VOLKSWAGEN AG

Electromagnetic Compatibility of Automotive Electronic Components

Conducted Interference

TL 820 66

Konzernnorm

Descriptors: electronic component, line, interference, electromagnetic compatibility, EMC, conducted interference, line fault

Contents

Changes

The following changes have been made as compared to TL 820 66: 1997-05:

– Standard restructured
– Artificial mains network section extended by 42 V vehicle power supply system
– Environmental conditions section added
– Pulse 5b for 42 V power supply system added
– Table 3 extended by values for 42 V power supply system
– Table 6 extended by values for 42 V power supply system
– Table 7 extended by pulse 5b for 42 V power supply system
– Functional states section
  Functional states A to E redefined
– Instructions for interference immunity test added
– Table 8: maximum permissible transient emission for 12 V and 42 V interference sources

Previous issues

1982-05; 1983-02; 1984-03; 1992-11; 1993-09; 1994-09; 1995-06; 1997-05

1 Scope

This TL standard includes requirements and tests for determining the electromagnetic compatibility (EMC) of electronic components with respect to interferences due to the vehicle power supply system. These interferences are caused by electric and electronic components and affect power supply lines, signal and sensor cables that are directly or indirectly galvanically connected to the power supply lines (via switch or relay contacts or valves / actuators / sensors). Component-related requirements (pulses) are specified in the given drawings or in the TL.

NOTE: This TL largely reflects the specifications in ISO 7637-1, -2.

Fachverantwortung/Responsibility		Normung/Standards (EZTN, 1733)
EEIZ Schindler Tel: -78556	I/EE-31 Bierer Tel: -89679	Guse Tel.: +49-5361-932438 Sobanski

2 Definitions

2.1 Vehicle power supply system

The vehicle power supply system is the electrical circuitry present in a motor vehicle to provide electrical power, including the attached battery and generator with regulator.

2.2 Supply voltage

The voltage measured at any arbitrarily chosen pair of terminals on the power supply system, one terminal may also be a ground connection.

2.3 Nominal voltage of the power supply system

The nominal voltage of the power supply system is specified in order to achieve independence of batteries.

2.4 Transient

Electromagnetic quantity causing an undesirable effect in electronic equipment.

NOTE: Transient serves as a generic term for such terms as 'disturbance voltage', 'interference current', 'interference signal', interference energy'.

2.4.1 Interference source

The origin of transients, i.e. electric equipment in vehicles.

2.4.2 Interference sink

Electric equipment in the vehicle the function of which can be influenced by transients.

2.4.3 Transient emission

Transient emitted by interference source.

2.4.4 Interference immunity

Ability of electronic equipment to withstand transients of given values without malfunctioning.

2.5 Steady condition

The state occurring after the switch-on procedure with the values of electric quantities basically remaining constant.

2.6 Ripple

More or less regular change in voltage around the voltage level, which is apparent in the system in the steady condition.

Transitional processes are excluded and so are frequencies below 10 Hz, unless starting.

2.7 Ripple size

The maximum change of voltage caused by rippling over or under the average level are termed top or bottom amplitude. Ripple from amplitude to amplitude is defined by the maximum distance between the top and bottom amplitude.

2.8 Transitional process of supply voltage

Temporary increase or decrease of the supply voltage caused by rapid changes in load.

2.9 Peak

Transitional process, during which the height of the ripple amplitude is exceeded for less than 150 µs. Generally, there is an oscillating peak as a result of high-frequency currents caused by sudden load changes. The duration of a decreasing oscillation is according to definition shorter than 1/20 of the interval between a sequence of two peaks. Thus, decreasing oscillation exceeding this value shall be regarded as ripple. Frequent causes for decreasing oscillations are for instance ignition systems or rectifiers located at the output of generators.

2.10 Peak energy

This is the energy to be absorbed if a peak is attenuated to given voltage values with the aid of a load that is connected to the interference sink terminals. With this load the voltage shall be attenuated to a specified value for positive current and to zero value for negative current.

2.11 Peak power

Energy per unit time for decreasing peaks.

2.12 Single pulse

A single pulse is a non-oscillating transitional process, singularly and infrequently occurring, with a duration considered long compared to 150 µs, lying outside the ripple amplitude.

2.12.1 Height of single pulse (U, I)

Maximum height exceeding the ripple amplitude.

2.12.2 Duration of single pulse (td)

Time interval between rise of the pulse over 10% of the amplitude and subsequent decrease below this value.

2.12.3 Rise time (tr), fall time (tf)

The time interval that it will take the value to rise from 10 % to 90 % of the amplitude value, or that it will take the value to fall from 90 % to 10 % of the amplitude respectively.

2.12.4 Pulse repetition frequency

Number of pulses per unit time.

2.12.5 Pulse interval

Time interval between the end of one pulse and the start of the following pulse.

2.13 Return time

Interval between the state in which the voltage increases above its normal value due to a transitional process and the point in time at which the voltage drops back to its original value and stays there.

2.14 Disturbances during starting

Voltage drop below the normal level, caused by switching and turning the starter. For engaging generators this disturbance generally includes an initial single pulse when switching the starter and a state when turning the starter.

3 Test equipment

3.1 Artificial mains network for 12 V / 24 V / 42 V vehicle power supply systems

The artificial mains network is used to simulate the average impedance of the vehicle power supply circuitry in order to evaluate the behavior of equipment and electrical / electronic components under bench test conditions.

A schematic diagram is shown in figure 1. Figure 2 shows how the impedance of the artificial mains network changes as a function of frequency.

Direct current voltage drop at maximum load shall not exceed 250 mV.

NOTE: The artificial mains network is defined for measuring peaks rather than ripple and single pulses.

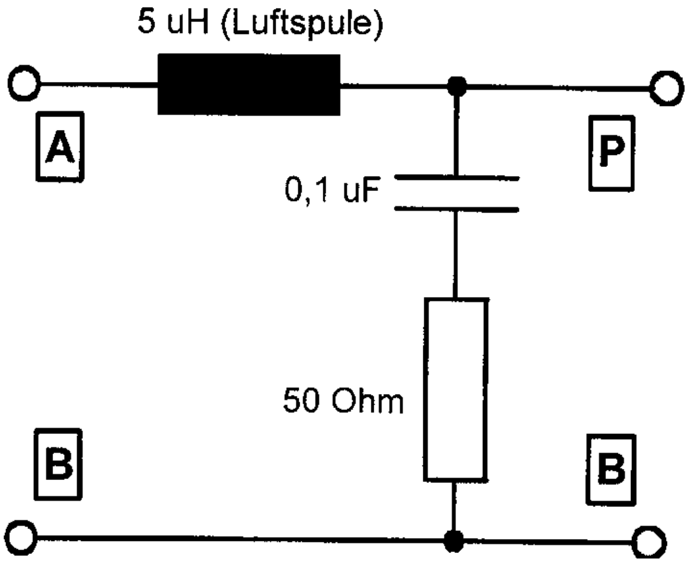

Figure 1 – Schematic cabling diagram of artificial mains network

A: power supply terminal
B: reference ground terminal
P: connection DUT

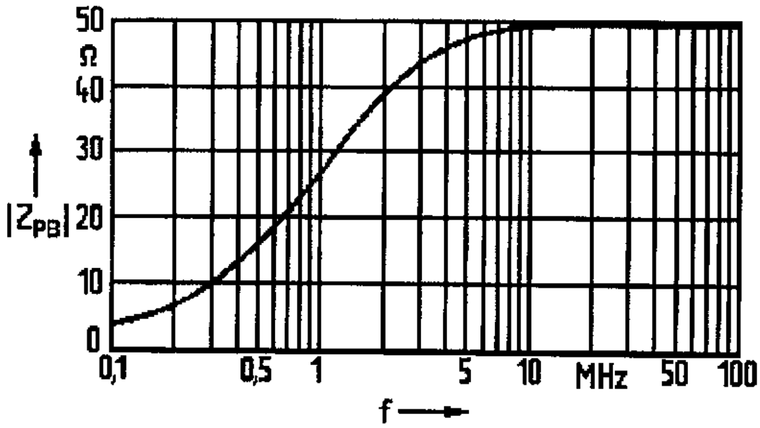

Figure 2 - Z_{PB} (Ω) impedance of artificial mains network as a function of frequency

As seen from the DUT side (between terminals P and B).
Tolerance ± 10 %; terminals A and B are short-circuited.

3.2 Voltage test equipment

Oscilloscope (preferably with digital storage function):

Bandwidth	a min. of 400 MHz
Writing time division	min. 5 ns / div.

Scanner head:

Division ratio	a min. of 10/1
perm. input voltage	a min. of 1 kV
Length of connecting line	max. 150 cm
length of ground line	max. 10 cm

NOTE: Differing line lengths may affect the measuring result; they shall be documented in the report.

3.3 Circuit breaker

For measuring the transient emission (interference pulses) the electric or electronic equipment shall be switched via the vehicle power supply system. This is achieved using the circuit breaker.

3.3.1 Electronic switch

This device shall ensure the switching-on and the transmission of the current avoiding too great a voltage drop; it shall also ensure contact breaking without bouncing and arcing (see table 2).

Table 2 – Requirements on electronic switches

	Electronic switch	
Current capacity I_{max}	25 A	2.5 A
Peak current (t ≤ 1 s) I_{peak}	100 A	10 A
Voltage protection U_{max}	400 V	
Voltage drop U_{diff}	≤ 1 V with 25 A	≤ 1 V with 2.5 A
Test voltages	13.5 V; 27 V; 41.5 V	
Switching times t_r	300 ns ± 20 % with DUT *) at 12 V R= 0.6 Ohm, L = 50 µH at 24 V: R= 2.4 Ohm, L = 200 µH at 42 V: R= 5.4 Ohm, L = 450 µH	300 ns ± 20 % with DUT *) at 12 V: R= 60 Ohm, L = 50 µH at 24 V: R= 240 Ohm, L = 200 µH at 42 V: R= 560 Ohm, L = 450 µH
Short circuit protection	yes	
Trigger options	externally and internally	
*) Total resistance including internal resistances of the air-core inductors ± 10 %, while L is measured at 1 kHz, ± 20 %		

NOTE: Considering the current state of the art, the big switch (for 25 A) is not suitable for switching currents less than 1 A (capacity of the transistors). In this case an electronic switch made up of less parallel transistors shall be used.

3.3.2 Mechanical switch

The switch (or relay) that is specified for the later application with the DUT shall be used. Alternatively, a switch or relay with silver contacts may be used.

3.4 Pulse generator

The generators must be capable to produce pulses acc. to the definitions in section 5. Under load with the prescribed internal resistance R_i the voltage pulse shall not drop below half its initial intensity. In stationary mode, the generator must be capable to supply the currents required by the DUT. For pulse 4, generators must display the required internal resistance also for negative current direction.

Tolerances: voltage and resistance values ± 10 %; time periods ± 30 %

4 Environmental conditions

4.1 Temperatures

4.1.1 Operating temperatures

According to drawing and/or TL.

4.1.2 Test temperature

(23 ± 5) °C, operating temperature in special cases.

4.2 Voltages

Nominal voltages see table 3.

Table 3 – Nominal voltages

	Supply power system, nominal voltage (in V)		
	12	24	42
Operating voltage	10.8 to 15	21 to 30	32 to 45
Test voltage	13,5 ± 0,5	27 ± 1	41,5 ± 1,5

5 Interference immunity verification test

5.1 Measuring Setup

The DUT is connected to the starter battery via the substitute interference source (pulse generator) as specified in figure 3. The connecting line between substitute interference source and interference sink shall have a length of (50 ± 5) cm for pulses 1, 1b, 2, 4, 4b and 5 and a length of (20 ± 2) cm for pulses 3a and 3b.

Voltages are set with the substitute interference source in idle state by using the oscilloscope or, in the case of automated test sequences, by using suitable measuring instruments integrated into the testing system. The measuring instruments shall be inspected for proper function before testing.

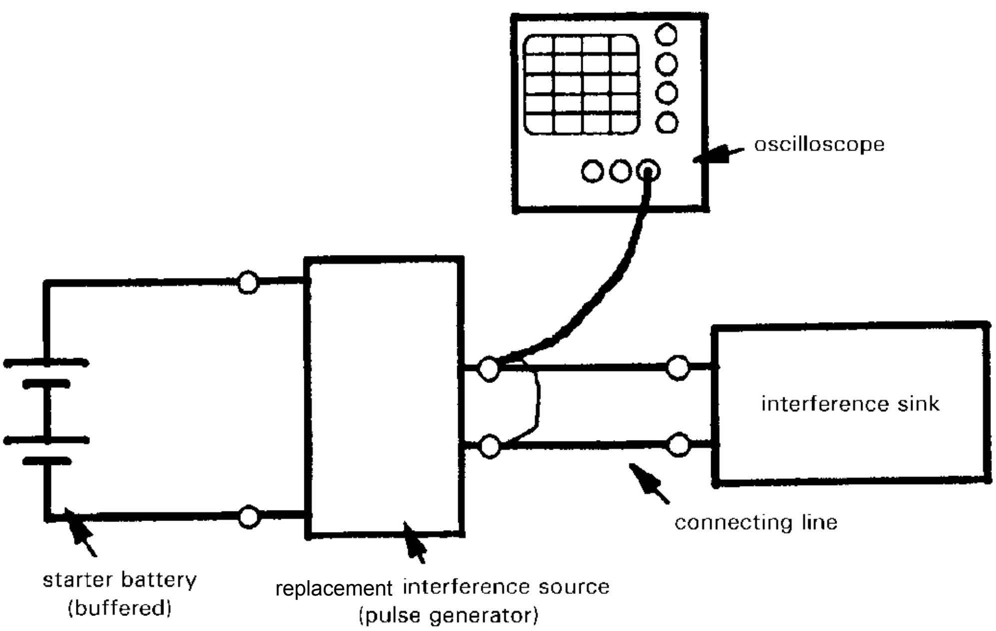

Figure 3 - Measuring setup for interference immunity testing

5.2 Test sequence

The following sequence with settings acc. to tables 2 to 5 shall be applied for testing.

1. Pulse 4 10 pulses

2. Pulse 4b **additionally** 10 pulses if required by part-specific TL or drawing

NOTE: Testing with pulse 4 is only applicable for interference sinks that operate or remain in operation when starting the engine. This pulse is not applicable especially to power consuming devices connected to terminal 75 (or terminal X).

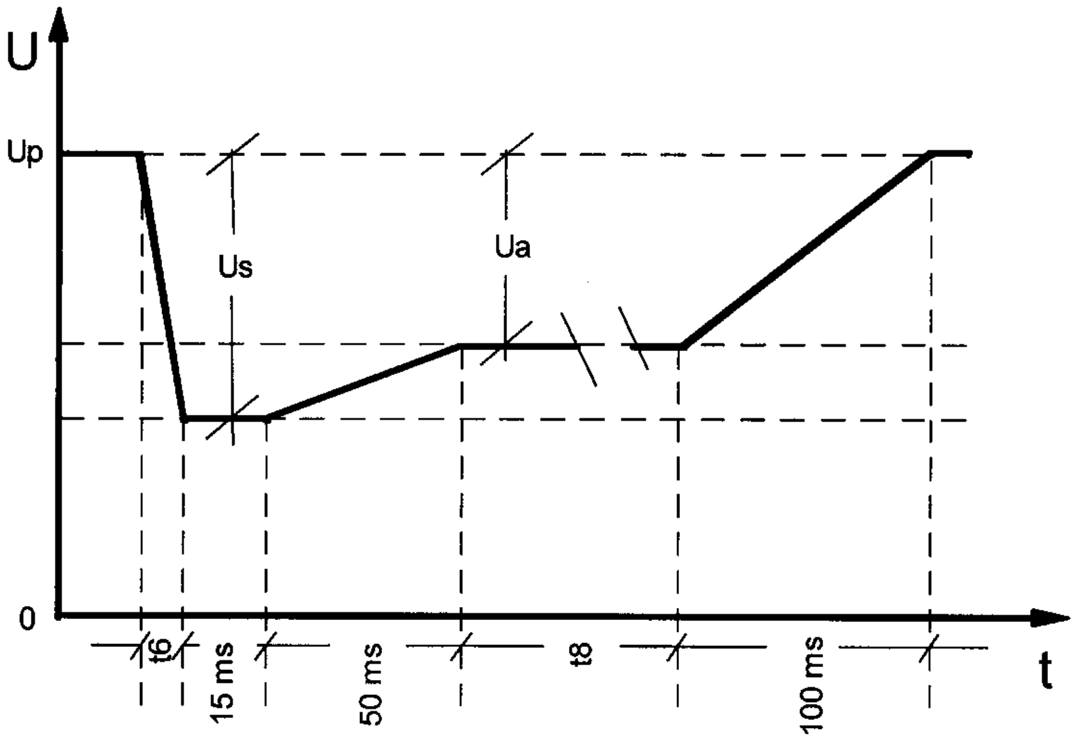

Figure 4 – Pulses 4 and 4b

NOTE: This voltage curve is characteristic of engaging starter motors. The curve has not yet been defined for crankshaft starter generators. The starting current can be considered as almost constant current because of the inverters possibly required for such starters. For example the voltage curve in the case of an UltraCap used as accumulator is almost identical to the curve of a capacitor discharging with constant current.

3. Pulse groups 3a + 3b 10 Hz repetition frequency, at least every 2 hours

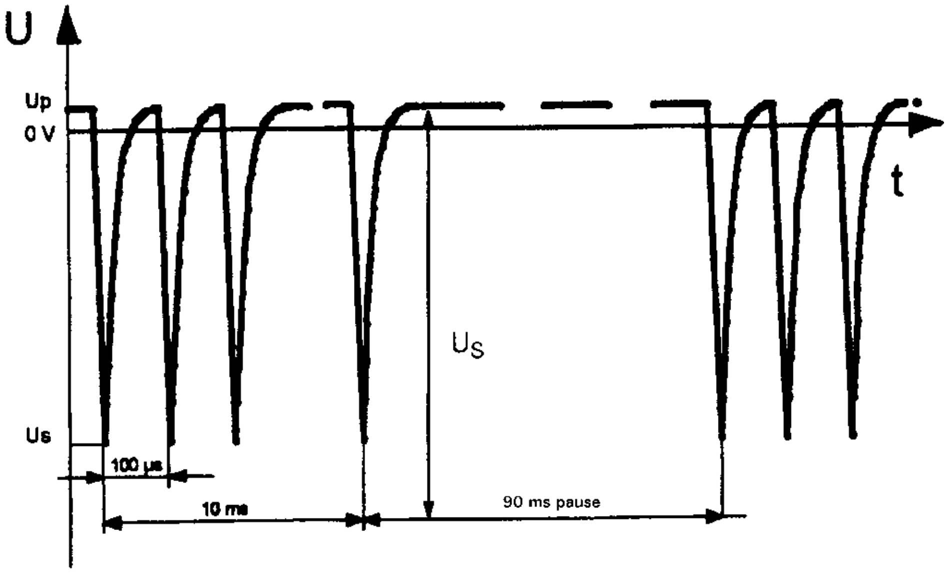

Figure 1 – Pulse 3a

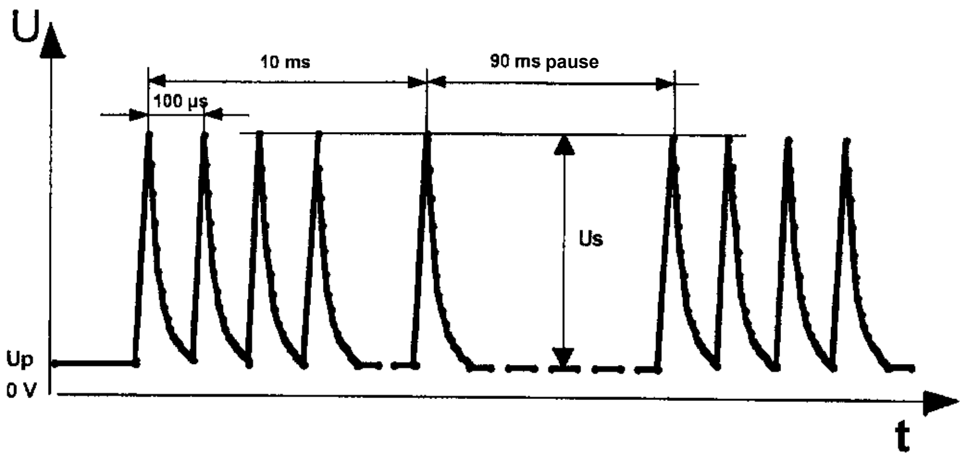

Figure 2 – Pulse 3b

4. Pulse 1b 5 Hz (t_{rep} = 0.2 s) pulse repetition frequency, at least 1 minute

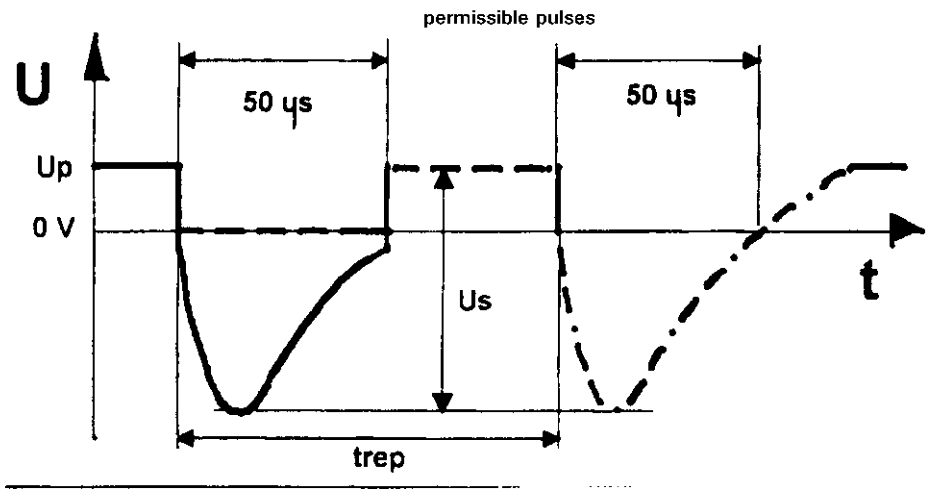

Figure 3 – Pulse 1b

5. Pulse 2 5 Hz (t_{rep} = 0.2 s) pulse repetition frequency, at least 5,000 pulses

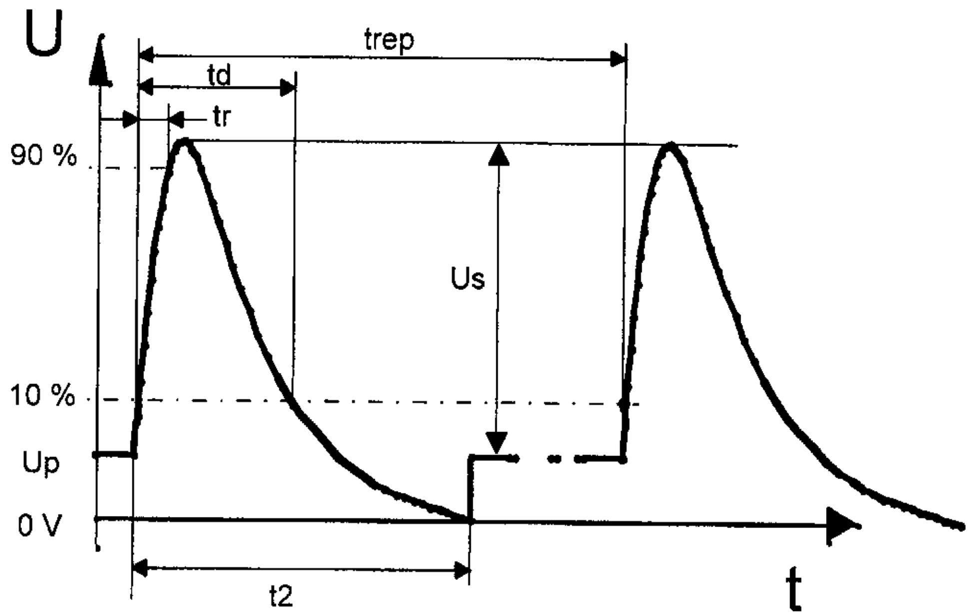

Figure 4 – Pulse 2

6. Pulse 1 0.2 Hz (t_{rep} = 5 s) pulse repetition frequency, at least 5,000 pulses, 50 pulses on terminal 30

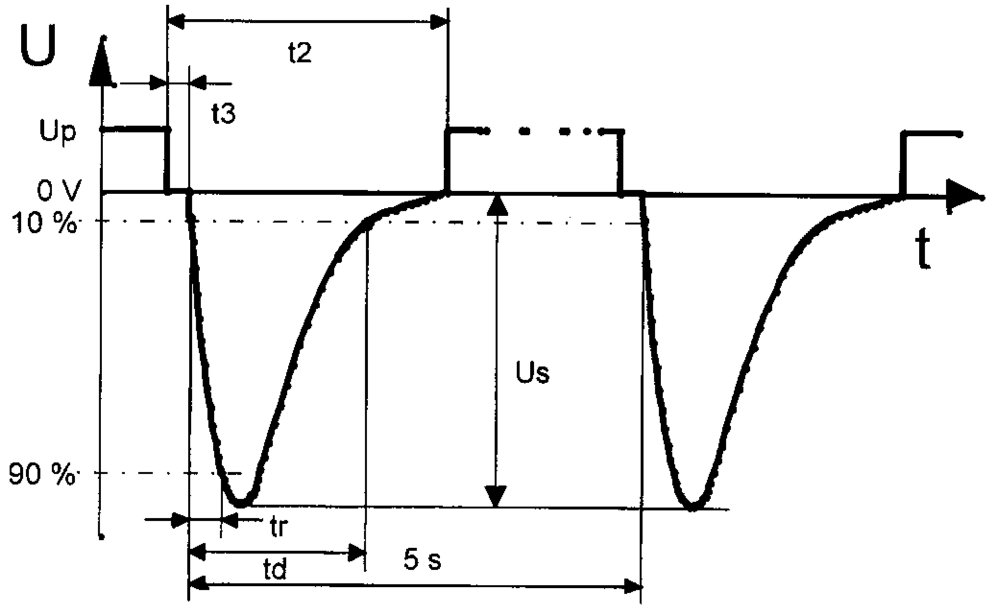

Figure 5 – Pulse 1

7. Pulse 5b 10 pulses at 1 minute intervals (only for 42 V power supply systems)

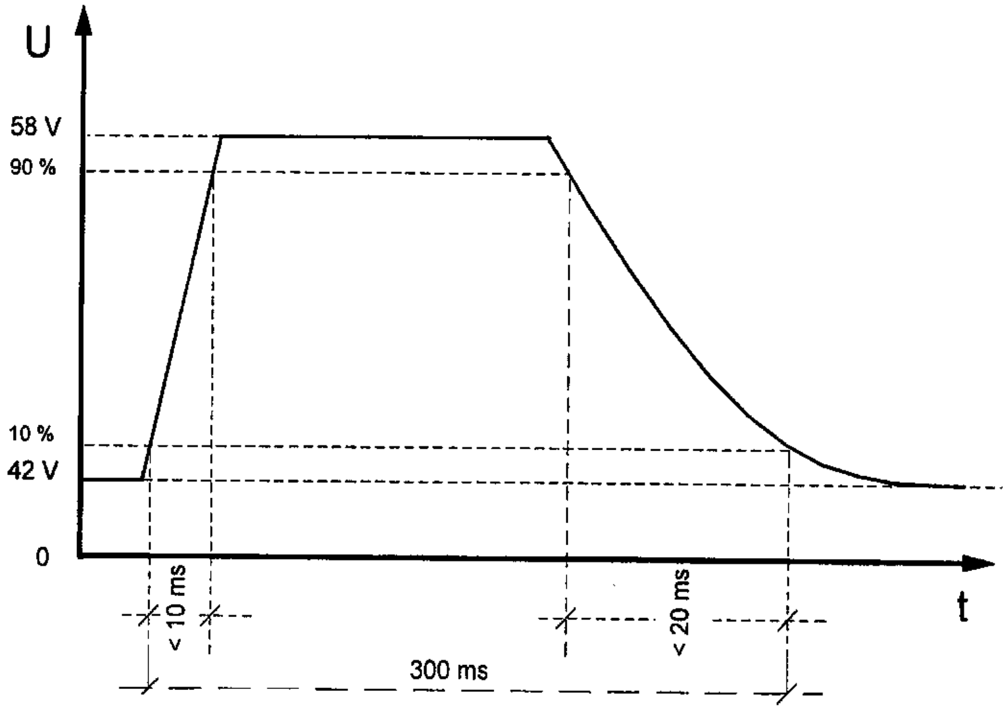

Figure 6 – Pulse 5b

NOTE: It is planned to use energy return technologies for 42 V. Increased voltage up to 55 V is applied for fast loading of the accumulators. This voltage shall be used as maximum operating voltage in calculations for t > 10 s!

Table 4 - Settings for interference immunity measurements: pulses 1 to 3 (12 V and 42 V)

Pulse	Number	U_s (V)	t_d (µs)	t_r (µs)	Generator R_i (Ω)		Remarks
					12 V	42 V	
Pulse 1	5 000 pulses	-100	2 000	1	4	10	Voltage switch-off for 200 ms
Pulse 1b	1 min 5 Hz	0 to -50	50	1	4	10	Voltage switch-off for t_d
Pulse 2	5 000 pulses	+50	50	1	4	10	Voltage switch-off for 200 ms
Pulse 3b	2 h 10 Hz	-150	0,1	0,005	50		Burst pulse
Pulse 3	2 h 10 Hz	+100	0,1	0,005	50		Burst pulse
NOTE: 42 V pulses have not yet been defined by standards and therefore vary significantly. Thus, the values stated here shall be considered as mere recommendations. Additional agreements with the responsible EMC departments in the Volkswagen Group are obligatory until further notice.							

Table 5 - Settings for interference immunity measurements: pulses 1 to 3 (24 V)

Pulse	Number	U_s (V)	t_d (µs)	t_r (µs)	Generator R_i (Ω)	Remarks
Pulse 1	5,000 pulses	-150	2 000	1	10	Voltage switch-off for 200 ms
Pulse 1b	1 min 5 Hz	0 to -50	50	1	10	Voltage switch-off for t_d
Pulse 2	5,000 pulses	+75	200	1	10	Voltage switch-off for 200 ms
Pulse 3a	2 h 10 Hz	-150	0,1	0,005	50	Burst pulse
Pulse 3b	2 h 10 Hz	+100	0,1	0,005	50	Burst pulse

Table 6 – Setting values for pulses 4 and 4b

Pulse		Number	U_p (V)	U_s (V)	U_a (V)	t_r (ms)	t_8 (ms)
4	12 V	10	12	7	5,5	≤ 5	2 000
4b	12V	10	12	9	7	≤ 5	1 000
4	24 V	10	24	18	12	≤ 10	3 000
4	42 V	10	36	18	15	≤ 10	2 000

Table 7 - Pulse 5b for 42 V power supply system

Pulse 5b	Number	U_p (V)	U_s (V)	t_d (ms)	t_r (ms)	t_f (ms)	R_i (Ω)
42 V	10	42	16	300	≤ 10	≤ 20	3

5.3 Functional states

The following functional states can occur during or as a result of testing:

Functional state A

The assembly / system operates during and after exposure as designed and within the permissible tolerances.

Functional state B

Individual functions of the assembly / system work beyond the prescribed tolerances, but independently return to normal operation after the disturbance has been removed. Requirements acc. to functional state A apply to memory functions. Warning lights shall not go on. Error log data are not permissible.

Functional state C

Individual functions of the assembly / system fail and warning lights may go on, but the functions return to normal operating state after removal of the disturbance. Automatic elimination of error log data which are not customer-relevant (emergency mode) is permissible.

Functional state D

Individual functions or the complete assembly / system fail. Function can be returned to normal after the exposure has been removed by simple operations like e.g. fuse replacement without the aid of customer service shops.

Functional state E

Individual functions or the complete assembly / system fail. The function cannot be returned to normal without repair or replacement in a customer service shop.

5.4 Notes on interference immunity test

- If specific requirements are missing, there shall be complete testing. Functional state A is required in this case.
- The pulses with a switch-off time of 200 ms simulate the switching-off of loads that are switched off together with the DUT. In this case functional state C is required. The DUT shall be checked for damaged components. This may be done if the voltage is switched off for a duration of t_d only.
- Pulse 1 normally does not reach terminal 30 because this would require switching off ignition. However, pulse 1 may occur there during fuse removal. A test comprising 50 pulses thus is necessary for this terminal, too. In this case functional state D is permissible.
- Pulse 1b is used in testing for disturbance of function caused by short-term voltage drops to zero. During testing it is possible to switch off supply voltage for the specified duration of t_d.
- Pulse 4b can be included in the performance specifications for specific DUT functions. Proper function is represented by a reset of the DUT without loss of stored data.

  EXAMPLE: When fulfilling the requirements for the "normal" pulse 4 it is still possible to start the engine, even if the voltage drop is more severe than required for testing. This can even lead to defects in other systems, losing data programmed by the customer (time, personal comfort adjustments, security codes etc.). When starting the engine the customer cannot recognize insufficient charge condition of the accumulator and will possibly consult the customer service shop about allegedly defective components.

- Pulse 5, load dump on generator. The load dump pulse (for 12 V and 24 V power supply system voltages) is only tested upon special requirement. Requirements for overvoltage protection are specified in VW 801 01.

  Modern compact-build generators currently use bridge rectifiers with Zener diodes, limiting overvoltage to approx. 30 V (for the 12 V power supply system) and thus serving as central load dump protection in the very unlikely event of failure. If vehicles are manufactured using other generators, the necessity to perform the test shall be agreed upon separately.

  Only the values specified in table 7 are permissible for 42 V generators acc. to VDA recommendation (VDA 2000-1).

  NOTE: The following signal and sensor cables mentioned in the scope section must be considered:

  - Terminal 58 d, interior lighting: The PWM dimmer normally comprises a MOSFET which transmits all terminal 30-related interferences without filtering.
  - Stop lamp switch, brake test switch, clutch switch: connected directly to terminals 30 and 15, respectively.

6 Transient emission measurement

6.1 Measuring setup

The setup depicted in figure 4 shall be used for measuring permanent interferences, switching bursts as well as switch-on transients and switch-off transients, the switch is located in the connecting line to the interference source. Having switched on the power supply, the permanent interferences generated by the interference source can be measured. Switch-off transients shall be registered at the instant the power supply is switched off. Switch-on transients can be measured when closing the switching contacts. Switching bursts result from glow discharges or arcing when opening the switching contacts. Therefore, they can be measured either when switching off the interference source power supply or at bouncing switching contacts when switching on.

Measurement is carried out directly on the DUT. All switch statuses designated for operation of the DUT, including deliberate engine deceleration by short circuit, shall be run through 10 times each. In this context, for DUT with moving weight (e.g. engines) the switching element specified for standard production or an equivalent one with silver contacts shall be used in order to include possible switch bouncing in the test. For DUT which cannot accumulate energy using moving weight an electronic switch acc. to section 3.3.1 is also permissible. The maximum value may not exceed the limit values specified in section 6.2.

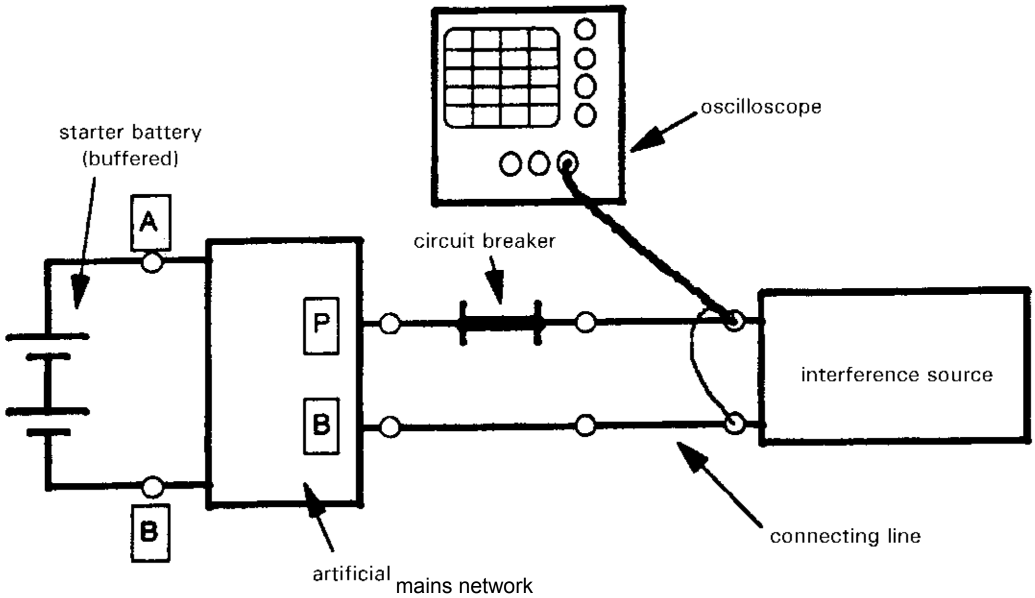

Figure 7 - Measuring setup for switching bursts and transients that are generated by the interference source and/or by the switch.

6.2 Limit values for transient emission in vehicle power supply systems

Disturbance voltage occurs in the shape of a pulse as a function of time or as interference oscillation. The actual voltage curve cannot be directly compared with the “standard” pulses 1 to 5 in most cases. However, the measured pulses can at least be assigned to the “standard” pulses. Disturbance voltage amplitudes and pulse time periods shall not exceed the limit values given in tables 8 and 9.

The test voltage serves as reference potential for the disturbance voltage (except for pulse 1). For pulse 1 mass potential serves as reference.

The maximum value out of 10 individual measurements shall be the voltage amplitude value.

Table 8 - Maximum permissible transient emission for 12 V and 42 V interference sources

Pulse	U_s (V)	t_d (µs)	t_r (µs)
Pulse 1	≥ -100	≤ 2 000	≥ 1
Pulse 2	≤ +50	≤ 50	≥ 1
Pulse 3a	≥ -150	≤ 0,1	≥ 0,005
Pulse 3b	≤ +100	≤ 0,1	≥ 0,005
Pulse 4	omitted		
Pulse 5b (only 42 V)	≤ 16	≤ 300	10 000
NOTE: 42 V pulses have not yet been defined by standards and therefore vary significantly. Thus, the values stated here shall be considered as mere recommendations. Additional agreements with the responsible EMC departments in the Volkswagen Group are obligatory until further notice.			

Table 9 - Maximum permissible transient emission for 24 V interference sources

Pulse	U_s (V)	t_d (µs)	t_r (µs)
Pulse 1	≥ -150	≤ 2 000	≥ 1
Pulse 2	≤ +75	≤ 200	≥ 1
Pulse 3a	≥ -150	≤ 0,1	≥ 0,005
Pulse 3b	≤ +100	≤ 0,1	≥ 0,005
Pulse 4	omitted		
Pulse 5	omitted		

7 Referenced standards[1]

VW 801 01 Electrical and Electronic Assemblies in Motor Vehicles

DIN 40 839-1 Electromagnetic Compatibility (EMC) in Road Vehicles; Interferences Conducted along Supply Lines in 12 V and 24 V Power Supply Systems

ISO 7637-1 Road vehicles - Electrical disturbances from conduction and coupling - Part 1: Definitions and general considerations

ISO 7637-2 Road vehicles; electrical disturbance by conduction and coupling; part 2: commercial vehicles with nominal 24 V supply voltage; electrical transient conduction along supply lines only

VDA 2000-1 Electric and Electronic Equipment for Vehicles with 42 V power supply system, Part 1: General

VDA 2000-2 Electric and Electronic Equipment for Vehicles with 42 V power supply system, Part 2: General

[1] In this section terminological inconsistencies may occur as the original titles are used.