ESD Simulator Voltage at the Instant of Test

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INTRODUCTION

As an air-discharge ESD simulator approaches an equipment under test (EUT), simulator tip voltage is invariant for some simulator designs. For other designs, however, corona and increased simulator-to-victim capacitance can reduce simulator tip voltage by as much as 25 to 30 percent.[1] (Corona is the name for a partial discharge effect, and is due to local breakdown in air near a high-voltage electrode.)

A 25- to 30-percent decrease in simulator voltage upon approach to the EUT can significantly affect the outcome of the test; i.e., whether the EUT fails or passes. The effect can be particularly important for tests at seams and apertures in plastic-encased products, at high test voltages such as 15, 20 and 25 kV, where corona effects intensify (Figure 1).

Unfortunately, voltage drop just before discharge is an effect that is too unquantifiable and uncontrollable to be useful in a precision test plan. Any attempt to consider that it represents "reality" will result in chaotic test results. ESD testing, like most simulation, cannot exactly reproduce reality. Instead, it should be simply an agreed-upon representation of reality that gives repeatable test results. Of course, those results should correlate well with reality, and they should be independent of both the investigator and the test location.

Some ESD simulator outputs drop by up to 30 percent of selected voltage just before the discharge.

WHY VOLTAGE DROP OCCURS

There are two basic designs for ESD simulators. In the constant-voltage ESD simulator design shown in Figure 2, simulator voltage is invariant during victim approach. This holds true even for moderate to high amounts of corona, and is independent of simulator capacitance to either the victim or to ground. The output voltage is set and maintained at the selected level by taking feedback directly from the output capacitor. This feedback facilitates precision voltage generation, using conventional operational amplifier technology. Accuracies within one or two percent of the setting are achievable in this way. In addition, the one or two gigohm feedback resistor that is typically used constitutes a bleeder which causes the capacitor voltage to decay in just seconds when a charged simulator is put down on the bench.

In contrast, the tip voltage of the second type of simulator design, the isolated-capacitor configuration shown in Figure 3, may decrease due to corona, and increase in capacitance as the simulator nears the equipment victim. Corona current from the simulator tip draws down the voltage stored on the capacitor. (Such current ranges from a few tenths of a μA to a few tens of μA according to actual measurement.) And since capacitor charge is fixed, as capacitance to ground increases with approach to the EUT, the

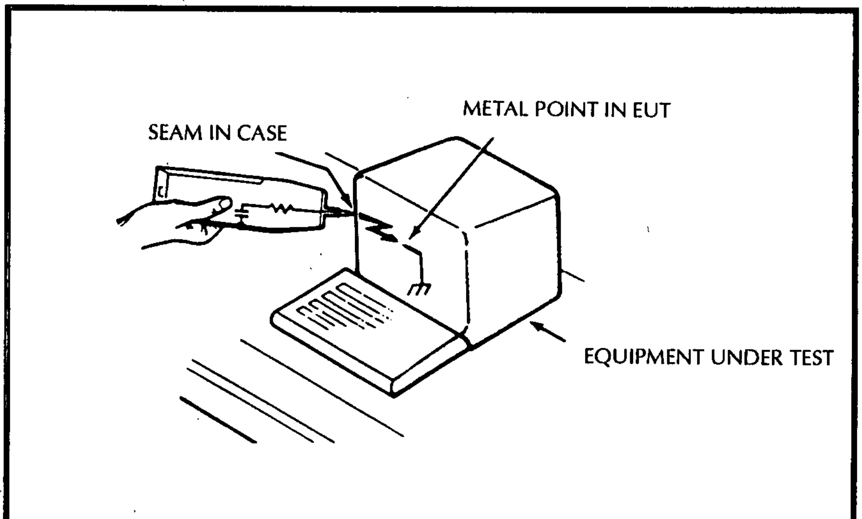

FIGURE 1. *Air-discharge Testing of an EUT at Its Plastic Housing Seam.*

effective simulator capacitance also increases, thereby decreasing simulator capacitor voltage. (In other words, C_1V_1 must equal C_2V_2.)

The isolated (or floating) capacitor design in Figure 3 is shown in a configuration used to generate a positive output voltage. The rectifier's anode is connected to the high-voltage supply and its cathode is connected to the simulator capacitor, C_s. The control circuit shuts off the high-voltage supply after C_s is charged, usually after 50 to 100 ms, effectively isolating the capacitor.

Typically, several seconds are needed between power supply shutdown and the actual ESD discharge. Ideally, the output voltage should drop less than one or two percent in this time interval. However, as noted, an isolated-capacitor design output voltage can actually drop by 10, 20, or 30 percent just before the instant of test. Consequently, the voltage at which the test was actually run is unclear. (In addition, since there is no high voltage feedback resistor, there is no bleeder to cause the capacitor voltage to decay in just a few seconds when a charged simulator is put down on the bench.)

IDENTIFYING SIMULATORS

One way to identify an isolated-capacitor simulator, with its inherent voltage-drop feature, is to check for a quick output voltage decay when the tester is put down. To test the simulator, it is set to a high voltage, the "trigger" is released, and then the simulator is put down. After 5 to 10 seconds, a ground lead is touched to the tip. If it sparks, it is probably an isolated-capacitor design.

The decay time can be used to identify a simulator for the following reason. To prevent the isolated capacitor voltage from dropping due to leakage current alone, the total leakage of the capacitor, the high-voltage rectifier and the terminals to which the high-voltage rectifier and capacitor are connected must be less than a few nA or tens of nA. From the formula CE = IT for capacitor voltage, a 10 nA leakage current will cause a 150 pF capacitor to decay by over 300 V in 5 seconds, already 5 percent at 6 kV. This implies that leakage resistance must be so great that capacitor voltage decay may, under some circumstances, take minutes. Thus, if a simulator zaps an operator when touched long after the simulator was put down, or if it must be discharged to bring its voltage down, it is an isolated-capacitor simulator.

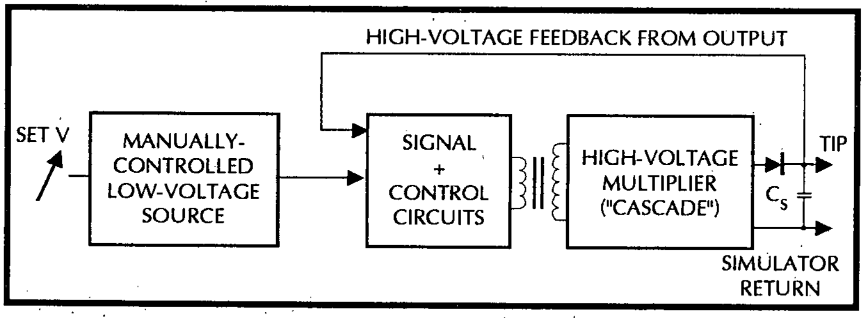

***FIGURE 2.** A Typical Constant-voltage Design. Feedback from the high-voltage output point holds output voltage to the dialed value in spite of corona and increase in capacitance as the simulator approaches the EUT.*

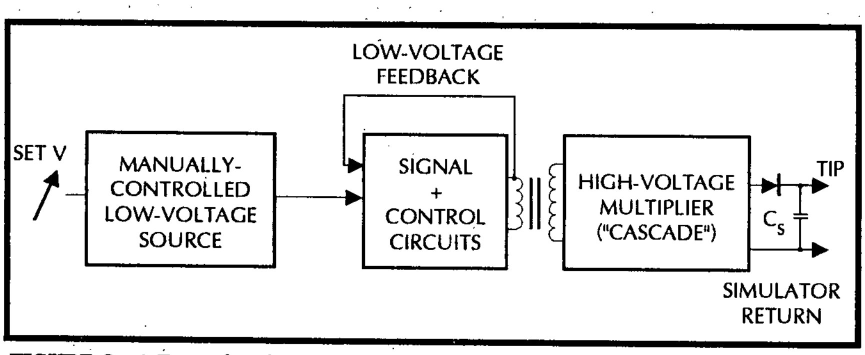

***FIGURE 3.** A Typical Isolated-capacitor Simulator Design. Voltage-control feedback is taken from a low-voltage point, and the voltage is relied upon to maintain an invariant ratio. But since the power supply turns off after 50 to 100 ms, both corona and increasing capacitance with approach to the EUT bring down capacitor voltage just before the test discharge.*

CONCLUSION: REALITY AND REPRODUCIBILITY

At times, testing at a lower voltage than specified is necessary because corona can reduce the voltage on human intruders before they can discharge to a product. These cases should be handled by reducing the voltage specified for doing the test. Then the test should be performed with a simulator whose output voltage is repeatable, and will not decrease in an unknown manner. With a constant voltage simulator, the test can be considered repeatable and also realistic.

REFERENCES

1. Richman, P., Weil, G. and Boxleitner, W., ESD Simulator Tip Voltage at the Instant of Test, Proceedings of the IEEE International Symposium on EMC, Washington, DC, Aug. 21-23, 1990, pp. 252-257.

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