



Vehicle Air Conditioning Compressor and HVAC System 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. To define vehicle level measurements of noise and vibration performance related to the heating, ventilation, and air conditioning (HVAC) system including air conditioning (A/C) compressor operation.

1.2 Applicability. This test procedure is appropriate for all passenger cars and multipurpose passenger vehicles with belt driven A/C compressors.

1.3 Remarks. This test is used to assess HVAC system and A/C compressor vehicle level noise and vibration performance that may be used to establish and validate vehicle level requirements.

2 References

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

2.1 External Standards/Specifications.

ANSI/ASA S1.4 Part 1 DIN 45631/A1

2.2 GM Standards/Specifications.

GMW14172 GMW14264

2.3 Additional References.

- Subsystem Technical Specification (SSTS)
- Vehicle Technical Specification (VTS)

3 Resources

3.1 Facilities. 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 10 dB below the signal being measured. A semi-anechoic test room is preferred, but an outdoor area free from interfering noise is acceptable.

A semi-anechoic chassis dynamometer test room might be required in specific cases for root cause analysis.

Optional cold, mild and hot ambient subjective or objective evaluations at temperature require a test chamber with environmental control or an outside environment with the appropriate ambient for the specified evaluation.

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. Instrument grade tachometer signal probes, such as optical pickups, capable of providing a one pulse per revolution signal of the engine crank shaft and the A/C compressor pulley. Compressor tachometer should be set up to produce the same signal whether the compressor clutch is engaged or disengaged.

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3.2.2 Microphones. Two (2) 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.

3.2.3 Accelerometers. Five (5) 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 System. Multi-channel data acquisition hardware capable of calculating both frequency domain and order domain results between 0 Hz and 11.2 kHz with a minimum of 80 dB dynamic range. This hardware shall meet class 1 accuracy corresponding to ANSI/ASA S1.4 Part 1 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$).

At a minimum, a single channel of data acquisition hardware with at least 16 bit quantization at a sample rate of 48 kHz is required for clutch engagement noise.

3.2.5 Pulse Width Modulation (PWM) Controller(s). Device capable of variable frequency and duty cycle digital control of PWM signal to the A/C compressor such as the Model 205 PWM Controller from Applied Processor and Measurement, Inc. is required. Optionally, a second PWM controller might be used to control engine cooling fan speed in some cases (see 3.2.6).

3.2.6 A/C Head Pressure Control System. A device capable of controlling the A/C system discharge pressure. This system includes discharge pressure readout and means to control airflow across the condenser. This is accomplished by one of the following methods:

- Use an external variable voltage power supply to vary the speed of the fan (this method only applies to brushed fan motors).
- Wire a switch into the vehicle's fan circuit and cycle the fan on and off to keep discharge pressure within a specified range (this method applies to any brushed or brushless electric fan motor).
- Use an external power supply and a dedicated PWM controller to control fan speed (this method applies to brushless electric fans or brushed fans with PWM control).
- Use Vehicle Network Interface such as neoVI and Vehicle Spy to control fan (this method applies to any General Motors vehicle with electric fan).
- Disable vehicle's fan and use external variable speed fans (this method applies to engine driven fans or electric fans).

Note: In vehicles with dual electric fans, a single external power supply capable of controlling both fan voltages simultaneously is preferred to two independent power supplies. Alternately, an acceptable strategy is to control one of the two fans and disable the other.

3.2.7 Suction Pressure Transducer. A device which senses the gage pressure along the suction line for acquisition as a data channel. This is typically attached to the low pressure service port in the vehicle.

3.2.8 Current Measurement Device. An inductive current clamp to measure output of the PWM controller in milliampere (mA), with minimum 1 A range and a tolerance $\pm 2\%$.

3.2.9 Clutch Engagement Control (Optional). Use a wiring harness to control clutch engagement through relays or by directly wiring a fused, switched lead from the battery to the A/C compressor clutch.

3.2.10 Power Supply(ies). A 12 V DC power supply (or other appropriate voltage range per PWM controller specifications) is required for powering the PWM controller. Optionally, a second DC power supply might be used to power engine cooling fan in some cases (see 3.2.6).

3.2.11 Vehicle Network Interface (Optional). NeoVI device and Vehicle Spy software from Intrepid Systems (or similar equipment) can be used to monitor and control many variables such as refrigerant pressure, engine cooling fan speed, and engine idle speed.

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 hours:	8 h
Data processing time:	6 h
Coordination hours:	2 h

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3.5 Test Required Information. Compressor PWM control signal frequency is required for external variable displacement compressors. Also required is the supplier specific compressor operating range, i.e., compressor minimum and maximum ECV (Electronic Control Valve) current. ECV operating range can be obtained from the part drawing, which is accessed through Global Product Description System (GPDS), in the form of a Control Valve Characteristic Chart. See details and example Figure C1 in Appendix C.

3.6 Personnel/Skills. One qualified engineer or technician trained in the use of noise and vibration data acquisition, basic digital signal processing and knowledge of HVAC charging systems is required to complete this test along with (optional) chassis dynamometer operator.

4 Procedure

4.1 Preparation. Verify that the vehicle meets the requirements of 3.3. Record VIN, GM fleet number, vehicle build stage, engine displacement, engine configuration (Vee or in-line), fuel type, driveline configuration (Front Wheel Drive (FWD), Rear Wheel Drive (RWD) or All Wheel Drive (AWD)) and HVAC system content as appropriate in test project documentation section and/or on Data Sheet D1 in Appendix D. Document the status of all hardware relative to the current release status.

4.2 Conditions.

4.2.1 Environmental Conditions. The ambient temperature shall be between 20 °C and 30 °C except for the specific cold, mild and hot ambient evaluations at the temperature ranges that follow.

Optional cold ambient evaluations of the Vehicle Drive-Away A/C Off Sweep shall be completed at temperatures between -30 °C and 0 °C.

Optional mild ambient evaluations for external variable displacement compressor testing shall be completed at temperatures between 10 °C and 20 °C.

Optional hot ambient evaluations shall be completed at temperatures between 35 °C and 40 °C.

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 Standard Test Conditions.

4.2.2.1.1 Drive-Away Sweep A/C-On – Maximum Displacement. Engine/compressor speed sweeps with the compressor engaged and the discharge gage pressure controlled to 2000 kPa and 1500 kPa are used to capture compressor growl and tonal noise replicating high load noise and vibration performance. For external variable displacement compressors use maximum compressor displacement by operating at or above control valve characteristic curve.

In some cases this condition can be more readily achieved at ambient temperatures between 35 °C and 40 °C for evaluation of noise and vibration performance subjectively or objectively.

4.2.2.1.1.1 Drive-Away Sweep A/C-On - Low Displacement. Additional Drive-Away A/C-On Sweeps are used for variable displacement compressors at discharge gage pressures of 1000 kPa and 1500 kPa with ECV current and suction pressure maintained at low displacement (see Appendix C), to evaluate mild ambient noise and vibration performance.

In some cases these conditions can be more readily achieved at ambient temperatures between 10 °C and 20 °C for evaluation of noise and vibration performance subjectively or objectively.

Note: Due to the potential difficulty in identifying all possible low displacement compressor noises, a subjective evaluation of the vehicle in a range of mild ambient conditions is recommended prior to conducting objective/subjective testing in laboratory conditions. For these subjective evaluations, the vehicle should be operated using normal vehicle calibrations without controlling instrumentation. Only monitoring instrumentation should be used for subjective evaluation.

4.2.2.1.2 Drive-Away Sweep A/C-Off. An engine/compressor speed sweep with the compressor not engaged (or below minimum ECV current for clutchless compressors) is used to capture background noise used to mask compressor noise.

4.2.2.1.2.1 Drive-Away Sweep A/C-Off - Cold Ambient (Optional). The Drive-Away A/C-Off Sweep condition at ambient temperatures of -30 °C to 0 °C is used to evaluate cold ambient noise performance of the compressor and pulley bearing assembly subjectively or objectively.

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4.2.2.1.3 Idle Steady State. Vehicle idle performance with the A/C compressor operating at each of the following discharge gage pressures and listed compressor displacements:

- 2500 kPa, Maximum compressor displacement
- 2000 kPa, Maximum compressor displacement
- 1500 kPa, Maximum compressor displacement
- 1500 kPa, Low compressor displacement
- 1000 kPa (or lowest value achievable), Minimum compressor displacement
- Compressor Disengaged

Caution: Operating for an extended period of time (greater than 5 minutes) at any of the low pressure conditions may create evaporator core freeze. Turn A/C compressor off for 2 minutes between extended tests. Alternately, consult with an HVAC system specialist to determine what additional instrumentation may be required if greater flexibility in operation times is needed.

4.2.2.1.4 Return to Idle Transient Noise. For external variable displacement compressors, this condition is used to assess transient noise (e.g., hiss, gurgle, etc.) as the refrigerant flow reduces through the HVAC system. With compressor discharge gage pressure controlled to 2000 kPa at maximum compressor displacement, maintain engine speed for 60 s at 3000 engine revolutions per minute (ERPM) and then allow the vehicle to return to idle. Monitor noise parameters as the engine speed returns to idle and for 60 s after it reaches idle.

4.2.2.1.5 Idle Transient A/C Clutch Engagement. Vehicle idle performance during compressor clutch cycling is used to assess transient clutch noise, vehicle vibration disturbances and refrigerant expansion noise.

If possible, expose vehicle to environment with high ambient temperature (35 °C to 40 °C). Allow the vehicle to adjust to the ambient temperature. Idle the vehicle with the A/C compressor on allowing the vehicle to control the A/C compressor clutch operation. Ensure that the HVAC blower is set to its lowest speed with air flow directed at the floor and that all other accessories are off. Using the front interior control turn the A/C system on and off allowing the vehicle calibration to control the A/C compressor clutch. Subjectively rate the A/C compressor clutch engagement noise, the transient vibration response at the driver interfaces and the evaporator/refrigerant hiss. Reference GMW14264 for subjective rating scale.

4.3 Instructions.

4.3.1 Set Up Vehicle in Test Cell. Set up the vehicle in test cell as required by facility policy, including exhaust collectors, safety equipment, and control hardware.

4.3.2 Calibration Verification. Check equipment for valid calibration date. Replace out of date equipment. Perform accelerometer and microphone calibration verification. Reference GMW14172.

4.3.3 Install Data Acquisition Equipment.

4.3.3.1 Tachometers. Install tachometer probes or optical pick-ups to accurately capture the engine speed, in engine revolutions per minute (ERPM), and the A/C compressor speed, in compressor revolutions per minute (CRPM).

4.3.3.2 Microphones. Install microphones in positions specified in Figure A1 and Figure A2 in Appendix A. Standard positions are the left front (LF) seat and the right front (RF) seat. Use center of seat location unless the seat is occupied. Position seats according to Appendix B.

4.3.3.3 Accelerometers. Install two (2) triaxial accelerometers on the liquid and suction lines in the vehicle engine compartment at the Thermal Expansion Valve (TXV) near the front of dash.

Install triaxial accelerometers at the driver interfaces. The standard driver interface locations include the 12 o'clock position on the steering wheel and the front outboard position on the driver's seat track.

Install accelerometers so that the X direction aligns with the fore/aft direction of the vehicle, the Y direction aligns with the lateral (cross-car) direction of the vehicle and the Z direction aligns with vertical. Adjust steering column to mid-travel positions for tilt and telescope.

Optional: For root cause analysis, install an additional triaxial accelerometer on the A/C compressor body.

4.3.4 Install A/C Control Equipment.

4.3.4.1 A/C Head Pressure Control System. Install hardware to control compressor discharge pressure at the service port.

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4.3.4.2 Clutch Engagement Control. Install hardware to control compressor clutch engagement, if available. If it is not possible to directly control compressor clutch, the A/C on/off button in the vehicle's front interior control may be used to engage and disengage the clutch. However, the vehicle's A/C button is subject to layers of calibrated controls and may not produce the desired on/off effect.

4.3.4.3 PWM Control and Current Probe. Install PWM controller with power supply for external variable displacement compressors. Set PWM frequency as required for compressor control and duty cycle as required for test condition. Attach current probe to one of the two leads going to the ECV. If the current probe produces a negative value when the ECV is appropriately powered, reverse polarity by reversing the path of the wire through the probe. See Figure 1 for PWM controller and current probe configuration.

Note: Many current probes have a "zero" adjustment. In order to accurately read ECV current, the current probe output should be adjusted to "zero" current (± 10 mA), before energizing the ECV.

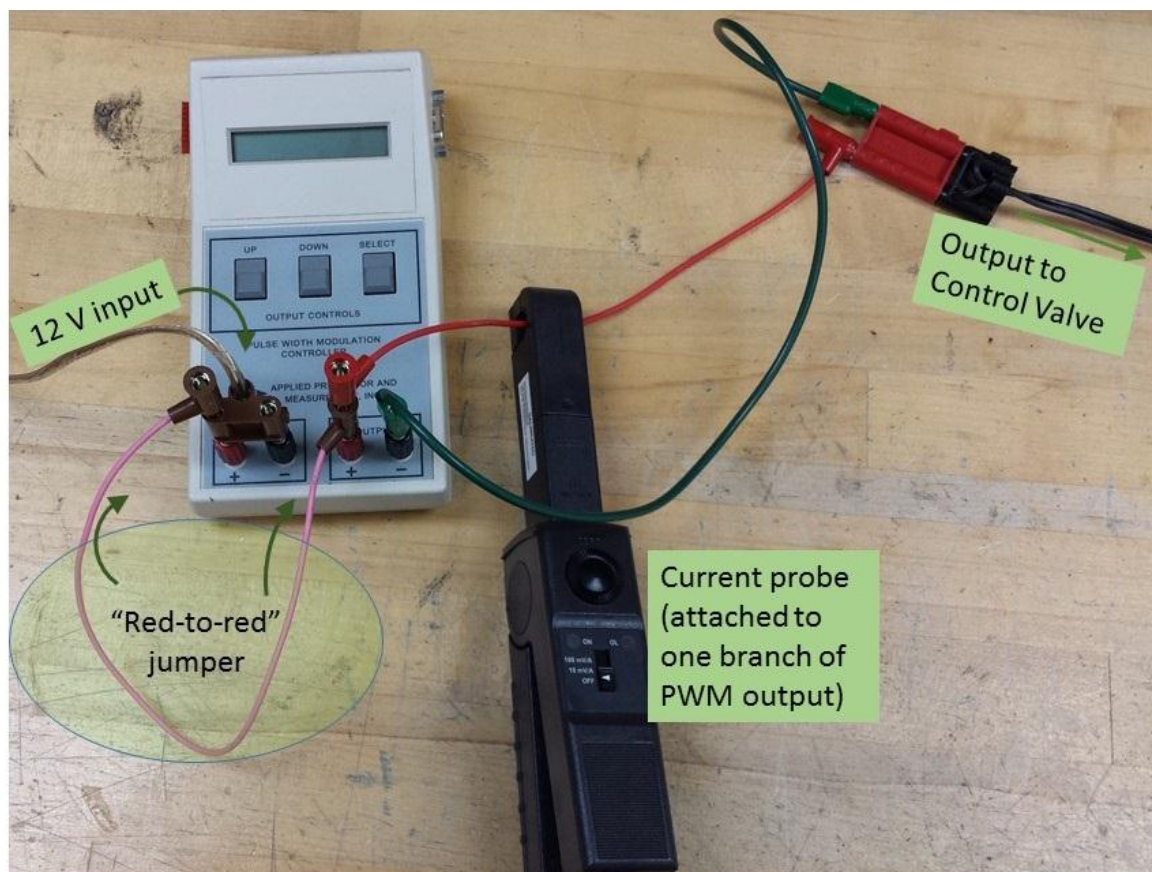


Figure 1: PWM Controller and Current Probe Wiring

4.3.5 Background Measurement. With all instrumentation installed and enabled, acquire 20 s to 30 s of ambient room data with engine off and exhaust collection fans off. Repeat this measurement with engine off and exhaust collection fans on.

4.3.6 Data Acquisition. With voltage being supplied to the engine cooling fan, confirm the vehicle is warmed up and check that engine/vehicle operation is stable. Turn off all ancillary systems including the entertainment system and rear blower. Run the engine until normal operating temperatures are reached.

Note: Engine cooling fans are disabled! Carefully monitor engine coolant temperature and compressor discharge pressure!

4.3.6.1 Drive-Away Sweeps A/C-On – Maximum Displacement. Interior noise and TXV vibration data are required for this test condition.

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