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Passenger cars — Simulation model classification —

Part 1: Vehicle dynamics

Voitures particulières — Classification des modèles de simulation —

Partie 1: Dynamique du véhicule

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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).

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For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

A list of all parts in the ISO 11010 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

This document has been developed in response to worldwide demand for the standardization of simulation models and their requirements for use in specific applications and driving manoeuvres. During the development and testing of road vehicles questions arise around which simulation models should be applied and how well matched they need to be for performing certain applications with related driving manoeuvres. In the absence of standards it is common practice that experts in different organizations develop their own methods and processes as response to these questions. This causes obstacles when it comes to comparability and model exchange between project partners. Currently, unless the requirements for simulation models undergo extensive elaboration and coordination among the experts involved, there will be major uncertainty with their implementation and quality.

The main purpose of this document is to provide a framework that enables a systematic assignment of certain applications and driving manoeuvres to suitable simulation models and their elements and characteristics. This document classifies the simulation models into certain model classes, their designation number and related elements, characteristics and common modelling method. Assigning models to classes related to specific applications is the responsibility of the user or other regulations and standards. This document contains recommendations in the sense of an appropriate simulation quality in terms of performance tests, thus enabling the user to specify the requirements for the models with reference to this document. This document thus also creates the basis for model recommendations relevant to vehicle dynamics with regard to advanced driver assistance systems and automated driving (ADAS/AD)[19].

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Passenger cars — Simulation model classification —

Part 1: Vehicle dynamics

1 Scope

A systematic framework has been created that facilitates the definition of the requirements of simulation models for certain applications and driving manoeuvres in a standardized manner.

For this purpose, the proposed framework systematically divides the vehicle model into model classes and all model classes into different model types, corresponding to various model characteristics and common modelling methods. The vehicle dynamics manoeuvres have been additionally structured and clustered. Manoeuvres can be assigned to model classes and model types using an allocation and requirements table. This document thus also creates the basis for model recommendations relevant to vehicle dynamics with regard to advanced driver assistance systems and automated driving (ADAS/AD).

The application of the framework and the specification of the model requirements are the responsibility of the user. Alternatively, they may be determined by other regulations and standards. This document contains recommendations for selectable model characteristics in terms of adequate simulation quality with respect to performance tests and associated application patterns. The recommendations can be adapted accordingly to be applied to functional testing.

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 3833, *Road vehicles — Types — Terms and definitions*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
simulation model
mathematical model for the calculation of the system state variables based on equations describing a vehicle or vehicle sub-system

Note 1 to entry: The vehicle's environment is only modelled as far as required, i.e. friction of the road surface, wind, etc. Models in this context are both, the unit under test (UuT) as well as models to supplement or complete the simulation loop.

3.2
model class
mathematical model based on the vehicle or vehicle sub-systems

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3.3
model designation number
gradation of model type and depth with associated model characteristics, represented effects and minimal model inputs and outputs

3.4
steady state model
physical model representing the definitions of steady state equilibrium mentioned in ISO 8855

Note 1 to entry: The model represents the transfer function between model input and output for steady-state equilibrium. The model is not capable of representing the correct time behaviour. Effects caused through small changes in time may be neglected. The model is usually mathematically described by a gain.

3.5
first order model
model, in addition to the *steady state model* (3.4), capable of representing the transient behaviour

Note 1 to entry: The physical model is usually described mathematically by a differential equation with a first order lag force element such as PT1 behaviour with a first order.

3.6
second order model
model defined by a second order force element such as PT2 behaviour with second order

Note 1 to entry: Due to its conjunct complex poles, a time variant input results in an oscillatory output.

3.7
model-in-the-loop
MiL
testing method in which the controller is integrated as a unit under test (UuT) with a *full-function controller* (3.12) into the *simulation model* (3.1) as a controller model

3.8
software-in-the-loop
SiL
testing method whereby the controller is integrated as a UuT with complete controller functionality as application software from the ECU into the *simulation model* (3.1)

Note 1 to entry: See Figure 1.

3.9
processor-in-the-loop
PiL
testing method whereby the controller together with processor emulation is integrated as UuT into the *simulation model* (3.1)

3.10
open-loop control
controller that influences a system's behaviour without a feedback loop, for example based on maps

3.11
principal logic closed-loop controller
controller that influences a system's behaviour with a feedback loop

Note 1 to entry: For principal logic, the controller is implemented in a simplified form, for example, with a PID controller, to demonstrate the control logic.

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3.12
full-function controller
controller that is implemented with complete functionality, but with operation restricted to the function control algorithm under test

Note 1 to entry: The controller is realized as either *MiL* (3.7) or *SiL* (3.8).

3.13
ECU-in-the-loop
test method whereby the controller is integrated as a UuT into the *simulation model* (3.1) as a real ECU (Figure 1)

Note 1 to entry: In this document it refers primarily to the controller. The controller is typically implemented in hardware-in-the-loop (HiL).

3.14
full-function virtual ECU
vECU
controller that is implemented as a UuT with the whole ECU software with application and base software (Figure 1)

Note 1 to entry: The controller is realized virtually via emulation in SiL mode. Full-function architecture means software modules such as AUTOSAR connect the virtual ECU to the vehicle's communication network.

3.15
electric brake booster
brake booster that has the ability to amplify the braking force applied by the driver through electrical actuation and autonomously build up pressure without driver actuation

Note 1 to entry: Electric brake boosters consist of a control unit, electric actuator and transmission device [20].

4 Model designation numbers

4.1 General

Each model class may consist of a physical system, including hydraulics and pneumatics, and a controller. This segmentation can be extended to sensor and actuator.

4.2 Physical system

The model of a physical system shall have a model designation number from Table 1, according to the definitions in Clause 3. The force element characteristic ranges from level 0 – no model – to level 3 – second order model and within the sub-designation levels 1.x to 3.x. If a model requires a deeper sub-categorization, the dot notation and a second digit starting from 1 shall be used.

NOTE The model designation numbers are valid for all vehicle sub-systems from 5.1 except the suspension model, since its designation numbers 1 and 2 lack body masses. Nevertheless, the suspension model designation numbers are adapted reasonably.

Table 1 — Model characteristic and designation number of a physical system

Force element characteristic	Model designation number
None	0
Steady state model	1
First order model	2
Second order model	3

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