INTERNATIONAL STANDARD

ISO 16750-2

Fifth edition
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Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 2:
Electrical loads

Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique —

Partie 2: Contraintes électriques

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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 document 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 32, *Electrical and electronic components and general system aspects*.

This fifth edition cancels and replaces the fourth edition (ISO 16750-2:2012), which has been technically revised.

The main changes are as follows:

— introduction of use of operating mode for the electrical tests;

— introduction of concept with redundant supplies for relevant test cases;

— more detailed specification of direct current supply voltage test;

— more detailed specification of jump start test (overvoltage test at RT);

— introduction of transient overvoltage test;

— complete update of superimposed alternating voltage test (e.g. updated test method, extension of frequency range to 200 kHz, etc.);

— more detailed specification of slow decrease and increase of supply voltage test;

— introduction of micro interruption in supply voltage test;

— more detailed specification of reset behaviour at voltage drop test;

— explanation of severity levels in starting profile test;

— more detailed specification of reversed voltage test;

— more detailed specification of ground reference and supply offset test;

— single line interruption test divided in two test cases; static interruption (single interruption event) and dynamic interruption (multiple interruption events, i.e. bursts);

— short circuit protection test changed to short circuit/overload protection test. more detailed specification on test cases. Introduction of test case overloading of load circuits;

— more detailed description of origin of load dump pulse in Annex B;

— various editorial updates and clarifications.

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.

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

Part 2:
Electrical loads

1 Scope

This document applies to electric and electronic systems/components for road vehicles. This document describes the potential environmental stresses and specifies tests and requirements for the specific mounting location on/in the road vehicle.

This document describes electrical loads.

This document is not intended to apply to environmental requirements or testing for systems and components of motorcycles and mopeds. Electromagnetic compatibility (EMC) is not covered by this document.

Electrical loads are independent from the mounting location, but can vary due to the electrical impedance (including both the resistance and the inductance) in the vehicle wiring harness and connection system.

Systems and their components released 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 8820 (all parts), *Road vehicles — Fuse-links*

ISO 16750-1, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16750-1 apply.

ISO and IEC maintain terminology 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/

4 Test and requirements

4.1 General

If not otherwise specified, the following tolerances shall apply:

— frequency and time: ±5 %;

— voltages: ±0,2 V;

— currents: ±2 %;

— inductance: ±10 %;

— resistance: ±10 %.

All voltage curves are shown without load.

If not otherwise specified, measure all voltages at the relevant terminals of the DUT.

For devices and units operating on secondary feed (e.g. 5 V sensor being supplied from 12 V supplied DUT), special considerations shall apply to voltage supply range, and specific tests shall be adjusted with consideration to the actual vehicle installation. Which tests that are applicable and what considerations that apply shall be agreed between the customer and the supplier.

NOTE   For a device or unit working on secondary feed, the electrical testing is sometimes carried out together with the 12/24 V supplied DUT providing the secondary feed.

A minimum of two DUTs shall be used for validation. If judged necessary by agreement between the customer and the supplier, an increased sample size may be used for final validation phases (process validation).

For redundant supplies and redundantly supplied DUTs, see definition in ISO 16750-1.

4.2 Direct current (DC) supply voltage

4.2.1 Purpose

The purpose of this test is to verify equipment functionality at minimum and maximum supply voltage.

4.2.2 Test method

Set the supply voltage as specified in Table 3 or Table 4 to all relevant inputs (connections) of the DUT. Use the test profile as described in Figure 1 and Table 2. The test profile shall be run with the DUT in operating mode 3.3, with the DUT in operating mode 3.4 (i.e. to test both minimum and maximum load conditions), and at both T_{min} and T_{max}, as defined in ISO 16750-1. If agreed between the customer and the supplier, one of the operating modes 3.3 or 3.4 may be chosen for the test.

The test profile shall also be run once at room temperature at normal loading conditions, operating mode 3.2 as defined in ISO 16750-1.

See Table 1 for combinations of test conditions.

Table 1 — DC supply voltage, combinations of test conditions

Temperature / operating mode	T_{min}	RT	T_{max}
Operating mode 3.3	U_{Smin} / U_{Smax}	-	U_{Smin} / U_{Smax}
Operating mode 3.2	-	U_{Smin} / U_{Smax}	-
Operating mode 3.4	U_{Smin} / U_{Smax}	-	U_{Smin} / U_{Smax}

Key
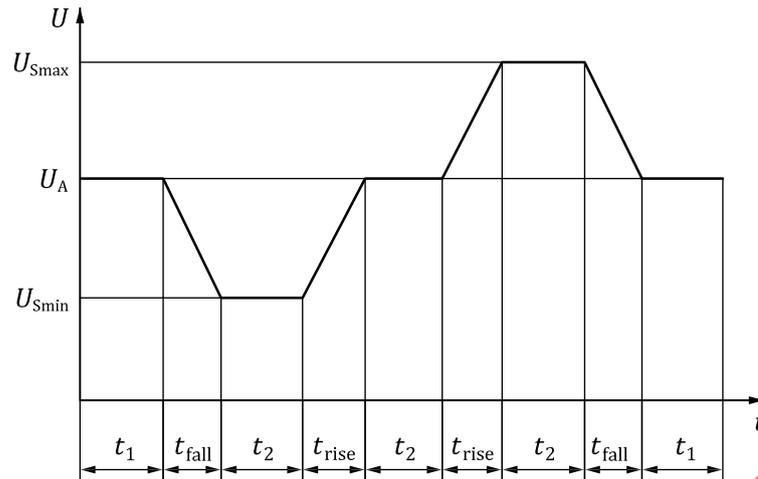
t time, in seconds

U test voltage, in volts

Figure 1 — DC supply voltage test profile

Table 2 — Test parameters for DC supply voltage

U_A	See ISO 16750-1
U_{Smax}	See Table 3 or Table 4
U_{Smin}	See Table 3 or Table 4
t_1	30 s
t_2	60 s
t_{rise}	1 V/s
t_{fall}	1 V/s

If the DUT is supplied by two or more redundant supplies, all different possible combinations of U_{Smin} and U_{Smax} on the supply input ports of the DUT shall be tested.

The voltages listed in Table 3 or Table 4 are relevant within the operating temperature range as specified in ISO 16750-4, without time limits. When considering the minimum and maximum voltage levels in the vehicle it should be noted that these are highly dependent on the voltage supply in the electrical system, e.g. DC/DC, alternator.

Table 3 — Supply voltage for system devices with 12 V nominal voltage

Code	Minimum supply voltage, U_{Smin}	Maximum supply voltage, U_{Smax}
A	6 V	16 V
B	8 V	16 V
C	9 V	16 V
D	10,5 V	16 V
Z	As agreed	

Table 4 — Supply voltage for system devices with 24 V nominal voltage

Code	Minimum supply voltage, U_{Smin}	Maximum supply voltage, U_{Smax}
E	10 V	32 V
F	16 V	32 V

Table 4 *(continued)*

Code	Minimum supply voltage, U_{Smin}	Maximum supply voltage, U_{Smax}
G	22 V	32 V
H	18 V	32 V
Z	As agreed	

4.2.3 Requirements

Functional status class A as defined in ISO 16750-1 is required during active operating modes when tested in the supply voltage ranges given in <u>Table 3</u> or <u>Table 4</u>, respectively.

4.3 Overvoltage

4.3.1 Long term overvoltage

4.3.1.1 Test at a temperature of (T_{max} – 20) °C for alternator failure

4.3.1.1.1 Purpose

This test simulates the condition where the alternator regulator fails, so that the output voltage of the alternator rises above normal values.

This test is relevant for both 12 V and 24 V systems.

4.3.1.1.2 Test method

Heat the DUT in a hot air oven to a temperature that is 20 K below the maximum operating temperature, T_{max}.

For 12 V systems, apply a voltage of 18 V for 60 min to all relevant inputs (connections) of the DUT.

For 24 V systems, apply a voltage of 36 V for 60 min to all relevant inputs (connections) of the DUT.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage as specified above shall be applied to one of the redundant supply lines at a time. The other supply or supplies shall then be kept at U_A as defined in ISO 16750-1.

4.3.1.1.3 Requirements

Minimum functional status class C as defined in ISO 16750-1 is required.

Where more stringent requirements are necessary, functional status class A as defined in ISO 16750-1 is required during active operating modes.

4.3.1.2 Test at room temperature and T_{min} for jump start

4.3.1.2.1 Purpose

This test simulates a jump start from a 24 V system to a 12 V system vehicle. A simulated use case could be a jump start from a donor vehicle using a 24 V system, but without engine running in the donor vehicle (i.e. without applied charging on the 24 V side). A use case could also be a jump start from a 24 V stand-alone battery pack. This test is only applicable for 12 V systems. The test shall be done both in room temperature conditions and at T_{min}. If agreed between the customer and the supplier, test at T_{min} can be omitted.

4.3.1.2.2 Test method

Ensure that the DUT has stabilized at temperature given in Table 5. Apply a voltage of 26 V for (60 ± 6) s to all relevant inputs (connections) of the DUT as described in Figure 2 and Table 5.

For DUTs necessary for engine start, the operating mode shall be 2.2, as defined in ISO 16750-1. For all other DUTs, the operating mode shall be 2.3.

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage shall be applied to one of the redundant supply lines at a time. The other supply or supplies shall then be kept at U_B as defined in ISO 16750-1.

Test shall be performed one time for each temperature value given in Table 5.

Key
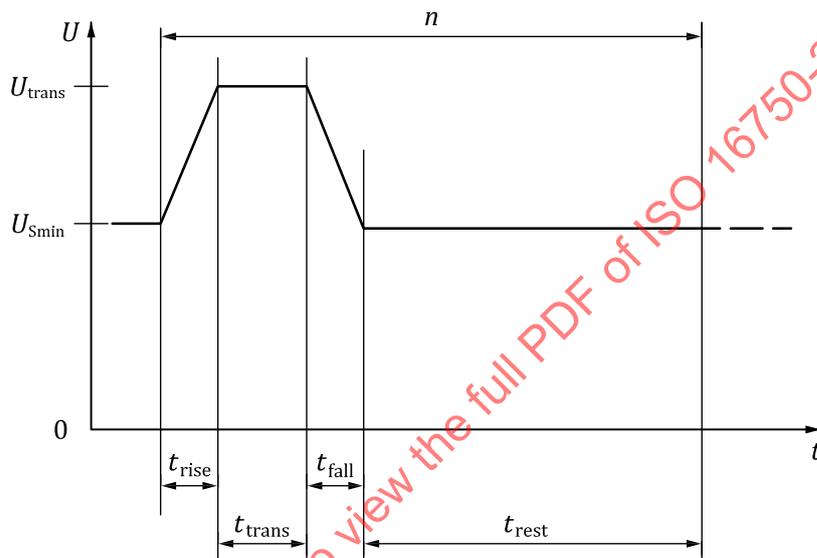
t	time, in seconds
U	test voltage, in volts
U_{trans}	transient test voltage, in volts
U_{Smin}	supply voltage, in volts
n	number of transients in sequence
t_{fall}	fall time, in seconds
t_{trans}	transient duration, in seconds
t_{rise}	rise time, in seconds
t_{rest}	rest time between transient events, in seconds

Figure 2 — Jump start transient

Table 5 — Jump start test values

Parameter	Temperature	t_{rise}	t_{fall}	t_{trans}	t_{rest}	U_{Smin}	U_{trans}	n
12 V system	RT	≤ 10 ms	≤ 10 ms	60 s	120 s	10,8 V	26 V	1
	T_{min}	≤ 10 ms	≤ 10 ms	60 s	120 s	10,8 V	26 V	1

4.3.1.2.3 Requirements

If not otherwise agreed between the customer and the supplier, minimum functional status class C as defined in ISO 16750-1 is required.

Where more stringent requirements are necessary, functional status class A as defined in ISO 16750-1 is required during active operating modes.
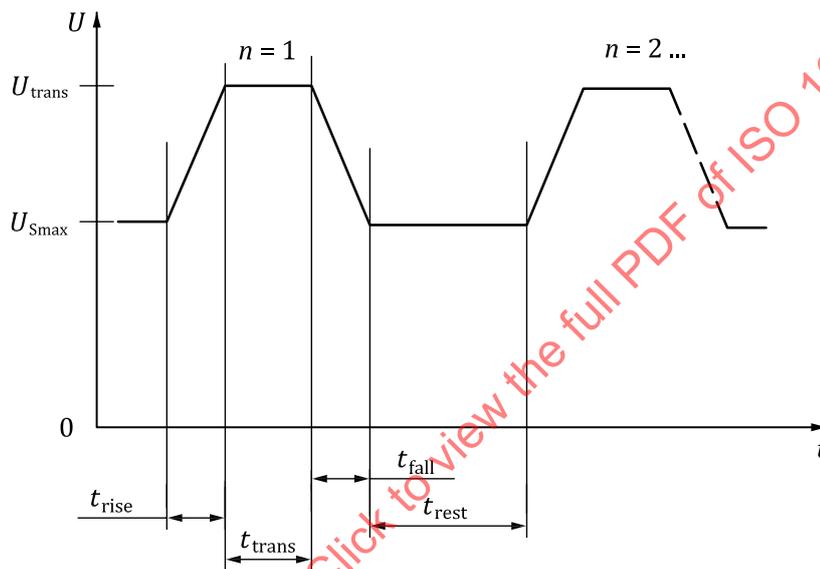
4.3.2 Transient overvoltage

4.3.2.1 Purpose

This test simulates when a DUT is affected by switching loads or loads injecting current in the electrical distribution system. This test is relevant for both 12 V and 24 V systems.

4.3.2.2 Test method

Apply the test pulse five times as specified in Figure 3 and Table 6 simultaneously to all relevant inputs (connections) of the DUT. The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

Key

t	time, in seconds
U	test voltage, in volts
U_{Smax}	maximum supply voltage, in volts
U_{trans}	transient overvoltage, in volts
n	number of test pulse in sequence
t_{fall}	fall time, in seconds
t_{trans}	transient pulse duration, in seconds
t_{rise}	rise time, in seconds
t_{rest}	rest time between transient pulses, in seconds

Figure 3 — Test profile for transient overvoltage

Table 6 — Transient overvoltage test values

Parameter	t_{rise}	t_{fall}	t_{rest}	t_{trans}	U_{trans}	n
12 V system	1 ms	1 ms	1 s	400 ms	18 V	5
24 V system	2 ms	2 ms	1 s	400 ms	36 V	5

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage cycle as specified in Figure 3 and Table 6 shall be applied to one of the

redundant supply lines at a time. The other supply or supplies shall then be kept at U_A as defined in ISO 16750-1.

4.3.2.3   Requirements

Minimum functional status class B as defined in ISO 16750-1 is required during active operating modes.

For specific applications where there is a need for more stringent control of the voltage range (where deviations outside of normal voltage range could be considered harmful for design reasons) functional status class C as defined in ISO 16750-1 can be considered if agreed between the customer and the supplier.

4.4   Superimposed alternating voltage

4.4.1   Purpose

This test is intended to check immunity of a component to ripples in the on-board system, caused, for example, by an alternator or a DC/DC converter.

It specifies a conducted voltage test method and procedure for determining the immunity of electronic components. The method is applied to all DUT power supply lines simultaneously. For a DUT with redundant supplies, any combination of exposures shall be agreed between the customer and the supplier.

The severity level 1, 2, 3 and 4 shall be chosen in accordance with the application, see Table 8.

This test is relevant for both 12 V and 24 V systems.

4.4.2   Test method

4.4.2.1   General

Figure 4 is showing a rough overview of the test voltage profile for min. and max. applied superimposed alternating voltage, a more precise description of the voltage profile can be found in 4.4.2.2 and 4.4.2.3.
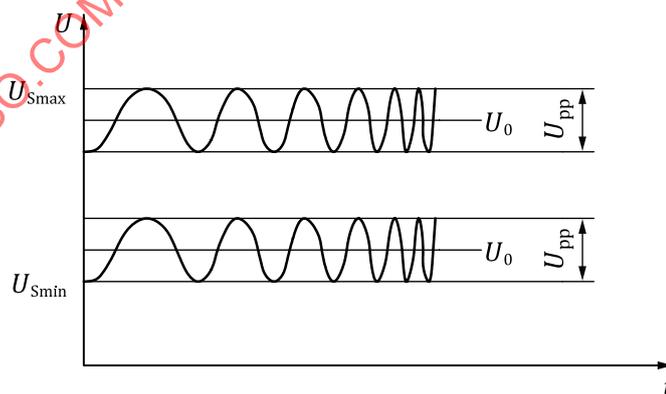
Key

t	time, in seconds
U	test voltage, in volts
U_{Smin}	minimum supply voltage, in volts
U_{Smax}	maximum supply voltage, in volts
U_0	DC level of applied test voltage, in volts
U_{pp}	voltage ripple peak-to-peak value, in volts

Figure 4 — Test profiles for Superimposed alternating voltage

The values of U_{Smax} and U_{Smin} are selected according to code (A … H) in 4.2.2 (Table 3 and Table 4).

Setup the test with reference to Table 7.

Table 7 — Test parameters for superimposed alternating voltage

U_N	12 V system	24 V system
Operating mode	3.2	3.2
Frequency range	f_1: 10 Hz to 30 kHz f_2: 30 kHz to 200 kHz	f_1: 10 Hz to 30 kHz f_2: 30 kHz to 200 kHz
U_0	$U_0 = U_{Smax} - U_{pp}/2$ $U_0 = U_{Smin} + U_{pp}/2$	$U_0 = U_{Smax} - U_{pp}/2$ $U_0 = U_{Smin} + U_{pp}/2$
Dwell time	≥ 2 s	≥ 2 s
Frequency step	logarithmic 2 %	logarithmic 2 %
Voltage ripple limit: U_{pp}	f_1: Severity level 1-3 f_2: Severity level 4	f_1: Severity level 1-3 f_2: Severity level 4
Current limit: I_{pp}	f_1: 15 A f_2: 10 A	f_1: 15 A f_2: 10 A
Requested test combinations	See Table 8	See Table 8
Number of cycles	1 test sequence for each test combination	1 test sequence for each test combination

Table 8 — Severity level for test Superimposed alternating voltage

	Severity level U_{pp}	Frequency range	U_{pp} for 12 V	U_{pp} for 24 V
1	DUT supplied by alternator without battery (emergency run)	10 Hz to 30 kHz	6 V ± 0,2 V	10 V ± 0,2 V
2	DUT supplied by alternator	10 Hz to 30 kHz	3 V ± 0,2 V	3 V ± 0,2 V
3	DUT supplied by DC/DC converter	10 Hz to 30 kHz	2 V ± 0,1 V	2 V ± 0,1 V
4	DUT supplied by DC/DC converter	30 kHz to 200 kHz	1 V ± 0,1 V	1 V ± 0,1 V

The power source shall be able to produce the requested ripple voltage and/or the currents in the specified frequency range.

Prior to starting this test, measure and record the impedance of the DUT at its 12/24 V supply terminals.

Connect an AC voltage measurement (e.g. oscilloscope with voltage probe) to the test signal generator output (loaded by the DUT) and an AC current measurement device (e.g. oscilloscope with current probe) and an AC voltage measurement to the DUT input as shown in Table 7 and Figure 5.
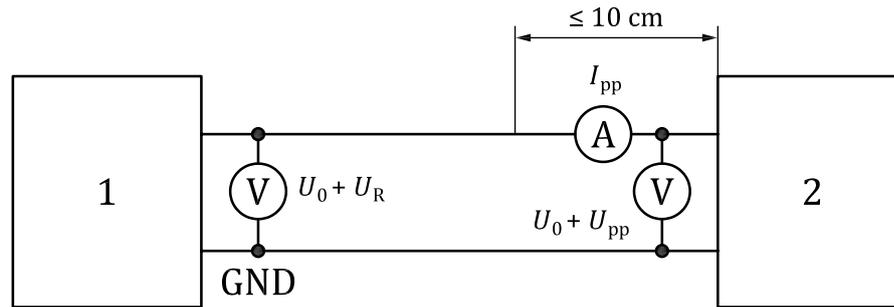
Key

1   power supply
2   DUT
U_R AC ripple voltage at power supply
U_{pp} peak-to-peak AC voltage at DUT
U_0 DC level of applied test voltage, in volts
I_{pp} peak-to-peak AC current at DUT

Locate voltage meter and ampere meter within 10 cm from the DUT.

Figure 5 — Test setup for superimposed alternating voltage

4.4.2.2   Reference test

Before the test is pursued in operating mode 3.2, a reference test is applied in operating mode 3.3. While operating the device in 3.3, it shall be ensured that all DUT internal energy buffers (e.g. capacitors, inductors) are active/present.

NOTE 1   The impedance of energy buffers which are connected in operating mode 3.3 are very important for the reference test, because it mainly determines the current ripple during the reference test. If the architecture of the DUT features any switch which disconnects the energy buffers from the power supply, the reference test would not determine the correct voltage ripple U_R.

The reference test determines the necessary voltage ripple U_R at the power supply which shall be applied to the DUT in order not to exceed the current limit I_{pp} for the applied excitation frequency.

For the reference test, each frequency range is tested at the voltage values given in Table 7.

The power supply shall inject an AC voltage ripple U_R on top of U_0 which shall be progressively increased until either the maximum voltage ripple U_{pp} at the DUT or the maximum current limit I_{pp} is reached. The ascertained ripple voltages of U_R of the power supply for every frequency step shall be documented. It is necessary to distinguish between U_R and U_{pp} due to the impedance of the cable harness and input impedance of the DUT. Therefore, U_R can be much higher than U_{pp}.

NOTE 2   If the DUT contains a low pass input filter (e.g. EMC filter), it is possible that the test is only relevant to be performed for frequencies where the filter of the DUT has a frequency response of more than -20 dB. Evidence of the frequency response of the input filter is helpful when determining the appropriate frequency range of the test. Depending on the impedance of the DUT and the cable harness, too high and unrealistic values of U_R would be tested at higher frequencies. Therefore, performing the test until this threshold is considered sufficient.

4.4.2.3   Voltage ripple test

In order to perform the voltage ripple test, the ascertained voltage ripple U_R from the reference test for each frequency step is applied to the DUT in operating mode 3.2. It is not allowed to further reduce the voltage ripple U_R even if the current limit I_{pp} is now exceeded.

The setup of the test shall be the same as in the reference test (type and length of cable).

Record I_{pp} and U_{pp} during the voltage ripple test.

If the DUT is supplied by two or more redundant supplies, the following test combinations shall be performed:

— voltage ripple test as defined in 4.4.2.3 is applied to all redundant supply lines simultaneously;

— voltage ripple test as defined in 4.4.2.3 is applied to one of the redundant supply lines, the other supply lines held at U_{Smin} as defined in ISO 16750-1. Repeat for each redundant supply line.

4.4.3   Requirements

Functional status class A as defined in ISO 16750-1 is required during active operating modes. The DUT impedance shall be measured before and after the test. Tolerance for the impedance measurement shall be agreed between the customer and the supplier. In case the impedance deviation is bigger than the agreed tolerance the test is failed corresponding to functional status class E.
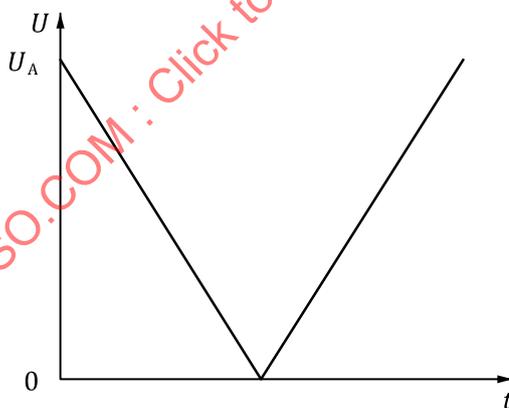
4.5   Slow decrease and increase of supply voltage

4.5.1   Purpose

This test simulates a gradual discharge and recharge of the battery. This test is relevant for both 12 V and 24 V systems.

4.5.2   Test method

Apply the following test simultaneously to all relevant inputs (connections) of the DUT.

Decrease the supply voltage from U_A to 0 V, then increase it from 0 V to U_A, as described in Figure 6, applying a change rate of $(0,5 \pm 0,1)$ V/min, either linear, or in equal steps of not more than 25 mV.

Key

t time, in seconds

U test voltage, in volts

U_A supply voltage for alternator in operation, in volts (see ISO 16750-1)

Figure 6 — Test profile for Slow decrease and increase of supply voltage

The operating mode of the DUT shall be 3.2, as defined in ISO 16750-1.

If the DUT is supplied by two or more redundant supplies, the following test combinations shall be performed:

— test voltage is applied to all redundant supply lines simultaneously;

— test voltage is applied to one of the redundant supply lines, the other supply lines held at U_A as defined in ISO 16750-1. Repeat for each redundant supply line.

4.5.3 Requirements

Functional status class A as defined in ISO 16750-1 is required during active operating modes when tested in the supply voltage ranges given in Table 3 or Table 4, respectively. Outside these ranges, minimum functional status class D as defined in ISO 16750-1 is required.

Where more stringent requirements are necessary, functional status class C as defined in ISO 16750-1 may be specified.

For a DUT with redundant supplies, depending on the combination of exposures, up to functional status class A may be specified. This shall be agreed between the customer and the supplier.

4.6 Discontinuities in supply voltage

4.6.1 Drops or interrupts in supply voltage

4.6.1.1 Momentary drop in supply voltage

4.6.1.1.1 Purpose

This test simulates the effect when a conventional fuse element melts in a parallel circuit. This test is relevant for both 12 V and 24 V systems.

4.6.1.1.2 Test method

Apply the test pulse (see Figure 7 and Figure 8) simultaneously to all relevant inputs (connections) of the DUT. The rise time and fall time shall be not more than 10 ms.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

Key
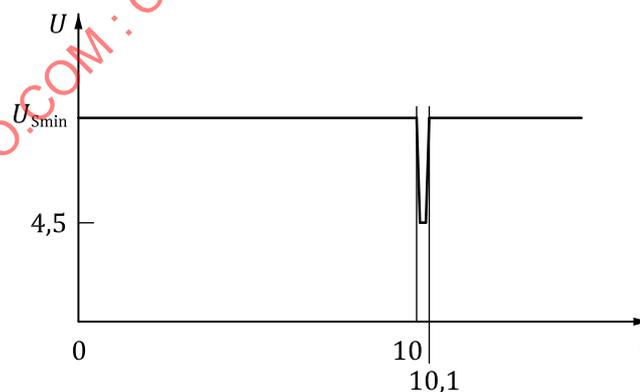
t time, in seconds

U test voltage, in volts

U_{Smin} minimum supply voltage, in volts

Figure 7 — Short voltage drop for systems with 12 V nominal voltage

Key

t	time, in seconds
U	test voltage, in volts
U_{Smin}	minimum supply voltage, in volts

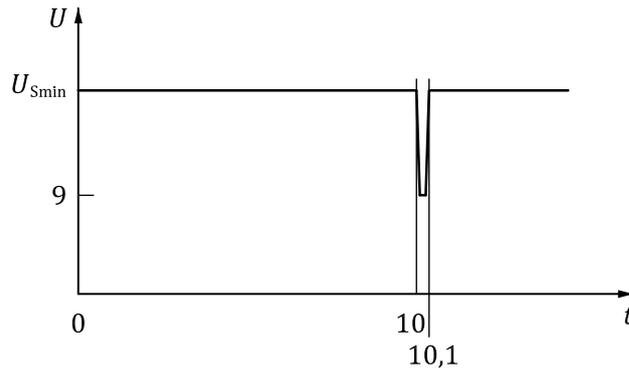**Figure 8 — Short voltage drop for systems with 24 V nominal voltage**

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage with short voltage drop shall be applied to one of the redundant supply lines at a time. The other supply or supplies shall then be kept at U_{Smin} as defined in ISO 16750-1.

4.6.1.1.3 Requirements

Minimum functional status class B as defined in ISO 16750-1 is required during active operating modes. Functional status class C can be permitted if agreed between the customer and the supplier.

For a DUT with redundant supplies, up to functional status class A may be specified. This shall be agreed between the customer and the supplier.

4.6.1.2 Micro interruption in supply voltage

4.6.1.2.1 Purpose

This test simulates the effect of micro interruption events in supply voltage caused by short circuits or open circuits of the supply lines, for instance by contact faults, defect relays, relay-contact bounce or by switching from the main power supply to a redundant power supply.

This test is relevant for both 12 V and 24 V systems.

4.6.1.2.2 Test method

4.6.1.2.2.1 General

To verify the switch reaction time, two reference measurements shall be performed and documented with the test setup given in Figure 9. In the first reference measurement, the DUT is replaced with a 1 kΩ resistor, and in the second measurement, the DUT is replaced with a 10 Ω resistor. The reference measurements enable the reaction time of the switch to be verified as acceptable before the full test is performed. The resistors used shall, therefore, have low inductance. Acceptable reaction time for the switch shall be ≤ 10 μs. After the transition time performance of the switch has been verified, the DUT shall be tested with the full setup as shown in Figure 9.

Apply the test simultaneously to all power supply inputs (connections) of the DUT. Both test case 1 (see Figure 10 and Table 9 in 4.6.1.2.2.2) and test case 2 (see Figure 11 and Table 10 in 4.6.1.2.2.3) shall be performed.

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage with micro interruptions shall be applied to one of the redundant supply lines while the others are supplied. The other supply or supplies shall then be kept at U_B as defined in ISO 16750-1.

While the supply line is interrupted by a switch, inductive voltage peaks shall be avoided, e.g. by connecting a low resistance parallel load, if agreed between the customer and the supplier.

The following test condition shall be met:

— open switch resistance: ≥ 10 MΩ.

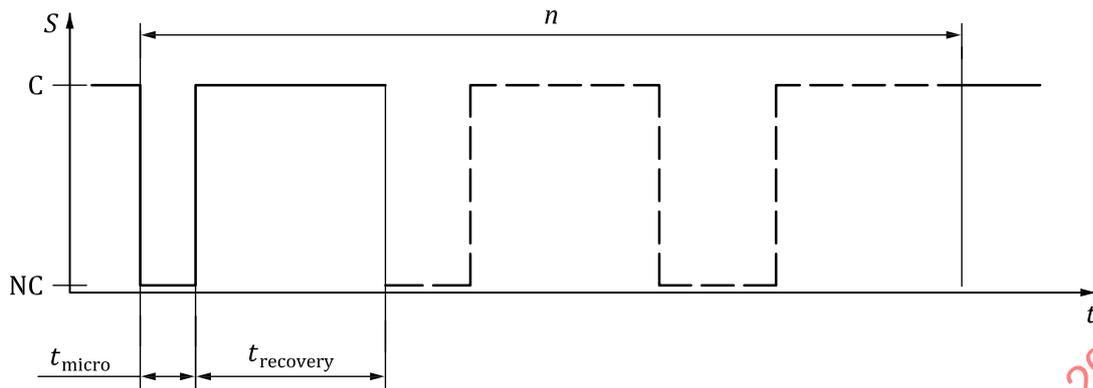The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.
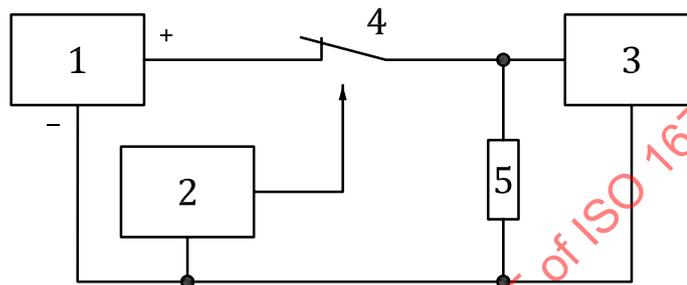
Key

1   power supply
2   programmable control circuit to open the switch connection
3   DUT
4   normally closed switch
5   optional low resistance parallel load

Figure 9 — Test set up for micro interruption with 12/24 V nominal voltage (U_N)

4.6.1.2.2.2   Test case 1 - variable interruption time

Key

t	time, in seconds
S	switch control signal
C	switch closed
NC	switch open
n	number of complete test sequences
t_{micro}	micro interruption duration, in seconds
$t_{recovery}$	recovery time between voltage interrupts, in seconds

Figure 10 — Micro interruption for variable interruption with 12/24 V nominal voltage (U_N)

Table 9 — Micro interruption test value for variable interruption duration time exposure with 12 V and 24 V nominal voltage (U_N)

t_{micro}	t_{micro} increased in steps of	$t_{recovery}$	n
10 µs to 100 µs	10 µs		
100 µs to 1 ms	100 µs	≥ 5 s	
1 ms to 10 ms	1 ms	The test voltage U_B shall be held at least until the DUT has achieved 100 % serviceability (all systems rebooted without error)	1
10 ms to 100 ms	10 ms		
100 ms to 2 s	100 ms		

4.6.1.2.2.3 Test case 2 - variable recovery time
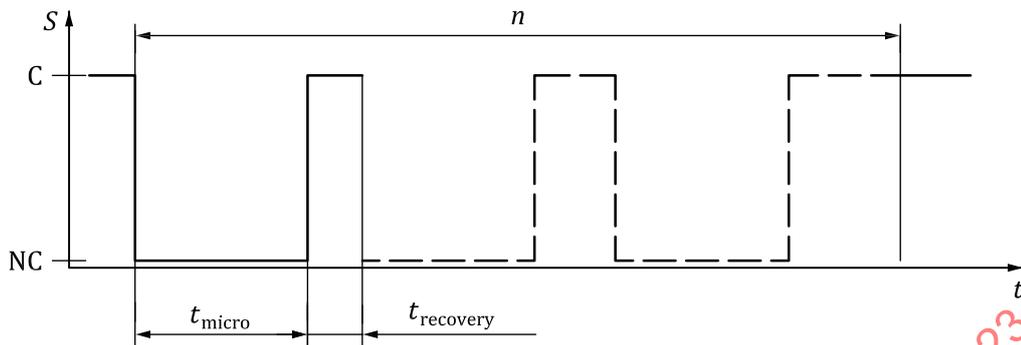
Key

t	time, in seconds
S	switch control signal
C	switch closed
NC	switch open
n	number of complete test sequences
t_{micro}	micro interruption duration, in seconds
$t_{recovery}$	recovery time between voltage interrupts, in seconds

Figure 11 — Micro interruption for variable recovery with 12/24 V nominal voltage (U_N)

Table 10 — Micro interruption test value for variable recovery duration time exposure with 12 V and 24 V nominal voltage (U_N)

t_{micro}	$t_{recovery}$	$t_{recovery}$ increased in steps of	n
≥ 100 ms The test voltage U_B shall be at least interrupted until the DUT has achieved reset condition.	100 μs to 1 ms	100 μs	1
	1 ms to 10 ms	1 ms	
	10 ms to 100 ms	10 ms	
	100 ms to 1 s	100 ms	
	1 s to 10 s	1 s	

4.6.1.2.3 Requirements

4.6.1.2.3.1 Test case 1

For t_{micro} ≤ 100 us, functional status class A as defined in ISO 16750-1 is required during active operating modes.

For t_{micro} > 100 us, minimum functional status class C as defined in ISO 16750-1 is required.

For a DUT with redundant supplies, up to functional status class A may be specified for all interrupt durations. This shall be agreed between the customer and the supplier.

4.6.1.2.3.2 Test case 2

Minimum functional status class C as defined in ISO 16750-1 is required.

For a DUT with redundant supplies, up to functional status class A may be specified for all recovery durations. This shall be agreed between the customer and the supplier.

4.6.2 Reset behaviour at voltage drop

4.6.2.1 Purpose

This test verifies the reset behaviour of the DUT at different voltage drops. This test is applicable to equipment with reset function, e.g. equipment containing microcontroller(s).

This test is relevant for both 12 V and 24 V systems.

4.6.2.2 Test method

Apply the test pulse simultaneously in Figure 12 to all relevant inputs (connections) of the DUT and check the reset behaviour of the DUT.

Decrease the supply voltage by 5 % from the minimum supply voltage, U_{Smin}, to $0{,}95U_{Smin}$. Hold this voltage for at least 5 s. Raise the voltage to U_{Smin}. Hold U_{Smin} for at least 10 s and perform a functional test. Then decrease the voltage to $0{,}9U_{Smin}$. Continue with steps of 5 % of U_{Smin}, as shown in Figure 12, until the lower value has reached 0 V. Then raise the voltage to U_{Smin} again.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

If the DUT has internal capacitor buffer on the voltage supply lines that may sustain the internal voltages of the DUT during a voltage drop, monitoring of the DUT internal supply voltage is recommended to be done during the test to assure that the DUT supply voltage level has dropped to the test level defined by each step in Figure 12. If voltage monitoring cannot be done in the actual test set-up for reasons of test feasibility (e.g. sealed DUT), the internal voltage drop followability shall be shown in some other way, e.g. simulations, lab measurements, calculations, engineering judgement.

Key
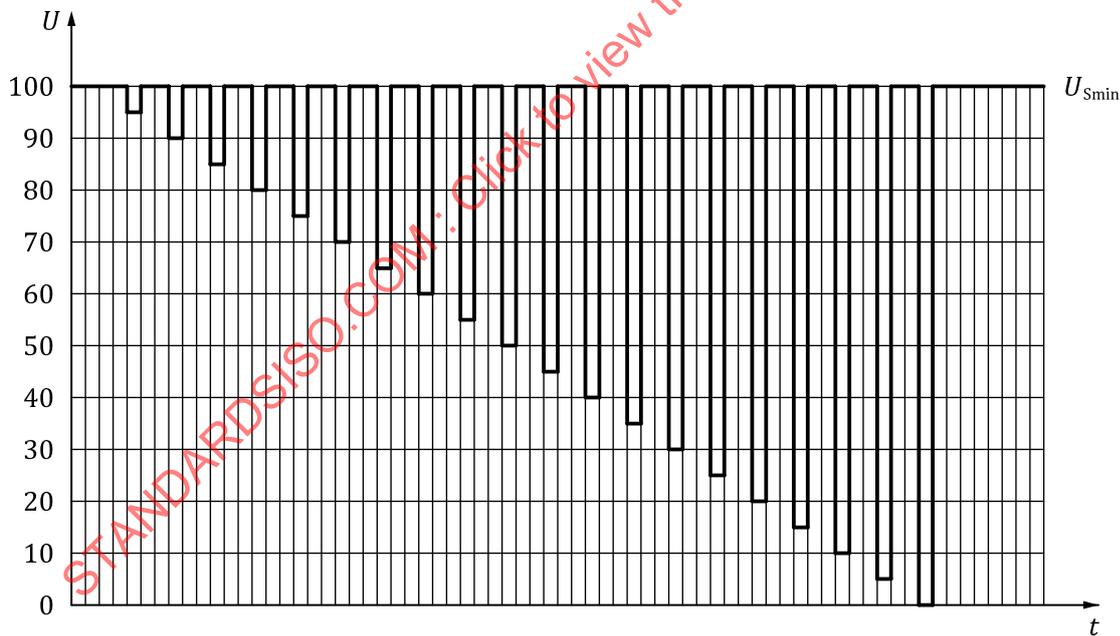
t time, in seconds

U test voltage measured as a percentage of U_{Smin}

U_{Smin} minimum supply voltage, in volts

Figure 12 — Test profile for reset behaviour at voltage drop

If the DUT is supplied by two or more redundant supplies, the test voltage according to Figure 12 shall be applied to all redundant supply lines simultaneously.

4.6.2.3 Requirements

Minimum functional status class C as defined in ISO 16750-1 is required.

### 4.6.3 Starting profile

4.6.3.1 Purpose

This test verifies the behaviour of a DUT during and after cranking. This test is relevant for both 12 V and 24 V systems.

4.6.3.2 Test method

Apply the starting profile 10 times, as specified in Figure 13 and Table 11 or Table 12, simultaneously to all relevant inputs (connections) of the DUT. Recovery period between each starting cycle shall be ≥ 2 s, until the DUT becomes 100 % operational. One or more profiles as described in Table 11 or Table 12 shall be chosen in accordance with the application.

The operating mode of the DUT shall be 3.2, as defined in ISO 16750-1.

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage with starting profile shall be applied to one of the redundant supply lines at a time. The other supply or supplies shall then be kept at U_{Smin} as defined in ISO 16750-1.

Key
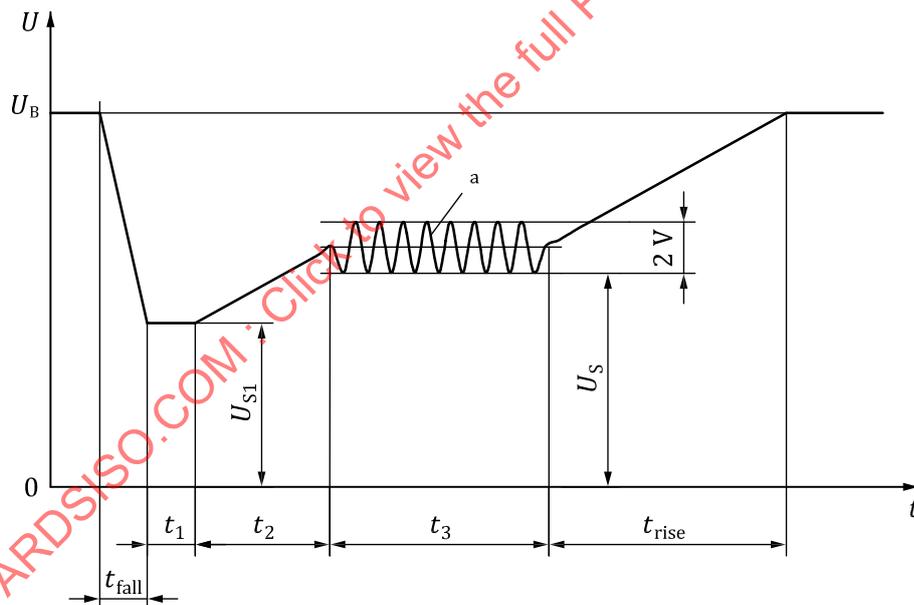
t	time, in seconds
U	test voltage, in volts
t_{fall}	falling slope, in seconds
t_{rise}	rising slope, in seconds
t_1, t_2, t_3	duration parameters, in seconds (in accordance with Table 11 and Table 12)
U_B	supply voltage for alternator not in operation, in volts (see ISO 16750-1)
U_S	supply voltage, in volts
U_{S1}	supply voltage at t_1, in volts
a	f = 2 Hz.

Figure 13 — Starting profile

Table 11 — Starting profile values for systems with 12 V nominal voltage (U_N)

Parameter		Level			
		I (Warm crank)	II (Cold crank with good battery at cold temperature)	III (Cold crank with aged battery at cold temperature)	IV (Cold crank with good battery at room temperature)
Voltage [V]	U_{S1}	$8^{0}_{-0,2}$	$4,5^{0}_{-0,2}$	$3^{0}_{-0,2}$	$6^{0}_{-0,2}$
	U_S	$9,5^{0}_{-0,2}$	$6,5^{0}_{-0,2}$	$5^{0}_{-0,2}$	$6,5^{0}_{-0,2}$
Duration [ms]	t_{fall}	5 (±0,5)	5 (±0,5)	5 (±0,5)	5 (±0,5)
	t_1	15 (±1,5)	15 (±1,5)	15 (±1,5)	15 (±1,5)
	t_2	50 (±5)	50 (±5)	50 (±5)	50 (±5)
	t_3	1 000 (±100)	10 000 (±1 000)	1 000 (±100)	10 000 (±1 000)
	t_{rise}	40 (±4)	100 (±10)	100 (±10)	100 (±10)
Minimum functional status		A[a]	B[a]	B[a]	A[a]
		A[b]	B[b]	C[b]	B[b]
		B[c]	C[c]	C[c]	C[c]
		B[d]	C[d]	C[d]	C[d]
[a] U_{Smin} = 6 V; U_{Smax} = 16 V (see Table 3, Code A).					
[b] U_{Smin} = 8 V; U_{Smax} = 16 V (see Table 3, Code B).					
[c] U_{Smin} = 9 V; U_{Smax} = 16 V (see Table 3, Code C).					
[d] U_{Smin} = 10,5 V; U_{Smax} = 16 V (see Table 3, Code D).					

Table 12 — Values for systems with 24 V nominal voltage (U_N)

Parameter		Level		
		I	II	III
Voltage [V]	U_{S1}	$10^{0}_{-0,2}$	$8^{0}_{-0,2}$	$6^{0}_{-0,2}$
	U_S	$20^{0}_{-0,2}$	$15^{0}_{-0,2}$	$10^{0}_{-0,2}$
Duration [ms]	t_{fall}	10 (±1)	10 (±1)	10 (±1)
	t_1	50 (±5)	50 (±5)	50 (±5)
	t_2	50 (±5)	50 (±5)	50 (±5)
	t_3	1 000 (±100)	10 000 (±1 000)	1 000 (±100)
	t_{rise}	40 (±4)	100 (±10)	40 (±10)
Minimum functional status		A[a]	B[a]	B[a]
		A[b]	B[b]	C[b]
		B[c]	C[c]	C[c]
		B[d]	C[d]	C[d]
[a] U_{Smin} = 10 V; U_{Smax} = 32 V (see Table 4, Code E).				
[b] U_{Smin} = 16 V; U_{Smax} = 32 V (see Table 4, Code F).				
[c] U_{Smin} = 22 V; U_{Smax} = 32 V (see Table 4, Code G).				
[d] U_{Smin} = 18 V; U_{Smax} = 32 V (see Table 4, Code H).				

4.6.3.3 Requirements

For functions of the DUT that are relevant to vehicle operation during cranking, functional status class A as defined in ISO 16750-1 is required; all other functions of the DUT shall fulfil functional status class in accordance with Table 11 or Table 12.

4.6.4 Load dump

4.6.4.1 Purpose

This test is a simulation of load dump transient occurring in the event of a discharged battery being disconnected while the alternator is generating charging current with other loads remaining on the alternator circuit at this moment. The severity level for test B (1, 2, 3 or 4) shall be agreed between the customer and the supplier. This test is relevant for both 12 V and 24 V systems.

4.6.4.2 Test method

4.6.4.2.1 General

The test pulse generator shall be capable of producing the load dump test pulse according to 4.6.4.2.2 and 4.6.4.2.3, for more information about the load dump pulse, see ISO 7637-2:2011, Annex D. Load dump generator performance and tolerances shall be verified according to test method given in Annex A, or equivalent test method. In Annex B, some more information is given on the origin of the load dump pulse.

4.6.4.2.2 Test A – without centralized load dump suppression

The pulse shape and parameters for an alternator without centralized load dump suppression are given in Figure 14 and Table 13. For the test voltage U_A, see ISO 16750-1.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

Key
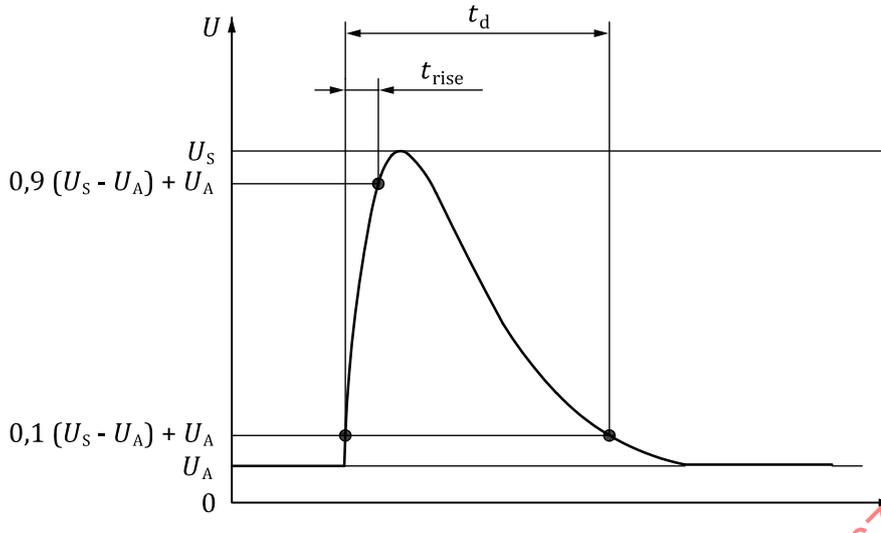
t	time, in seconds
U	test voltage, in volts
t_d	duration of pulse, in seconds
t_{rise}	rising slope, in seconds
U_A	supply voltage for alternator in operation, in volts (see ISO 16750-1)
U_S	supply voltage, in volts

Figure 14 — Test without centralized load dump suppression

Table 13 — Pulse for test A in systems with 12 V and 24 V nominal voltage

Parameter	Type of system		Minimum test requirements
	$U_N = 12$ V	$U_N = 24$ V	
U_S[a] [V]	$79 \leq U_S \leq 101$	$151 \leq U_S \leq 202$	10 pulses at 1 min intervals
R_i[a] [Ω]	$0.5 \leq R_i \leq 4$	$1 \leq R_i \leq 8$	
t_d [ms]	$40 \leq t_d \leq 400$	$100 \leq t_d \leq 350$	
t_{rise} [ms]	$10_{-5}^{\,0}$	$10_{-5}^{\,0}$	
[a] If not otherwise agreed, use the upper voltage level with the upper value for internal resistance or use the lower voltage level with the lower value for internal resistance.			

The internal resistance, R_i, of the load dump test pulse generator can be obtained as follows:

$$R_i = \frac{10 \times U_{nom} \times N_{act}}{0.8 \times I_{rated} \times 12\,000\,\text{min}^{-1}}$$

where

U_{nom} is the specified voltage of the alternator;

I_{rated} is the specified current at an alternator speed of 6 000 min^{-1}, as given in ISO 8854;

N_{act} is the actual alternator speed, in reciprocal minutes.

4.6.4.2.3 Test B – with centralized load dump suppression

The pulse shape and parameters for an alternator with centralized load dump suppression are given in Figure 15 and Table 14. For the test voltage U_A, see ISO 16750-1.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

Key
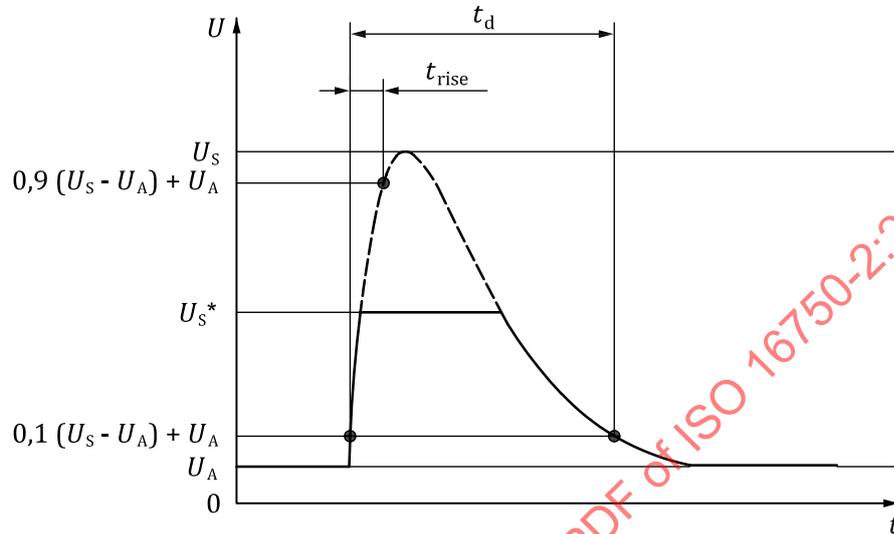
t	time, in seconds
U	test voltage, in volts
t_d	duration of pulse, in seconds
t_{rise}	rising slope, in seconds
U_A	supply voltage for alternator in operation, in volts (see ISO 16750-1)
U_S	supply voltage, in volts
U_S^*	supply voltage with load dump suppression, in volts

Figure 15 — Test with centralized load dump suppression

Table 14 — Pulse for test B in systems with 12 V and 24 V nominal voltage

Parameter	Type of system		Minimum test requirements
	U_N = 12 V	U_N = 24 V	
U_S [a] [V]	$79 \leq U_S \leq 101$	$151 \leq U_S \leq 202$	5 pulses at 1 min intervals
U_S^* [V]	Severity 1: 27 V Severity 2: 30 V Severity 3: 32 V Severity 4: 35 V	As specified by customer (typical value 58 V)	
R_i [a] [Ω]	$0{,}5 \leq R_i \leq 4$	$1 \leq R_i \leq 8$	
t_d [ms]	$40 \leq t_d \leq 400$	$100 \leq t_d \leq 350$	
t_{rise} [ms]	$10\,_{-5}^{0}$	$10\,_{-5}^{0}$	
[a] If not otherwise agreed, use the upper voltage level with the upper value for internal resistance or use the lower voltage level with the lower value for internal resistance.			

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the test voltage with load dump pulse shall be applied to one of the redundant supply lines at a time. The other supply or supplies shall then be kept at U_{Smin} as defined in ISO 16750-1.

4.6.4.3   Requirements

Minimum functional status class C as defined in ISO 16750-1 is required.

For a DUT with redundant supplies, up to functional status class A may be specified. This shall be agreed between the customer and the supplier.

4.7   Reversed voltage

4.7.1   Purpose

This test checks the ability of a DUT to withstand the connection of a reversed battery in case of using an auxiliary starting device.

This test is relevant for 12 V systems (test case 1 or test case 2) and 24 V systems (only test case 2).

This test is not applicable for:

— alternators;

— terminals with clamping diodes without external reverse polarity protection device.

4.7.2   Test method

4.7.2.1   General

Connect and fuse the DUT as in the real vehicle, but without alternator and battery. Choose the applicable voltages from the following cases and apply them simultaneously to all relevant power terminals with reversed polarity.

Operating mode is not applicable during this test.

If the DUT is supplied by two or more redundant supplies, and if agreed between the customer and the supplier, the reversed voltage according to applicable test cases below shall be applied to one of the redundant supply lines at a time. The other supply or supplies shall then be kept at U_B as defined in ISO 16750-1.

4.7.2.2   Test case 1

This test case applies if the DUT is used in a vehicle with a 12 V nominal voltage system where the alternator circuit is not fused and the rectifier diodes withstand a reversed voltage for 60 s. Apply a test voltage of -4 V simultaneously to all relevant inputs (connections) of the DUT for a duration of (60 ± 6) s (see Figure 16 and Table 15).

This test case is not applicable for systems with 24 V nominal voltage.
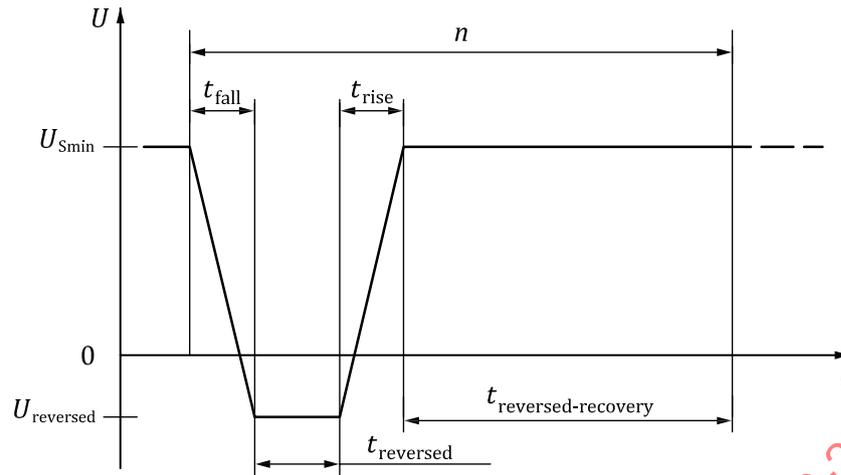
Key

t	time, in seconds
U	test voltage, in volts
$U_{reversed}$	reversed test voltage, in volts
U_{Smin}	minimum supply voltage, in volts
n	number of reversed voltage events in sequence
t_{fall}	fall time, in seconds
$t_{reversed}$	reversed voltage duration, in seconds
t_{rise}	rise time, in seconds
$t_{reversed-recovery}$	recovery between reversed voltage events, in seconds

Figure 16 — Reversed voltage test case 1

Table 15 — Reversed voltage test case 1 values

Parameter	t_{fall}	t_{rise}	$t_{reversed}$	$t_{reversed-recovery}$	U_{Smin}	$U_{reversed}$	n
12 V system	≤ 10 ms	≤ 10 ms	60 s	120 s	10,5 V	-4 V	1

4.7.2.3   Test case 2

In all other cases, apply the test voltage $U_{reversed}$ (see Figure 17 and Table 16) simultaneously to all relevant inputs (connections) of the DUT for a duration of (60 ± 6) s.

Key

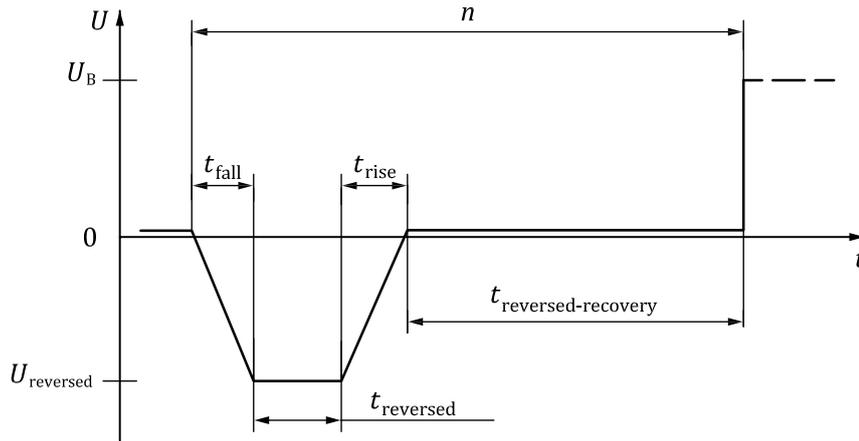|	
t	time, in seconds
U	test voltage, in volts
$U_{reversed}$	reversed test voltage, in volts
U_B	supply voltage, in volts
n	number of reversed voltage events in sequence
t_{fall}	fall time, in seconds
$t_{reversed}$	reversed voltage duration, in seconds
t_{rise}	rise time, in seconds
$t_{reversed\text{-}recovery}$	recovery between reversed voltage events, in seconds

Figure 17 — Reversed voltage test case 2

Table 16 — Reversed voltage test case 2 values

Parameter	t_{fall}	t_{rise}	$t_{reversed}$	$t_{reversed\text{-}recovery}$	U_B	$U_{reversed}$	n
12 V system	≤ 10 ms	≤ 1 000 ms	60 s	120 s	12 V	-14 V	1
24 V system	≤ 10 ms	≤ 1 000 ms	60 s	120 s	24 V	-26 V	1

4.7.3 Requirements

After replacing all blown fuse-links, functional status class A as defined in ISO 16750-1 is required during active operating modes.

4.8 Ground reference and supply offset

4.8.1 Purpose

This test shall be agreed between the customer and the supplier.

This test serves to verify reliable operation of a component if two or more power supply paths exist (note that this is not necessarily the same as redundant power supply feeds to a DUT). For instance, a component can have a power ground and a signal ground that are outputs on different circuits (e.g. for a DUT with two ground connections and two supply connections given in Figure 18).

This test is relevant for both 12 V and 24 V systems.
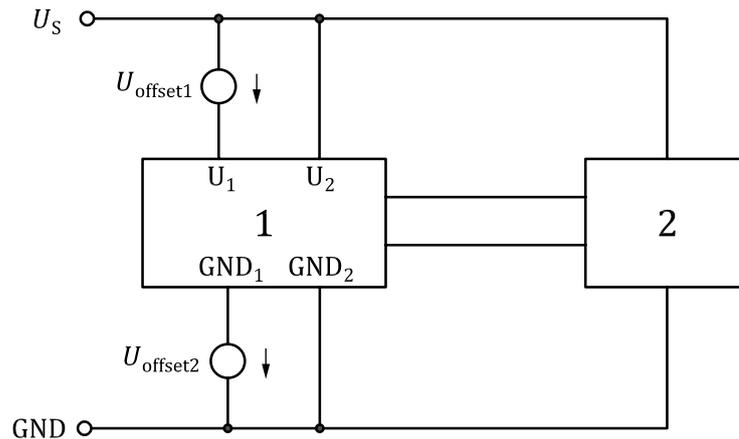
Key

U_S	supply voltage for 12/24 V system as defined in ISO 16750-1, in volts
U_1, U_2	supply lines to DUT
GND_1, GND_2	ground lines to DUT
$U_{offset1}$	offset voltage on supply line, in volts
$U_{offset2}$	offset voltage on ground line, in volts
1	DUT
2	additional components in the vehicle
NOTE 1	Supply offset voltage is applied to all power supply pins of the DUT separately.
NOTE 2	GND offset voltage is applied to every GND pin of the DUT separately. If GND pins are directly connected to each other within the DUT, the GND offset voltage is applied to those GND pins simultaneously (e.g. for DUT with only two ground connections that are both internally tied together, ±1 V variation of $U_{offset2}$ is not relevant).

Figure 18 — Example of ground reference and supply offset on a DUT with two ground/supply paths

4.8.2 Test method

Table 17 — List of test variations for one supply and one GND pin

Test	Test case	U_S	$U_{offset1}$	$U_{offset2}$
1	1 V GND offset and no U_S offset	$U_B+(U_A-U_B)/2$	0 V	1 V
2	1 V GND offset and 1 V U_S offset	$U_B+(U_A-U_B)/2$	1 V	1 V
3	1 V GND offset and -1 V U_S offset	$U_B+(U_A-U_B)/2$	-1 V	1 V
4	-1 V GND offset and no U_S offset	$U_B+(U_A-U_B)/2$	0 V	-1 V
5	-1 V GND offset and 1 V U_S offset	$U_B+(U_A-U_B)/2$	1 V	-1 V
6	-1 V GND offset and -1 V U_S offset	$U_B+(U_A-U_B)/2$	-1 V	-1 V
7	No GND offset and 1 V U_S offset	$U_B+(U_A-U_B)/2$	1 V	0 V
8	No GND offset and -1 V U_S offset	$U_B+(U_A-U_B)/2$	-1 V	0 V

All inputs and outputs shall be connected to representative loads or networks to simulate the in-vehicle configuration. Apply U_S to the DUT and confirm normal operation.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

The offset shall be applied to each ground/supply line separately (see Figure 18), and test shall be repeated for each possible ground/supply line combination. For overview of the test coverage, creating

a test matrix showing the possible combinations can be advisable. Example of such a test matrix is given in Table 17.

For all DUTs, the offset voltage shall be $(1,0 \pm 0,1)$ V.

a) Apply U_S to the DUT.

b) Subject ground/supply line to the offset voltage relative to the DUT ground/supply line.

c) Perform a functional test under this condition.

d) Repeat step a) to c) for each new ground/supply line combination.

Repeat the test with reverse offset voltage.

4.8.3   Requirements

Functional status class A as defined in ISO 16750-1 is required during active operating modes.

4.9   Open circuit tests

4.9.1   Single line interruption

4.9.1.1   Purpose

This test simulates an open contact condition, for instance, if a single wire or electrical connection to a DUT has an interruption. The kind of interruption can be static or dynamic (loose contact). Static interruption is simulated by test method 1, dynamic interruption is simulated by test method 2. This test is applicable for both power, ground, signal and load circuits for the DUT. Both test method 1 and test method 2 shall be performed.

This test is relevant for both 12 V and 24 V systems.

NOTE   This is not a test for connectors.

4.9.1.2   Test method 1

Connect and operate the DUT as intended. Open one circuit of the DUT/system interface, then restore the connection. Observe the device behaviour during and after the interruption.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

Perform this test for load-circuits in addition with the conditions for:

— outputs active;

— outputs inactive.

Repeat for each circuit of the DUT/system interface. The following test conditions shall be met:

— interruption time: (10 ± 1) s;

— open circuit resistance: ≥ 10 MΩ;

— maximum interrupt transition time ≤ 10 ms.

4.9.1.3   Test method 2

Connect and operate the DUT as intended. A sequence of short-term open circuit events, followed with restore of the connection (see Figure 19 and Table 18), shall be applied to the DUT/system interface. Observe the device behaviour during and after the interruption pattern.

The operating mode of the DUT shall be 3.4, as defined in ISO 16750-1.

Repeat for each circuit of the DUT/system interface. The following test conditions shall be met:

— open circuit resistance: ≥ 10 MΩ;

— maximum interrupt transition time ≤ 10 μs.
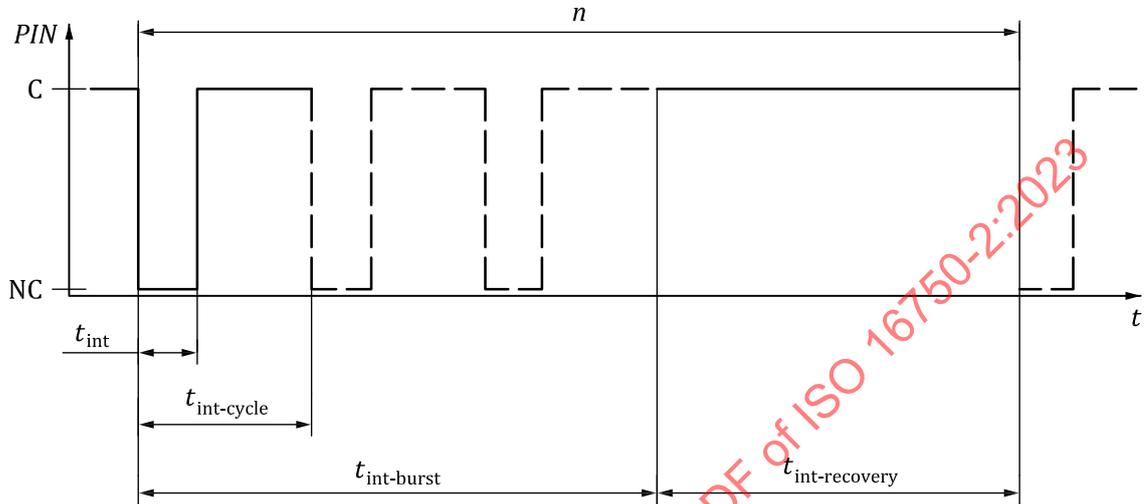
Key

t	time, in seconds
PIN	line connection condition
C	single wire or electrical connection present to DUT
NC	single wire or electrical connection with interruption
t_{int}	short-term open circuit time, in seconds
$t_{int\text{-}cycle}$	short-term open circuit repetition time, in seconds
$t_{int\text{-}burst}$	burst duration of open circuit pattern, in seconds
$t_{int\text{-}recovery}$	recovery time between interruption pattern, in seconds
n	number of complete interruption pattern sequences

Figure 19 — Interruption pattern of short-term open circuit events

Table 18 — Interruption pattern test values

Parameter	t_{int}	$t_{int\text{-}cycle}$	$t_{int\text{-}burst}$	$t_{int\text{-}recovery}$	n
Value	100 μs	1 ms	10 s	10 s	2

4.9.1.4   Requirements

Minimum functional status class C as defined in ISO 16750-1 is required. Functional status class D can be permitted due to safety concept of system, if agreed between the customer and the supplier.

For a DUT with redundant supplies, up to functional status class A may be specified. This shall be agreed between the customer and the supplier.