The Impact of Voluntary Versus Legal ESD Standards

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UNANSWERED QUESTIONS IN ESD

ESD impacts billions of dollars of U.S. domestic and exportable equipment. This statement appears in article after article discussing ESD and its effects on electronic equipment. After all the publications on ESD over so many years, a statement to the effect that much of the ESD research still remains incomplete or, in some cases, still undefined, may seem to be inaccurate or overly expansive. The justification for this argument can be made by considering what work must still be done. (References indicate areas for additional support and reading, but are not comprehensive.)

VERY FAST SINGLE-SHOT DIAGNOSTICS

Recent ESD measurements with very fast diagnostics (>12 GHz single-shot capture oscilloscope measurements) show that low ESD charging voltages (less than 2.0 kV events) create typical ESD rise times of 100 ps, or less.

IEC-1000-4-2 and ANSI C63.14 require fixed rise time simulation of 0.7 to 1 ns, a rise time ten times slower than typical real ESD events.[1] Measurements on a statistically reasonable sample of people have never been done with these bandwidths. In effect, the ESD standards do not have the data necessary to define the basic ESD waveform(s).[1]

VARIABLE RISE TIMES

Research shows that rise times for the current pulse in an ESD simulation should be a variable depending upon the voltage testing levels. ESD standards specifying fixed rise times for testing do not represent the real world and the 1.0 ns requirement makes comparison of simulation with real world ESD events irrelevant.[2-4]

ESD standards which affect the total range of electronic products need major revisions based upon good experimental data.

ESD SIMULATOR PERFORMANCE DEFINITION

ESD simulator correlations performed with calibrated diagnostic systems capable of bandwidths exceeding the performance requirements outlined in the IEC standards show that no two commercially available simulators create ESD-simulated events sufficient for correlation of results.[2,5]

CALIBRATIONS

ESD calibration methods remain a major stumbling block to meaningful standards. No existing ESD standard defines a valid ESD measurement technique. This includes national standards and internal company standards. IEC-1000-4-2 does call a step in its procedure a calibration, but the so-called calibration procedure neither calibrates a test, nor requires measuring of ESD events as testing occurs.

Specifically, IEC-1000-4-2 uses the ESD simulator to calibrate itself and then removes all the elements of the calibration from the actual equipment test. As configured, there is no correlation between the waveforms captured during calibration and the EUT test as defined in IEC-1000-4-2. Correlations to the actual human waveforms deviate even further. This method is totally invalid. The calibration technique must first validate the measurement equipment, then the simulator's ESD output, then be able to verify that each pulse into a piece of equipment under test (EUT) conforms to the desired waveform and amplitude parameters. In addition, a full calibration methodology would provide for independent, NIST-traceable certification of simulators, diagnostics and the simulation facilities as well as a verification of day-to-day operation traceable to the certification.[2,3,6,7,8]

FAILURE DEPENDENCIES ON DI/DT AND DV/DT

Recent work indicates that most ESD-driven failures in system level equipment depend not on the absolute simulation voltage settings but on the derivation of the current (di/dt). Some tentative work shows dependence on the derivative of the electric field (dE/dt or dv/dt). Failure mechanisms clearly follow the dynamic electric and magnetic fields created during the ESD event.[2] No existing standards on ESD address the issues of electric and magnetic field-induced failures in any way that can be controlled, monitored, calibrated or that are based on a traceable calibrated measurement method.[2-4]

HUMAN ESD EVENT SURVEY

Since the very fast, single-shot capabilities of the Tektronix SCD5000 oscilloscopes now allow believable,

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single-shot 25-30 picosecond (ps) rise times, it is time to remeasure an unbiased sample of human and non-human sources of ESD using this equipment and calibrated diagnostics. The early data on all forms of ESD was taken with bandwidth-limited diagnostics. It is time to redo the ESD research with the maximum bandwidth equipment available. Until this is done, all ESD standards will have an element of uncertainty that will invalidate some EUT testing.[9]

INANIMATE OBJECT ESD SURVEY

Besides the human ESD event, any material object carrying an electric charge can discharge into another object if the potential difference between them is sufficient. Recent studies of inanimate objects and studies of device-handling equipment suggest that the inanimate-object ESD event is at least as severe, if not more so. Extensive work has yet to be done to understand the ESD threat from inanimate objects. The assumption that human ESD testing will also specify hardness to discharges from other structures is not correct. This area of research clearly needs to be expanded, and the results converted to meaningful components of an ESD standard.

CHARGED DEVICE MODELS (CDM) OR SELF-INDUCED FAILURES

In addition to human sources of ESD, charged device models (CDM) for standards are also being considered. Again, the problem in creating a standard for ESD from discrete, electrostatically-charged devices centers on the ability to measure and verify results. Research on charged devices, such as charged integrated circuits and charged printed circuit boards suggests current waveform rise times can be faster than 40 ps. Single-shot data acquisition equipment capable of 20 to 30 ps resolution, necessary to capture CDM ESD events, is not generally available to the majority of researchers. The high-speed data must be collected and analyzed before CDM standards can be written with a minimum of error and revision. One effort by the ESD Association to field diagnostics and calibration procedures at these very fast levels has been ongoing for some time, but the CDM work is poorly funded.[10]

HUMAN ESD PHANTOM

One completely ignored element of ESD standards is the need for a standard human body physical model. These physical models are commonly called phantoms. Typically, physical models provide a standardized response for some precisely defined class of test. For example, the medical community uses a particular saline solution for determining the density and conductivity of blood and assumes that electromagnetic fields will be absorbed by this medium similarly to absorption by the human body. An ESD phantom would create an electric field environment and a current discharge typical of actual human bodies. The design of such a tool will require significant analysis and supporting research on a wide range of physics problems including nonlinear electromagnetic materials.

ESD SIMULATOR DEFINITION

Lack of simulator standardization may be the most severe limitation to realistic ESD testing that manufacturers face today. Several papers and reports discuss the inadequate correlation of ESD test results between ESD simulators made by different manufacturers. In a paper presented at EMC 95, this author showed that, depending upon the human body simulator chosen, failure levels created varied from 3 kV to over 18 kV on one specific computer. A clever engineer could choose to pass or fail that particular computer, depending upon which simulator was chosen. No reasonable standard can afford to have failure levels vary by factors of over six. This problem also occurs with CDM simulators as it does with human body simulators.[2,5]

FIELD THEORY IN ESD

The ESD area that is the least defined today and which needs the most study centers on the actual electromagnetic environments existing at the moment of an ESD event. Electric and magnetic field monitors capable of measuring the very fast transient are available, but require significant skill to use and to interpret. To create a human phantom, or to verify that results of other classes of measurements, such as a survey of human ESD, meet minimum correlations to the physics involved requires that the electromagnetic field environment be well-understood.[11]

U.S. NATIONAL POLICY

The overwhelming evidence that ESD costs manufacturers and consumers exorbitant sums annually notwithstanding, ESD in the United States continues to be treated as a necessary evil. Manufacturers test when required by customers or when the field returns get to levels that impact bottom lines. Certainly, the largest electronic device and system level equipment manufacturers have extensive programs to control ESD problems in manufacturing, and some begin product ESD hardening at the design level. The issue discussed here is not that of individual corporate ESD awareness, but the overall lack of national policy addressing the issue.

Why should there be a national policy? First and foremost, a national policy is needed because many U.S. corporations market heavily within the European Community (EC) where ESD and EMC laws apply. Contrary to the voluntary nature of U.S. standards on ESD, all manufacturers that desire to export to Europe must comply with myriad legal standards on ESD and EMC. In particular, the European ESD standard IEC-1000-4-2 (formerly IEC-801-2) defines the test conditions and pass/fail criteria for all electronic equipment. IEC standards are not voluntary; compliance is mandated by law. That a corporation must test its products and conform to legal performance constraints isn't in and of itself a problem. The problem with the ESD laws in Europe is far more fundamental. The ESD standard IEC-1000-4-2 cannot accurately measure, verify, certify or define the very performance the EC law mandates. IEC-1000-4-2 bases its compliance definition for equipment on a physically invalid premise.

The invalid premise is that ESD failures can accurately and repeatedly be determined from voltage settings on an ESD simulator. This is false. The history of papers presented at ESD and EMC conferences is replete with anecdotal descriptions of systems that would pass in one test at one location and fail the same test at another location. Yet, with this false basis for compliance, a U.S. company could be excluded from European markets. At a time when treaties, such as GATT, are attempting to normalize trade relationships between countries, the problems presented by IEC-1000-4-2 could be viewed as a step in the opposite direction and will result in restraint of trade.

What should the U.S. do? First, the U.S. electronics industry must as a group come to a consensus that it is in its best interest to support physically sound ESD standards. Sound ESD standards based upon the physics of the ESD event, not on the design constraints of ESD simulators, can not only eliminate the confusing results of ESD tests, but can also reduce the total cost to manufacturers' testing to prove product compliance. As an additional benefit, reasonable and physically sound ESD standards provide a means to rebut the results and findings of standards inadequately based on true ESD phenomena.

Second, there must be a means for tracing the performance of ESD simulators to a U.S. standard that can be verified by valid physical measurement methods. Requiring traceability to valid measurement methods by default leads to definite and traceable calibration techniques.

Furthermore, the opportunity that the U.S. had in creating a national standard, albeit a voluntary one, never resulted in a true standard, but rather was relegated to the lesser position of an ESD guideline, ANSI C63.14. Clearly, the policy of U.S. industry and Congress to minimize regulatory controls is in full swing. The argument here is that ESD is one area that needs to be an exception to the process of eliminating regulations. The necessity for regulations in ESD springs from a clear understanding that ESD interferes with all classes of computer-controlled electronics. Electronics from aircraft autopilots to computer banking and automobile engine controls must survive in an environment which continually generates ESD. Some of these classes of electronics must be hardened to the zero-defects level for safety. Today's standards do not provide a zero-defects level of certainty in performance certification.

The creation of any standard assumes that sufficient information exists to form a valid measurement and certification program. The difficulty with both the ESD standards of the U.S. and EC comes from the fact that recent research indicates the assumptions used for these standards need to be substantially modified. Evidence now exists in both the open literature and in ongoing ESD research programs indicating that much more work needs to be done. The areas of ESD waveform definition, measurement techniques and sensors, environmental ESD source measurement calibration techniques, and computation methods for identifying and analyzing failures all must be improved before standards can produce the confidence levels for certifying performance that must be achieved on some electronic equipment.

NIST and ESD

The obvious center for traceability of measurements is the National Institute for Standards and Technology (NIST). However, to date NIST has no internal body tasked with the establishment of an ESD measurements certification. NIST has not gotten the response from industry that it needs to create this function. NIST responds to the demands of its customers: industry. The U.S. electronics industry has not wished to create more regulations and limitations on their businesses and as such has not demanded support in the ESD field. Only since early 1995 have clear arguments been presented to NIST addressing the reasons that NIST is the appropriate body to implement this certification and traceability policy. Although significant data necessary to the development of a realistic and meaningful standard have been known for years, the majority of research on ESD still has to be done.

ESD RESEARCH

The U.S. has no ESD standards equivalent to the EC regulations with the standing of law. Yet joint U.S. and European work can lead to improved U.S. standards more quickly than the EC alone since major modifications to IEC regulations can happen only once every five years, while the ANSI C63.14 ESD Guideline is under review at the moment. Extensive efforts to upgrade the U.S. standards on ESD have been underway for some time through the ESD Association (formerly the EOS/ESD Association) and the IEEE. The difficulty with completion of the standards work here or in Europe, however, is centered directly on the lack of information as outlined in the research yet to be done, discussed above. Many concerns about whether the present ESD tests are over-test or under-test to the specification of a meaningful ESD simulator performance criteria cannot be completely settled without the completion of this research.

ESD research must continue with full support from the entire user community. Without serious community support, the window of opportunity for the U.S. to make a meaningful impact on these "standards in evolution" will close. The U.S. electronics community has a chance to regain some control of its own destiny with respect to ESD standards by insisting on credible and reliable ESD research now. The stumbling block, as always, is money. These research tasks will cost money.

Generation of usable ESD testing guidelines, whether in the form of standards or as general procedures published as an extension of the ANSI C63.14, requires definite answers to the issues addressed above. What is needed to get these answers? First, the community of ESD engineers and companies dependent upon successfully passing ESD testing must decide to support the research needed to acquire the data, not just as a group of uncoordinated efforts by individuals and companies around the country but as a defined program.

To date, progress in the field only occurs when a specific problem arises and usually without sufficient funding to acquire the very equipment required to eliminate questions. Without an overall program specifically targeting the full set of ESD events and the way that these events can cause failures, standards will continue to contain major errors, and will fail to test equipment in ways that provide real information on survivability in real-world situations.

SUMMARY

To reiterate, what must be done to build a complete ESD threat picture? The answer to this question also indicates the magnitude of support needed from industry and government. At a minimum, ongoing ESD research must include four areas. First, very fast electrical measurements in a single-shot mode must be studied. This area recently gained significant help with the software enhancement of SCD5000 bandwidths to over 15 GHz.

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Second, diagnostic research should expand on the extensive basis of electromagnetic sensors developed by the electromagnetic pulse (EMP) community. Standards must allow any physically valid measurement techniques. Research should at a minimum address the following sensors and their applicability to ESD measurement systems: H-dot and H-field monitors; E-field and E-dot monitors; balanced probe measurements; antennas designed for capturing ESD events; on-PCB sensors; Rogowski monitors; and resistive current monitors. The 1.0-ohm or 2.0-ohm current monitors do not provide good references, traceable to first principles analysis.

Third, experimental measurements must provide the basis for standards. At a minimum the experimental work needs to survey human, CDM and other ESD environments with very fast diagnostics to define the range of variability and typical ESD events. Fourth, computational analysis of the electromagnetic field environment must support the experimental work.

ESD standards impacting the total range of electronic products need major revisions based upon good experimental data. These revisions can only come from extensive research, which requires significant funding beyond individual support and limited corporate interest. With the EC limited to modifying its regulatory laws for the next five years, the U.S. manufacturing community has a window of opportunity for contributing to meaningful ESD standards by providing ESD research with funding now.

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