

Submitted for recognition as an American National Standard

(R) Immunity to Conducted Transients on Power Leads

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1. Scope—This SAE Standard defines methods and apparatus to evaluate electronic devices for immunity to potential interference from conducted transients along battery feed or switched ignition inputs. Test apparatus specifications outlined in this procedure were developed for 12-V passenger cars and light trucks, 12-V heavy-duty trucks, and vehicles with 24-V systems. Presently, it is not intended for use on other input/output (I/O) lines of the device under test (DUT).

1.1 Measurement Philosophy—Installed electrical equipment is powered from sources which contain, in addition to the desired electrical voltage, transients with peak values many times this value, caused by the release of stored energy during the operation of a relay and/or other loads connected to the source while starting and/or turning off the vehicle. These tests are designed to determine the capability of equipment to withstand such transients. The tests are performed in the laboratory (bench tests). Bench test methods give results, which allow comparison between laboratories.

These tests may not cover all types of transients, which can occur in a vehicle. The test pulses described in Section 8 are, however, characteristic of typical pulses. To ensure proper operation of a vehicle in the electromagnetic environment, vehicle testing should be performed in addition to bench testing.

2. References—General information regarding this document, including definitions, references, and general safety considerations is found in SAE J1113-1.

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1113-1—Electromagnetic Compatibility Measurement Procedure and Limits for Vehicle Components

2.1.2 ISO PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002

ISO 7637-2—(Release date Summer 2000) Road vehicles—Electrical disturbance by conduction and coupling—Part 2: Vehicles with nominal 12 V or 24 V supply voltage—Electrical transient conduction along supply lines only
 ISO 8854—Road vehicles—Alternators with regulators—Test methods and general requirements

3. Test Equipment

3.1 Test Facility—Care shall be taken to ensure that the electromagnetic environment (radiated background noise) is not so high as to interfere with the measurement instrumentation setup.

3.2 Test Instrumentation—The following list defines the equipment needed to perform the test.

3.2.1 OSCILLOSCOPE—The use of a digitizing oscilloscope is preferred. If a digitizing oscilloscope is not available, a storage oscilloscope may be used. The oscilloscope used shall meet the following requirements:

a. Digitizing Oscilloscope

- Sampling Rate 2 gigasamples/s (min)
- Memory Size 1000 samples (min)
- Bandwidth DC to 400 MHz (min)
- Input Sensitivity 5 mV/div (min)

b. Storage Oscilloscope

Bandwidth (Single Shot) DC to 400 MHz (min)
 Input Sensitivity 5 mV/div (min)
 Writing Speed 100 cm/ μ s (min)

3.2.2 VOLTAGE PROBE

Attenuation 100:1
 Min. Breakdown Voltage 1.5 kV
 Input Impedance according to Table 1.
 Probe Cable Length 3 m (max)
 Probe Ground Length..... 130 mm (max)

Voltage Probes with other specifications may be used as required. Probe specifications shall be documented in the test report when other than previously stated.

TABLE 1—VOLTAGE PROBE PARAMETERS

f(MHz)	R(k Ω)	C(pF)
1	>40	<4
10	>4	<4
100	>0.4	<4

3.2.3 DC POWER SUPPLY—If a power supply is to be used instead of a battery, the supply source shall have an internal resistance R_i less than 0.01 Ω dc and an internal impedance $Z_i = R_i$ for frequencies less than 400 Hz. The output voltage shall not deviate more than 1 V from 0 to maximum load (including inrush current) and shall recover 63% of its maximum excursion within 100 μ s. The superimposed ripple voltage, V_r , shall not exceed 0.2 V peak-to-peak and have a minimum frequency of 400 Hz.

If a standard power supply (with sufficient current capacity) is used to simulate the battery, it is important that the low internal impedance of the battery is also simulated.

When a battery is used, a charging source may be needed to achieve the specified reference levels.

3.2.4 VEHICLE SIMULATOR—A vehicle simulator unit shall be provided. This device must be capable of providing the inputs and loads necessary to exercise the DUT such that it operates as if it were installed in the vehicle.

3.2.5 DUT MONITORING INSTRUMENTATION—Instrumentation and/or visual observation shall be used to monitor the parameters of the DUT as stated in the Test Plan.

3.2.6 TEST PULSE GENERATOR—The test pulse generator shall be capable of producing the open circuit test pulses described in Section 8 at the maximum value of $|V_s|$. V_s shall be adjustable up to its limits.

NOTE—Some tolerances in Section 8 are wider than in ISO 7637-2 to ensure that existing generators don't become obsolete. They will be harmonized with ISO in future revisions.

The peak voltage V_s shall be adjusted to the test levels specified in Appendix B with tolerances of +10% and -0%. The timing (t) tolerances and internal resistance (R_i) tolerance shall be $\pm 20\%$ unless otherwise specified.

A verification procedure for the generator performance and tolerances is described in Appendix A.

Recommended values for the evaluation of immunity of devices can be chosen from Appendix B.

- 3.3 Test Voltages**—The test voltages shall be as shown in Table 2 unless other values are agreed upon by the users of this document, in which case such values shall be documented in the test report.

TABLE 2—TEST VOLTAGES

Test voltage	12 V system V	24 V system V
V_A	13.5 ± 0.5	27 ± 1
V_B	12 ± 0.2	24 ± 0.4

- 3.4 Test Set-Up Documentation**—When testing is performed, all related details of the test shall be documented per Section 7. This includes details on test set-up, wiring harnesses, equipment used, and the DUT.

4. Test Plan

- 4.1** Prior to testing, a Test Plan shall be developed by those responsible for the specific DUT. In general, the Test Plan is based on the Product Specification and is agreed upon by the customer and supplier. The Test Plan should include all the details of the tests to be performed, such as: the DUT functions to be monitored; their function performance status classifications and Test Severity Levels as defined in Section 6 and Appendix B; the definitions of DUT performance deviations; and the order, level, repetition rate, and number of applications of the waveforms. Unless otherwise specified by the Test Plan, all tests shall be conducted at room temperature ($23\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$).

NOTE—Special consideration for time between test pulses and number of test pulses: Period t_1 , the time between test pulses given with each test pulse definition, is a default value, which applies to DUTs without timing or dynamic processes. Consideration should be given in the Test Plan for each DUT function whose susceptibility may vary according to its internal timing or processing functions. Selection of time between pulses and number of pulses should maximize the probability that a test pulse will be applied during times of highest DUT susceptibility. In no case should the time between test pulses be less than the response time of the transient generator.

5. Test Procedure

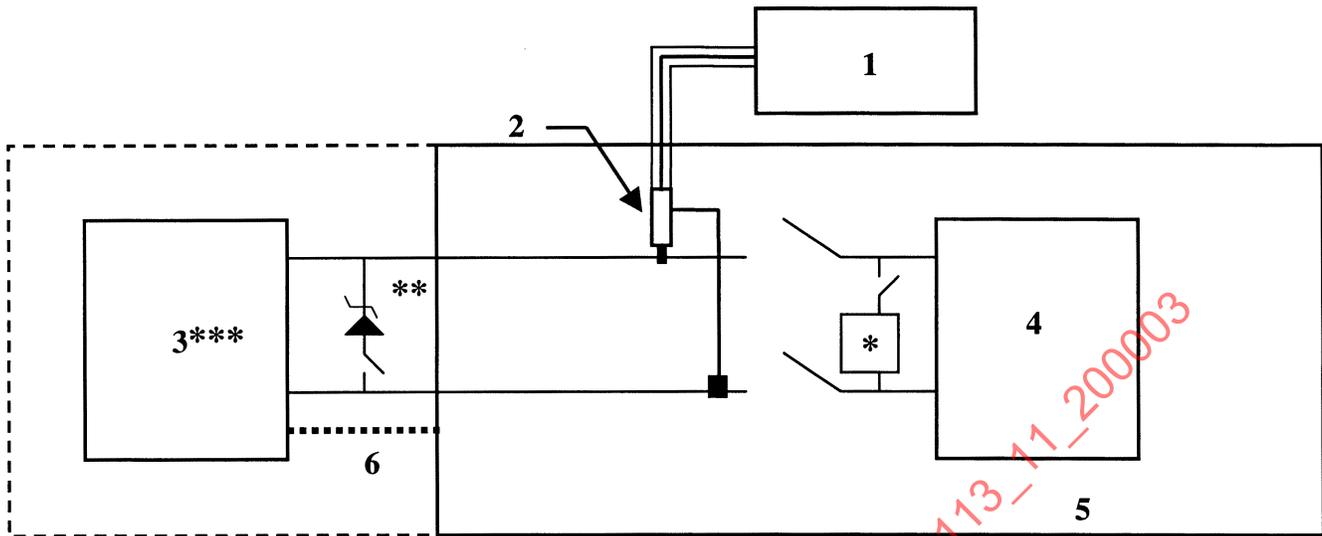
- 5.1** The test setup is given in Figures 1A and 1B.

For test pulses 3a and 3b, the leads between the terminals of the test pulse generator and the device under test shall be laid out in a straight parallel line, shall have a height of $(50\text{ mm} + 10/-0\text{ mm})$ and shall have a length of $0.5\text{ m} \pm 0.1\text{ m}$.

The test pulse generator (see 3.2.6) shall be capable of producing the open circuit waveforms shown in Figures 2 through 9 with the parameters given in Tables 3 to 10.

The test pulse generator is verified according to Appendix A and then set up to provide the specific pulse polarity, amplitude, duration, and resistance with the DUT and optional resistance R_V and suppression diode bridge disconnected (see Figure 1A). (The appropriate voltage values are selected from Appendix B).

A way to simulate the waveform of an alternator with centralized load dump suppression (Figure 9), is to connect the suppression diode (or diode bridge) across the output terminals of the test pulse generator (Figures 1A and 1B). Since a single diode will generally have part-to-part variation and may not be able to handle the large alternator currents, the use of a bridge arrangement (an example is shown in Figure 1C) is recommended. The same generator shall be used for test pulses 5a and 5b.



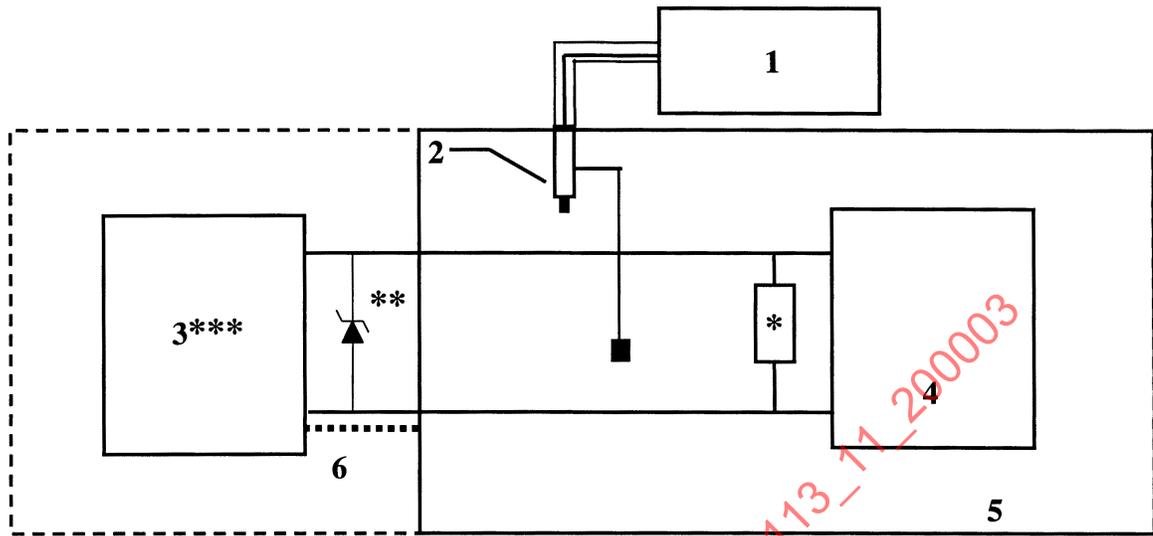
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Legends:

- 1: Oscilloscope or equivalent
- 2: Voltage Probe
- 3: Test Pulse Generator with internal power supply resistance R_i
- 4: Device Under Test (DUT)
- 5: Ground Plane
- 6: Bond to Ground Plane connection. Maximum length for test pulse 3 is 100 mm

- * Optional resistor (R_v) to simulate vehicle system loading for load dump test pulse 5a and 5b only. If used, the value of (R_v) shall be specified in the test plan (typical value 0.7 - 40 Ω)
- ** Optional diode bridge for simulation of load dump waveform for alternator with centralized load dump suppression for pulse 5b only (see figure 1c)
- *** Test Pulse Generator can be on or off the Ground Plane

FIGURE 1A—TRANSIENT IMMUNITY TEST SET-UP—PULSE ADJUSTMENT



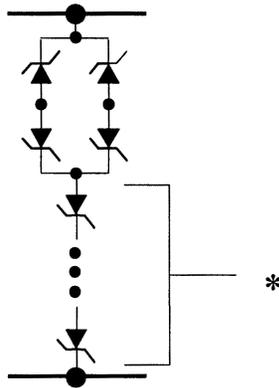
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Legends:

- 1: Oscilloscope or equivalent
- 2: Voltage Probe
- 3: Test pulse generator with internal power supply resistance R_i
- 4: Device Under Test (DUT)
- 5: Ground Plane
- 6. Bond to Ground Plane connection. Maximum length for test pulse 3 is 100 mm

- * Optional resistor (R_v) to simulate vehicle system loading for load dump test pulse 5a and 5b only. If used, the value of (R_v) shall be specified in the test plan (typical value 0.7 - 40 Ω)
- ** Optional diode bridge for simulation of load dump waveform for alternator with centralized load dump suppression for pulse 5b only (see figure 1c)
- *** Test Pulse Generator can be on or off the Ground Plane

FIGURE 1B—TRANSIENT IMMUNITY TEST SET-UP—PULSE INJECTION



- * Add forward biased diodes as required to achieve maximum open-circuit (suppressed) voltage

FIGURE 1C—EXAMPLE OF SUPPRESSION DIODE BRIDGE FOR TEST PULSE 5B ONLY

The suppression diodes and the suppressed voltage levels (clamping voltage) used by different car manufacturers are not standard. The supplier (parts manufacturers) must, therefore, obtain the diode and clamping voltage specification information from the manufacturer to be able to perform this test. The single diodes are added to the Diode Bridge as needed to provide the specified clamping voltage.

- 5.2 Connect the DUT to the generator (see Figure 1B) and disconnect the oscilloscope.
- 5.3 Apply the transient to the DUT. (For Load Dump test, Pulse 5, apply Rv as necessary.)
- 5.4 Monitor the DUT's performance during/after transient injection for any deviations.
- 5.5 Perform the appropriate functional tests, per the test plan, to determine deviations and record the results as outlined in Section 7.

NOTE 1—In determining the susceptibility level, care must be exercised to eliminate the effects of cumulative deterioration such as dielectric “punch through” in semi-conductor devices.

NOTE 2—When testing to a specified level, unnoticed deviations may occur which may be detected only by running functional tests and comparing the results of tested components against those of untested components.

6. Test Severity Levels and Evaluation of Results

- 6.1 A full description and discussion of the Function Performance Status Classification including Test Severity Levels are given in SAE J1113-1. It should be reviewed prior to using the Test Severity Levels presented in Appendix B.
- 6.2 A careful examination of the DUT shall be made during and after the completion of a test to determine proper operation. Any irregularities shall be recorded in the Test Report and shall be evaluated based on the Test Plan, the specifications covering the product being tested, or by agreement between the purchaser and supplier.

7. **Test Documentation**—The following information shall be recorded, unless otherwise prescribed in the Test Plan covering the product being tested:
- 7.1 Part number and/or description of the DUT.
 - 7.2 Copy of the original Test Plan.
 - 7.3 Description of the test set-up and equipment used.
 - 7.4 Description of the harness used between the injection apparatus and the DUT.
 - 7.5 Test Pulse being applied (by number).
 - 7.6 Order of injection for each of the waveform amplitudes.
 - 7.7 Number (repetitions) of the pulse applied.
 - 7.8 Pulse period (interval between pulses).
 - 7.9 Any deviation from the waveforms prescribed for testing.
 - 7.10 Point of application of pulse (pin number, letter, or name).
 - 7.11 Exact characteristics of any disturbance during injection of the pulse.

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8. Test Pulses

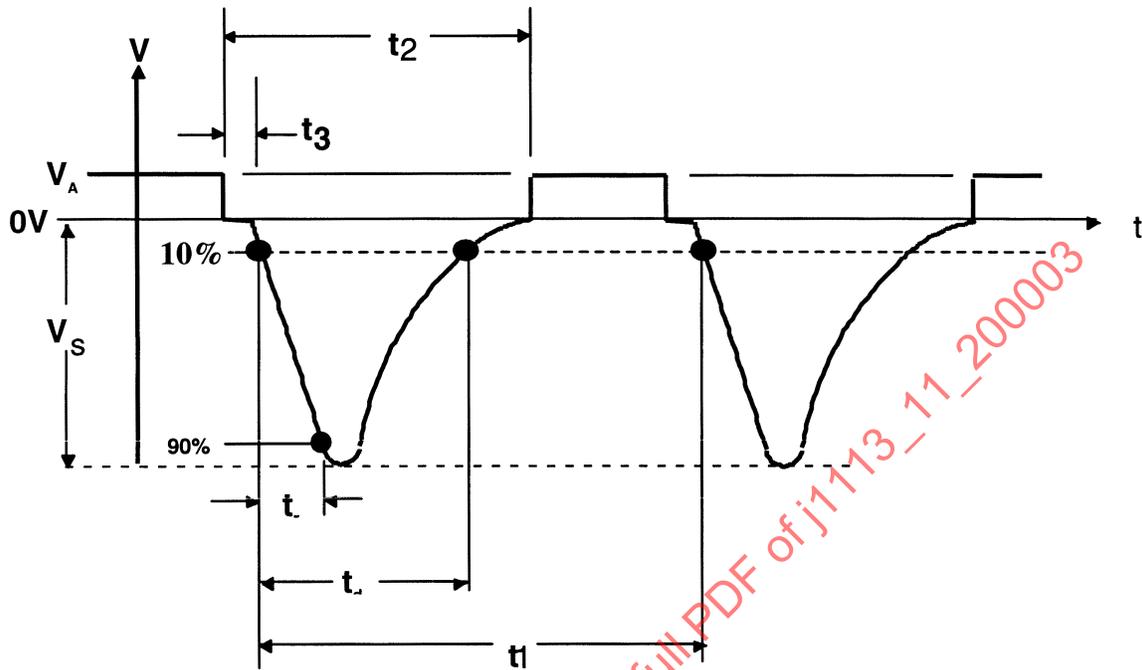


FIGURE 2—TEST PULSE 1
SUPPLY DISCONNECTION FROM INDUCTIVE LOADS WITH DUT REMAINING
CONNECTED DIRECTLY IN PARALLEL WITH THIS INDUCTIVE LOAD

TABLE 3—TEST PULSE 1 PARAMETERS

Parameters	12 V System Passenger Car and Light-Duty Trucks Pulse 1a	12 V System Heavy-Duty Trucks Pulse 1b	24 V System Pulse 1c
V_s	-25 V to -100 V	-150 V to -600 V	-300 V to -600 V
R_i	10 Ω	20 Ω	50 Ω
t_d	2 ms	1 ms	1 ms
t_r	1 μ s +0/-50%	1 μ s +0/-50%	3 μ s +0/-50%
$t_1^{(1)}$	0.5 s to 5 s	0.5 s to 5 s	0.5 s to 5 s
t_2	200 ms	200 ms	200 ms
$t_3^{(2)}$	<100 ms	<100 ms	<100 ms

- t_1 shall be chosen such that the device under test is correctly initialized before the application of the next pulse.
- t_3 The smallest possible time necessary between the disconnection of the supply source and the application of the pulse.

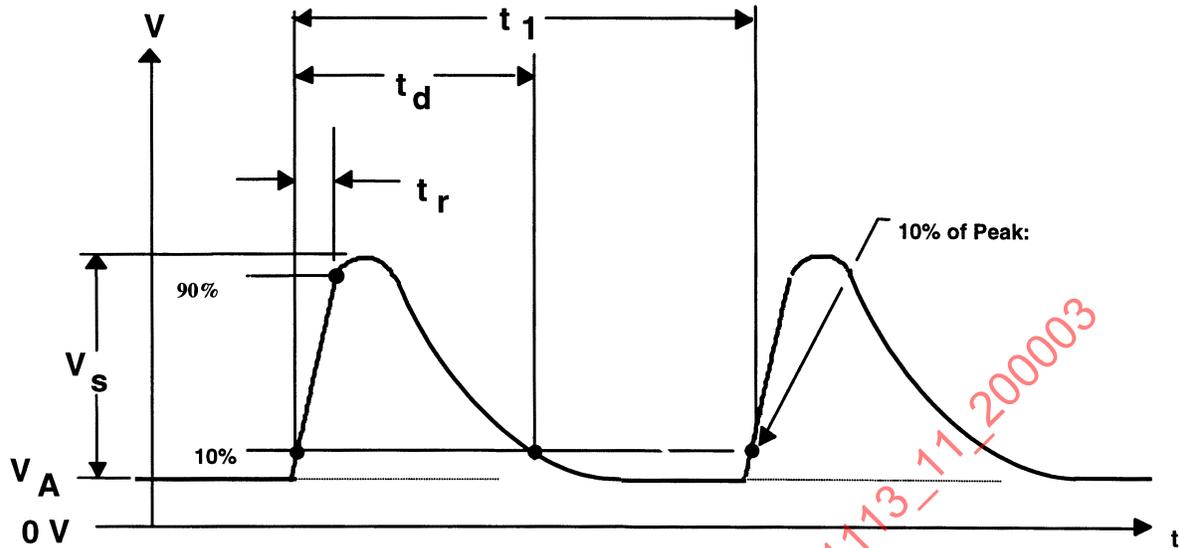


FIGURE 3—TEST PULSE 2A
SUDDEN INTERRUPTION OF CURRENT IN A DEVICE CONNECTED IN PARALLEL
WITH THE DUT DUE TO THE WIRING HARNESS INDUCTANCE

TABLE 4—TEST PULSE 2A PARAMETERS

Parameters	12 V System	24 V System
V_s	+12 V to +50 V	+12 V to +50 V
R_i	2 Ω	2 Ω
t_d	0.05 ms	0.05 ms
t_r	1 μ s +0/-50%	1 μ s +0/-50%
t_1	0.2 s to 5 s	0.2 s to 5 s

1. t_1 shall be chosen such that the device under test is correctly initialized before the application of the next pulse.

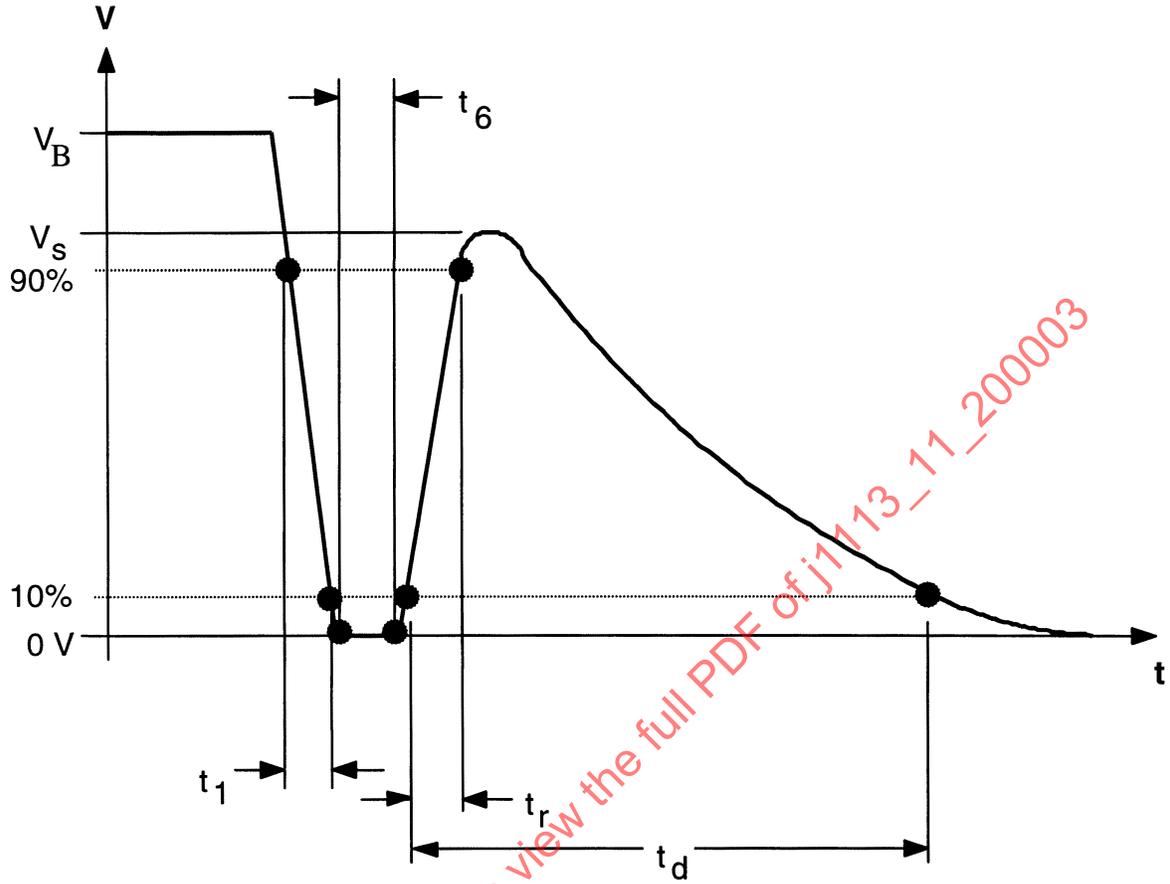


FIGURE 4—TEST PULSE 2B
TRANSIENT FROM DC MOTORS ACTING AS GENERATORS AFTER IGNITION SWITCH - OFF

TABLE 5—TEST PULSE 2B PARAMETERS

Parameters	12 V System	24 V System
V_s	10 V	20 V
R_i	0 Ω to 0.02 Ω	0 Ω to 0.02 Ω
t_d	0.2 s to 2 s	0.2 s to 2 s
t_1	1 ms \pm 50%	1 ms \pm 50%
t_r	1 ms \pm 50%	1 ms \pm 50%
t_6	1 ms \pm 50%	1 ms \pm 50%

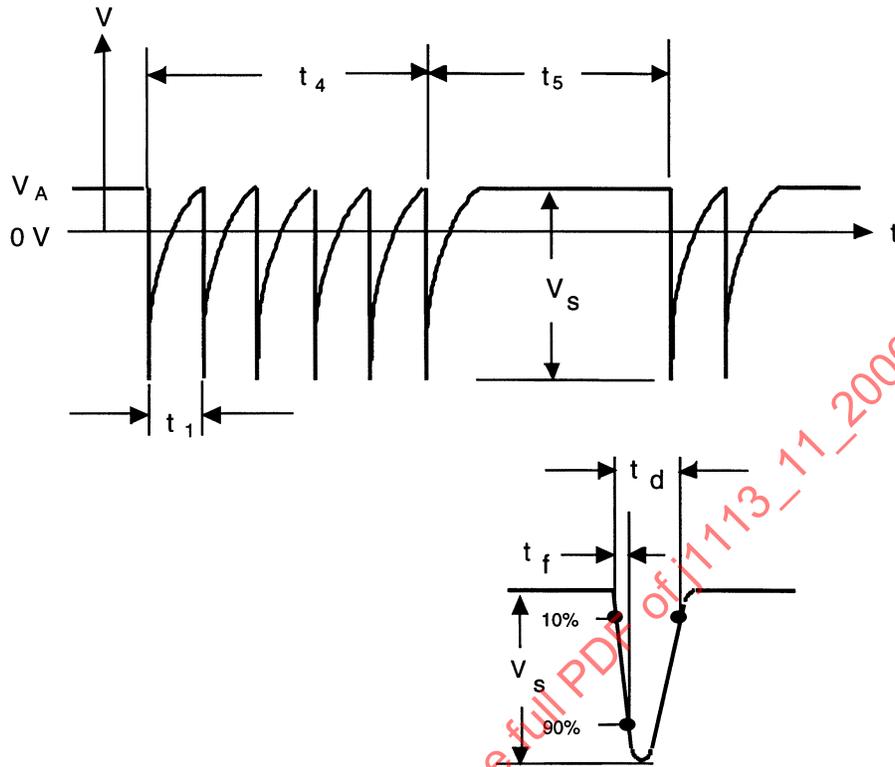


FIGURE 5—TEST PULSE 3A
SWITCHING SPIKES

TABLE 6—TEST PULSE 3A PARAMETERS

Parameters	12 V System	24 V System
V_s	-37 V to -150 V	-50 V to -200 V
R_i	50 Ω	50 Ω
t_d	0.1 μ s + 100/-0%	0.1 μ s + 100/-0%
t_f	5 ns \pm 50%	5 ns \pm 50%
t_1	100 ms	100 ms
t_4	10 ms	10 ms
t_5	90 ms	90 ms

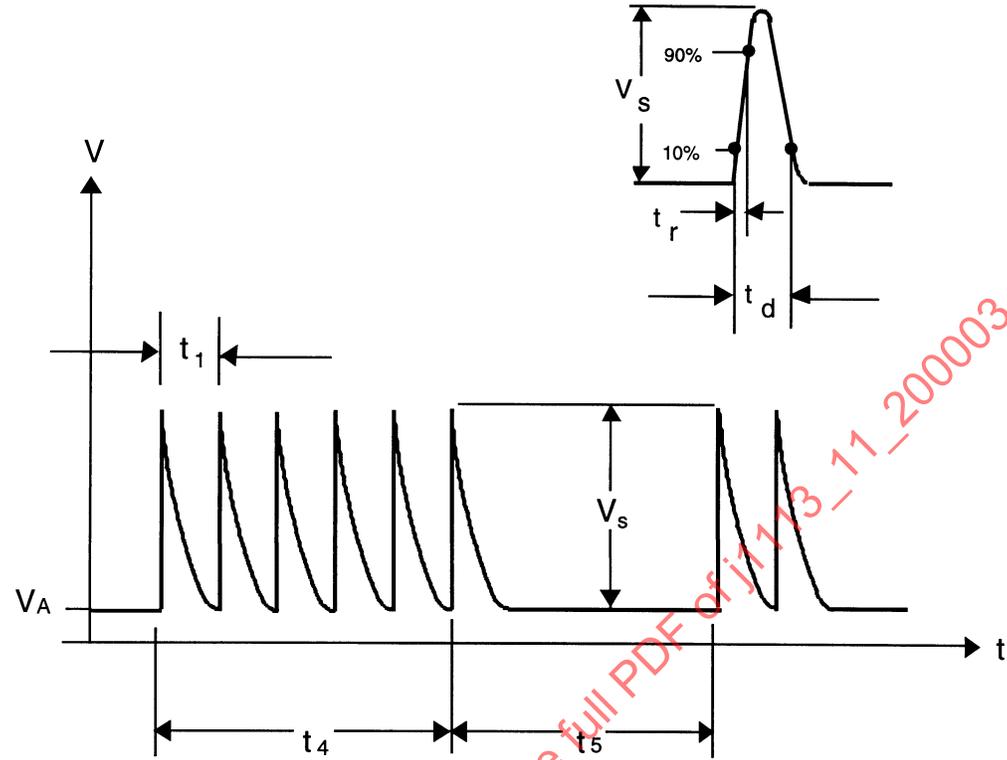


FIGURE 6—TEST PULSE 3B
SWITCHING SPIKES

TABLE 7—TEST PULSE 3B PARAMETERS

Parameters	12 V System	24 V System
V_s	+25 V to +100 V	+50 V to +200 V
R_i	50 Ω	50 Ω
t_d	0.1 μ s + 100/-0%	0.1 μ s + 100/-0%
t_r	5 ns \pm 50%	5 ns \pm 50%
t_1	100 ms	100 ms
t_4	10 ms	10 ms
t_5	90 ms	90 ms

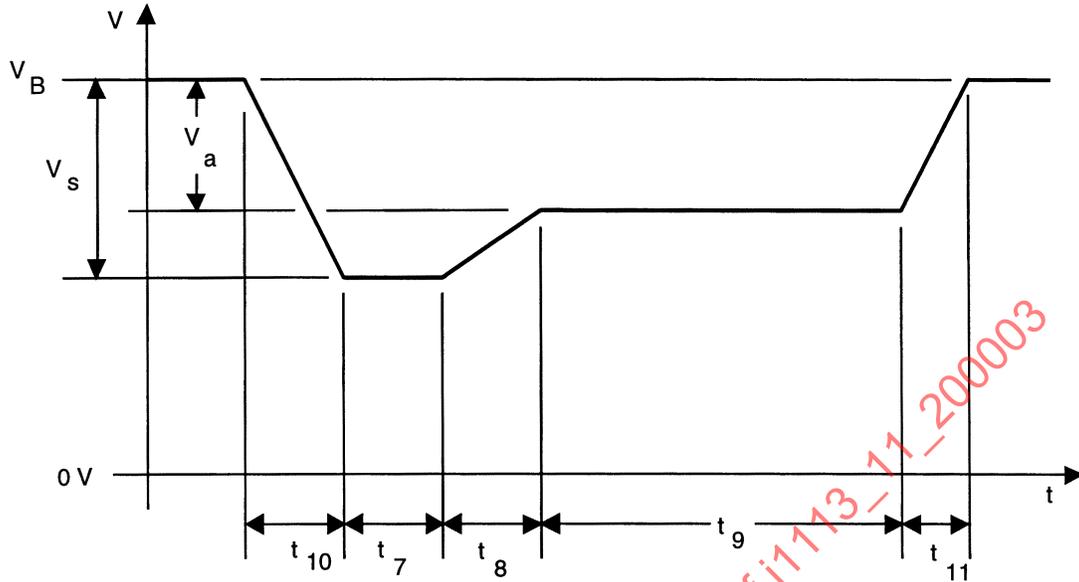


FIGURE 7—TEST PULSE 4
SINGLE PULSE, i.e., STARTER MOTOR ENGAGEMENT DISTURBANCE

TABLE 8—TEST PULSE 4 PARAMETERS

Parameters	12 V System	24 V System
V_s	-4 V to -7 V	-5 V to -16 V
V_a	-2.5 V to -6 V with $ V_a \leq V_s $	-5 V to -12 V with $ V_a \leq V_s $
R_i	0 Ω to 0.02 Ω	0 Ω to 0.02 Ω
t_7	15 ms to 40 ms ⁽¹⁾	50 ms to 100 ms ⁽¹⁾
t_8	≤ 50 ms	≤ 50 ms
t_9	0.5 s to 20 s ⁽¹⁾	0.5 s to 20 s ⁽¹⁾
t_{10}	5 ms	10 ms
t_{11}	5 ms to 100 ms ⁽²⁾	10 ms to 100 ms ⁽³⁾

1. The value used should be agreed between the vehicle manufacturer and the equipment supplier to suit the proposed application.
2. $t_{11} = 5$ ms is typical of the case when engine starts at the end of the cranking period, while $t_{11} = 100$ ms is typical of the case when the engine does not start.
3. $t_{11} = 10$ ms is typical of the case when engine starts at the end of the cranking period, while $t_{11} = 100$ ms is typical of the case when the engine does not start.

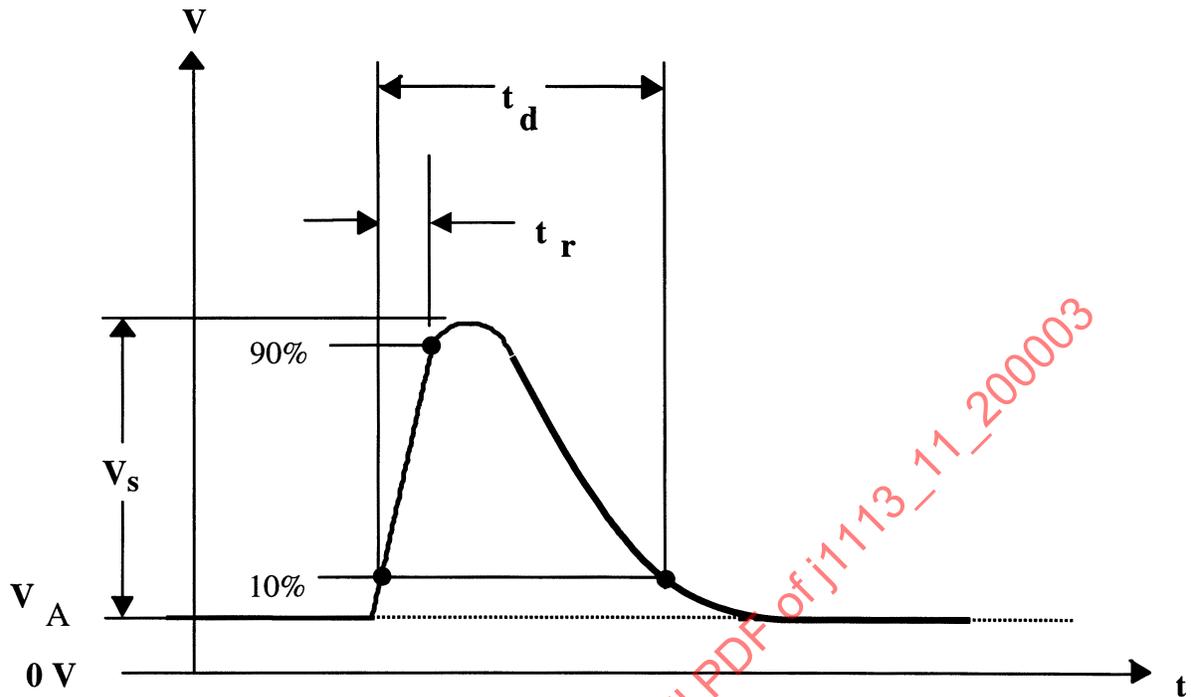


FIGURE 8—TEST PULSE 5A
LOAD DUMP, SINGLE PULSE

TABLE 9—TEST PULSE 5A PARAMETERS

Parameters	12 V System	24 V System
V_s	22 V to 87 V	44 V to 174 V
R_i	0.5 Ω to 4 Ω	1 Ω to 8 Ω
t_d	40 ms to 400 ms	100 ms to 350 ms
t_r	10 ms +0/-5 ms	10 ms +0/-5 ms

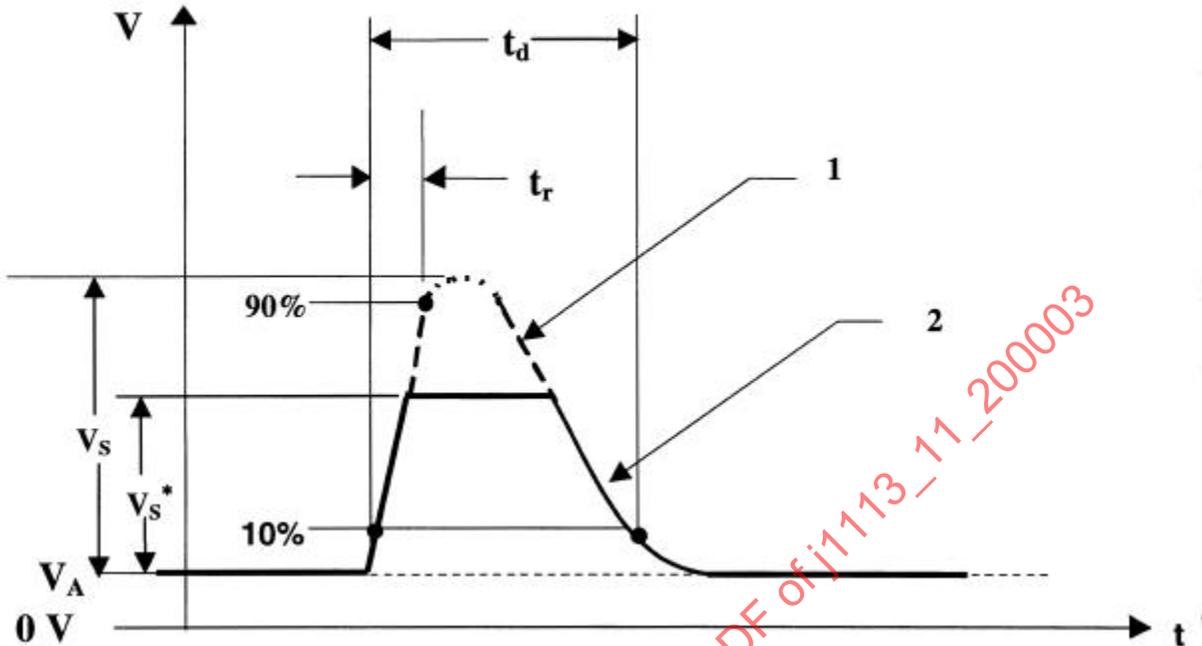


FIGURE 9—TEST PULSE 5B
LOAD DUMP—CENTRALIZED LOAD DUMP SUPPRESSION

TABLE 10—TEST PULSE 5B PARAMETERS

Parameter	12 Volt System	24 Volt System
V_s	22 V to 87 V	44 V to 174 V
V_s^*	As specified by customer	As specified by customer
t_d	Same as Unsuppressed Value	Same as Unsuppressed Value

The following general considerations of the dynamic behavior of alternators during load dump apply:

- The internal resistance of an alternator, in the case of load dump, is mainly a function of alternator rotational speed and excitation current.
- The internal resistance, R_i , of the load dump test pulse generator shall be obtained from the following relationship

$$R_i = \frac{10 \times U_{\text{nom}} \times N_{\text{act}}}{0.8 \times I_{\text{rated}} \times 12000 \text{ min}^{-1}} \quad (\text{Eq. 1})$$

where:

U_{nom} is the specified voltage of the alternator

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

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

- The pulse is determined by the peak voltage V_s , the internal resistance R_i , and the pulse duration t_d ; in all cases small values of V_s are correlated with small values of R_i and t_d , and high values of V_s with high values of R_i and t_d .

9. **Notes**

9.1 **Marginal Indicia**—The change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

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