



Frequency Response

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.

Note: This standard uses terminology related to the directional control of vehicles as defined by SAE J670.

1.1 Purpose. The purpose of this procedure is to measure the vehicle steering response transfer functions in the frequency domain using a swept frequency sine wave steering input. Linear understeer, steering sensitivity, roll gain, peak roll gain, lateral acceleration and yaw velocity bandwidth, and sideslip gain metrics are derived from these transfer functions.

1.2 Applicability. This test procedure applies to any two (2) axle, pneumatic rubber tired vehicle, at all load conditions.

2 References

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

2.1 External Standards/Specifications.

ISO 9001 SAE J670

2.2 GM Standards/Specifications.

GMW14798 GMW14799

2.3 Additional References.

Global Document Management (GDM) System (<https://documents.gm.com/gdm3/component/main>) (ID)

Oxford Technical Solutions Ltd, Oxfordshire, UK (<http://www.oxts.com/products/rt3000-family/>)

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

3 Resources

3.1 Facilities. This procedure requires a straight roadway with a minimum recommended width of 12 m and a length sufficient to permit at least 42 s running at the test speed. The gradient of the surface shall not exceed 2.5% in any direction.

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 Steering Wheel Angle Transducer.

3.2.2 Steering Wheel Torque Transducer.

3.2.3 Vehicle Speed Sensor. Vehicle velocity and side slip is typically measured with Global Positioning Satellite (GPS)/Inertial sensors (e.g., Oxford Technologies RT3000 series). Alternatively, vehicle velocity and sideslip can also be measured with an optical sensor placed at the front-center or rear-center of the vehicle, or radar based sensors, or sonar based sensors. Sensor outputs are transmitted simultaneously to the data acquisition

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system and the instrument panel mounted display. The instrument panel mounted display allows the driver to accurately monitor vehicle speed.

3.2.4 Multi-Axis Inertial Sensor. A multi-axis inertial sensing system is used to measure fore/aft and lateral accelerations and yaw rates (e.g., Oxford Technologies RT3000 series). The position of the multi-axis inertial sensing system must be accurately measured relative to the total vehicle Center of Gravity (CG) or centroid of the vehicle in its test configuration. These data points are required to translate the motion of the vehicle at the measured location to that which occurred at the actual centroid to remove roll, pitch and yaw effects. Alternatively, a motion box package may be used to measure lateral and fore/aft acceleration and yaw rate.

3.2.5 Roll Height Sensors. Height sensors are used to measure left and right side vertical displacements for the calculation of vehicle roll angle by using one (1) ultrasonic or laser ranging module mounted on each side of a vehicle. With these data points, roll angle is calculated during post processing using trigonometry.

3.2.6 Data Acquisition System (DAS). See 3.5 and 4.1.1 for more information about the data acquisition method.

3.3 Test Vehicle/Test Piece. Any vehicle with two (2) axles and pneumatic rubber tires at any load condition.

3.4 Test Time.

Calendar time: 1 day to 2 days

Test hours: 1 hour to 4 hours

Coordination hours: 1 hour to 4 hours

3.5 Test Required Information.

3.5.1 DAS Channels and Full Scale Values. See Table 1.

Table 1: DAS Channels and Full Scale Values

Channel	Value
Steering Wheel Angle	1440 degrees
Steering Wheel Torque	40 N·m
Vehicle Speed	150 km/h (93.2 mph)
Vehicle Sideslip	10 degrees
Lateral Acceleration	10 m/s ²
Yaw Velocity (Rate)	10 degrees/s
Roll Angle	10 degrees

Note: If using an Oxford Technical Solutions RT3000 to measure vehicle side slip, it should be noted that a single antenna setup cannot generate accurate sideslip measurements at vehicle speeds less than 40 km/h (24.85 mph). For best accuracy and reliable results, a dual-antenna setup should be used with the RT3000.

3.5.2 Additional Channels. May be used as required.

3.5.3 Sample Rate. All data is to be sampled at 100 Hz. Typical anti-aliasing filter frequency is 25 Hz.

3.6 Personnel/Skills. Operator must be qualified and documented as capable to run this test as required by ISO 9001.

4 Procedure

4.1 Preparation.

4.1.1 Installation.

4.1.1.1 The DAS must be restrained inside the vehicle. The front passenger seat is a typical and acceptable location.

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4.1.1.2 The multi-axis inertial sensor must be installed and securely mounted at or near the total vehicle center of gravity (centroid or CG), with the location recorded on the Test Vehicle Description (TVD) sheet (or similar). Refer to Appendix A, Data Sheet A1 for a sample TVD sheet. The CG of a vehicle is typically located in the area between the front driver and passenger seats. Interior components such as the center console may need to be removed in order to mount the multi-axis inertial sensor in a suitable location.

4.1.1.3 The roll height sensors must be securely mounted on the left and right side of the vehicle. Typically the sensors are installed at the end of a bar that can be strapped securely to the front of the vehicle. The fore/aft location of the sensors and the lateral distance between the sensor heads should be recorded in the TVD sheet.

4.1.1.4 If an optical speed sensor is used, it should be mounted at the front or rear of the vehicle and centered laterally. If the sensor cannot be mounted at the precise lateral center of the vehicle, the magnitude and direction of offset from center should be documented and reported to the appropriate test engineer.

4.1.1.5 If a motion box package is used, it should be installed in a level position as close to the centroid as is practical. The front passenger seat foot well is a typical and acceptable location. The for/aft location of the motion package should be recorded on the TVD sheet.

4.1.1.6 All ballast inside the passenger compartment of the vehicle must be secured in place. Water dummies must be secured with straps in addition to the seat belts. All loose equipment should be removed from the passenger compartment, including tools, extra transducers, and personal belongings.

4.1.2 Vehicle Preparation.

4.1.2.1 The test vehicle should be inspected to ensure that the proper tires and suspension components are installed, and that all chassis components are in good mechanical condition.

4.1.2.2 The vehicle suspension should be aligned to nominal specifications.

4.1.2.3 With the fuel tank full, the vehicle test weights should be determined and recorded.

4.1.2.4 Vehicles equipped with a "tilt-wheel" steering column should be adjusted such that the steering wheel is in the center of the tilt range.

4.1.3 Tire Preparation.

4.1.3.1 Tire pressures should be set to the requesting engineer's recommended cold pressure for each tire, unless otherwise stated on the test request.

4.1.3.2 Note the condition of the tires. New tires should be broken in by driving 10 km (6.21 mi) at 100 km/h (62.1 mph), including moderate cornering and several heavy brake stops (without inducing skidding). Obviously worn tires should be noted and the appropriate wear state checked on the TVD worksheet.

4.1.4 Operator Precautions.

4.1.4.1 Seat belts must be worn during testing. Lock all doors and close all windows prior to testing.

4.1.4.2 The test operator (driver) must inform any others at the test site of their presence using the appropriate site-specific communications protocol.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 The test shall be carried out on a smooth, clean, dry and uniform paved road surface.

4.2.1.2 The ambient air temperature should be above 0 °C (32 °F) and below 40 °C (104 °F).

4.2.1.3 The wind speed should be less than 35 km/h (22 mph) for cars and 17 km/h (11 mph) for trucks.

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 The standard test speed is 100 km/h, and should not vary by more than ± 2 km/h. If other test speeds are requested, it is recommended to perform these tests in 20 km/h increments, and also should not vary by more than plus or minus 2 km/h.

4.2.2.2 This test requires that a steering ratio test be performed, per GMW14798.

4.2.2.3 Varying steer frequencies are input. The minimum input frequency is limited by the width of the road, and the maximum input frequency input is limited by human capability to approximately 3 Hz to 4 Hz.

4.2.2.4 Peak lateral acceleration should not exceed 0.4G.

4.2.2.5 The steering wheel angle channel must never be saturated.

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4.3 Instructions.

4.3.1 Turn on all instrumentation and data acquisition equipment and allow at least five (5) minutes to warm up.

4.3.2 Establish the straight-ahead setting on the steering wheel by driving in a straight-ahead direction at 100 km/h (62 mph). Mark the 12 o'clock position on the steering wheel with a piece of tape. If the steering wheel transducer is equipped with a protractor to reference steering wheel zero and steering amplitudes, line up the steering wheel protractor zero degree mark with the pointer when the steering wheel is directing the vehicle in a straight-ahead direction.

4.3.3 With the vehicle at rest, the steering wheel in the straight-ahead position and hands off the wheel, record the balance and calibration data. If the steering wheel transducer is equipped with a digital readout, zero the steering wheel angle and torque outputs.

4.3.4 Drive at 100 km/h, or the selected test speed, (set cruise control if available) and input a steering wheel angle such that the lateral acceleration is 0.4G. A step steer input and/or low frequency sinusoidal steer input may be used. Mark the steering wheel with tape and/or note the value on the digital readout for this steering wheel angle. If a steering wheel stop is going to be used for the test, set it at this angle.

4.3.5 Drive at 100 km/h, or the selected test speed, (set cruise control if available) and maintain test speed for the entire test segment.

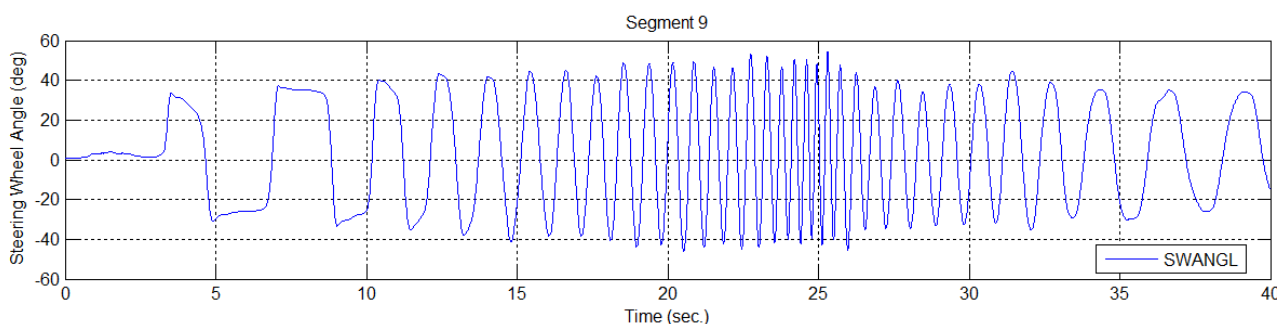
- Begin recording with the data acquisition/storage equipment.
- After maintaining a straight path for 2 s, begin steering the vehicle with two (2) to three (3) step steer inputs in each direction at the steering wheel angle established in 4.3.4. Each of these step inputs should be held for 1 s to 2 s or to the limit of the available road width.
- Following the step inputs, steer the vehicle in a sinusoidal manner at the steering wheel angle established in 4.3.4. Start with a low frequency steer input and gradually increase the frequency to the maximum rate attainable while maintaining the same steering wheel angle amplitude. This should be done in the first 30 s of the test segment.
- Gradually decrease the steer input frequency until the end of the test segment, which should be approximately 40 s.
- To help obtain a constant rate of steering input frequency increase, an acoustic or optical signal may be used.

4.3.6 Do not squeal tires during any part of the test segment.

4.3.7 There should not be any activation of the Electronic Stability Control (ESC) system during the test. If ESC does activate, disable it by using the in-vehicle button or by disconnecting a wheel speed sensor. If a wheel speed sensor is disconnected, it should be reconnected at the end of test.

4.3.8 The steering wheel angle output should look like the plot shown in Figure 1. The peak steering wheel angles should be the same throughout the test. Lateral acceleration and roll may decrease as the steering input frequency increases.

Figure 1: Sample Steering Wheel Output



4.3.9 Repeat 4.3.5 through 4.3.8, generating eight (8) segments of data.

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