4008 (or approved equivalent) headstand to mount transmission to dynamometer.

3.3 Test Vehicle/Test Piece.

3.3.1 Transmission Identification. Serial number, name of transmission, bell housing interface and output shaft type must be specified.

3.3.2 Transmission Ratios. Ratios such as gear ratios, final drive ratio, chain ratio and differential ratio must be specified. For hybrids, motor speed to output speed ratios are needed. For CVT, pulley ratios are needed.

3.3.3 Transmission Fluid Type/Setting. Fluid type and fluid setting procedure must be provided.

3.3.4 Driveshaft Identification and Orientation. Driveshaft should be installed and oriented as it is in the vehicle, if dynamometer has vehicle capability. A zero-angle driveshaft installation may be acceptable to avoid special dynamometer arrangements.

3.4 Test Time.

Calendar time: 3 days

Test time: 16 hours

Coordination time: 8 hours

3.5 Test Required Information. Specific transmission model and build level.

3.6 Personnel/Skills. Minimum of one (1) person is required to perform this test. Each person should be trained in dynamometer operation, transmission installation, equipment calibration, test setup (transducer placement, etc.), data recording and analysis. Some knowledge of signal processing is required. The personnel should also

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be able to use graphics software on the PC, LMS data acquisition (i.e., Siemens LMS Test.Lab) and analysis software.

4 Procedure

4.1 Preparation.

4.1.1 Data Acquisition System (DAS). A data acquisition system appropriate for noise and vibration measurements should be used, such as Siemens LMS Test.Lab. Refer to Appendix B, B1 and B2 for channel assignments, and data acquisition/processing parameters.

4.1.2 Instrumentation Locations.

4.1.2.1 Accelerometers. Accelerometers should be mounted using super glue or equivalent epoxy medium, and should be electrically isolated from the transmission, e.g., a thin layer of paper towel can be used to break the ground connection. Allow sufficient cure time per the adhesive instructions to ensure a robust attachment. Ensure that no undue errors are introduced by the electrical isolation material and the attachment material. See Appendix A, A4. Guidelines for accelerometer placement are specified in Appendix A, A2.1 and Figure A1.

4.1.2.2 Microphones. Guidelines for microphone placement are specified in Appendix A, A2.2 and Figures A2 thru A5.

4.1.2.3 Pressure Transducers. Install transducer at the line pressure tap (if available) for all automatic transmissions.

4.1.2.4 Thermocouple. Install the thermocouple in a location that monitors fluid sump temperature.

4.1.2.5 Translational Laser Orientation. See Appendix A, A2.8 and Figure A6 for proper orientation of laser (FWD only).

4.2 Conditions.

4.2.1 Environmental Conditions. Test facility should have ambient temperatures between 18 °C and 30 °C (64.4 °F and 86 °F).

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.

4.2.2.1 A test matrix containing gear states (automatic and manual transmissions), ratios (mechanical CVT transmissions), mode states (electrical CVT states), speeds, loads, pressures, sweep time and torque converter state (as applicable) will be provided by the GM test engineer.

The GM test engineer should use the TLAT Load Calculator workbook to generate the test matrix.

4.3 Instructions. Refer to Appendix A content for test setup and Appendix B content for operating conditions.

5 Data

5.1 Calculations.

5.1.1 Sound and Vibration Calculations.

5.1.1.1 Sound Power. Sound power data is calculated from the individual sound pressure measurements in the microphone array to produce A-weighted sound power level in decibels re 10⁻¹² W.

The sound power calculation is to be determined by the GM Test Engineer, using the GM Sound Power Procedure spreadsheet. The microphone data is averaged on an energy basis. The general near-field sound power formula is shown immediately following.

$$L_w = 0.29dB + 10 \log_{10} \sum_{i=1}^M \left[\left(\frac{1}{P_o^2 \cdot N_{mics}} \sum_{j=1}^{N_{mics}} P_{j-rms}^2 \right) \times \frac{A_i}{A_o} \times w_i^2 \right]$$

Where:

- L_w = Sound Power Level; dB re 1 pW ("re" = sound power level reference of 1 pW).
- i = 1 to M: Number of transmission radiating surfaces.
- j = 1 to N: Number of microphones on face "i".

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- P_o = Sound pressure reference value (i.e., $2e^{-5}$ Pa).
 P_{j-rms} = Root Mean Square (rms) sound pressure for microphone j (Pa).
 A_i = Area of transmission surface "i" (m^2).
 A_o = Reference area; $1 m^2$.
 w_i = Ratio of average Power Based Noise Reduction (PBNR) to individual face PBNR "i":
 $(w/Pa^2)_{avg}/(w/Pa^2)_i$.

Note: PBNR is the transmission to driver's seat function.

If the PBNR for each face is not available or the PBNR weighting factors result in a deviation of less than 1 dB on the sound power, the equation can be simplified to the following:

$$L_w = L_{pNF} + 10 \log_{10} \left(\frac{A_{ts}}{A_o} \right) + 0.29 \text{ dB}$$

Where:

- L_w = Sound Power Level; dB re 1 pW.
 L_{pNF} = rms Near-field Sound Pressure Level; dB re $20e^{-6}$ Pa rms, "Power average" (rms) of microphones spread over the transmission surface.
 A_{ts} = Area of Transmission Surface (m^2).

For reference, the implementation of this formula in Siemens LMS Test.Lab including the PBNR area weighting factors ("w" in formula) are as follows:

$$(0.0026726 * (w1^2 * A1 * POWAVG(CH1:CH7) + w2^2 * A2 * POWAVG(CH13:CH20) + w3^2 * A3 * POWAVG(CH8:CH12) + w4^2 * A4 * POWAVG(CH21:CH25) + w5^2 * A5 * POWAVG(CH26:CH30))) [w]$$

Where:

- CH1 thru CHn = The sound pressure from each microphone measured in Pa.
 $A1$ thru $A5$ = The areas of each sound power face in m^2 . If area weighting is not significant for the application, set to 1 for average face weighting.
 $w1$ thru $w5$ = The ratios of each PBNR face to interior in linear units i.e., $(w/Pa^2)_{avg}/(w/Pa^2)_{individual}$.
Note: If individual face PBNRs are not available, set to 1 for average PBNR.
 $[w]$ = The units marker used to change the units to Watts (W) in Siemens LMS Test.Lab, so the correct reference ($1e^{-12}$) is used when plotting decibels (dB). Ensure that the unit $[w]$ is defined in the Siemens LMS Test.Lab units editor.

5.1.1.2 Mount Vibration. Mount Vibration **data** is processed to produce vibration acceleration amplitude in meter per second squared (m/s^2) rms for each acceleration measurement. The data from each location and direction is also combined to produce a "weighted sum" of vibration. The weighted sum is calculated as follows:

$$X(f) = \sqrt{\sum_{i=1}^n w_i^2(f) \times x_i^2(f)}$$

Where:

- $X(f)$ = Weighted sum of vibration at n directions and locations [m/s^2 rms].
 $x_i(f)$ = rms acceleration at location and direction i [m/s^2].
 $w_i(f)$ = Weighting factor for location and direction i .
 n = Total number of locations and directions = (number of transmission mounts) $\times$ 3.

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- i = Vibration location and direction index, 1 thru n .
 f = Frequency in Hertz (Hz), " f " indicates a function of frequency.

Weighting factors, $w_i(f)$, are based on acoustic sensitivities of the vehicle application, and are to be provided by the test requestor. If no sensitivities are provided, they are to be set to a value of 1.0 for each $w_i(f)$, referred to as "uniform weighting" of the vehicle structure-borne noise paths.

5.1.1.2.1 Weighting factors, if any, should be provided by the test requestor.

5.1.2 Data Processing. Data is processed to produce frequency spectra, order cuts and 1/3 Octave steady-state spectra.

For steady-state operating conditions, spectral averaging is to be set to achieve average data for a minimum signal time of 20 s. For Fast Fourier Transform (FFT) spectral averaging, overlap processing should be used if possible, using an overlap value of 66.67% in order to achieve uniform time domain weighting of signals. The number of spectral averages can be calculated from the following formula:

$$\#avg = \frac{(\Delta f \cdot TotalTime) - overlap}{1 - overlap}$$

Where:

- $\#avg$ = Number of spectral averages.
 Δf = FFT frequency line resolution (Hz).
 $TotalTime$ = Total signal time (seconds (s)).
 $Overlap$ = Overlap fraction. For example: use 0.6667 for 66.67% overlap.

5.1.2.1 Data Processing Specifics. Following, are listed specific types of data processing for steady-state and sweep data.

5.1.2.1.1 Steady-State Sound Power.

5.1.2.1.1.1 Calculate 1/3 Octave bandwidth spectra, 250 Hz to 10 000 Hz bands, A-weighted.

5.1.2.1.2 Sweep Data.

5.1.2.1.2.1 Narrowband autospectra should be calculated using the acquisition and processing parameters listed in Appendix B, B2.

5.1.2.1.2.2 Calculate rms amplitude of rotating component orders and harmonics, vs. rpm (A-weighted for sound data). The orders are chosen based on rotating components of interest, and a color map or waterfall of sound power order spectra is to be generated.

5.1.2.1.2.2.1 Order Bandwidth. To capture the order and sidebands generated by a component, two (2) methods can be applied for estimating the order bandwidth. The first method involves compiling an order summation for a given sweep and identifying a point 10 dB less than the peak closest to the center frequency of the order of interest. The second method is based on studies on pure tones and critical bandwidths (see Greenwood reference in 2.3). The order bandwidth should not exceed 17% of the order.

5.2 Interpretation of Results. Not applicable.

5.3 Test Documentation.

5.3.1 Steady-State Sound Power. Display results on a 1/3 Octave plot as shown in the example in Appendix C, Figure C1.

5.3.2 Sweep Data.

5.3.2.1 Sound Power Colormap. Display sound power results in a colormap form with the x-axis as frequency, the y-axis as either input or output speed, and the (color) z-axis as Sound Power Level, as shown in Appendix C, Figure C2.

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5.3.2.2 Mount Vibration Colormap. Display mount vibration results in a colormap form with the x-axis as frequency, the y-axis as either input or output speed, and the (color) z-axis axis as weighted sum of vibration in decibels, as shown in Appendix C, Figure C3.

5.3.2.3 Sound Power Order Spectrum. Display sound power order spectral results in a FrontBack display form with the x-axis as either input or output speed, and the y axis as Sound Power Order spectral level, as shown in Appendix C, Figure C4.

5.3.2.4 Mount Vibration Order Spectrum. Display mount vibration results in a FrontBack display form with the x-axis as either input or output speed, and the y axis as weighted sum of vibration order cut in decibels, as shown in Appendix C, Figure C5.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

7 Notes

7.1 Glossary.

0-pk: Zero (0) to peak amplitude of a wave form.

1/3 Octave: Constant percentage frequency band-widths of width equal to 1/3 of doubling in frequency on a logarithmic scale.

Free-field: That portion/condition of a sound field that is far-field, and without sound from locations other than the location of a specified source. Usually referring to an absence of reflections.

Free-field Microphone: A microphone that has a uniform frequency response to a free-field pressure field at 0 degree angle of incidence.

Fundamental Order: Order equal to the first harmonic.

Mode/Electronically Variable Transmission (EVT) State: Hybrid Electric Vehicle (HEV) operating state with an infinitely variable input and output speed ratio, made possible through the use of electric motors.

Narrowband: Frequency bands associated with narrow bandwidths that result from Fast Fourier Transform (FFT) frequency analysis.

Near-field: The region with distance less than or equal to the wavelength of the lowest frequency emitted by the source, or at less than or equal to twice the greatest dimension of the source. In this procedure Near-field distance is 10 cm.

Order: Number of occurrences per revolution, relative to a specific rotating component.

Overall Level: Root mean square (rms) level associated with a very broad (large) frequency range.

Power Based Noise Reduction (PBNR): A transfer function of source sound power divided by receiver sound pressure. See GMW14174 for more information.

Powertrain: Engine, Transmission, Accessory Drive System.

Pressure Microphone: A microphone that has a uniform frequency response to a diffuse pressure field.

X, Y, Z: Powertrain coordinate system directions for mount vibration measurements; defined as fore-aft, lateral, and vertical, respectively. See Appendix A, Figure A1.

7.2 Acronyms, Abbreviations, and Symbols.

#	number
Δ	Delta
AFM	Active Fuel Management
BEV	Battery Electric Vehicle
CVT	Continuously Variable Transmission

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DAS	Data Acquisition System
dB	decibel(s)
DCT	Dual-clutch Transmission
deg	degrees
DFSS	Design for Six Sigma
DU	Drive Unit
EV	Electric Vehicle (or a state with all electrically supplied propulsion (engine off))
EVT	Electronically Variable Transmission
FFT	Fast Fourier Transform
FWD	Front Wheel Drive
HEV	Hybrid Electric Vehicle
Hz	Hertz
N&V	Noise and Vibration
Nm	Newton meter(s)
NVH	Noise, Vibration and Harshness
Pa	Pascal(s)
PLAT	Powertrain Level Allocable Test
PNBR	Power Based Noise Reduction
rms	root mean square
RWD	Rear Wheel Drive
s	second(s)
TCC	Torque Converter Clutch
TLAT	Transmission Level Allocable Test
w	weighting factor
W	Watt(s)

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW14619

9 Release and Revisions

This standard was originated in October 2005. It was first approved by the Global N&V Powertrain Harmonization Team in December 2006. It was first published in February 2007.

Issue	Publication Date	Description (Organization)
1	FEB 2007	Initial publication.
2	NOV 2015	Revised to current template. (GM Powertrain Global NVH)
3	MAR 2016	Previous Approved and Published version had incorrect Figure A5. Selected "NVH" instances revised to "N&V". (GM Propulsion Systems Global NVH)
4	FEB 2017	Included further provisions for hybrids. Included the rattle test procedure. Included mount boss location appendix. Included example error from accelerometer mounting. (Global N&V - GM Propulsion Systems Global NVH)

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Appendix A: Instrumentation Placement and Test Preparation

A1 Test Facility

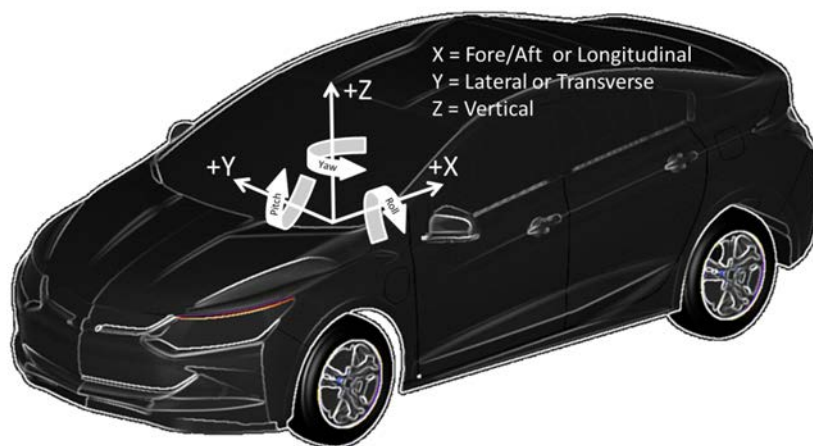
A1.1 Hemi-Anechoic Transmission Dynamometer.

A2 Transducer Locations

A2.1 Accelerometers.

A2.1.1 Triaxial accelerometers are placed at all transmission mount locations and at the shifter cable bracket boss location (This assumes a mechanical linkage exists for the shifter cable, otherwise this location can be ignored). If there is more than one (1) shifter cable bracket boss, use the boss farthest from the manual shaft. A single-axis accelerometer should also be placed at the manufacturing end-of-line test measurement location. Use coordinate system as shown in Figure A1. If a specific mount boss vibration study is requested by the Noise and Vibration Center, see Appendix D for additional locations.

Figure A1: Powertrain Coordinate System



A2.2 Near-Field Microphones. An array of microphones should be placed 10 cm from the surface of the transmission, as follows:

- Measure distance from nearest surface, normal to the surface ("as the crow flies").
- Treat outer edge of closely spaced rib patterns as the surface, ignore "small" features.

A2.2.1 Rear Wheel Drive (RWD) (Longitudinal) Transmission Microphone Array.

- Nine (9) microphones: Three (3) on the left, three (3) on top and three (3) on the right. Placement is shown in Figure A2.
- Exception, if bell housing length (dimension a in Figure A2) is less than $\frac{1}{4}$ of barrel length b then space all microphones at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ of the overall length ($a + b$) from the bell housing interface to engine.

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