

BS ISO 19365:2016



BSI Standards Publication

# Passenger cars — Validation of vehicle dynamic simulation — Sine with dwell stability control testing

**National foreword**

This British Standard is the UK implementation of ISO 19365:2016.

The UK participation in its preparation was entrusted to Technical Committee AUE/15, Safety related to vehicles.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2016.  
Published by BSI Standards Limited 2016

ISBN 978 0 580 84951 0

ICS 43.100

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2016.

**Amendments issued since publication**

Date	Text affected
------	---------------

---

INTERNATIONAL  
STANDARD

**ISO**  
**19365**

First edition  
2016-10-01

---

---

**Passenger cars — Validation of vehicle  
dynamic simulation — Sine with dwell  
stability control testing**

*Voitures particulières - Simulation et validation dynamique des  
véhicules - Essais de contrôle de la stabilité en sinus avec palier*



Reference number  
ISO 19365:2016(E)

© ISO 2016



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2016, Published in Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
Ch. de Blandonnet 8 • CP 401  
CH-1214 Vernier, Geneva, Switzerland  
Tel. +41 22 749 01 11  
Fax +41 22 749 09 47  
copyright@iso.org  
www.iso.org

# Contents

Page

<b>Foreword</b> .....	<b>v</b>
<b>Introduction</b> .....	<b>vi</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
<b>4 Principle</b> .....	<b>2</b>
<b>5 Variables</b> .....	<b>3</b>
<b>6 Simulation tool requirements</b> .....	<b>3</b>
6.1 General.....	3
6.2 Mass and inertia.....	3
6.3 Tires.....	3
6.4 Suspensions.....	4
6.5 Steering system.....	4
6.6 Aerodynamics.....	4
6.7 Brake system.....	4
6.8 Powertrain.....	4
6.9 Active control system (ESC system, active roll control, etc.).....	5
6.10 Data acquisition.....	5
6.11 Driver controls.....	5
<b>7 Physical testing</b> .....	<b>5</b>
7.1 General.....	5
7.2 Conditioning the vehicle.....	5
7.3 Slowly increasing steer tests.....	5
7.3.1 Slowly increasing steer procedure.....	5
7.3.2 Reference steering wheel angle “A”.....	6
7.4 Sine with dwell test series.....	6
7.4.1 Sine with dwell steering pattern.....	6
7.4.2 Speed.....	6
7.4.3 Steering amplitude.....	6
7.4.4 Steering amplitude for final runs in a series.....	6
7.5 Data processing.....	6
7.5.1 Filtering and conditioning.....	6
7.5.2 Lateral displacement.....	6
7.5.3 ESC system intervention.....	6
7.6 Performance requirements.....	7
7.6.1 Stability criteria.....	7
7.6.2 Responsiveness criterion.....	8
<b>8 Simulation</b> .....	<b>9</b>
8.1 Limits on the simulated procedure.....	9
8.2 Slowly increasing steer tests.....	9
8.3 Sine with dwell test series.....	9
8.4 Data processing.....	9
8.4.1 Filtering and conditioning.....	9
8.4.2 Lateral displacement.....	9
<b>9 Comparison between simulation and physical test results</b> .....	<b>9</b>
9.1 Steady state turning validation.....	9
9.2 Metrics from a sine with dwell series.....	10
9.2.1 General.....	10
9.2.2 Number of first test run in which ESC intervention occurs.....	10
9.2.3 Test runs used for comparison.....	10
9.2.4 Metric definitions and tolerances.....	10

9.3	Validation of the simulation tool .....	11
<b>10</b>	<b>Documentation</b> .....	<b>11</b>
	<b>Bibliography</b> .....	<b>12</b>

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

## Introduction

The main purpose of this document is to provide a repeatable and discriminatory method for comparing simulation results to measured test data from a physical vehicle for a specific type of test.

The dynamic behaviour of a road vehicle is a very important aspect of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, constitutes a closed-loop system that is unique. The task of evaluating the dynamic behaviour is therefore very difficult since the significant interactions of these driver-vehicle-environment elements are each complex in themselves. A complete and accurate description of the behaviour of the road vehicle involves information obtained from a number of different tests.

Since this test method quantifies only one small part of the complete vehicle handling characteristics, the validation method associated with this test can only be considered significant for a correspondingly small part of the overall dynamic behaviour.



# Passenger cars — Validation of vehicle dynamic simulation — Sine with dwell stability control testing

## 1 Scope

This document specifies a method for comparing computer simulation results from a vehicle mathematical model to test data measured for an existing vehicle undergoing sine with dwell tests that are typically used to evaluate the performance of an electronic stability control (ESC) system. The comparison is made for the purpose of validating the simulation tool for this type of test when applied to variants of the tested vehicle.

It is applicable to passenger cars as defined in ISO 3833.

**NOTE** The sine with dwell test method described in this document is based on the test method specified in regulations USA FMVSS 126 and UN/ECE Regulation No. 13-H.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19364, *Passenger cars — Vehicle dynamic simulation and validation — Steady-state circular driving behaviour*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1176, ISO 2416, ISO 3833, ISO 8855 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

### 3.1

#### **simulation**

calculation of motion variables of a vehicle from equations in a mathematical model of the vehicle system

### 3.2

#### **simulation tool**

*simulation* (3.1) environment including software, model, input data, and hardware in the case of hardware-in-the-loop simulation

### 3.3

#### **electronic stability control system**

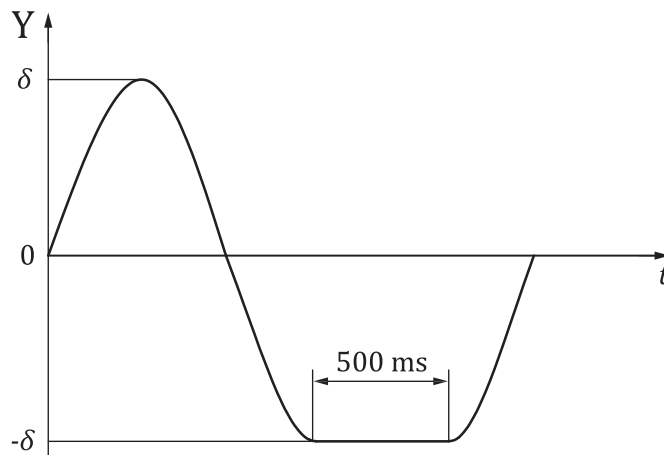
##### **ESC system**

control system that intervenes to maintain directional stability of vehicle and responsiveness on steering input

### 3.4 sine with dwell test

test in which the vehicle is steered by a robot using a steering pattern of a sine wave at a frequency of 0,7 Hz with a delay of 500 ms beginning at the second peak amplitude

Note 1 to entry: See [Figure 1](#).



#### Key

Y steering-wheel angle  
t time

**Figure 1 — Steering-wheel input for a sine with dwell test**

### 3.5 sine with dwell test series

series of *sine with dwell tests* ([3.4](#)) in which the amplitude of the steering pattern is increased with each test

### 3.6 beginning of steer BOS

time at which the steering begins for a *sine with dwell test* ([3.4](#))

### 3.7 completion of steer COS

time at which the steering is completed for a *sine with dwell test* ([3.4](#))

### 3.8 ESC system performance standard

published standard, typically issued by a regulatory organization, that defines *ESC system* ([3.3](#)) performance requirements using a *sine with dwell test* ([3.4](#)) series

Note 1 to entry: For example, UN/ECE Regulation No. 13-H or USA FMVSS 126.

## 4 Principle

A sine with dwell test sequence is used to evaluate the behaviour of a vehicle with ESC. In this sequence, the vehicle is subjected to two series of tests that are run using a steering pattern of sine with dwell as shown in [Figure 1](#). One series uses counterclockwise steering for the first half cycle, and the other series uses clockwise steering for the first half cycle.

Within this document, the purpose of the test is to demonstrate that a simulation tool can predict vehicle behaviour in the sine with dwell test sequence as described in a specific ESC system performance standard.

A comparison is made between measured and simulated behaviour using samples taken at a few specified points during each run, using tolerances specified in this document.

A simulation tool being evaluated for use with the sine with dwell test should first be validated for steady-state circular driving behaviour as specified in ISO 19364. A simulation tool that cannot reproduce steady-turning behaviour should not be considered for use in simulating the sine with dwell response.

## 5 Variables

The following variables shall be measured from the physical testing and obtained from the simulation tool:

- steering-wheel angle;
- yaw rate;
- lateral acceleration.

## 6 Simulation tool requirements

### 6.1 General

The simulation tool used to predict behaviour of a vehicle of interest shall include a mathematical model capable of calculating variables of interest (see [Clause 5](#)) for the test procedures being simulated. In this document, the mathematical model is used to simulate a sine with dwell test series as specified in the ESC system performance standard of interest.

The procedure for obtaining input data from experiments may differ for simulation tools; however, the input data shall not be manipulated for better correlation. However, adaptation of input data to actual testing conditions such as road friction should be allowed.

### 6.2 Mass and inertia

The mathematical model should include all masses, such as the chassis, engine, payloads, unsprung masses, outriggers, etc. The value of the mass, the location of the centre of mass, and moments and products of inertia are essential properties of the vehicle for the tests covered in this document.

Vehicles with significant torsional frame compliance require a more detailed representation that includes frame-twist effects that occur in extreme manoeuvres.

### 6.3 Tires

The vertical, lateral, and longitudinal forces and aligning and overturning moments where each tire contacts the ground provide the main actions on the vehicle. The fidelity of the prediction of vehicle movement depends on the fidelity of the calculated tire forces and moments. Differences between the tire force and moment measurements used for the model and those used in vehicle testing can be expected due to different wear and aging histories. Although difficult to account for these differences, it is important to acknowledge and understand them.

Large lateral slip angles and camber angles can occur under the conditions covered in this document. Large longitudinal slip ratios might be generated as a result of intervention of the ESC. The tire model shall cover the entire range of slip (lateral and longitudinal), inclination angle relative to the ground, and load that occur in the tests being simulated. Note in particular that the tire lateral force reduction at

high slip angles is a critical characteristic that shall be comprehended by the tire testing and modelling. The effect of combined tire lateral and longitudinal slip on forces and moments shall also be modelled.

The surface friction coefficient between the tire and ground is an important property for the limit friction conditions that are typically encountered in a sine with dwell test series.

The simulated tests take place on a flat homogenous surface; detailed tire models that handle uneven surfaces are not needed. If the test surface has inclination for water drainage, this should be included in the simulation.

## 6.4 Suspensions

The properties of the suspensions that determine how the tire is geometrically located, oriented, and loaded against the ground shall be represented properly in order for the tire model to generate the correct tire forces and moments. The suspension properties also determine how active and reactive forces and moments from the tires are transferred to the sprung mass.

The suspension properties should include change of location and orientation of the wheel due to suspension vertical deflection, steering, and compliance due to applied load as would be measured in a physical system in kinematics and compliance (K and C) tests.

The model shall cover the full nonlinear range encountered in the sine with dwell tests for springs, jounce and rebound bumpers, and auxiliary roll moments due to anti-roll bars and other sources of roll stiffness.

Rate-dependent forces such as shock absorbers are significant and should cover the range of suspension jounce and rebound rate encountered in the sine with dwell tests.

## 6.5 Steering system

The steering system interacts with the suspensions to determine how the tire is oriented on the ground.

The sine with dwell test requires that a robot provide steering wheel control. The model should include kinematical and compliance relationships needed to calculate the road wheel angles from the steering-wheel angle.

The model should include the effects of active control systems, if applicable in the sine with dwell tests.

NOTE Because a robot controller provides the steering, the model does not need to predict the associated steering-wheel torque for this document. However, it should be recognized that inadequate steering robot torque capacity can result in steering displacement inputs that do not match the intended displacements. This can be a source of discrepancy between simulation and test results.

## 6.6 Aerodynamics

The model should include aerodynamic effects that influence tire load and overall vehicle drag for speeds up to 80 km/h.

## 6.7 Brake system

The vehicle brake model shall include the actuators and dynamic response properties that affect the interventions generated by the ESC. Accurate prediction of the dynamic interaction of the brake torque and the controls from the ESC, including the sequence of brake torque application, are critical for successful simulation of sine with dwell testing.

## 6.8 Powertrain

In the sine with dwell manoeuvre covered in this document, the vehicle is coasting in the highest gear from an initial speed of 80 km/h. The model should include the drag on the driven wheels, as needed to

replicate this behaviour. Inertial effects that influence the wheel spin dynamics during ESC intervention shall be included.

Other aspects of powertrain behaviour that are important for other kinds of tests (engine power, dynamic responses to throttle, shifting and clutch behaviour) are probably not needed for the coast-down condition of this manoeuvre; however, if a chassis control system engages, then any aspects of the powertrain that influence the controller behaviour shall be included in the powertrain model.

## **6.9 Active control system (ESC system, active roll control, etc.)**

Any electronic control system that engages in the physical vehicle for the sine with dwell manoeuvre covered in this document shall be included in the simulated version. In particular, the representation of the ESC system is critical to the validity of the simulation.

Physical controllers and/or mechanical components may be linked to the simulated vehicle by hardware-in-the-loop.

The control system model shall include actuators that are not already part of the vehicle brake model (see [6.7](#)), transfer delays, and control logic.

The transmission behaviour of the signal quality and the time delay should be included in the model.

## **6.10 Data acquisition**

Procedures for extracting signals from the simulation should mimic the procedures used to obtain signals from the physical vehicle for the variables listed in [Clause 5](#). For example, sensor location, orientation, data processing including filtering, etc. in the simulation should match the physical test setup.

## **6.11 Driver controls**

The simulation tool shall be capable of providing steering control for the sine with dwell test.

# **7 Physical testing**

## **7.1 General**

An existing vehicle of interest shall be tested using the sine with dwell test sequence as defined in the applicable ESC system performance standard. The applicable ESC system performance standard shall be identified in the report.

**NOTE** This document does not define all of the details of the testing procedure; these details are obtained from the applicable ESC system performance standard. This subclause does describe the parts of the test procedure that are typically simulated.

## **7.2 Conditioning the vehicle**

The vehicle is prepared as described in the applicable ESC system performance standard. This involves loading as needed with fuel and ballast, setting tire pressures, possibly installing outriggers to prevent rollover, and other steps covered in published test descriptions. Once equipped, the vehicle is typically exercised to condition the tires and brakes.

## **7.3 Slowly increasing steer tests**

### **7.3.1 Slowly increasing steer procedure**

The vehicle is subjected to two series of runs of the slowly increasing steer test using a constant vehicle speed of  $(80 \pm 2)$  km/h and a steering pattern that increases by  $13,5^\circ/\text{s}$  until a lateral acceleration of

approximately 0,5 g is obtained. Three repetitions are performed for each test series. One series uses counterclockwise steering, and the other series uses clockwise steering.

### 7.3.2 Reference steering wheel angle “A”

The quantity “A” is determined from the slowly increasing steer tests, where “A” is the steering-wheel angle in degrees that produces a steady-state lateral acceleration (corrected using methods specified in the ESC system performance standard) of 0,3 g for the test vehicle. “A” is calculated by linear regression to the nearest 0,1°, from each of the six slowly increasing steer tests. The absolute values of the six “A” values are averaged and the result is rounded to the nearest 0,1° to produce the final quantity, “A”, used below.

## 7.4 Sine with dwell test series

### 7.4.1 Sine with dwell steering pattern

The vehicle is subjected to two series of test runs using a steering pattern of sine with dwell (see [Figure 1](#)). One series uses counterclockwise steering for the first half cycle and the other series uses clockwise steering for the first half cycle.

### 7.4.2 Speed

The steering motion is initiated with the vehicle coasting in high gear at  $(80 \pm 2)$  km/h.

### 7.4.3 Steering amplitude

The steering-wheel angle amplitude for the initial run of each series is 1,5 A, where “A” is the steering-wheel angle determined in [7.3.2](#).

In each series of test runs, the steering amplitude is increased from run to run by 0,5 A, provided that no such run will result in a steering amplitude greater than the final run amplitude specified in [7.4.4](#).

### 7.4.4 Steering amplitude for final runs in a series

The steering-wheel angle amplitude of the final run in each series is the greater of 6,5 A or 270°, provided the calculated magnitude of 6,5 A is less than or equal to 300°. If any 0,5 A increment, up to 6,5 A, is greater than 300°, the steering amplitude of the final run shall be 300°.

## 7.5 Data processing

### 7.5.1 Filtering and conditioning

Raw measurements of steering-wheel angle, steering-wheel rate, yaw rate, and lateral acceleration shall be filtered and conditioned as specified in the applicable ESC system performance standard.

### 7.5.2 Lateral displacement

The lateral displacement of the vehicle centre of gravity with respect to its initial straight path is obtained by double-integrating the lateral acceleration signal measured by a transducer located near the vehicle centre of gravity.

### 7.5.3 ESC system intervention

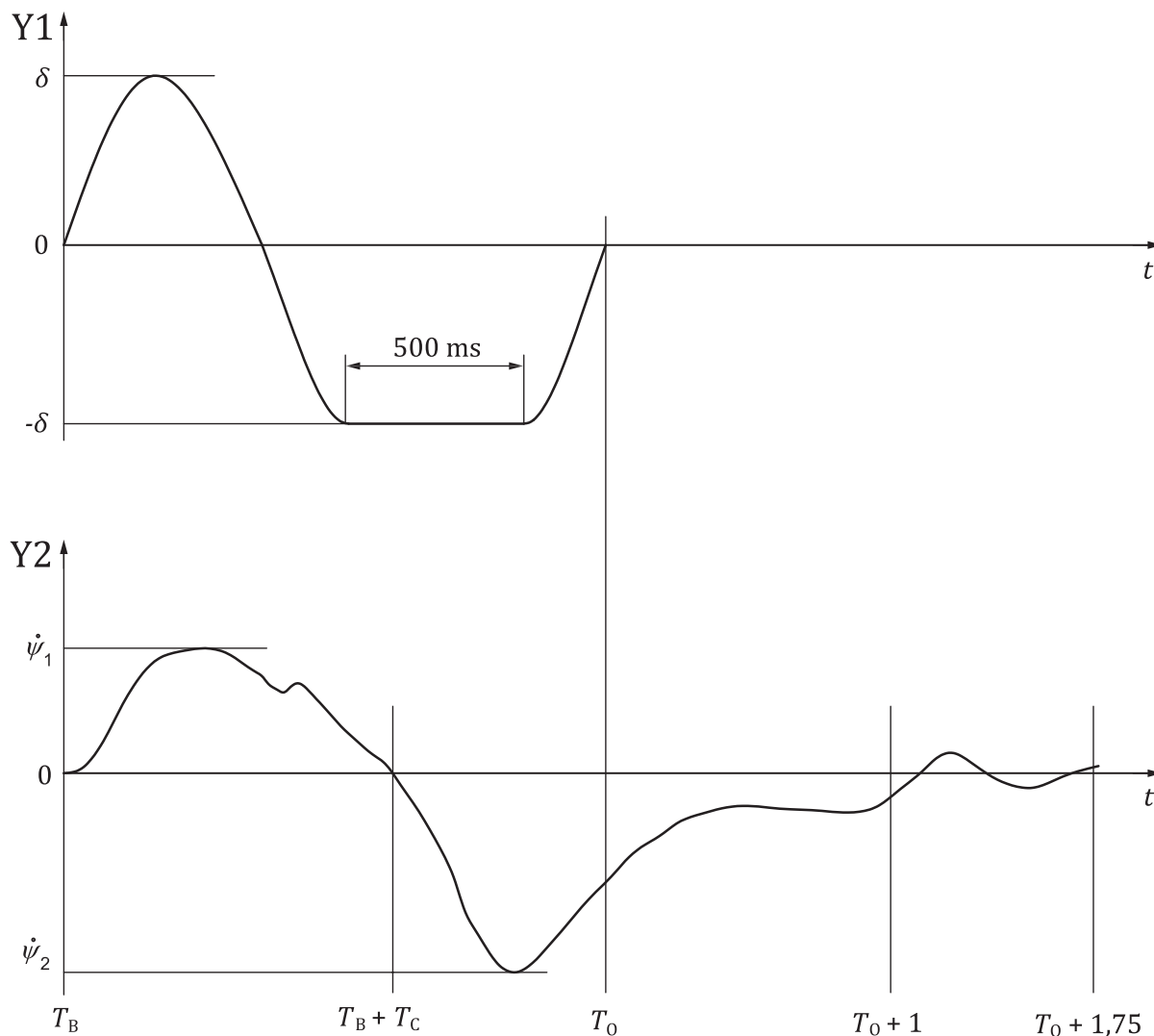
In each sine with dwell test, it shall be noted whether the ESC intervenes.

## 7.6 Performance requirements

### 7.6.1 Stability criteria

During each sine with dwell test, the vehicle shall satisfy the following two directional stability criteria, as specified in the applicable ESC system performance standard.

- a) The value of yaw rate measured 1 second after the COS time shall not exceed 35 % of the value of the first peak value of yaw rate recorded after the steering-wheel angle changes sign ( $\dot{\psi}_2$  in [Figure 2](#)).
- b) The value of yaw rate measured 1,75 seconds after the COS time shall not exceed 20 % of the value of the first peak value of yaw rate recorded after the steering-wheel angle changes sign ( $\dot{\psi}_2$  in [Figure 2](#)).



- Key**
- Y1 steering-wheel angle
  - Y2 yaw rate
  - $t$  time
  - $T_B$  beginning of steer (BOS)
  - $T_0$  completion of steer (COS)
  - $T_B + T_C$  zero crossing for yaw rate

**Figure 2 — Relationship between yaw rate information and sine with dwell steering-wheel angle input**

### 7.6.2 Responsiveness criterion

During each sine with dwell test, the lateral displacement of the vehicle centre of gravity with respect to its initial straight path, computed 1,07 seconds after the BOS time, shall meet the requirement of the applicable ESC system performance standard.



## 8 Simulation

### 8.1 Limits on the simulated procedure

The simulation tool shall be configured to simulate the sine with dwell test series described in [7.4](#). Because the computer simulations are not sensitive to some factors of interest in physical testing, not all of the details specified in the ESC system performance standard apply.

Actions taken to prepare a physical vehicle for testing, such as checking tire pressures, driving manoeuvres to warm up the tires and brakes, and so on, might not be needed for the simulation tool.

### 8.2 Slowly increasing steer tests

For the purpose of this document, the same steering-wheel angle inputs are used for both simulation and physical testing.

The reference steering-wheel angle amplitude “A” may be obtained from the physical testing results or from simulation of the slowly increasing steer test. In either case, the same amplitude “A” shall be used for both simulation and physical tests in the sine with dwell series described in [7.4](#).

### 8.3 Sine with dwell test series

The sine with dwell test series described in [7.4](#) is simulated.

### 8.4 Data processing

#### 8.4.1 Filtering and conditioning

Time histories of the variables of interest (see [Clause 5](#)) should be filtered in the same manner as the measured signals.

NOTE ESC system performance standards typically specify phaseless low-pass filtering to reduce measurement noise yet not disturb the phase relationships between the measured variables. Time histories of the variables of interest from simulation are typically not subject to measurement noise, and therefore, the filtering and conditioning specified in the ESC system performance standard might not be necessary.

#### 8.4.2 Lateral displacement

The lateral displacement of the vehicle centre of gravity with respect to its initial straight path is obtained by double-integrating the lateral acceleration of the vehicle centre of gravity, corresponding to the signal defined for the test data in [7.5.2](#).

Vehicle simulation tools can typically provide the lateral coordinate of the vehicle centre of gravity without errors introduced by the approximations underlying the double-integration method specified in ESC system performance standard. However, for the purpose of simulation validation, the same definition of lateral displacement shall be used for test and simulation data.

## 9 Comparison between simulation and physical test results

### 9.1 Steady state turning validation

A simulation tool being evaluated for simulating tests specified in the ESC system performance standard shall also be validated for steady-state circular driving behaviour using the cross plots of steering-wheel angle, side slip angle, and roll angle versus lateral acceleration, as specified in ISO 19364. A tool that cannot reproduce steady-turning behaviour shall not be considered for use in simulating response for an ESC system performance standard.

## 9.2 Metrics from a sine with dwell series

### 9.2.1 General

The comparisons provided in this document can extend the validation to include the transient behaviour seen in the sine with dwell test. The simulation and physical test results are compared on the basis of values of variables recorded at the specific conditions described in [7.4](#), [7.5](#), [8.3](#) and [8.4](#).

### 9.2.2 Number of first test run in which ESC intervention occurs

The number of the first run in each of the two series of sine with dwell test runs (see [7.4](#)) in which ESC intervention occurs for the physical testing shall match the corresponding number for the first run in the simulated series in which ESC intervention occurs, with a tolerance of  $\pm 1$  test run number.

**NOTE** Conditions that lead to an ESC intervention are sensitive to test conditions that are not fully repeatable (speed, vibrations, wind, etc.), such that the first run in which intervention occurs can differ with repeated series of test runs. Agreement between the simulation and the physical testing is not expected to be better than the agreement between repeated series of physical test runs; therefore, first runs in which ESC intervention occurs may differ between a series of simulations and physical tests.

### 9.2.3 Test runs used for comparison

#### 9.2.3.1 General

Metrics from the physical testing shall be compared to the corresponding metrics obtained from simulation for three of the test runs for each direction.

#### 9.2.3.2 Last run without ESC intervention

Metrics are compared for the last run without intervention in both physical testing and simulation.

For example, if the first intervention in the series of physical test runs with initial counterclockwise steering occurs in the fourth run, and the first intervention in the simulated series occurs in the fifth run, then metrics shall be compared for the third run from each series.

#### 9.2.3.3 First run with ESC intervention

Metrics are compared for the first run after intervention in both physical testing and simulation.

For example, if the first intervention in the series of physical test runs with initial counterclockwise steering occurs in the fourth run, and the first intervention in the simulated series occurs in the fifth run, then metrics shall be compared for the fifth run from each series.

#### 9.2.3.4 Last run

Metrics are compared for the last run from each series.

### 9.2.4 Metric definitions and tolerances

#### 9.2.4.1 General

Metrics obtained from the physical tests shall be subtracted from the corresponding metrics from the simulated tests. Those differences shall be compared to the tolerances listed in [Table 1](#). The metrics named in the table are defined below.

**Table 1 — Tolerances allowed between metrics obtained from physical testing and simulation**

Metric	Test run	Tolerance
First peak yaw rate ( $\dot{\psi}_1$ in <a href="#">Figure 2</a> )	Last run without ESC intervention	±15 %
	First run with ESC intervention	
	Last run	
Time of yaw rate crossing zero ( $T_C$ in <a href="#">Figure 2</a> )	Last run without ESC intervention	±0,1 s
	First run with ESC intervention	
	Last run	
Second peak yaw rate ( $\dot{\psi}_2$ in <a href="#">Figure 2</a> )	Last run without ESC intervention	±20 %
	First run with ESC intervention	±25 %
	Last run	±25 %
Lateral displacement of the vehicle C.G.	Last run without ESC intervention	±15 %
	First run with ESC intervention	±18 %
	Last run	±18 %

#### 9.2.4.2 First peak yaw rate

The first peak yaw rate ( $\dot{\psi}_1$  in [Figure 2](#)) is the first metric. The same tolerance is used for all three runs.

#### 9.2.4.3 Time of yaw rate crossing zero

The value of the time of yaw rate crossing zero  $T_C$  after the BOS time is the second metric. The same tolerance is used for all three runs.

#### 9.2.4.4 Second peak yaw rate

The second peak yaw rate from testing ( $\dot{\psi}_2$  in [Figure 2](#)) is the third metric. [Table 1](#) shows that a tighter tolerance is used for the run without ESC intervention.

#### 9.2.4.5 Lateral displacement of the vehicle centre of gravity

In those test runs in which the lateral displacement of the vehicle centre of gravity with respect to its initial straight path is required by the applicable ESC performance standard to reach a specified level, the lateral displacement as determined from the test is used as the fourth metric. [Table 1](#) shows that a tighter tolerance is used for the run without ESC intervention.

### 9.3 Validation of the simulation tool

If the number of the first test in each series in which ESC intervention occurs for the physical testing matches the corresponding number for the first test in the simulated series ±1 as specified in [9.2.2](#), and the conditions specified in [9.2.4](#) are met for the three tests used for comparison (see [9.2.3](#)), then the simulation tool is considered valid for representing vehicle behaviour in the sine with dwell test.

## 10 Documentation

The ESC system performance standard that defines details of the test series shall be identified. If driver can select a control mode for any active intervention system, the selected mode shall be reported.

The simulation should be documented to the extent needed to reproduce the simulated tests. This should include names of software tools, including version numbers, and internal model names. A list of files used to run the simulation shall be provided, and copies of the files shall be archived.

## Bibliography

- [1] ISO 1176, *Road vehicles — Masses — Vocabulary and codes*
- [2] ISO 2416, *Passenger cars — Mass distribution*
- [3] ISO 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*
- [4] ISO 15037-1, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*
- [5] US DEPARTMENT OF TRANSPORTATION, NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION. FMVSS 126 Electronic Stability Control Systems. *Fed. Regist.* 2007 April 6, **72** (66)
- [6] UN/ECE Regulation No. 13-H, “Uniform provisions concerning the approval of passenger cars with regard to braking”
- [7] ISO 3833, *Road vehicles — Types — Terms and definitions*







# British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

## About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards-based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

## Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at [bsigroup.com/standards](http://bsigroup.com/standards) or contacting our Customer Services team or Knowledge Centre.

## Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at [bsigroup.com/shop](http://bsigroup.com/shop), where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

## Copyright in BSI publications

All the content in BSI publications, including British Standards, is the property of and copyrighted by BSI or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use.

Save for the provisions below, you may not transfer, share or disseminate any portion of the standard to any other person. You may not adapt, distribute, commercially exploit, or publicly display the standard or any portion thereof in any manner whatsoever without BSI's prior written consent.

## Storing and using standards

Standards purchased in soft copy format:

- A British Standard purchased in soft copy format is licensed to a sole named user for personal or internal company use only.
- The standard may be stored on more than 1 device provided that it is accessible by the sole named user only and that only 1 copy is accessed at any one time.
- A single paper copy may be printed for personal or internal company use only.

Standards purchased in hard copy format:

- A British Standard purchased in hard copy format is for personal or internal company use only.
- It may not be further reproduced – in any format – to create an additional copy. This includes scanning of the document.

If you need more than 1 copy of the document, or if you wish to share the document on an internal network, you can save money by choosing a subscription product (see 'Subscriptions').

## Reproducing extracts

For permission to reproduce content from BSI publications contact the BSI Copyright & Licensing team.

## Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to [bsigroup.com/subscriptions](http://bsigroup.com/subscriptions).

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

**PLUS** is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit [bsigroup.com/shop](http://bsigroup.com/shop).

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email [subscriptions@bsigroup.com](mailto:subscriptions@bsigroup.com).

## Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

## Useful Contacts

### Customer Services

**Tel:** +44 345 086 9001

**Email (orders):** [orders@bsigroup.com](mailto:orders@bsigroup.com)

**Email (enquiries):** [cservices@bsigroup.com](mailto:cservices@bsigroup.com)

### Subscriptions

**Tel:** +44 345 086 9001

**Email:** [subscriptions@bsigroup.com](mailto:subscriptions@bsigroup.com)

### Knowledge Centre

**Tel:** +44 20 8996 7004

**Email:** [knowledgecentre@bsigroup.com](mailto:knowledgecentre@bsigroup.com)

### Copyright & Licensing

**Tel:** +44 20 8996 7070

**Email:** [copyright@bsigroup.com](mailto:copyright@bsigroup.com)

### BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK