



Exhaust System Modal Analysis Evaluation Procedure

1 Introduction

The Shaker Frequency Response Function (FRF) Acquisition Master Test and Experimental Modal Parameter Estimation Master Test Procedures, GMW14228 and GMW14229, shall be referenced for more detailed information corresponding to the following procedure.

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 determine the in-situ exhaust system natural frequencies up to 100 Hz.

1.2 Applicability. This test procedure is appropriate for use with all powertrain and exhaust combinations.

1.3 Remarks. Exhaust system modal performance is called out to benefit vehicle noise and vibration performance at idle.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14228 GMW14229

2.3 Additional References.

Subsystem Technical Specification (SSTS)

3 Resources

3.1 Facilities. A test room.

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. Refer to GMW14228.

3.2.1 Shakers:

- Number: One (1) or two (2). Two (2) is preferred for the case of an exhaust system using a flex coupling, see 4.3.4.
- 100 N to 200 N maximum rating.
- Low armature mass.
- Low armature support stiffness.

3.2.2 Tri-axial Accelerometers:

- Number: 20 is the typical minimum for one (1) setup test (actual number depends on the exhaust system under evaluation, as described in section 4.3.2.2.) If roving accelerometers are required, refer to 4.3.6.
- Low mass (less than 40 g/tri-pack).

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- Maximum range: 51 m/s² to 510 m/s².
- Less than 1% linearity from 1 Hz to 100 Hz.
- Less than 5 degree phase shift from 1 Hz to 100 Hz.
- Less than 5% transverse sensitivity from 1 Hz to 100 Hz.
- 18 °C to 30 °C temperature range.
- 5×10^{-4} m/s² to 2×10^{-3} m/s² resolution range.
- More than 20 kHz natural frequency

3.2.3 Force Transducers:

- Number: 1 or 2 (same as number of shakers).
- Maximum range: 135 N to 270 N.
- Less than 1% linearity 1 Hz to 100 Hz.
- 18 °C to 30 °C temperature range.

It is recommended to measure FRFs at shaker driving point either by adding a uni-axial accelerometer connected to force transducer or by using an impedance head (i.e. force transducer integrated to uni-axial accelerometer).

3.2.4 Data Acquisition System (DAS):

- Multi-channel spectrum analyzer front end with analog-to-digital converters, computer and software for measurement and analysis (e.g., LMS SCADAS Front End and LMS Test Lab software, available from Siemens PLM Software, Siemens Industry, Inc.).
- Number of channels: 64 is the typical minimum for one (1) setup test with two (2) shakers (actual number depends on the exhaust system under evaluation, as described in 4.3.2.2.) An acquisition system featuring a minimum of 32 channels can be used if the test will use roving accelerometers, refer to 4.3.6.

3.2.5 Excitation Signal Generators. Appropriate source module(s) (contained in the DAS) or external dynamic signal generator(s) shall be used.

3.3 Test Vehicle/Test Piece. Exhaust/powertrain combination mounted in vehicle.

3.4 Test Time.

Calendar time:	1 to 2 days
Test time:	8 hours
Analysis time:	2 hours
Coordination time:	2 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Engineer and/or technician skilled in vibration data acquisition and analysis, and operation of the equipment.

4 Procedure

4.1 Preparation. Place the vehicle in the test room.

4.2 Conditions.

4.2.1 Environmental Conditions. See GMW14228.

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 Set and maintain following acquisition parameters:

- 1% (of time block) trigger delay (pre-trigger) for all channels. ^{Note 1}
- 0 Hz to 100 Hz acquisition bandwidth (minimum).
- 0.125 Hz frequency resolution (maximum).

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Documents

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- Approximately 80% burst length. ^{Note 2}
- Uniform Windows.
- AC Coupled (1 Hz high pass filter).
- Enable overload detection.
- 50 averages (minimum). ^{Note 3}
- 0% overlap.
- H1 FRF estimator.
- Maximum range: 135 N to 270 N
- Less than 1% linearity 1 Hz to 100 Hz.
- 18 °C to 30 °C temperature range.

Note 1: A trigger delay should be implemented so that the analyzer recalls buffered time data and considers the input and response data starting from rest. It is typically set as a negative number (e.g., -40 ms) and may vary in sign depending on the type of analyzer used.

Note 2: Burst random excitation frequency bandwidth should be within the acquisition bandwidth. Set burst length to completely observe the event. To prevent leakage, the response must decay to approximately 95% within the acquisition window. If the response does not sufficiently decay, reduce the burst length accordingly.

Note 3: The number of averages used may also vary depending on the number needed to obtain a consistent FRF.

4.3.2 Mount accelerometers as appropriate to uniquely identify exhaust modes up to 100 Hz.

4.3.2.1 Transducer Placement Guidelines (see Table 1):

Table 1: Transducer Placement Guidelines

Description	Minimum Number of Points
Powertrain	3
Body/Frame	4
Spindles	4
Isolated Cradle (if applicable)	3
Exhaust	Depends on Exhaust System (refer to 4.3.2.2)

4.3.2.2 Specific Guidelines for Exhaust:

- If the largest dimension of a tuning element is less than 20 cm, use one (1) point at each interface side (example at Appendix A, Figure A1). Otherwise, besides the interface points, add one (1) point at least at every 20 cm, on lateral and longitudinal directions (example at Appendix A, Figure A2).
- One (1) point at each bend in the exhaust (example at Appendix A, Figure A3).
- Two (2) points at the flex couplers interfaces (example at Appendix A, Figure A4).
- One (1) point at the exhaust tip (example at Appendix A, Figure A5).
- Others as necessary to define the exhaust geometry (example at Appendix A, Table A1).
- Additional points at the hangers can be used to evaluate acceleration transmissibility across exhaust mounts (example at Appendix A, Figure A6). This information can be useful for troubleshooting.

4.3.3 Document geometry (example at Appendix A, Figure A7 and Table A1).

4.3.4 Mount a shaker to the powertrain such that pitch and yaw are excited (example at Appendix A, Figure A5). For exhaust systems using a flex coupling, attach a second shaker (example at Appendix A, Figure A4) just forward of the flex coupler such that fore aft, lateral and vertical directions are excited. Use fixtures as appropriate.

4.3.5 Set force levels. A reference value is approximately 10 N Root Mean Square (RMS) but linearity must be checked according to GMW14228, Appendix C, C1.2.4.1. In the case of two (2) shakers setup, use the same force level for each shaker. Check reciprocity of the Cross Point FRFs between the two (2) shakers references (example at Appendix A, Figure A8). Refer to GMW14228, Appendix C, C1.2.4.3.

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4.3.6 The test should be performed in one (1) setup. The use of roving accelerometers is acceptable when all accelerometers or channels are not available or mass loading concerns are possible. A mass loading effect verification could be made placing the instrumentation only at drive points at the test start and/or end in order to quantify/compare the potential mass loading effects between the drive point measurements (only drive point vs. full instrumentation drive point comparison). If there are mass loading concerns and roving accelerometers are practiced, an overlay comparison of the drive point measurements should be made to ensure the distributed accelerometers do not cause inconsistencies in the test.

4.3.7 Acquire and store FRFs and reference input force Spectrum.

5 Data

5.1 Calculations. Develop the natural frequencies and mode shapes featuring exhaust participation from 0 Hz to 100 Hz using the process specified in GMW14229. See example at Appendix A, Figures A9, A10 and Table A2.

5.2 Interpretation of Results. The resultant frequencies from 5.1 should fulfill the Subsystem Technical Specification (SSTS) requirement.

5.3 Test Documentation. Complete the mode SSTS summary table and any other relevant information as outlined in GMW14229.

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. Wholly contained in GMW14228 and GMW14229.

7.2 Acronyms, Abbreviations, and Symbols.

DAS	Data Acquisition System
FRF	Frequency Response Function
IDSR	Integration Driven Subsystem Requirements
N&V	Noise and Vibration
RMS	Root Mean Square
VPO	Vehicle Performance Owner

8 Coding System

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

Test to GMW14202

9 Release and Revisions

This standard was originated in June 2005. It was first approved by the Global Noise and Vibration Structural Vibration IDSR Harmonization Team in September 2005. It was first published in September 2005.

Issue	Publication Date	Description (Organization)
1	SEP 2005	Initial publication.
2	JUL 2010	5 year refresh, no change to technical content. (Global Noise and Vibration Team)
3	NOV 2015	Revised to current template. (Global N&V VPO Team – Structural Vibration)

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