

ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

ELECTROSTATIC DISCHARGE IMMUNITY TESTING OF INFORMATION TECHNOLOGY EQUIPMENT

TR/40

July 1987

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BRIEF HISTORY

This Technical Report replaces ECMA TR/23 Electrostatic Discharge Susceptibility.

ECMA TR/23 was published in September 1984 giving basic descriptions of the popular methods in use in the industry at that time.

IEC Publication 801-2 for industrial process measurement and control equipment was also published in 1984 by IEC TC65.

Over the past two years considerable difficulty has been experienced with the methods used for testing electrostatic discharge susceptibility. Research has been conducted by members of ECMA TC20 and of IEC TC65 WG4 into the basic environmental phenomenon and into the effective simulation of this phenomenon.

This ECMA Technical Report represents the agreed conclusions of the European Information Technology industry drawn from collected research.

Thanks are recorded to experts and organizations external to ECMA for their contributory support in preparing this Technical Report.

Adopted as an ECMA Technical Report by the General Assembly of
25 June 1987.

TR/40

CORRIGENDUM

Please replace Figure 4 on page 7 with the corrected Figure 4 reproduced below:

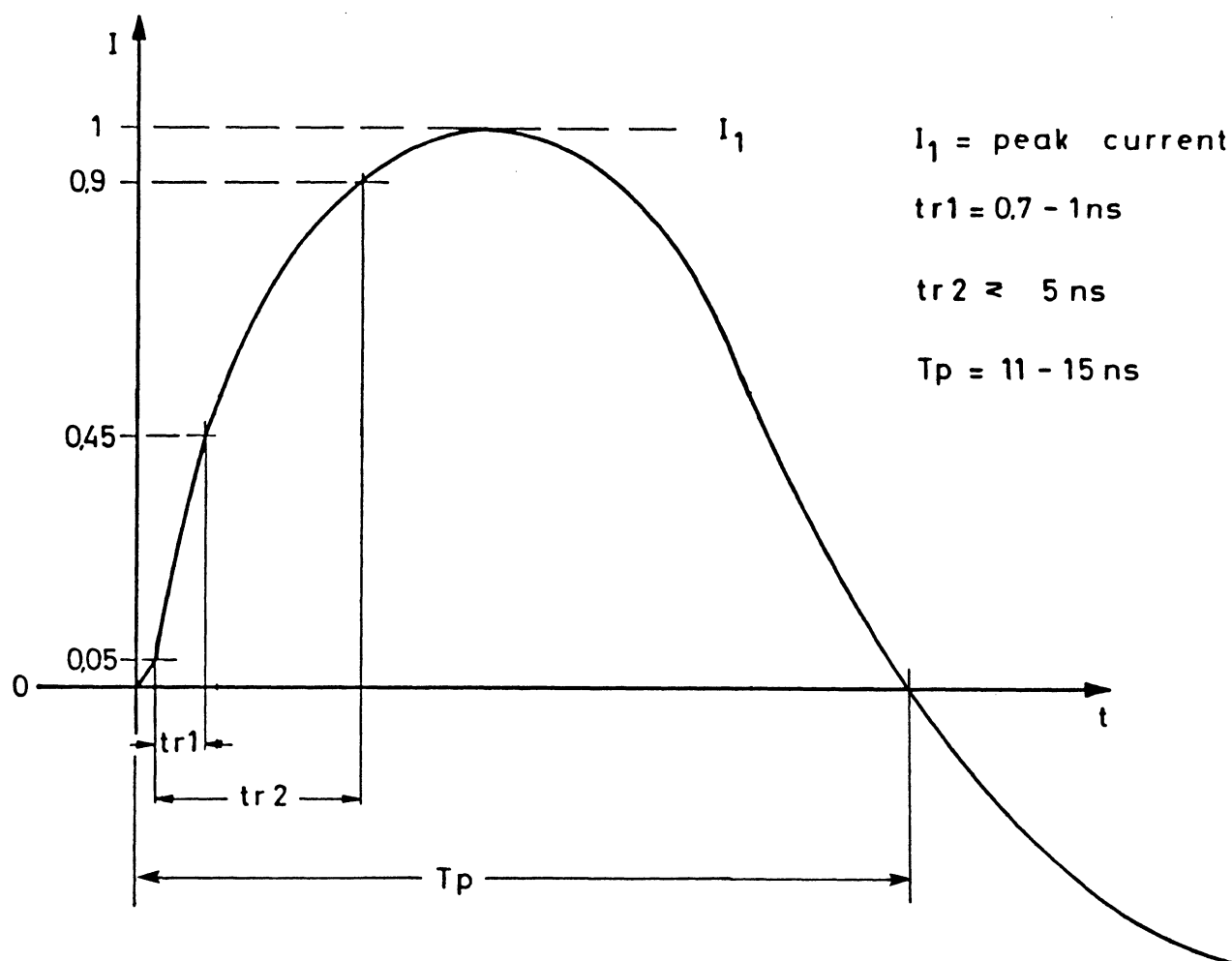


Figure 4 : Pulse Shape for Furniture Discharge

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1. SCOPE

This Technical Report defines electrostatic discharge techniques using:

- specified current pulses with fast rise times,
- firm metallic contact to the discharge sink.

The test is to assess the immunity of equipment to typical electrostatic discharges which can occur in the user environment.

This Technical Report does not cover, at this time, the effects of sparkover; the relevance of such tests and methods is being addressed by ECMA TC20.

2. FIELD OF APPLICATION

This Technical Report applies to Information Technology Equipment (ITE).

3. DEFINITIONS

For the purpose of this Technical Report the following definitions apply.

3.1 Electrostatic Discharge (ESD)

The transfer of electrostatic charge between bodies of different electrostatic potential.

3.2 Energy Storage Capacitor

The capacitor of the Electrostatic Discharge (ESD) generator representing the capacitance of a body charged to the test voltage value.

3.3 Equipment Under Test (EUT)

A single unit or a total system of interconnected units.

3.4 Ground Reference Plane

A conductive sheet or plate used as common voltage reference level for the EUT, the ESD generator, the operator and the auxiliary equipment.

3.5 Immunity

The capability of a device, equipment or system to resist a disturbance. It is the converse of susceptibility.

3.6 Information Technology Equipment (ITE)

Electrical/electronic units or systems which predominantly generate a multiplicity of periodic binary pulsed electrical/electronic wave forms and are designed to perform functions such as electronic word processing, electronic computation, data transformation, recording, filing, sorting, storage, retrieval and transfer, and reproduction of data and/or images.

4. RATIONALE

4.1 Limitations of IEC 801-2 and ECMA/TR 23

Existing standards and test methods require considerable revision in the light of testing experience and research into the ESD phenomenon and its simulation.

Principal documents involved are IEC 801-2 for process control equipment and ECMA TR/23 on ESD.

The requirement to revise these documents has been agreed by IEC TC65 WG4 in close collaboration with ECMA TC20. The main areas of concern recognized in both documents are the reproducibility of testing and the correct pulse shape simulation. In addition, ECMA TR/23 suggests different test methods and is therefore not appropriate as a Standard.

This Technical Report, however, may be considered as a Draft ECMA Standard for finalization during the coming year.

IEC Publication 801-2, First Edition, must therefore no longer be used for Information Technology Equipment.

4.2 Technical Rationale

In general the weaknesses in the previous test methods were influenced by, for example, speed of approach of the test probe, humidity, and construction of the test equipment, leading to variations in pulse rise time and magnitude of the discharge current.

In most conventional ESD testers, the ESD event is simulated by discharging a charged capacitor through a discharge electrode at the EUT. The discharge electrode forms a spark gap at the surface of the EUT. The spark is a very complicated physical phenomenon. It has been shown that with a moving spark gap the resulting rise time (or rising slope) of the discharge current can vary between less than 1 ns and more than 20 ns, as the approach speed is varied. Keeping the approach speed constant does not result in constant rise time. For some voltage/speed combinations, the rise time still fluctuates by a factor of up to 30.

One proposed way to stabilize the rise time is to use a mechanically fixed spark gap. Although the rise time is stabilized with this method, it cannot be recommended because the resulting rise time is much slower than the rise time of the natural event to be simulated. The high frequency content of the real ESD event is not properly simulated with this method.

Using various types of triggering devices (for example gas tubes or thyratrons) instead of the open spark is another possibility. These kinds of triggering devices produce rise times which are still too low compared to the rise times of the real ESD event.

The only triggering device known today which is able to produce repeatable and fast rising discharge currents is the relay. The relay should have sufficient voltage capability and a single contact (to avoid double discharges in the rising part). For higher voltages, vacuum relays prove to be useful. Experience shows that by using a relay as the triggering de-

vice, not only the measured discharge pulse shape is much more repeatable in its rising part, but also the test results with real EUTs are more reproducible.

Consequently the relay-driven impulse tester is a device that produces a specified current pulse (amplitude and rise time). This current is related to the real ESD voltage, as described in Appendix A of this Technical Report.

In the real ESD situation the capacitances are widely distributed, as indicated in Figure 1.

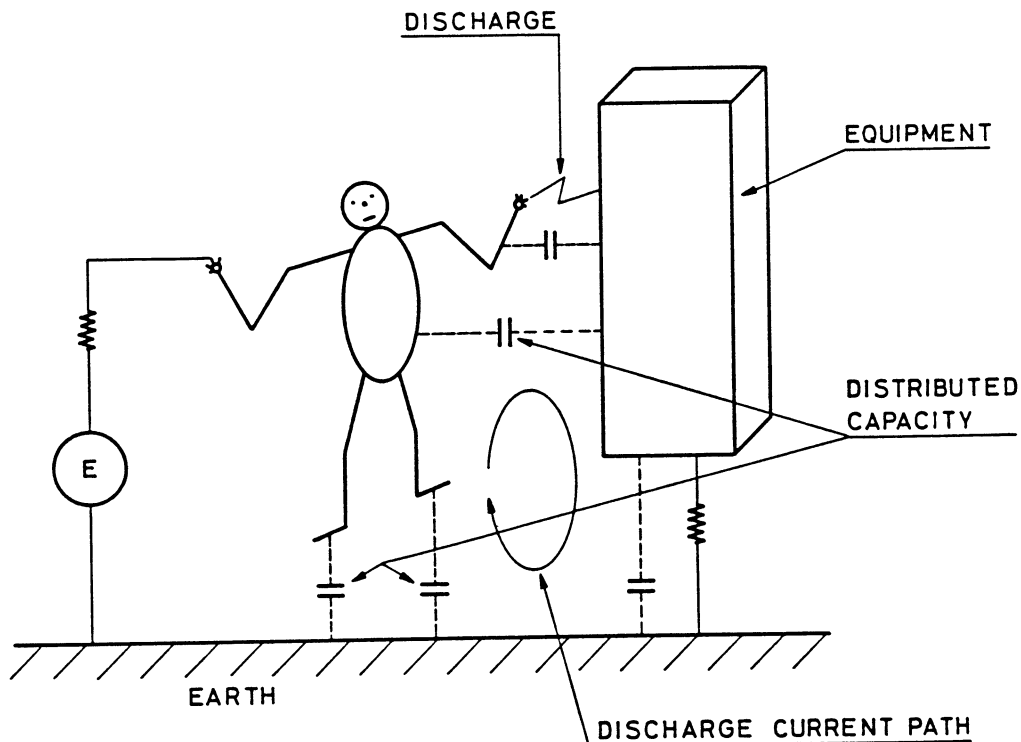


Figure 1 : Human Body - Electrostatic Discharge

However, from the point of view of producing the rise time only the capacitance very close to the discharging point is relevant.

Ideally, simulation of the distributed body capacitance is recommended, but from the point of view of ease of handling it may be necessary to substitute that distributed capacitance using discrete components (see Appendix B). It has to be assured that stray fields produced by compromise test circuits do not influence the measurement results.

A likely circuit for the simulator is shown in Figure 2.

By using firm metallic contact between probe and discharge sinks, the weaknesses in ESD testing that have been addressed are eliminated.

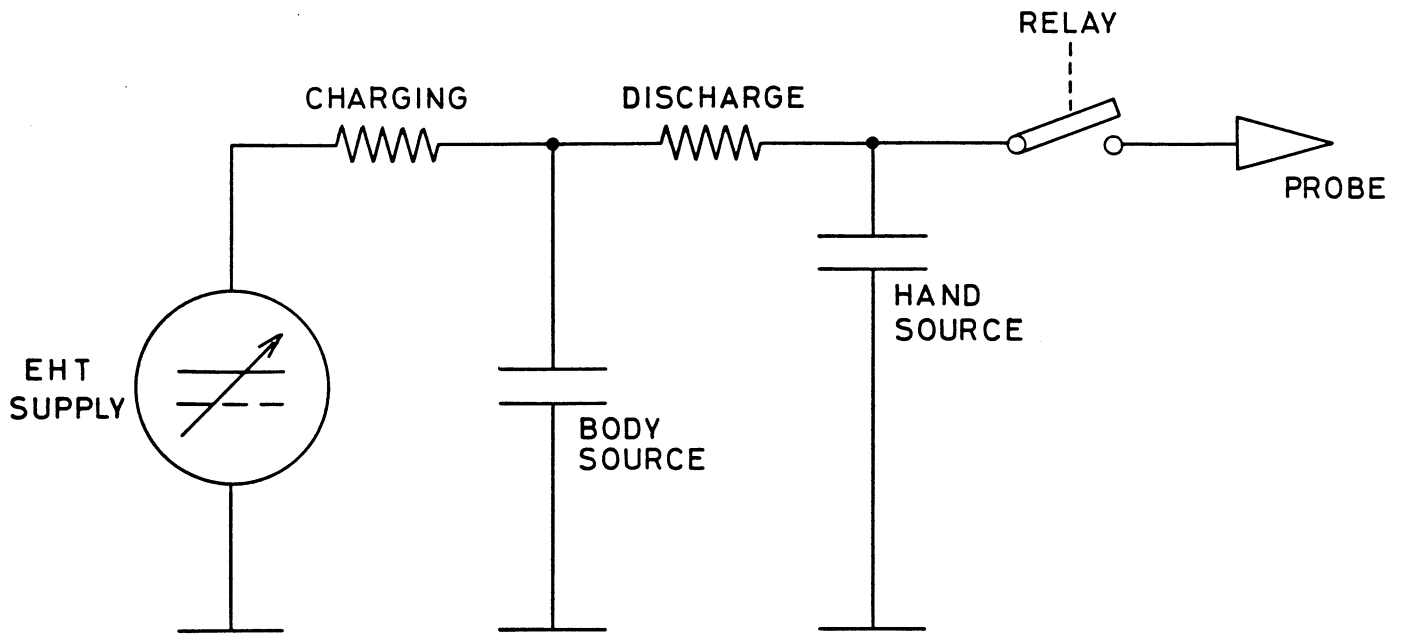


Figure 2 : Circuit of Simulator

4.3 Statistical Considerations

Susceptibility to ESD is often time-dependent during operation due to dynamic activation/deactivation of circuits, each having its own response level. Obviously, the probability of coincidence with a susceptible time window by a single test discharge (trial) is less than 'one' and, consequently, more than one trial is necessary on average to determine product susceptibility at a given discharge energy (see Appendix C).

With certain failure mechanisms, malfunction may occur with every trial at a given discharge energy. Such occurrences are revealed by a single trial.

4.4 Objectives

In conclusion, it is important to highlight the objectives of this Technical Report. These objectives are as follows:

- the test shall cover the main properties of the real event,
- the test shall be repeatable,
- the test shall be simple, fast, cheap, and convenient to perform,
- the test shall be capable of being agreed internationally.

5. DISCHARGE PARAMETERS

5.1 Energy Source for the Test Discharge

A storage capacitance shall be used which is representative of the capacitance of both the human body and metallic furniture. A nominal value of 150 pF has been determined suitable for this purpose. Dimensional details for a distributed capacitance approach are shown in Appendix B.

5.2 Switch

A switch device shall be used to simulate the natural spark in a controlled way. The switch shall be designed to satisfy the following objectives:

- a) produce worst case rise time of natural spark,
- b) maintain minimum deviation for each discharge,
- c) allow discharge rates according to the needs of multi-pulse testing,
- d) be able to handle current and voltage ranges involved,
- e) have a life time in conformance with multi-pulse testing.

NOTE 1

It has been demonstrated by experimental studies that a mechanical contact is the only technique to satisfy objectives a) and b).

Vacuum relay technique has been proven adequate to satisfy objectives c) and d).

Mercury wetted contacts have an advantage of long life time and can best satisfy objective e), however have a disadvantage of limited tiltability.

5.3 Coupling Probe

The objectives of 4.4 require a firm metallic contact to conductive surfaces of an EUT.

Insulating coatings not designed to insulate against ESD discharges for the lifetime of a product shall be penetrated to obtain metallic contact. Penetration can be made with insignificant degradation of the EUT appearance using a sharp needle tip for the probe.

The physical arrangement of components and dimensions of the probe significantly affect the current pulse shape and energy. The design shall be such that the pulse shape specification of 5.4 is satisfied.

NOTE 2

It has been shown that a discharge resistor of 330 Ω for worst case human body discharge simulation (held metallic object) and a discharge resistor of 15 Ω for furniture discharge simulation are suitable to obtain the desired pulse shapes. Further, it has been shown that stray capacitance and inductance of the probe are significant design elements to obtain the desired pulse shapes.

5.4 Pulse Shape of Discharge Current

The shape of the current pulse is most significant to the validity of testing. The shape shall be such that it is representative of the spectral energy distribution of natural ESD discharges.

Discharge phenomena considered essential to product ESD performance are discharge from human bodies through a metallic object and discharge from metallic furniture. It is assumed that test simulation of the human body - metal discharge situation is sufficiently severe to represent all human body discharges in the field.

Due to different source impedances, the discharge pulse shapes have different distribution of their spectral energy.

The actual discharge pulse shape is also affected by victim parameters such as impedance and physical dimensions. The pulse shapes specified in Figure 3 and in Figure 4 are related to discharge into the centre of a vertical metal sheet of sufficient dimensions. See Note 3.

Product susceptibility is physically determined by the current amplitude at which malfunction occurs according to the error criteria of Clause 9.

The amplitude setting of a tester should be indicated linearly proportional to the discharge current amplitude.

Relation to immunity requirements by the user environment is discussed in Appendix A.

NOTE 3

For pulse shape verification purposes, the generator should be discharged into the centre of a vertical metal sheet which must be large enough to shift reflections from the edges in time such that they are not superimposed on specified sections of the pulse shape when displayed on an oscilloscope. A sheet size of 1,5 m by 1,5 m has been found to be adequate for this purpose. The charge must be drained from the sheet to ground by a resistor (1 M Ω) to allow continuous discharges.

A transducer (current probe or resistor) must be used to pick up the current right at the probe tip. All components must satisfy the bandwidth and current requirements implied by the pulse shape (1 MHz to 1,5 GHz). Coaxial design and common mode filtering are recommended. The mechanical transducer arrangement must be such, that the probe capacitance to the metal plate is not affected.

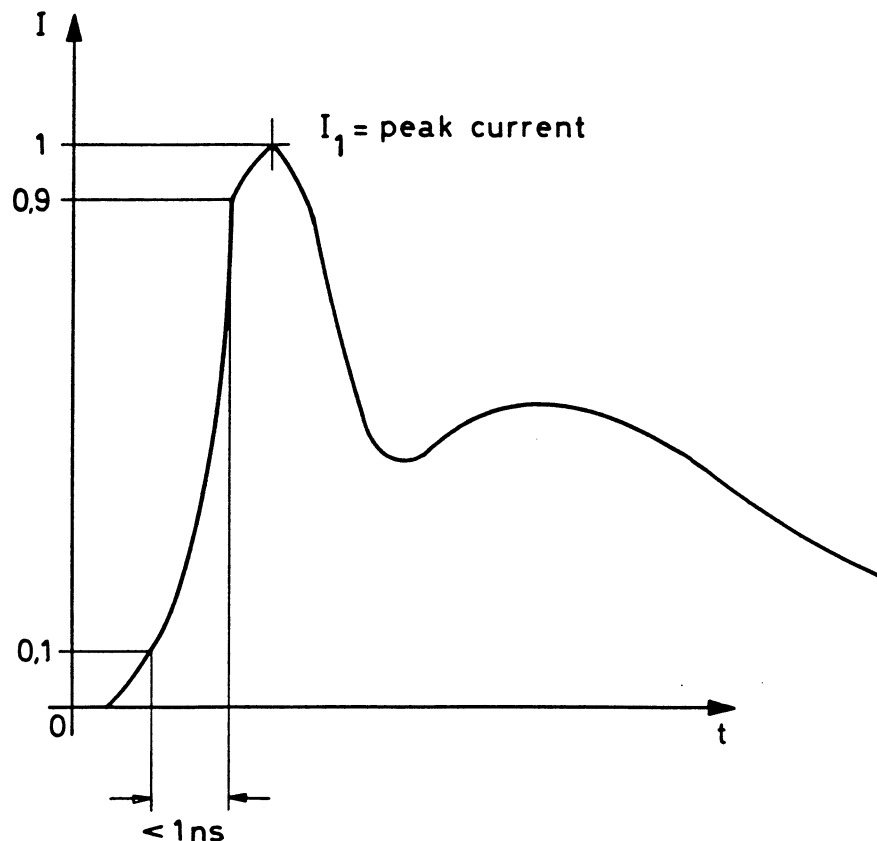


Figure 3 : Pulse Shape for Human Body with Metal Object Discharge

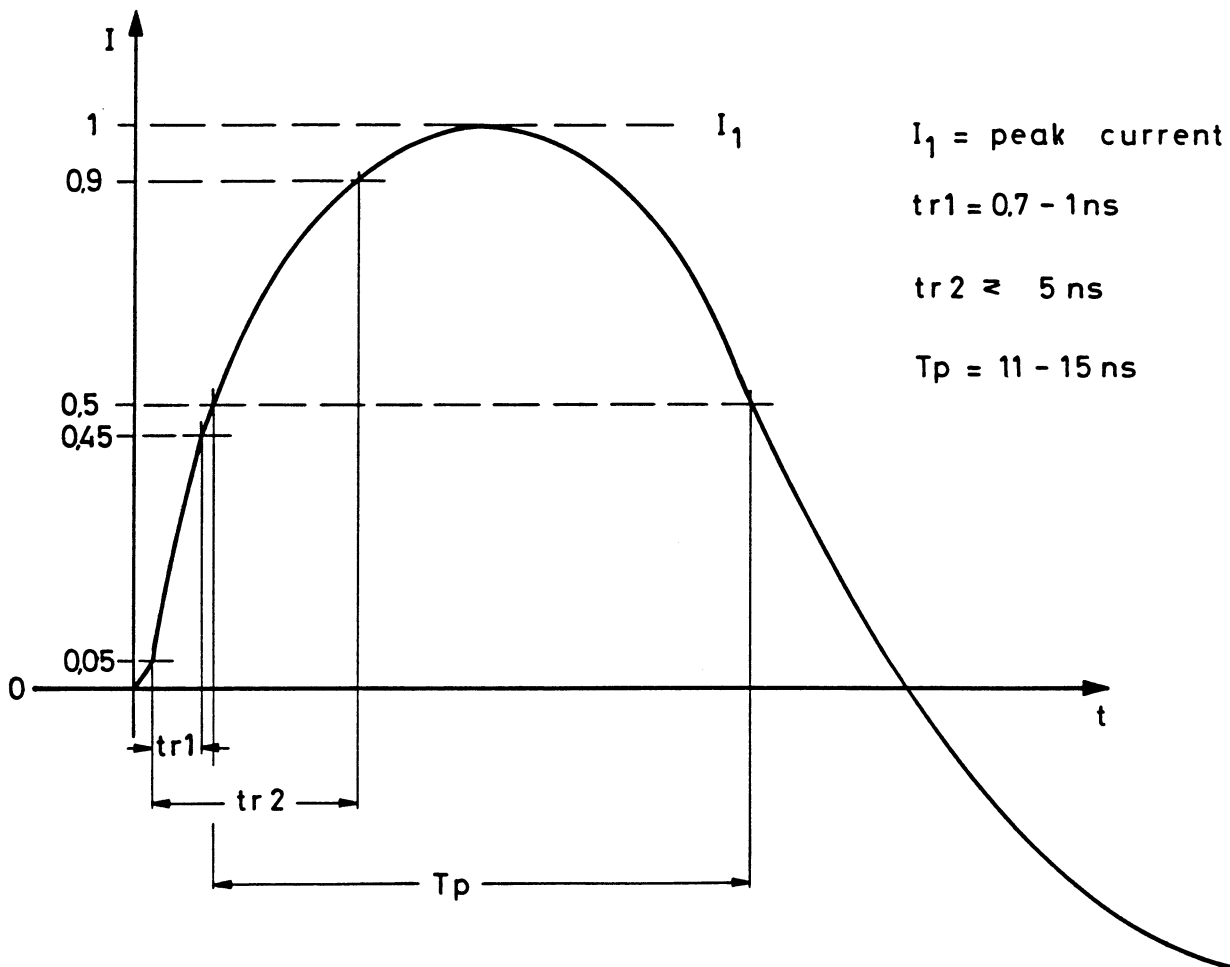


Figure 4 : Pulse Shape for Furniture Discharge

6. TEST CONDITIONS

6.1 Climatic Conditions

Due to the use of enclosed contacts (for example vacuum relay) and firm metallic contact of the coupling probe to the EUT or to the discharge sink, climatic conditions are not critical. Normal EUT specification conditions are therefore acceptable for test.

6.2 Electromagnetic Conditions

The ambient electromagnetic conditions shall be such as not to influence the results of this test.

7. TEST SET-UP

7.1 Equipment Under Test (EUT)

The EUT shall be tested under normal operating conditions, with particular attention to the installation specifications.

At least one example of each interface type available shall be operational.

Ground connections other than in the installation specifications shall not be used during testing.

The EUT shall be placed at a minimum horizontal distance of 1 m from any metallic structure.

7.2 Indirect Discharge Testing

For indirect discharge testing a parallel metal plate of dimensions 600 mm by 600 mm is spaced 100 mm from the EUT, where a surface of the equipment cannot be contacted directly. This plate shall be presented in turn to each portion of each face of the EUT. The plate shall be connected to the ground reference plane through a resistance of 1 M Ω .

The plate might be the body of the tester itself that will be discharged into the reference ground (see Appendix B).

7.3 Table-top Equipment

The ground reference plane for table-top EUT shall be represented by a conductive plate on the table which shall extend at least 100 mm around the EUT. In the case of direct testing, it shall be earthed in accordance with normal safety practice. For indirect testing, the plate shall be connected to the ground reference plane through a resistance of 1 M Ω . The EUT shall be insulated from the conductive plate by the minimum practicable thickness. Mounting feet, if any, shall be left in situ.

The disposition of the signal cables shall be representative of installation practice.

7.4 Floor-standing Equipment

The ground reference plane for floor-standing equipment shall be represented by a conductive plate laid on the floor under the equipment, which shall extend at least 500 mm around all sides of the equipment. The minimum size of the ground reference plane shall be 2 m by 2 m. The ground reference plane shall be connected to the safety earth system of the installation. The EUT shall be insulated from the conductive plate. The signal cables shall be separated from the ground reference plane by 100 mm.

8. TEST PROCEDURE

8.1 Selection of Test Current Value

The value of the test current shall be selected in accordance with the actual environmental conditions where the equipment is to be installed; in particular the materials or fabrics involved in the production of static electricity and the relative humidity shall be taken into account.

NOTE 4

See Appendix A for the correlation between test current and environmental voltage.

8.2 Selection of Test Points

The electrostatic discharges shall be applied to the EUT on preselected, operator-accessible points and, in the case of table-top equipment, to the surface of the metal plate supporting the EUT.

The test points to be considered may include the following locations as applicable:

- any point in the control or keyboard area and any other point of man-machine communication devices such as switches, knobs, buttons and other operator-accessible areas,
- points of each portion of the metallic cabinet where such portions are isolated electrically from ground,
- areas on insulated enclosures which are nearest to conductive portions of the enclosed circuitry for indirect testing,
- other points which are likely to be touched by the human body or by furniture.

Where equipment metalwork or the test plate is isolated from ground it may acquire a charge which inhibits further discharge pulses, in which case that item shall be discharged to earth through a resistance of $1M\Omega$.

The discharges shall be applied to each interconnected equipment or peripheral, if any.

8.3 Equipment Under Test (EUT) Software

Test software for the EUT shall be chosen in such a way as to exercise all modes of normal operation.

8.4 Application of the Discharges

Discharges shall be applied to all previously selected test points with the equipment operating normally. Human body and furniture discharges, as well as direct and indirect discharges, shall be applied, respectively, as determined with test point selection.

Appendix C discusses the significance of multi-trial testing, number of trials and repetition rate of the discharges.

9. EVALUATION OF TEST RESULTS

During testing the EUT shall conform to the specifications of the manufacturers. The following is the preferred list of failure criteria, in order of severity:

- 0) Transient disturbances with no immediate or lasting effects.
- 1) Not indicated as machine error but recognized by end-user as unsuccessful operation and can be corrected by end-user with manual retry.
- 2) Indicated as machine error and can be corrected by end-user with manual retry.
- 3) Indicated as machine error and must be corrected by system restart.
- 4) Critical error:
 - a) Undetected error,
 - b) Loss of data,
 - c) Restart effort high,
 - d) Operational safety affected,
 - e) Credibility affected.

5) Equipment damage.

NOTE 5

Unsuccessful operation which is automatically corrected by software retry is not considered as a malfunction in the context of these error criteria.

The test results shall be evaluated and compared with the acceptable values stated in the functional specifications (or upon agreement between manufacturers and users).

APPENDIX A

IMMUNITY REQUIREMENTS RELATED TO THE USER ENVIRONMENT

As a measurable quantity, static voltage levels found in user environments have been applied to define immunity requirements. On the other hand, it has been shown that energy transfer is a function of the discharge current rather than of the electrostatic voltage existing prior to the discharge. Further, it has been found that the discharge current typically is less than proportional to the pre-discharge voltage in the higher level ranges.

Possible reasons for this non-proportional relationship between pre-discharge voltage and discharge current are suggested to be:

- The discharge of high voltage charges typically should occur through a long arcing path which increases the rise time, hence keeps the higher spectral components of the discharge current less than proportional to the pre-discharge voltage.
- High charge voltage levels will more likely develop across small capacitance assuming the amount of charge should be constant for a typical charge generation event. Vice-versa, high charge voltages across large capacitance would need a number of successive generation events which is less likely to occur. This means the charge energy tends to become constant between higher charge voltages found in the user environment.

As a conclusion from the above, the immunity requirements for a given user environment need to be defined in terms of discharge current amplitudes.

Having recognized this concept, the design of the tester is eased. Trade-off in the choice of tester charge voltage and discharge impedance can be applied to achieve desired discharge current amplitudes.

A limited tester voltage is the key to discharge control by relay, which is mandatory to generate reproducible discharges and to permit multi-pulse testing in order to obtain statistical relevance for the test results.

An anticipated relationship between charge voltage found in the user environment and discharge current used for immunity specification is shown in Figure A.1 for the human body discharge. Modifications may become necessary if conflicting empirical data are obtained.

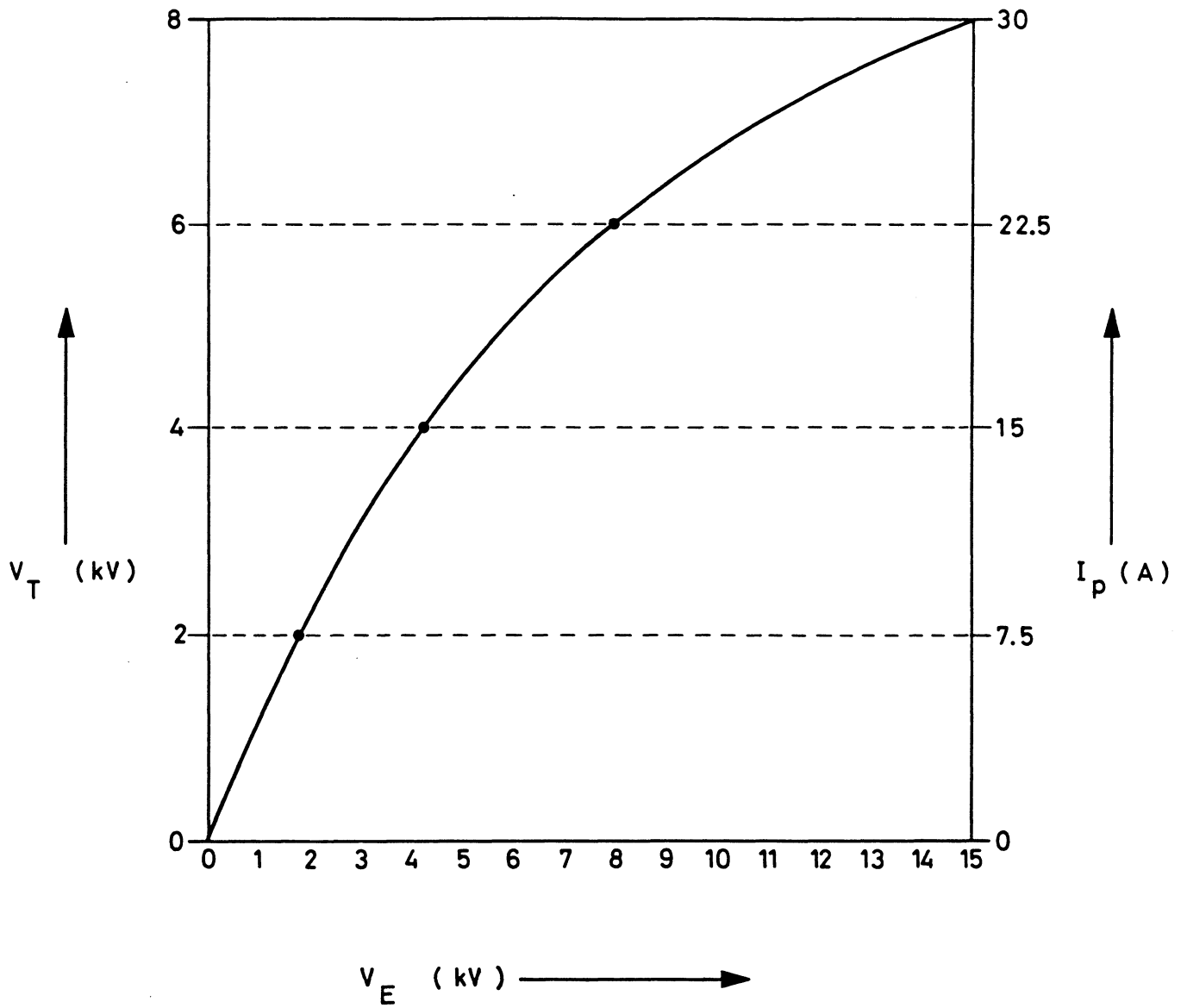


Figure A.1 : Anticipated Relationship between Environment Voltage (V_E), Test Voltage (V_T), and Peak Current (I_P)

APPENDIX B

PHYSICAL DESIGN OF THE STORAGE CAPACITANCE

The distributed capacitances shown in Figure 1 have been represented in tester design by a discrete capacitor or by a metallic structure each focussing on specific objectives.

Discrete Capacitor

A discrete capacitor has been used in hand-held, pistol-shaped, testers which clearly offers superior mobility for the exploration of EUT surfaces. See Figure B.1

It has been concluded from recent studies that the probe of such testers can be made to simulate the distributed capacitance of a human hand by the normal stray capacitances of the components. There are expectations that this simulation will essentially satisfy the conditions of a natural discharge into a metallic surface of an EUT.

Distributed Capacitance

Analytical studies of charged bodies (human body and metallic furniture) as well as a need for a reproducible set-up have led to a vane structure simulating more ideally the distributed capacitances, as well as minimizing variability of placement. The most significant dimensions of a practical example are shown in Figure B.2. As an advantage over a flat metal plate, the capacitance of the vane structure is relatively insensitive to its distance from other bodies.

The vane structure is recommended for the storage capacitance where the radiated field of a discharging body is considered to be a determining factor of energy transfer to an EUT, as it can be assumed in the following cases.

Obviously, the radiated field should be the only coupling medium between the tester and EUT in the case of discharging the storage capacitance through a non-EUT current path (indirect discharge) as required by 7.2. With products not completely shielded, intermediate situations are conceivable where both current pulse and field radiation determine the compliance level.

To perform an indirect discharge test, the charged vanes are discharged through the probe into the metal base (drained to earth). The fixture required for this purpose is not shown in the drawing. The vane assembly itself is placed at the EUT such that the two probe slides (left-hand edges in the drawing) are equidistant from and parallel to the vertical surface plane to be tested. A distance of 70 mm from the surface plane is recommended.

As recommended in 4.2, the vane assembly can be used for direct discharge into metallic surface elements of an EUT. For this purpose, the probe is clamped at a suitable position on the vane edges as indicated in Figure B.2.

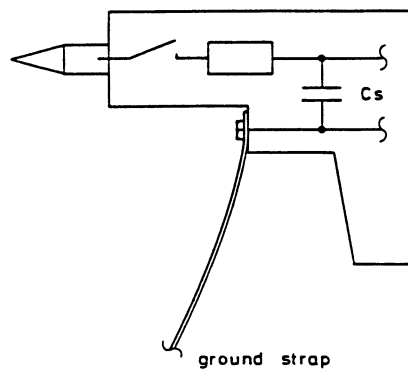


Figure B.1 : Discrete Component for Storage Capacitance

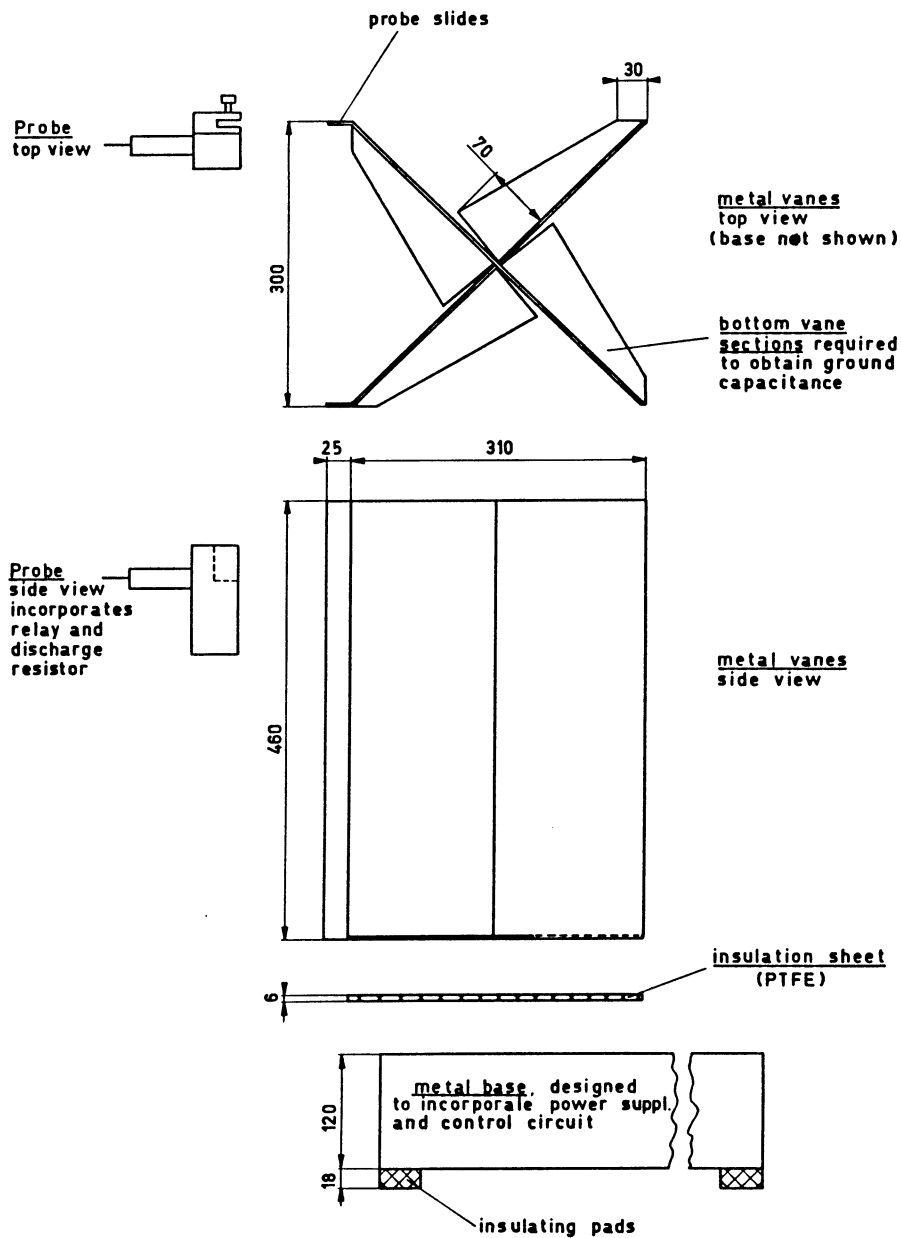


Figure B.2 : Distributed Storage Capacitance

APPENDIX C

MULTI-TRIAL TESTING

Significance of Multi-Trial Testing

Test results have confirmed that in clocked systems there are time windows during which product ESD immunity is low. It is important to understand that, in principle, the probability of missing such susceptible time windows cannot be reduced by setting more stringent product susceptibility limits in terms of discharge energy.

Setting a product susceptibility limit makes an implicit assumption of the error rate acceptable to a user. This error rate is given by the number of ESD events at the user location which exceed the product susceptibility limit.

Since ESD event rates increase dramatically at lower energy levels, susceptible time windows have the potential of degrading product ESD immunity even if their time occupation is small. Neglecting them would lead to invalid product characterization.

Permitted Average Test Error Rate (ET)

In addition to the above-mentioned "user acceptable error rate" (EU) a "permitted average test error rate" (ET) is introduced for the purpose of this discussion. A decision made for ET leads to the number of trials required to determine product susceptibility at a given test energy level.

Certainly, ET should be smaller than "one" (each trial causes malfunction). A reasonable number of ET should conform to EU which is adopted (implicitly) by setting a susceptibility limit as discussed above. The difference between ET and EU is given by the test program which has to exercise all features and circuits during an ESD test while a user application may concentrate by chance on a subset of circuits. This means the rate of susceptible time windows may be much lower in a test situation compared to a user application, hence ET should be smaller than EU to compensate the difference.

Assuming that EU should conform with specified product reliability criteria (e.g. MTBF), the latter may be used as a starting point to specify ET. Analogous with the ESD energy limit, different EU (hence ET) may be chosen for different malfunction severity. This possibility has little practical relevance to testing however, since, in general, the kind of actual malfunction is unknown prior to a test.

As a result of the above considerations, numbers between 0,01 and 0,001 (average errors per trial) have been suggested for ET.

Number of Trials (N)

A number of 10000 trials has been suggested reasonable based in the assumptions used in the following discussion.

Knowing the Permitted Average Test Error Rate (ET), the number of trials (N) must be chosen to allow a decision at an acceptable accuracy on whether or not the test object satisfies the susceptibility limit. The accuracy is related to the probability of rejecting a sample which actually is compliant (type 1 decision error) and to the probability of accepting a sample which actually is not compliant (type 2 decision error).

With given targets for tolerable decision errors, N can be determined for a given ET by statistical calculation. As an example, the magnitude of type 2 decision errors is shown for several trial numbers in Table C.1. The calculation is based on a specified ET of 0,001 and on the target not to reject more than 1% of samples which actually meet the susceptibility specification. The latter leads to the number of machine errors which have to be tolerated in the test as shown in the table.

Samples accepted by type 2 decision error	Factor by which ET of 0,001 is exceeded			
	N = 50	N = 100	N = 1000	N = 10000
1%	130	65	12	3,2
50%	33	17	5	1,8
70%	22	11	4	1,7
Number of EUT errors to be tolerated for N trials	1	1	4	19

Table C.1 : Type 1 decision errors vs. trial number for ET = 0,001 and a type 2 decision error probability below 1%

This example demonstrates that the trial number significantly affects test validity.

Other Assumptions

Multi-trial testing is based on the statistical rule that as a stream of ESD discharges is applied to an EUT, malfunction is assumed to occur with equal probability after each discharge. For this reason the injection rate must be such that accumulation effects of any kind are avoided. Practice has shown that an injection rate of about 50 discharges per second satisfies this requirement for most error mechanisms. Accumulation effects, when suspected, can easily be checked by reducing the injection rate.

Further, it is required that susceptible time windows, as exercised by the test program, are equally exposed to the discharges according to time relationships. For this reason, the period of injections

must sufficiently cover the periods of program cycling. For the purpose of averaging, many program cycles should be passed during the period of injections.

