Vehicle Level Powertrain/Driveline Noise and Vibration Evaluation Procedure for Manual Transmission

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 this procedure is to measure vehicle powertrain and driveline noise and vibration (N&V) during idle, drive-away and cruising operating conditions on manual transmission vehicles. The data acquired is used to assess the performance of GM and competitive vehicles, establish N&V requirements and validate to those requirements.

1.2 Applicability. This procedure is appropriate for use with passenger cars, multi-purpose passenger vehicles, minibuses, and light commercial vehicles with a maximum authorized total weight of 3500 kg. It is applicable to hybrid and conventional transmissions that require manual operation to change ratio.

1.3 Remarks. This procedure is also known as the Vehicle Level Allocatable Test (VLAT).

2 References

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

2.1 External Standards/Specifications.

IEC 651	ISO 2631	ISO 5349

2.2 GM Standards/Specifications.

GMW14218	GMW16206 (ID)

(ID) = This standard is limited to internal distribution within General Motors and shall not be distributed outside this company. Contact the GM Lead Engineer for further instructions.

2.3 Additional References.

- Determining Road Load Parameters for Different Vehicles (Bosch Automotive Handbook, Current Edition)
- Information including technical references and standard test setup files are included on the VLAT SharePoint site: https://gmweb.gm.com/engineering/GNVC/Pages/VLATReference.aspx

  Note: The supplier shall work with the GM Design Release Engineer to comprehend this requirement.
- Siemens Leuven Measurement Systems (LMS) software support at: www.plm.automation.siemens.com/en_us/products/lms/testing/test-lab
- Vehicle Spy (Vspy) Professional software support at: http://www.intrepidcs.com/VehicleSpy
- Vehicle Technical Specification (VTS)

3 Resources

3.1 Facilities. The tests shall be performed in the designated testing environment at each GM regional site. The environment specified in the VTS must be used for validation purposes. The test shall be performed in an anechoic environment, with a hard, flat floor surface. The ambient background noise level must be a minimum of 15 dB less than the signal being measured. The ambient temperature shall be between 18 °C and 25 °C. The test facility for the rolling tests shall be a semi-anechoic chassis dynamometer capable of speed control, load control and road load simulation (RLS) up to 160 km/h (100 mph) and 6600 N tractive effort.

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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.

3.2 Equipment. Required equipment types and specifications are provided in the following sections.

3.2.1 Tachometers. Driveline tachometer (propshaft or axle shaft) and engine tachometers are required. Output must be compatible with data acquisition system (DAS) input requirements. Angular resolution of one or more pulses per revolution is required except for 3-cylinder engines. For 3-cylinder engines, a tachometer that has an angular resolution equal to 1.5 pulse/revolution is needed. For GM vehicles, this can be accomplished using a 58x tachometer with a virtual tachometer setup in LMS (see Appendix H, Figures H1 for setup) or the high-speed Controller Area Network (CAN) engine speed. If 58x tachometer or high-speed CAN is not available, the tachometer will need to be smoothed before processing data (see Appendix H, Figure H2 for setup).

3.2.2 Microphones. Random incidence microphones are preferred for vehicle interior locations. Free-field microphones may be used for interior locations if random incidence microphones are not available. Free-field microphones are preferred for the exterior exhaust tailpipe location. Pressure microphones may be used at the tailpipe location if free-field microphones are not available. All devices shall meet class 1 accuracy corresponding to IEC 651 or be equivalent for the application (precision ± 0.7 dB or ± 8%).

3.2.3 Accelerometers. High sensitivity accelerometers with a flat frequency response between 2 Hz and 2 kHz and a temperature range of 10 °C to 50 °C or greater shall be used.

3.2.4 Data Acquisition Equipment. The preferred digital DAS is a personal computer running LMS Test.Lab software connected to an LMS Scadas III front end, or equivalent as approved by the Global Noise and Vibration Center (GNVC) Infrastructure Team. This setup allows simultaneous digital recording of time domain data and online or post-processing of frequency and order domain data.

3.2.5 Acoustic Roll Covers. Chassis dynamometer shall be equipped with acoustic roll covers to minimize tire noise (see Appendix E, Figures E1 thru E4).

3.3 Test Vehicle/Test Piece. The tests shall be performed on a production vehicle or development vehicle which represents the current release status. Any unwanted content or problems shall be eliminated prior to test.

3.4 Test Time.

Calendar time:	2 d
Test time:	12 h
Coordination time:	4 h

3.5 Test Required Information. Vehicle information as required in 4.1.1.1.

3.6 Personnel/Skills. One qualified engineer or technician trained in the use of data acquisition equipment and having basic knowledge of acoustic and vibration signal processing. One unqualified chassis dynamometer operator. Dynamometer operation may be conducted by test engineer or technician if approved by local management.

4 Procedure

4.1 Preparation.

4.1.1 Vehicle Preparation.

4.1.1.1 Documentation. Fill out the Global Pretest Road Data Sheet provided in Appendix A, Data Sheet A1. Verify and note within the documentation tab of the LMS Test.Lab project the status of all hardware relative to the current release status.

4.1.1.2 Static Preparation. Verify/accomplish that vehicle meets the requirements stated in 3.3. Verify/accomplish that the tires are inflated to the nominal (cold) pressure as specified by the vehicle manufacturer. Refill the fuel tank if it is < 75% full.

4.1.1.3 Vehicle Mass. Proceed to vehicle scale to determine vehicle test weight. Do not include driver or any additional instrumentation when measuring test weight. Record vehicle weight (in kilograms (kg)) and add 70 kg (150 lb) on Global Pretest Road Data Sheet (see Appendix A, Data Sheet A1).

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4.1.1.4 Road Test. A road test must be conducted to ensure proper operation of the vehicle and to determine the vehicle operating parameters that will be used to control the chassis dynamometer. Proceed to a test track with smooth level road surface, with sufficient straightaway length to safely accomplish the road tests included in the following sections. Drive the vehicle to check for proper operation of the engine and transmission and ensure that the vehicle is free from squeaks, rattles and extraneous noises. Eliminate all extraneous noises prior to testing.

4.1.1.4.1 Speedometer Verification. Verify speedometer accuracy using a global positioning system (GPS) navigation device.

4.1.1.4.2 Off-Brake Speed Determination. With gear selector in lowest gear position, release the clutch and allow vehicle to accelerate from rest. With zero throttle pedal application, allow the vehicle to stabilize at a constant speed. Record the indicated speed as the "Off Brake" vehicle speed on the Global Pretest Road Sheet (see Appendix A, Data Sheet A1).

4.1.1.4.3 Coast-Down Measurements for RLS Coefficient Determination.

Measurements may be performed using a stopwatch or data recording software through the Assembly Line Diagnostic Link (ALDL) connector.

Note: The following warm-up step is critical to establish consistent vehicle frictional losses during coast down. Drive vehicle under load for a minimum of 20 minutes to establish normal operating temperature.

Perform the following coast down tests to determine the road load coefficients for dynamometer simulation:

1. Operate the vehicle on a dry straight smooth road with zero grade.
2. Establish a cruising speed of approximately 112 km/h (70 mph).
3. Shift into Neutral and allow the vehicle to coast down.
4. Measure and record, to ± 0.1 s, the time required to coast from 105 km/h to 97 km/h (65 mph to 60 mph).
5. Enter the result on the Global Pretest Road Sheet (see **Appendix A, Data Sheet A1**).
6. Next, operate the vehicle at a cruising speed of approximately 32 km/h (20 mph).
7. Shift into Neutral and allow the vehicle to coast down.
8. Measure and record, to ± 0.1 s, the time required to coast from 24 km/h to 16 km/h (15 mph to 10 mph).
9. Enter the result on the Global Pretest Road Sheet (see **Appendix A, Data Sheet A1**).
10. Repeat process as necessary to obtain reliable data.

Note: To compensate for directional wind resistance effects and variation, conduct a minimum of two coast downs in each direction of a two-way straightaway track, then average the individual results to obtain coast down times for calculation. Repeat process as necessary to obtain consistent and reliable data.

4.1.1.4.4 Full Pedal Passing Gear Determination. Passing gear is determined by the highest gear that is able to achieve redline without exceeding 140 km/h (87 mph). This can be calculated on road or through the use of the gear ratios for the vehicle. For passing gear, determine the road speed and engine speed for fuel cut-off and record on Global Pretest Road Sheet (see Appendix A, Data Sheet A1). This engine speed minus 200 Engine Revolutions per Minute (eRPM) will be for the full pedal drive away test maximum speed. Record Lowest full pedal speed in each passing gear on Global Pretest Road Sheet (see Appendix A, Data Sheet A1).

4.1.1.4.5 Determination of Vehicle Speed at 2500 eRPM. Determine the 2500 eRPM vehicle speed and load as follows:

a. Drive the vehicle at a constant speed while the transmission is in 1st gear and the indicated engine speed is as close as possible to 2500 eRPM.
b. At this steady state operating condition, record the indicated engine speed and indicated vehicle speed in the Global Pretest Road Sheet (see Appendix A, Data Sheet A1).

Note: If the indicated engine speed for the previous step was not exactly 2500 eRPM, use the measured engine speed/vehicle speed ratio to calculate the corresponding vehicle speed at 2500 eRPM.

4.1.1.4.6 Determination of Vehicle Speed at 1500 eRPM (Diesel Engines Only). For Diesels only, determine the 1500 eRPM vehicle speed and load as follows:

a. Drive the vehicle at a constant speed while the transmission is in 1st gear and the indicated engine speed is as close as possible to 1500 eRPM.

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b. At this steady state operating condition, record the indicated engine speed and indicated vehicle speed in the Global Pretest Road Sheet (see Appendix A, Data Sheet A1).

Note: If the indicated engine speed for the previous step was not exactly 1500 eRPM, use the measured engine speed/vehicle speed ratio to calculate the corresponding vehicle speed at 1500 eRPM.

4.1.1.4.7 RLS Coefficient Calculation. Enter coast-down times and vehicle mass into the Pre Vehicle Level Allocatable Test (PreLAT) calculator tool. Contact the Global VLAT lead for this calculator or visit the VLAT SharePoint Site (see 2.3). The tool will calculate the road load coefficients based on the information provided. If the PreLAT calculator tool is not available, compute the road load simulation coefficients manually using the Bosch RLS estimation equation provided in Appendix C.

The PreLAT calculator tool and the Bosch RLS equation produce estimates of the RLS coefficients based on coast down data and vehicle mass. If more accurate RLS coefficients are available from other sources, then these coefficients may be used instead of the coefficients estimated from the road test coast down in this procedure. Other RLS coefficient sources include, but not limited to, the Energy Test Database on the GM intranet, and the US Government Environmental Protection Agency (EPA) website.

4.1.2 Vehicle Preparation on Chassis Dynamometer. Allow the vehicle to adjust to test laboratory ambient temperature. Attach vehicle to chassis dynamometer rolls. If lateral body tie-downs are used ensure all tie downs do not induce rattles in the vehicle. Ensure that wheel chocks do not contact the body. Ensure that the vehicle rolls freely, with tires aligned with chassis rolls.

4.1.2.1 Set the exhaust collector and ventilation system to properly remove exhaust gases without affecting engine performance or microphone location. The exhaust removal system should be placed in line with the exhaust exit at a minimum of 0.3 m away from the tailpipe(s).

4.1.2.2 Connect instrumentation to remotely monitor engine coolant temperature, catalytic converter/exhaust temperature, and inlet air temperature.

4.1.2.3 Install thermocouple after the catalytic converter to monitor exhaust temperatures with channel in the dynamometer. Set a warning limit if temperature is above a certain level.

4.1.2.4 Install thermocouple at the intake as an inlet air temperature monitor with a channel in the dynamometer. Set a warning at 35 °C to ensure repeatability in measurements. This can also be done using VehicleSpy (see 2.3).

4.1.2.5 Install engine tachometer (tachometer channel name T1) and note the number of pulses per revolution for entry into the DAS.

4.1.2.5.1 For vehicles equipped with an exposed rear propshaft between transmission and rear axle, install propshaft tachometer (tachometer channel name T2) and enter the number of pulses per revolution into the DAS. For vehicles equipped with an enclosed rear propshaft, install tachometer on rear axle (tachometer channel name T2).

4.1.2.5.2 For all other vehicles, install a wheel (or drive axle) speed tachometer (tachometer channel name T2) and enter the number of pulses per revolution into the DAS. When a wheel or drive axle tachometer is used, multiple pulses per revolution are often necessary to improve tachometer accuracy at the start of the drive-away sweeps.

4.1.2.6 Install emergency engine shut-off lead. Check for proper operation. Close hood.

4.1.2.7 Set up an external cooling fan directed toward the engine cooling system. Raise all movable chassis dynamometer floors.

If required to maintain desired operating temperatures, install spot cooling hoses as required. Typical spot cooling locations include catalytic converter, muffler, intake air, and differential.

Note: Spot cooling is to be used to maintain temperatures in between test runs and must be shut off during data acquisition.

4.1.2.8 Install throttle controller. Throttle controller must be self-supporting on floor, and not contact seat, dashboard or steering wheel.

4.1.2.9 Turn off vehicle radio.

4.1.2.10 Turn off air conditioner. Set Heating, Ventilation and Air Conditioning (HVAC) fan speed to off. If off is not available, set to minimum speed available. Set HVAC position selector to floor only. Do not use combination or defrost switch settings which engage air conditioning compressor for dehumidification.

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4.1.2.11 Verify that parking brake is released.

4.1.2.12 Remove all camouflage for validation testing. Eliminate any unwanted content or problems (e.g., ground-outs). Check that the spare wheel is securely seated.

4.1.2.13 Position the seats and headrests per Appendix B, B1. If equipped with tilt/telescope steering, position the steering column in the center position of travel for both tilt and telescope. Make sure electronic key remote is not inside the vehicle or manually prevent the driver door from locking. Check that all windows, sliding roof and sun screen are fully closed.

4.1.3 DAS Preparation. Open data acquisition software capable of acquiring tracked orders of a tachometer (LMS Signature Testing Advanced or equivalent).

4.1.3.1 Channel Assignments. Use the following recommended channel assignments and naming conventions (see Appendix B, Figures B1 thru B8 for typical location photos):

1. LFRE_SPL (Left Front Right Ear Sound Pressure Level). For Right Hand Drive (RHD) vehicles, use RFLE_SPL (Right Front Left Ear Sound Pressure Level).
2. RR_SPL (Right Rear Sound Pressure Level). For RHD vehicles, use LR_SPL (Left Rear Sound Pressure Level).
3. ROW_3_SPL (3rd Row Center Seat Sound Pressure Level, applicable vehicles only).
4. 50_CM_EXH_SPL_L (50 cm Exhaust Sound Pressure Level – Left (if applicable)).
5. 50_CM_EXH_SPL_R (50 cm Exhaust Sound Pressure Level – Right (if applicable)).
6. FA_ST_WH_ACCEL_12 (Steering Wheel Fore/Aft Acceleration at 12:00).
7. LAT_ST_WH_ACCEL_12 (Steering Wheel Lateral Acceleration at 12:00).
8. VERT_ST_WH_ACCEL_12 (Steering Wheel Vertical Acceleration at 12:00).
9. FA_DFOST_ACCEL (Front Outboard Driver's Seat Track Fore/Aft Acceleration).
10. LAT_DFOST_ACCEL (Front Outboard Driver's Seat Track Lateral Acceleration).
11. VERT_DFOST_ACCEL (Front Outboard Driver's Seat Track Vertical Acceleration).
12. FA_DRIST_ACCEL (Rear Inboard Driver's Seat Track Fore/Aft Acceleration).
13. LAT_DRIST_ACCEL (Rear Inboard Driver's Seat Track Lateral Acceleration).
14. VERT_DRIST_ACCEL (Rear Inboard Driver's Seat Track Vertical Acceleration).
15. FA_ST_WH_ACCEL_9 (Steering Wheel Fore/Aft Acceleration at 9:00). For RHD vehicles use FA-ST_WH_ACCEL_3.
16. LAT_ST_WH_ACCEL_9 (Steering Wheel Lateral Acceleration at 9:00). For RHD vehicles use LAT-ST_WH_ACCEL_3.
17. VERT_ST_WH_ACCEL_9 (Steering Wheel Vertical Acceleration at 9:00). For RHD vehicles use VERT-ST_WH_ACCEL_3.
18. VERT_DIFF_ACCEL (All Wheel Driver (AWD)/Rear Wheel Drive (RWD) only for identifying the first (or primary) and second harmonics of axle gear mesh order).
19. DYNO_SURF_FORCE (Dynamometer Total Surface Force).
20. DYNO_SPEED (Dynamometer Vehicle Speed).
21. Exhaust Temperature (optional).

Verify that each channel has the appropriate settings for the data acquisition equipment installed.

4.1.3.2 Calibration Verification. Check equipment for valid calibration date. Replace out of date equipment. Turn on all instrumentation 5 minutes prior to calibration verification. Verify calibration of the transducers as follows:

4.1.3.2.1 Microphone Calibration Verification. Mount the first measurement microphone on a certified calibrator and switch the calibrator on. Using the Calibration function of the software, enter the calibrator frequency and sound level, then measure the signal and observe the calculated sensitivity of the channel. If the calculated sensitivity of the channel is not within 15% of the latest calibration certificate for the microphone, replace the microphone and repeat calibration verification. Before conducting verification of next channel, accept

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the calculated sensitivity to store the sensitivity in the test setup. Repeat for each microphone. As an alternative, read Transducer Electronic Data Sheet (TEDS) from the microphone for factory calibration values.

4.1.3.2.2 Accelerometer Calibration Verification. Mount the first measurement accelerometer on a certified calibrator and switch the calibrator on. Using the Calibration function of the software, enter the calibrator frequency and vibration level, then measure the signal and observe the calculated sensitivity of the channel. If the calculated sensitivity of the channel is not within 15% of the latest calibration certificate for the accelerometer, replace the accelerometer and repeat calibration verification. Before conducting verification of next channel, accept the calculated sensitivity to store the sensitivity in the test setup. Repeat for each accelerometer. As an alternative, read TEDS from the accelerometer for factory calibration values.

4.1.3.3 Tracking Setup. Verify the tachometers are functional and that the trigger levels are set to the appropriate level.

Set dynamometer to control vehicle speed. Operate vehicle at 20 km/h and note engine and driveline revolutions per minute (rpm).

Determine the Vehicle/Driveline (V/D) ratio by using the observed driveline speed indicated by driveline tachometer and the vehicle speed indicated by the dynamometer control panel. This ratio will be needed to set up a derived tachometer for online processing. The V/D ratio is calculated as follows:

$$V/D = \frac{\text{Vehicle Speed (km/h)}}{\text{Driveline Speed (RPM)}}$$

Set up a derived tachometer with name Vehicle Speed, using the relationship Vehicle Speed = Driveline Tachometer (T2) × V/D. Set tachometer settings to trigger and capture immediate rpm.

Establish dynamometer roll speed of 100 km/h. Then, verify derived tachometer indicates vehicle speed at 100 km/h within 2%.

4.1.3.4 Acquisition Setup. Verify/accomplish the following fixed sampling acquisition settings:

- Acoustic channels:
  1. Bandwidth: 12.8 kHz.
  2. Resolution: 1.0 Hz.
- Vibration channels:
  1. Bandwidth: 800 Hz.
  2. Resolution: 1.0 Hz.

4.1.3.5 Online Processing Setup.

4.1.3.5.1 Verify/accomplish the following fixed sampling online processing settings for the Acoustic channels:

- Format: Autopowers Linear
- Window: Hanning
- Final Weighting: A
- Format: Root Mean Square (RMS)
- Saving Waterfalls: Optional

4.1.3.5.2 Set up the Vibration channels to process fixed sampling online data with the following parameters:

- Format: Autopowers Linear
- Window: Hanning
- Final Weighting: Linear
- Format: RMS
- Saving Waterfalls: Optional

4.1.3.5.3 Also set software to acquire the following:

- Fixed Sampled Orders of engine speed (eRPM) from 0.5 to 20, in 0.5 increments at a 0.1 order bandwidth

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- Overall Level
- Articulation Index (AI)

4.1.3.6 Measure Setup. Set the software to save time data files.

4.1.3.7 Build Test Variant Sections. Using the automated test setup software that corresponds to the current local version of Test.Lab, run the PreLAT calculator. Fill out information forms and follow prompts. Select Build Sections to generate test variant sections. A new section will be created for each variant. The measurement tracking will need to be set up prior to recording each variant. If automated test setup software is not used, manually create individual test sections with the naming convention provided in Appendix F.

4.1.4 Data Acquisition Equipment Preparation.

4.1.4.1 Install interior microphones as specified in Appendix B, Figures B9 thru B12. Standard positions are the driver's seat and the rear seat opposite side. For the driver's position only, install a dummy head/torso unit if a human driver is not used. Driver's microphone position shall be established prior to test with seat positioned as specified in Appendix B, Figures B9 and B10. When test must be conducted with human driver, seat position may be readjusted the minimum amount necessary to allow safe operation of controls. Install exterior exhaust tailpipe microphone as specified in GMW14218. Connect remote speaker to one interior measurement microphone or to a dedicated interior monitor microphone so that interior noise may be monitored aurally in real time during data collection.

4.1.4.2 Install accelerometers as specified in Appendix B, Figures B1 thru B8. Install accelerometers so that the X direction aligns with Fore/Aft of vehicle, Y direction aligns with Cross-Car (lateral) direction of vehicle and Z direction aligns with Vertical. Install a triaxial accelerometer at the twelve o'clock (12:00) position (for X, Y, Z) and nine o'clock (9:00) position (for X, Y, Z) of the steering wheel, using a machined accelerometer mounting pad with two tape bands to secure the pad to the wheel rim. Install triaxial accelerometers at the rear inboard and front outboard locations of the driver's seat track. If seat position must be adjusted to provide access to seat track during accelerometer installation, readjust seat position to mid-travel position as specified in Appendix B, B1 prior to test. On AWD and RWD vehicles, install a uniaxial accelerometer on the pinion nose of the rear differential in the vertical direction as specified in Appendix B, Figure B4.

4.2 Conditions.

4.2.1 Environmental Conditions. Check that the environmental conditions meet the requirements outlined in 3.1. If conditions are outside of the specified range, make a note in the deviation section of the test log.

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.

4.3 Instructions.

4.3.1 Vehicle Warm-up.

Prior to start of this procedure, operate the vehicle under load in highway driving condition for at least 20 minutes, to increase driveline temperature to operating temperatures. Conduct Vehicle Rotational Loss Calculation immediately following described warm-up procedure. If the vehicle is turned off for an extended time (> 30 minutes), then the vehicle must be warmed back up to operating temperatures.

4.3.2 Vehicle Rotational Losses. Use the dynamometer to calculate the vehicle losses in Neutral as specified by local dynamometer procedure. Losses must be calculated for operating speeds between 5 km/h and 140 km/h (3 mph and 87 mph) or greater. Set the dynamometer controller to apply the calculated vehicle losses when in RLS control mode.

4.3.3 Road Load Coefficient Verification.

4.3.3.1 Shift vehicle transmission to neutral.

4.3.3.2 Use the dynamometer controller to accelerate the rolls to a speed of 140 km/h (87 mph). Set dynamometer to control vehicle throttle and RLS force. Allow the vehicle to coast down at minimum accelerator pedal position. Measure and note, to ± 0.1 s, the time required to coast from 105 km/h to 97 km/h (65 mph to 60 mph) and from 24 km/h to 16 km/h (15 mph to 10 mph).

4.3.3.3 Compare 4.3.3.2 coast down times to coast down times measured on the road in neutral (refer to Global Pretest Road Data Sheet (Appendix A, Data Sheet A1)). The time difference must not exceed 10%. If the difference is > 10%, re-check RLS coefficient entry, units, proper operating temperature, etc. Correct any

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discrepancies and re-measure the coast down times on the dynamometer until the difference is 10% or less. Small adjustments to the RLS coefficients are allowed, to finely tune coast down times.

4.3.4 Measurement Test Variants. Prior to the start of the data acquisition phase of the test, re-verify all instrument and vehicle settings. Confirm radio/entertainment system is off and HVAC settings are as specified in Vehicle Preparation on Chassis Dynamometer (see 4.1.2). For online data processing, set adjustments to process data according to Section 5 prior to the start of test.

Verify parameters are set up correctly for each test variant section (see 4.1.3 and 4.1.4).

Set the digital acquisition input voltage range such that it maximizes the signal resolution without causing an overload during the course of the test. Make a pre-test for range adjustment if necessary.

During all tests, listen to the monitor speaker for any warning tones or other abnormal noises that do not represent intended operating conditions. Reject data from any non-representative run, correct the condition and repeat the run.

4.3.4.1 Sweep Variants. For each variant, assess the run-to-run repeatability of the data acquired before proceeding to the next test variant. Check accelerometer data for evidence of transducers loosening or falling off (such as would be shown by extreme changes in levels from run-to-run). The repeatability acceptance guideline for sound pressure data is that overall level should be within 2 dB (A-weighted) run-to-run. Engine firing order, harmonic orders of firing, primary imbalance orders and secondary imbalance orders should be within 3 dB (A-weighted) run-to-run at local maxima. If run-to-run repeatability does not converge to meet these guidelines after multiple runs, document the level of variation achieved by storing data from a minimum of 3 runs representing the range of variation.

4.3.4.1.1 Variant A (Required): Drive-away Acceleration Sweeps – Fixed Pedal. Set dynamometer to control vehicle speed through the throttle pedal and apply RLS. Put the transmission selector in desired gear (see Tables 1 thru 4). Set the data acquisition method to tracked, and tracking mode to time, with an increment of 0.1 s. Set the acquisition duration to 5 s for Light and Moderate Sweeps and 7 s for Hard Sweep. Set vehicle speed to approximately 2 km/h below the starting speed. Begin recording data when the vehicle speed reaches the target starting speed. For each of the drive-away sweep variants, the single point vehicle speed vs. time target is specified in Tables 1 thru 4. Depress the vehicle accelerator to a fixed point and plot the vehicle speed vs. time. If the vehicle speed plot does not pass through the target point within ± 2% while increasing, adjust the pedal position and repeat the run. A vehicle speed plot within ± 2% of the target point is considered an acceptable run. Reference Appendix G, Figure G1 for an example plot. Stop measurement at the end of the recording time or when maximum eRPM is achieved (whichever comes first). If the vehicle cannot achieve these targets in a specific gear, then stop recording that run and move to the next load case.

Table 1: Drive-away Acceleration Sweep for 1st Gear

Time	Light (Δt = 5 s)	Moderate (Δt = 5 s)	Hard (Δt = 7 s)
Seconds	**km/h**	**km/h**	**km/h**
0	8	8	16
2.5	20.5	26	39

Note: Δt = sweep duration, km/h = kilometers per hour.

Table 2: Drive-away Acceleration Sweep for 2nd Gear

Time	Light (Δt = 5 s)	Moderate (Δt = 5 s)	Hard (Δt = 7 s)
Seconds	**km/h**	**km/h**	**km/h**
0	18	30	40
2.5	28.7	43.5	57.5

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Table 3: Drive-away Acceleration Sweep for 3rd Gear

Time	Light (Δt = 5 s)	Moderate (Δt = 5 s)	Hard (Δt = 7 s)
Seconds	**km/h**	**km/h**	**km/h**
0	30	45	75
2.5	38.5	56	87

Table 4: Drive-away Acceleration Sweep for 4th Gear

Time	Light (Δt = 5 s)	Moderate (Δt = 5 s)	Hard (Δt = 7 s)
Seconds	**km/h**	**km/h**	**km/h**
0	39	60	79
2.5	46.5	69	90

For RWD and AWD vehicles, set the DAS to acquire fixed-sampled online noise and vibration data for first, second, integer orders from 6 thru 16, and even orders from 18 thru 32 relative to propshaft speed (tachometer channel T2), with order resolution of 0.1 order. For front wheel drive (FWD) vehicles, set the DAS to acquire the integer orders 1 thru 10 of the drive axle (tachometer channel T2), with order resolution of 0.1 order.

A trial run for each gear is required to verify the vehicle can accelerate from the starting speed listed in Tables 1 thru 4 and that the engine does not exceed red line at the end of the 5 s or 7 s sweep.

4.3.4.1.2 Variant B: High Gear Cruise Sweep. For RWD and AWD vehicles, set the DAS to acquire fixed-sampled online noise and vibration data for first, second, integer orders from 6 thru 16, and even orders from 16 thru 32 of propshaft speed (tachometer channel T2), with order resolution of 0.1 order. For FWD vehicles, set the DAS to acquire the integer orders 1 thru 10 of the drive axle (tachometer channel T2), with order resolution of 0.1 order. Set the acquisition duration as required to capture the entire high gear sweep, using a practice run if necessary after establishing sweep start and end points as specified in the following steps. Set dynamometer to control vehicle speed through the throttle pedal, and to use RLS as the applied load. Place the vehicle into its highest selectable gear position. Reduce the vehicle speed such that engine speed is < 1000 eRPM. Note this vehicle speed as the minimum high gear cruise speed. Set the dynamometer controller to sweep from the minimum high gear cruise speed to 140 km/h (87 mph), using an acceleration rate of 0.70 (km/h)/s.

Note: This acceleration is approximately equivalent to 2% grade load, with zero acceleration.

4.3.4.1.2.1 Variant B: High Gear Cruise Sweep – Grade Study. Increase the percent grade to 1% on the dynamometer and repeat the High Gear Cruise Sweep specified in 4.3.4.1.2. Continue to increase the percent grade in 1% increments, until the vehicle can no longer achieve the acceleration rate of 0.70 (km/h)/s or up to an additional 5%.

4.3.4.1.3 Variant C: Full Pedal Acceleration Sweep. Put the gear selector into 2nd gear position. Set dynamometer to control throttle position and apply RLS. Be sure to establish 100% pedal position in 1 s or less (by programming the dynamometer controller or by a human driver). Record data as the vehicle accelerates from < 1000 eRPM to fuel cutoff minus 200 eRPM.

Repeat for a minimum of 2 runs or until data is repeatable.

Put the gear selector into 3rd gear position. Repeat procedure accordingly to 2nd gear position variant.

Note: If tire slip occurs at starting speed, increase starting speed to minimum starting speed without tire slip.

Note: When using 3rd gear position, vehicle speed could exceed 140 km/h (87 mph). Ensure that prior to the test, the chassis dynamometer is capable of running over 140 km/h (87 mph) without causing emergency stop or breakdown.

4.3.4.1.4 Variant D: Coast-Down Sweep. Put the gear selector into 2nd gear position. Set dynamometer to control throttle position and apply RLS. Use the dynamometer to increase roll speed to fuel cutoff minus 200 rpm by depressing throttle. Set the data acquisition duration as required to capture the entire coast-down sweep,

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Release the throttle and record data as the vehicle coasts down from fuel cutoff minus 200 eRPM to < 1000 eRPM without depressing the clutch.

Repeat for a minimum of 2 runs or until data is repeatable.

Put the gear selector into 3rd gear position. Repeat procedure accordingly to 2nd gear position variant.

Repeat measurement in 3rd gear position for a minimum of 2 runs or until data is repeatable.

4.3.4.2 Steady State Variants. Set DAS to allow stationary speed data acquisition and that real time ⅓ octave band is on.

Note: For each steady state variant, verify/accomplish the following Tracking parameters are set up as follows:

- Set Tracking Mode to Stationary
- 2 averages/s

Note: For each steady state variant, verify that the Online Processing parameters are set up correctly:

- Overall Level
- Map Statistics: Peak Amplitude Spectrum
- Average Amplitude Spectrum
- Psychoacoustics: Articulation Index (AI)
- Real Time Octave Maps: ⅓ Octave

Before proceeding to next variant, assess run-to-run repeatability. All ⅓ Octave bands must be within 1 dB (A) of previous run.

4.3.4.2.1 Variant E: Steady State Wide Open Throttle (WOT). Set DAS to allow steady state speed data acquisition.

Switch to proper variant section. Set Tracking Mode to Stationary. Set 15 s time duration.

Verify online processing parameters are set up per 4.3.4.2.

Refer to completed Global Pretest Road Data Sheet (Appendix A, Data Sheet A1) to obtain road test information to be used in this variant.

Set chassis dynamometer to control throttle position and vehicle speed. Turn on external and spot cooling. Conduct this variant for passing gear, at the specified engine speed. The engine speed for a gasoline vehicle is 4000 eRPM and the engine speed for a diesel vehicle is 3000 eRPM. Adjust dynamometer speed control to achieve the vehicle speed corresponding to the specified engine speed. Adjust vehicle pedal position to full pedal. Adjust equipment gain settings to optimize the dynamic range without overloads. With external and spot cooling fans on, acquire 15 s of data. Ensure that engine coolant temperature remains between 90 °C and 110 °C (194 °F and 230 °F) during data acquisition. Upon completion of data acquisition, reduce dynamometer speed and return to closed throttle. When engine coolant temperature has stabilized (approximately 3 minutes to 5 minutes), repeat as required to ensure that repeatable data was acquired.

4.3.4.2.2 Variant F: Steady State 2500 eRPM. Set DAS to allow stationary speed data acquisition.

Switch to proper variant section. Set Tracking Mode to Stationary. Set 30 s time duration.

Verify online processing parameters are set up per 4.3.4.2.

Set chassis dynamometer to control throttle position and vehicle speed. Turn on external and spot cooling. Raise all chassis dynamometer floors. Shift the vehicle transmission to the 1st gear. Set dynamometer load control to $F_{2500ERPM}$, where the load is calculated as follows:

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