Available online at www.sciencedirect.com
SCIENCE @ DIRECT®
ELSEVIER
Journal of Power Sources 116 (2003) 73–78
JOURNAL OF POWER SOURCES
www.elsevier.com/locate/jpowsour

International standard for future automotive 42 V supply voltages (PowerNet)

Wolfgang Bremer

Robert Bosch GmbH, P.O. Box 300240, 70442 Stuttgart, Germany

Abstract

The development of innovative automotive systems is determined by the demand for cut in fuel consumption and increase in fuel efficiency, reduction of environmental pollution and comfort improvement. A basic condition for such developments is the introduction of a 42 V power supply in future vehicles. The characteristics of future power supplies and the resulting consequences for the system, the components and the whole vehicle power supply architecture need standardisation in different areas. The electrical stress for the vehicle components is addressed in the standard ISO 21848 and this paper gives details about the status of the standardisation work.

Keywords: Electrical equipment; Vehicle power supply; 42 V standardisation; PowerNet

1. History

The standardisation of the 42 V PowerNet started in 1996 as a German national project and was conducted by the ‘‘Forum Bordnetzarchitektur’’ (Forum Vehicle Electrical Systems Architecture).

In 1997, VDA (association of German vehicle manufacturers and suppliers) and FAKRA (German standardisation body for vehicle applications) charged and co-financed this forum to continue the work and prepare a basic proposal for the inclusion in the international standardisation work of ISO as a new project. The forum prepared a working draft in close co-operation with the MIT/Industry Consortium and finished the work at the beginning of year 2000.

The draft was submitted to ISO where its technical committee TC22 (road vehicles) charged its subcommittee SC3 (electrical and electronic equipment) to conduct the work within a newly established working group (WG14).

End of 2002, this WG14 will have finished the main technical work of the envisaged standard and after some voting procedures at ISO level the standard will be finally published at the end of 2003.

2. Introduction

All vehicle manufacturers today are faced with the challenge of providing more electrical power to achieve well-known benefits and features like, e.g.:

- Fuel economy improvements.
- Emissions reductions.
- New vehicle designs through repackaging of systems and components (downsized wiring harnesses, increased use of semiconductor technologies).
- Improved efficiency in the generation, distribution, and control of electrical power.
- Introduction of hybrid vehicles.
- Lower costs of power semiconductors (reduced chip area).
- Lower currents and reduction of harness length.

The electrical power demand in motor vehicles is expected to significantly exceed the 4–5% annual growth rate that has been characteristic over the past two decades. Continued electrification of traditional mechanical loads, such as power assist steering, as well as the introduction of new loads, will quickly exceed the capability of the conventional 14 V power generation and distribution system.

The 42 V PowerNet has gained today a world-wide consensus as the next generation electrical system for vehicles. Table 1 gives some examples of today’s and future electrical systems together with benefits for the OEMs (mainly packaging and weight) and the consumers (fuel, safety and comfort) which will be enabled by introducing a 42 V power supply.

As a few automotive OEMs announce plans for dual/higher voltage production already within the next years (split 14 V/42 V power supply systems starting in 2005

0378-7753/03/$ – see front matter © 2003 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0378-7753(02)00712-7

Table 1
The 42 V systems and related benefits

	Remarks	Fuel	Safety	Comfort	Packaging	Weight
Electric oil and water pumps		×			×	
Electric ac compressor		(×)		×	×	(×)
Electric turbo-charger		×				
Windscreen heating (non wire)			×	×		
Integrated starter–generator	a	×		×		
Electric motor fan	a	×		×	×	(×)
Electric power steering	a	×	×	×	×	
Electric roll stabiliser	b		×	×		
Electrohydraulic valve drives	b	×			×	
Electromechanical brakes	b				(×)	

a, 42 V required for large engines/heavy cars; b, 42 V required.

and pure 42 V systems in 2007), global standardisation of 42 V components will play a major role in assuring the cost effectiveness of these electrical systems.

International Standards Organisation (ISO) as well as main regional standardisation bodies (like SAE, JSAE) are working to provide the standards necessary for this important new technology.

ISO and its technical committee TC22 (responsible for road vehicles) accepted end of 2000 a new project on the 42 V PowerNet with the following numbering and title: ‘‘ISO 21848: road vehicles—electrical and electronic equipment for a 42 V network—electrical loads’’.

The subcommittee 3 (SC3) of ISO/TC22 was charged to conduct the project. A new working group (WG14) was created and four meetings took place in the meantime to prepare a possible international standard. Experts from UK, Germany, Italy, Japan, Sweden, and USA are members in this WG14.

3. Structure of the standard

The standard under development applies to electrical and electronic systems/components for a 42 V network in road vehicles. It gives essential definitions and describes the potential stress and specifies, from the resulting requirements, the necessary tests recommended.

The objective is to standardise the voltages by establishing permitted voltage levels and test procedures for 42 V networks, without prescribing any specific technical solutions. It is not intended to specify a certain battery technology nor to specify any power network structure.

For the moment the following tests are drafted:

- direct current;
- overvoltage;
- superimposed alternating voltage;
- slow decrease and increase of supply voltage;
- discontinuities in supply voltage;
- reversed voltage;
- short circuit protection;
- dielectric strength;
- insulation resistance;
- electromagnetic compatibility.

Each test is specified in the same simple manner. In a first chapter is given the purpose of the test, then follows the second chapter with a detailed description of the test itself with all physical values, how to conduct the test and how to measure the result. Finally in the third chapter, the requirements for the device under test (DUT) during and after the test are given in a general sentence like this: ‘‘Functional status shall remain class A, B, C, D, or E’’. These five classes are defined within another standard ISO 16750-1 as follows:

- *Class A*: All functions of the device/system perform as designed during and after the test.
- *Class B*: All functions of the device/system perform as designed during the test. However, one or more of them may go beyond the specified tolerance. All functions return automatically to within normal limits after the test. Memory functions shall remain class A.
- *Class C*: One or more functions of a device/system do not perform as designed during the test but return automatically to normal operation after the test.
- *Class D*: One or more functions of a device/system do not perform as designed during the test and do not return to normal operation after the test until the device/system is reset by simple ‘‘operator/use’’ action.
- *Class E*: One or more functions of a device/system do not perform as designed during and after the test and cannot be returned to proper operation without repairing or replacing the device/system.

4. Description of the tests in ISO 21848

4.1. Direct current

The purpose of this test is to assure the full functionality of the device under test (DUT) at the minimum and maximum dc voltage power supply.

Table 2
Supply voltage for 42 V system devices

U_{low} (V)	30
U_{high} (V)	48

Table 3
Values for superimposed ripple

U_{PP} (ac voltage, sinusoidal)	
Test 1	4 V (50–1000 Hz)
Test 2	1 V (1–20 kHz)
Test voltage (U_T)	48 V $\pm$ U_{PP} sin(ωt)
Internal resistance of the power supply	≤100 mΩ
Frequency range	50–20,000 Hz
Type of frequency sweep	Triangular, linear
Sweep duration (one sweep)	120 s
Number of continuous sweeps per test	5

The minimum and maximum supply voltages as in Table 2—which are relevant within the full operating temperature range—have to be applied to all relevant inputs of the DUT (concerning temperature range details see ISO 16750-4). The functional status during this test shall remain class A.

4.2. Superimposed alternating voltage

This test shall assure the full functionality of the DUT at the test voltages specified as follows in Table 3 and detailed in Fig. 1. The tests simulate ripple (alternator, load, etc.) on top of the dc voltage and check the DUT for undesirable resonance modes and induced thermal stress. The functional status shall be class A.

An additional proposal is under consideration to create also a test with an alternating voltage superimposed to the low voltage U_{low} to check the higher stress on capacitors mainly in dc/dc converters.

4.3. Overvoltage

Concerning possible overvoltages in a 42 V network three statements/tests are in consideration.

4.3.1. Maximum continuous voltage

Under all conditions the maximum continuous supply voltage of the DUT shall not exceed U_{high} as defined in Table 2.

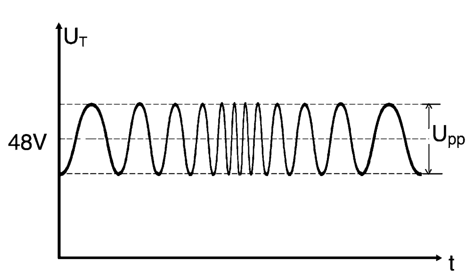

Fig. 1. Test voltage (example).

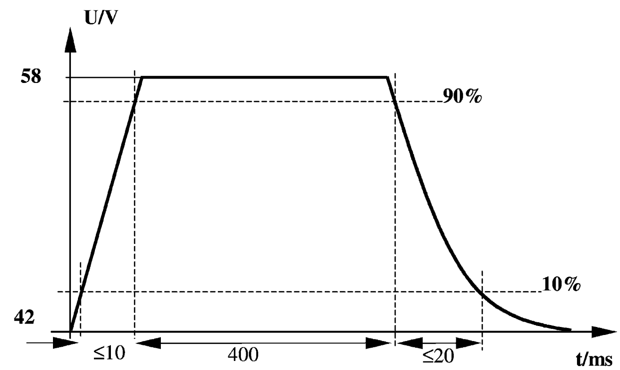

Fig. 2. Test pulse for $U_{max,dyn}$.

4.3.2. Maximum dynamic voltage

Susceptibility to dynamic overvoltages is covered by ISO 7637-2 except as specified below for a possible load dump. The purpose of the proposed test is to assure functionality of the DUT when subjected to a maximum dynamic voltage, $U_{max,dyn}$. This test simulates the maximum dynamic voltage for high-energy pulses in a 42 V vehicle electrical system, caused by load dump, and is the upper voltage limit for load dump protection (LDP). The test pulse to be applied to the DUT is shown in Fig. 2.

The functional status of the DUT after the test shall be minimum class D but special requirements may be agreed between vehicle manufacturer and supplier.

4.3.3. Emission

No electrical equipment shall produce a voltage exceeding 50 V except the generator during load dump and pulses as specified by ISO 7637-2. Measures shall be taken to ensure that 50 V is never exceeded (e.g. protection devices at the source and/or adjustment of generator voltage).

4.4. Slow decrease and increase of supply voltage

The purpose of this test is to assure functional status operation as defined in the specification when the DUT is subjected to a gradual discharge and recharge of the battery. It is proposed to apply the test voltage simultaneously to all applicable inputs (connections) of the DUT.

The supply voltage is decreased from U_{high} to 0 V and afterwards increased from 0 V to U_{high} with a change rate of 3 ± 0.1 V/min. The functional status shall be class A between U_{high} and U_{low} and minimum class D between U_{low} and 0 V.

4.5. Discontinuities in supply voltage

Three different discontinuities are described in the draft standard and for each of these a test is proposed.

4.5.1. Momentary drop in supply voltage

The purpose of the proposed test is to assure functional status operation of the DUT when subjected to an intermittent voltage drop.

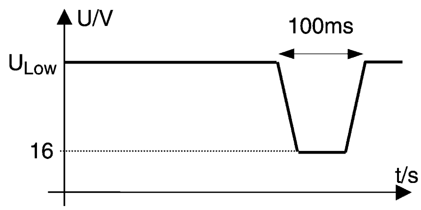

Fig. 3. Short voltage drop.

This test simulates the impact on the power supply of a short circuit in another harness branch while a fuse element melts and clears. All relevant inputs of the DUT are exposed to a test pulse as described in Fig. 3. The rise and fall time between U_{low} and the 16 V level is <10 ms. The functional status shall be class B. A reset of the DUT is permitted upon agreement.

4.5.2. Reset behaviour at voltage drop

The proposed test is only applicable to equipment with reset function (e.g. equipment containing one or more microcontrollers). The purpose of this test is to assure the correct reset function at different voltage drops.

The supply voltage is decreased by 5% from U_{low} (100%) to $0.95U_{low}$. This voltage is hold for 5 s and afterwards raised to U_{low}. At least for 10 s, U_{low} is hold before performing a functional test. Then the supply voltage is once again decreased now to $0.9U_{low}$. As shown in Fig. 4 the test continues with steps of 5% of U_{low} until the lower value has reached 0 V. Finally the voltage is raised to U_{low} again.

The minimum and maximum rise and fall times shall be $10\,\text{ms} \leq t_r \leq 1$ s. Functional status shall be class C for each test.

4.5.3. Starting profile

The proposed test voltage (as given in Fig. 5) to be applied to the DUT shall insure functional status operation of the device during and after cranking. U_{start} is the lowest threshold for the permitted operating voltage at start-up. It represents a minimum value including a possible ripple at start-up. The starting profile is applied simultaneously to all relevant inputs (connections) of the device under test.

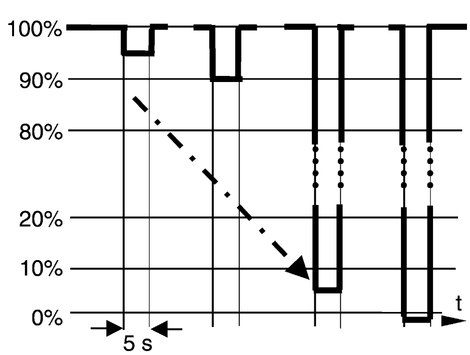

Fig. 4. Supply voltage profile for the reset test.

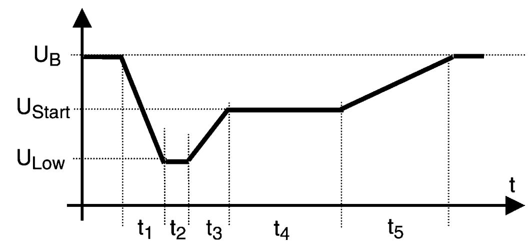

Fig. 5. Starting pulse.

Table 4
Values for the starting pulse

U_{start} (V)	21
t_1 (ms)	5
t_2 (ms)	15
t_3 (ms)	50
t_4 (ms)	500–20,000
t_5 (ms)	100

U_B = voltage due to battery technology.

The voltage and timing values are given in Table 4. The functional status during the different phases of the simulated starting pulse will be specified for each device. Devices that are relevant to vehicle function during cranking shall be class A, others shall be class C.

4.6. Reversed voltage

With this test the robustness of a device against the connection of a reversed battery shall be checked. This test will only be applicable in a 42 V electrical system incorporating centralised reverse voltage protection consisting of a series fuse and a reverse polarity shunt diode. This test is not applicable to alternators and to relays with clamping diodes without external reverse polarity protection device.

For the test a negative voltage with the specifications given in Table 5 is proposed to be applied simultaneously to all relevant power terminals of the DUT. The values for the time and the negative voltage are chosen on the basis of the capability of current semiconductor technology. The functional status shall be class C.

4.7. Short circuit protection

For testing the short circuit protection ability of devices and components in a 42 V system it is proposed to address

Table 5
Values for reversed voltage test

U (V)	−2
t (ms)	100
R_i (mΩ)	1

the following three issues: short circuits of electronic equipment to U_{high} and ground, short circuits of load circuits to U_{high} and ground, and short circuits from 42 V to other voltages.

4.7.1. Signal circuits

This test shall assure functional status of the DUT when short circuits are applied to the inputs and outputs of an electronic device.

All inputs and outputs of the device under test are connected in sequence for a duration of 60 s to U_{high} and to ground and the test shall be performed with the following conditions:

- supply voltage and ground connected;
- supply voltage disconnected;
- ground disconnected.

Functional status shall be class C.

4.7.2. Load circuits

The purpose of the proposed tests is to verify that all outputs shall withstand the short circuit currents as allowed by the corresponding protection. Values shall be given in the specification of the device under test. The DUT is connected to the power supply. The load circuits shall be in operation.

For high side outputs, the output circuit is connected to ground for a test duration which is specified in ISO 8820 considering the upper tolerance plus 10%. For low side outputs, U_{high} is connected to the output circuit for a test duration (see also ISO 8820) considering the upper tolerance plus 10%.

In a dual voltage system, outputs may be subjected to a short to 12 V also. Since the circuit protection of the 12 V source cannot be predicted, no test is specified for this condition. If other protection than fuses is used (e.g. electronic protection) the test duration shall be agreed between manufacturer and user.

All outputs with internal short circuit protection shall withstand the currents as ensured by the corresponding protection and shall return to normal operation either upon removal of the short circuit current or following reset.

For devices with unprotected outputs, the device under test may be damaged by the test current (functional status class E) provided that the flammability class V0 according to UL94[1] is complied with.

4.7.3. Short circuit from 42 V to other voltages

The probability of short circuits in split voltage systems between components/systems with e.g. nominal 12 V and those with nominal 42 V power supply is highly depending, e.g. on the wiring architecture of power lines or on the precautions taken by the vehicle designer to avoid such dangerous situations. A prediction today of the wiring architecture of future 42 V vehicles is nearly impossible until a significant number of suitable vehicles will be on the market and therefore it is also impossible to propose realistic tests for such short circuit situations.

Today the standard gives only a recommendation to include an overvoltage protection in the 12 V system for a vehicle designed for a 12 V/42 V dual voltage electrical system. The maximum overvoltage protection level shall not exceed the maximum voltage level defined for the 12 V system.

4.8. Dielectric strength

The purpose of this test is to check the withstand voltage of circuits with galvanic separation containing inductive elements (e.g. relays, motors and coils).

Heat the device under test in a hot air oven to a temperature of 35 ± 5 °C and a humidity of $50 \pm 5\%$. Apply a test voltage of 500 V_{eff} ac with a frequency of 50–60 Hz for a duration of 2 s to the device under test as follows:

- between terminals without galvanic connection;
- between terminals and housing with electrically conductive surface without galvanic connection;
- between terminals and an electrode wrapped around the housing (for example, metal foil and sphere bath) in the case of plastic housing.

Neither dielectric breakdown nor flash-over shall occur during this test.

4.9. Insulation resistance

The purpose of this test is to check the insulation behaviour of circuits with galvanic separation such as connector pins, relays or cables.

Heat the device under test in a hot air oven to temperature of 35 ± 5 °C and a humidity of $50 \pm 5\%$.

Apply a test voltage of 100 V dc for devices containing circuitry of 3.8 mm pitch or below, and a test voltage of 500 V dc for devices containing circuitry of more than 3.8 mm pitch, both for a duration of 60 s ($\pm 10\%$) to the device under test as follows:

- between terminals without galvanic connection;
- between terminals and housing with electrically conductive surface without galvanic connection;
- between terminals and an electrode wrapped around the housing (for example, metal foil) in the case of plastic material housing.

The insulation resistance shall be at least 100 mΩ.

4.10. Electromagnetic compatibility

The following EMC specifications are listed for reference. Performance measurements based on these specifications are not the requirements of ISO 21848:

[1] UL94 flammability test of plastic materials for parts in devices and appliances.

- ISO 7637-1, -2, -3;
- ISO 11451-1, -2, -3, -4;
- ISO 11452-1, -2, -3, -4, -5, -6, -7;
- CISPR 25;
- CISPR 12;
- ISO 10305;
- ISO 10605.

The applicability of these standards to the 42 V network is still under discussion and investigation.