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Surge Testing Requirements Analysis

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Atmospheric discharges (lightning), switching actions, nuclear reactions and the activation of overvoltage protection devices can all induce impulse-shaped interference voltages or currents in electronic equipment. These electromagnetic equalizing processes often have catastrophic consequences; they can make components fail, cause measurement instrumentation to yield incorrect data and even destroy the units in which they appear.

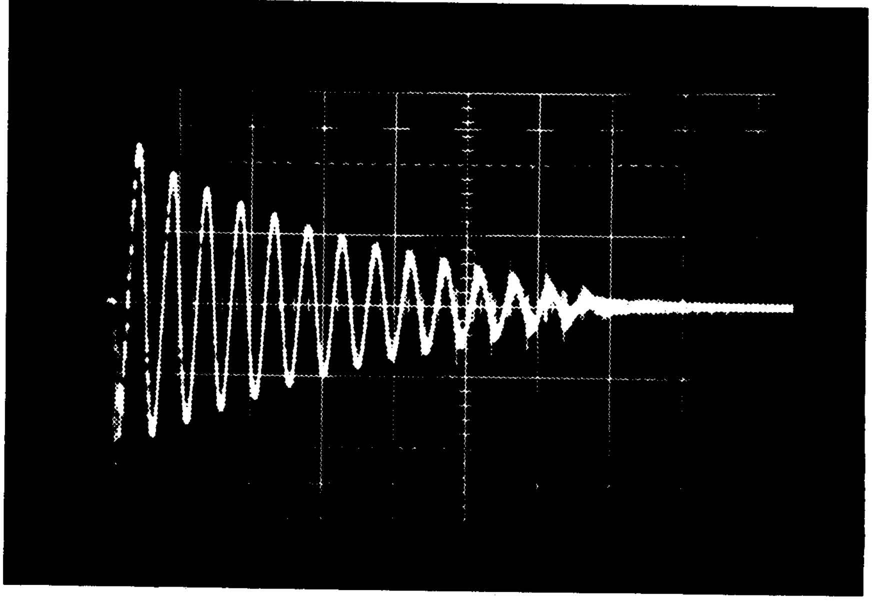
As the trend toward lower signal levels in electronics technology augments susceptibility to error, the ratio of useful signals to interference signals becomes more and more unfavorable. The voltage levels of ICs, for instance, range from 5 to 15 V, with limit frequencies of a few megahertz. Compared with conventional measuring and control technology for valve-equipped instruments incorporating mechanical switches, the signal and internal measurement levels of electronic instrumentation have decreased by one order of magnitude, while frequencies have increased by a factor of 10^4. In addition, current process automation requirements dictate the use of commercially available μPs that have to work impeccably – and often on-line – under these conditions.

Components, subassemblies and electronic circuits require sufficient prototype and routine interference testing, both to ensure proper function and to prove the immunity of devices against transient overvoltages. This article proposes some test techniques for simulating the real-world overvoltages that occur during system operation.

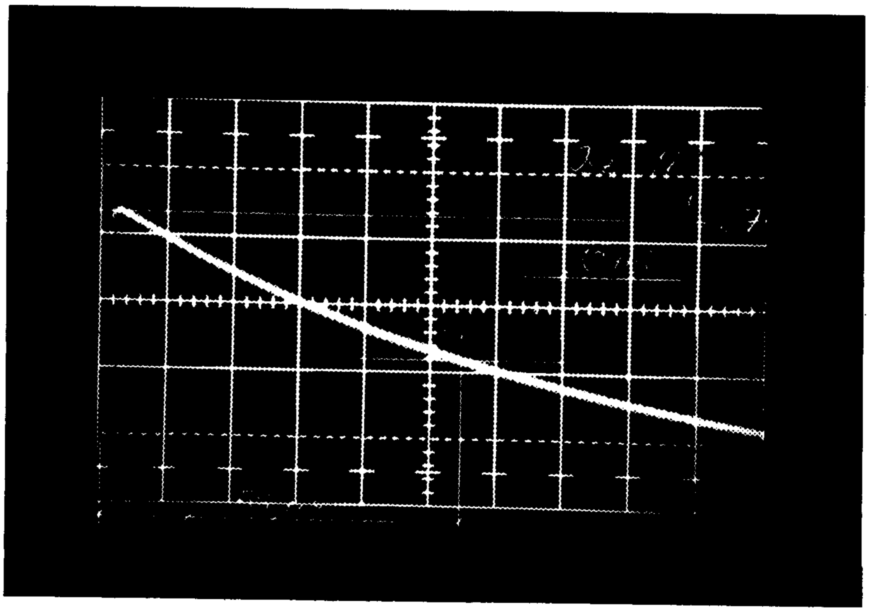
some background

The causes of interference voltages in electronic measurement/control circuits include direct EMI, line-bound interferences, and cable-sheath and ground balancing currents. To simulate interference voltages in electronic units, you need to evaluate both direct EMI and line-bound interference voltages emanating from the voltage supply and coupled into the UUT either via the mains or the measuring/control circuitry.

Dealing with interference problems actually involves three different techniques:



This impulse shape shows 1 MHz damped oscillation.



Some commercially available surge generators use standardized lightning impulses of 1.2/50 μsec for testing energy absorption.

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- making measurements at the interference source,
- suppressing and effectively reducing interference transmission,
- eliminating the effects of interference on the receiver.

Furthermore, test technology for electronic measurement/control systems must ensure that these inevitable interference voltages do not create any undesirable effects at the measuring and control end of the system.

overvoltage amplitudes and impulse shapes

Classifying possible interference currents and voltages proves important for realistic and cost-effective preliminary testing. Such a classification should take into account the voltage/current amplitude and the impulse shape of various statistically occurring interferences.

At present, a number of organizations are developing recommendations and standards to specify overvoltage conditions for electronic units. As a result, validity ranges and application limits have become clearly circumscribed (see Table 1).

The amplitude of the test voltage depends to a large extent on the overvoltages encountered at the test site. An IEEE working group (Surge Voltages in Low-Voltage AC Power Systems) has proposed a classification system that enables optimizing the exposure risk to conform to application and environmental requirements. This scheme makes it possible to select the highest exposure-risk class for extremely important systems, simultaneously reducing the statistical probability that interference voltages/currents will appear.

The proposed classification defines exposure potential in these terms:

- **low exposure** – systems in geographic areas noted for low lightning activity, with minimal load switching.
- **high exposure** – systems in geographic areas noted for heavy lightning activity, with frequent and severe switching transients.
- **extreme exposure** – systems in geographic areas with high lightning activity and frequent, severe switching transients, where a high insulation strength is available; also, systems designed to function reliably under extremely rigorous conditions (e.g.,

Impulse Shapes	Applications	Standards/ Recommendations
	Insulation Test	
No load 1.2/50 µsec 0.1/2,500 µsec	• Electronic components • Cables, switches, capacitors transformers • Counters, remote-controlled receivers	VDE 0845 IEC 60-2 VDE 0418 IEC 521 VDE 0420 VDE 0663 VDE 0664 IEC 23(E) IEEE 587.1 VDE 110b VDE 0565
	Energy Absorption Test	
Short circuit 8/20 µsec 20/60 µsec 10/1,000 µsec	• Surge arresters • Varistors • Current load for low ohmic test samples • Contact points	CENELEC/CECC WG4/67 VDE 0845 IEC 60-2 CCITT K.12
No load 1.2/50 µsec 0.5/700 µsec 10/700 µsec 100/700 µsec	• Transistorized equipment in telecommunications systems and related equipment	CCITT K.17 CNET
No load 1.2/50 µsec	• Electronic protective relays and related components • Octocouplers • Counters • Measuring relays	IEC 255-4 IEC 255-5 IEC 255-6 IEC 255-10 SEV 3313 BEAMA 219
No load $T_a \cong 100$ nsec $T_r \cong 50$ msec Energy at 12 kV: 72 mJ	• Consumer electronics • Radio & TV sets • Data processing	VDE 0860 IEC 65
Impulse shape not defined	• Electronic components in EDP, offices, telecommunications	PTT 20.3.79
	Surge Withstand Capability Test (Malfunction Test)	
No load $T_{a10\text{-}90\%} = 0.1$ µsec f = 1 MHz	• Electronic protective relays • Measuring relays • Relay systems	IEC 255-4 IEC 255-5 IEC 255-6 IEC 255-10 SEV 3313 SEN 361503 ANSI C 37.90a IEEE 472
No load $T_{a10\text{-}90\%} = 0.5$ µsec f = 100 kHz	• Power supply disturbances • Malfunctioning equipment and components	IEC 60-5 IEEE P 587.1 IEC 23-E
1 MHz oscillation At short circuit, 10/400 nsec at 50 Ω load	• Electronic components in telecommunications systems, EDP, weapons systems, measuring & control/signal circuitry, avionics	IEC 60-5

Table 1. Impulse Shapes and Standards

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safety systems for military field applications).

Table 2 gives the preferred series of impulse-withstand values for rated voltages, based on a controlled voltage situation. The table refers primarily to switching overvoltages, which can occur in proportion to the rated voltage of an appliance. The amplitudes of overvoltages generated by lightning or short circuits, on the other hand, remain virtually independent of rated voltage; the only limiting factor is the ability of a unit's insulation to withstand sparkovers. For electronic units without surge-protected inputs, the impulse-withstand value usually falls in the kilovolts range.

In the majority of measurements performed in low-voltage systems, interference voltages have either an oscillating or aperiodic impulse shape, depending on line conditions (transmission ratio) and the causes of origin of the surge voltage. Frequently, the sparkover distance for an insulation clearance of a few millimeters determines the first rise of a surge, implying possible voltage rise times of a few nanoseconds.

test requirements

Unfortunately, the multiplicity of amplitudes and impulse shapes encountered makes it extremely difficult to classify interferences by these criteria. Therefore, we have attempted to develop an alternative classification on the basis of test requirements, in which each requirement evaluates certain critical parameters.

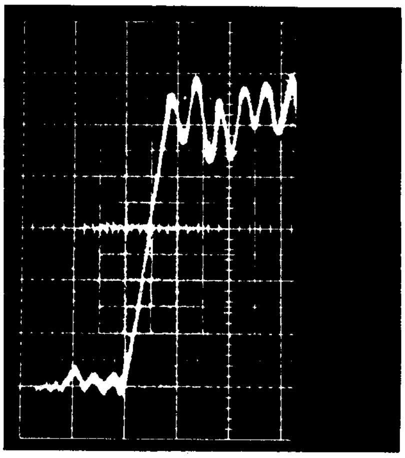
You should perform the following tests on electric/electronic units:

- **Voltage/insulation check.** This test simulates the overvoltages – either periodic or aperiodic – generated by switching actions. For insulation materials from 1 to 20 kV, the voltage shape does not exert any noticeable influence on the sparkover voltage; thus, a 1.2/50 μsec lightning impulse shape proves suitable for high-voltage insulation testing. If available, an additional impulse shape with a fast rise time of approximately 100 nsec and a time-to-half value of approximately 2,500 μsec should accommodate all waveshapes occurring in real-world applications.
- **Energy absorption.** For many electric/electronic units, ability to absorb energy proves more important than impulse shape. Examples include:

  – testing the response characteristics and absorption capabilities of protective circuitry and elements (e.g., gas arresters and varistors). Fitted in instruments used in switching installations, these protective circuits must partially suppress lightning or short-circuit currents, IEC standard 99-1 specifies the impulse shape and amplitude of the currents for such tests; the amplitude of a lightning current, for instance, can go up to 10 kA or higher.

  – testing the protective circuits of transistorized devices in telecommunications equipment. Although these devices are not directly exposed to lightning discharges or high-voltage short circuits, induced currents of 100 A can easily occur.

  – testing the energy absorption of electronic components used in completely shielded enclosures (e.g., μPs and computers). This test should simulate the charged static energy of a person touching an electronic circuit of the type being checked. Energies of 10 mJ at voltages up to 30 kV may appear.
- **Surge-withstand capability.** Also known as a malfunction test, the surge-withstand check simulates the high frequencies of interfering impulses, which are sometimes superimposed on the ac voltage of the mains. Sparkover times of 10 nsec or less may appear. Ground-compensation and chassis currents may also require a short-circuit current with an amplitude of 100 A or a multiple of 100 A.



The surge generator above has a 10 nsec rise time with 400-800 nsec time to half value, in accordance with IEC draft proposal 60-5.

direct EMI testing

This article does not cover direct EMI evaluation (see "Electromagnetic Interference Testing: Standards and Specs" by R. K. Bossart, *Electronics Test*, May 1980, for a complete introduction to this subject). However, since externally generated interference voltages and currents can reach sensitive electronics via interconnecting lines, you should test entire electronic systems in conformity with real-world conditions by simulating lightning flashes or nuclear reactions. A preliminary check of all instruments that couple induced interference voltages/currents directly into signal, measurement and ground circuitry is also advisable. Instrument and device manufacturers can carry out these tests – but a vendor cannot always determine a unit's ultimate application in a complex system. ET

[illegible]	Preferred Impulse-Withstand Voltages in Installation Exposure Risk Categories			
[illegible]	I	II	III	IV
50	330	550	800	1,500
100	500	800	1,500	2,500
150	800	1,500	2,500	4,000
300	1,500	2,500	4,000	6,000
600	2,500	4,000	6,000	8,000
1,000	4,000	6,000	8,000	12,000

[1] Derived from rated system voltages under controlled voltage conditions.

Table 2: Impulse-Withstand Voltage Values