SEPTEMBER 2010

IN COMPLIANCE™ Magazine

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Equivalent Transmission-Line Model for Vias Connected to Striplines in MULTILAYER PRINT CIRCUIT BOARDS

DECREASED CDM RATINGS FOR ESD-SENSITIVE DEVICES in Printed Circuit Boards

The Truth About ESD CLASS 0

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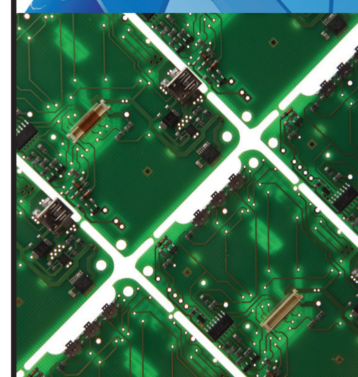
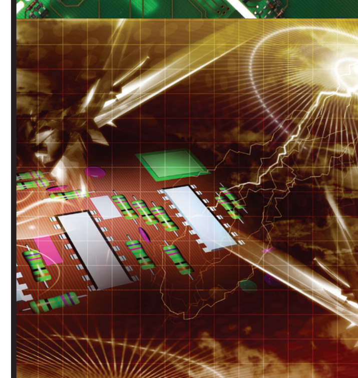


European Commission Asks CENELEC to Produce a European Standard for Powerline Modems

by Brian Jones

Following the failure of the Power Line Telecommunications (PLT) amendment of CISPR 22 to reach the Committee Draft for Vote (CDV) stage, the European Commission has asked the European electrotechnical standards committee, CENELEC, to produce a European standard for emission limits for PLT apparatus. This will be a stand-alone standard rather than an amendment to EN 55022 (the European equivalent of CISPR 22) that can be listed in the Official Journal of the European Union under the EMC and R&TTE Directives and give a presumption of conformity for emissions requirements under those directives.

The intention is to produce two parts to the standard: part 1 for in-house apparatus and part 2 for access apparatus. These parts will describe test methods and limits relating to the PLT aspects, the remaining aspects will still be covered by EN 55022, which will be referenced from the new standard.

Such a standard would also allow the wired network standard, the EN 50529 series, to be completed. Parts 1 and 2, dealing with telephone lines and co-axial cables respectively, have recently received a positive vote, but the third part, dealing with mains networks, cannot be completed until a standard for the terminal apparatus is available.

The new standard will therefore fulfil the joint functions of providing a standard for apparatus, and enabling the network standard to be completed.

Timescales are tight; the intention is for the draft for in-house apparatus to be ready for vote by July 2011 and the draft for access apparatus to ready for vote by December 2011.

CENELEC has set up a new Working Group, TC210/WG11 to carry out the necessary drafting, and this will hold its first meeting 24 - 26 August 2010, in Brussels, Belgium.

Work Starts to Amend CENELEC Standards Affected by the Digital Dividend in Europe

by Brian Jones

In Europe, terrestrial television is currently broadcast in the UHF band in the frequency range 470 - 862 MHz. As a result of spectrum efficiencies brought about by the switch to digital broadcasting, in the next few years across Europe the frequency range 790 - 862 MHz will be cleared of broadcast use to enable new mobile services to be offered. The spectrum will be auctioned without specifying the technology to be employed. The major use is expected to be Long Term Evolution (LTE) - the fourth generation mobile phone system that will in addition bring broadband services to some rural areas for the first time, although other technologies could also make an appearance.

Although there will be no frequency conflict with off-air broadcasts, the current design of TV tuners will still be sensitive to signals in that range, and the cable TV networks will continue to use these frequencies for their services after the switch-over to mobile use. It is recognised that the higher field strengths created by these new mobiles in close proximity to TV sets and cable boxes have significant potential to cause interference.

Over the past six months, the European electrotechnical standards body, CENELEC, and the European Telecommunications Standards Institute (ETSI) have been working to define the nature of the expected problems and make recommendations for changes to standards, and for mitigation measures for currently available broadcast and cable TV receivers.

CENELEC will be holding a meeting of its EMC committee, TC210, together with its committee for cable TV networks, TC209, in Dublin, Ireland, on 12 and 13 August 2010 to plan the work needed to make the necessary changes to the standards. Changes to the European harmonised standards in these fields can be expected in the near future.

Brian Jones is an independent EMC Consultant, specializing in compliance with European legislation and standards. He is also secretary to the CENELEC EMC committee TC210, but is writing here in a personal capacity, and his views do not necessarily reflect the views of any organization. He may be contacted at emc@brianjones.co.uk.

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Dear Editor:

Jack Black's recent article, "EMC And Aerospace," in the July issue of In Compliance was an interesting read, but there are some issues that must be addressed.

First, there is no mention that the standard cited, SMC-S-008, belongs to the United States Air Force Space & Missile Command. SMC-S-008 is definitely not a NASA standard; unfortunately, an association with NASA is strongly implied in both the text and by the juxtaposed picture of the Space Shuttle. The undersigned does not now, nor ever has worked for NASA, nor does he speak for NASA; however, twenty years of working with NASA EMC standards and NASA EMC engineers is a sound basis for stating that NASA would never release a standard such as this one. NASA's standards have much more in common with the recently published gov't-industry collaboration American Institute of Aeronautics and Astronautics (AIAA) standard S–121-2009, "EMC Requirements for Space Equipment and Systems." In fact, two different NASA Centers and the affiliated Jet Propulsion Laboratory sent representatives to the AIAA committee which drafted S-121.

Second, while the Space & Missile Command is part of the US Air Force, their EMC organization operates apart from, and very differently than the mainstream USAF which is the custodian for MIL-STD-464 and MIL-STD-461. To say that the SMC-S-008 standard is based on these standards is at best only partially correct. The AIAA standard S-121 mentioned above is correctly described as being based on tailoring these standards. MIL-STD-464 and MIL-STD-461 are but some of the ingredients making up SMC-S-008.

The Aerospace Corporation, which develops EMC (and other) standards for the Space & Missile Command, reached far and wide to find as many different requirements as they could muster to include in SMC-S-008, in an apparent attempt to make sure that every EMI requirement ever considered was included.

The SMC-S-008 approach could not be more different from the mainstream process, in which the USAF, Army and Navy cooperate with each other to write the MIL-STD-46X series of standards. The guiding philosophy of the –46X standards is to address known problems, in a manner that minimizes the cost and schedule impact of both the problems being avoided, and the programs put in place to prevent future occurrences of these problems.

Circa the late 1980s, MIL-STD-461C and MIL-STD-462 had been placed on a list of "problem standards" that required immediate attention by the relevant authorities. The end result of that process was the completely revamped MIL-STD-461D and –462D, and their direct descendant today, MIL-STD-461F. SMC-S-008 makes copious use of MIL-STD-461C requirements and MIL-STD-462 test methods juxtaposed side-by-side with MIL-STD-461F requirements which in the rest of the DoD supplanted the obsolete requirements.

For the small minority of EMC engineers who will have to work to SMC-S-008, a special section has been devoted at the EMC Compliance website, www.emccompliance.com. Click on "EMC Info." Scroll down to SMC-S-008. It is a work in progress - check it out on a periodic basis to see what new challenges and problems have been identified.

Disclaimer: The author was a member of the AIAA committee that drafted S-121, a representative to the DoD committees that draft the MIL-STD-464 and -461 standards, and has worked in the field of military and commercial aerospace EMC for thirty years.

Ken Javor
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Dear Editor:

The recently published article "EMC and Aerospace" has some areas that need clarification as a result of feedback from various sources. The clarification is as follows:

The SMC-S-008 standard is a Space and Missile Command Standard, issued by the Space and Missile Systems Command Center, Air Force Command, in El Segundo, CA. While this is clearly identified as a reference document, it is not clearly identified in the test of the article. It is not a NASA standard. The author regrets any unintended implication.

References to NASA regarding the RFD/CS and the OLMS projects are not accurate, as referenced materials used for this article identify and reference NASA, but not for these specific projects, as they were performed by Aerospace Corporation as NOM projects. The author regrets the use of any reference to NASA in this or any other regard.

I am sorry for any misunderstanding with respect to this article.

Thank you.

Jack Black
D.L.S. Electronic Systems, Inc.

SEMINAR OVERVIEW

- FCC rules and regulations overview
- TCB applications and certifications
- FCC submissions from a Laboratory perspective
- Modular Approvals and integration of modules
- Co-location of transmitter devices
- RF Exposure for Mobile and Portable devices (SAR and MPE)
- The FCC's KDB (Knowledge Database) system
- The FCC PBA (Permit But Ask) system
- Notified Body opinions
- Updates from TCB Council workshop in Baltimore, April 2010 and the latest requirements and changes from FCC and IC.
- Updates from the R&TTECA and ECANB in Prague, May 2010 and the latest changes in Europe.

EXPERT INSTRUCTION

Our guest lecturers are from AmericanTCB (ATCB).

Dennis Ward is senior applications examiner and Technical Director for ATCB in the US and has been involved in many aspects of EMC, wireless and product conformance for over 30 years. He has worked as an EMC test engineer and Director of Laboratories in the United States and has consulted on numerous products for world-wide approval, including cellular, 3G, Wi-Fi, Spread Spectrum, Digital Transmission Systems, Wireless Access Points, and numerous licensed and unlicensed products. He has performed certification review for conformance with Specific Absorption Rate (SAR) requirements and radiation hazards. Dennis has been directly responsible for accreditation issues and activities supporting Telecommunications Certification Bodies, accreditation to ISO Guide 65 and ISO Guide 17025.

Michael Derby is a regulatory review engineer and a representative of ATCB in Europe and he has been involved in many aspects of EMC and Radio compliance for 20 years. He has worked as an EMC and Radio test engineer and has been Leader of a Radio test laboratory and he is now a Notified Body for the R&TTE and EMC Directives, a TCB for the FCC and an FCB for Industry Canada. Michael has been an active member of ETSI and contributed to the creation of EN standards. He presently contributes to the TCB Council and the R&TTCA, providing liaison services between organizations.

COURSE OUTLINE

Wednesday September 22

8:00 am	Registration
8:30 am	Introduction and overview of course FCC Overview FCC Technical Rules FCC Licensed verses unlicensed devices FCC TCB Applications, problem applications, common mistakes
Noon	Lunch
1:00 pm	FCC Modular Approvals FCC from European perspective Updates from TCB Council Training FCC Integrating Modules FCC Permissive changes Questions and answers
5:00 pm	End

Thursday, September 23

8:30 am	Begin FCC RF hazards: Portable vs Mobile RF Exposure, Maximum Permissible Exposure (MPE) RF Exposure, Specific Absorption Rate (SAR) FCC Submissions from a Laboratory Perspective FCC Latest KDBs from TCB Council Training Industry Canada Certification requirements
Noon	Lunch
1:00pm	IC Certification IC Modular approvals IC Permissive changes R&TTE Compliance and CE Marking Updates from ECANB and R&TTECA R&TTE Directive future Questions and answers
5:00 pm	End

FEE/REGISTRATION

Radio Transmitter Approvals Workshop: All You Need to Know
Registration Fee: US$895 per student
Discounts! Second student from same company, 10% discount for second enrollment.

Fee includes:
Lecture notebook, copy of the standard, lunch, breaks, and completion certificate.

Payment in advance via check, VISA or MasterCard (preferred credit cards) or bank transfer (ask for transfer details).

FCC Rated "Most Improved Federal Agency"

The Federal Communications Commission (FCC) has been voted the "most improved" federal agency in the entire federal government, according to the 2010 Federal Employee Viewpoint Survey of employee satisfaction.

According to the U.S. Office of Personnel Management (OPM), which oversees employee administration issues for the federal government, the bi-annual survey measures "employees' perceptions of whether, and to what extent, conditions that characterize successful organizations are present in their agencies." OPM uses the data from the Viewpoint Survey to develop strategies to improve individual agency performance.

"The survey results reflect the hard work being done throughout the agency to make the FCC a model of excellence in government," said FCC Chairman Julius Genachowski in a prepared statement. "The FCC's reform agenda… includes creating new opportunities for employees to provide feedback, improving employee communications through technology and new media, and focusing on leadership development and opportunities for employees."

The complete results of the 2010 Viewpoint Survey are available at http://www.fedview.opm.gov/2010.

FCC Amends Rules for Amateur Radio Operators in Emergencies

As expected, the Federal Communications Commission (FCC) has amended its regulations to allow amateur radio operators to participate in emergency and disaster preparedness drills, regardless of whether the radio operators are employees of those organizations participating in the drill.

In a Report and Order issued in July 2010, the Commission overturned its previous restrictions against such activity, arguing that "employee status should not preclude or prevent participation in government-sponsored emergency and disaster tests and drills," and that "extending authority to operate amateur radio stations during such drills will enhance emergency preparedness and thus serve the public interest."

The Commission has consistently acknowledged the important role that amateur radio has played in past natural disasters, including emergency communications in the aftermath of Hurricane Katrina in September 2005.

In a Notice of Proposed Rulemaking in March 2010, the Commission sought comments on its plan to remove restrictions on the participation in drills by amateur radio operators who are employees of public safety agencies, hospitals, and other entities, and to allow them to transmit messages on behalf of their employers during such tests. The proposed rule change was met with widespread support from public safety agencies and emergency first responder entities.

The text of the FCC's Report and Order is available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-124A1.pdf.

FCC Program Expands Investment in Broadband Healthcare Technology

Consistent with its National Broadband Plan announced earlier this year, the Federal Communications Commission (FCC) has released details of a new healthcare connectivity program that it says will expand investment in broadband Internet access for medically underserved communities across the country.

In a Notice of Proposed Rulemaking (NPRM) issued in July 2010, the Commission has proposed the establishment of a new program that would invest up to $400 million annual to bring broadband access to approximately 2000 rural hospitals and clinics. The program, which would be funded by fees collected under the Universal Service Fund, is envisioned to be a healthcare counterpart to the Commission's E-Rate program for schools.

The program includes a number of specific proposals, including the formation of partnerships with public and non-profit healthcare providers to invest in regional and statewide broadband networks where they are either unavailable or insufficient, and contributing up to half the monthly recurring network costs incurred by hospitals, clinics and other healthcare providers;

The FCC says that nearly 30% of federally-funded rural healthcare clinics can't afford secure and reliable broadband Internet services, and that only 8% of Indian Health Service providers have broadband access.

The complete text of the Commission's NPRM for expanded broadband access for rural healthcare is available at http://www.fcc.gov/Daily_Releases/Daily_Business/2010/db0715/FCC-10-125A1.pdf.

EU Commission Confirms Dumping of Chinese WWAN Modems

The Commission of the European Union (EU) has taken steps to stem the dumping of wireless wide area networking (WWAN) modems originating from the Peoples Republic of China.

Responding to a complaint from an EU-based manufacturer of WWAN modems, the Commission has determined that manufacturers based in the China have been shipping quantities of comparable products into the EU at prices well below market value. The Commission's conclusion was based on documented export prices from mid 2009 through March 2010, although the Commission says that the evidence supports the belief that "there was an history of dumping over an extended period of time."

The Commission's Regulation, published in June 2010 in *Official Journal of the European Union*, requires EU Customs authorities to immediately being the registration of all WWAN modems imported into the EU from China. According to the Regulation, the registration process will provide the documentation necessary to impose anti-dumping financial duties retroactively.

The complete text of the EU Commission's Regulation regarding WWAN modems from China is available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:163:0034:0036:EN:PDF.

EU Revises Spectrum Harmonization Provisions for Short-Range Devices

The Commission of the European Union (EU) has updated its harmonization of the technical conditions for the use of the electromagnetic spectrum by a wide variety of short-range electrical and electronic devices, including alarms, local communications equipment, door openers and implantable medical devices.

The changes are reflected in a Commission Decision issued in June 2010 and published in the *Official Journal of the European Union*. The Decision includes a revised version of the technical Annex, originally published in 2006, which details power limitations and other operating conditions for various types of short-range devices, based on their operating frequencies.

The release of an updated Annex was prompted by a recommendation from the European Conference of Postal and Telecommunications Administrations (CEPT) in November 2009 to revise a number of technical aspects to reflected technological advances in short-range devices.

The Commission's Decision, including the revised Annex detailing the updated harmonization provisions for short-range devices, is available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:166:0033:0041:EN:PDF.

Updated Standards List Published for EU Directive on In-Vitro Medical Devices

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 98/79/EC, dealing with in-vitro diagnostic medical devices.

According to the EU's Directive, an in-vitro diagnostic medical device is "any medical device which is a reagent, reagent product, calibrator, control material, kit, instrument, apparatus, equipment, or system, whether used alone or in combination, intended by the manufacturer to be used in-vitro for the examination of specimens, including blood and tissue donations, derived from the human body."

Under the Directive's definition, specimen receptacles are considered to be in-vitro diagnostic medical devices, while products for general laboratory use are not, unless such products are intended to be used for in-vitro diagnostic examination.

The updated list of CEN and Cenelec standards that can be used to support compliance with the Directive was published in July 2010 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

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The list is available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:183:0045:0049:EN:PDF.

EU Commission Revises Standards List for Medical Device Directive

The Commission of the European Union (EU) has issued a revised and updated list of standards that can be used to demonstrate conformity with the essential requirements its Directive 93/42/EEC concerning medical devices.

The Directive defines a 'medical device' as "any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including the software necessary for its proper application….to be used for human beings for the purpose of: 1) diagnosis, prevention, monitoring, treatment or alleviation of disease; 2) diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap; 3) investigation, replacement or modification of the anatomy or of a physiological process; or 4) control of conception."

The revised list of CEN and Cenelec standards replaces all previously published standards lists for the Directive, and was published in July 2010 in the *Official Journal of the European Union.*

The revised list of standards for the EU's Medical Device Directive can be viewed at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:183:0015:0044:EN:PDF.

Sony Recalls Laptop Computers

Sony Electronics, Inc. of San Diego, CA has announced the voluntary recall of about 233,000 of its VAIO-brand laptop computers, manufactured in both China and the United States.

According to a notice issued by the U.S. Consumer Product Safety Commission (CPSC), the recalled computers can overheat, posing a burn hazard to users. Sony says that it has received 30 reports of the laptop computers overheating, resulting in deformed keyboards and computer casings. However, there have been no reports of injuries related to the hazard.

The laptop computers were sold at Best Buy, Costco, Frys, and at Sony Style retail stores, as well as through Amazaon.com and sonystyle.com, from January 2010 through April 2010 for between $800-1500.

To view the CPSC notice regarding this recall, go to http://www.cpsc.gov/cpscpub/prerel/prhtml10/10284.html.

External Laptop Batteries Recalled

Tekkeon, Inc. of Tustin, CA is recalling about 500 of its myPower-brand external laptop batteries, which were manufactured in China.

According to the company, the battery cell can short-circuit and overheat, posing a fire hazard to consumers. Tekkeon has received one report of an overheated battery that resulted in minor damage to nearby furnishings, but no reports of injuries associated with the product.

The recalled battery can also be used to power MP3 players, mobile phones, DVD players, and other portable electronic devices. It was sold through Amazon.com and other online retailers from September 2009 through December 2009 for about $180.

For more information regarding this recall, go to http://www.cpsc.gov/cpscpub/prerel/prhtml10/10744.html.

Baseboard Heaters Recalled Due to Fire Hazard

Marley Engineered Products of Bennettsville, SC has recalled about 30 of its Dayton Electric-brand baseboard heaters, manufactured in the United States.

According to a notice issued by the U.S. Consumer Product Safety Commission (CPSC), the baseboard heaters are labeled for 240 or 208 volt use, but some of the heaters have an internal heater built for a maximum of 120 volts. In such cases, connecting the heater to a 240 or 208 volt electrical circuit could result in a fire.

The company says that it has not received reports of any incidents or injuries associated with the recalled heaters, but has initiated the recall to prevent any such incidents.

The recall heaters were sold through Grainger branch stores nationwide from December 2009 through March 2010 for about $50.

The CPSC's notice regarding this recall can be viewed at http://www.cpsc.gov/cpscpub/prerel/prhtml10/10745.html.

2010 IEEE SYMPOSIUM ON

PRODUCT COMPLIANCE ENGINEERING

OCTOBER 18-20, 2010
Boston, Massachusetts

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DON'T MISS OUT ON THE 2010 SYMPOSIUM

The technical program this year includes more than papers and workshops from an outstanding group of authors. Attendees will have the opportunity to:

- **Refresh perspectives with the return of our popular basic safety workshop (PS 102) or updates on important regulatory topics**
- **Reconnect on some more popular topics:**
  Touch currents, Burn injury, Forensics
- **Catch up on some popular technology papers:**
  Lithium batteries, Power Supplies, Portable Equipment Acoustics, Applied Hazard Based Safety Engineering techniques.
- **Broaden your outlook with papers on topics as relevant as today's technology headlines:**
  Smart grid, RoHS, System safety for automotive applications, and a TASER Cased Study
- **Attend updated workshops on Product Liability, and Environmental Compliance.**

Registration
To register for the conference, please go to http://www.psessymposium.org/registration. Advance registration deadline is September 24, 2010.

Venue
The symposium is being held at the beautiful Boston Marriott Burlington Hotel in Burlington, a suburb of Boston, MA. We have negotiated a room rate of $139 at the Marriott Burlington. Reservations should be made online through the Syposium web site (http://www.psessymposium.org).

http://www.psessymposium.org

IEEE

The iNARTE Informer

Provided by the International Association for Radio, Telecommunications and Electromagnetics

WHAT IS CERTIFICATION?

A recent IN Compliance survey showed that many readers wanted to know more about iNARTE's Certification Programs and the process of Certification.

We have therefore decided that this issue of the Informer will be devoted to addressing these requests and providing answers to many frequently asked questions.

iNARTE is an independent credentialing agency that provides validation of an individual's professional credentials in a number of specific disciplines. Individuals who demonstrate their ability to meet certain established criteria in these disciplines are awarded a Certificate attesting to their proficiency. For many professionals, this Certification step is the only way to demonstrate their cumulative knowledge and experience as a result of working years following their post secondary education.

iNARTE Certification is currently offered in:

- Telecommunications Engineering
- Electromagnetic Compatibility, EMC
- Electrostatic Discharge Control, ESD
- Product Safety Engineering, PSE
- Unlicensed Wireless Systems Installation, WSI
- Internal Laboratory Auditing, iNCLA

iNARTE operates under the guidelines of ISO 17024, as a result of which we do not ourselves provide training in our various disciplines. However, we can and do provide advice as to where and what training may be available. A number of training organizations and individuals have sent details of their training courses for our consideration. Those that we have found to be appropriate for the furtherance of education and understanding of the disciplines in which we operate are listed as Approved Training Centers on our web site. Appropriately most of these Training Centers will also offer their services as Authorized Test Centers.

WHO DEFINES REQUIREMENT AND THE SKILL SET?

As a general rule, the need to identify top performers within a discipline is created by industry or government needing to have confidence in their staffing decisions, their subcontractors or their service providers. As this need emerges, Certification or a similar professional credential is required. iNARTE then acts as a facilitator to develop, implement and administer the program. However, the following questions all need to be answered:

Is there a real and significant need in the marketplace to identify an individual practitioners engineering excellence?

Are there enough individuals working in the field to allow a large enough pool of top performers to be identified?

Is there a technology partner that can assist in the development of a suitable skill set by which to identify the top performers.

Many readers of In Compliance will have interest in the EMC field, and iNARTE's EMC Certification Program. For this discipline the above questions were answered as follows:

In 1988 a Command of the United States Navy identified a significant number of EMC problems within the fleet, resulting in the need to identify appropriately skilled contractors to implement solutions. Seeking a credible and respected certification entity, the uS Navy command selected iNARTE as the administrative agent for the certification of engineers and technicians in the field of Electromagnetic Compatibility (EMC).

At that time the EMC community in the USA was extremely active. Regulatory standards for unwanted emissions and immunity against Electromagnetic ambients for both military and commercial equipment were well developed and had *resulted in a significant number of practitioners entering the field with widely varying levels of understanding.*

Many experts were already working for the US Navy and they in turn were easily able to identify a cadre of other acknowledged EMC experts, willing and able to assist in defining a skill set for EMC proficiency. The IEEE EMC Society was formed in 1957and by 1988 had grown to more than 10,000 members within which iNARTE was able to identify experts in all of the different EMC disciplines.

Working with the US Navy and other identified experts in the field, iNARTE developed a set of criteria for both EMC Engineers and EMC Technicians covering Education, Experience, Examination and Peer Evaluation.

The purpose of the iNARTE EMC Credential Certification Program is to foster technical "excellence" in EMC engineering. This approach established technical competency criteria for EMC and enforces these criteria for technical personnel performing EMI control work. The program benefits the individual engineer, the technician and the EMC community as a whole by establishing a standard of excellence in EMC engineering that will endure and extend across the boundaries of private and government agencies.

EDUCATION

Part of the basic requirement for certification as an EMC engineer or technician is a specific record of approved experience in EMC work. Part of that experience may be gained during post secondary education. An official transcript, the supply of which is the responsibility of the applicant, as defined in the following, must substantiate any experience gained by such study.

For an engineer:

1. Graduation in an approved engineering college curriculum of four years is equivalent to four years of the required experience.
2. Satisfactory completion of each year of such an approved engineering curriculum is equivalent one year of experience.

CERTIFIED PRODUCT SAFETY ENGINEER

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Certificate Number:PS-99999-NE

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International Association for Radio, Telecommunications and Electromagnetics

finds

Count Alessandro Volta

has demonstrated knowledge, proficiency, expertise and experience in Product Safety Engineering and is hereby certified in this discipline as a fully qualified Product Safety Engineer in accordance with iNARTE administrative rules and guidelines.

Brian F. Lawrence, Certification Chairman

H. Stephen Berger, President

INTERNATIONAL ASSOCIATION FOR RADIO iNARTE TELECOMMUNICATIONS AND ELECTROMAGNETICS, INC.

3. Graduation in a curriculum other than engineering will be evaluated by *iNARTE*.
4. Postgraduate study in engineering may be given credit up to one year.
5. Engineering teaching of a character satisfactory to *iNARTE* may be recognized as engineering experience up to a maximum of two years.

Similarly for certification as an EMC Technician:

1. Graduation in an approved technician curriculum of two years or US Navy Class "A" School is equivalent to one-year experience.
2. Satisfactory completion of each year of such an approved technician curriculum is equivalent to one-year experience.
3. Graduation in a curriculum other than a technician curriculum will be evaluated by iNARTE.
4. Technician teaching of a character satisfactory to iNARTE may be recognized as technician experience up to a maximum of two years.

All student credit from curricula approved by the Engineers Council for Professional Development are accepted. Students' credits from other curricula than those approved by the Engineer Council for Professional Development may be accepted at the discretion of *iNARTE*.

"Watch for more information in the next iNARTE Informer"

EMC QUESTION OF THE MONTH

Following is a typical EMC Exam question that should be answerable by both engineers and technicians within 5 minutes.

The broadband impulse signal (the sequence of regular short pulses with uniform spectral density) is measured with a test receiver meeting CISPR requirements for the frequency range 0.15 - 30 MHz.

The PRF is 100 Hz. The reading of the test receiver with a peak detector is 60.5 dBμV. What would be the reading in dBμV if the PRF decreases to 2 Hz?

A) 26.5
B) 40.0
C) 60.5
D) 81.0
E) 83.0

The answer will appear in the next issue of IN Compliance!

UPCOMING EVENTS

Below is a table of upcoming iNARTE events.

Several other workshops are in the pipeline, so be sure to visit the iNARTE web site regularly to be sure not to miss those in your region or field of interest.

WHEN	WHAT	WHERE	iNARTE/PARTNER/PRESENTER
Sept. 14th–17th	Laboratory Auditor ISO 17025 Training and Credentialing, www.narte.org/d/ACLASS2010Flyer.pdf	Marriot O'Hare Airport Chicago, IL	ANSI-ASQ National Accreditation Board, (ACLASS)
Oct. 3rd-8th	ESD Association Symposium www.esda.org/symposia.html	John Ascuaga's Nugget Resort Sparks (Reno), NV	iNARTE exhibition and Certification Examination sessions
Oct. 18th-21st	IEEE PSES Symposium www.psessymposium.org	Boston Marriott Burlington Mall Road Burlington, MA	iNARTE exhibition and Certification Examination sessions

Lightning *and* Miss Liberty

by Mike Violette

One hundred million volts, more or less. That is the potential that is developed as roiling masses of air and water and ice molecules furiously swap electrons during a thunderstorm. Charge separation, caused by the friction in the air, related to the mechanism of static built up by rubbing balloon on cat, fills the atmosphere with pockets of ions–positive and negative. As the voltages build, the normally-insulating air molecules stress and disassociate and filaments of current crackle across the sky, releasing mega-joules of energy in each stroke. The supersonic expansion of the ionized air along the stroke path, boiled to a plasma, cracks in a sonic boom, rolling across the sky as thunder.

Upwelling currents of air lift charged particles, lofting them thousands of meters into the sky. Positively-charged ions congregate in the ground below, rushing to equalize the negative charges floating in the wind-whipped sky. At some point, the air fractures and an ionized channel opens between the Earth and Sky; a "stepped leader"–an opening parry–bridges the opposite charges with a flow of a few tens of amperes. Once the ionized channel is open, tens of thousands of amps or more rush to equalize the charge, dumping buckets of coulombs in the spasm, which may be repeated several times until all the charge is dissipated. The equalization temporarily sates the uneven voltage distribution, until further kinetic activity in the unstable air mass of the thunderstorm shakes loose another gazillion electrons and the process starts anew.

As there is no known method of preventing a lightning strike, management of lightning effects–shock, fire, structural damage–depends on understanding this key mechanism of charge equalization and the flow of currents during the few seconds of a lightning event. As all know, the best thing to do during a thunderstorm is to get out of the open and indoors. So who would know better about the hazards of standing out in the open during a thunderstorm with arm in the air than the Statue of Liberty, the gift of friendship from the people of France.

Standing tall in New York Harbor since 1886, the Statue of Liberty rises to a height of just over 300 feet–pedestal and all–her famous torch pointing East, welcoming the immigrants that make up the backbone of the United States. The half-million pound copper and steel structure reportedly gets struck by lightning over 600 times in a year. During the restoration of 1984-1986, my father Norm Violette and I were involved in assessing the lightning protection of the famous monument. We had the opportunity to climb and crawl and inspect and make measurements and an assessment of her condition. Reporting to the general contractor, we composed a report and analysis of the lightning protection elements and made recommendations.

The key goal of the study was to understand how the statute has been affected by the six thousand or so lightning strikes over her (then) 100 year history as well as to look at the design of the protection system to safeguard people and the facility itself. This article is a summary of some of those findings.

SURFACE INSPECTION

First, we did a visual inspection of the entire structure taking the elevator to various points along the height of the statue. (The scaffolding was an engineering marvel in itself, rising from the pedestal to the torch without contacting the statue anywhere along its height.) The statue is made of hand-hammered sheets of copper; the thickness that of 2 pennies. "Attachment points"–where the lightning contacts the skin of the statue–were observed to be all along the height of the statue, on her shoulders and skirt and even on the tablet cradled in her left arm. Why would lightning strike at less-than-the-highest point? During a strike, lightning travels in short intervals of 50 to 100 meters or so, giving its characteristic jagged appearance. That means that, for tall structures, the tallest point may not be the most-struck. A mass of charge can build up in any direction and a lightning bolt may find its path to ground anywhere along the rise of a "tall" structure.

We found many quarter-sized scorch marks on the surface of the statue, with only a small handful of actual punctures in the skin. The scorch-marks on the *patina* of the statue (the copper compounds that give the statue its characteristic aqua color) were thin and black and spattered. The patina is a fine insulator and the lightning currents punch through to the inner mass of conductor. Many of the scorch marks were weathered-over and fading and it was straightforward to guess which ones were "fresh."

It was not a stretch to conclude that the skin of the Statue protects her just fine from lightning discharges. Our main focus was on what happens *after* the Statue gets hit.

GROUNDING AND BONDING

As related in the short phenomenology introduction, the key to coping with a lightning strike is to equalize all charges as efficiently as possible. This is where Mother Earth comes in (in a cloud to ground strike, that is). It is important to have a low impedance path for the lightning currents to flow. Thick, wide, short and direct conductors are the best, so the skin of the statue is ideal: monolithic plates of solid copper. The plates ride on teflon-coated stainless steel bars (the "armature) that was completely rebuilt during the reconstruction. The old system of support was of thick iron bars, hand-formed to match the curvature of the copper skin. During the restoration, each of these was removed, a drawing made and the part re-fitted with stainless steel.

Thus, the bulk of the statue proper is an excellent conductor and the flow of charge flows outward from the point of attachment. The impedance of the copper sheets is extremely low. We took a look under her skirt, so to speak, where the statue stands on her concrete pedestal.

We found four rods of solid copper, about 5/8" in diameter. They are bent to follow the curve of the drapes of her skirt and soldered for about 1 meter or so along the underside of the feet, placed approximately in each corner of the statue. At that point, the down-conductors disappear into the top of the pedestal, which is a huge monolithic structure, composed of discrete 12" pours of concrete, stacked to a height of 300 feet.

To reach Mother Earth, the down-conductors connect to an unknown grounding structure. It is posited that a ring of copper was laid around the base during construction of the pedestal, but many of the drawings for the Statue disappeared during a fire at the turn of the century. In order to assess the condition of the grounding of the down-conductors, it was necessary to perform a ground resistance measurement.

The standard method for measuring ground resistance is to use the "fall of potential" method. To make this measurement, a three or four probe instrument (sometimes generically referred to as a "Megger") is used to inject current into the ground and a voltmeter measures the induced potential. The resistance is inferred from Ohm's law. We used this method to check the grounding resistance of the Statue earth electrode system as well as continuity of the down-conductors connected to the shell of the Statue.

The three-terminal fall of potential method is shown in Figure 1. A (usually AC) current is injected between current electrodes E (the structure under test) and C, the current injection point. The voltage probe, P, measures the resultant voltage. Every grounding system has a "theoretical" ground resistance, which is the resistance between the ground system and infinitely-distant electrode. In practice, a 30 to 50 meter spacing is sufficient, although it depends on the extent of the earth electrode system being measured.

The measured resistance follows a curve shown in Figure 2, which shows the measured resistance as a function of spacing of electrode P relative to E. The plateau of the graph is the true Earth resistance and it occurs at a spacing of 61.8% of the distance between electrodes E and C.

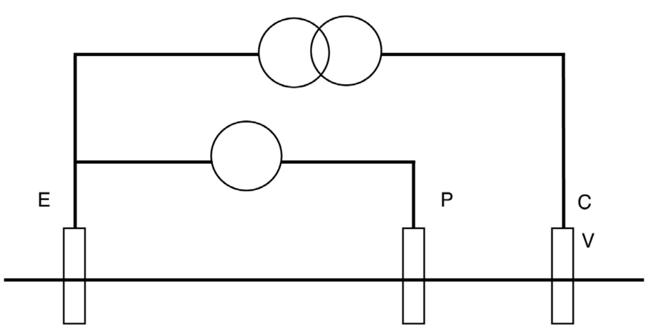


Figure 1

An AC current is used because in the vicinity of metallic structures there are often galvanic currents that flow because of the cathode/anode behavior of buried metals (two dissimilar metals buried in ground act like a giant battery, essentially. These currents can incorrectly bias the measurements if a DC-based measurement is made.)

We found that the earth resistance was within acceptable levels–a few ohms. We also ran checks of the down-conductors using the same instrumentation. One out of the four copper cables showed a discontinuity, probably caused by a shift in the concrete; it was not possible to tell. Instead of trying to remedy the existing down-conductor, we specified the addition of a fourth conductor, using a stranded copper cable of the same diameter as the original. We ran the new down-conductor in an electrical chase, bonding the cable with the metal conduit at intervals of 10 meters or so.

A number of new metallic structures were installed in the pedestal, including staircases, structural equipment, HVAC, etc. These large metal objects, some stretching the several stories from the ground to the statue's skirt, were incorporated into the lightning protection design.

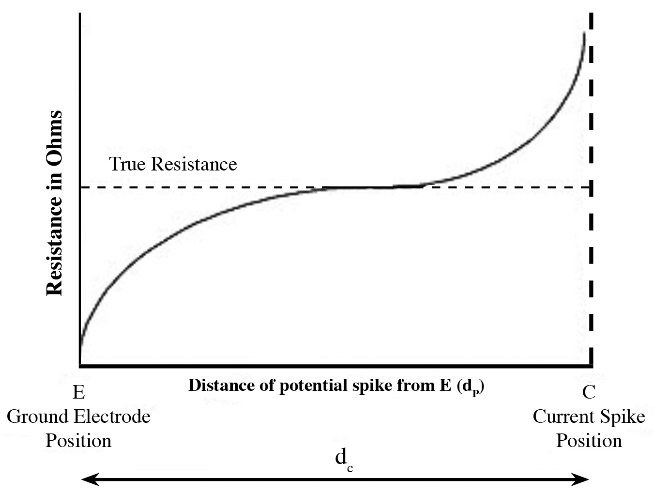


Figure 2

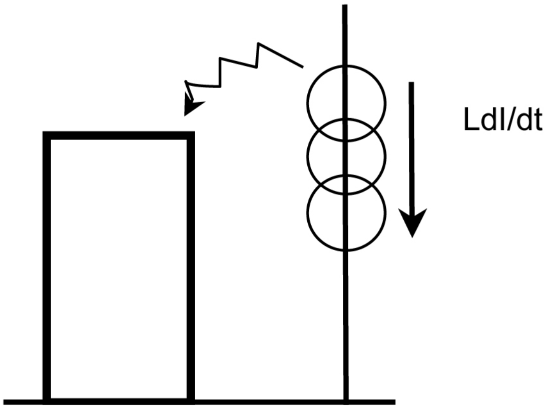


Figure 3

During a lightning event, the current flowing to ground induces a potential due to the LdI/dt, where L is the self-inductance of the conductor and dI/dt on the order of 10,000+ Amperes per microsecond (Figure 3). The instantaneous voltage may "flash over" to nearby grounded objects due to the instantaneous potential difference.

Hence, we specified that all metallic structures be connected to the lightning protection down-conductors at intervals of 10 meters. The benefits are several: in addition to reducing the likelihood of flash over, the net of the metal structures lowers the overall grounding impedance of the down-conductor system.

TORCH

The torch was rebuilt by a band of metal artisans from France, in the true spirit of the original collaboration. The original torch was pretty messed up, having been modified in the early 1900s by Gutzom Bordlum (he of Mount Rushmore fame) who cut away much of the copper to install 250 panes of tinted glass. The idea was to light the structure from within. This compromised the water-tightness of the torch and over the years the elements leaked into the structure contributing to the deterioration.

The top of the torch was removed and hauled to Earth to be rebuilt at a workshop on site. A new torch was constructed from essentially the hilt upwards and covered with 24 karat gold leaf. The old torch rests in the visitor's center. One of the concerns that the architects had was the preservation of the gold leaf over time. The gold leaf, an excellent conductor, of course, was at the highest part of the Statute. It would undoubtedly absorb dozens of strikes a year. We suggested a pair of lightning rods to be installed at each end of the torch. The architects bristled and, in the end, aesthetics prevailed and no protection was installed.

WORKING ON THE STATUE

The site visits that we took to New York Harbor are memorable. A small fleet of chartered boats took workers to Liberty Island in shifts, leaving from Manhattan, Staten Island and New Jersey. From the nose of the Statue the Twin Towers could be seen dominating the skyline of lower Manhattan. Liberty Island was closed to the public and we got a first-hand lesson in New York City labor practices. The project employed workers in every industry: iron fitters, painters, laborers, longshoremen and carpenters, and there was a certain amount of reverence about the site, but sometimes daily realities caught up with workers. The Statue was accessed by an elevator that was integrated into the scaffolding. On one ride up the elevator, our "driver"–

a grizzled union electrician sipping a cold beer (well, it was after 3 o'clock)–told us that the project management had to put up signs not to relieve themselves on the Statue as it was creating its own "patina."

I haven't returned to visit the Statue proper in these many years, but each time I visit New York City, I try to catch a glimpse of "Liberty Enlightening the World." It was an interesting and exciting project and much of the anecdotal information above was often related with enthusiasm–and a chuckle–by dad who loved lightning phenomenology and lightning protection as much as anyone I know and enjoyed telling people about our small contribution to an iconic monument to freedom. ■

Mike Violette is President of Washington Labs and Director of AmericanTCB. He had nothing to do with the new patina marks on the Statue of Liberty.

Statue Fun Facts

The sculpture was designed by Frédéric-Auguste Bartholdi, who was fascinated by oversized monuments and traveled to Egypt to tour the Sphinx and other grand monuments.

The structure of the statue was designed by Gustave Eiffel, of Eiffel Tower Fame.

The Statue was constructed at the workshops of Gaget, Gauthier & Cie on the Rue de Chazelles in Paris. It was fully assembled in the courtyard and rose over the Parisian suburbs until it was disassembled, packed up and shipped to NY.

In 1916 German Saboteurs allegedly blew up a munitions storage area due east of the Statue on Black Tom in New Jersey. The shock wave damaged the arm supports and the torch, which previously was open for visitors (via a ladder inside the arm) was closed.

During the restoration, it was determined that the arm and head were misaligned during assembly in New York Harbor. The decision was made to build in reinforcement, rather than try to correct the errors as the main mission was preservation, not restoration. The misalignments caused structural weaknesses that compromised Eiffel's original design.

Fundamentals of Electrostatic Discharge

Part 2: Principles of ESD Control

by the ESD Association

In Part 1 of this series, *An Introduction to ESD*, we discussed the basics of electrostatic charge, discharge, types of failures, ESD events, and device sensitivity. We concluded our discussion with the following summary:

1. Virtually all materials, even conductors, can be triboelectrically charged.
2. The level of charge is affected by material type, speed of contact and separation, humidity, and several other factors.
3. Electrostatic fields are associated with charged objects.
4. Electrostatic discharge can damage devices so they fail immediately, or ESD may result in latent damage that may escape immediate attention, but cause the device to fail prematurely once in service.
5. Electrostatic discharge can occur throughout the manufacturing, test, shipping, handling, or operational processes.
6. Component damage can occur as the result of a discharge **to** the device, **from** the device, or from charge transfers resulting from electrostatic fields. Devices vary significantly in their sensitivity to ESD.

Understanding these key concepts is crucial to protecting your products from the effects of static damage. Armed with this information, you can then begin to develop an effective ESD control program. In Part 2 we will focus on some basic concepts of ESD control.

BASIC PRINCIPLES OF STATIC CONTROL

Sometimes, controlling electrostatic discharge (ESD) in the electronics environment seems to be a formidable challenge. However, the task of designing and implementing ESD control programs becomes less complex if we focus on just six basic principles of control. In doing so, we also need to keep in mind the ESD corollary to Murphy's law, "no matter what we do, static charge will try to find a way to discharge."

1. Design In Protection

The first principle is to *design products and assemblies to be as resistant as reasonable* from the effects of ESD. This involves such steps as using less static sensitive devices or providing appropriate input protection on devices, boards, assemblies, and equipment. For engineers and designers, the paradox is that advancing product technology requires smaller and more complex geometries that often are more susceptible to ESD. Recent (2009) published work by the Industry Council on ESD Targets and the ESDA Technology Roadmap suggests that designers will have less ability to provide the protection levels that were available in the past. When very sensitive devices must be used and handled, application-specific controls beyond the principles described here may be required.

2. Define the Level of Control Needed in Your Environment

What is the sensitivity level of the parts you are using and the products that you are manufacturing and shipping? In order to have a complete picture of what is required, it is best to know the Human-Body Model (HBM) and Charged-Device Model (CDM) sensitivity levels for all devices that will be handled in the environment. ANSI/ESD S20.20 defines a control program for items that are sensitive to 100 volts HBM. The procedures in ANSI/ESD S20.20 may need to be tailored or expanded in specific situations.

3. Identify and Define the Electrostatic Protected Areas (EPA)

These are the areas in which you will be handling sensitive parts and the areas in which you will need to implement the basic ESD control procedures including bonding or electrically connecting all conductive and dissipative materials, including personnel, to a known ground.

4. Eliminate and Reduce Generation

Obviously, product design will be increasingly less effective in minimizing ESD losses. The fourth Principle of control is to *eliminate or reduce the generation and accumulation of electrostatic charge* in the first place. It's fairly basic: no charge–no discharge. We begin by reducing as many static generating processes or materials, such as the contact and separation of dissimilar materials and common plastics, as possible from the work environment. We keep other processes and materials at the same electrostatic potential. Electrostatic discharge does not occur between materials kept at the same potential or at zero potential. We provide ground paths, such as wrist straps, flooring and work surfaces, to reduce charge generation and accumulation. While the basic principle of reasonable minimization of charging should be followed, complete removal of charge generation is not achievable.

5. Dissipate and Neutralize

Because we simply can't eliminate all generation of static in the environment, our fifth Principle is to *safely dissipate or neutralize those electrostatic charges* that do occur. Proper grounding and the use of conductive or dissipative materials play major roles. For example, workers who "carry" a charge into the work environment can rid themselves of that charge when they attach a wrist strap or when they step on an ESD floor mat while wearing ESD control footwear. The charge goes to ground rather than being discharged into a sensitive part. To prevent damaging a charged device, the rate of discharge can be controlled with static dissipative materials. For some objects, such as common plastics and other insulators, grounding does not remove an electrostatic charge because there is no conductive pathway. Typically, ionization is used to neutralize charges on these insulating materials. The ionization process generates negative and positive ions that are attracted to the surface of a charged object, thereby effectively neutralizing the charge.

6. Protect Products

Our final ESD control Principle is to *prevent discharges that do occur from reaching susceptible parts and assemblies*. One way is to provide our parts and assemblies with proper grounding or shunting that will "dissipate" any discharge away from the product. A second method is to package and transport susceptible devices in proper packaging and materials handling products. These materials may effectively shield the product from charge, as well as reduce the generation of charge caused by any movement of product within the container.

ELEMENTS OF AN EFFECTIVE ESD CONTROL PROGRAM

While these six principles may seem rather basic, they can guide us in the selection of appropriate materials and procedures to use in effectively controlling ESD. In most circumstances, effective programs will involve all of these principles. No single procedure or product will do the whole job; rather effective static control requires a full ESD control program.

How do we develop and maintain a program that puts these basic principles into practice? How do we start? What is the process? What do we do first? Ask a dozen experts and you may get a dozen different answers. But, if you dig a little deeper, you will find that most of the answers center on similar key elements. You will also find that starting and maintaining an ESD control program is similar to many other business activities and projects. Although each company is unique in terms of its ESD control needs, there are at least six critical elements to successfully developing and implementing an effective ESD control program.

1. Establish an ESD Coordinator and ESD Teams

A team approach particularly applies to ESD because the problems and the solutions cross various functions, departments, divisions and even suppliers in most companies. Team composition includes line employees as well as department heads or other management personnel. The team may also cut across functions such as incoming inspection, quality, training, automation, packaging, and test. ESD teams or committees help assure a variety of viewpoints, the availability of the needed expertise, and commitment to success. An active ESD committee helps unify the effort and brings additional expertise to the project.

Heading this team effort is an ESD Program Coordinator. Ideally this responsibility should be a full-time job. However, we seldom operate in an ideal environment and you may have to settle for the function to be a major responsibility of an individual. The ESD coordinator is responsible for developing, budgeting, and administering the program. The coordinator also serves as the company's internal ESD consultant to all areas.

2. Assess Your Organization, Facility, Processes and Losses

Your next step is to gain a thorough understanding of your environment and its impact on ESD. Armed with your loss and sensitivity data, you can evaluate your facility, looking for areas and procedures that may be contributing to your defined ESD problems. Be on the lookout for things such as static generating materials and personnel handling procedures for ESD-sensitive items.

Document your processes. Observe the movement of people and materials through the areas. Note those areas that would appear to have the greatest potential for ESD problems. Remember that ESD can occur in the warehouse just as it can in the assembly areas. Then conduct a thorough facility survey or audit. Measure personnel, equipment, and materials to identify the presence of electrostatic fields in your environment.

Before seeking solutions to your problems, you will need to determine the extent of your losses to ESD. These losses may be reflected in receiving reports, QA and QC records, customer returns, in-plant yields, failure analysis reports, and other data that you may already have or that you need to gather. This information not only identifies the magnitude of the problem, but also helps to pinpoint and prioritize areas that need attention. Where available, the potential for future problems as a result of technology roadmaps and internal product evolution should be considered.

Document your actual and potential ESD losses in terms of DOA components, rework, customer returns, and failures during final test and inspection. Use data from outside sources or the results of your pilot program for additional support. Develop estimates of the savings to be realized from implementing an ESD control program.

You will also want to identify those items (components, assemblies, and finished products) that are sensitive to ESD and the level of their sensitivity. You can test these items yourself, use data from suppliers, or rely on published data for similar items. However, estimates can be wrong when the person making the estimate doesn't have enough information. In general, two functionally identical items from two different suppliers may *not* have similar ESD ratings.

3. Establish and Document Your ESD Control Program Plan

After completing your assessment, you can begin to develop and document your ESD control program plan. The plan should cover the scope of the program and include the tasks, activities, and procedures necessary to protect the ESD sensitive items at or above the ESD sensitivity level chosen for the plan. Prepare and distribute written procedures and specifications so that everyone has a clear understanding of what is to be done. Fully documented procedures will help you meet the administrative and technical elements of ANSI/ESD S20.20 and help you with ISO 9000 certification as well.

4. Build Justification to Get the Management Support Top Management

To be successful, an ESD program requires the support of your top management, at the highest level possible. What level of commitment is required? To obtain commitment, you will need to build justification for the plan. You will need to emphasize quality and reliability, the costs of ESD damage, the impact of ESD on customer service, and product performance. It may be useful to conduct a pilot program if the experience of other companies is not sufficient and you have an expectation that you can show meaningful results in the pilot.

Prepare a short corporate policy statement on ESD control. Have top management co-sign it with the ESD coordinator. Periodically, reaffirm the policy statement and management's commitment to it.

5. Define A Training Plan

Train and retrain your personnel in ESD and your company's ESD control program and procedures. Training should include testing to verify comprehension. Proper training for line personnel is especially important. They are often the ones who have to live with the procedures on a day-to-day basis. A sustained commitment and mindset among all employees that ESD prevention is a valuable, on-going effort by everyone is one of the primary goals of training.

6. Develop and Implement a Compliance Verification Plan

Developing and implementing the program itself is obvious. What might not be so obvious is the need to continually review, audit, analyze, feedback, and improve. Auditing is essential to ensure that the ESD control program is successful. You will be asked to continually identify the return on investment of the program and to justify the savings realized. Technological changes will dictate improvements and modifications. Feedback to employees and top management is essential. Management commitment will need reinforcement.

Include both reporting and feedback to management, the ESD team, and other employees as part of your plan. Management will want to know that their investment in time and money is yielding a return in terms of quality, reliability, and profits. Team members need a pat on the back for a job well done. Other employees will want to know that the procedures you have asked them to follow are indeed worthwhile. It is helpful to integrate the improvement process into the overall quality system and use the existing root cause analysis and corrective action infrastructure.

Conduct periodic evaluations of your program and audits of your facility. You will find out if your program is successful and is giving you the expected return. You will spot weaknesses in the program and shore them up. You will discover whether the procedures are being followed.

As you find areas that need work, be sure to make the necessary adjustments to keep the program on track.

CONCLUSION

Six principles of static control and six key elements to program development and implementation are your guideposts for effective ESD control programs. In Part 3, we'll take a close look at specific procedures and materials that become part of your program. ■

FOR ADDITIONAL INFORMATION

- *ANSI/ESD S20.20—Standard for the Development of Electrostatic Discharge Control Program*, ESD Association, Rome, NY
- Dangelmayer, Theodore, *ESD Program Management: A Realistic Approach to Continuous, Measurable Improvement in Static Control*, 1999, Kluwer Academic Publishers, Boston, MA
- *ESD TR20.20, ESD Control Handbook*, ESD Association, Rome, NY
- *ESD TR53, Compliance Verification of ESD Protective Equipment and Materials*
- Industry Council White Papers I & II
- ESDA Technology Roadmap

Each year the IEEE Electromagnetic Compatibility Society sponsors a Best Student Paper competition as part of the IEEE International Symposium on EMC. The contest is administered by the Educational and Student Activities Committee (ESAC) of the Society. For the 2010 Symposium 33 student papers were submitted, the largest number in recent memory. An ESAC panel reviewed and ranked the submissions based on technical contribution, accuracy, and clarity. It always proves to be a challenge to select a single winner from the many fine papers covering many diverse aspects of EMC that are received. The paper selected for 2010 use modal decomposition to derive a transmission line model for printed circuit board vias that can be implemented in circuit simulators. The new model has a significantly faster computation time than that of a full-wave simulator while giving results that are in good agreement. The practical benefit is an improved facility for of the design and optimization of high speed digital circuit boards for both signal integrity and EMC compliance.

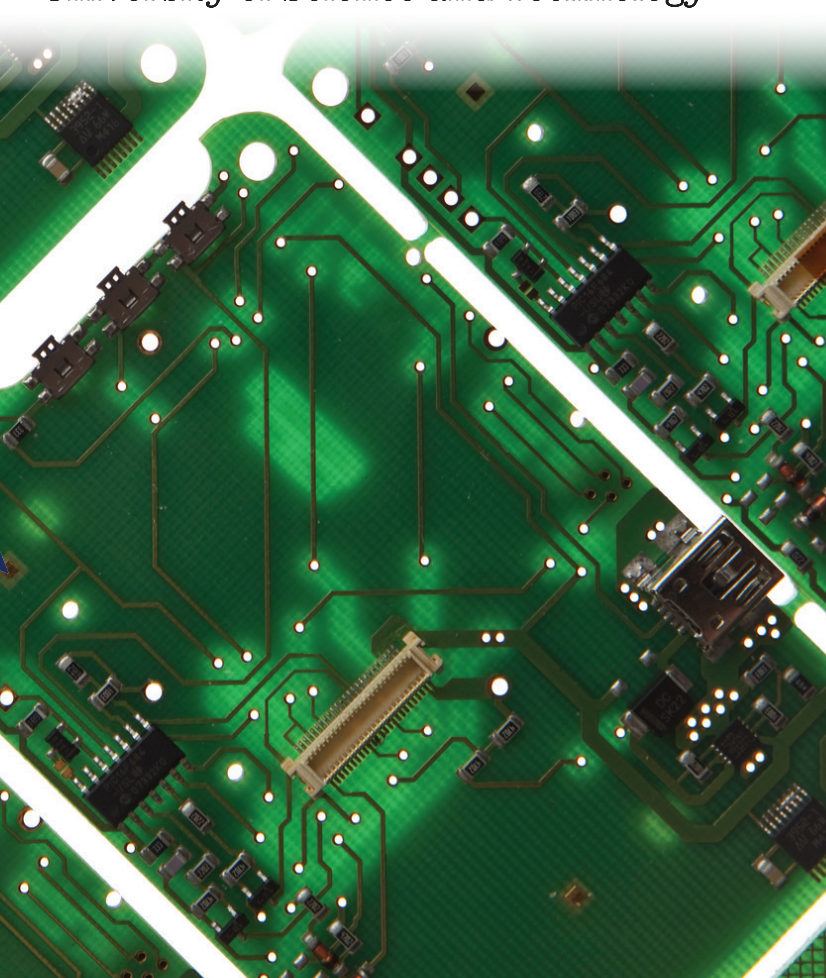
Equivalent Transmission-Line Model for Vias Connected to Striplines in Multilayer Print Circuit Boards

Siming Pan, EMC Laboratory, Missouri University of Science and Technology

Jianmin Zhang, Cisco Systems, Inc.

Qinghua B. Chen, Cisco Systems, Inc.

Jun Fan, EMC Laboratory, Missouri University of Science and Technology



High-speed digital systems require high performance in signal links for data communications. Off-chip interconnects often limit the maximal achievable data rate as they introduce frequency-dependent distortions. Modeling the passive components in a signal link path in print circuit boards becomes critical to help designers balance the tradeoffs between cost and performance in practical engineering designs. Different modeling approaches in previous studies have addressed this issue. Most of them are based on numerical methods [1], [2]. However, the computational burden of numerical methods, namely memory and time cost, grow rapidly when the geometry under study is complex. Analytical techniques have been introduced as well, especially for relatively simple structures such as the parallel plane pairs in power distribution networks (PDN) [3] [4] and the transverse electromagnetic (TEM) structures.

As common discontinuities in printed circuit boards, via structures have been extensively studied [5] [6]. For those connected to striplines, the signal propagates through them, excites the parallel plane cavity formed by the two reference planes of the striplines, and causes the two reference planes at different potential levels. As a result, the striplines cannot be considered as pure transmission-line structures anymore. Thus, a modal decomposition approach has been proposed in [7] [8], to model the signal transitions between vias and striplines.

In this paper, the prior work in [6] to model via structures as equivalent transmission lines is extended to include the stripline connections for both single-ended and differential cases based on the modal decomposition approach. The equivalent transmission-line model is based on physical geometry and can provide design insights for engineering issues such as back drilling, via placement, and impedance matching. The equivalent transmission-line model is first extended for the via structures connected to striplines based on the modal decomposition approach inside a parallel plane cavity in *Extended Equivalent Transmission-Line Model for Vias Connected to Striplines*. In *Validation of the Proposed Model*, the extended equivalent transmission-line model is validated using the comparisons with other published approaches. Potential applications of the extended equivalent transmission-line model are discussed in *Design Implications* from the perspective of signal transmission through the geometry under study.

EXTENDED EQUIVALENT TRANSMISSION-LINE MODEL FOR VIAS CONNECTED TO STRIPLINES

Mode Decomposition Inside a Parallel Plane Pair

A typical geometry with coupled striplines connected to signal vias is shown in Figure 1. The cross sectional view is shown in Figure 2. The thickness of the strip conductors is assumed negligible. The spacings from the strip conductors to the top and bottom planes are h_1 and h_2, respectively. When the top and bottom planes are at the same potential level, only the TEM waves can propagate in the striplines inside of the plane pair, and the striplines can be modeled as a coupled multi-conductor transmission line (MTL). Thus the voltage and current waves in the striplines can be described in the telegraph equations as:

$$\begin{aligned} \frac{\partial}{\partial z} V_{strip} &= -R I_{strip} - L \frac{\partial}{\partial t} I_{strip} \\ \frac{\partial}{\partial z} I_{strip} &= -G V_{strip} - C \frac{\partial}{\partial t} V_{strip} \end{aligned} \qquad (1)$$

The per-unit-length RLGC matrices can be obtained from 2-D cross sectional analysis. The TEM waves described in (1) are also denoted stripline mode waves.

When signal flows though the vias, the parallel plane cavity formed by the two reference planes is excited and the electromagnetic waves in the parallel-plane modes are generated. When the dielectric substrate between the two

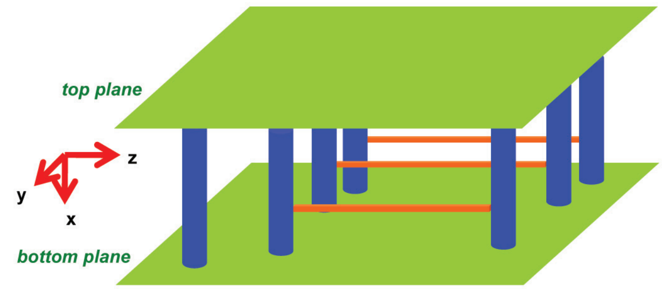


Figure 1: Coupled striplines connected to vias between two parallel metal planes

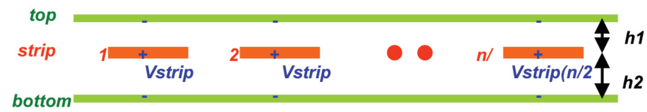


Figure 2: Illustration of the stripline mode ports and voltages.

planes is thin, only the x-directional electric field and the horizontal (y- and z-directional) magnetic field components are dominant. In other words, the TM_{z0} modes dominate in such parallel plane cavities. Under this assumption, voltages and currents can be defined at the parallel-plane ports defined between the two planes as shown in Figure 3. These parallel-plane voltages and currents can be related as:

$$V_{pp} = Z_{pp} \cdot I_{pp}, \tag{2}$$

where Z_{pp} is the impedance matrix of the parallel plane pair, which has been extensively studied [10], [11].

It can be shown that the stripline mode and the parallel-plane modes are orthogonal. In other word, the physical voltages and currents defined in Figure 4 can be expressed as the supposition of the stripline mode and the parallel-plane mode voltages and currents, as:

$$\begin{bmatrix} V_{st1} \\ \vdots \\ V_{st\frac{n}{2}} \\ V_{sb1} \\ \vdots \\ V_{sb\frac{n}{2}} \end{bmatrix} = [T_v] \cdot \begin{bmatrix} V_{strip1} \\ \vdots \\ V_{strip\frac{n}{2}} \\ V_{pp1} \\ \vdots \\ V_{pp\frac{n}{2}} \end{bmatrix}, \tag{3}$$

$$\begin{bmatrix} I_{st1} \\ \vdots \\ I_{st\frac{n}{2}} \\ I_{sb1} \\ \vdots \\ I_{sb\frac{n}{2}} \end{bmatrix} = [T_i] \cdot \begin{bmatrix} I_{strip1} \\ \vdots \\ I_{strip\frac{n}{2}} \\ I_{pp1} \\ \vdots \\ I_{pp\frac{n}{2}} \end{bmatrix}, \tag{4}$$

where

$$[T_v] = \begin{bmatrix} 1 & \cdots & 0 & k & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 1 & 0 & \cdots & k \\ 1 & \cdots & 0 & 1+k & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 1 & 0 & \cdots & 1+k \end{bmatrix},$$

$$[T_i] = \begin{bmatrix} 1+k & \cdots & 0 & -1 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 1+k & 0 & \cdots & -1 \\ -k & \cdots & 0 & 1 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & -k & 0 & \cdots & 1 \end{bmatrix},$$

and

$$k = \frac{-h_1}{h_1 + h_2}.$$

Figure 3: Illustration of the parallel-plane mode ports and voltages.

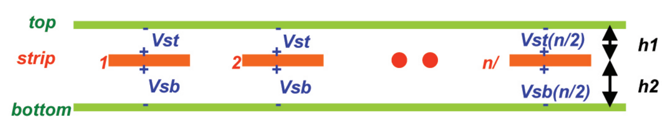


Figure 4: Illustration of the physical ports and voltages.

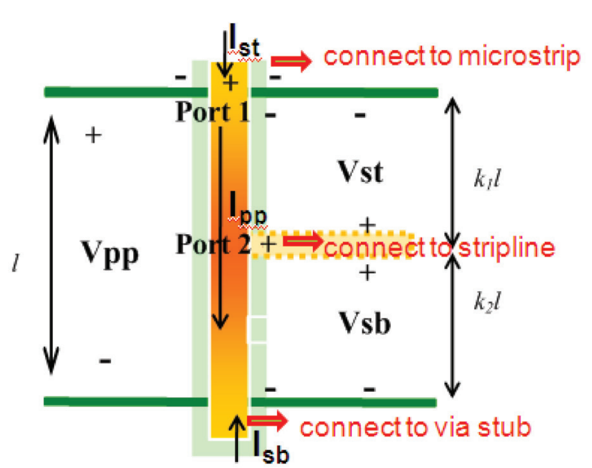


Figure 5: A single-ended signal via connects to a single-ended stripline.

Circuit Model for Single-Ended Case

For single-ended signal transition from a signal via to a stripling, as shown in Figure 5, (3) and (4) can be reduced to:

$$\begin{aligned} V_{st} &= V_{strip} - k_1 \cdot V_{pp} \\ V_{sb} &= V_{strip} + k_2 \cdot V_{pp} \\ I_{st} &= k_1 I_{strip} + I_{pp} \\ I_{sb} &= k_2 I_{strip} - I_{pp} \end{aligned} \qquad (5)$$

The equivalent circuit model for the structure shown in Figure 5 is illustrated in Figure 6. The signal via inside the cavity is modeled as an equivalent transmission line with a characteristic impedance of:

$$Z_0 = \sqrt{Z/Y} \qquad (6)$$

where Z and Y are the per-unit-length impedance and admittance, respectively, and their analytical expressions are given in [12]. All the ports are clearly defined in Figure 5. Two additional current sources are added in the model so that all the voltages and currents can satisfy (5).

All the circuit parameters in Figure 6 are related to certain geometrical dimensions. When signal flows from the top of the via to the stripline, the via stub underneath Port 3,

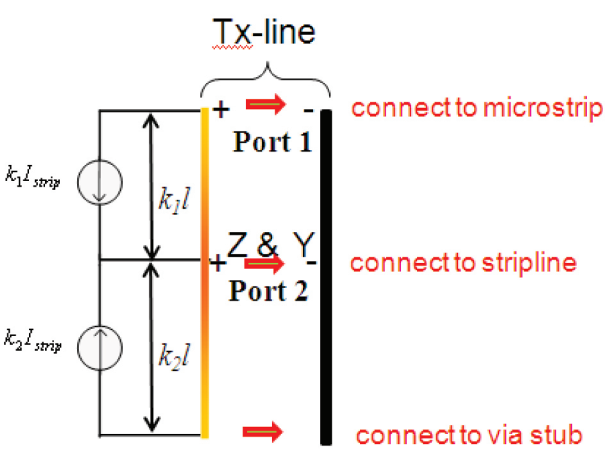


Figure 6: An equivalent circuit model for the structure shown in Figure 5.

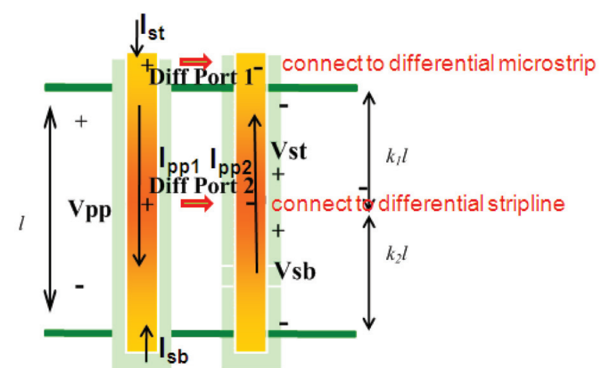


Figure 8: Two differential signal vias connects to two coupled striplines.

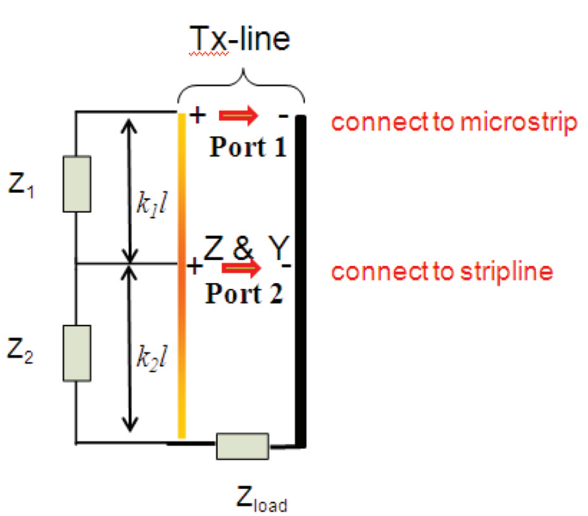


Figure 7: Equivalent circuit model including the via stub effect for the structure shown in Fig. 5. The current sources in Figure 6 has been replaced with equivalent impedances.

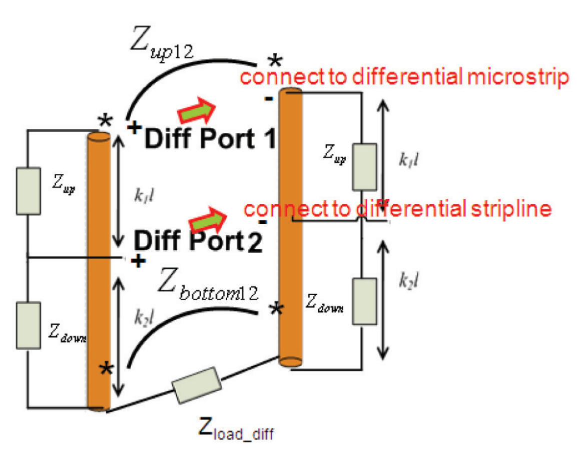


Figure 9: Equivalent differential transmission line model including the via stub effect for the structure shown in Figure 8. The reference plane is omitted.

if any, can be treated as a load Z_{load}. The value of the load is the input impedance of the via stub looking at Port 3, which can be calculated using the analytical expression given in [13]. In addition, the current sources in Figure 6 can be further converted to two impedances, as shown in Figure 7, as:

$$Z_1 = \frac{k_1 Zl(Z_c + k_1(Z_{load} // (k_1 l / Y)))}{k_2((Z_{load} // (k_1 l / Y)) + k_2 Zl)},\qquad Z_2 = \frac{-k_2 Zl(Z_c + k_1(Z_{load} // (k_1 l / Y)))}{k_1((Z_{load} // (k_1 l / Y)) + k_2 Zl)} \quad (7)$$

Circuit Model for Differential Case

The geometry of the differential case under study with a differential signal flows through two symmetric signal vias to two coupled striplines is shown in Figure 8. For differential signals, (3) and (4) become:

$$\begin{bmatrix} V_{st1} \\ V_{st2} \\ V_{sb1} \\ V_{sb2} \end{bmatrix} = \begin{bmatrix} 1 & 0 & -k_1 & 0 \\ 0 & 1 & 0 & -k_1 \\ 1 & 0 & k_2 & 0 \\ 0 & 1 & 0 & k_2 \end{bmatrix} \cdot \begin{bmatrix} V_{strip1} \\ V_{strip2} \\ V_{pp1} \\ V_{pp2} \end{bmatrix}, \quad (8)$$

$$\begin{bmatrix} I_{st1} \\ I_{st2} \\ I_{sb1} \\ I_{sb2} \end{bmatrix} = \begin{bmatrix} k_2 & 0 & -1 & 0 \\ 0 & k_2 & 0 & -1 \\ k_1 & 0 & 1 & 0 \\ 0 & k_1 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} I_{strip1} \\ I_{strip2} \\ I_{pp1} \\ I_{pp2} \end{bmatrix}. \quad (9)$$

For differential signals of balanced signal paths,

$$I_{pp1} = -I_{pp2} \quad (10)$$

Similar to the single-ended case, the equivalent circuit model for the geometry shown in Figure 8 is developed as shown in Figure 9. Only the differential mode is considered in deriving the circuit parameters. The analytic expressions to calculate the per-unit-length impedance matrix **Z** and the admittance matrix **Y** can be found in [6], and

$$Z = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

The differential-mode input impedance looking into the via stubs, if any, beneath the bottom plane is Z_{load_diff}, which can be obtained using the expression given in [13]. Similar to the single-ended case, in Figure 9, the parallel impedances Z_{up} and Z_{down} are converted from the extra current sources as:

$$Z_{up} = \frac{k_1 Z_{11} l (Z_{dd} + k_1((Z_{load\_diff}/2) // (k_1 l / Y_{11})))}{k_2((Z_{load\_diff}/2) // (k_1 l / Y_{11})) + k_2 Z_{11} l},\qquad Z_{down} = \frac{-k_2 Z_{11} l (Z_{dd} + k_1((Z_{load\_diff}/2) // (k_1 l / Y_{11})))}{k_1(((Z_{load\_diff}/2) // (k_1 l / Y_{11})) + k_2 Z_{11} l)} \quad (11)$$

where Z_{dd} is the differential-mode characteristic impedance of the coupled striplines.

The mutual impedance of via above and below the stripline changes from Z_{12} to Z_{up12} and $Z_{bottom12}$ respectively, with:

$$Z_{up12} = \frac{-k_1 Z_{12} l (Z_{dd} + k_1((Z_{load\_diff}/2) // (k_1 l / Y_{11})))}{1 - k_2(((Z_{load\_diff}/2) // (k_1 l / Y_{11})) + k_2 Z_{11} l)},\qquad Z_{bottom12} = \frac{Z_{12} l (-Z_{dd} + k_1((Z_{load\_diff}/2) // (k_2 l / Y_{11})))}{-Z_{dd} + k_1(2((Z_{load\_diff}/2) // (k_2 l / Y_{11})) + k_2 Z_{11} l)} \quad (12)$$

The per-unit-length self impedance of the via remains the same as the diagonal terms in the matrix **Z**. Z_{load_diff} is the differential-mode input impedance looking from the cavities below the bottom plane. We assume differential port 2 is matched with differential striplines. The equivalent transmission line model shown in Figure 9 satisfies equation (2), (8), (9) and (10).

Equivalent Transmission-Line Model

For both the single-ended and the differential cases, the equivalent circuit models developed earlier can be further simplified using an equivalent transmission line terminated with a load, as shown in Figure 10.

For the single-ended case shown in Figure 7, the per-unit-length impedance Z' and admittance Y' in the simplified model in Figure 10 can be obtained as:

$$\begin{aligned} Z' &= Z // (Z_1 / (k_1 l)) \\ Y' &= Y \end{aligned} . \qquad (13)$$

The value of Z_{load_port2} can be calculated from the circuit parameters in Figure 7 as:

$$Z_{load\_port2} = (Z_2 // Zk_2 l + Z_{load} // (k_2 l / Y)) . \qquad (14)$$

Figure 10: A simplified model using an equivalent transmission line with terminations for both single-ended and differential cases. For differential cases, the reference plane is omitted

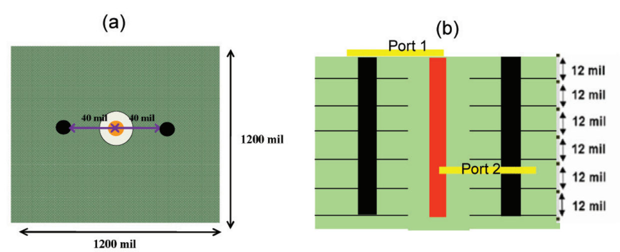


Figure 11: (a) Top view; (b) side view of a single-ended test case.

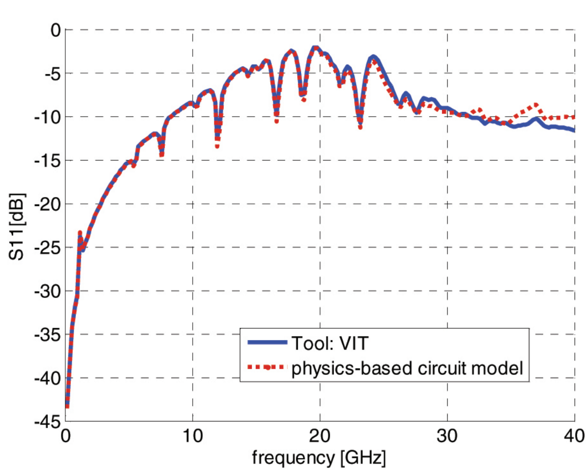


Figure 12: Comparison of the S_{11} magnitudes for the single-ended case shown in Figure 11.

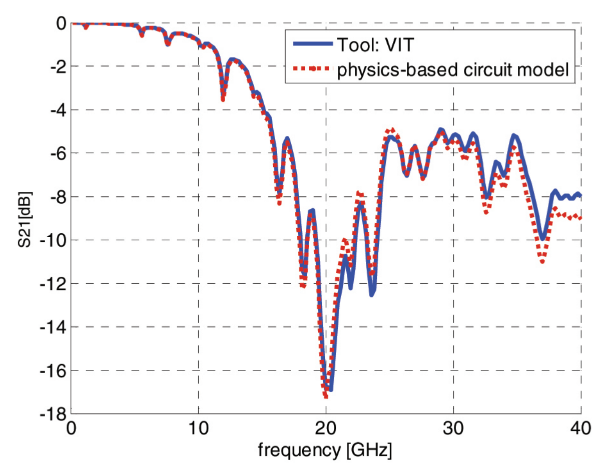


Figure 13: Comparison of the S_{12} magnitudes for the single-ended case shown in Figure 11.

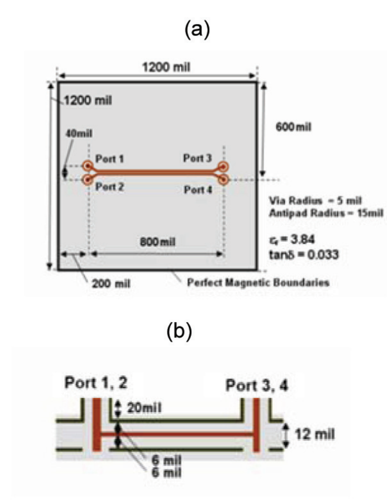


Figure 14: (a) Top view; (b) side view of a differential test case.

Similar derivations can be applied for the differential case, as:

$$Z_{diff\_load\_port2} = 2(Z_{down} // Z_{11}k_2l - Z_{down12} + (Z_{load\_diff}/2)//(k_2l/Y_{11})) \tag{15}$$

VALIDATION OF THE PROPOSED MODEL

A test geometry shown in Figure 11 including a single-ended signal via connected to a stripline in a multi-layer PCB is used as a validation example. Signal flows from a microstrip trace in the top layer to a stripline trace in a middle layer. The two traces are assumed short enough so that the ports are approximately defined at the via-trace intersections. Two ground vias are placed surrounding the signal via. The radii of the via drills and the anti-pads are 10 mils and 30 mils, respectively. The thickness of the copper planes is 1 mil. The dielectric layers have a dielectric constant of 3.84 and a loss tangent of 0.033. The other geometrical details can be found in Figure 11.

The geometry is modeled layer by layer. In the fourth parallel-plane cavity where the via connects to the stripline, the equivalent transmission-line model proposed in this paper is used. In all other cavities, a standard equivalent transmission-line model introduced in [12] is used instead.

The simulated S_{11} and S_{12} magnitudes between Ports 1 and 2 defined in Figure 11 using the method described above are compared with those obtained using a physics-based equivalent circuit model combined with modal decomposition [8] in Figures 12 and 13. Good agreements between the two methods are observed up to 40 GHz.

A differential validation example is shown in Figure 14. Two pairs of differential signal vias are connected though a differential stripline embedded in the cavity. The ports are defined at the top of the vias. The differential stripline is modeled using an HSPICE W-element model assuming a homogeneous and constant cross section.

The differential mode S_{dd11} and S_{dd21} magnitudes are calculated using the equivalent transmission-line model proposed in this paper, and are compared with those obtained using a physics-based equivalent circuit model with modal decomposition [8] and using HFSS, a full-wave finite element method, in Figures 15 and 16. The differential Port 1 is comprised of the single-ended Ports 1 and 2 defined in Figure 14, and the differential Port 2 is comprised of Ports 3 and 4. It can be clearly seen that the equivalent transmission-line model proposed in this paper has a good accuracy compared with the other methods. The unique advantage of the proposed method is that via analyses and designs can rely on some conventional transmission-line concepts such as the characteristic impedance for impedance matching.

DESIGN IMPLICATIONS

Smooth transitions between vias and traces are desirable for high-speed signal transmission in multi-layer PCBs. Impedance matching is important when signal transits from trace to via and vice verse. The simplest design philosophy is to ensure that the characteristic impedance of the equivalent transmission line in Figure 10 representing vias is the same as the characteristic impedance of the traces that connect to the vias. The effects of via stubs are also critical to the signal transmission through the vias. The value of Z_{load_port2} in Figure 10 describes the effects of via stubs. Ideally, Z_{load_port2} should be desired to be infinitely

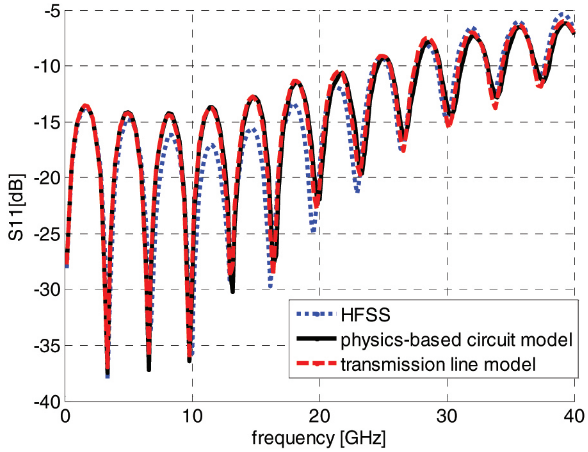


Figure 15: Comparison of the S_{dd11} magnitudes for the differential case shown in Figure 14.

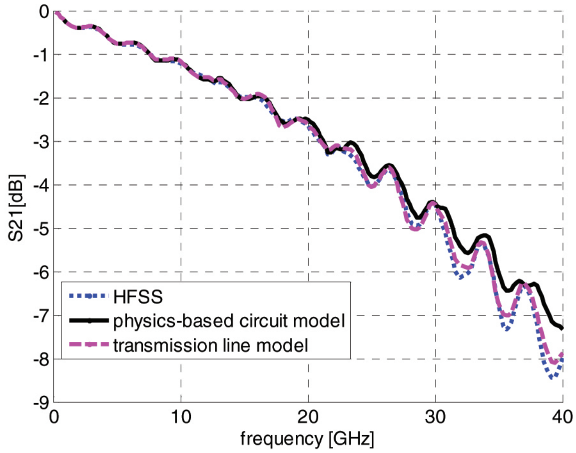


Figure 16: Comparison of the S_{dd21} magnitudes for the differential case shown in Figure 14.

large, which means the electrical length of the via stubs shall be zero. If Z_{load_port2} becomes relatively small at the frequencies of interest, the via stubs can impose adverse effects on the signal transmission, and back drilling may be necessary. Therefore, Z_{load_port2} can be used to determine when a back drilling is needed.

CONCLUSION

An equivalent transmission-line model is extended in this paper for the via structures connected to striplines based on the modal decomposition approach, which has been validated with other methods. As a result, the characteristic impedance of the equivalent transmission line can be used for impedance matching between the vias and the traces. In addition, the value of the load impedance representing the effects of via stubs can be used to determine when a back drilling is necessary. ■

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Decreased CDM Ratings for ESD-Sensitive Devices in Printed Circuit Boards

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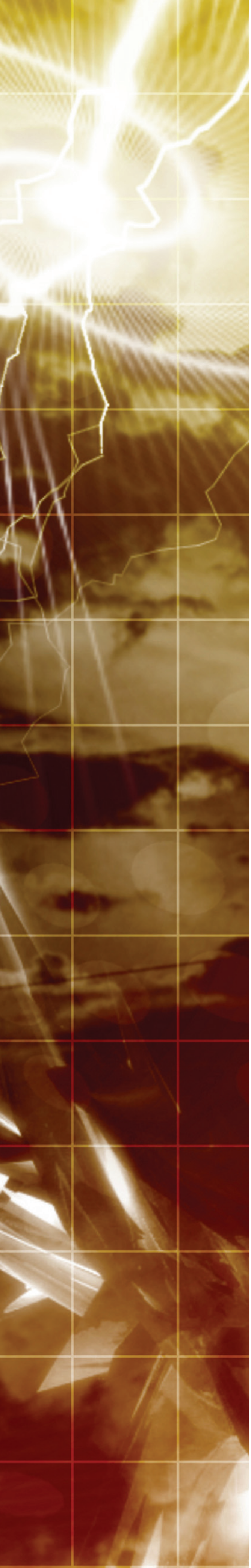


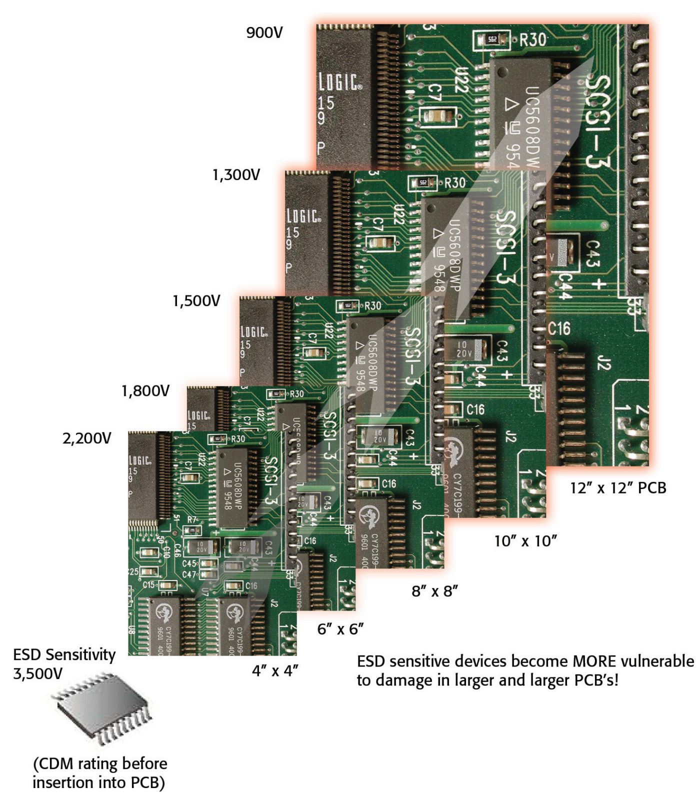
Many sources recently have reported that electrical failures to components previously classified as EOS (Electrical Overstress) are instead the result of ESD (Electrostatic Discharge) failures due to charged-board events (CBE) [1,2]. A charged printed circuit board assembly stores substantially more charge than a discrete device as its capacitance is larger. A subsequent discharge of the board assembly results in increased current for that event - versus that of the discrete component. Consequently, a device's CDM (charged device model) rating ***is lowered*** when mounted in a printed circuit board (PCB). In an attempt to get a feel for just how much it is lowered, we conducted CDM stress tests on components in discrete form, and again after insertion into larger and larger sized pc boards. We found that the CDM ratings are lowered dramatically!

BACKGROUND

There is considerable confusion and misinformation in the industry in general surrounding how to protect vulnerable devices from ESD risks. Many people assume that the value of a device's HBM rating *entirely defines its vulnerability to all potential ESD events*. It is tempting and convenient to use that voltage rating and apply it to maximum levels that should be allowed on charged insulators, charged printed circuit board assemblies, and other potential CDM failure modes. We hear routinely: *"My most sensitive part is 500 volts (HBM), so we insure that our production processes have no charged insulators above that 500 volt level near the ESDS items."* A more relevant vulnerability value would be the device's CDM rating (not its HBM rating) in that instance, as the potential failure mode here is the device becoming charged by the nearby insulator – and subsequently discharging upon contact with a conductor such as a person, machine, etc. HBM ratings are easier to obtain from the manufacturers. CDM ratings are typically far less available, and many users end up having to perform CDM testing themselves when they have the absolute need to know.

It is quite difficult (if not impossible) to predict a device's CDM rating by knowing its HBM rating. For example, we have observed devices with identical 500 volt HBM ratings – and their respective CDM ratings were 150 volts in one case and >2,000 volts in the other. Regardless, developing ESD controls for CDM failure modes is much better served when the *CDM rating* is known and utilized in the analysis. To make the confusion level even worse, as our experiments indicate here, a device's *CDM rating changes dramatically* as it is inserted into larger and larger PCBs.

Hence, the CDM rating for a device should be adjusted to account for the increased capacitance (increased storage capability) of the printed circuit board it is inserted into. We have attempted here to provide a rudimentary start in that effort.



TEST SET-UP AND RESULTS

In the experiments conducted here, we desired to determine the increased vulnerability to a component when connected to the larger mass of a printed circuit board assembly. The determination of CDM ratings on devices are accomplished typically when the device is in component form. If one end of the device is then connected to a larger mass (let's say the ground plane in a printed circuit board) – and this ***entire structure*** is now charged – *a **lower** voltage charging mechanism is now able to produce the same current during a discharge* as when the device was in component form. This means that the device's CDM rating can be actually lowered when mounted into a printed circuit board. We set about to conduct studies where the "new" lower device rating could be predicted based on the size of the printed circuit board.

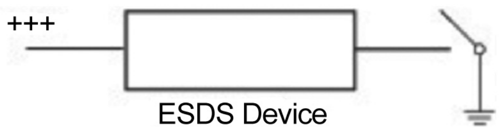


Figure 1

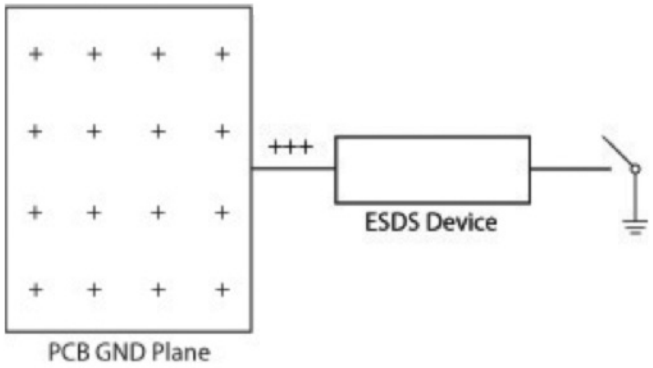


Figure 2

PCB Size (inches)	CDM Rating	% Reduction	Multiplying Factor
Device only (no PCB)	3500 volts	-----	-----
4 x 4"	2200	37 %	(.63)
6 x 6"	1800	49 %	(.51)
8 x 8"	1500	57 %	(.43)
10 x 10"	1300	63 %	(.37)
12 x 12"	900	74 %	(.26)

Table 1

We used a two-leaded ESD sensitive device that was vulnerable to 3,500 volts CDM. An ETS Model 910 Charged Device Tester was used to conduct the CDM stress testing (to ESDA industry standards). In this case (see Figure 1), only the charge stored on one lead travels through the ESDS device when the grounding mechanism causes the discharge.

We then conducted the CDM testing with various sized printed circuit board ground planes attached to one side of the device – to simulate a component "sinking" the entire charged pc board ground plane during a discharge, as shown in Figure 2.

In this case, all the stored energy on now both the lead ***and*** the ground plane travels through the device upon the grounding mechanism. (We selected a typical PCB ground plane material (.0014" thickness) and cut it into the desired sizes.) Five devices were tested for each size printed circuit board ground plane size listed in Table 1. The determined new CDM ratings summarized are *simple mathematical averages* of the 5 tested samples for each size board. The results are tabulated in Table 1.

Reviewing the 12" by 12" printed circuit board results (highlighted in gray in Table 1 as an example), the data reflects the following:

1. The *3500 volt* CDM rating on the component fell to *900 volts* when attached to a 12 x 12 inch printed circuit board ground plane.
2. That is a 74% reduction in its CDM rating.
3. The "Multiplying Factor" in the last column (.26 in this case) is what we multiply the "component CDM rating" in order to calculate its new CBM rating in the 12" x 12" board (to first order). So, a ***3.5 Kv*** CDM component rating times (.26) = ***900 volts*** CBM rating in a 12" x 12" board.

Taking the liberty to play loosely with these numbers, if these percentages and multiplying factors are similar for all devices (not proven yet, but certainly possible), it means that a component - with a fairly robust CDM rating of ***950 volts*** – when inserted into a 12" x 12" PCB - now has a rating of (.26) x (950 volts) = ***247 volts***.

If a user's most sensitive device (225v CDM) is placed into an 8" x 8" board, its new CDM rating (actually its CBM rating) would be (225v) x (.43) = ***97 volts*** – which is under 100 volt sensitivity. ***S20.20***, the universally accepted ESD control specification, does not apply to devices more sensitive than 100 volts! If that same device was placed into a 12" x 12" board, its new CBM rating would be 225v x (.26) = ***59 volts***... and could not safely be handled with the existing controls currently at many facilities. [3]

FOOD FOR THOUGHT

We present this ***rudimentary*** information to begin to raise awareness to the issue of devices becoming more and more vulnerable in larger and larger PCBs. We encourage the ESD community to perform testing of this kind, perhaps eventually leading to better standards as a result. There are many unanswered questions that result from this initial experiment (and we caution the reader from drawing too many conclusions from this first cursory set of tests). One question for sure is: Do the multiplying factors given in the table here hold true for all devices - regardless of their basic component CDM rating? Do the results vary with device geometries? Much more work needs to be accomplished, but we feel the method of connecting PCB ground planes of various sizes (as we described herein) to determine CBM ratings, has the potential to become a useful tool. ■

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The Truth About ESD Class 0

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The electronics industry is terribly confused by the term Class 0. Particularly when it comes to electrostatic discharge (ESD) device sensitivity and how the term applies to factory controls designed to mitigate ESD. The confusion manifests itself through the many companies and engineers seeking direction on how to "become qualified to handle Class 0 devices." They are seeking this information because their equally confused customers have imposed requirements on them to meet this mythical level of performance. Not only is Class 0 as a factory level of performance a contrived ideal, it is not a realistic or useful goal. Our purpose here is to explain reality and what is necessary for understanding device ESD sensitivity and establishing control.

Currently, there is only one proper use of the term Class 0 and that is in the context of Human Body Model (HBM) component level testing. Developed over two decades ago and long outdated, Class 0 specifies components with a damage threshold sensitivity of <250 volts when tested using the HBM method. This is a component level test designation and has nothing to do with factory handling capability. Also, the device classification is only valid until the device is incorporated in a higher level assembly. For example, a device with a HBM classification of 250 volts may be damaged by lower voltages once that device is mounted on a printed circuit board.

ALPHABET SOUP

To further complicate the situation components are also classified with other testing models such as the Charged Device Model (CDM) and Machine Model (MM). Neither of the aforementioned testing models have a Class 0 designation. Class 1 CDM rated parts are <125 volts and Class 1 MM parts are <100 volts (with 3 subcategories M1A <25 volts, M1B 25 to <50 volts, and M1C 50 volts to <100 volts). Again, not any of these component levels test designations have anything to do with factory handling capability, or anything remotely associated with a Class 0 designation.

SO WHAT DOES CLASS 0 REALLY MEAN?

In the grand scheme of ESD control in the factory, Class 0 has no purposeful meaning. Adopted and perpetrated by some companies as a marketing tool for their products or services, the term is being used to alert the electronics manufacturing industry about electronic devices that have lower damage thresholds than typical devices. Because of lower thresholds, the manufacturing company may need additional products or services from these companies in order to safely handle the "Class 0" devices. Since there is currently no industry accepted definition of Class 0 (other than the <250V HBM classification discussed above) the use of this term causes confusion as it means different things to many people. In fact some companies have expanded on the Class 0 marketing term to create Class 00 and even Class 000, which further confuses the situation beyond reason and technical validity.

DETERMINING DEVICE SENSITIVITY

Regardless of any device ESD classification (real or contrived), it is imperative that the factory ESD manager identify the failure thresholds and models (HBM, CDM and MM) for the most sensitive devices being processed in the factory. Only after obtaining this information can an ESD program manager effectively design an effective ESD program to protect their devices. Essentially, there are three options for determining device sensitivity:

1. Vendor information and test data
2. In-house testing
3. Third party device test laboratories

If device sensitivity information is not available, a reasonable approach would be to adopt the lower limits set by the "*ESD Technology Roadmap,*" which is available at the ESD Association web site at www.esda.org . In the conclusion of the Roadmap document it is recommended that companies determine their ESD process capability and to limit HBM potential to <100 volts, MM to <10 volts and CDM potential to <50 volts. Once you know actual device sensitivity of critical components you can assess your process for suitable control levels and develop or enhance your ESD control program.

DEVICE SENSITIVITY & PROCESS CAPABILITY ANALYSIS

Device damage voltage thresholds are indispensable when developing ESD control of critical or high value manufacturing and handling operations. Process capability analysis is a means of assessing the entire manufacturing process to determine its protective electrostatic thresholds to various failure models. This analysis technique defines the most sensitive device(s) that the process can safely handle without ESD damage. Properly conducted, a process capability analysis will define the maximum voltages exhibited in the manufacturing critical path as they relate to HBM, CDM and MM. This is why specific device failure voltage thresholds are essential guidelines to experienced ESD practitioners. General classification of devices without specific damage threshold detail is meaningless to the development of highly effective process ESD control.

CURRENT INDUSTRY STANDARDS

There are currently two widely accepted industry standards for ESD control programs. The standards are ANSI/ESD S20.20 and IEC 61340-5-1.

HBM Device Sensitivity & Body Resistance to Ground

In an ANSI/ESD or IEC certified or compliant facility, there is confidence in the process to safely handle devices with HBM thresholds of >100 volts. But what do you do if you handle a device that has an HBM sensitivity threshold of *less than* 100 volts? In this case, fundamental modifications may be required, such as reduction of your ESD control limits and modification of measurement procedures and/or frequency.

Industry ESD control program standards specify grounding requirements for personnel. One of the specifications is a resistance to ground for personnel of <35 megohms ($<3.5 \times 10^7\ \Omega$). One aspect of this specification applies to personnel using wrist straps. At this resistance to ground level, it has been shown experimentally that a person will not be able to generate or accumulate greater than 100 volts of static electricity on their body regardless of how fast they move as shown in Table 1.

For a 100 volt HBM rated ESD Control Program, the <35 megohm specification provides an adequate safety margin. Obviously, the resistance to ground specification for personnel should be set to a lower level when handling parts with sensitivities below 100 volts HBM.

- In North America, normally a resistance to ground level of <10 megohms is used since the maximum voltage level on personnel will be under 40 volts even with very rapid movement.
- A person sitting down while wearing a wrist strap will be held to less than a few volts with a resistance to ground of one megohm or less.

Thus, it is obvious that by knowing the HBM threshold of the most sensitive device in the process, one would know the maximum body resistance to ground requirement for their process. More information on this subject is in the "*ESD Technology Roadmap.*"

Body Resistance to Ground (Megohms)	Approximate Peak Body Voltage (Volts)
1	<10
10	40
16	50
28	75
35	93

Table 1: Body Resistance to Ground versus Approximate Peak Body Voltage (Gibson et al)

Another aspect of HBM damage prevention and body resistance limits is the use of ESD flooring and footwear systems to provide a ground path for personnel. If a person's *combined* resistance to ground using a floor and footwear system is less than 35 megohms then the same <100 volts requirement is met. If however, their flooring/footwear system resistance to ground is greater than 35 megohms, then additional walking tests must be performed to measure body voltage and qualify the personnel grounding system. The requirement in this case is to assure that a person, using the defined system, will not accumulate a body voltage of greater than 100 volts.

As discussed above, for more sensitive areas, the resistance to ground and body voltage accumulation specifications need to be set lower than the damage threshold voltage of most sensitive device. Using the outdated HBM Class 0 guideline of *"…less than 250 Volts"* is certainly not helpful in developing defined control to protect current technologies, nor does it correlate to standards that presently specify HBM control to 100 volts.

MM & HBM Device Threshold Concerns

The ESDA Standards device working groups agree that an acceptable general guideline for Machine Model (MM) device sensitivity is 10% of the device's HBM damage threshold. Device engineers have recently presented data to The Device Industry Council on ESD Target Levels (Industry Council) that indicates MM damage thresholds of new device technologies are as low as 3 to 5 percent of the device's HBM threshold. As a result, a device having an HBM damage threshold of 100 volts will have MM sensitivity in the area of 3 to 10 volts. Knowing the HBM damage voltage of device is important to understanding the level of control one must have for preventing MM damage.

To reduce the possibility of MM failures, all conductors in the process must be bonded or electrically connected and attached to ground. By grounding all conductors, the potential for MM discharges is mitigated. In process capability analysis direct voltage measurements are made on conductors that may contact devices and subassemblies to confirm that they are properly grounded *and* do not carry voltages higher than MM damage thresholds. Again, a general classification does not provide the detail one needs to determine MM damage thresholds and establish proper control levels.

CDM Trends

While the Industry Standards documents address control measures for CDM issues through the management of insulators, they have not identified a CDM threshold that can be used along with the previously established HBM thresholds.

The Industry Council, consisting of members across the electronics industry, published their White Paper 2 in April 2010 regarding component level CDM ESD specifications and related requirements. Based on an extensive study, the council reports that devices with CDM sensitivity thresholds of ≥250 volts can be handled safely with basic ESD control methods, including the grounding of conductors and the control of insulators as described in current industry ESD program standards. Devices with thresholds of less than 250 volts require additional measures to control the charging of the devices, including:

- **For devices 125 – 250 V_{CDM} requires implementation of "process specific measures** to reduce the charging of the device **OR** to avoid a hard discharge (high resistive material in contact with the device leads)."
- **For devices <125 V_{CDM} the Council specifies making "charging/discharging measurements at each process step**" in addition to the above requirements.

Again, simply saying that one has a Class 0 CDM device reveals nothing helpful in determining necessary ESD controls or suitable protective procedures.

At the time of this writing, standards bodies have not published a Standard Test Method or Standard Practice for determining process capability as it applies to CDM. However, case studies and detailed procedural papers have been presented at the EOS/ESD Symposium on this important topic. The ESDA and IEC standards organizations have plans to address process capability studies and related procedures in the near future.

CONCLUSION

While the term "Class 0" is being heavily propagated for ESD factory control, there is no formal definition for this term in the industry. It is not possible to be qualified or certified as a "Class 0" facility since specific and helpful guidelines have not been created by an accredited organization.

Instead, it is critical to know the actual damage thresholds for each model and to compare that information with the process capability of the facility. By determining your process capability to safely handle all failure model threshold voltages, you will determine the process ESD risks that require correction and establish quantifiable limits and control guidelines to protect your products. ■

Stephen Halperin has over 30 years of industrial ESD experience and is known internationally for his work in process evaluation, control of sensitive environments, measurement and test innovations, and his many contributions to the electrostatics industry and ESD Association. He served two terms as ESDA president, and chaired Standards, Local Chapter Development, Education, and Professional Certification committees. Mr. Halperin is a recipient of the Symposium's Outstanding Paper Award, the Association's Outstanding Contribution Award for his work on behalf of industry and the Joel Weidendorf Memorial Award for his extensive contributions to ESD standards development. He formed Stephen Halperin & Associates (SH&A - 1983), an international electrostatic consulting firm, and established Prostat Corporation (1992) for design of high performance electrostatic instruments. Mr. Halperin has delivered several papers and authored over 100 articles on ESD related subjects.

David E. Swenson retired from 3M Company in 2003 after 35 years of service. Most of his career was involved with investigation and resolution of static electricity problems, development of new static control products and training of 3M and customer personnel globally. After retirement, David and his wife Geri established Affinity Static Control Consulting, LLC, to offer electrostatic solutions to industry. He has been a member of the ESD Association since 1984 and has served in many capacities including Sr. VP and president for a total of 4 years each. He is a four term elected member of the Board of Directors and currently serves as President Emeritus of the Board of Directors. He has served as Symposium General Chair, long term Standards Committee member and Working Group Chair of several committees and is the current chair of the Grounding WG. In addition, Dave was the ESD Association Technical Advisor and Chief Delegate of the US National Committee to IEC TC101 for 8 years and is currently a US Technical Expert. He was awarded the ESD Association Outstanding Contributions Award in 2002 and the Joel P. Weidendorf Memorial Award for service to Standards in 2004. A life member of the ESD Association, Dave has authored numerous technical papers covering ionization, grounding, packaging, triboelectrification, test methods for ESD materials and ESD control program implementation, presented around the world. He is Treasurer of the Texas Chapter of the ESD Association and a long term member of The Electrostatic Society of America. Dave can be reached at static2@swbell.net

Craig Zander is the Sales Manager for Prostat Corporation. Craig has been in the ESD control industry for over 20 years and served as Vice-Chair of the ESDA Standards Organization for nearly 10 years. He is currently a member of the ESDA Standards Committee. Craig served on the ESDA Board of Directors for six years as Business Unit Manager for Marketing and Communications. He has authored several articles regarding ESD control and he is currently an officer of the ESDA North Central Chapter. Craig can be reached at czander@prostatcorp.com.

Seminars, Training & Tradeshows

September 8
EMC/SI Seminar with Troubleshooting Workshop
Tektronix and Kimmel Gerke Associates, Ltd.
Lincoln, NE
www.incompliancemag.com/events/100908_1

September 8
EMC/SI Seminar
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Seminars and Training
www.incompliancemag.com/events/100908_2

September 13
EMC/SI Seminar
Tektronix and Kimmel Gerke Associates, Ltd.
Denver, CO
www.incompliancemag.com/events/100913

September 14
Green Services, Lighting, Solar, and Medical Seminar
Intertek
Lake Forest, CA
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September 14
Understanding Ground Resistance Testing
AEMC Instruments
Chicago, IL
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September 14
Developing a Compliance Verification Program for S20.20
ESD Association
Webinar
www.incompliancemag.com/events/100914_3

September 14 - September 17
Training and Credentialing Workshops for Laboratory Auditor Certification, iNCLA
iNARTE
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September 15
Test Area and Personnel/Common Electrical Product Safety Tests Seminar
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Lake Forest, CA
www.incompliancemag.com/events/100915

September 17
2010 Minnesota EMC Event
Hoolihan EMC Consulting and local IEEE EMC Chapter
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September 22
Is Repeated Hipot Testing Destructive?
Associated Research, Inc.
Webinar
www.incompliancemag.com/events/100922_1

September 22 - 23
Radio Transmitter Approvals Workshop: All You Need to Know
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www.incompliancemag.com/events/100922_2

September 23 - 24
SCV EMC 2010 Mini Symposium
IEEE EMC Society - Santa Clara Valley Chapter
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www.incompliancemag.com/events/100923

September 27
EMC/SI Seminar
Tektronix and Kimmel Gerke Associates, Ltd.
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September 28
Data Acceptance Program and ISO/IEC 17025 Requirements and Implementation
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September 28 - September 29
The CE Marking: Strategies for European Compliance
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September 28 - September 30
Three-Day Electromagnetic Compatibility Engineering Seminar
Henry Ott Consultants
East Hanover, NJ
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September 28 - September 30
Photovoltaics: Overview of UL 1703 and IEC 61730
UL University
Research Triangle Park, NC
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Automated 3-Phase CDN Provides Reliable High Power Consumption EUT Testing

Teseq Inc. recently released an automated 3-phase coupling/decoupling network (CDN) for EFT and surge testing. The new CDN 3063 provides safe, reliable operation in a wide range of test setups, including higher current level and 3-phase EUT (equipment under test) testing.

The CDN 3063 comes standard with over temperature protection that allows short term operation at current exceeding the nominal rating. A phase rotation indicator in the 3-phase models shows a correctly sequenced power connection for safe EUT operation.

The new system meets IEC requirements for EUT currents over 16 A and ANSI specifications for special coupling modes and pulse amplitude control making it fully compliant with both industry standards. For more information, please visit www.teseq.com.

Fiber-Optic Signal Monitor and a Stimulus/Control Link – Two Instruments in One

Michigan Scientific has introduced its Model FO-HBST/HBSR Fiber-Optic Systems 1 MHz Analog Link. The FO-HBST and FO-HBSR form a versatile Fiber-Optic Analog Signal TX/RX pair. Input signals at pre-selected full-scale input levels and at bandwidths from DC to 1 MHz may be transmitted fiber-optically in either direction by transposing the module . The tester can externally access a 3-position slide switch to select the transmitter module full-scale input level of ±8, ±16, or ±48 VDC. Internal gain jumpers in the receiver module are factory configured for full-scale output levels of ±4, ±8 or ±16 VDC with ±16 VDC standard. Systems may be configured to other user defined full-scale inputs and outputs on request.

The satellite modules have shielding and special input/output filtering that provides high immunity from electromagnetic interference (EMI), electromagnetic pulse (EMP) or high voltages associated with plasma research to allows for rigorous electromagnetic compatibility (EMC) testing/engineering. The satellite modules are validated for EMC up to 200 V/m (46 dB V/m) at 500 kHz to 18 GHz and 600 V/m (pulsed 5% duty-cycle &5µs rise-time) 1GHz to 2.5 GHz. For further information visit www.michsci.com.

Advanced Test Equipment Rentals Announces New Alliance with Emerson Process Management

Advanced Test Equipment Rentals has agreed with Emerson Process Management Rosemount division, to be a distributor of the 475 Field Communicator. The 475 Field Communicator builds on the industry leading technology of the 375 Field Communicator, while adding innovative new capabilities, including color display, Bluetooth communication, and advanced field diagnostic applications like ValveLink™ Mobile. The 475 Field Communicator helps maintenance personnel identify and troubleshoot issues in the field, processing plants, manufacturing facilities and assembly lines.

This 475 Field Communicator has been designed to simplify work in the field. The intuitive full color user interface allows users to leverage the same practices for both HART and FOUNDATION fieldbus devices. It includes a larger touch screen than PDAs or Pocket PCs, supports HART versions 5, 6, and 7 (including IEC-approved *Wireless*HART®) devices, and can be upgraded onsite using an Internet application. For more information visit www.atecorp.com.

Adams Magnetic Products adds outside sales representative

Keith Hook joins Adams Magnetic Products Co. as an outside sales representative assisting manufacturers and purchasers of ferrite cores and accessories in the electronics industry. Drawing from five years of sales, marketing and magnetics distribution industry experience, Hook has worked with many of the key contacts in the coil winding and transformer manufacturing industries. Throughout his 14 years in distribution, he has developed an expertise in managing a wide range of accounts, just-in-time inventory support and new product development.

Most recently, Hook was responsible for new business development and product line management at Lodestone Pacific in Anaheim, Calif. "I'm looking forward to helping customers benefit from Adams' Micrometals-Arnold powder core products. I'm proud to represent other top-rate manufacturers like Ferroxcube, EPCOS and our newest line, VAC USA," says Hook. "Adams has a great combination of resources, positioning itself well as the leading U.S. distributor of magnetic components."

Registration Underway for the 32nd Annual EOS/ESD Symposium and Exhibits

The Electrostatic Discharge Association (ESDA), in conjunction with IEEE, Electron Devices Society, and the Reliability Society, will host the 32nd Annual EOS/ESD Symposium from October 3-8, 2010 at the John Ascuaga Nugget resort in Sparks (Reno) NV.

It's the international technical forum on electrical overstress and electrostatic discharge that features research, technology, and solutions to increase understanding, enhance quality and reliability, reduce and control costs, and improve yields and productivity. It's the one event where you will find technical papers that emphasize the latest research and technology; basic, intermediate, and advanced tutorials; exhibits of ESD control products and services; workshops; authors' corners; Program Manager Certification; Device/Design Certification; and more. This year's event is shaping up to be the best ever with:

- 33 tutorials- including 4 new titles.
- 14 technical sessions with over 60 papers being presented on many hot topics related to the phenomena of static electricity and applications. Papers will be presented about semiconductor technology, products through systems robustness and manufacturing control, even issues on the space station.
- 9 workshops on Tuesday and Wednesday afternoon will provide you the forums to talk and comment, receive feedback and learn from colleagues in a 'no necktie' environment. 2010 will offer a new workshop format with no formal panel, so as to encourage more attendee participation

Visit www.esda.org/symposia.html for additional details about the program, registration costs, and for a registration instructions.

Technical Seminars on Green Market updates, Energy Star/Lighting Facts Label updates, Certifying solar products, and IEC 60601-1

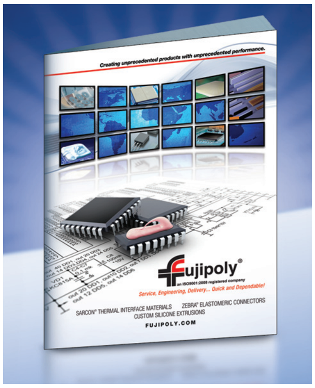
Intertek is offering a complimentary technical seminar on September 14th at their facility located at 25791 Commercentre Drive, Lake Forest, CA. Topics being covered will be a Green Market update for those involved with electronics, changes in Energy Star requirements, as well as Lighting Facts Label updates. Attendees will have a chance to tour Intertek's lab and enjoy a complimentary lunch.

An afternoon session will be offered covering the process of certifying solar products to enter the global marketplace. Concurrently, a talk will be given on IEC-60601-1 3rd Edition. Engineers in the lighting, medical, manufacturing, or electrical industries will be invited to attend. Visit www.intertek.com/events/2010/lake-forest-seminar to register.

New Catalog Released

Fujipoly has announced its new Thermal Interface Material and Elastomeric Connector product catalog. The free 52-page product overview and technical design guide includes helpful installation suggestions as well as detailed thermal performance and electrical conductivity data points.

Several new pages of high-performance and low-cost thermal materials have been added to complement the company's current product assortment. Fujipoly's new expanded catalog also features a complete section dedicated to high density, low resistance, electrically conductive silicone connectors.



The catalog can be downloaded at www.fujipoly.com/catalog or copies may be requested by calling (732) 969-0100.

U.S. Environmental Protection Agency Recognizes A2LA

The American Association for Laboratory Accreditation (A2LA) has announced the expansion of its laboratory accreditation activities to encompass the United States Environmental Protection Agency (EPA) ENERGY STAR Program.

On June 30, 2010, the EPA released its Final Conditions and Criteria for Recognition of Accreditation Bodies and Final Conditions and Criteria for Recognition of Testing Laboratories documents. A2LA met or exceeded the EPA criteria based upon their experience and positive MRA evaluations. A2LA is now recognized by the EPA to provide Accreditation for ENERGY STARtesting laboratories that perform product testing in support of the ENERGY STARprogram and its specific product family test methods and requirements.

A2LA is currently accepting new applications for accreditation from laboratories who intend to test to the newly enacted EPA ENERGY STAR requirements. Further, A2LA is working with existing accredited laboratories to add compliance with these new requirements to their existing scopes of accreditation. There are resources devoted to ensure prompt attention to all interested parties' needs. Please direct any questions on applying for accreditation to Mike Buzzard (301)-644-3484 or by email: mbuzard@A2LA.org.

Existing laboratories should direct their questions on expanding their scope (through the use of A2LA Form F108) to their current Accreditation Officer contact at A2LA. The original requirements documents for Accreditation Bodies, as well as Testing Laboratories, can be found at the EPA's Enhanced Testing and Verification website (www.energystar.gov/index.cfm?c=partners.enhanced_test_verification).

New EMC Measurement Application Offers Accurate Pre-Compliance Emissions Testing

Agilent Technologies Inc. has introduced the N/W6141A Electromagnetic Compatibility (EMC) measurement application for its X-Series signal analyzers. The new measurement application allows R&D engineers to evaluate the electromagnetic interference (EMI) performance of their designs. Ideal for R&D engineers in the aerospace/defense, automotive and communications industries, the EMC measurement application enables easier, more accurate pre-compliance emissions test of prototype electronic components, sub-assemblies and systems.

Key features include: signal lists that can be used to mark, sort or delete signals to quickly reduce the measured signal list to only those signals that are out of specification; real-time detectors for measuring peak, quasi-peak and the EMI/RMA average amplitude of selected signals to maximize emissions using real-time measurements; and the ability to re-measure signals in the signal list for easy verification of failed signal emissions repairs.

More information about the X-Series' EMC measurement application is available at www.agilent.com/find/X-Series_EMC.

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