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Electric and Electronic Components in Motor Vehicles up to 3,5t – General Requirements, Test Conditions and Tests
Part I: Electrical Requirements and Tests
12 V On-Board Electrical System

Foreword

This edition of this Standard is based on the document LV 124 which has been established by representatives of the automotive manufacturers AUDI AG, BMW AG, Daimler AG, Porsche AG and Volkswagen Aktiengesellschaft within Working Group 4.9 "Process Assurance of Supplier Hardware Quality of Electronic Components".
Any deviations from LV 124 are listed on the cover sheet of this Standard (in justified exceptional cases, deviations may be represented in the body of the standard in italics). If in individual cases modifications to individual test sections are required, such modifications shall be agreed separately between the departments responsible of the automotive manufacturer and the supplier.
Within the framework of common development projects of the automotive manufacturers, test reports will be recognized provided that the tests have been performed by an independent institute accredited in accordance with DIN EN ISO/IEC 17025. Approval does not automatically follow from acceptance of the test reports. Other test reports may be recognized at the discretion of the buyer.
The contents of LV 124, version 2.2, edition 2013-02-28, have been adopted unchanged, but divided into two parts, into the set of standards of Mercedes-Benz with the exception of the test parameters in test E-05 in accordance with the following Table:

MBN standard number	LV number	Contents	Pages of LV 124
MBN LV 124-1	LV 124	Part I: Electrical Requirements and Tests - 12 V On-Board Electrical System	2-3; 6-54; 160
MBN LV 124-2	LV 124	Part II – Environmental Requirements and Tests	2; 4-5; 55-159

Application note:
Application of the present version of this Standard is binding for new vehicle projects or components of this scope, for which no concept/basic specifications or component requirement specifications have been approved yet at the date of issue of this version.
The respective contract documents regulate the mandatory application of the present version of this Standard by the supplier.

General requirements:
For safety requirements, homologation (in particular, exhaust emissions) and quality, the existing statutory requirements and laws shall be complied with. In addition, the relevant requirements of the Daimler Group apply.
All materials, procedures, processes, components, and systems shall conform to the current regulatory (governmental) requirements regarding regulated substances and recyclability.

Changes

In comparison with edition 2011-03, the following changes have been made:

- Cover sheet updated
- For other changes, refer to Section "Change history" of LV 124

NOTE: This translation is for information purposes only.
The German version shall prevail above all others.

LV124

Electric and Electronic Components in Motor Vehicles up to 3,5 t - General Requirements, Test Conditions and Tests

Change history

Edition	
2013-02	Editorial changes integrated. **Part I: Electrical Requirements and Tests - 12 V On-Board Electrical System:** Complete revision - each test adjusted to latest requirements. **Part II – Environmental Requirements and Tests:** Extension to components which are described in several operating modes, components connected to coolant circuits, and revision of life tests.

Contents

Pages 4 and 5 of LV 124 concern Part II Environmental Tests: see MBN LV 124-2

Part I: Electrical Requirements and Tests - 12 V On-Board Electrical System

1 Scope

This document specifies requirements, test conditions and tests for electric, electronic and mechatronic components and systems for use in motor vehicles with a 12 V on-board electrical system. Unless otherwise indicated, the tests do not represent electric service life tests.

Any additional or deviating requirements, test conditions and tests shall be defined in the respective Component Requirement Specifications.

Note: The represented tests are intended for the examination of part of the required properties of the component; they are not intended for component qualification or a qualification of the manufacturing process.

2 Normative references

Table 1: Normative references

ANSI/UL94	Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
DIN 72552-2	Terminal Markings for Motor Vehicles: Codes
DIN EN 13018	Non-Destructive Testing – Visual Testing - General Principles
DIN EN ISO/IEC 17025	General Requirements for the Competence of Testing and Calibration Laboratories

3 Terms and definitions

3.1 Terms and abbreviations

Table 2: Abbreviations for electrical requirements and tests

Term / Abbreviation	Meaning
Modules/devices	Electric, electronic or mechatronic device (e.g. resistor, capacitor, transistor, IC, relay)
DUT	Device Under Test – the system or component to be tested
Functions	Comprises system-specific functions and diagnostic functions
ICT	In Circuit Test
Component	Complete unit, control unit or mechatronic system (with housing)

Term / Abbreviation	Meaning
Short circuit	A short circuit of a load output is defined by a lower impedance load case than with specified load up to the limit case 0 Ω. Creeping short circuits i.e. current just below short circuit detection are also included. A short circuit may be permanently present (component in operation/not in operation).
On-grid parking	Operating mode of a vehicle with alternative drive which is connected to a charging station/socket during parking, but is not being charged. The vehicle can normally communicate with the charging station.
Off-grid parking	Operating mode of a vehicle with alternative drive which is not connected to a charging station/socket during parking.
Power user	Real application case with maximum conceivable usage.
PTB	Physikalisch-Technische Bundesanstalt (German national metrology institute providing scientific and technical services)
Start-relevant	Components which are directly or indirectly required for a combustion engine starting procedure
System	Functionally linked components, e.g. brake control system (control unit, hydraulic, sensors)

3.2 Voltages and currents

Table 3: Abbreviations for voltages and currents

U_N	Nominal voltage
U_{Bmin}	Lower operating voltage limit
U_B	Operating voltage
U_{Bmax}	Upper operating voltage limit
U_{max}	Maximum voltage that may occur during a test
U_{min}	Minimum voltage that may occur during a test
U_{PP}	Peak-to-peak voltage
U_{rms}	rms value of a voltage
U_{test}	Test voltage
I_N	Nominal current
GND	Device ground
U_A, U_T, U_S, U_R	Voltage level of the start voltage pulse

3.3 Temperatures

Table 4: Abbreviations for temperatures

T_{min}	Minimum operating temperature
T_{RT}	Room temperature
T_{max}	Maximum operating temperature
T_{test}	Test temperature

3.4 Times/durations

Table 5: Abbreviations for times/durations

t_r	Rise time (e.g. of a voltage profile)
t_f	Fall time (e.g. of a voltage profile)

3.5 Internal resistance, terminal designations, frequency

Table 6: Abbreviations for resistance, terminals and frequencies

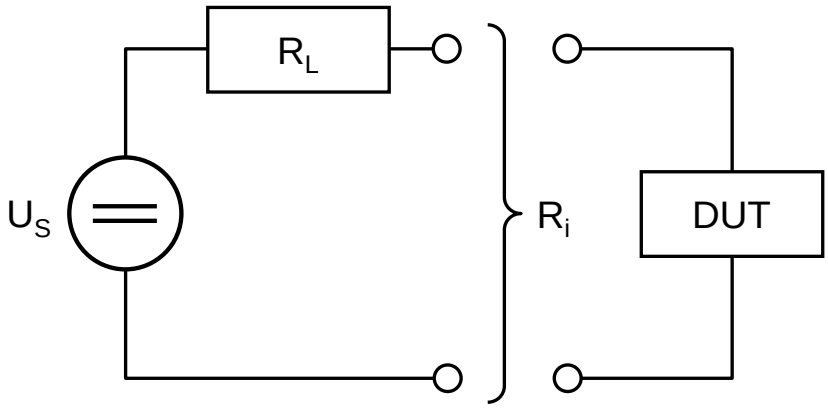
R_i	Internal source resistance inclusive of the power supply wiring harness (see Figure 1: Internal resistance)
Terminal designations	According to DIN 72552-2
f	Frequency

4 General requirements

4.1 Voltages and currents

The voltage curves indicated shall be interpreted as envelope. Real voltage curves are to be expected with random profile within the specified test and reference curves.

All voltage and current indications refer to the component (at its terminal).This does not apply to tests for which the internal resistance R_i is specified. In this case, the voltage and current indications refer to the source (see Figure 1: Internal resistance).



Key

U_S Source
R_L Line and contact resistance
R_i Internal resistance at the terminals of the component source direction

Figure 1: Internal resistance

All edge descriptions refer to the 10% or 90% voltage values.

4.2 Temperatures

Unless otherwise indicated, the temperature indications refer to the ambient air of the DUT.

4.3 Standard tolerances

Unless otherwise indicated, the tolerances according to Table 7 apply.
The tolerances refer to the required measured value.

Table 7: Standard tolerances

Frequencies	± 1 %
Temperatures	± 2 °C
Humidity	± 5 %
Times/durations	+ 5 %; 0 %
Voltages	± 2 %
Currents	± 2 %

4.4 Standard values

Unless otherwise indicated, the standard values according to Table 8 apply.

Table 8: Standard values

Room temperature	T_{RT} = 23 °C ± 5 °C
Humidity	F_{rel} = 25 % to 75 % relative humidity
Test temperature	$T_{test} = T_{RT}$
Operating voltage (for test)	U_B = 14 V

4.5 Sampling rates and measured value resolutions

The sampling rate and bandwidth of the measuring system shall be adapted to the respective test. All measured values with all maximum values (peaks) shall be recorded.

The resolution of the measured values shall be adapted to the respective test. Care shall be taken to ensure that occurring voltage peaks do not lead to an overflow or cannot be measured in the case of insufficient resolution. Any data reduction/abstraction (e.g. limit value monitoring, bus message evaluation) shall not suppress irregularities.

4.6 Test voltages

Test voltages, especially for over- and undervoltage tests, may deviate significantly from the voltage ranges in Section 4.7 and will be specified individually.
Functional status A (see Section 4.8) shall always be fulfilled within the voltage range applicable for the component.

4.7 Operating voltage ranges and coding

Table 9: Operating voltage ranges

Code	U_{Bmin}	U_{Bmax}	Description
a	6 V	16 V	For functions that must retain their performance during starting of the engine
b	8 V	16 V	For functions that do not have to retain their performance during starting of the engine This code shall only be used if the component cannot be classified under codes a, c or d.
c	9 V	16 V	For functions that must retain their performance when the engine is not running
d	9,8 V	16 V	For functions that must retain their performance when the engine is running

4.8 Functional status classification

4.8.1 General

This Section describes the functional status of the DUT during and after the test. The functional status of the DUT shall be indicated for each test.
The functional behavior (including derating, e.g. with regard to temperature and voltage) of the component in the functional statuses and the buyer perception (e.g. visual, acoustic, haptic, thermal) shall be defined by the buyer on the drawing or in the component requirement specifications.

Memory functions shall always remain in functional status A. The integrity of the non-volatile memories shall be ensured at any time. The time sequences of the functional statuses shall be specified in the component requirement specifications. Permissible fault memory entries shall be coordinated and specified in conjunction with the buyer.

For functional statuses A to D no damage to the DUT is permissible. The permissible limit values specified in the data sheets (e.g. electric, thermal, mechanical) of the electric/electronic devices installed in the DUT shall not be exceeded. Evidence shall be provided at least by the parameter test (small) according to Section 4.12.2.

4.8.2 Functional status A

The DUT shall perform all functions during and after the exposure to the test parameters.

4.8.3 Functional status B

The DUT shall perform all functions during the exposure to the test parameters; however, one or more functions may lie outside the specified tolerance. After the exposure to the test parameters, the DUT shall automatically revert to functional status A.

4.8.4 Functional status C

The DUT does not fulfill one or several functions during exposure to the test parameters. After the exposure to the test parameters, the DUT shall automatically revert to functional status A. Undefined functions are not permissible at any time.

4.8.5 Functional status D

The DUT does not fulfill one or several functions during exposure to the test parameters. After the exposure to the test parameters, the DUT shall automatically revert to functional status A by means of a change of terminal, a reset or a straightforward intervention (e.g. replacement of a defective fuse). Undefined functions are not permissible at any time.

4.8.6 Functional status E

The DUT does not fulfill one or several functions during exposure to the test parameters and must be repaired or replaced after the exposure to the test parameters.
The DUT shall comply with the flammability requirement specified in UL94-v0.

4.9 Operating modes

4.9.1 General

The electric, electronic and mechatronic components and systems will be operated in different operating modes during their service life, which shall be simulated correspondingly during the tests. Details concerning the operating modes, operating loads (e.g. actuation, bus messages, original sensors, original actuators or replacement circuitry) and the necessary boundary conditions shall be coordinated between the buyer and supplier and documented.

4.9.2 Operating mode I - DUT not electrically connected

4.9.2.1 Operating mode I.a

The DUT is without power; connector and harness are not connected.
Any existing coolant circuit is unfilled, and the connections are sealed.

4.9.2.2 Operating mode I.b

The DUT is without power; but the connector and harness are connected.
Any existing coolant circuit is filled, and the coolant hoses are connected.

4.9.3 Operating mode II – DUT electrically connected

4.9.3.1 Operating mode II.a

The DUT shall be operated without operating load.
Any existing coolant circuit shall be filled, and the coolant hoses shall be connected. If required, the flow rate and temperature of the coolant shall be adjusted - as specified in the component requirement specifications.

4.9.3.2 Operating mode II.b

The DUT shall be operated with minimal operating load.
The DUT shall be operated such that minimal self-heating occurs (e.g. by means of a reduction of continuous output power or through infrequent activation of external loads).
Any existing coolant circuit shall be filled, and the coolant hoses shall be connected. If required, the flow rate and temperature of the coolant shall be adjusted - as specified in the component requirement specifications.

4.9.3.3 Operating mode II.c

The DUT shall be operated with maximum operating load (power user, but no misuse).
The DUT shall be operated such that maximum self-heating occurs (for example by means of a realistic maximization of a continuous output power or frequent activation of external loads).
Any existing coolant circuit shall be filled, and the coolant hoses shall be connected. If required, the flow rate and temperature of the coolant shall be adjusted - as specified in the component requirement specifications.

4.9.3.4 Examples of operating modes

Table 10: Examples of operating modes

Example of component	Operating mode II.a	Operating mode II.b	Operating mode II.c
Car radio with navigation	Component as in parked vehicle (sleep). Follow-on current stopped Terminal 30 "ON"	Component in running vehicle. Component switched off by driver, BUS/µC's active, Terminal 15 "ON"	Component in running vehicle. Component switched on (CD, navigation system, output stage), BUS/navigation computer active
Anti-theft alarm system	No operation when vehicle is running	Vehicle interior is monitored while vehicle is parked	
Brake control system	Component as in parked vehicle. Follow-on current stopped	Driving without brake actuation	Driving with frequent brake cycles (no misuse, such as uninterrupted brake control operation)
On-board charger	Off-grid parking or driving	On-grid parking (power line communication only, no charging) Vehicle conditioning	Charging
HV battery (battery management system)	Off-grid parking	On-grid parking with power line communication	Driving, charging

4.10 Interface description

The states and electrical properties of all interfaces shall be described completely. This description is intended as a basis for the evaluation of the test results and shall therefore be available in detail.

4.11 Procedural limitations

The test laboratory shall be organized and operated according to DIN EN ISO/IEC 17025. All test equipment used for measuring shall be calibrated according to DIN EN ISO/IEC 17025 (or as specified or recommended by the manufacturer) and be traceable to PTB or another equivalent national metrology laboratory. The test equipment, workshop equipment, set-ups and test methods used shall not limit/falsify the behavior of the DUT (e.g. current input). These shall be documented in the test report together with the accuracies and the expiry date of the calibration.

4.12 Electrical tests

4.12.1 Test sequence

An electrical test shall commence when the DUT has started up completely and is in functional status A.

The sequence of the electrical tests can be selected freely. For each test, the permissible fault memory entries and the functional statuses of the component shall be specified.

All test cases of a test shall be executed unless specified in the test selection table according to Section 5.

The electrical tests may be performed during an environmental test (see LV 124 Part II) unless this contradicts the test requirements of the electrical test and provided that the buyer has agreed to this procedure. If the DUT shows irregularities during combined tests, the tests shall be repeated individually.

In the component requirement specifications or in agreement with the buyer, a set of sensitive parameters, so-called key parameters, such as closed-circuit current consumption, operating currents, output voltages, transition resistances, input impedances, signal rates (rise and fall times) and bus specifications shall be defined. These parameters shall be checked for their compliance with the specifications before the start and after the end of each test.

During each test, the key parameters to be monitored shall be recorded. Resets of the components shall be monitored and documented in a suitable form.

Before and after each test the DUTs shall be subjected to a parameter test (small) according to Section 4.12.2 in line with requirement specifications.

Before the first and after the last electrical test, the parameter test (large) according to Section 4.12.3 shall be performed in line with requirement specifications.

The measuring results and the data of the before/after tests shall only differ within the specified permissible tolerances. Changes in the measuring values which are larger than the measuring accuracies shall be marked. The measuring results from the continuous parameter monitoring shall be examined for trends and drifting to detect abnormalities, aging or malfunctions of the component.

The physical analysis according to 4.12.4 shall be performed on at least one DUT after completion of all electrical tests.

4.12.2 Parameter test (small)

The key parameters shall be measured and the functional behavior of the components checked at T_{RT} and U_B. For components with fault memory, the fault memory shall be read out. The components shall be checked for external damage/changes such as cracks, chipping/peeling, discoloration, deformation etc. by visual testing according to DIN EN 13018, without opening the DUT.
Changes in the values of the key parameters, the functional behavior or the fault memory entries as well as irregularities found during the visual test shall be evaluated against the new condition with regard to the previous test exposures.

All results shall be documented in the test report.

4.12.3 Parameter test (large)

The key parameters shall be measured and the functional behavior of the components measured at temperatures T_{max}, T_{RT} and T_{min} at each of the voltages U_{Bmin}, U_B and U_{Bmax}.
For components with fault memory, the content of the fault memory shall be read out. The components shall be checked for external damage/changes such as cracks, chipping/peeling, discoloration, deformation etc. by visual testing according to DIN EN 13018.

Changes in the values of the key parameters, the functional behavior or the fault memory entries as well as irregularities found during the visual test shall be evaluated against the new condition with regard to the previous test exposures.

All results shall be documented in the test report.

4.12.4 Physical analysis

For the physical analysis, the DUT shall be opened, and a visual test shall be performed according to DIN EN 13018.
Additional analyses shall be agreed between the buyer and the supplier.
Examples of examinations are given in Annex G.
Changes of the component compared to the new condition shall be evaluated.
If a DUT demonstrates irregularities, the additional analysis shall be agreed with the buyer, if appropriate by adding additional DUTs or using additional analytical methods.
The results shall be documented and evaluated in the test report.

5 Test selection table

Table 11: Test selection table

Test	Applicable to	To be specified by buyer in addition
E-01 Long-term overvoltage	Components supplied by the 12 V on-board electrical system	Component required for the driving mode
E-02 Transient overvoltage	Components supplied by the 12 V on-board electrical system	None
E-03 Transient undervoltage	Components supplied by the 12 V on-board electrical system	None
E-04 Jump start	Components supplied by the 12 V on-board electrical system	Start-relevant/ not start-relevant component
E-05 Load dump	Components supplied by the 12 V on-board electrical system	Safety-related component
E-06 Superimposed alternating voltage	Components supplied by the 12 V on-board electrical system	Test cases based on connection in on-board electrical system
E-07 Slow decrease and increase of the supply voltage	All components	Relevant terminal status
E-08 Slow decrease, abrupt increase of the supply voltage	All components	Relevant terminal status
E-09 Reset behavior	All components	Relevant terminal status, test boundary conditions
E-10 Short interruptions	All components	None
E-11 Start pulses	Components supplied by the 12 V on-board electrical system	Start-relevant/ not start-relevant component
E-12 Voltage profile for on-board electrical system control	Components supplied by the 12 V on-board electrical system	None
E-13 Pin interruption	All components	Relevant terminal status
E-14 Connector interruption	All components	None
E-15 Reverse polarity	Components which may be subjected to reverse polarity in the vehicle	Severity, shutdown of component in the case of reverse polarity

Test	Applicable to	To be specified by buyer in addition
E-16 Ground offset	All components	None
E-17 Short circuit in signal circuit and load circuits	All components	None
E-18 Insulation resistance	Components with galvanically isolated parts	None
E-19 Closed-circuit current	Components which are continuously supplied with voltage (e.g. Terminal 30, Terminal 30f, Terminal 30g,…)	None
E-20 Dielectric strength	Components with inductive parts (e.g. motors, relays, coils)	None
E-21 Backfeeds	Components which are electrically connected to Terminal 15 or other terminals with wake-up function	None
E-22 Overcurrents	Components which have an output	None

6 Electrical tests and requirements

6.1 E-01 Long-term overvoltage

6.1.1 Purpose

The resistance of the component to long-term overvoltages is tested. A generator control fault during driving operation is simulated.

6.1.2 Test

Table 12: Test parameters E-01 Long-term overvoltage

Operating mode of the DUT	Operating mode II.c
U_{max}	17 V (+4 %, 0 %)
U_{min}	13,5 V
t_r	< 10 ms
t_f	< 10 ms
t_1	60 min
T_{test}	T_{max} – 20K
Number of cycles	1
Number of DUTs	at least 6

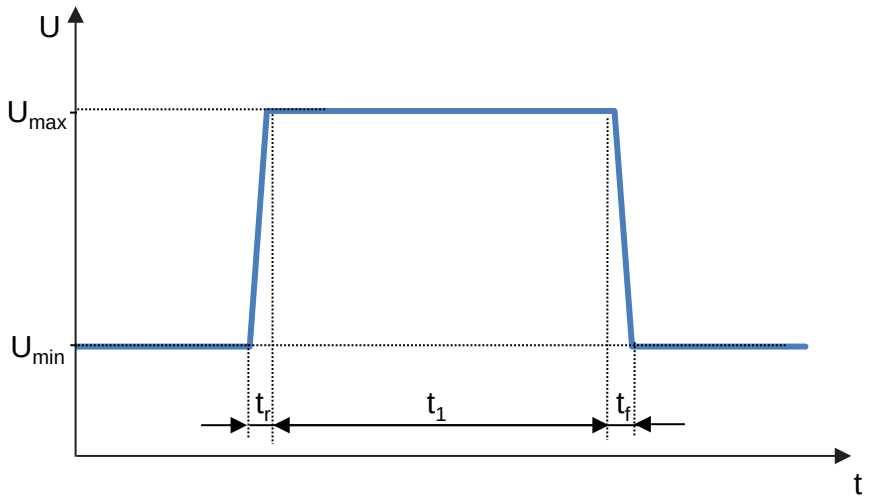


Figure 2: Test pulse E-01 Long-term overvoltage

6.1.3 Requirement

The assessment of the test result depends on the application of the component. A distinction is made between:

a) Functions required for the driving mode:
functional status B
If required, an emergency mode shall be defined. The corresponding "derating strategy" shall be described in the component requirement specifications.

b) All other components:
functional status C

6.2 E-02 Transient overvoltage

6.2.1 Purpose

Transient overvoltages in the on-board electrical system may occur due to the switching off of loads and due to short accelerator tip-ins. These overvoltages are simulated by means of this test.

6.2.2 Test

Table 13: Test parameters E-02 Transient overvoltage

Operating mode of the DUT	Operating mode II.c
U_{min}	16 V
U_1	17 V
U_{max}	18 V (+4 %, 0 %)
t_r	1 ms
t_f	1 ms
t_1	400 ms
t_2	600 ms
Number of DUTs	at least 6
Test case 1	
T_{test}	T_{max}
Number of cycles	3
t_3	2 s
Test case 2	
T_{test}	T_{min}
Number of cycles	3
t_3	2 s
Test case 3	
T_{test}	T_{RT}
Number of cycles	100
t_3	8 s

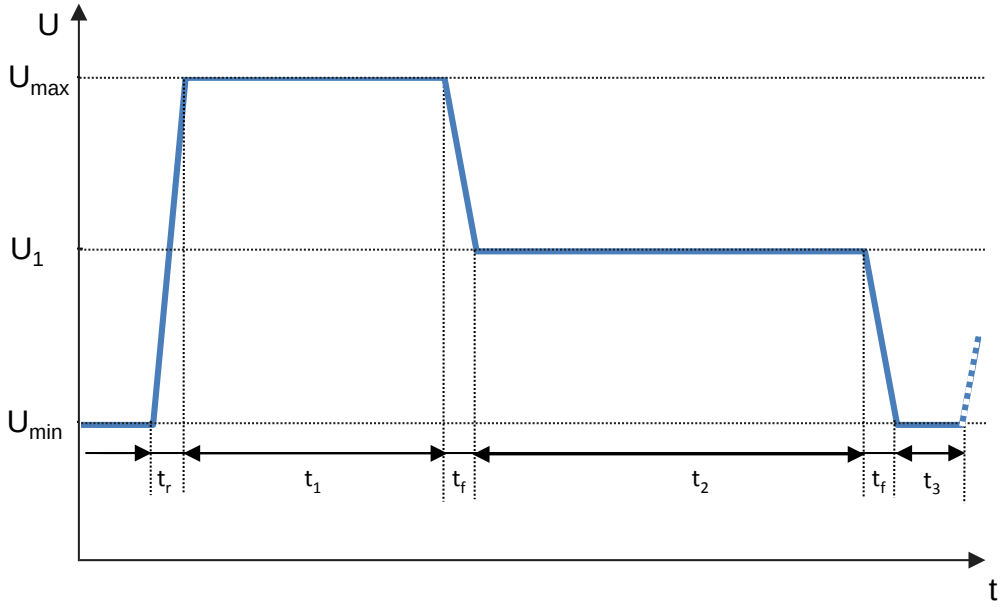


Figure 3: Test pulse E-02 Transient overvoltage

6.2.3 Requirement

Functional status A

6.3 E-03 Transient undervoltage

6.3.1 Purpose

Transient undervoltages in the on-board electrical system may occur due to switching on of loads. This test is intended to simulate such undervoltages.

6.3.2 Test

Table 14: Test parameters E-03 Transient undervoltage

Operating mode of the DUT	Operating mode II.c
U_{max}	10,8 V (+4 %, 0 %)
U_{min}	9 V (0 %, -4 %)
t_r	1,8 ms
t_f	1,8 ms
t_1	500 ms
t_2	1 s
Number of DUTs	at least 6
Test case 1	
T_{test}	T_{max}
Number of cycles	3
Test case 2	
T_{test}	T_{min}
Number of cycles	3

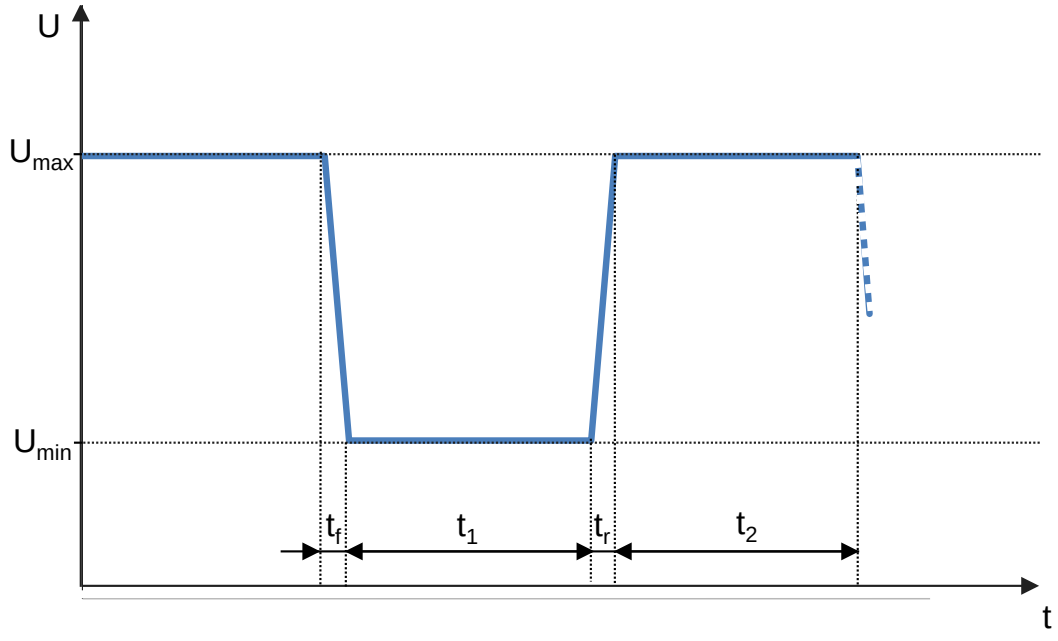


Figure 4: Test pulse E-03 Transient undervoltage

6.3.3 Requirement

Functional status A

6.4 E-04 Jump start

6.4.1 Purpose

External starting of the vehicle is simulated. The maximum test voltage originates from commercial vehicle systems and their increased on-board electrical system voltages.

6.4.2 Test

Table 15: Test parameters E-04 Jump start

Operating mode of the DUT	Operating mode II.c
U_{min}	10,8 V
U_{max}	26 V (+4 %, 0 %)
t_1	60 s
t_r	< 10 ms
t_f	< 10 ms
Number of cycles	1
Number of DUTs	at least 6

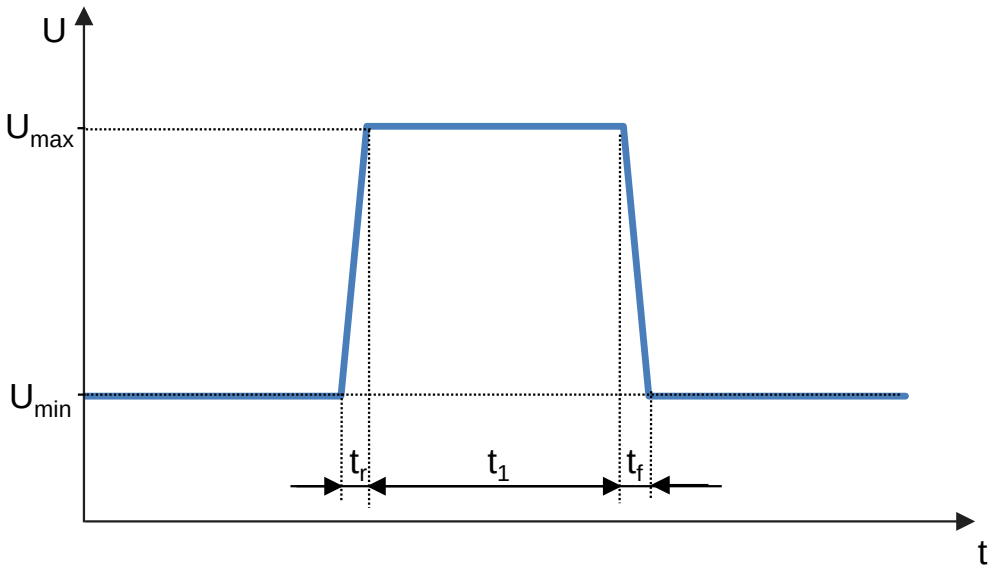


Figure 5: Test pulse E-04 Jump start

6.4.3 Requirement

A distinction is made between:

a) For components relevant for starting (e.g. starter):
functional status B
The sensors shall deliver valid values over the whole time (or be safeguarded by means of replacement tables in the components).

b) All other components:
functional status C

6.5 E-05 Load dump

6.5.1 Purpose

Dumping of an electric load, in combination with a battery with reduced buffering ability, results in an energy-rich overvoltage pulse due to the generator characteristics. This pulse is simulated by means of this test.

6.5.2 Test

Table 16: Test parameters E-05 Load dump

Operating mode of the DUT	Operating mode II.c
U_{min}	13,5 V
U_{max}	~~27 V (+4 %, 0 %)~~ *32 V*
t_r	≤ 2 ms
t_1	300 ms
t_f	≤ 30 ms
Break between cycles	1 min.
Number of cycles	10
Number of DUTs	at least 6

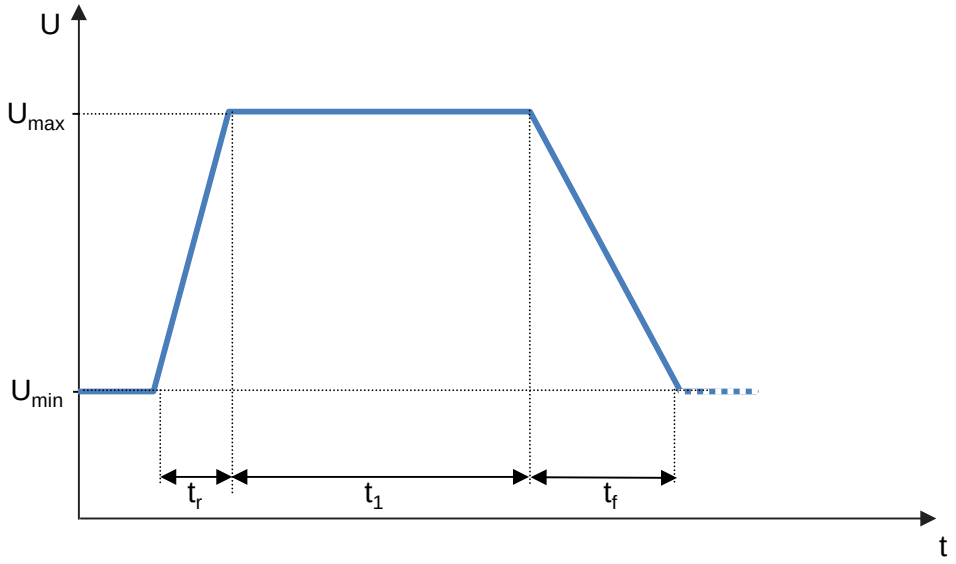


Figure 6: Test pulse E-05 Load dump

6.5.3 Requirement

A distinction is made between:

a) Safety-related components:
functional status B

b) All other components:
functional status C

6.6 E-06 Superimposed alternating voltage

6.6.1 Purpose

Voltages may be superimposed on the on-board electrical system. The superimposed alternating voltage may be applied during the entire running time of the engine. These tests are intended to simulate such situations.

6.6.2 Test

Table 17: Test parameters E-06 Superimposed alternating voltage

Operating mode of the DUT	Operating mode II.c
U_{max}	U_{Bmax}
R_i	≤100 mΩ
Frequency range	15 Hz – 30 kHz
Frequency sweep duration t_1	2 min
Type of frequency sweep	triangular, logarithmic
Number of cycles	15
Number of DUTs	at least 6
Test case 1	
U_{PP}	2 V (+4 %, 0 %)
Test case 2	
U_{PP}	3 V (+4 %, 0 %) only for components between battery and generator, in particular in the case of battery connection remote from generator
Test case 3	
U_{PP}	6 V (+4 %, 0 %) for all components when driving without battery (emergency operation) or in the case of connection close to generator

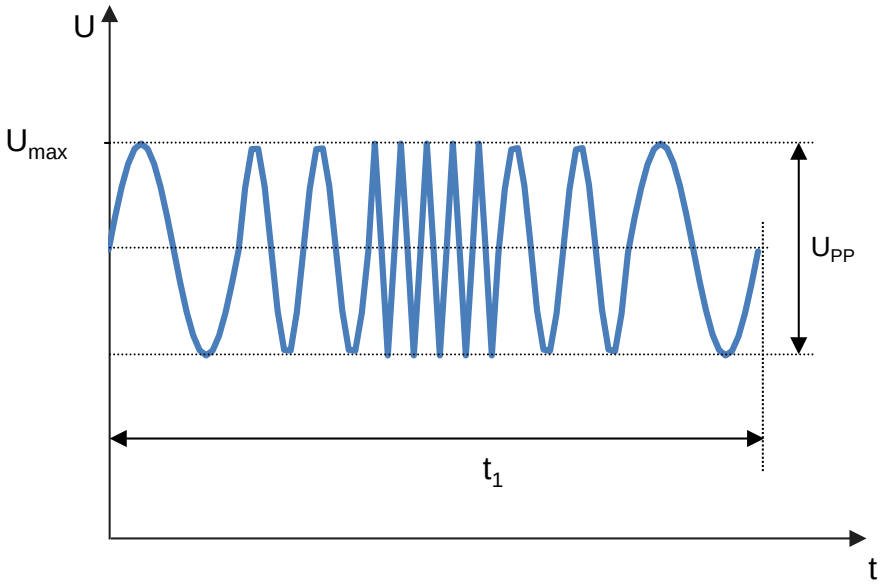


Figure 7: Test pulse E-06 Superimposed alternating voltage

6.6.2.1 Test set-up

The conditions for the on-board electrical system shall be agreed with the departments responsible. The test set-up shall be documented in detail, including line inductances, line capacities and line resistances.

6.6.3 Requirement

Test case 1: functional status A
Test case 2: functional status A
Test case 3:

a) Components required for the driving mode:
   functional status A

b) All other components:
   functional status B

6.7 E-07 Slow decrease and increase of the supply voltage

6.7.1 Purpose

The slow decrease and increase of the supply voltage is simulated as it occurs during the slow discharging and recharging processes of the vehicle battery.

6.7.2 Test

Table 18: Test parameters E-07 Slow decrease and increase of the supply voltage

Operating mode of the DUT	Operating modes II.a and II.c To be performed for all relevant statuses of the voltage supply terminals (e.g. Terminal 15, Terminal 30, Terminal 87, ...) and their combinations.
Start voltage	U_{Bmax} (+4 %, 0 %)
Rate of voltage variation	0,5 V/min (+10 %, -10 %)
U_1	U_{Bmin}
t_1	Holding time at U_1 until fault memory has been completely read out
Minimum voltage	0 V
U_2	U_{Bmin}
t_2	Holding time at U_2 until fault memory has been completely read out
Final voltage	U_{Bmax} (+4 %, 0 %)
Number of cycles	Depending on relevant terminal status and their combinations: 1 cycle in operating mode II.a 1 cycle in operating mode II.c
Number of DUTs	at least 6

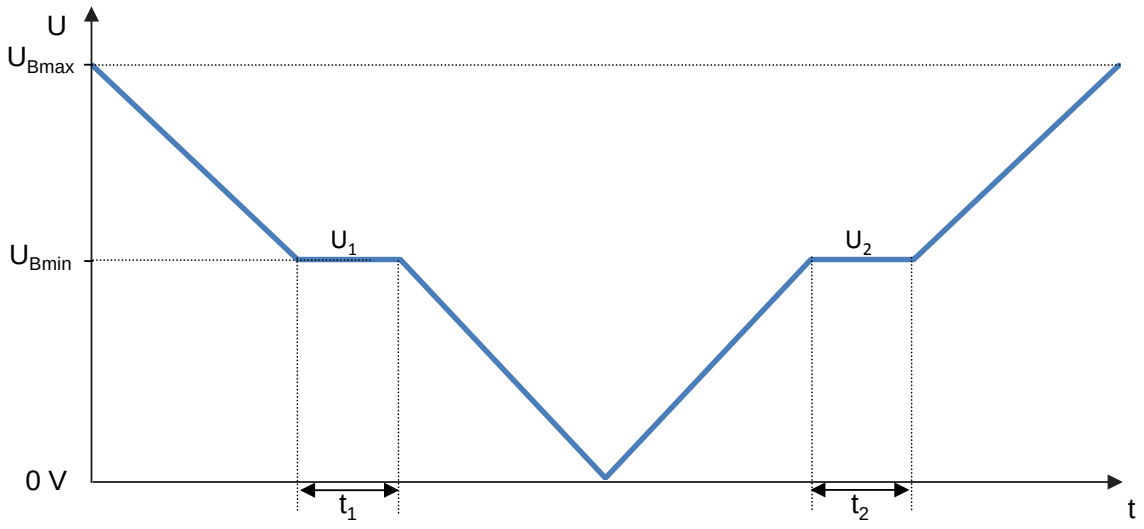


Figure 8: Test pulse E-07 Slow decrease and increase of the supply voltage

6.7.3 Requirement

The assessment of the test result depends on the voltage range applied to the component during the test.

A distinction is made between:

a) within the defined operating voltage of the component:
functional status A

b) outside the defined operating voltage of the component:
functional status C

6.8 E-08 Slow decrease, abrupt increase of the supply voltage

6.8.1 Purpose

This test simulates the slow decrease of the battery voltage to 0 V, followed by the abrupt reconnection of the battery voltage, e.g. by means of applying a jump start source.

6.8.2 Test

Table 19: Test parameters E-08 Slow decrease, abrupt increase of the supply voltage

Operating mode of the DUT	Operating modes II.a and II.c To be performed for all relevant statuses of the voltage supply terminals (e.g. Terminal 15, Terminal 30, Terminal 87, ...) and their combinations.
Start voltage	U_{Bmax} (+4 %, 0 %)
Voltage fall	0,5 V/min (+10 %, -10 %)
U_1	U_{Bmin}
t_1	Holding time at U_1 until fault memory has been completely read out
Holding time at U_{Bmin}	Until the fault memory is completely read out
Minimum voltage	0 V
t_2	At least 1 min; however, until internal capacities are completely discharged.
Final voltage	U_{Bmax} (+4%, 0 %)
t_r	≤ 0,5 s
Number of cycles	Depending on relevant terminal status and their combinations: 1 cycle in operating mode II.a 1 cycle in operating mode II.c
Number of DUTs	at least 6

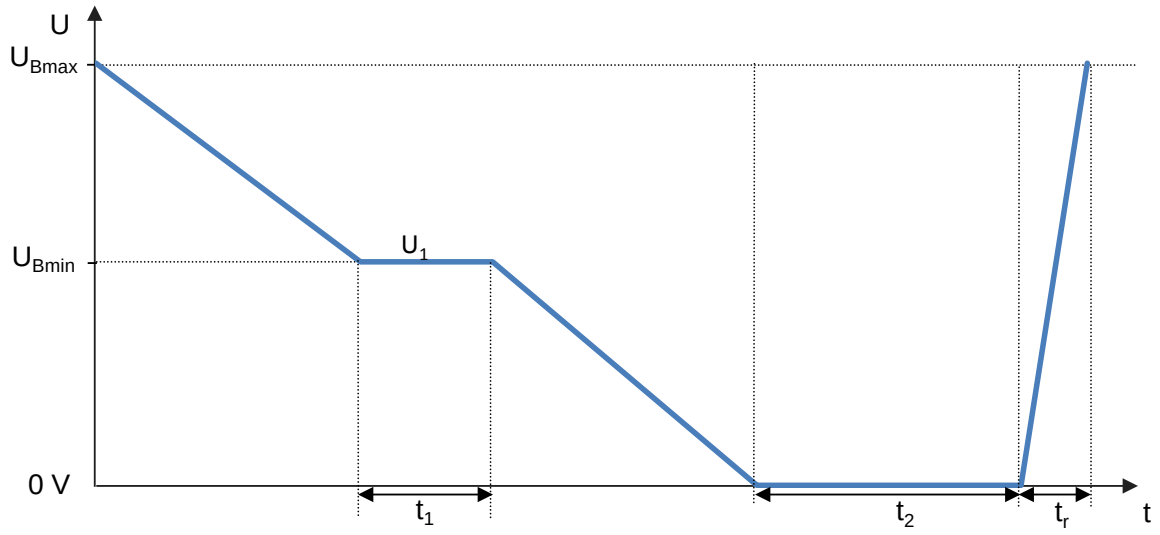


Figure 9: Test pulse E-08 Slow decrease, abrupt increase of the supply voltage

6.8.3 Requirement

The assessment of the test result depends on the voltage range applied to the component during the test.

A distinction is made between the areas:

a) within the defined operating voltage of the component:
functional status A

b) outside the defined operating voltage of the component:
functional status C

6.9 E-09 Reset behavior

6.9.1 Purpose

The reset behavior of a component in its environment is simulated and tested. Test boundary conditions (e.g. assembly, terminal, system) shall be described in detail.
During operation, an arbitrary sequence of repeated switching-on/off processes occurs; this shall not lead to an undefined behavior of the component.
The reset behavior is reflected by a voltage variance and a time variance. Two different test sequences are required to simulate different switch-off times. A component shall always be subjected to both sequences.

6.9.2 Test

Table 20: Test parameters E-09 Reset behavior

Operating mode of the DUT	Operating modes II.a and II.c To be performed for all relevant statuses of the voltage supply terminals (e.g. Terminal 15, Terminal 30, Terminal 87, ...) and their combinations.
U_{max}	U_{Bmin} (0%, -4 %)
U_{th}	6 V
ΔU_1 (range U_{max} to U_{th})	0,5 V
ΔU_2 (range U_{th} to 0 V)	0,2 V
t_2	At least ≥10 s and until the DUT has returned to 100% serviceability (all systems rebooted without error).
t_r	≤ 10 ms
t_f	≤ 10 ms
Number of cycles	For each test sequence per relevant terminal status and their combinations: 1 cycle in operating mode II.a 1 cycle in operating mode II.c
Number of DUTs	at least 6
Test case 1	
t_1	5 s
Test case 2	
t_1	100 ms

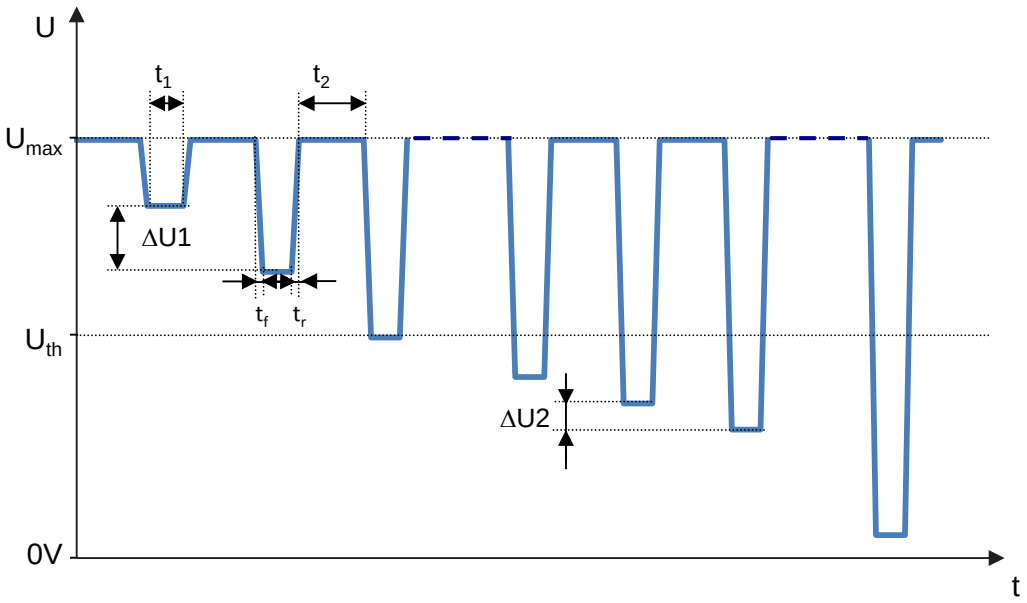


Figure 10: Test pulse E-09 Reset behavior

6.9.3 Requirement

Functional status A when U_{max} is reached again.

Undefined operating statuses shall not occur under any circumstances.

Evidence of compliance with the specified threshold, at which the component leaves the functional status A for the first time, shall be provided and documented.

6.10 E-10 Short interruptions

6.10.1 Purpose

The behavior of the component in the case of short interruptions of different durations is simulated.
Test case 1 models the supply voltage interruption at the component.
Test case 2 models the supply voltage interruption in the on-board vehicle electrical system.
Such interruptions may be caused by events such as contact and line defects or bouncing relays.

6.10.2 Test

Table 21: Test parameters E-10 Short interruptions

Operating mode of the DUT	Operating mode II.c	
U_{test}	11 V	
Z1	S1 closed	
Z2	S1 open	
t_r	≤ (0,1 * t_1)	
t_f	≤ (0,1 * t_1)	
The switch S1 shall be switched with the following sequences:	t_1	Steps
	10 µs to 100 µs	10 µs
	100 µs to 1 ms	100 µs
	1 ms to 10 ms	1 ms
	10 ms to 100 ms	10 ms
	100 ms to 2 s	100 ms
t_2	> 10 s The test voltage U_{test} shall be held at least until the DUT and the periphery have regained 100% serviceability.	
Number of cycles	1	
Number of DUTs	at least 6	
Test case 1	S1 switched, S2 statically open	
Test case 2	S1 switched, S2 negates S1	

The duration of the voltage dip increases at the intervals specified in Table 21. This results in a diagram as shown in Figure 11.

The voltage at the DUT can be limited by the test set-up to the maximum voltage of test E-05 Load dump (see Section 6.5).

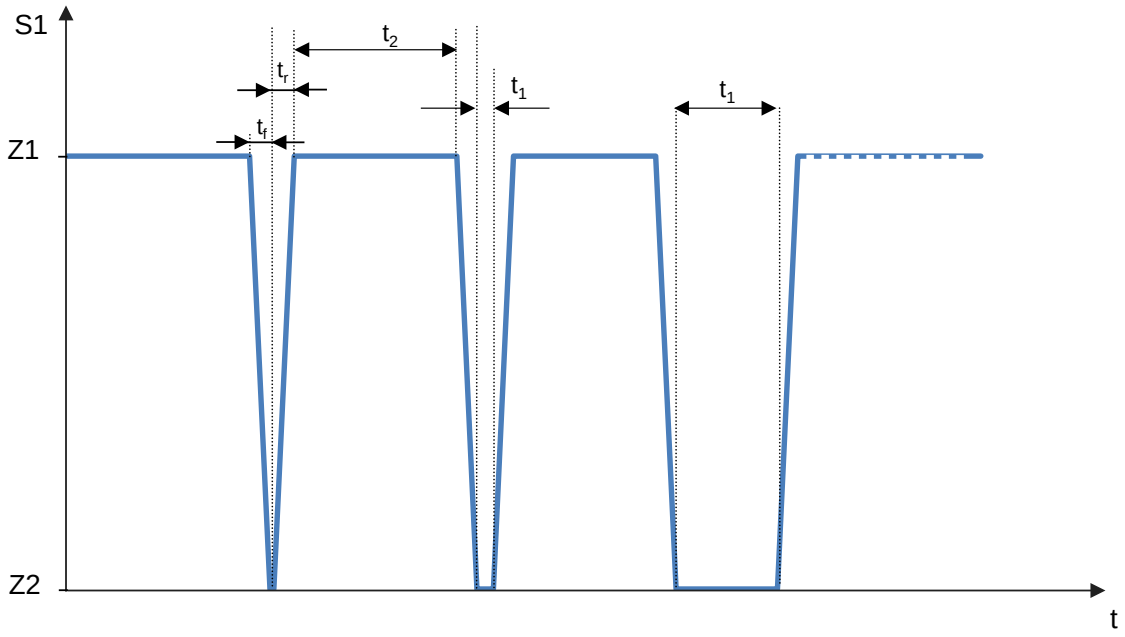


Figure 11: Change in status switch S1 E-10 Short interruptions

6.10.2.1 Test set-up

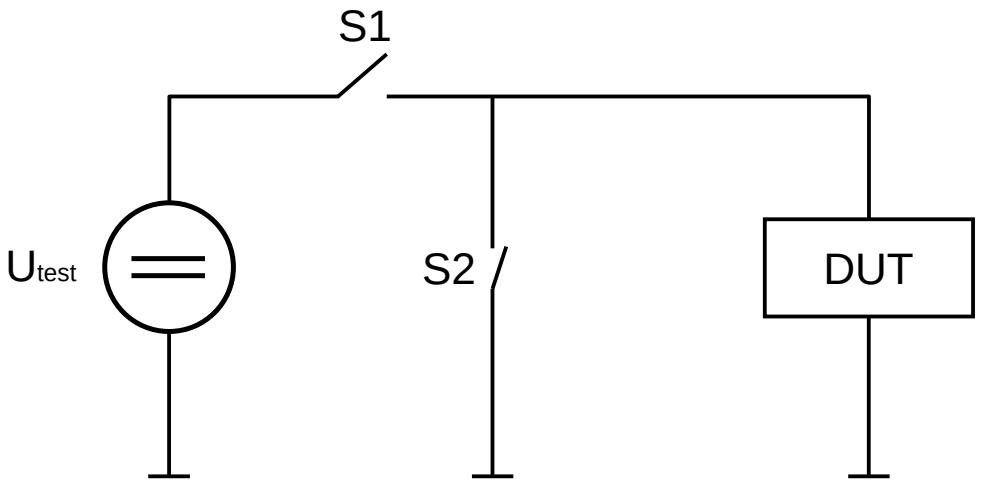


Figure 12: Schematic circuit diagram E-10 Short interruptions

The closed switch S2 including the required lines shall be realized with a series resistance of <100 mΩ.

6.10.2.2 Test sequence

One reference measurement each with 100 Ω (±5 %) and 1 Ω (±5 %) as DUT substitute shall be performed and documented. This test is intended to provide evidence of the edge steepness. Low-inductance modules shall be used as resistors.
Then the tests according to Table 21 shall be performed.

6.10.3 Requirement

For $t_1 < 100$ µs: functional status A
For $t_1 \geq 100$ µs: functional status C

The time value t_1 at which the DUT leaves functional status A for the first time shall be recorded .

6.11 E-11 Start pulses

6.11.1 Purpose

When starting the engine, the battery voltage drops to a low value for a short period and then slightly rises again. Most components are briefly activated directly before starting, then deactivated during starting and activated again after starting when the engine is running. This test is intended to examine the behavior of the component under start-related voltage dips.
The starting process may be performed under different vehicle starting conditions, cold start and warm start (automatic restart for start/stop). In order to cover both cases, two different test cases are required. A component shall always be subjected to both sequences.

6.11.2 Test

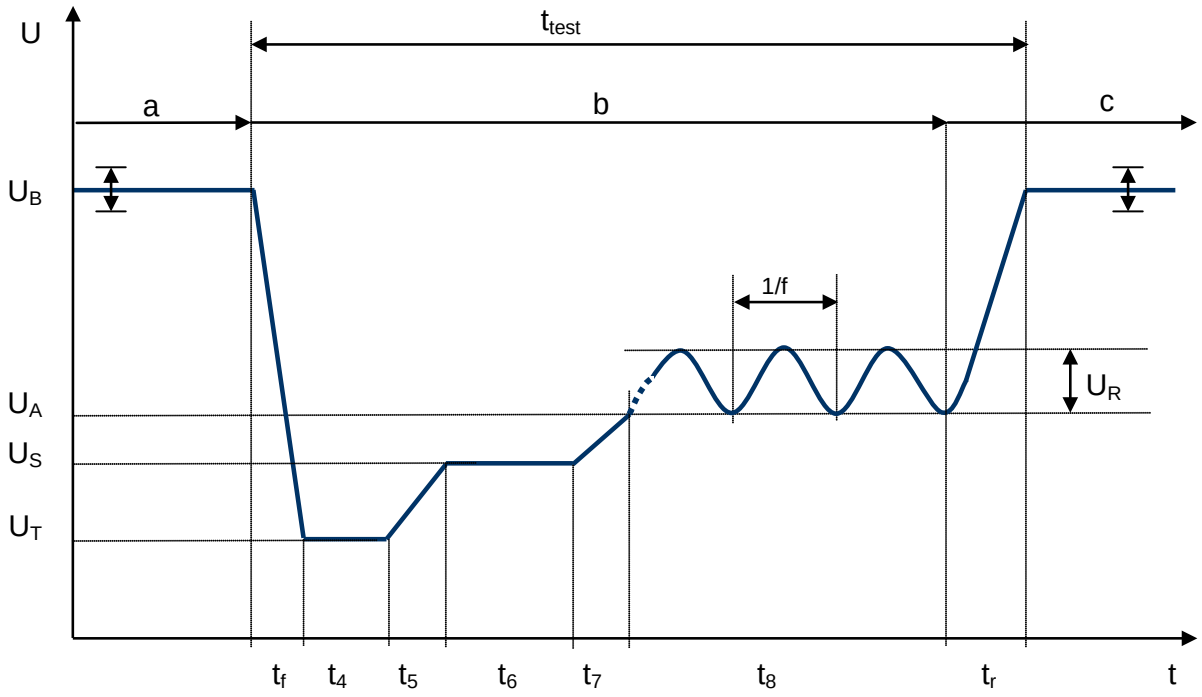
Table 22: Test parameters E-11 Start pulses

Operating mode of the DUT	Operating modes II.a, II.b and II.c If appropriate, additional operating loads shall be specified for the relevant operating mode.
Test pulse	- Cold start: test pulse "normal" and "severe" according to Table 23 - Warm start: test pulse "short" and "long" according to Table 24
Number of DUTs	at least 6

6.11.2.1 Test case 1 – cold start

Table 23: Test parameters E-11 Start pulses

Parameters	Test pulse "normal"	Test pulse "severe"
U_B	11,0 V	11,0 V
U_T	4,5 V (0 %, -4 %)	3,2 V $^{+0,2V}$
U_S	4,5 V (0 %, -4 %)	5,0 V (0 %, -4 %)
U_A	6,5 V (0 %, -4 %)	6,0 V (0 %, -4 %)
U_R	2 V	2 V
t_f	≤ 1 ms	≤ 1 ms
t_4	0 ms	19 ms
t_5	0 ms	≤ 1 ms
t_6	19 ms	329 ms
t7	50 ms	50 ms
t_8	10 s	10 s
t_r	100 ms	100 ms
f	2 Hz	2 Hz
Break between cycles	2 s	2 s
Test cycles	10	10



Key

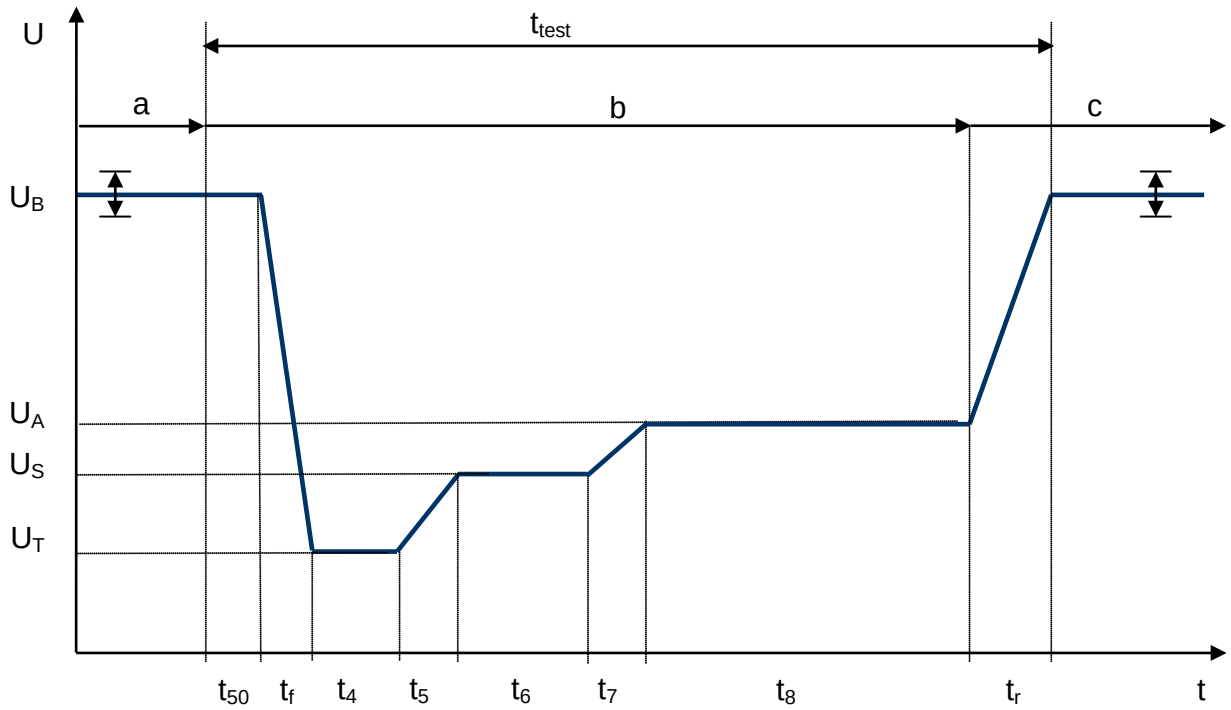
a Terminal 50 off
b Terminal 50 on
c Terminal 50 off
t_{test} Cycle

Figure 13: Test pulse cold start

6.11.2.2 Test case 2 – warm start

Table 24: Test parameters E-11 Start pulses warm start

Parameters	**Test sequence "short“**	**Test sequence "long"**
U_B	11,0 V	
U_T	7,0 V (0 %, -4 %)	
U_S	8,0 V (0 %, -4 %)	
U_A	9,0 V (0 %, -4 %)	
t50	≥ 10 ms	
t_f	≤ 1 ms	
t_4	15 ms	
t_5	70 ms	
t_6	240 ms	
t7	70 ms	
t_8	600 ms	
t_r	≤ 1 ms	
Break between cycles	5 s	20 s
Test cycles	10	100



Key

a Terminal 50 off
b Terminal 50 on
c Terminal 50 off
t_{test} Cycle

Figure 14: Test pulse warm start

6.11.3 Requirement

No fault memory entry shall occur.
The vehicle shall always be capable of being started.

6.11.3.1 Components relevant for starting:

Test case 1 – cold start
Test pulse "normal": functional status A
Test pulse "severe": functional status B

Test case 2 – warm start:
Test sequence "long": functional status A
Test sequence "short": functional status A

6.11.3.2 Components not relevant for starting:

Test case 1 – cold start
Test pulse "normal": functional status C
Test pulse "severe": functional status C

Test case 2 – warm start:
Test sequence "long": functional status A
Test sequence "short": functional status A

6.12 E-12 Voltage profile for on-board electrical system control

6.12.1 Purpose

The behavior of the on-board electrical system is simulated, for example when intelligent generator or DC-DC converter controls are used. The control allows voltage profiles to be set in the range between constant voltage and permanent voltage fluctuations in line with the test cases according to Table 25.
This is relevant for all load cases which the component can assume for "engine running" / "vehicle ready for operation".

6.12.2 Test

Table 25: Test parameters E-12 Voltage profile for on-board electrical system control

Operating mode of the DUT	Operating mode II.c
U_{min}	(11,8 V - ΔU) (0 %, -4 %)
U_{max}	(15 V - ΔU) (+4 %, 0 %)
t_1	2 s
t_r	≥300 ms
t_f	≥300 ms
Number of cycles	10
Number of DUTs	at least 6
Test case 1	
ΔU	0 V
Test case 2	
ΔU	0,7 V
Test case 3	
ΔU	2 V

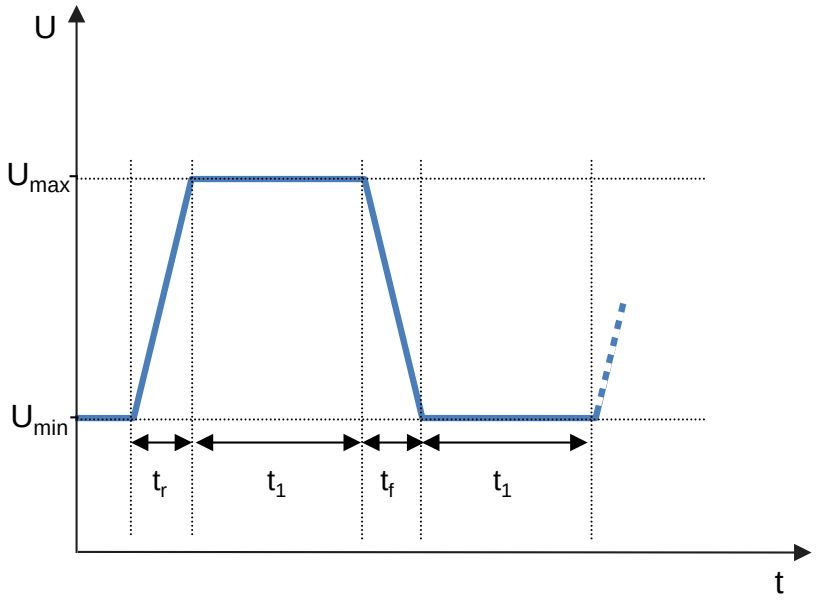


Figure 15: Test pulse E-12 Voltage profile for on-board electrical system control

6.12.3 Requirement

Functional status A

6.13 E-13 Pin interruption

6.13.1 Purpose

The line interruption of individual pins is simulated. Testing shall be carried out in two different operating statuses. Different pulse forms shall be used since the possible interruptions may differ greatly regarding their duration (from loose contacts to permanent interruption).

6.13.2 Test

Table 26: Test parameters E-13 Pin interruption

Operating mode of the DUT	Operating modes II.a and II.c To be performed for all relevant statuses of the voltage supply terminals (e.g. Terminal 15, Terminal 30, Terminal 87, ...) and their combinations.
Z1	Status 1: pin connected
Z2	Status 2: pin interrupted
t_r	≤ (0,1 * t_1)
t_f	≤ (0,1 * t_1)
Number of cycles	The following applies to the two test cases and the relevant terminal status: 3 cycles in operating mode II.a 3 cycles in operating mode II.c Each test shall be assessed separately.
Number of DUTs	at least 6
Test case 1	
	Each pin shall be removed for t = 10s and then replaced (slow interval)
Test case 2	
	Pulse package on each pin in order to simulate a loose contact (Figure 16)
Number of pulses t_2 in pulse package	4 000
a	Pulse package
t_1	0,1 ms
t_2	1 ms
t_3	10 s

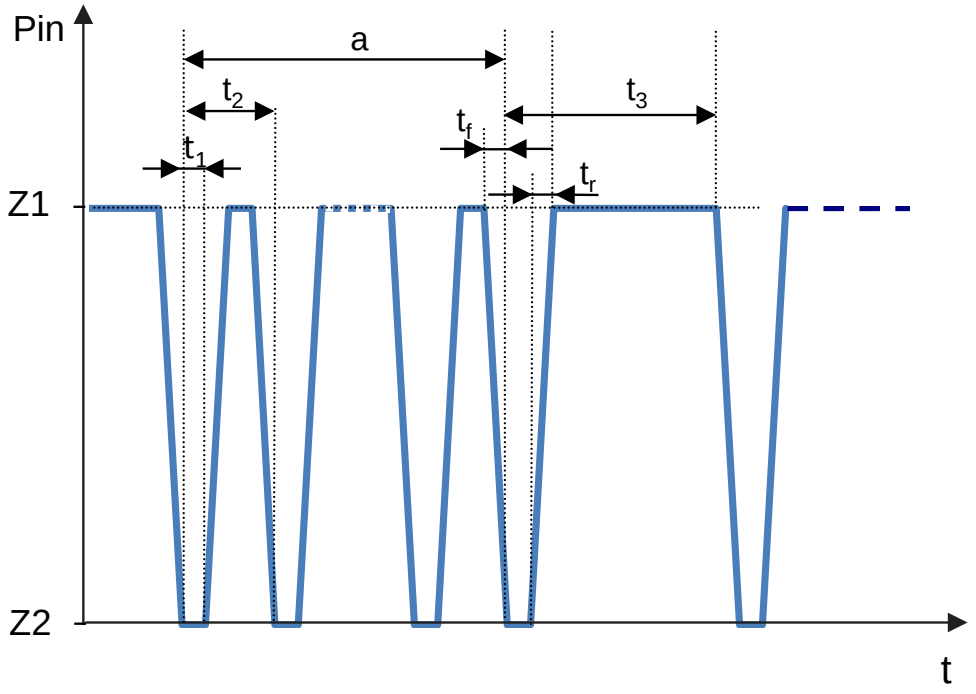


Figure 16: Test pulse E-13 Pin interruption, Test case 2

6.13.2.1 Test sequence

The component is connected to the voltage supply.
The test shall not be applied to the supply pins (e.g. Terminal 15, Terminal 30, Terminal 87, ...). The test shall also be applied to the ground pins (Terminal 31).

The voltage at the pin can be limited to the maximum voltage of test E-05 Load dump (see Section 6.5).

One reference measurement each with 1 kΩ (±5 %) and 1 Ω (±5 %) as DUT substitute shall be performed and documented. This test is intended to provide evidence of the edge steepness. Low-inductance modules shall be used as resistors.

Then the tests according to Table 26 shall be performed.

6.13.3 Requirement

All other test cases functional status C.

6.14 E-14 Connector interruption

6.14.1 Purpose

The line interruption of connectors is simulated.

6.14.2 Test

Table 27: Test parameters E-14 Connector interruption

Operating mode of the DUT	Operating modes II.a and II.c
Number of cycles	Each connector shall be removed once in both operating modes.
Number of DUTs	at least 6

6.14.2.1 Test sequence

Each connector shall be removed from the DUT for 10 s and then replaced. If the DUT has several connectors, each connector shall be tested individually. The sequence shall be varied. In the case of several connectors, their various combinations shall also be examined.

6.14.3 Requirement

Functional status C

6.15 E-15 Reverse polarity

6.15.1 Purpose

This test is intended to examine the resistance of the DUT against reverse-polarity battery connection during jump starting. Reverse polarity may occur several times and shall not lead to component damage. The reverse polarity resistance shall be assured for any voltages up to the minimum test voltage. The vehicle fuse is not part of the reverse polarity protection concept.

6.15.2 Test

All relevant connections of the original circuitry must be tested.
The DUT shall be operated as connected in the vehicle circuit.
The test shall be performed at different voltages between 0 V and the maximum values specified in Table 29.

The current input during the test shall be recorded.

Table 28: Test parameters E-15 Reverse polarity

Operating mode of the DUT	Operating mode II.a
Test case 1	Polarity static according to Table 29
Test case 2	Polarity dynamic according to Table 30
Number of DUTs	at least 6

6.15.2.1 Test case 1 - polarity static

This test case is intended to examine the robustness of the component at different polarity reversal voltages which might occur depending on the vehicle status.

Table 29: Test parameters E-15 Reverse polarity static

U_{max}	0 V
U_{min}	-14,0 V
ΔU_1	-1 V
Severity 1	R_i < 100 mΩ
Severity 2	R_i < 30 mΩ
t_1	60 s For a component in which the operating voltage is switched off by means of a relay in the case of polarity reversal, the following applies deviating from the value mentioned above: 8 ms
t_2	≥ 60 s, but at least until the component has reached the same thermal condition as at the beginning of the test
t_r	≤ 10 ms
t_f	≤ 10 ms
Number of cycles	1

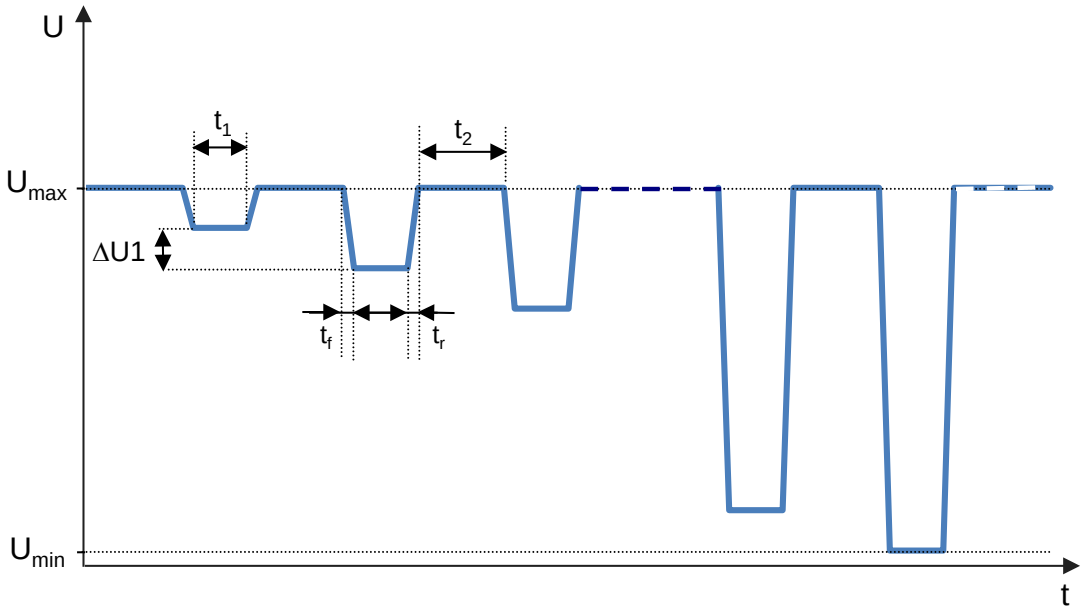


Figure 17: Test pulse E-15 Reverse polarity - polarity reversal static

6.15.2.2 Test case 2 - polarity dynamic

This test case is intended to examine polarity reversal of the component during ongoing operation when the vehicle is no longer able to start.

Table 30: Test parameters E-15 Reverse polarity dynamic

U_{max}	10,8 V
U_{min}	- 4,0 V
Severity 1	R_i < 100 mΩ
Severity 2	R_i < 30 mΩ
t_1	60 s For a component in which the operating voltage is switched off by means of a relay in the case of polarity reversal, the following applies deviating from the value mentioned above: 8 ms
t_2	≤ 5 min
t_r	≤ 10 ms
t_f	≤ 10 ms
Number of cycles	3

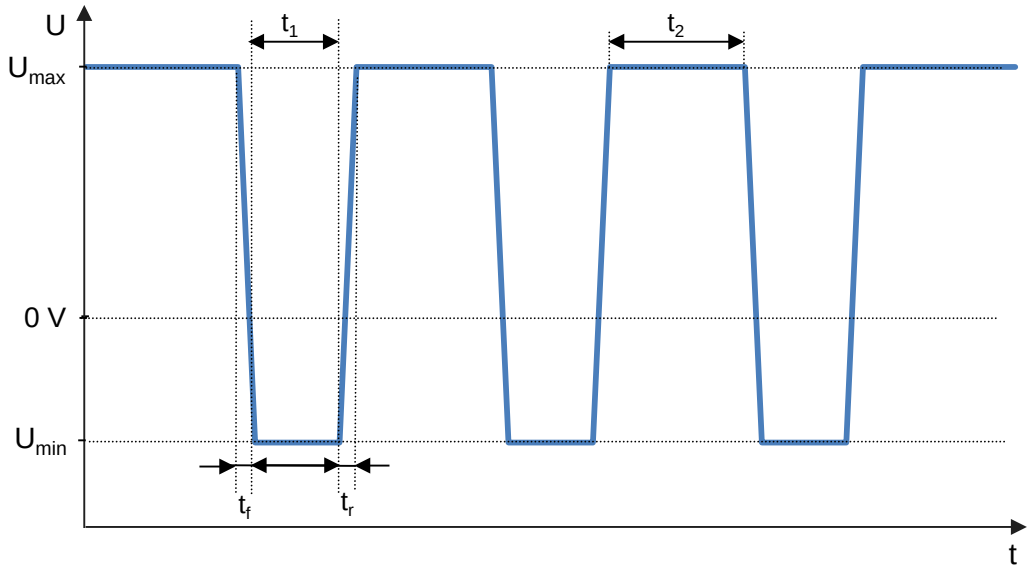


Figure 18: Test case E-15 Reverse polarity - polarity reversal dynamic

6.15.3 Requirement

When reverse polarity is applied, no safety-relevant functions shall be triggered, e.g. for electric windows, electric sunroof, starter, etc.

Functional status C

6.16 E-16 Ground offset

6.16.1 Purpose

Potential differences between different ground connection locations may result in signal distortions between components and these connection locations**.** Care shall be taken to ensure that the functionality of the component is not influenced in the case of potential differences between ground points up to a height of static ± 1 V in the electrical network.

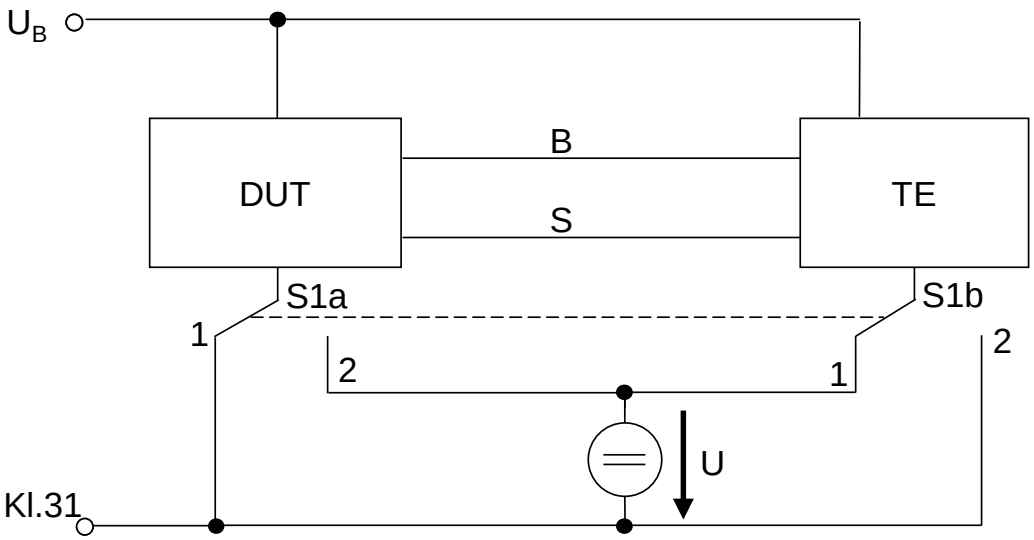
6.16.2 Test

If the DUT has several voltage and ground connections, the test shall be performed separately for each connection point.

The component shall be connected as shown in Figure 19.

Table 31: Test parameters E-16 Ground offset

Operating mode of the DUT	Operating mode II.c
U	1 V
Number of cycles	both switching positions
Number of DUTs	at least 6



Key

B Bus system
S Signaling line
S1 Two-pole (a/b) switch
TE Additional component such as test reference, test bench, simulation control unit, actuator, sensor or load

Figure 19: Schematic circuit diagram E-16 Ground offset

6.16.3 Requirement

Functional status A

6.17 E-17 Short circuit in signal circuit and load circuits

6.17.1 Purpose

This test simulates short circuits on all device inputs and outputs and in the load circuit. All inputs and outputs shall be designed short-circuit-proof against + U_B and GND (for activated and non-activated outputs with and without voltage supply and with and without ground connection).
The component shall be permanently short-circuit-proof.

6.17.2 Test

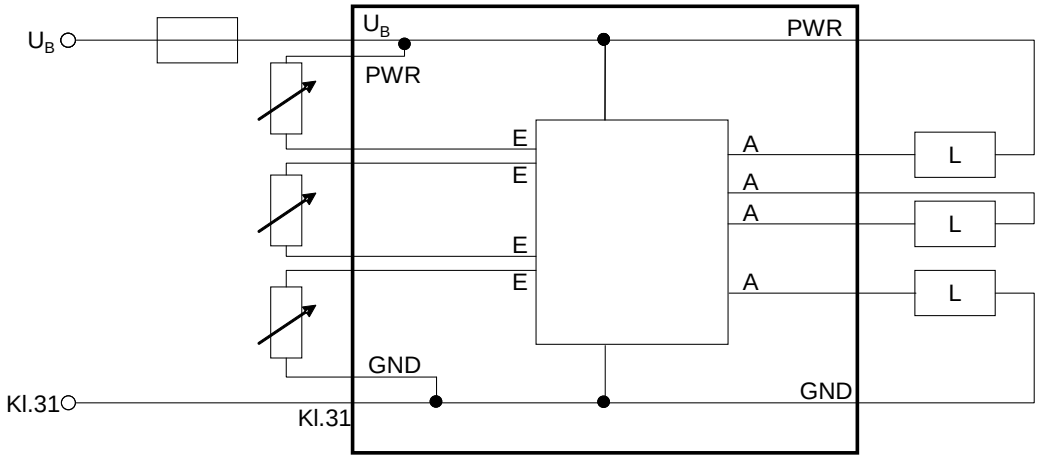
Table 32: Test parameters E-17 Short circuit in signal circuit and load circuits

Operating mode of the DUT	Operating mode II.c
Test duration	Short circuit of each pin individually for 60 s to ground and to U_B
Test voltages	U_{Bmin} and U_{Bmax}
Test case 1	Each pin alternating to U_B and GND with voltage supply and with ground connection
Test case 2	Each pin alternating to U_B and GND without voltage supply and with ground connection
Test case 3	Each pin alternating to U_B and GND with voltage supply and without ground connection
Number of DUTs	at least 6

If several pins are involved in the voltage supply/ground supply, the combination possibilities shall also be taken into account.

6.17.2.1 Test set-up

The power supply unit used for the test shall be capable of supplying the short-circuit currents expected by the component. If this is not possible, buffering of the power supply unit by means of a car battery is permissible (U_{Bmax} is the maximum charging voltage in this case).



Key

L	Load
E	Input
A	Output
PWR	Output U_B
GND	Input / output Terminal 31

Figure 20: Schematic circuit diagram E-17 Short circuit in signal circuit and load circuits

6.17.2.2 Test sequence

For inputs, outputs: recording and evaluation of time profile of short-circuit current.
The functional effects of the short circuits shall be documented.

6.17.3 Requirement

For inputs and outputs (E and A): functional status C
For looped-through supply voltages (PWR): functional status D
For device mass (GND): functional status E

6.18 E-18 Insulation resistance

6.18.1 Purpose

This test is intended to determine the insulation resistance between modules with galvanic isolation. Only the galvanically isolated pins shall be considered which are connected in the vehicle and which require insulation properties for their function.

6.18.2 Test

Table 33: Test parameters E-18 Insulation resistance

Operating mode of the DUT	Operating mode I.a
Test voltage	500 V DC
Test duration	60 s
Test points	Application of the test voltage - to terminals without galvanic connection - between connection pins and conducting housings without galvanic connection - between connection pins and an electrode around the housing if the housing is non-conducting - additional test points agreed with the relevant department responsible
Number of cycles	1 cycle shall be passed with each of the above points being tested at least once.
Number of DUTs	at least 6

6.18.2.1 Test sequence

As preparation for the test, the DUTs shall pass through the test "Damp heat, cyclic" which shall be agreed with the buyer. Before the measurement, the DUTs shall be allowed to dry for 30 minutes.

6.18.3 Requirement

The insulation resistance shall be at least 10 MΩ.
After the test, evidence of functional status A shall be provided.

6.19 E-19 Closed-circuit current

6.19.1 Purpose

This test is intended to determine the closed-circuit current consumption of the component.

6.19.2 Test

For components with follow-on current (e.g. fan), the closed-circuit current consumption shall be determined after the follow-on current has stopped.
The component shall be measured with the related peripherals and circuits.

Table 34: Test parameters E-19 Closed-circuit current

Operating mode of the DUT	Operating mode II.a
Test voltage	12,5 V (+4%, 0 %)
Number of DUTs	at least 6
Test case 1	
T	T_{min}
Test case 2	
T	T_{RT}
Test case 3	
T	T_{max}

6.19.3 Requirement

For all DUTs, a closed-circuit consumption target of 0 mA applies in principle.

For DUTs required to be operated after Terminal 15 OFF, a closed-circuit current consumption equivalent (average over 12 h) of ≤ 0,1 mA, corresponding to 1,2 mAh (above +40 °C ≤ 0,2 mA) applies in the at-rest phase. This shall be complied with under any conceivable at-rest conditions of the vehicle and at any 12 h period. Otherwise, release by the department responsible for closed-circuit current management is required.

Follow-on current functions shall also be approved by the department responsible for closed-circuit current management.

6.20 E-20 Dielectric strength

6.20.1 Purpose

This test is intended to simulate the dielectric strength between galvanically isolated parts of the DUT, e.g. pins, relays, windings or cables. The test shall be applied to components containing or actuating inductive devices.

6.20.2 Test

Table 35: Test parameters E-20 Dielectric strength

Operating mode of the DUT	Operating mode II.a
Test voltage U_{eff}	500 V AC, 50 Hz, sinusoidal
Test duration	60 s
Test points	Application of the test voltage - to terminals without galvanic connection - between connection pins and conducting housings without galvanic connection - between connection pins and an electrode around the housing if the housing is non-conducting - additional test points agreed with the relevant department responsible
Number of cycles	1 cycle shall be passed with each of the above points being tested at least once.
Number of DUTs	at least 6

6.20.2.1 Test sequence

As preparation for the test, the DUTs shall pass through the test "Damp heat, cyclic". Before the measurement, the DUTs shall be allowed to dry for 30 minutes.

6.20.3 Requirement

Functional status C
Dielectric breakdowns and arcs are not permissible.

6.21 E-21 Backfeeds

6.21.1 Purpose

This test is intended to simulate the behavior of the DUT at Terminal 15 and all lines which can be used as wake-up lines in the on-board electrical system. This test shall be performed for all components connected to Terminal 15 and/or other lines with "wake-up" capability.

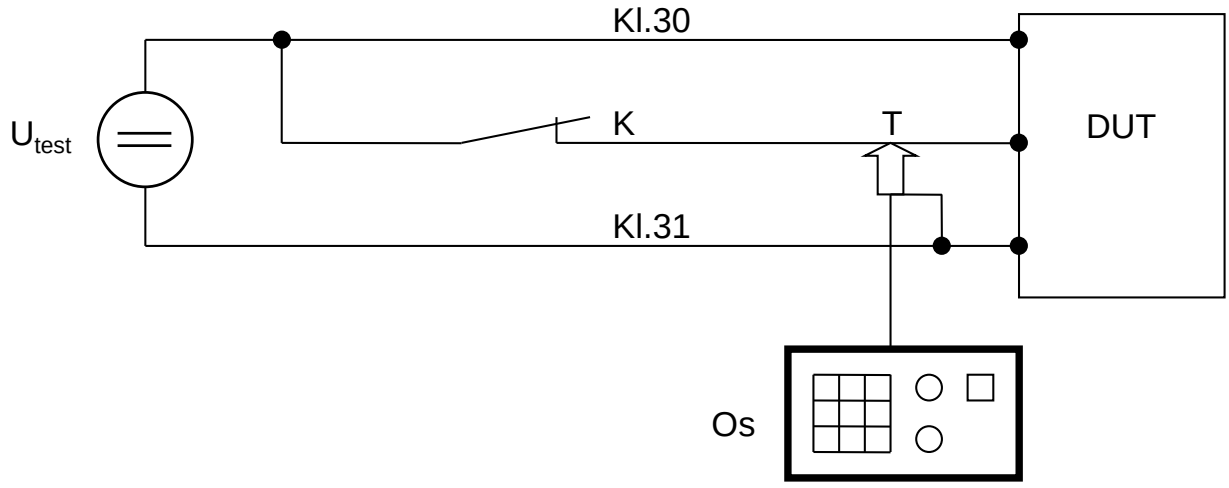
6.21.2 Test

Table 36: Test parameters E-21 Backfeeds

Operating mode of the DUT	Operating mode II.c
U_{test}	U_{Bmax} – 0,2 V
Test temperatures	T_{Bmax}, T_{RT} and T_{Bmin}
Number of DUTs	at least 6

6.21.2.1 Test sequence

The DUT shall be connected identical to the wiring situation in the vehicle (including sensors, actuators, etc.) and operated in normal operation. The voltage profile at the terminal to be tested shall be measured when it is switched off. The terminal shall be cut off by means of a relay or a switch ($R_{switch\_open} \rightarrow \infty$). Other possible voltage sources such as Terminal 30, shall not be interrupted or cut off during the test (according to the behavior in the vehicle). Other resistors at the terminal to be tested are not permissible for this test.
The voltage profile at the Terminal to be tested shall be examined using an external resistor ≥10 MΩ (e.g. oscilloscope) to Terminal 31.



Key

T	Probe
Os	Oscilloscope
K	Terminal to be tested

Figure 21: Schematic circuit diagram E-21 Backfeeds

6.21.3 Requirement

Voltage backfeeds to the terminal to be tested are only permissible up to a level of 1 V max. This voltage range shall be achieved within t = 20 ms after cutoff.

The voltage on the unconnected terminal to be tested shall decrease below a voltage of 1 V within t = 20 ms from the time of switch-off.

The voltage time profile shall be continuously decreasing. A discontinuity of the profile due to positive pulses is not permitted.

6.22 E-22 Overcurrents

6.22.1 Purpose

The overcurrent protection of mechanical switches, electronic outputs and contacts is tested. Higher currents than in the normal load case (e.g. maximum blocking current I_{block} of a motor) shall also be considered.

6.22.2 Test

Table 37: Test parameters E-22 Overcurrents

Operating mode of the DUT	Operating mode II.c
Temperature	T_{max}
Test conditions for electronic outputs	The output shall withstand at least the triple value of the nominal load without damage. Load duration 30 min
Test conditions for switched outputs	For components with $I_N \leq 10$ A: $I_{test} = 3 \times I_N$ For components with $I_N > 10$ A: $I_{test} = 2 \times I_N$, but at least 30 A and max. 150 A For components with $I_{block} > 3 \times I_N$: $I_{test} = I_{block}$ Switch "OFF", "ON" and "OFF" again under load. Load duration 10 min Each contact shall be tested individually in the case of multiple-contact relays and multiple-contact switches.
Number of DUTs	at least 6

6.22.3 Requirement

Functional status A for mechanical components without fuse. If fuse elements are available in the load circuit, these may be triggered.

Functional status C for electronic outputs with overload detection (current, voltage, temperature).

In addition, no dangerous changes that impair the function or service life (visual and electrical characteristics) shall be visible during a visual inspection of all components.

Pages 55 to 159 of LV 124: see MBN LV 124-2

Annex G (informative)

Examples of examination methods for physical analysis

- Screw loosening torques (e.g. housing screw connection, screws for fastening the component, ...)
- Soldering spot defects
- Device / circuit board discolorations (in particular if thermally caused)
- Stiffness/ease of operation, rubbing, play (where parts are moved mechanically)
- Traces of abrasion
- Breaks, cracks, deformations of materials (in particular of casting and sealing materials). A suitable test method (X-ray, CT, metallographic sections,…) shall be selected by agreement
- Opacity (in particular of parts of optical sensor systems)
- Condition of latch and clip locking mechanisms
- Traces of corrosion and migration, in particular silver and tin migration
- Assessment of plastics for their resistance to hydrolysis (in particular in the case of components with inserted stamped grids and Terminal 30 switch circuits)
- Damage to through-hole plated boards, in particular thermal vias
- Damage to internal connection (paddles) of large electrolytic capacitors after mechanical load (vibration, mech. shock, drop test)
- Damage to connector pins (e.g. resulting from current, temperature, rubbing, oxidation)
- Other irregularities
- ICT result (where possible)