



Engine Startup and Shutdown 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. Measure vehicle noise and vibration experienced by the driver during engine startup and shutdown events in hybrid vehicles.

1.2 Applicability. All hybrid vehicles.

1.3 Remarks. This test is used to assess the performance of GM and competitive vehicles during engine startup and shutdown events to establish vehicle level noise and vibration requirements.

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.

GMW14172 GMW14264

2.3 Additional References.

- MATLAB data processing programs are available in the Start/Stop Knowledge Set stored in the Global Document Management (GDM) Repository. (ID)
- Start/Stop Knowledge Set stored in the GDM Repository. (ID)
- Start/Stop Vibration Objective measurement to Subjective evaluation correlation study is available in the Start/Stop Knowledge Set stored in the GDM Repository. (ID)
- Vehicle Technical Specification (VTS)

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

3 Resources

3.1 Facilities. The tests shall be performed on smooth, flat, zero grade roads with no impact bumps comparable to the smooth noise roads at the Milford Proving Grounds.

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.

3.2.1 Tachometers. A high-resolution tachometer pickup off of the flywheel ring gear is preferred to accurately measure engine speed during the cranking and startup event. If data is only being acquired for benchmarking or VTS validation purposes, a once-per-revolution optical or laser tachometer pickup is acceptable.

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The crank shaft rotational speed can also be extracted from the vehicle controller area network (CAN) signal if the signal is only being used to determine when the crankshaft begins to rotate.

For strong hybrid vehicles, an accurate speed signal is also required from either the prop shaft for rear wheel drive (RWD) vehicles or the drive axle for front wheel drive (FWD) vehicles in order to capture vehicle speed during the event. An optical or laser tachometer pickup is the preferred choice, but the vehicle wheel speed sensor may also be used provided that it is capable of measuring down to 0 revolutions per minute (rpm).

3.2.2 Accelerometer. A high sensitivity accelerometer (minimum of 100 mV/g) with a flat frequency response between 2 Hz and 2 kHz and a temperature range between 10 °C and 50 °C shall be used.

3.2.3 Microphone. Free-field microphone (omnidirectional characteristics) with appropriate signal conditioning and cables, meeting class 1 accuracy corresponding to IEC 651 or equivalent for the application (precision ± 0.7 dB or $\pm 8\%$) shall be used.

3.2.4 Data Acquisition Equipment. A portable data acquisition system (DAS) is the preferred equipment to directly acquire the time data. The system should have a minimum dynamic range of 80 dB and the minimum sample rate of 12.8 kHz.

All devices shall meet class 1 accuracy corresponding to IEC 651 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$). A digital audio tape recorder can be used as alternate recording equipment.

3.3 Test Vehicle/Test Piece. The tests shall be performed on a production or development vehicle. Eliminate any unwanted content or problems. Verify and record the status of all hardware relative to the current release status. Adjust tire pressure to nominal values as stated by the tire manufacturer (cold). Ensure the fuel tank is at least $\frac{3}{4}$ full and all accessories and Heating Ventilation and Air Conditioning (HVAC) are off.

Record vehicle identification number, vehicle year, make and model, transmission type (automatic, manual, continuously variable, dual clutch, hybrid etc.), engine layout (L4/V6/etc.), engine displacement, fuel type, intake type, injection type (spark injection direct injection (SIDI), port fuel injection (PFI), etc.), driveline layout (transverse front wheel drive (TFWD), longitudinal rear wheel drive (LRWD), etc.), fleet number, evaluator and build stage if appropriate. Fully document any and all hybrid powertrain characteristics. Record any other options that could influence vehicle noise and vibration levels. Record the testing date, time, and location.

3.4 Test Time.

Calendar time:	1 d (Non-Hybrid) 2 d (Hybrid)
Test time:	4 h
Coordination time:	1 h (Non-Hybrid) 2 h (hybrid)

3.5 Test Required Information. For strong hybrids, the vehicle speed to shaft speed ratio (propshaft speed for RWD vehicles or drive axle speed for FWD vehicles) is required so that vehicle speed can be calculated from the appropriate shaft tachometer signal.

3.6 Personnel/Skills. A qualified engineer or technician trained in the use of data acquisition and noise and vibration signal processing is required. It may be necessary for a driver to operate the vehicle for conditions that require the vehicle to be moving.

4 Procedure

4.1 Preparation. Check that the vehicle meets the requirements outlined in 3.3. Drive the vehicle to ensure that the vehicle is free from squeaks and rattles and extraneous noises. Eliminate all extraneous noises prior to testing. Remove all camouflage for validation testing.

For autostart measurements, drive the vehicle to become familiar with the operation of the hybrid system and to determine methods to get the engine to start and stop at the minimum road speeds possible. Ensure engine is at a stable operating temperature, and that temperature is maintained during the duration of the testing.

For keyed start measurements, only room temperature measurements are required. Record any deviations for low temperature or high temperature ambient conditions.

4.2 Conditions.

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4.2.1 Environmental Conditions. Dry or damp (no standing puddles) road conditions are required. Record any deviations along with the wind speed, temperature and humidity.

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 Calibration Verification. Check equipment for valid calibration date. Replace out-of-date equipment. Turn on all instrumentation 5 minutes prior to calibration verification. Perform microphone calibration verification, see GMW14172.

4.3.2 Install Data Acquisition Equipment.

4.3.2.1 Install Tachometer Probe(s). Install a tachometer probe to accurately capture the startup and shutdown speed of the engine in rpm. If tachometer signal information is being taken from vehicle sensors, verify that the proper signal conditioning is applied so that the signal to the vehicle is not corrupted.

For strong hybrid vehicles, install a tachometer to accurately capture propshaft speed in rpm for RWD vehicles or drive axle speed in rpm for FWD vehicles.

If engine speed information is being collected from the CAN, connect the Assembly Line Diagnostic Link (ALDL) connector and make the appropriate settings to enable the DAS to decode the digital data string.

4.3.2.2 Install Accelerometer. A triaxial accelerometer should be positioned at the front outboard position of the driver's seat track to measure acceleration in the fore/aft, lateral and vertical directions. A triaxial accelerometer may be positioned on the steering wheel at the 12:00 o'clock position to measure acceleration in the fore/aft, lateral and vertical directions if that data is required.

4.3.2.3 Install Microphone. Install microphone in position as specified in Appendix A, Figure A1 and Figure A2. The standard position for left hand drive (LHD) vehicles is the right front (RF) seat position. The standard position for right hand drive (RHD) vehicles is the left front (LF) seat position. Adjust the seat and headrest according to Appendix B.

4.3.3 Data Acquisition Setup. Verify that the data acquisition parameters are set for the following sampling frequencies:

- Acoustic channels: 12.8 kHz
- Vibration channels: 256 Hz

Use the following recommended channel assignments and naming conventions:

- Channel 1: RF_SPL
- Channel 2: FA_DFOST_ACCEL
- Channel 3: LAT_DFOST_ACCEL
- Channel 4: VERT_DFOST_ACCEL
- Channel 5: FA_SW12:00_ACCEL (optional for benchmarking and VTS validation)
- Channel 6: LAT_SW12:00_ACCEL (optional for benchmarking and VTS validation)
- Channel 7: VERT_SW12:00_ACCEL (optional for benchmarking and VTS validation)

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

Note: If an Leuven Measurement Systems (LMS) International Test Lab acquisition system is being used, a specific test template file found in the GDM repository is available, see 2.3. This template file will load all of the data acquisition parameters and channel settings.

4.3.4 Measurement. Warm up the vehicle to ensure that the engine and transmission are at normal operating temperatures.

The data acquisition input voltage shall be set so that it maximizes the signal without causing an overload during the course of the test. Make a pre-test if necessary. Record event numbers, gain, and range settings as applicable.

4.3.4.1 Variant A: Strong Hybrid.

4.3.4.1.1 Vehicle Stationary in Drive, Start/Stop. Ensure all accessories are off. Try to have the battery at a fairly low state of charge (less than 30% of usable range) so the engine will more easily start. Place the vehicle

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