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## Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

### Part 3: Mechanical loads

*Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique —  
Partie 3: Contraintes mécaniques*

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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](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 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](http://www.iso.org/iso/foreword.html).

ISO/EDIS 16750-3

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

This fourth edition cancels and replaces the third edition (ISO 16750-3:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

- Integrating and harmonizing content from ISO 19453-3:2018;
- Distinction between small and lightweight versus large and heavy DUTs;
- Revising vibration profiles where necessary due to extended datasets of and experience from vehicle measurements;
- New vibration test for rotating machines on combustion engines and Annex C;
- New vibration tests for hybrid-electric/fully-electric commercial vehicles;
- Guided fall test description and Annex D;
- Annex E as guidance for 3D shaker testing;
- Test order appearing in the document has been changed for a logical grouping depending on test type, however test numbers have been kept for backwards compatibility.

A list of all parts in the ISO 16750 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](http://www.iso.org/members.html).

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# Road vehicles — Environmental conditions and testing for electrical and electronic equipment— Part 3: Mechanical loads

## 1 Scope

This document applies to electric and electronic systems and components for vehicles including electric propulsion systems and components with maximum working voltages according to voltage class B. It describes the potential environmental stresses and specifies tests and requirements recommended for the specific mounting location on/in the vehicle.

This document describes mechanical loads.

This document is not intended to apply to environmental requirements or testing for systems and components of motorcycles and mopeds.

Systems and their components for production, or systems and their components already under development prior to the publication date of this document, can be exempted from fulfilling the changes in this edition compared to the previous one.

## 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 16750-1:2023, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 16750-4:2023, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment— Part 4: Climatic loads*

IEC 60068-2-6, *Environmental testing — Part 2-6: Testing, Test Fc: Vibration (Sinusoidal)*

IEC 60068-2-14, *Environmental testing — Part 2-14: Tests — Test N: Change of temperature*

IEC 60068-2-27, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

IEC 60068-2-31, *Environmental testing — Part 2-31: Tests — Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-47:2005, *Environmental testing - Part 2-47: Test - Mounting of specimens for vibration, impact and similar dynamic tests*

- 31 IEC 60068-2-64, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and*  
32 *guidance*
- 33 IEC 60068-2-80, *Environmental testing — Part 2-80: Tests — Test Fi: Vibration — Mixed mode*
- 34 UL 969, *Standard for Marking and Labeling Systems*, 5th edition, 2017
- 35 ISO 20567-1:2017, *Paints and varnishes — Determination of stone-chip resistance of coatings — Part 1:*  
36 *Multi-impact testing*

37

### 38 **3 Terms and definitions**

- 39 For the purposes of this document, the terms and definitions given in ISO 16750-1 apply.
- 40 ISO and IEC maintain terminology databases for use in standardization at the following addresses:
- 41 — ISO Online browsing platform: available at <https://www.iso.org/obp>
- 42 — IEC Electropedia: available at <https://www.electropedia.org/>

43

### 44 **4 Tests and requirements**

#### 45 **4.1 Vibration**

##### 46 **4.1.1 Testing conditions during the vibration test**

###### 47 **4.1.1.1 General**

48 The vibration test methods specified consider various levels of vibration severities applicable to on-  
49 board electrical and electronic equipment. The customer and the supplier should choose the test  
50 method, environmental temperature and vibration parameters depending on the specific mounting  
51 location.

52 A clear dependence of the typical vibration load on the size and mass of the DUT is evident from vehicle  
53 measurements. This applies to all mounting locations due to dynamic system coupling. That is why in  
54 this document a distinction is made between small and lightweight E/E components (typically < 2 kg,  
55 unless stated otherwise in the individual test description, e.g. sensors, ECUs or fuel injection  
56 equipment), mostly belonging but not limited to ICE vehicles, and much larger and heavier components  
57 (typically ≥ 2 kg, unless stated otherwise in the individual test description, e.g. electric motors, inverters,  
58 DC/DC converters or alternators), mostly belonging but not limited to electric powertrains in electric  
59 propulsion vehicles. In each application the applicability of the intended vibration profile should be  
60 verified with a vehicle measurement. See a mass classification example in ISO 16750-1:—<sup>1</sup>, Annex C. For  
61 further information and guidance please refer to Table 38 (code letters).

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<sup>1</sup> Fourth edition under preparation. Stage at the time of publication: ISO/DIS 16750-1:2022.

62 The following basic idea of environmental test methods is expressed in Reference [4], Foreword.

63 When applied properly, the environmental management and engineering processes described in this  
64 document can be of enormous value in generating confidence in the environmental worthiness and  
65 overall durability. However, it is important to recognize that limitations inherent in laboratory testing  
66 make it imperative to use proper caution and engineering judgment when extrapolating these  
67 laboratory results to results that can be obtained under actual service conditions. In many cases, real  
68 world environmental stresses (singularly or in combination) cannot be duplicated practically or reliably  
69 in test laboratories. Therefore, users of this document should not assume that a system or component  
70 that passes laboratory tests of this document would also pass field/fleet verification trials.

71 The specified values are the best estimation that can be obtained up to the moment when results from  
72 measurements in the vehicle are received, but they do not replace a vehicle measurement.

73 The specified values apply to direct mounting in defined mounting locations. The specified vibration  
74 profiles apply to direct mounting in defined mounting locations. Since the use of an installation support  
75 (e.g. mounting bracket) can influence test vibration loads on the shaker to be much higher or much  
76 lower than actual vehicle loads, in principle, each vibration test should be carried out with only DUT  
77 itself. If using an installation support, the applied loads on the shaker should be checked to reproduce  
78 the actual vehicle loads as realistically as possible.

79 Carry out the vibration with the DUT rigidly mounted on a vibration table for reasons of comparability  
80 and reproducibility (see also clauses 5 and 6 in IEC 60068-2-47:2005). If using a bracket is technically  
81 unavoidable in order to fix the DUT to the shaker instead of a rigid mounting, then the transfer  
82 functions from the excitation to the DUT compared to vehicle measurements as well as a proper control  
83 strategy shall be considered. For further information refer to A.3. The mounting method(s) used shall  
84 be noted in the test report. The scope of the recommended vibration tests is to avoid malfunctions and  
85 breakage mainly due to fatigue in the field. Testing for wear has special requirements and is not covered  
86 in this document.

87 If active operation and/or signal monitoring is applied during the test, extra care shall be taken with  
88 respect to the fixation of the power cables and the wiring harnesses. This aims at avoiding signal  
89 disturbances and negative mechanical impact on the connector, caused by dynamic motion of the  
90 harness itself. The routing, rigidity, mass and fixation of wire harness in vehicle installation should also  
91 be considered when deciding on the fixation of wire harness in a test setup in order to avoid a wrong  
92 testing load for the DUT.

93 Loads outside the designated test frequency ranges can be considered separately if agreed between the  
94 customer and the supplier. If it is known that resonance frequencies of the DUT are present that are  
95 critical for fatigue and are not covered by the test frequency ranges, then it is recommended to perform  
96 separate durability tests, such as resonance dwell testing.

97 NOTE Deviations from the load on the DUT can occur if vibration testing is carried out according to this  
98 document on a heavy and bulky DUT, as mounting rigidity and dynamic reaction on the vibrator table excitation  
99 are different compared to the situation in the vehicle. Such deviations can be minimized by applying the average  
100 control method (see A.3).

101 The application of the weighted average control method in accordance with IEC 60068-2-64 may be  
102 agreed upon.

103

104 **4.1.1.2 Overlaid temperature cycles during vibration testing**105 **4.1.1.2.1 General**

106 Vibration tests are typically run with an overlaid temperature cycle. The intention is not to create  
107 additional aging of the DUTs but to induce a temperature-dependent dynamic response of or within the  
108 DUT that might otherwise not occur if only tested at room temperature.

109 In the vehicle, vibration stress can occur together at low or high temperatures; for this reason, this  
110 interaction between mechanical and temperature stress is simulated in the test, too. A failure  
111 mechanism occurs when material characteristics of components change and cannot withstand the  
112 acceleration under this condition. For example, a plastic part may mellow due to the high temperature.

113 The mass of the DUT as well as the installation area are the main influence factors that determine the  
114 design of the temperature cycle which is why in the following clauses the different use cases are  
115 distinguished.

116 For longer test durations of the vibration test the test cycles can be either repeated for a sufficient  
117 number of times or stretched to fit the test duration. None of the following temperature cycles shall be  
118 further compressed in their duration, otherwise a temperature equilibrium within the DUT might not  
119 be ensured.

120 Depending on the failure mode of the DUT, a deviating temperature profile may be used if agreed  
121 between the customer and the supplier.

122 Intentional humidity control is not permitted even if water condensation on the DUT occurs during  
123 temperature cycles.

124

125 **4.1.1.2.2 Temperature profile for small and lightweight components not mounted on the**  
126 **combustion engine**

127 During the vibration test, for small and lightweight DUT not mounted on the combustion engine,  
128 perform the temperature cycling in accordance with IEC 60068-2-14, Test Nb, not using its specified  
129 temperature changing rates, using the variant given in Figure 1 and Table 1.

130 NOTE 1 This temperature profile can also be applied to small and lightweight components mounted on electric  
131 drive systems or components.

132 Perform temperature cycling with the following as one cycle. Decrease ambient temperature from RT to  
133  $T_{\min}$ , expose the DUT at  $T_{\min}$ , increase ambient temperature from  $T_{\min}$  to  $T_{\max}$ , expose the DUT at  $T_{\max}$  and  
134 decrease ambient temperature from  $T_{\max}$  to RT (see Figure 1).

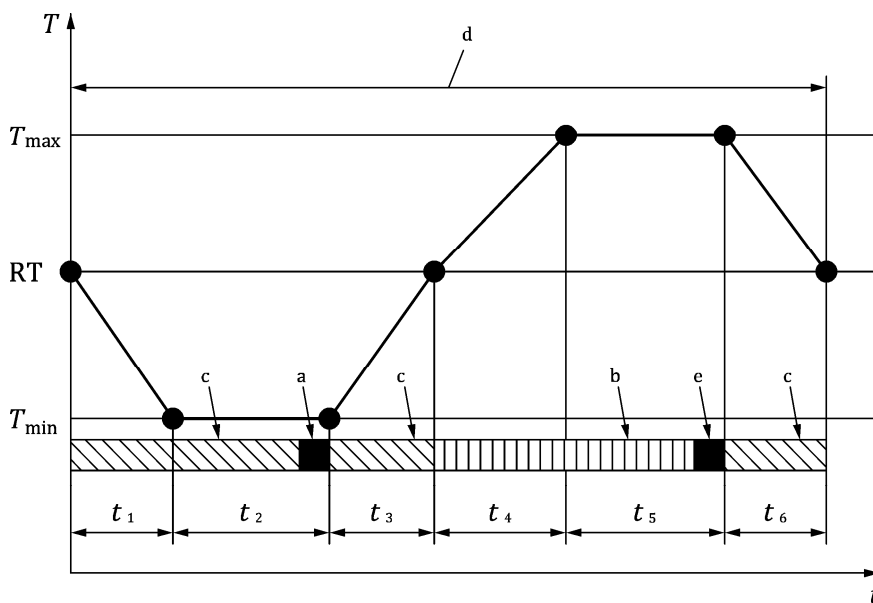
135 Perform a functional test at the end of  $T_{\min}$  and  $T_{\max}$  as short as possible with operating mode 3.3 or 4.3  
136 as defined in ISO 16750-1 (see key "a" in Figure 1). In addition, operate with operating mode 3.4 or 4.4  
137 as defined in ISO 16750-1 (see key "b" in Figure 1) during the section from room temperature (RT) to  
138  $T_{\max}$ . During the other sections, operate with operating mode 2.1 as defined in ISO 16750-1 (see key "c"  
139 in Figure 1). If operating mode 4.3/4.4 is not technically feasible, operating mode 3.3/3.4 may be used if  
140 agreed between the customer and the supplier.

141

142 NOTE 2 A permanent operation starting at  $T_{\min}$  prevents possible condensation of humidity on DUT because the  
143 self-heating of the DUT occurs. An electrical operation starting at RT allows this phenomenon.

144 NOTE 3 Condensation can lead to swelling of plastic sub-components of the DUT and therefore, influence the  
 145 dynamic behaviour under vibrational load.

146



147

148

**Key**

- $T$  temperature
- $t$  time [min]
- $T_{min}$  minimum operating temperature as defined in ISO 16750-4
- $T_{max}$  maximum operating temperature as defined in ISO 16750-4
- RT room temperature as defined in ISO 16750-1
- $t_1, t_2, t_3, t_4, t_5, t_6$  time parameter as defined in Table 1
- a Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
- b Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
- c Operating mode 2.1 as defined in ISO 16750-1.
- d One cycle.
- e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

149

150

**Figure 1 - Temperature cycle with specified change rate for the vibration test of a small and lightweight DUT**

151

152

153

**Table 1 - Temperatures versus time duration for temperature cycling for the vibration test of a small and lightweight DUT**

| Parameter | Duration<br>min | Temperature<br>°C          |
|-----------|-----------------|----------------------------|
| $t_1$     | 60              | From RT to $T_{min}$       |
| $t_2$     | 90              | Exposure time at $T_{min}$ |
| $t_3$     | 60              | From $T_{min}$ to RT       |
| $t_4$     | 90              | From RT to $T_{max}$       |

|   |     |                             |
|---|-----|-----------------------------|
| $t_5$   | 110 | Exposure time at $T_{\max}$ |
| $t_6$   | 70  | From $T_{\max}$ to RT       |
| NOTE $T_{\min}$ and $T_{\max}$ are defined in ISO 16750-4:— <sup>2</sup> , Table 1. |     |                             |

154

155 **4.1.1.2.3 Temperature profile for large and heavy components not mounted on the combustion**  
 156 **engine**

157 During the vibration test, for large and heavy DUT not mounted on the combustion engine, perform the  
 158 temperature cycling in accordance with IEC 60068-2-14, Test Nb, not using its specified temperature  
 159 changing rates, using the variant given in

e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

160 Figure 2 and Table 2.

161 Perform temperature cycling with the following as one cycle. Decrease ambient temperature from RT to  
 162  $T_{\min}$ , expose the DUT at  $T_{\min}$ , increase ambient temperature from  $T_{\min}$  to  $T_{\max}$ , expose the DUT at  $T_{\max}$  and  
 163 decrease ambient temperature from  $T_{\max}$  to RT (see

e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

164 Figure 2).

165 Before performing this test, a separate temperature measurement (with DUT in operating mode 2.1 as  
 166 defined in ISO 16750-1) shall be performed to determine what exposure time at  $T_{\max}$ ,  $T_{\min}$  (see

e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

167 Figure 2) is necessary to warrant that this desired temperature is also reached in DUT temperature. The  
 168 measuring point of the DUT shall be agreed between the customer and the supplier, considering a target  
 169 device (e.g. microprocessor, motor coil) which is temperature-influenced in functionality or  
 170 performance.

171 If operating mode 2.1 is technically not feasible for the separate temperature measurement, operating  
 172 mode 1.2 as defined in ISO 16750-1, can be used as agreed between the customer and the supplier.

173 Measures regarding the functional performance, for example, de-rating of the e-motor, are allowed to  
 174 avoid overheating of the DUT during high-temperature operation with self-heating effects.

175 The dwell time  $t_x$  of the DUT at  $T_{\min}$  and  $T_{\max}$  shall be more than 30 min each per temperature cycle;  
 176 therefore, exposure time shall be adjusted accordingly depending on the size and other characteristics  
 177 of the DUT. The customer and the supplier shall agree on a complete profile of temperature cycle  
 178 including dwell time and stabilisation time depending on the size and other properties of the DUT.

179 NOTE This temperature profile can also be applied to large and heavy components mounted on electric drive  
 180 systems or components.

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<sup>2</sup> Fourth edition under preparation. Stage at the time of publication: ISO/DIS 16750-4:2022.

181 Perform a functional test at the end of  $T_{\min}$  and  $T_{\max}$  as short as possible with operating mode 3.3 or 4.3  
 182 as defined in ISO 16750-1 (see key “a” in

e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

183 Figure 2). In addition, operate with operating mode 3.4 or 4.4 as defined in ISO 16750-1 (see key “b” in

e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

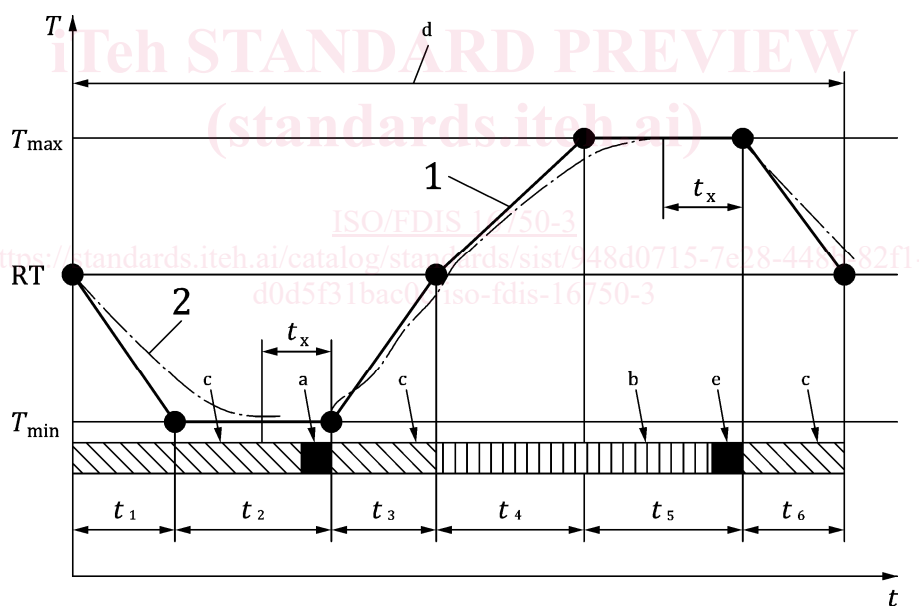
184 Figure 2) during the section from room temperature (RT) to  $T_{\max}$ . During the other sections, operate  
 185 with operating mode 2.1 as defined in ISO 16750-1 (see key “c” in

e Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

186 Figure 2). If operating mode 4.3/4.4 is not technically feasible, operating mode 3.3/3.4 may be used if  
 187 agreed between the customer and the supplier. For electric motors, active operation in operation mode  
 188 3.3 or 4.3 instead of 2.1 can be performed in order to avoid unrealistic failure mechanism, e.g. wear in  
 189 the bearing of an e-motor due to the vibration input.

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193 Key

- $T$  temperature
- $t$  time
- 1 ambient temperature
- 2 DUT temperature, exemplary for non-heat dissipating DUTs
- $T_{\min}$  minimum operating temperature as defined in ISO 16750-4
- $T_{\max}$  maximum operating temperature as defined in ISO 16750-4
- RT room temperature as defined in ISO 16750-1
- $t_1, t_2, t_3, t_4, t_5, t_6$  time parameter as defined in Table 2
- $t_x$  dwell time at  $T_{\min}$  or  $T_{\max}$