



Axle Noise and Vibration Evaluation Procedure

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. This procedure provides objective measurement data for development and validation of vehicle level and driveline system level axle noise and vibration under operating conditions on a dynamometer (dyno).

1.2 Applicability. This procedure applies to vehicles and drivelines using hypoid type final drive gears in the rear driveline, front driveline or both. The operating conditions specified in this procedure are applicable to vehicle level tests conducted on a chassis dyno, on-road and driveline system level tests conducted on a driveline dyno. For driveline system level tests, the driveline operating speeds and loads shall be obtained from full-vehicle on-road evaluations described in the preparation section of this procedure and GMW16178. The vehicle-level interior noise measurements described in this procedure are not applicable to driveline dyno tests.

1.3 Remarks. This procedure is used to assess the axle noise and vibration performance of GM and competitive vehicles and drivelines to establish requirements and to validate to those requirements.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14172 GMW14227 GMW16178

2.3 Additional References.

- LMS SCADAS Data Acquisition Systems (DAS) available at www.plm.automation.siemens.com/en_us/products/lms/testing/scadas/
- Subsystem Technical Specification (SSTS)
- Vehicle Technical Specification (VTS)

3 Resources

3.1 Facilities. The tests shall be performed in the designated testing environment at each GM regional site as specified in GMW16178. The environment specified in the VTS must be used for validation purposes.

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. See GMW16178 for equipment type and specifications.

3.2.1 Accelerometers. In addition to the equipment specified in GMW16178, high sensitivity accelerometers with a flat frequency response between 2 Hz and 2 kHz and a temperature range of 10 °C to 100 °C are required.

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3.2.2 Thermocouple Probe. A thermocouple probe is required to monitor axle temperature in the range of 10 °C to 100 °C. A probe capable of measuring axle internal oil temperature is preferred, and can usually be mounted in the fill or drain plug. If an internal probe is not available, a surface probe is acceptable.

3.3 Test Vehicle/Test Piece. Refer to GMW16178 for required documentation. Applicable test vehicle/test piece information must be stored with test data for later reference.

3.4 Test Time.

Calendar time: 1 day
Test time: 8 hours
Coordination time: 2 hours

3.5 Test Required Information.

3.5.1 Pinion Tooth Count. If possible, obtain the pinion tooth count for the axle of interest. This is available for most GM vehicles if the axle ratio or Regular Production Option (RPO) code is known. If the tooth count cannot be obtained prior to test (e.g., competitive vehicle testing), it must be inferred from preliminary external vibration measurements on the axle. The pinion tooth count is an integer number usually in the range of 8 to 15, and will often be evident as the highest amplitude order of vibration on the axle housing (propshaft reference).

3.5.2 Cruising Road Load. If validation testing is to be performed, the Road Load Simulation (RLS) coefficients must be known prior to test. The RLS coefficient values may be obtained as specified in GMW16178.

3.6 Personnel/Skills. To complete this test, at least one (1) test technician/dyno operator and one (1) data acquisition system (DAS) operator/engineer are required. The dyno operator and the DAS operator/engineer shall have completed the specific training applicable to the task.

4 Procedure

4.1 Preparation.

4.1.1 Vehicle Preparation. Accomplish GMW16178 Vehicle Preparation section. Verify body sealing and acoustic parts are correct (remove camouflage if possible to avoid potential masking of tonal noises). Conduct a thorough subjective road evaluation using the following procedure. On a level smooth road surface, evaluate axle noise by conducting the following recommended drive events while listening for axle whine noise. The speed range of evaluation shall cover the range from 40 km/h to 140 km/h, or as needed to cover regional validation requirements or specific noise issues (testing above 140 km/h may be required for vehicles sold in Gulf Coast Countries (GCC) and Europe). Axle noise evaluation sheet shown in Appendix A, Data Sheet A1 can be used to document subjective results.

Note: Axle whine noise may be distinguished from tire tread noise by the fact that axle noise is usually load-sensitive. Evaluate all suspected axle whine noise periods for load sensitivity by tipping in/out of the throttle while the noise is evident. If the suspected axle whine noise level varies greatly, axle noise is a likely cause. Axle whine noise may be distinguished from transmission and engine tonal noises by driving the vehicle in different transmission gear states at the same road speed. If the noise occurs in more than one gear state at the same road speed, axle noise is a likely cause.

4.1.1.1 Road Evaluation Drive Sweep. With the vehicle and axle at normal operating temperature (achieved by driving the vehicle for several kilometers at freeway speeds), conduct a drive sweep as follows. Establish a vehicle speed of 35 km/h, then steadily accelerate the vehicle to a speed of at least 145 km/h over a period of approximately 1 minute while listening for axle noise. Note the road speed range of any suspected axle noise periods, and screen other possible tonal noise sources according to the note in the preceding section. Record notes and subjective ratings for reference (see Appendix A, Data Sheet A1).

4.1.1.2 Road Evaluation Coast Sweep. Establish a steady vehicle speed of 145 km/h, then establish minimum accelerator position and allow the vehicle to coast down to a speed of 35 km/h while listening for axle noise. Note the road speed range of any suspected axle noise periods, and screen for other possible tonal noise sources according to the note in the preceding section. Record notes for reference.

4.1.1.3 Road Evaluation for Float Noise. Some axles exhibit increased noise on very light drive or coast loads, approaching zero (0) load. This is termed "float" noise. To evaluate this condition, conduct further evaluation of any trace noise periods identified in the drive and coast sweeps. At each noise period, manipulate the accelerator

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pedal to achieve very light loads on the drive and coast side and note the effect of the float load condition on suspected axle noise periods. Record notes for reference.

4.1.1.4 Road Evaluation for Modulation Noise. Some axles exhibit modulation between two (2) or more closely spaced mesh orders or sidebands. This may result in amplitude modulation of the interior sound pressure, which is described subjectively as a beating or warble noise. For any suspected axle noise periods identified in the preceding sections, note the presence of any beating or warble that is present. Record notes for reference.

4.1.2 Vehicle Installation. Install the test vehicle on the chassis dyno in accordance with applicable facility safety requirements. If the vehicle has tires with aggressive tread that may mask axle noise, install blank tires or dyno roll acoustic covers.

4.1.3 Tachometer Installation. Install an optical tachometer on the input driveshaft to the axle of interest on the test vehicle. Alternatively, input shaft speed can be tracked via CANBUS by selecting the appropriate high-speed signal.

4.1.4 Instrumentation Preparation. Determine the appropriate type, number and location for each transducer. This will be determined by the specific vehicle and axle noise and/or vibration measurement objective. For cruising axle noise validation testing, refer to GMW16178. Also see Appendix A, Figures A1 and A2.

4.1.5 Data Channel Assignment. On the DAS, assign each instrumentation channel to a corresponding data acquisition channel. Refer to the Channel Assignments in GMW16178.

4.1.6 Data System Connection. Connect the transducers to the assigned data acquisition channels.

4.1.7 Verify Transducer Calibration. Verify the calibration value of all transducers. Refer to Transducer Calibration Verification Master Test Procedure GMW14172.

Note: Microphone calibration may be verified before or after microphone mounting.

4.1.8 Transducer Location and Mounting.

4.1.8.1 Microphone Location and Mounting. Refer to GMW16178 for microphone seat stand placement details. Also see Appendix A, Figures A1 thru A4.

Note: Axle noise amplitude is very sensitive to microphone position. Ensure that the seat and stand details specified in GMW16178 are followed exactly. A minimum of two (2) interior microphones shall be used. Position one (1) interior microphone at the driver's ear location (inner) and one (1) additional at the opposite side rear occupant location (center head). For development, testing it is recommended to use optional microphone locations outlined in Appendix A, Figure A2, due to directional nature of gear whine. Mount each interior microphone on a seat stand fixture to position it at the occupant ear location of interest as specified in Appendix A, Figure A2. To ensure consistency the driver's seat must be positioned in the center of fore/aft and vertical adjustments (per GMW16178). Additional microphones may be placed on the exterior of the vehicle if desired for evaluation purposes (as shown in Appendix A, Figure A4). For reference it is helpful to note;

$$\Lambda = c/F$$

Where:

- Λ = wavelength
- c = speed of sound for a given medium
- F = frequency of the disturbance

Note: For rear wheel drive (RWD) trucks mount propshaft near field microphones located 100 mm off the surface at $\frac{1}{4}$ and $\frac{1}{2}$ lengths of the propshaft, measured from the end of tube section (see Appendix A, Figure A4). For a 2-piece rear propshaft, locate microphones at $\frac{1}{2}$ length of the front propshaft and $\frac{1}{2}$ length of the rear propshaft and 100 mm off the surface.

4.1.8.2 Accelerometer Placement. For consistency with other procedures and analyses, it is advised that measurement coordinate axes adhere to standard General Motors drafting vehicle coordinates;

- +X = longitudinal/rearward
- +Y = lateral/right hand rule
- +Z = vertical/upward

For all axle noise testing, mount a vertical accelerometer on the pinion noise of the axle housing as a reference for source vibration repeatability. Other accelerometer locations and directions may be added depending on the

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specific objective of the test. For axle attachment point vibration tests, mount a tri-axial accelerometer at each attachment point of the axle housing to the chassis. For these measurements, the accelerometer should be placed as close as possible to the actual point of attachment, i.e., at the chassis end of any axle-side attachment brackets. Attach the accelerometers to the axle housing with a rigid adhesive. Epoxy tape, cyanoacrylate adhesive and dental cement are acceptable rigid adhesives.

4.1.8.3 (Optional) Laser Placement. Place a laser at $\frac{1}{4}$ and $\frac{1}{2}$ lengths of each propshaft segment to quantify prop-bending and driveline system torsional modes. If laser setup requires dyno floors to be lowered, a separate test should be conducted with floors up to ensure the environmental change does not affect acoustic results.

4.1.8.4 Thermocouple Placement. For all axle noise testing, mount a thermocouple on the axle to monitor operating temperature variation. An internal probe type thermocouple in the axle fluid sump is the preferred location. If an internal probe thermocouple is not available, a surface thermocouple epoxied to the surface near the bottom of the sump cover is acceptable.

4.1.8.5 Data Acquisition Parameter Setup. The DAS may be programmed to calculate online orders and overall levels, and/or to record raw time data for subsequent post processing. For each test condition, time data from at least one (1) run on all channels is required for post-processing of modulation data (refer to subjective road evaluation notes) and unanticipated orders. If online processing is used, program the DAS to record the overall level on each data channel, and the first (or primary) and second harmonics of axle gear mesh order. The primary mesh order is equal to the pinion tooth count (reference Appendix A, Figure A5 for pinion tooth count lookup table), and the second harmonic is two (2) times the pinion tooth count. If the pinion tooth count is unknown, perform a preliminary run-up of the vehicle from 40 km/h to 140 km/h at cruising road load, then examine the pinion noise vibration data in waterfall or color map display format. The primary mesh order will be visible as a strong integer order of propshaft speed, usually between 8 orders and 15 orders.

Optional: Program the DAS to acquire higher mesh harmonics or side bands if road test or development data indicates the presence of higher order ($> 2 \times$ mesh) whine noise or modulating character. In addition to the first and second harmonics of mesh order, program the DAS to record first and second orders of propshaft rotation. These orders are recorded to monitor other important noise and vibration issues that may be present in the axle or driveline. Set the data acquisition parameters such that online or post-processed data will meet the following requirements:

Orders of Interest:	1 st and 2 nd mesh of the pinion (3 rd , 4 th and 5 th optional); 1 st and 2 nd of the propshaft. Side band orders of 1 st mesh may also be processed pending review of color maps. Optional orders for transverse All Wheel Drive (AWD)/Power Transfer Unit (PTU) primary mesh and diff gear primary mesh (for disconnecting differential only).
Order Resolution:	0.1
Bandwidth:	4096 Hz (vibration); 12.8 kHz (sound)
Delta F:	1 Hz
Delta rpm:	10 rpm to 15 rpm
Window:	Uniform (if synchronous sampling is used) Hanning (if fixed sampling is used)
Minimum rpm:	Propshaft speed corresponding to 40 km/h vehicle speed
Maximum rpm:	Propshaft speed corresponding to 140 km/h vehicle speed, the on-road speed of interest, or the maximum speed specified in the VTS, whichever is greater

4.1.8.6 DAS Ranging. Set the appropriate DAS front-end gains to maximize use of analyzer dynamic range for the each test condition. This may be done by autoranging or manually selecting ranges prior to each test condition.

4.1.8.7 Facility Floor Placement. Place all movable floors in the fully raised position to simulate the noise reflecting surface of the road.

4.2 Conditions.

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