SEPTEMBER 2012

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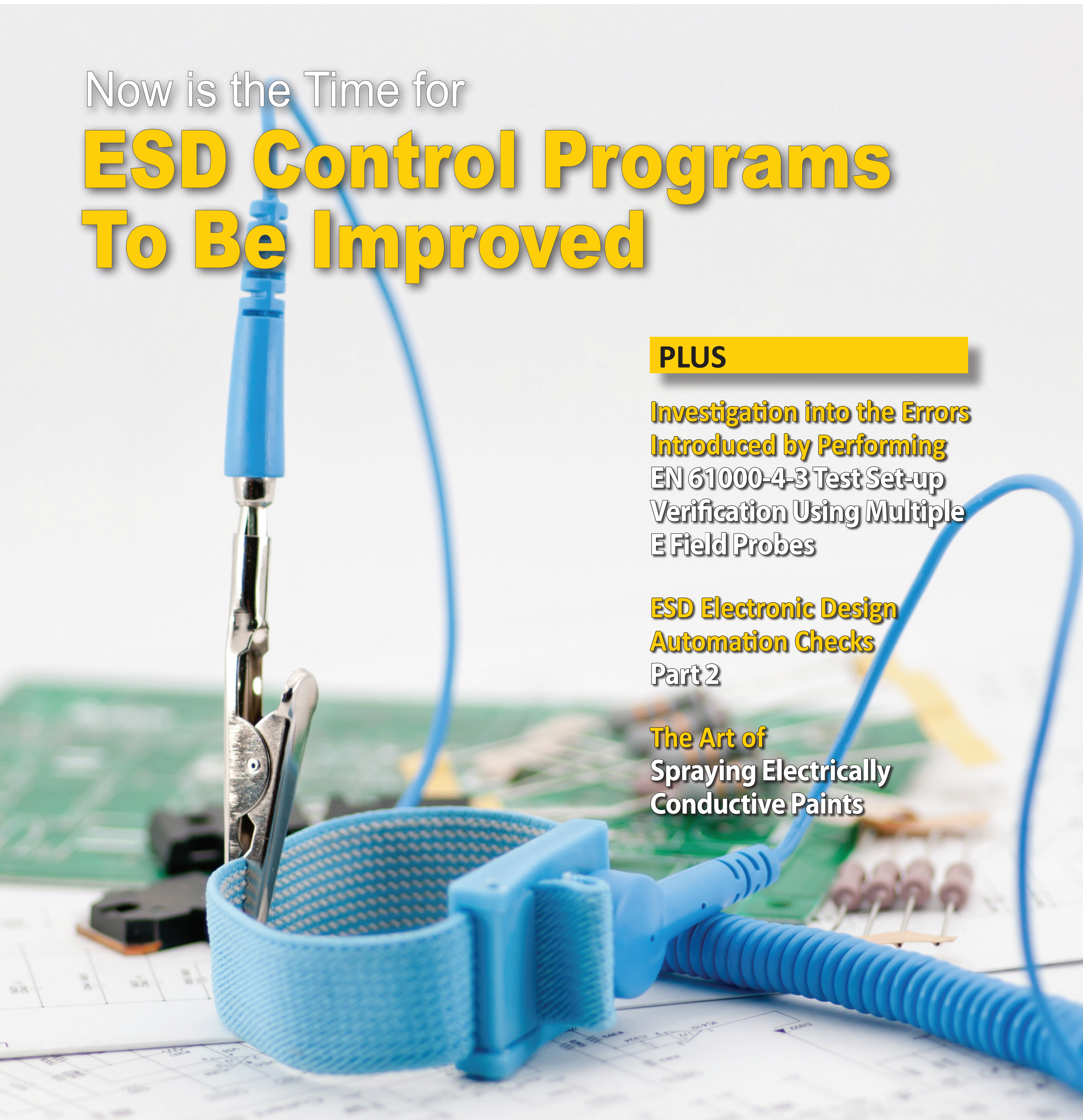

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ESD Electronic Design Automation Checks Part 2

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IN COMPLIANCE

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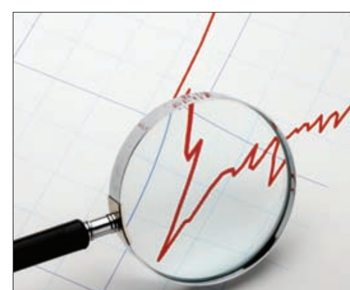
Volume 4 • Number 9



News in Compliance

FCC News

Fax Solicitation for Business Loans Results in $1.7 Million Proposed Fine

The U.S. Federal Communications Commission (FCC) has proposed forfeiture penalties in the amount of $1,680,000 against a California trio for delivering unsolicited advertisements to consumers via facsimile machine.

Issued in July 2012, the Notice of Apparent Liability for Forfeiture cites EZ Business Loans for delivering unsolicited fax advertisements to 99 different consumers. The fax advertisements offered recipients "a quick unsecured business loan."

Initially responding to 20 consumer complaints, the Enforcement Bureau of the Commission issued a Citation against the business owners in October 2010. The Commission received no response to the Citation, but did receive an additional 200 plus consumer complaints regarding unsolicited faxes from the company.

The Telephone Consumer Protection Act of 1991 makes it "unlawful for any person within the United States…to use any telephone facsimile machine, computer, or other device, to send, to a telephone facsimile machine, an unsolicited advertisement," without prior authorization of the recipient.

In this case, the Commission cited the business owners for willful and repeated violations of its regulations, levying $16,000 in fines for each of 105 apparent violations, for a total of $1,680,000. The Commission noted that the proposed penalty was based on the number of apparent, willful, repeat violations involved, as well as the business owners' efforts to "disguise their true identities as senders of these faxes…(which) strongly indicate knowing and deliberate effort to violate the junk fax rules and then to conceal and evade responsibility for such violations."

FCC Amends Automobile Radar System Operations Rules

The Federal Communications Commission (FCC) has eased its regulations covering automobile radar systems to support the development of improved vehicle collision avoidance systems and to increase driver safety. In a Report and Order issued in July 2012, the Commission eased emissions limits for vehicular radars operating in the 76-77 GHz spectrum. The original emissions limits were set in 1995, and had never been modified to reflect more recent FCC research on maximum permissible human exposure to RF electromagnetic fields. The Commission also eliminated the requirement that vehicular radars decrease their level of power when a vehicle is not in motion. This restriction was originally intended to protect pedestrians in close proximity to a stopped vehicle.

In the same ruling, the Commission also modified its rules to allow fixed radar applications in the 76-77 GHz spectrum at airport locations. According to the Commission, such devices can be used to detect foreign objects on runways, and to monitor aircraft and service vehicle traffic.

The Commission's actions were in response to petitions for rulemaking filed by Toyota Motor Corporation and Era System Corporation.

The complete text of the FCC Report and Order on automobile radar systems is available at incompliancemag.com/news/1209_02.

FCC News

FCC Releases Data on Internet Access

The U.S. Federal Communications Commission (FCC) has released its most recent report on access in the United States to fixed and mobile Internet connections, including information on the gap between current service levels and the benchmark Internet connection speeds recommended under the Commission's National Broadband Plan.

According to the Commission's report, entitled "Internet Access Services: Status as of June 30, 2011," 73% of fixed Internet connections to households meet or exceed the speed tier that most closely approximates the target set in the National Broadband Plan of 3 megabits per second (Mbps) downstream and 768 kilobits per second (kbps) upstream. This penetration rate for fixed high-speed service compares with just 49% at the end of 2009, and 53% at the end of 2010.

At the same time, high-speed Internet access for subscribers of mobile wireless service continues to grow. As of June, 2011, 14% of mobile subscribers had access to high-speed service, more than triple the 4% penetration rate achieved by the end of 2009.

Without accounting for speed, Internet connections overall are growing. By the end of June 2011, there were 206 million Internet connections offering access at speeds of at least 200 kpbs, a 31% year-over-year increase. Overall growth continues to be driven by dramatic increases in mobile connections, which increased by 59% in just one year. With nearly 120 million subscribers, the number of mobile Internet connections at the end of June 2011 was 50% greater than the number of fixed Internet connections.

The complete text of the Commission's report on Internet access is available at incompliancemag.com/news/1209_03.

News in Compliance

EU News

EU Commission Adds DMF to REACH Regulations

Acting on reports of health consequences related to consumer exposure to the chemical dimethylfumarate (DMF), the Commission of the European Union (EU) has added DMF to the list of restricted chemicals under its regulations concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH).

Published in the *Official Journal of the European Union*, in May 2012, the new Regulations bans the use of DMF in any article in concentrations greater than 0.1 mg/kg.

DMF is a biocide intended to prevent or inhibit the growth of mold on leather furniture or footwear during storage or transport in humid environments. The Commission's actions related to DMF follows reports that furniture and footwear containing DMF and available for sale in several EU member states have been linked to consumer health issues in France, Poland, Finland, Sweden and the United Kingdom.

The complete text of the EU Commission's regulation on the use of DMF is available at incompliancemag.com/news/1209_04.

Dimethylfumarate (DMF) is a biocide intended to prevent or inhibit the growth of mold on leather furniture or footwear during storage or transport in humid environments. The Commission's actions related to DMF follows reports that furniture and footwear containing DMF and available for sale in several EU member states have been linked to consumer health issues in France, Poland, Finland, Sweden and the United Kingdom.

EU Commission Modifies REACH Testing Methods

The Commission of the European Union (EU) has amended the approved test methods under its regulations concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH).

The EU's REACH regulations mandate the testing of certain chemical substances for their physico-chemical properties, and their potential toxicity to humans and the environment. Published in July 2012 in the *Official Journal of the European Union,* Commission Regulation (EU) No 640/2012 adopts new and updated alternative test methods intended to reduce the number of animals used for experimental purposes.

According to the Commission, the new and updated test methods have been adopted by the international Organization for Economic Co-operation and Development (OECD).

The complete text of the Commission's regulation regarding test methods under its REACH regulations is available at incompliancemag.com/news/1209_05.

UK Authorities Set EMC Limits for London Olympics

Authorities in the United Kingdom have issued a special measure in connection with the implementation of EU's EMC Directive intended to limit potential electromagnetic interference (EMI) with wireless communications devices during the 2012 London Olympic Games and Paralympic Games.

The measure stipulates that any apparatus that generates EMI must "operate at a sufficiently low intensity… such that it does not cause interference with wireless telegraphy used for public safety purposed with a protection area." According to the schedule provided with the measure, protection areas include the major Olympic event venues, as well as the city of London as a whole.

Notably, the requirement to limit interference applies "even if the maximum intensity of electromagnetic energy emitted by that apparatus is lower than a level permissible under the essential requirements" of the EU's Electromagnetic Compatibility Regulations. However, the requirements do not apply to radio and telecommunications equipment and apparatus covered by the EU's R&TTE Directive (1995/5/EC).

The complete text of the statutory instrument regarding EMC at the London Olympics was published

EU News

in July in the Official Journal of the European Union, and is available at incompliancemag.com/news/1209_06.

Commission Sets Transitional Symbols for EcoDesign Washing Machines

The Commission of the European Union (EU) has issued a communication implementing transitional symbols for use with washing machines designed to meet the EU's energy efficiency requirements.

The Commission's communication, which was published in July 2012 in the *Official Journal of the European Union*, illustrates transitional symbols intended to facilitate the consumer's selection of the most energy-efficient washing cycle for cotton clothes. These symbols are to be placed on the washing machine's program selection panel or display in order to comply with the Commission's requirements.

It is expected that these transitional symbols will eventually be replaced by symbols identified in the applicable harmonized standard when one becomes available.

The EU's energy efficiency regulations for washing machines (1015/2010), came into effect on December 1, 2011, and implements product-specific requirements under the EU's Eco-Design Directive, 2009/125/EC. That directive gives the Commission the authority to establish minimum efficiency standards for those "energy-related products representing significant volume of sales and trade, having significant environmental impact and presenting significant potential for improvement in terms of their environmental impact without entailing excessive costs."

The Commission's communication regarding transitional symbols for washing machines can be accessed at incompliancemag.com/news/1209_07.

News in Compliance

CPSC News

Big Lots Recalls Portable Ceramic Space Heaters

The retailer Big Lots of Columbus, OH is recalling more than 70,000 portable space heaters and portable oscillating space heaters manufactured in China.

Big Lots has reported to the U.S. Consumer Product Safety Commission (CPSC) that the heaters can overheat and melt, posing a fire or electric shock hazard to consumers. The company says that it has received four reports of the heaters overheating and melting, but no reports of injury, fire or property damage.

The recall space heaters were sold at Big Lot stores nationwide from September 2010 through March 2012 for between $20 and $25, depending on the model.

Additional details about this recall are available at incompliancemag.com/news/1209_08.

Air Movers/Blowers Recalled for Internal Capacitor Failure

Servepro has recalled about 24,000 Notus model air movers/blowers used by independently-owned Servepro franchises.

According to the company, the internal electrical capacitor of the air movers/blowers can fail and overheat, posing a fire hazard. Servepro says that it has received four reports of overheating incidents involving the recalled air movers/blowers. Three of the incidents resulted in property damage, including a residential fire in California that resulted in an estimated $475,000 in damage.

The air movers/blowers were manufactured by EDIC of Los Angeles, CA, and sold to Servepro's independent franchises nationwide from April 2004 through August 2010 for between $200 and $230.

Separately, EDIC has issued its own recall of an additional 53,000 air movers/blowers. According to EDIC, these units were sold to flood remediation contractors and other service professionals from January 2003 through September 2011 for between $160 and $285.

More information about the Servepro recall is available at incompliancemag.com/news/1209_09. Information about the EDIC recall can be found at incompliancemag.com/news/1209_10.

Alltrade Recalls Kawasaki Cordless Drills

Alltrade Tools LLC of Long Beach, CA has issued a recall for about 45,000 Kawasaki-brand cordless drills manufactured in China.

Alltrade, the importer of the drills, has notified the U.S. Consumer Product Safety Commission (CPSC) that the trigger switch on the drill can short circuit and generate excessive heat, posing a burn hazard to consumers. The company has received 33 separate reports of incidents related to the recalled drills, including one report of a minor burn injury.

U.S. Security Agency Seeking Hackers (from our "You Can't Make This Up" file)

Cyber security is a looming national security threat, and the head of the top security agency in the U.S. thinks he has a way to combat it. Hire hackers.

According to a report on CNN.com, General Keith Alexander, director of the U.S. National Security Agency, delivered a "recruiting speech" at the annual DefCon convention, held in July 2012 in Las Vegas, NV. "In this room, this room right here, is the talent our nation needs to secure cyberspace," Alexander told the standing-room-only audience. "We need great talent. We don't pay as high as everybody else, but we're fun to be around."

In support of its hacker recruiting efforts, the NSA has also set up a somewhat unconventional recruiting site for DefCon attendees and other interested parties at www.nsa.gov/careers/dc20.

Originally started in the early 1990s, DefCon is reportedly one of the largest and longest continuously running hacker conventions. An estimated 16,000 people were expected to attend this year's conference.

CPSC News

The recalled drills were sold at Costco stores nationwide from May 2011 through February 2012 for about $50.

Additional information about this recall is available at incompliancemag.com/news/1209_11.

IKEA Recalls Track Lighting Systems

Retailer IKEA is recalling about 5000 track lighting systems manufactured in China and sold in the United States, part of a worldwide recall of nearly 100,000 units.

According to IKEA, the ground connector in the lighting track is defective, and poses an electrical shock hazard to consumers. The company has not received any reports of incidents or injuries associated with the recall track lighting system, but has initiated the recall to reduce the risk of future incidents and injuries.

The recalled track lighting systems were sold in IKEA stores nationwide from September 2011 through March 2012 for between $12 and $20.

Further details regarding this recall can be found at incompliancemag.com/news/1209_12.

Nikon Recalls Rechargeable Battery Packs

Nikon Inc. of Melville, NY has issued a recall for about 5100 Nikon-brand digital SLR camera battery packs manufactured in Japan and China. The U.S. recall is part of a worldwide recall of nearly 200,000 camera battery packs.

News in Compliance

CPSC News

The company says that the battery packs can short circuit, causing them to overheat and melt, posing a burn hazard to consumers. Nikon has received seven reports outside of the U.S. of the battery packs overheating, but there have been no incidents reported in the U.S. and no reports of injuries.

The recalled battery packs were sold with Nikon digital SLR cameras in camera, office supply and mass merchandise stores nationwide, and through various catalogs and websites from in March and April 2012 for between $1000 and $3000.

For more information about this recall, go to incompliancemag.com/news/1209_13.

Family Dollar Recalls Decorative Lights

Family Dollar Services, Inc. of Mathews, NC has recall about 280,000 mini decorative lights manufactured in China.

Family Dollar says that the light sets do not meet UL standards for this product, thereby posing a fire and shock risk to consumers. The company has received three separate reports of overheating, but no reports of injuries or property damage.

The recalled decorative lights were sold in Family Dollar stores from September 2011 through December 2011 for $8.

Further information about this recall is available at incompliancemag.com/news/1209_14.

Burlington Coat Factory Recalls Power Strips

Burlington Coat Factory is recalling about 6000 Lush Life-brand power strips manufactured in China.

The recalled power strips, which were imported by Lush Life of LaJolla, CA, reportedly have undersized wiring which poses a risk of shock to consumers. In addition, the wiring and plastic strip do not meet fire resistance safety standards. Burlington has not received any reports of incidents or injuries related to the recalled power strips, but has initiated the recall to reduce the potential for future incidents.

The power strips were sold in Burlington Coat Factory stores, The Container Store stores and other retail outlets nationwide from July 2011 through March 2012 for about $10.

Additional information about this recall is available at incompliancemag.com/news/1209_15.

Do you have news that you'd like to share with your colleagues in the compliance industry? Send news items to the editor:

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UL Standards Update

Underwriters Laboratories has announced the availability of these standards and revisions. For additional information, please visit their website at www.ul.com.

STANDARDS

UL 305: Standard for Panic Hardware
New Edition dated July 12, 2012

UL 514B: Conduit, Tubing, and Cable Fittings
New Edition dated July 13, 2012

UL 514B: Conduit, Tubing, and Cable Fittings
New Edition dated July 13, 2012

UL 751: Standard for Vending Machines
New Edition dated July 20, 2012

UL 1004-7: Standard for Electronically Protected Motors
New Edition dated July 13, 2012

UL 1008: Transfer Switch Equipment
New Edition dated July 6, 2012

UL 2127: Standard for Inert Gas Clean Agent Extinguishing System Units
New Edition dated July 13, 2012

UL 2801: Standard for Sustainability for Printing Inks
New Edition dated July 18, 2012

UL 60745-2-22: Hand-Held Motor-Operated Electric Tools - Safety - Part 2-22: Particular Requirements for Cut-Off Machines
New Edition dated July 20, 2012

REVISIONS

UL 1: Standard for Flexible Metal Conduit
Revision dated July 3, 2012

UL 96A: Standard for Installation Requirements for Lightning Protection Systems
Revision dated July 18, 2012

UL 103: Standard for Factory-Built Chimneys for Residential Type and Building Heating Appliances
Revision dated July 27, 2012

UL 153: Standard for Portable Electric Luminaires
Revision dated July 27, 2012

UL 372: Automatic Electrical Controls for Household and Similar Use - Part 2: Particular Requirements for Burner Ignition Systems and Components
Revision dated July 27, 2012

UL 399: Standard for Drinking-Water Coolers
Revision dated July 20, 2012

UL 474: Standard for Dehumidifiers
Revision dated July 20, 2012

UL 474: Standard for Dehumidifiers
Revision dated July 25, 2012

UL 810: Standard for Capacitors
Revision dated July 26, 2012

UL 873: Standard for Temperature-Indicating and -Regulating Equipment
Revision dated July 27, 2012

UL 921: Commercial Dishwashers
Revision dated July 6, 2012

UL 1004-3: Standard for Thermally Protected Motors
Revision dated July 18, 2012

UL 1063: Standard for Machine-Tool Wires and Cables
Revision dated July 11, 2012

UL 1242: Standard for Electrical Intermediate Metal Conduit - Steel
Revision dated July 3, 2012

UL 1310: Standard for Class 2 Power Units
Revision dated July 25, 2012

UL 1413: Standard for High-Voltage Components for Television-Type Appliances
Revision dated July 24, 2012

UL 1449: Standard for Surge Protective Devices
Revision dated July 11, 2012

UL 1563: Standard for Electric Spas, Equipment Assemblies, and Associated Equipment
Revision dated July 30, 2012

UL 1838: Standard for Low Voltage Landscape Lighting Systems
Revision dated July 16, 2012

UL 2442: Standard for Wall- and Ceiling-Mounts and Accessories
Revision dated July 10, 2012

iNARTE Informer

The Transition Continues

BY BRIAN LAWRENCE

As reported last month, technology transfer and moving of hardware from our New Bern, NC office to the RABQSA Milwaukee office has begun. This process will take place gradually over the next four or five weeks in order that it is not too disruptive to our operations. By the end of August all systems should be operating smoothly in the RABQSA International offices.

For almost the complete month of July, operational and administrative personnel from RABQSA in Milwaukee have been with us in North Carolina getting indoctrinated into the iNARTE systems and procedures. It is expected that the established iNARTE procedures will be maintained in the short term, but as our database management system merges into a new system just coming on line at RABQSA, some streamlining and efficiencies are to be expected.

It is now time to introduce the staff members at RABQSA International who have been training with us in New Bern and who will be your primary contacts after August 2012.

Seated at the computer is Presley Quinn, Administrator, pquinn@rabqsa.com. Behind Presley is Monique Inman, Manager of Operations USA, minman@rabqsa.com.

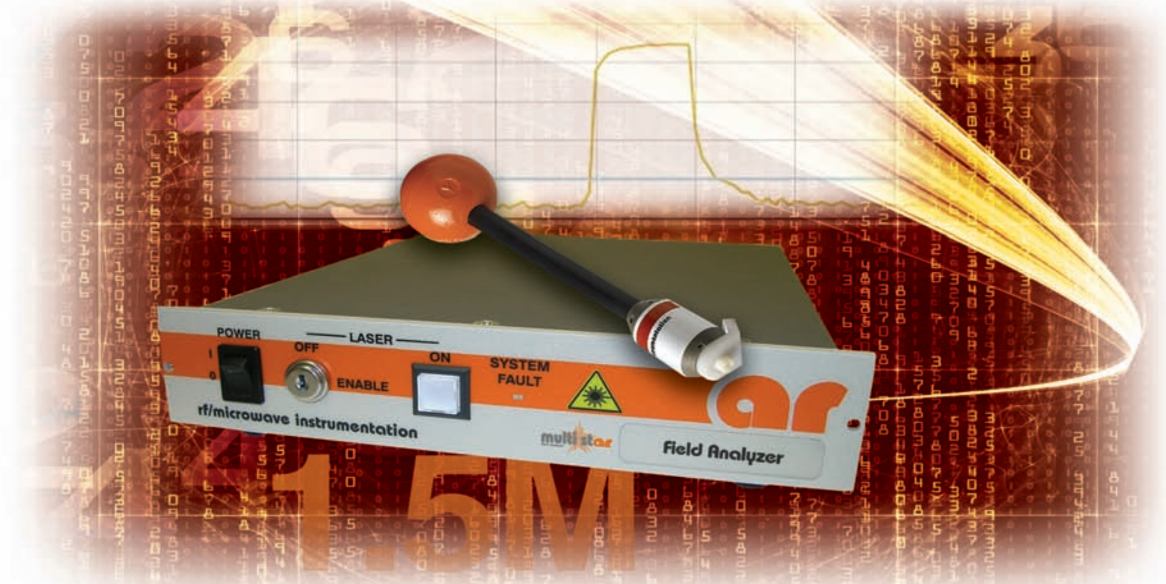
Presley Quinn and Monique Inman

For the next few months Presley will have primary responsibility for the iNARTE FCC Licencensure programs, while Monique will be your main contact for iNARTE certification matters. Kathy and I will still be around for back up, as and when needed.

WHO AND WHAT IS RABQSA INTERNATIONAL?

We are often asked this question since most of the engineers and technicians holding iNARTE certifications will not have encountered their name before. The head of the family from which RABSA International has emerged is the American Society for Quality (ASQ). ASQ had its origins in 1946 when a group of industry leaders formed an association dedicated to manufacturing quality and quality improvement. Their aim was to preserve the significant improvements in manufacturing processes derived from World War II activities.

A New Paradigm In Laser Powered Field Measurements



Modulated And CW Electric Field Measurements Are Faster, Easier And More Accurate

AR's new series of laser-powered electric field analyzers have an extremely high sample rate and can precisely measure pulsed electric fields in the microsecond range.

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The FA7000 series of field analyzers are based on an innovative approach that uses an isotropic field sensor to sample the composite field and transmit its amplitude digitally over optical fiber to a processor unit.

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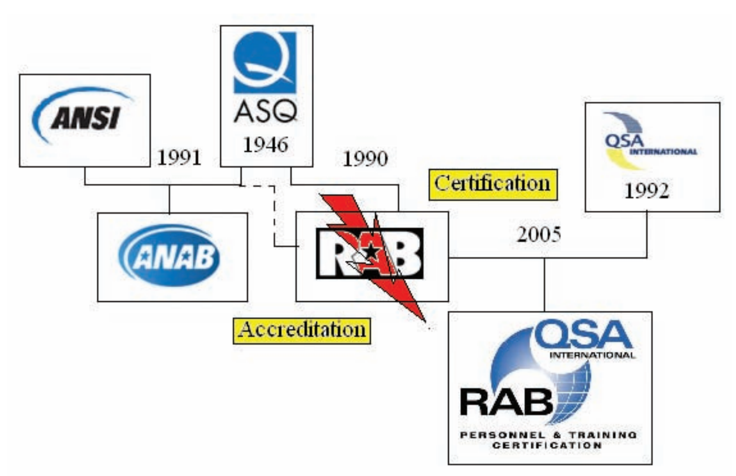
iNARTE Informer

The new organization, RABQSA International, is a subsidiary of ASQ with its official headquarters in Milwaukee WI and a larger main office still in Sydney, Australia. RABQSA International offers certification of personnel in over 30 disciplines and has a total of more than 10,000 active and current certificate holders. The 2012 merger with iNARTE and our 5,000 certificate holders has created the world's largest personnel certification body.

ASQ grew quickly and their activities broadened to include accreditation of facilities and credentialing of personnel. In order to preserve the integrity of these different operations, ASQ formed a new subsidiary in 1990, the Registrar Accreditation Board (RAB). ASQ retained its global membership, while RAB was created as a non-member governance organization.

It was immediately apparent that a conflict of interest could still exist within RAB, unless separation was created between accreditation and certification activities. Therefore in 1991, the accreditation activity was taken up by a new organization formed in partnership between ASQ and ANSI, the ANSI-ASQ National Accreditation Board (ANAB). This left RAB as a smaller organization with just certification of personnel. A search for a suitable partner for RAB was initiated to promote global growth of their activities, and in 2005 RAB merged with the Quality Society of Australasia, QSA International, an organization that had started in 1992 offering Certification of personnel and having its headquarters in Sydney, Australia.



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Today the organization still has ASQ as the overall parent with ANAB and RABQSA as its two subsidiaries. Each subsidiary offers two brands; ANAB provides accreditation under the ANAB brand and also the ACLASS brand, for laboratories operating in compliance with ISO 17025. RABQSA International offers certification brands under its own name and now also under the iNARTE brand. ASQ has approximately 85,000 members worldwide dedicated to all aspects of quality control and quality management.

The certification brands of iNARTE and RABQSA do not conflict; they are complimentary. In the future the differentiation between these brands will generally be that the RABQSA brand will be applicable to personnel engaged in assessing, auditing, inspecting and managing quality and regulatory compliance. The iNARTE brand will be applicable to engineers, technicians and practitioners actually responsible for designing, executing and testing of products and materials, including consulting services.

WHERE DO WE SEE CERTIFICATION GROWTH?

Not surprisingly, our most active disciplines today are in EMC and ESD control. Our traditional EMC programs are still the most sought after, although we do have great expectations for our new programs for EMC Design Engineering and Wireless Device Certification. EMC certification interest is highest in Japan where we regularly register over 250 applications each year, of which about 150 achieve certification. ESD certification activity is currently highest in Singapore, Malaysia and Indonesia, with a rapidly developing interest in Korea. Of course, certification activity at iNARTE is due in large part to the dedication and energies of our regional partners in certain countries and may not be a true reflection of actual commercial activity across a larger region.

To our surprise, Product Safety Engineering certification at iNARTE is limited to just Japan and the US markets, with Japan being most active, however lagging far behind their EMC activity. We have been unable to find regional partners or appropriate safety organizations in countries where we would expect there to be interest in this area.

(the author)

BRIAN LAWRENCE
began his career in electromagnetics at Plessey Research Labs, designing “Stealth” materials for the British armed services. In 1973 he moved to the USA and established a new manufacturing plant for Plessey to provide these materials to the US Navy. In 1980 he joined the “Rayproof” organization to develop an RF Anechoic Test Chamber product line. As a result of acquisitions, Rayproof merged into Lindgren RF Enclosures, and later into ETS-Lindgren. Following a career spanning more than 40 years in the electromagnetic compatibility field, Brian retired as Managing Director of ETS-Lindgren UK in 2006. Later that year he assumed the position of Executive Director for the National Association of Radio and Telecommunications Engineers, NARTE. Now renamed iNARTE, the Association has expanded its operations and is today an affiliate of RABQSA under the overall banner of the American Society for Quality, ASQ.

QUESTION OF THE MONTH

Last month we asked:

Intermodulation products are a result of which of the following:

A) Motor Brushes that arc when operated in an unshielded area.

B) Mixing of two or more RF signals in a nonlinear junction.

C) Transmitter primary frequencies that mix in linear junctions.

D) Nonlinear junctions rubbing together causing intermodulation.

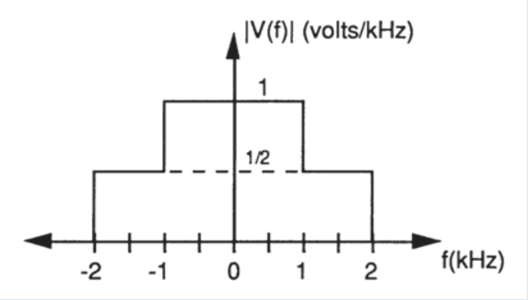
E) Adding an information signal to a carrier.

The answer is B) Mixing of two or more RF signals in a nonlinear junction.

Intermodulation products are sums and differences of harmonics generated across a nonlinear junction when excited by two or more carriers.

This month’s question is:

A signal with amplitude spectrum shown below



is passed through an ideal lowpass filter with unity gain and 1 kHz bandwidth. The percentage of the input energy appearing at the filter output is ______ .

A) 50%

B) 66.7%

C) 80%

D) 90%

Voltage and Field Strength

Part 2: Conductors

BY NIELS JONASSEN, sponsored by the ESD Association

Screening noncontacting meters will often reduce the field distortion caused by the presence of meters.

INTRODUCTION

Associate Professor Neils Jonassen authored a bi-monthly static column that appeared in *Compliance Engineering Magazine*. The series explored charging, ionization, explosions, and other ESD related topics. The ESD Association, working with *In Compliance Magazine* is re-publishing this series as the articles offer timeless insight into the field of electrostatics.

Professor Jonassen was a member of the ESD Association from 1983-2006. He received the ESD Association *Outstanding Contribution Award* in 1989 and authored technical papers, books and technical reports. He is remembered for his contributions to the understanding of Electrostatic control, and in his memory we reprise "Mr. Static".

~ The ESD Association

Anyone who has worked with static or dynamic electricity is familiar with the concept of voltage. After all, Ohm's law states that $V = R \cdot I$, voltage (difference) equals resistance times current. But this well-known relationship does not say anything about voltage; rather, it defines resistance, and it cannot be applied to ESD problems because there is no current. Then there is the definition of the voltage difference between points A and B as the work done per unit charge when a charge is brought from A to B. But here there is a metrological problem because there is no way to measure the work that is done on a charge. So, we have to go back to the basics and realize that voltage is not a fundamental quantity, but rather a property of an electric field.

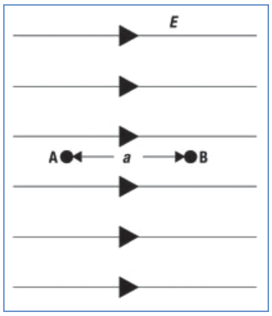


Figure 1: A homogeneous field with field strength E.

Figure 1 shows a section of a homogeneous field with field strength E, where the voltage difference between points A and B is defined by

$$V(A) - V(B) = E \cdot a \tag{1}$$

However, in most cases, fields are not homogeneous. Figure 2 shows the field from a positively charged insulator with a grounded conductor placed in front of the insulator. In this case, the voltage difference between A and B is defined by

$$V(A) - V(B) = \int_{A}^{B} E \cdot da \tag{2}$$

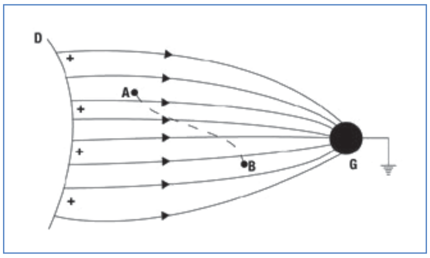


Figure 2: The field between a positively charged insulator and a grounded conductor.

Equations 1 and 2 only define voltage differences. The voltage of a point P in a field is defined as the integral of the field from P to infinity or to any grounded object, that is,

$$V(\mathrm{P}) = \int_{\mathrm{P}}^{\infty \text{ or ground}} E \cdot da \tag{3}$$

VOLTAGE OF A CONDUCTOR

Figure 3 shows an insulated conductor A with a charge q. The charge will automatically distribute itself on the surface of the conductor in such a

The voltage of an insulated conductor may be measured directly by connecting the conductor to an electrometer or static voltmeter.

way that (a) the field in the interior of the conductor is zero, (b) the field is perpendicular to the surface, and (c) the integral of the field strength from any point P in or on the conductor to a ground point G is constant:

$$V_{P_1} = \int_{P}^{G} E \cdot da \qquad (4)$$

V is the voltage or potential of the conductor. The voltage V and the charge *q* are proportional, and this is usually written as

$$q = C \cdot V \qquad (5)$$

C is the capacitance of the insulated conductor and is determined by the size and shape of the conductor and its placement relative to other conductors and ground.

The charged system stores an electrostatic energy given by

$$W = \frac{1}{2} C \cdot V^2 \qquad (6)$$

which can be dissipated in a single discharge or current pulse.

MEASUREMENT OF CONDUCTOR VOLTAGE

Direct-Contact Voltmeters

The voltage of an insulated conductor may be measured directly by connecting the conductor to an electrometer or static voltmeter (see Figure 4). The voltmeter measures the common voltage of the conductor and the voltmeter. If the capacitance C of the conductor is much larger than the capacitance C_i of the voltmeter, the voltage read on the voltmeter is, with good approximation, equal to the voltage of the conductor without the meter being attached.

However, the measuring range of most static voltmeters is in the order of tens or, at best, hundreds of volts. On the other hand, static voltages will often be in the kilovolt range.

This problem can be circumvented by the use of a capacitive voltage divider. In Figure 5, a capacitor with capacitance C_y is inserted in the connection between the conductor and the static voltmeter.

If the voltage read on the voltmeter is V_i, then the voltage V of the conductor is given by

$$V = \frac{C_y + C_i}{C_y} \cdot V_i \qquad (7)$$

As an example, let us assume that the maximum voltage to be read on the meter is $V_{i,\,max} = 10$ V, $C_i = 10$ nF $= 10^{-8}$ F, and $C_y = 10$ pF $= 10^{-11}$ F, then Equation 7 will give a maximum voltage of

$$V_{max} = \frac{10^{-11} + 10^{-8}}{10^{-11}} \cdot 10 \cong 10 \text{ kV} \qquad (8)$$

The necessary high capacitance in this application of the meter is usually obtained by running the meter in the charge-measuring mode. It appears that using a capacitive voltage divider expanded the measuring range of the voltmeter by a factor of 1000.

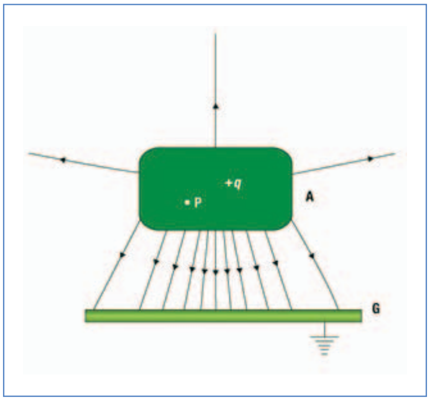


Figure 3: An insulated conductor A with a charge *q*, placed over a ground.

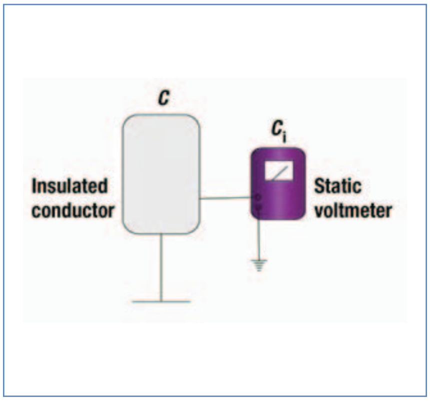


Figure 4: The direct measurement of voltage.

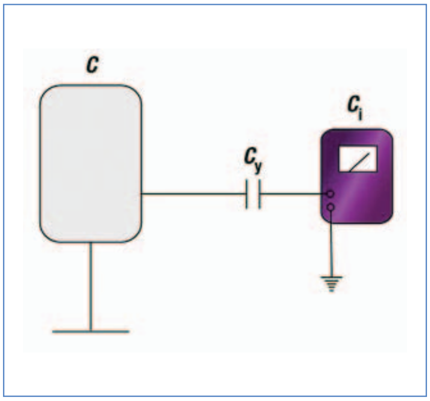


Figure 5: A capacitive voltage divider.

Noncontacting voltmeters may have greater sensitivity (but not necessarily greater accuracy) than do field meters.

Noncontacting Measurements

Electrostatic noncontacting measurements are always based on the effects of the fields of charges, whether they are located on conductors or insulators. There are basically two types of instruments: field meters, which measure the charge induced on a probe and convert it to the field strength in front of the probe, and noncontacting voltmeters, which raise the voltage of the probe until the field in front of the probe is zero. The noncontacting voltmeter then takes this voltage as the voltage of the object that it is pointing toward.

Noncontacting voltmeters may have greater sensitivity (but not necessarily greater accuracy) than do field meters. However, both types of instruments may distort the original field considerably unless the meters are suitable screened.

Figure 6 shows a charged insulated conductor. In the figure, the noncontacting voltmeter reads the voltage V of the conductor and estimates the mean field strength $E = V/d$ between the conductor and the meter, whereas the field meter reads the field strength E in front of the meter and estimates the voltage $V = E \cdot d$ of the conductor. However, it should be emphasized that the quantities read and calculated refer to the conditions that exist when the instruments are in place.

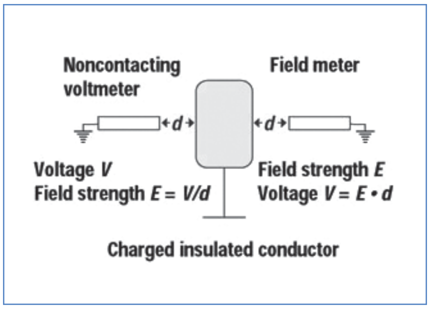


Figure 6: Noncontacting measurements.

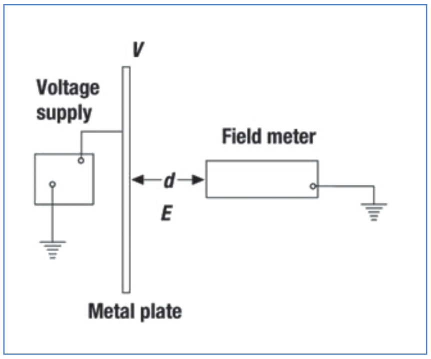


Figure 7: An unscreened field meter.

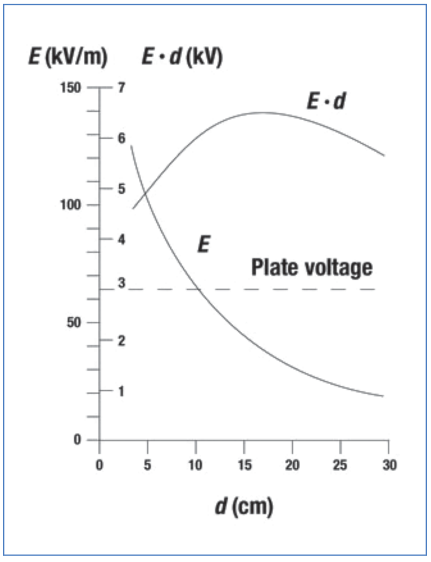


Figure 8: Measurement results from an unscreened field meter.

CONDUCTOR AT FIXED VOLTAGE

The experiment shown in Figure 7 was conducted to investigate the influence of the meters on the field from and the voltage of the charged conductor. A 35 · 35-cm metal plate was connected to a voltage supply kept at a constant voltage of 3 kV. A field meter was placed perpendicular to the plate, pointing at the center of the plate, and the field strength E was measured as a function of the distance d between the plate and the field meter. For each distance d, the product $E \cdot d$ was calculated.

The results of the measurements are shown in Figure 8. It appears that the field strength E decreased with increasing distance d, as expected. However, if the voltage V of the plate is calculated from Equation 1 as $V = E \cdot d$, the result would be a very poor approximation of the true value (3 kV) of the plate voltage.

The reason for this is that Equation 1 assumes the field to be homogeneous, as shown in Figure 1. But the setup in Figure 7 resembles much more closely the situation in Figure 2 because the housing of the field meter (or for that matter, the housing of a noncontacting voltmeter) is essentially at ground potential. The field strength read on the field meter (or compensated for in a noncontacting voltmeter) is therefore higher than the mean field strength between the meter and the target, and the $E \cdot d$ approximation of the voltage will therefore be too high. Figure 8 shows that in the range of distances from 4 to 30 cm, the estimated voltage $E \cdot d$ varies between 4.5 and 6.2 kV, rather than the true value of 3 kV.

However, both types of instruments may distort the original field considerably unless the meters are suitable screened.

The problem of the instruments distorting the field can be corrected partly by surrounding the meter with a grounded screen placed parallel to the face of the target, as shown in Figure 9. The experimental setup had a 25 · 25-cm screen and a 35 · 35-cm metal plate as the target.

Figure 10 shows the field strength E and the apparent voltage $E \cdot d$ as a function of the distance d. The results demonstrate that, with the screen attached, the voltage V of the metal plate is adequately determined by the product $E \cdot d$ out to a distance of approximately 15 cm between the plate and the field meter. In this range, the field is homogeneous and inversely proportional to the distance to the field meter, that is, the E-field curve is a hyperbola. At larger distances, the field again becomes inhomogeneous, and at this range, the field meter underestimates the voltage.

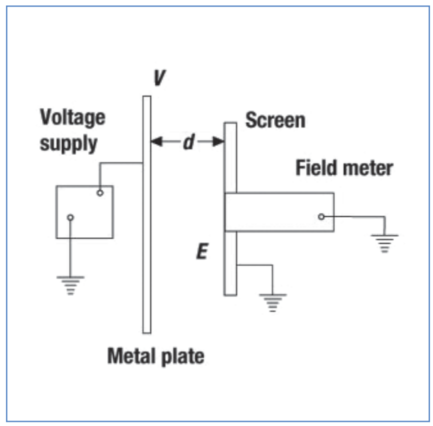


Figure 9: A screened field meter.

The distance to which the voltage can be determined with reasonable

MR. Static

The previous cases do not represent the ordinary, everyday situation in which a conductor has been charged and the voltage is measured by pointing a meter at the conductor.

accuracy also depends on the target size. If the measurements in Figure 10 were repeated with a 15 · 15-cm plate, the readings would yield reliable results only out to a distance of approximately 6–7 cm.

CONDUCTOR WITH CONSTANT CHARGE

In the previously discussed cases, the target conductor was locked to a voltage supply. The voltage of the conductor would therefore be kept constant, independent of field meter placement. The charge, on the other hand, might vary with the intercapacitance of the conductor and the field meter, that is, with the distance *d*.

The previous cases do not represent the ordinary, everyday situation in which a conductor has been charged and the voltage is measured by pointing a meter at the conductor. In this more common case, the charge stays constant while the voltage may change because of the coupling with the meter capacitance. Figure 11 shows an experimental setup for investigating this situation. In the experiment, a 35 · 35-cm metal plate was charged to an initial voltage of 3 kV (in the absence of the field meter), and then the connection to the voltage supply was broken. Next, the field meter was placed at various distances *d* from the metal plate, and the field strength *E* was measured.

Figure 12 shows the product $E \cdot d$ (the apparent voltage) as a function of *d* for plate capacitances C ≅ 20 pF (the plate alone) and C ≅ 220 pF (the plate and an additional external capacitor).

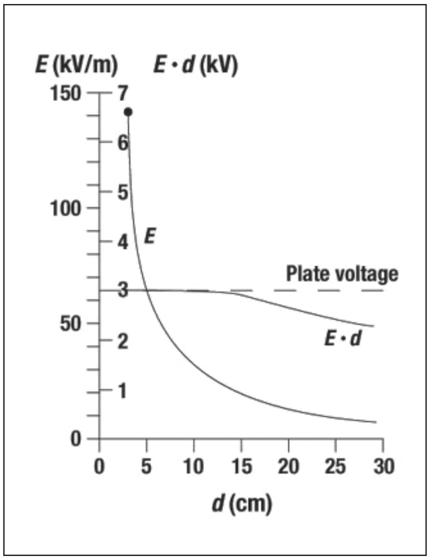


Figure 10: Measurement results from a screened field meter.

The greater plate capacitance of 220 pF provided a curve that is very similar to the one plotted in Figure 10, where the metal plate was locked at 3 kV. This means that the presence of the field meter does not significantly change the total capacitance and, hence, the plate voltage for a given distance. The lesser plate capacitance of 20 pF resulted in a calculated voltage that is lower at all distances than that found with the plate of greater capacitance. This is due to the added value of the meter capacitance. At the very short measuring distance, the presence of the meter increases the original value of the capacitance from 20 to about 45 pF, resulting in the voltage dropping from 3 to about 1.3 kV.

The measurements reported in Figure 12 were repeated with an unshielded field meter. The general trend was the same as demonstrated in Figure 8. At all distances (and with both capacitances tested), the unshielded field meters overestimated the true values of the plate voltage by up to 100%.

STATIC LOCATORS

Probably the most common way to do a fast static survey is to point a handheld meter at the suspicious item and pronounce a voltage. Often, this is the only measurement done. And very often, this is not enough.

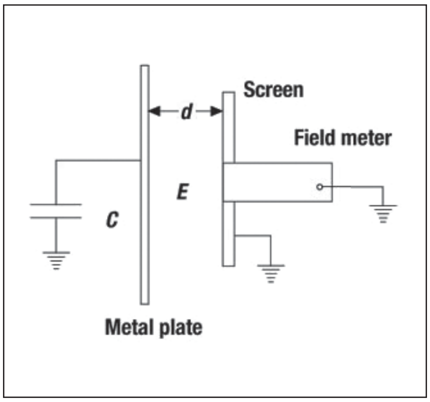


Figure 11: Measuring a conductor with constant charge.

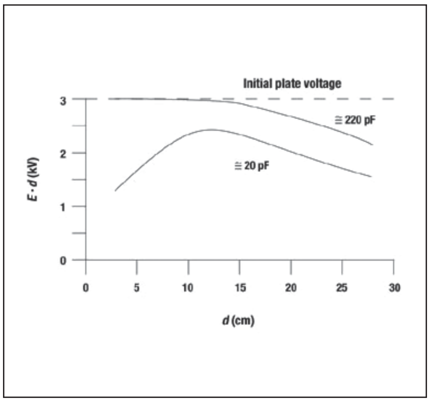


Figure 12: Measurement results from an unshielded field meter

It has been demonstrated that the instruments used will often distort the fields and hence change the properties to be measured.

These handheld meters are known as, and often even called, static locators. And that is exactly what they are—instruments to locate a static electric field. As long as that is the only thing they are being used for, everything is fine. But often, their use is being extrapolated into the absurd.

Figure 7 is an illustration of the typical use of a field meter as a static locator. The meter ranges may be in volts, but the meter is not a voltmeter. It does not react to a voltage, but rather to an electric field. Often, it is a regular field meter, for instance, a field mill, or it may essentially just contain an operational amplifier that reacts to the charge induced on a sensor plate at the front of the meter housing.

The meter also has a stipulated measuring distance. In the case shown, it is *d*. This means that the meter was calibrated by placing it at a distance *d* from, and parallel to, a metal plate, which was then raised to a range of voltages, and a corresponding scale was drawn.

So the question is this, after the calibration, what can the meter be used for? The answer is very simple: The meter can be used to measure the electric field at a distance d from a metal plate with the same dimensions and the same capacitance as the one used for factory calibration. For conductors, the value obtained is approximately equivalent to surface voltage. At any other distance or when measuring insulators, the measurement is not calibrated and the instrument has merely located an electric field.

The problem is that manufacturers seem very reluctant to mention this, or to just describe what the calibration conditions were and what happens if the instrument is used under other, and maybe even more-everyday, conditions. It is very rare, if it ever happens at all, for the dimensions of the calibration plate, not to mention its capacitance, to be given in the manual. Nor is there any warning that if the meter were to be pointed toward an insulator, the reading in volts would never refer to the insulator as a whole. As was mentioned in Part I of this article, an insulator does not have a voltage. If the user is lucky, a kind of surface voltage may be found.[1]

It is something of a puzzle why static locators are always calibrated in volts. After all, they are just ordinary field meters pretending to be voltmeters, without really being so. All they can do is measure the voltage of a certain metal plate at a certain distance. If these meters were calibrated in units of field strength, that is, $V \cdot m^{-1}$, they could be used much better to evaluate the static conditions of insulators as well as conductors.

But could the explanation simply be that most people understand voltage better than they do field strength? No, that does not seem possible. Just look at Equations 1, 2, and 3 of this article. A voltage is always defined by a field strength (and a distance), so if someone does not understand one, that person would not understand the other.

CONCLUSION

This article has analyzed the problems connected with measuring the voltage of a charged insulated conductor. The emphasis was placed on noncontacting measurements, that is, measurements based on the effect of the field from the charge. It has been demonstrated that the instruments used will often distort the fields and hence change the properties to be measured. It was also shown that, by screening the meters, it is often possible to reduce the field distortions considerably.

REFERENCE

1. Niels Jonassen, "Surface Voltage and Field Strength: Part I, Insulators" in Mr. Static, *Compliance Engineering* 18, no. 7 (2001): 26–33 and *In Compliance Magazine*, August 2012.

(the author)

NIELS JONASSEN, MSC, DSC, worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. After retiring, he divided his time among the laboratory, his home, and Thailand, writing on static electricity topics and pursuing cooking classes. Mr. Jonassen passed away in 2006.

Hot Stuff (and Warnings)

BY GEOFFREY PECKHAM

Given that this column is principally about graphical symbols and how they're used to convey safety messages, it's time we focus attention on one of the more common forms of energy warned about on equipment: heat.

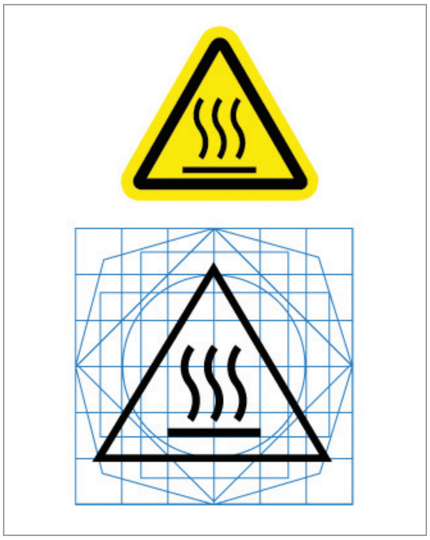


Figure 2: The standardized ISO symbol for "Warning Hot Surface" and the IEC "Caution - hot surface" function and control symbol #5041, respectively.

"CAUTION - HOT" is a commonly posted message. The sign typically consists of one or two words, "HOT" or "HOT SURFACE" below the signal word CAUTION as shown in Figure 1. This sign does not meet the latest ANSI or ISO standards in its formatting and it doesn't use symbols. Visual literacy is on the rise; people (especially the younger generations) better understand and process images than they do words. As we have seen in past articles in this periodical, the use of graphical symbols is now key to communicating safety effectively. Not only can they convey messages quickly, but symbols also have the capacity to transcend language barriers.

Figure 1: Typical word message-only sign failing to fully indicate the nature of the hazard, the consequences of interaction, and how to avoid the hazard.

When it comes to communicating safety messages about heat and hot surfaces there are really two types of symbols in use. First is the fairly abstract ISO symbol for hot surfaces shown in Figure 2. All graphical symbols are abstract to a degree, some more than others. The ISO symbol for heat using three wavy lines coming off a flat surface was originally derived off of an IEC symbol used for indicating heat on function and control buttons (see Figure 2). When it came time to create the ISO warning sign for hot surfaces, the IEC image was placed inside the standardized ISO warning sign template of a black-banded yellow triangle. Thus, the symbol for "warning, hot surfaces" was born. Although the symbol is initially abstract, it is learnable given some training.

Alternative symbols exist and as the engineer responsible for your products' safety labeling, you are able to choose which symbols you would prefer. You could choose to add a "do not touch" symbol to a label that already contains the ISO "hot surface" symbol, (see Figure 3) thereby communicating both the nature of the hazard and how to avoid it with two distinct pictorial representations. Another alternative is to use a symbol that combines both messages into a single graphic image. The example in Figure 4 is one that Clarion developed to convey the message, "hot surface - do not touch." This symbol uses a hand in profile to display both human

Figure 3: The combination of the ISO "Hot Surface" symbol and the "Do Not Touch" symbol communicates both the nature of the hazard and how to avoid it. (Image courtesy of Clarion Safety Systems © 2012).

Figure 4: Safety label with alternative word message and "Do Not Touch" symbol. (Image courtesy of Clarion Safety Systems © 2012).

interaction with the hazard and add a measure of realism, dramatization, and understandability to the graphic. The use of the ISO red prohibition circle-with-slash surround shape communicates the "do not" portion of the message in the same way similar signs used for "no smoking," "no left turn," and "no pedestrian crossing" are meant to prohibit certain actions.

One of the things you must pay attention to when labeling your product for hot surfaces is the need to take label materials durability into account. Simply put, heat can destroy things. Adhesives dry out and lose their adhesion, causing labels to fall off. Label base materials and overlaminates shrivel up and crack. Inks discolor. So the first thing to consider is whether or not you can mount the label on a surface that does not get hot but is still close enough to the hot surface so the label will be associated with the hazardous location. If that is not possible, you can mount the label on a plate that is raised above the hot surface so air flows between the two, providing a cooler surface for the label to adhere to. You can also choose to make your safety label out of heat resistant materials. Clarion uses anodized aluminum labels and plates when a safety message must be placed directly on a hot surface (Figure 5).

An anodized safety sign or label's image is actually dyed into the surface of a specialized aluminum material and then put through a chemical process to seal the image into the pores of the aluminum. Although the colors are not as vibrant as an ink-printed label, the color will be protected from heat degradation. As for mounting the anodized sign or label, specialized adhesives can be used that withstand higher temperatures.

Hot surfaces are not always readily discernible. So if you know that a surface could become dangerously hot, then it is likely that you have a duty to warn people of the possibility of a burn hazard. Once again, graphical symbols can come to the rescue and save the day by assisting you with carrying out this responsibility.

For more information about safety signs and symbols, visit www.clarionsafety.com.

Figure 5: A "CAUTION BURN HAZARD" anodized aluminum plate applied on a hot surface. (Image courtesy of Clarion Safety Systems © 2012).

(the author)

GEOFFREY PECKHAM

is president of Clarion Safety Systems and chair of both the ANSI Z535 Committee and the U.S. Technical Advisory Group to ISO Technical Committee 145- Graphical Symbols. Over the past two decades he has played a pivotal role in the harmonization of U.S. and international standards dealing with safety signs, colors, formats and symbols.

Now Is the Time for ESD Control Programs To Be Improved

“Factory ESD control is expected to play an ever-increasing critical role as the industry is flooded with even more HBM (Human Body Model) and CDM (Charged Device Model) sensitive designs.”

BY FRED TENZER AND GENE FELDER

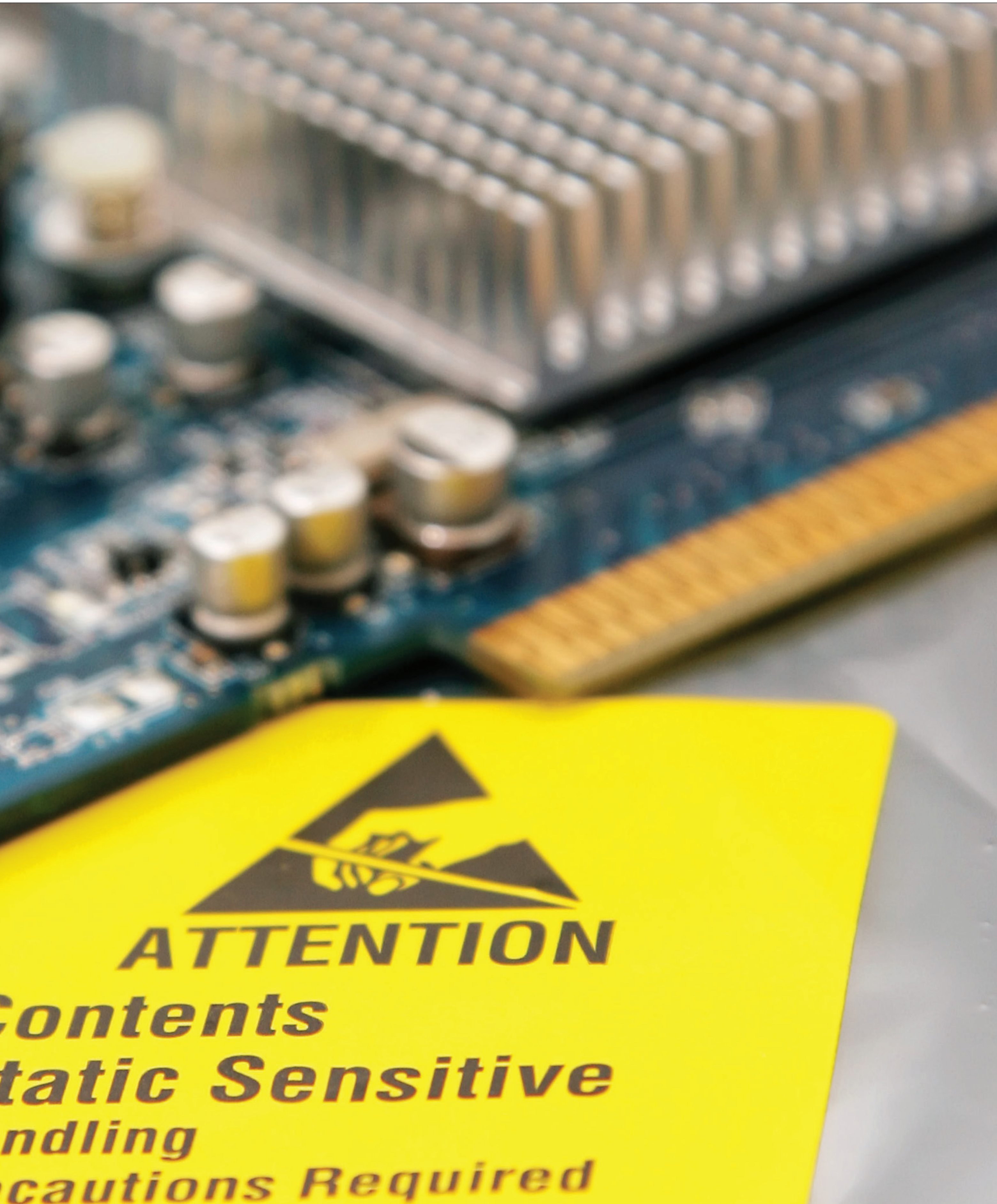
Electrostatic discharge (ESD) is the hidden enemy within your factory. You cannot feel or see most ESD events, but they can cause electronic components to fail or cause mysterious and annoying problems. There are two types of ESD damage: 1. catastrophic failures, and 2. latent defects. By definition, normal quality control inspections are able to identify catastrophic failures, but are not able to detect latent defects.

In general, modern electronics are more susceptible to ESD; that is their withstand voltages are lower. This is due to the drive for miniaturization and faster operation. Thus the semiconductor circuitry is getting smaller.

What’s happening currently? The width of electronic device structures continues to get smaller. Intel began selling a 32nm processor in 2010 that was 0.032 micrometer, equal to 0.000032 millimeter or 0.00000128 inch.

The ESD Association’s latest white paper, *Electrostatic Discharge (ESD) Technology Roadmap – Revised April 2010,* [1] (see www.ESDA.org) forecasts increased ESD sensitivities, continuing the recent trend,with the result that “the ICs became even more sensitive to ESD events in the years between 2005 and 2009. Therefore, the prevailing trend is circuit performance at the expense of ESD protection levels.” The white paper’s conclusions include:

- “With devices becoming more sensitive through 2010-2015 and beyond, it is imperative that companies begin to scrutinize the ESD capabilities of their handling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processes. Factory ESD control is expected to play an ever-increasing critical role as the industry is flooded with even more HBM (Human Body Model) and CDM (Charged Device Model) sensitive designs. For people handling ESD sensitive devices, personnel grounding systems must be designed to limit body voltages to less than 100 volts."

- "To protect against metal-to-device discharges, all conductive elements that contact ESD sensitive devices must be grounded."
- "To limit the possibilities of a field induced CDM ESD event, users of ESD sensitive devices should ensure that the maximum voltage induced on their devices is kept below 50 volts."
- "To limit CDM ESD events, device pins should be contacted with static-dissipative material instead of metal wherever possible."

Dr. Terry L. Welsher's article, "The 'Real' Cost of ESD Damage" [2], includes the observation that "Recent data and experience reported by several companies and laboratories now suggest that many failures previously classified as EOS (Electrical Overstress) may instead be the result of ESD failures due to charged board events (CBE). … Some companies have estimated that about 50% of failures originally designated as EOS were actually CBE or CDE (charged device events)."

ANSI/ESD S20.20 [3], the ESD Association document covering the development of an ESD control program, lists numerous ESD Protected Area (EPA) ESD control items. Each company can pick and choose which recommendations are appropriate for its program. "The selection of specific ESD control procedures or materials is at the option of the ESD Control Program Plan preparer and should be based on risk assessment and the established electrostatic discharge sensitivities of parts, assemblies, and equipment." [ANSI/ESD S20.20-2007 Annex B] "An EPA (ESD protected area) shall be established wherever ESDS (ESD Sensitive) products are handled. However, there are many different ways to establish ESD controls within an EPA. Table 3 lists some optional ESD control items which can be used to control static electricity." [ANSI/ESD S20.20-2007 section 8.3 ESD Protected Areas (EPAs)]

There are companies with good ESD control programs that are pleased with their quality and reliability results. But to maintain that level, they would be wise to consider ESD control program improvements. Now might be a good time to do that.

HUMAN BODY MODEL (HBM)

Part of the challenge may be the need to handle, for the first time, electronics having a HBM Class 0 withstand voltage. Per the ANSI/ESD S20.20 Foreword:

- This standard covers "electrical or electronic parts, assemblies and equipment susceptible to damage by

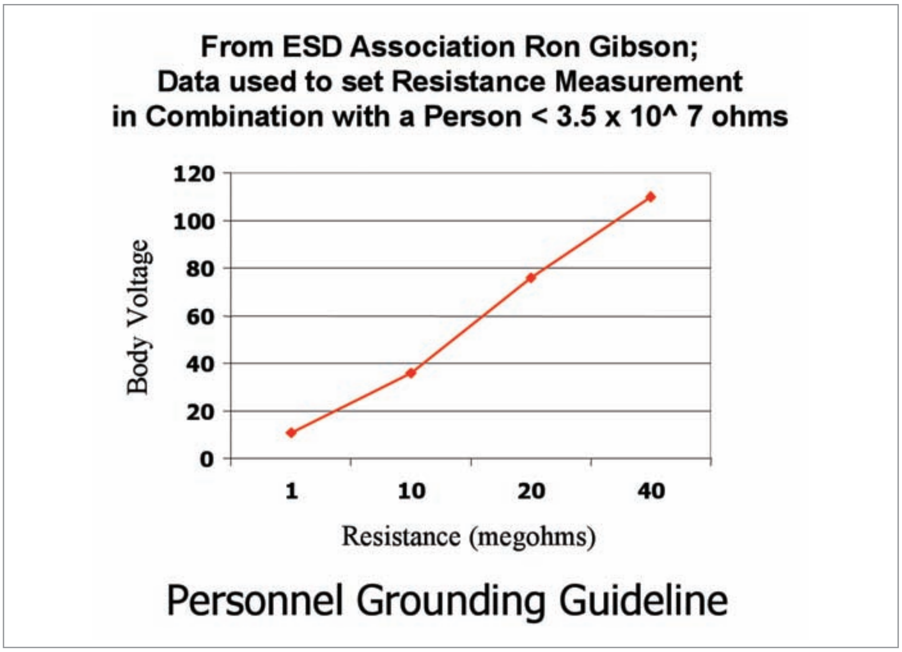

Figure 1: Graph setting the personnel grounding guideline from ESD Handbook ESD TR20.20 Figure 14 "Relationship between Body Voltage and Resistance to Ground"

Classification	Voltage Range (V)
0A	< 125
0B	125 to < 250
1A	250 to < 500
1B	500 to < 1000
1C	1000 to < 2000
2	2000 to < 4000
3A	4000 to < 8000
3B	≥ 8000

Table 1: Table showing HBM ESD component classification levels from ANSI/ESDA/JEDEC JS-001-2011

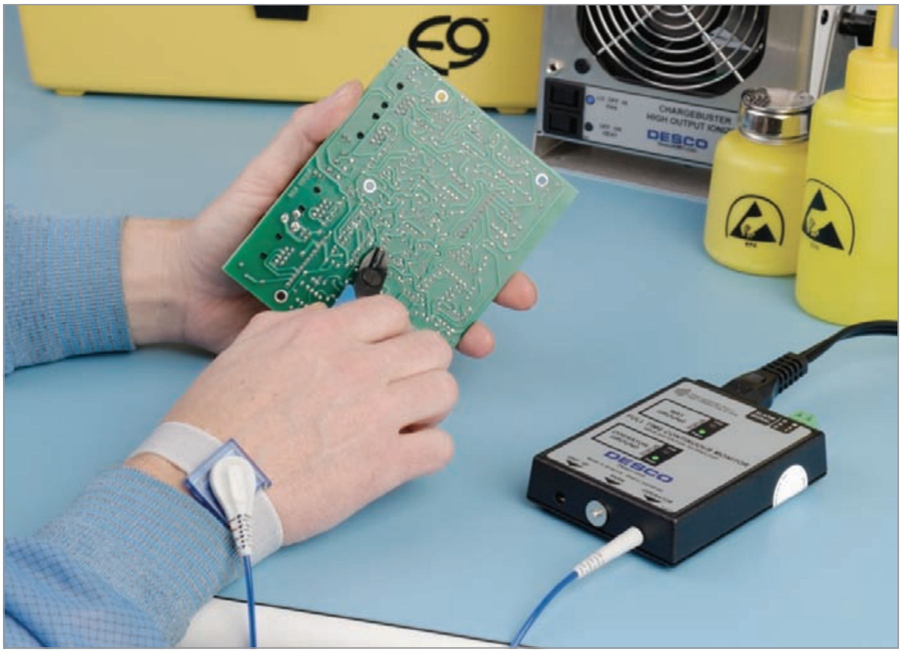

Figure 2: Wrist strap and continuous monitor

electrostatic discharges greater than or equal to 100 volts Human Body Model (HBM)"

- "When handling devices susceptible to less than 100 volts HBM, more stringent ESD Control Program Technical Requirements may be required, including adjustment of program Technical Element Recommended Ranges."

The Component Classification Level Table 3 from the updated standard ANSI/ESDA/JEDEC JS-001-2011, *Electrostatic Discharge Sensitivity Testing Human Body Model (HBM),* [4] (Table 1) has divided the Class 0 classification into two withstand voltage levels, with Class 0A being less than 125 volt sensitivity and Class 0B being 125 to less than 250 volts.

If handling class 0A items, or less than 125 volts, program improvements are called for. Basically, to control the environment to decrease the probability of ESD damage in class 0A situations, involves increasing ESD protective redundancies by adding EPA ESD control items and ensuring that they are working properly by increasing the frequency of compliance verifications of those ESD control items.

TACKLING HBM

Personnel grounding has historically been the foundation of most ESD control programs. Back in the early 1980s, the first standard written by the ESD Association was on wrist straps. Therefore, many companies mistakenly believe that operator grounding is no longer an issue. But there are areas of operator grounding where improvement should be considered.

While ANSI/ESD S20.20 has set the maximum upper limit of 35 megohms resistance for personnel grounding via a wrist strap system, consider lowering that upper limit within your ESD control plan to 10 megohms. The ESD Handbook ESD TR20.20 Figure 14 "Relationship between Body Voltage and Resistance to Ground" graph [5] (Figure 1) shows this would typically reduce body voltage from about 100 volts to less than 40 volts.

In addition, the use of continuous monitors should be evaluated. Wrist strap continuous monitors (Figure 2) will provide the benefit of detecting intermittent fault conditions, such as a coil cord wearing out or an operator having the wristband too loose. These will often not be detected by daily or even twice daily touch-testing. There are new models with technology that, besides monitoring the ground of operators and worksurfaces, will also alarm when body voltage exceeds 2.5 volts and alert the operator to actions, movements, or materials that are causing the operator to become charged.

If grounding personnel is achieved by use of a flooring/footwear system, heel grounders should be replaced with sole or full coverage grounders (Figure 3). The measurement of resistance alone is not sufficient to measure the effectiveness of the operator/flooring/footwear system. We see many companies with a conductive

Figure 3: Shoes with full coverage grounders and sole grounder

Figure 4: Workspace with a Statguard floor finish

ESD flooring requires maintenance to keep it clean and effective. All ESD flooring should be cleaned with a good quality ESD floor cleaner that will not leave behind an insulative residue that can raise floor resistance.

tile floor that measures mid-10^5 ohm resistance to ground and the operators are wearing foot grounders on each foot that passes the touch-testing. But what peak voltage on the body is generated? Over the years, there have been independent studies that have shown that with conductive flooring measuring less than 1 x 10^6 ohm resistance and footwear that measure low 10^6 ohm resistance, the following body voltage spikes were recorded when the ANSI/ESD STM97.2, Floor Materials and Footwear – Voltage Measurement in Combination with a Person [6] test was performed:

- using heel grounders, body voltage spikes to ±250 volts
- using sole grounders, body voltage spikes were reduced to ±75 volts or less
- using full coverage grounders, body voltage spikes were reduced to ±25 volts or less.

Basically, the greater the footwear contact surface, the higher the probability that while walking, bending, kneeling, reaching, etc. the operator will be in contact with the ESD floor.

"Procedures For The Design, Analysis and Auditing Of Static Control Flooring/Footwear Systems" by Stephen L. Fowler, William G. Klein, and Larry Fromm [7] includes, "With heel grounders, his potential dropped to 250 in one installation and 450 in the other, these being the peaks when both heels left the floor, as they did with nearly every step. When care was taken not to allow simultaneous contact loss with both grounders the values were 40 and 170 volts respectively. When he used a sole grounder, which is essentially a combination of heel and toe grounders, the peak voltage in both cases dropped below 30 volts."

Conductive flooring less than 1 megohm (1 x10^6 ohms) is often preferable. However, if the resistance upper limit is less than 1 x 10^9 ohms, end users must add the ANSI/ESD STM97.2 test method for body voltage to the qualification of their footwear/flooring operator grounding system in order to protect the sensitive devices of today and the more sensitive devices to come. It is no longer enough to know that a standing operator is grounded. When they are working, moving around with ESDS devices and assemblies, are they generating potentially harmful body voltage spikes? In addition, ESD flooring requires maintenance to keep it clean and effective. All ESD flooring should be cleaned with a good quality ESD floor cleaner that will not leave behind an insulative residue that can raise floor resistance. Many companies also want their floors to be shiny. Today, good quality dissipative floor finish can improve durability and gloss while also reducing the charge generation characteristic of the floor to less than <50 volts.

CHARGED DEVICE MODEL

It may seem to some that CDM has newly arrived as a problem for ESD control programs. However, the ESD Association first published ANSI/ESD STM5.3.1 *ESD Association Standard for Electrostatic Discharge Sensitivity Testing – Charged Device Model (CDM) – Component Level* [8] in 1999. Basically, CDM testing has to do with "testing, evaluating and classifying the electrostatic discharge (ESD) sensitivity of components to the defined charged device model (CDM)" … "to allow for accurate comparisons of component CDM ESD sensitivity levels."

From the JESD22-C101C *Field-Induced Charged-Device Model Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic*

If ionizers are already in use, a company should consider reducing the ionizer offset voltage limit of ±50 volts (the required limit in ANSI/ESD S20.20) to ±25 volts, depending on the application and device sensitivity.

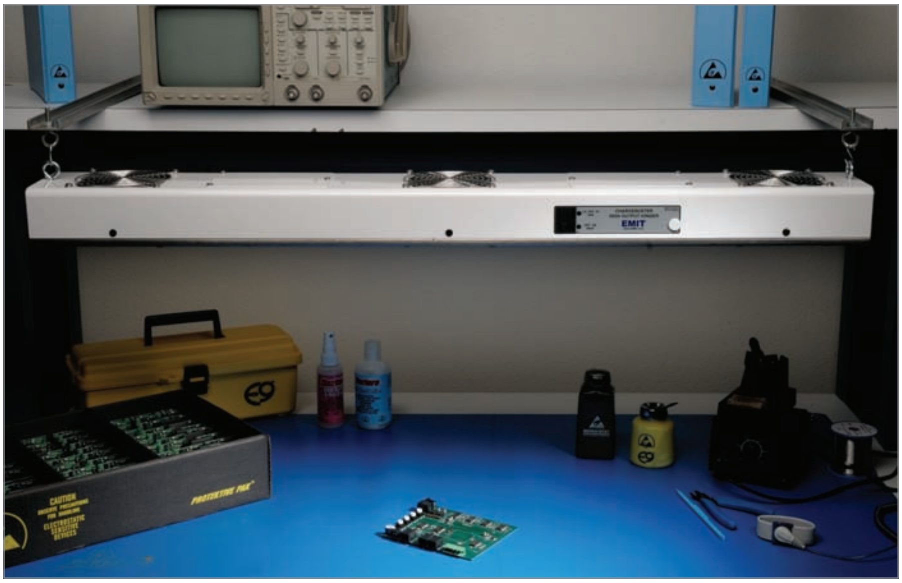

Figure 5: An overhead ionizer

Components Table 3, devices are classified as follows:

CLASS I	<200 volts
CLASS II	200 to <500 volts
CLASS III	500 to 1000 volts
CLASS IV	>1000 volts

The importance of CDM came about primarily because of the increased use of automated component handling systems. The Foreword of ANSI/ESD STM5.3.1 states, “In the CDM a component itself becomes charged (e.g., by sliding on a surface (tribocharging) or by electric field induction) and is rapidly discharged (by an ESD event) as it closely approaches a conductive object.”

In November 2002, Roger Peirce published an article entitled “The Most Common Causes of ESD Damage” [9]. There were actually 23 causes. As the founder and president of ESD Technical Services, Roger had investigated hundreds of companies for over eight years. All 23 causes were CDM failure modes. So CDM is really not so new, It has just received a lot of attention in the last few years.

TACKLING CDM

So, what are the things companies should look at to improve their ESD control program regarding CDM? It would seem to be easy: don’t slide ESDS devices and assemblies unless grounded at all times, keep insulators at least 12” away from ESDS, and don’t allow ESDS items to make contact with a conductive surface. Seems simple, but in actual application . . . not so easy.

If the ESD control program has not used ionization, that possibility should be considered. If ESDS items become charged, ionization will help neutralize the charge. The primary function of ionizers with regard to ESDS items are:

- to remove/neutralize charges from process necessary insulators, which can charge ESDS items and thus create the potential for a damaging CDM event.
  Remember that the PCB substrate is a process necessary insulator and can become charged during automated handling processes.
- to remove/neutralize charges from a charged, isolated/floating conductor which, when grounded, can result in a potentially damaging CDM event.
  Remember that during automated handling processes, the ESDS devices on the PCB are isolated or floating conductors.

The ESD Standards Committee has a Working Group (WG-17) which is currently involved with developing a standard for process assessment to help members of the electronics community assess their manufacturing and handling processes, and determine what levels of devices their process can handle. Once one fully understands where a process is with regard to ESDS devices and assemblies, one will have a clearer picture of what actions need to be taken to further improve the ESD Control Program.

If ionizers are already in use, a company should consider reducing the ionizer offset voltage limit of ±50 volts (the required limit in ANSI/ESD S20.20) to ±25 volts and maybe less, depending on the application and device sensitivity. Discharge times are user defined and should be considered for reducing the time required to neutralize a ± 1,000 volt charge to ± 100 volts.

The required limit for worksurfaces per ANSI/ESD S20.20 is less than 1 x 10^9 ohms, with no lower limit. Most companies handling electronics should

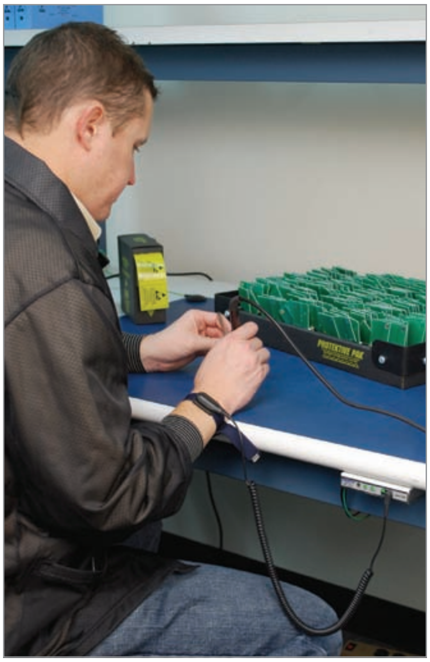

Figure 6: A Statfree Worksurface Mat

be following the recommendation of the worksurface standard ANSI/ESD S4.1 [10] that the lower limit be 1 x 10^6 ohms. To combat CDM failures, all surfaces that might come into contact with ESDS items should follow, where possible, the worksurface standard and be dissipative at the 1 x 10^6 to less than 1 x 10^9 ohms range used. Items such as static shielding bags will have a higher resistance on the interior and exterior surfaces, but still must be less than 1 x 10^11 ohms.

OTHER CONSIDERATIONS

Discipline

A significant increase in the discipline of implementing the fundamentals of ESD control, noted in the ANSI/ESD S20.20 Foreword, calls for:

- grounding all conductors in the EPA, including people.
- removing all insulators from the EPA or using ionizers for process-necessary insulators.
- packaging ESD sensitive items that go outside the EPA in packages that provide electrostatic discharge shielding.

Insulators

We encourage developing a hatred for insulators. The alternatives are to:

- remove the insulative item from the EPA.
- substitute the item with an ESD protective version (such as tape, document holders, material handling containers, plastic bottles, etc.)
- periodically treat insulative surface with a topical antistat.
- neutralize electrostatic charges using ionization.

Other ESD Control Items

Other EPA ESD control items to add to the ESD control program might include shelving, mobile equipment (carts), gloves, and/or seating.

Improve Compliance Verification Plan

- Consider greater frequency of internal audits per ESD TR53 [11].
- Use a computer data collection system for wrist straps and footwear testing, continuous monitors, and ionizers.
- Use ground continuous monitors for worksurfaces and other ESD elements.
- Test ionizers more frequently; consider self-monitoring ionizers and computer-based data collection.
- Increase testing that uses a static field meter to verify that automated processes (like auto insertion, tape and reel, etc.) are not generating charges above acceptable limits.

Improve Training

- Provide ESD-awareness training for everyone in the EPA and anyone who may come into the EPA, including suppliers.
- Improve testing to verify comprehension and training adequacy.
- Improve training on the proper use of test equipment.
- Enhance training on proper compliance verification test procedures.

Figure 7: A surface resistance test kit

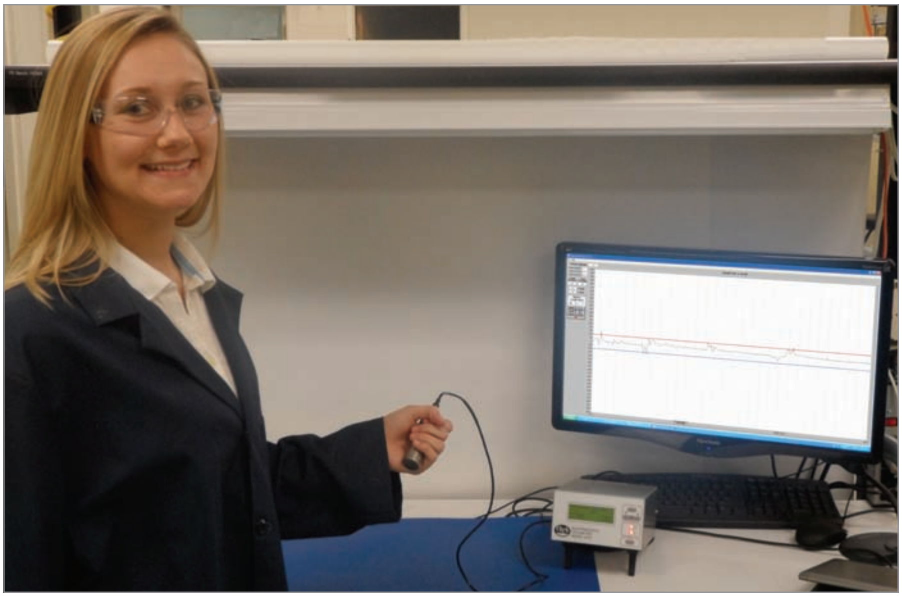

Figure 8: A volt meter and software in factory showing STM97.2 testing of voltage charge on a person (courtesy of TREK, INC.)

Just to maintain its current level of quality and reliability may require a substantial improvement in a company's ESD control program. Now is the time for improvement, as ESD sensitivity withstand voltages continue to get lower.

CONCLUSION

Just to maintain its current level of quality and reliability may require a substantial improvement in a company's ESD control program. Now is the time for improvement, as ESD sensitivity withstand voltages continue to get lower and companies may soon be handling class 0A HBM items. To combat HBM failures, improved personnel grounding is required. For example, heel grounders should be replaced with full coverage foot grounders. However, most failures are CDM. To combat CDM failures, ionization should be added or improved, and conductive surfaces should be covered with dissipative material. In general, discipline should be enhanced implementing ESD control fundamentals, compliance verification testing should be increased, and training should be improved.

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Investigation into the Errors Introduced by Performing EN 61000-4-3 Test Set-up Verification Using Multiple E Field Probes

BY DAVE CULLEN, GERARD EDWARDS AND ANDY MARVIN

The electromagnetic compatibility (EMC) test standard EN 61000-4-3 [1] requires the equipment under test (EUT) to be illuminated by an **E** field having a uniform intensity across the plane occupied by the forward-facing side of the EUT. To ensure the **E** field is sufficiently uniform, the test standard describes a verification method using an electric field probe to measure the field intensity across the test plane at sixteen (extending to twenty for floor-mounted EUT) points on a 0.5m x 0.5m grid. Should the field intensity across these points fall outside the prescribed limit (at least 75% must be within -0/+6dB of the target level) then action must be taken to improve the field uniformity.

The test is performed in an absorber-lined screened room acting as a free-space environment (Figure 1) and, in practice, modifications to obtain

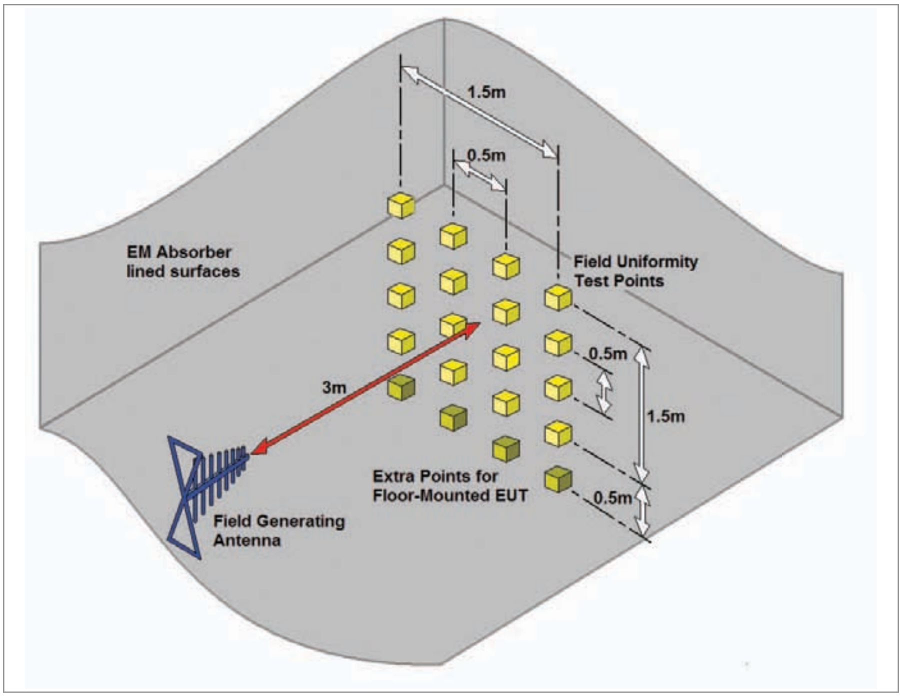


Figure 1: Field uniformity verification points for EN 61000-4-3 radiated immunity test setup.

Being able to measure all test points simultaneously would significantly reduce the time needed to perform the verification.

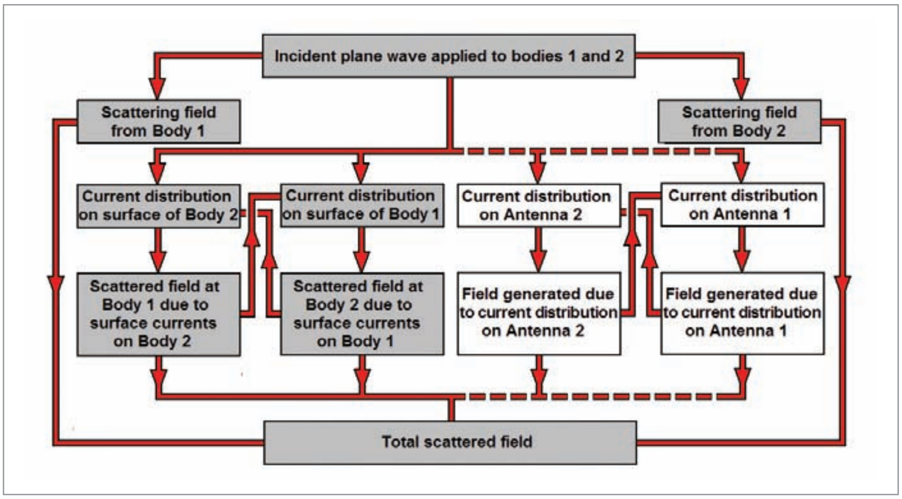


Figure 2: Flowchart for analyzing two-body scattering proposed by Elsherbeni and Harmid, expanded to include the case where bodies contain current-carrying antenna structures.

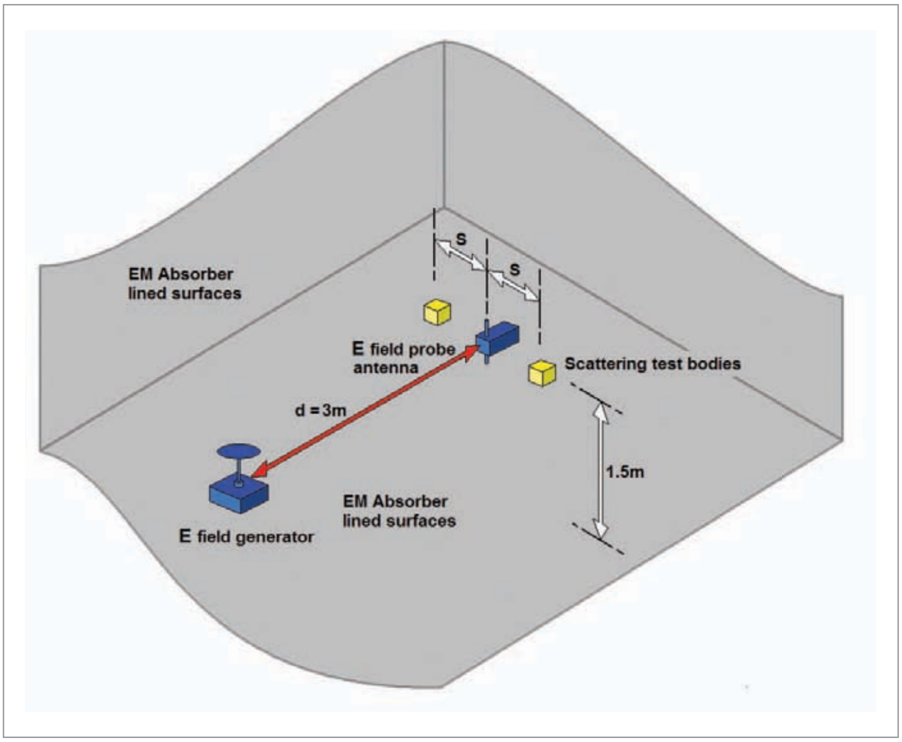


Figure 3: Test setup for evaluating the effect of nearby objects on E field measurements with the fixed distance between the field generator and test point probe position being *d* = 3m and the variable distance between probe and neighbors being *s* m.

field uniformity may involve simple strategies such as simply adjusting the field transmit power or the positioning of the transmit antenna and EUT. However, any remaining reflections within the interior of the room can establish interference patterns that lead to significant localized deviations in field intensity. Improvements may therefore extend to changing the characteristics of the room, for example by altering the type or arrangement of absorber material lining. This kind of work may be needed at regular intervals, where the room infrastructure and absorber are subjected to the daily wear and tear of a busy laboratory. Because the location and magnitude of any peaks and nulls in the interference pattern are affected by spatial position and source signal wavelength, adjusting the test environment to fix one problem spot may introduce a new problem at a different location/frequency combination. The verification process must therefore be repeated following any changes, meaning a fresh frequency sweep for each of the sixteen (or twenty) test points. Using a single probe, the verification process described in the test standard can take hours for a "good" test environment, while a room with "marginal" characteristics in need of adjustment can tie up time and resources with days of painstaking work. Furthermore, the test standard states that verification should take place before the facility is used to test an EUT, which in practice can be prohibitively difficult given the time constraints.

Being able to measure all test points simultaneously would significantly reduce the time needed to perform the

> However, leaving aside the cost of owning several probes, the problem with this approach is that each probe distorts the E field to some degree.

verification. However, leaving aside the cost of owning several probes, the problem with this approach is that each probe distorts the **E** field to some degree. The degree of field distortion caused by a hypothetical multiple **E** field probe array has been investigated to determine whether the resulting measurement error is small enough to make this a viable means of addressing the requirements of EN 61000-4-3. If the error lies within the order of a typical **E** field probe measurement accuracy of around 1dB [2 - 4], then this would be considered acceptable for pre-test verification of the test setup.

SOURCES OF MEASUREMENT ERROR

The presence of a conducting body, such as the metallic field probe, causes distortion of the **E** field by scattering the incident electromagnetic wave. Depending on the surface properties of the body, such scattering may be specular (e.g. from a mirrored surface) or random (e.g. diffuse reflection from a rough surface). The re-radiated fields combine with the source field to establish interference patterns, leading to field intensity peaks and nulls whose spatial position and magnitude vary depending on the wavelength of the incident wave and the relative positions of any scattering surfaces.

Further distortion is caused where the body absorbs energy from the incident wave and then, by some mechanism, causes a new field to be radiated. For a body such as an antenna, currents induced by the incident field will themselves radiate fields, the pattern and orientation of which will be dependent on the "shape" of the surface currents.

These effects are iterative, becoming increasingly complex with the number of bodies within the field. A flowchart indicating the interaction between two such bodies has been presented previously (Figure 2) [5]. To investigate the properties of field probes, the flowchart has been expanded to include the case where the bodies contain antenna elements. The antenna elements are considered to have scattering, absorption and re-radiation properties that can be analyzed separately from those of the body itself, relating as they do to currents flowing in the antenna due to their physical structure and the connected load circuitry.

SCATTERING EXPERIMENT METHOD

Comparing the measurement of the **E** field intensity in a typical radiated immunity (RI) test setup (Figure 3) using a single probe, with measurements made in the presence of nearby scattering objects (Table 1), shows the error introduced by field scattering. The objects were chosen to give a spread of sizes around that of the example 1GHz field probe, being roughly a 50mm metal cube. The measurement using 100mm cube scattering bodies was repeated with them covered in ferrite tile material to alter their reflective properties. The tests were performed inside a fully anechoic chamber compliant with the test standard and, to minimize their effect on the **E** field, low ε_r polystyrene stands were used to mount the source **E** field generator, probe and test objects.

The **E** field was generated by a 30MHz – 2GHz broadband noise source fitted with a monopole antenna [6], so that sweeping the source signal was unnecessary. Measurements were taken at a point *d* = 3m away using a dipole antenna fitted with two 20mm long elements.

Object	*Size*	*Construction*	*Separation (s)*
1	Cube, *l* = 100mm	Metal box	0.3m
2	Cube, *l* = 50mm	Metal box	0.5m
3	Diameter *h* = 15mm Length *l* = 100mm	Metal cylinder	1.0m
4	Cube, *l* = 120mm	100mm metal box with ferrite covering	

Table 1: Scattering bodies and their separation distances from the probe.

Adequate measurements were achieved using this setup to 2GHz, being limited by the upper frequency limit of the dipole probe. Further measurements to 6GHz are planned.

EXPERIMENTAL RESULTS

Figures 4 to 6 show the deviation introduced by the scattering bodies from the measurement made with the probe in isolation. In this case the source and test probe antennas are vertically polarized (i.e. the scattering bodies broadside to the field probe antenna), and the results are presented with increasing separation between the test probe and the scattering bodies. Where the source and test probes are horizontally polarized (i.e. the scattering bodies are end-on the field probe antenna) a lesser degree of distortion is noted, providing the distance between the probe antenna and scattering body does not become too small (<= 0.3m as measured). Given that **E** field probes typically employ electrically short antennas of only a few millimetres in length, this should not be a problem using the EN 61000-4-3 verification grid of 0.5m.

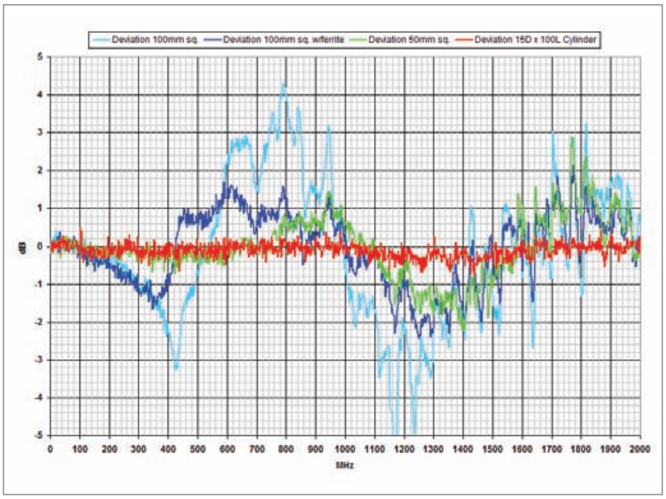


Figure 4: Deviation of the E field strength due to the presence of nearby test objects, where the separation between probe and objects *s* = 0.3m. Traces shown are: 100mm³ cube (cyan), 120mm³ cube with ferrite (blue), 50mm³ cube (green), 15mm dia. × 100mm (red).

The results support the intuitive notion that a larger body leads to a greater disturbance and the further it is from the test probe the weaker the disturbance. In addition, it is clear that the separation affects the periodicity of the constructive/destructive interference pattern at the measurement point, i.e. the closer the scattering objects, the shorter the effective disturbance wavelength and hence a larger periodicity between maxima/minima in the frequency domain.

A simplified example of the interference causing this error is shown in Figure 7, which considers the test setup using vertically polarized antennas as an approximation of the multipath propagation between two horizontally polarized dipoles over a reflecting ground plane. The only ray paths considered are ones with reflections from the corner of the adjacent object (Figure 7). The phase inversion associated with ground-plane reflections of horizontally polarized waves leads to maxima (where the waves at the observation point are in-phase) when the difference between path lengths is a half-integer number of wavelengths (n_{max}). Similarly, minima (where the waves at the observation point are in anti-phase) occur when the path length difference equals an integer multiple of wavelengths (n_{min}).

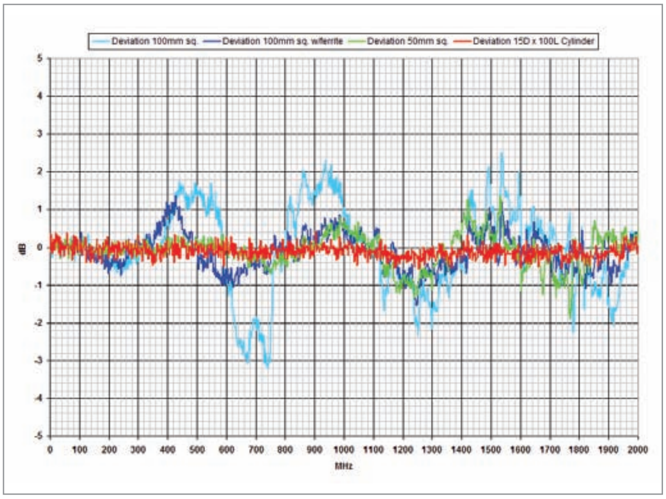


Figure 5: Deviation of the E field strength due to the presence of nearby test objects, where the separation between probe and objects *s* = 0.5m.

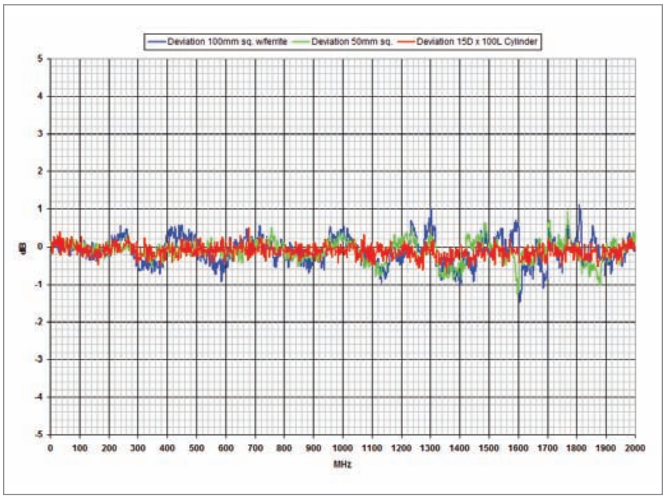


Figure 6: Deviation of the E field strength due to the presence of nearby test objects, where the separation between probe and objects *s* = 1m.

$$Maxima\ (f) = \frac{\left(\frac{c}{\lambda_{difference}}\right)}{2} = \frac{cn_{max}}{2\{(P_1+P_2)-d\}} Hz$$

Equation 1a

$$Minima\ (f) = \frac{c}{\lambda_{difference}} = \frac{cn_{min}}{\{(P_1+P_2)-d\}} Hz$$

Equation 1b

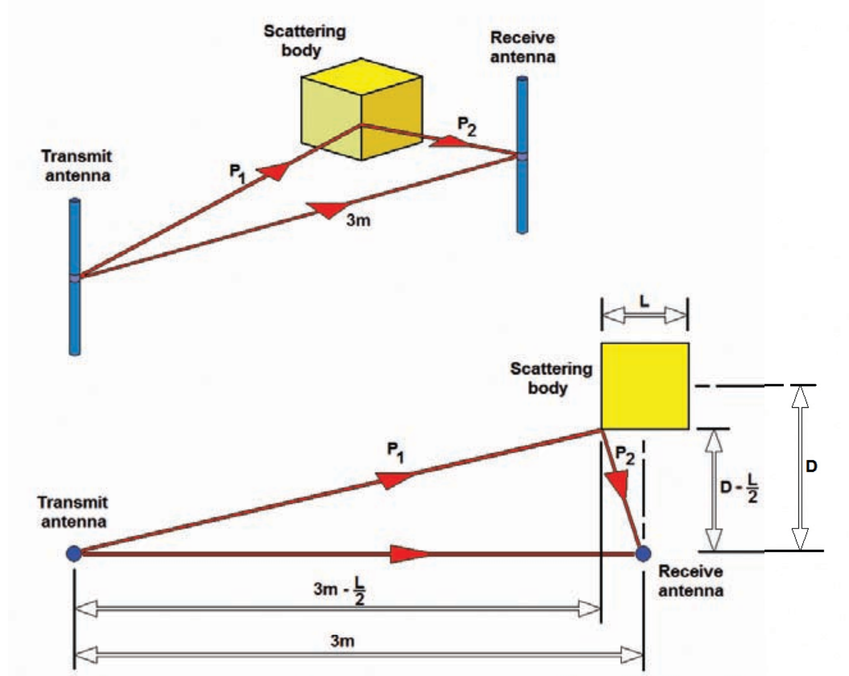
In reality, the effect will be the sum of all the rays reflecting from points on the body's surfaces. A fully descriptive closed-form analytical solution is therefore difficult to achieve, although formulae for simplified models involving pairs of scattering bodies with basic geometries have been presented [7, 8].

These results indicate that, up to a frequency of 2GHz, a disturbance of < 1dB could be achievable using probes 50mm x 50mm x 50mm in size, or smaller, on the 0.5m spaced grid defined by EN 61000-4-3. The selection of field probes for this kind of application should therefore favor a small footprint facing the source, with a shape designed to scatter any reflections away from the neighboring probes.

ANTENNA INTERACTION MODELING METHOD

The interaction between antenna elements is also iterative, with the net effect being the sum of transmitted fields from all parts of the antennas involved. A closed-form analytical solution is once again therefore difficult to achieve, although formulae for simplified models involving pairs of half-wave dipoles have been proposed [9]. Because of this, numerical modeling has been used to investigate the contribution to measurement error made by the antenna elements of a typical field probe.

One way of describing the interaction between antennas is by their mutual impedance characteristic. Consider two antennas in the presence of a common incident electromagnetic field described by two coupled equivalent circuits (Figure 8). For Antenna 2, the voltage induced by the common incident field (V_{E2}) causes current I_2 to flow through load impedance Z_2. This current flowing in Antenna 2 generates its own radiating field, which couples



	Displacement	Object dimension (m)	P1 (m)	P2 (m)	Sum (m)	Difference (m)	Fmaxima (lambda/2)	Fminima (lambda)
a)	0.3	0.015	3.007	0.293	3.299	0.299	1002.147 MHz	501.074 MHz
b)	0.3	0.05	2.988	0.276	3.264	0.264	1137.152 MHz	568.576 MHz
c)	0.3	0.12	2.950	0.247	3.197	0.197	1521.561 MHz	760.780 MHz
d)	0.5	0.015	3.033	0.493	3.525	0.525	571.087 MHz	285.544 MHz
e)	0.5	0.05	3.013	0.476	3.488	0.488	614.327 MHz	307.164 MHz
f)	0.5	0.12	2.973	0.444	3.417	0.417	719.744 MHz	359.872 MHz
g)	1	0.015	3.153	0.993	4.145	1.145	261.935 MHz	130.967 MHz
h)	1	0.05	3.131	0.975	4.106	1.106	271.244 MHz	135.622 MHz
I)	1	0.12	3.087	0.942	4.029	1.029	291.679 MHz	145.839 MHz

Figure 7: Calculations for predicted frequencies of maxima/minima in received signal due to multipath propagation (due to reflections from the leading edge only). The distance between the field generator and test point probe position is *d* = 3 m.

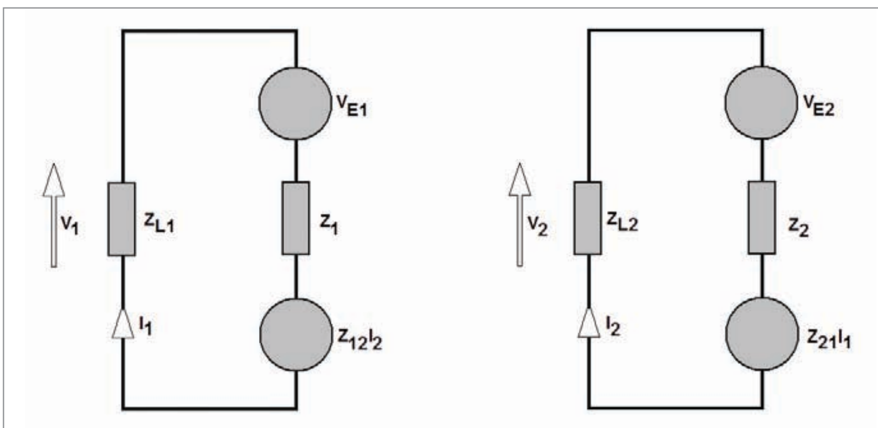


Figure 8: Equivalent circuit of mutually coupled antennas in a common incident E field. Where: V_{E1} and V_{E2} are the voltages induced by an incident wave on antenna 1 and 2 respectively. Z_1 and Z_2 are the impedances of Antennas 1 and 2 respectively. Z_{L1} and Z_{L2} are the load impedances. $Z_{12}I_2$ and $Z_{21}I_1$ are the voltages induced by mutual coupling.

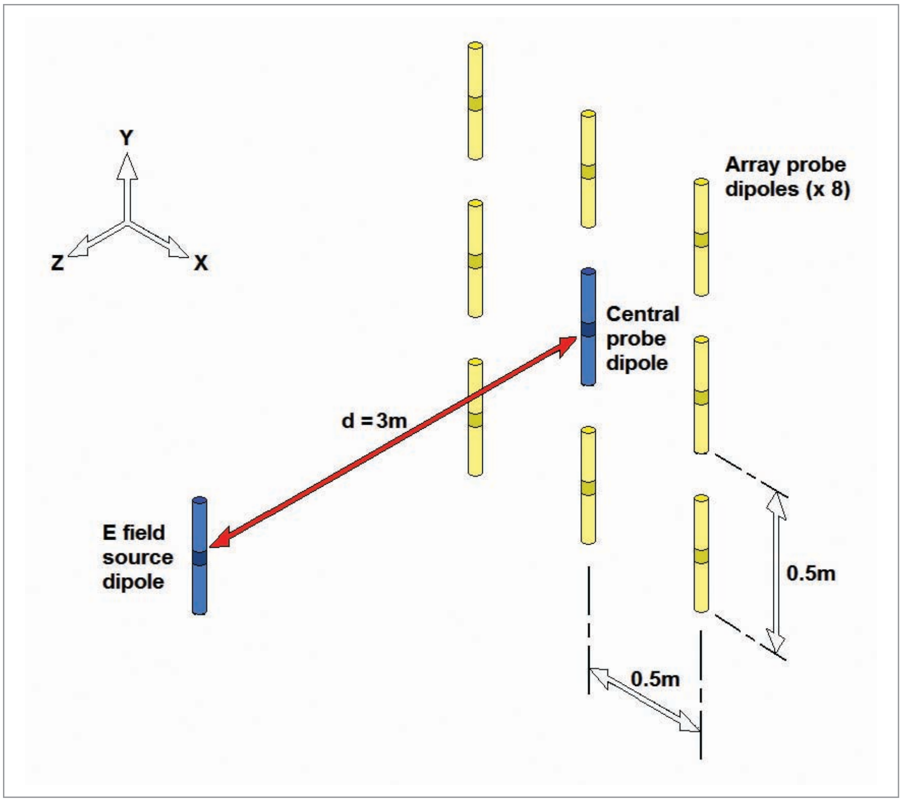


Figure 9: Model arrangement of source, receive and array dipoles. NEC E field results are presented later for a plane cutting this figure centrally containing the source and central probe dipole.

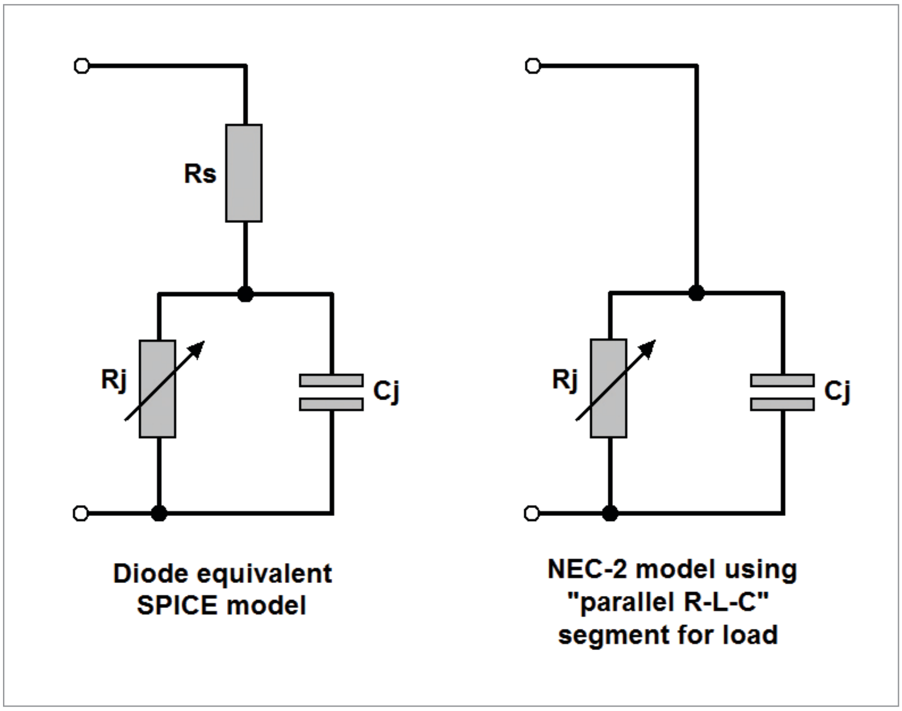


Figure 10: Simplified diode model and the equivalent load circuit consisting of a parallel R/C circuit.

with Antenna 1 in addition to the incident field, inducing a voltage that is proportional to the current I_2. This secondarily induced voltage in Antenna 1 can be defined as $Z_{12}I_2$, where Z_{12} is the term of mutual impedance.

By examination of Figure 8, it can be seen that increasing load resistances Z_{L1}, Z_{L2} will reduce I_1 and I_2 respectively. This will reduce voltages $Z_{12}I_2$ and $Z_{21}I_1$ and hence the effect of mutual impedances Z_{12}, Z_{21}, thereby lessening the error in the intended measurement of voltages V_{E1} and V_{E2}. For the field probes being investigated, the antenna loads are essentially Schottky detector diodes whose sensitivity and impedance characteristics are bias-current tuned. Since the impedance of the detector circuit within a given field probe is unknown to the user, a range of values needs to be investigated in order to find out whether this characteristic contributes significantly to the measurement error in the probe array.

The interaction between the probe antennas was modeled using the widely available NEC-2 software. This uses the Method of Moments (MOM) technique, which is particularly suited to problems involving elementary wires, currents and fields in homogenous environments encountered by the interaction between antennas in a free-space environment. Again, the response to an incident **E** field of a single probe antenna in isolation is compared with that obtained when the probe is the central object in the presence of the other nearby probe's antennas on the 0.5m test grid array (Figure 9).

The field probes are modeled as electric dipoles, comprising perfectly conducting rods with Shottky detector diode circuit equivalents at the central load points. This method has previously been used successfully to analytically and numerically study and predict the operation of electric dipole field probes [10]. Realistic values for dipole length and load are used to determine the error introduced in an actual antenna/detector pair.

Simplified equivalents of the diode detector loads have been implemented in the NEC-2 model as single-segment parallel R/C networks (Figure 10) with variable values of resistance R_j.

For a typical Schottky detector diode [11], the values given are $R_s = 6\Omega$, $C_j = 0.18$pF and $R_j = 8.33 \times 10^{-5}\, nT / (I_b + I_s)$, where $n = 1.08$, T = temperature (K), $I_s = 5\times10^{-8}$A (saturation current) and I_b = bias current. From the characteristics given, a bias current of 1µA gives $R_j = 26\text{k}\Omega$, zero-bias gives $R_j = 540\text{k}\Omega$ and 1mA bias gives $R_j \approx 27\Omega$. Simulations were performed using R_j values of 50Ω and 250kΩ.

The NEC-2 model uses a current-driven dipole at a distance d = 3m from the probe array to generate the incident **E** field (Figure 9). Comparing the voltages generated across the central probe dipole's load in the presence of this **E** field, in isolation and when surrounded by eight identical antennas in a grid array, gives the error due to antenna coupling.

MODELING RESULTS

An **E** field plot for the NEC-2 numerically generated results is shown in Figure 11. This shows a section defined by the plane containing the source and the three probe dipoles comprising the middle column of the array (Figure 8). The source antenna is visible at the top of the plot, with the cross-section through the generated **E** field clearly showing the characteristic toroidal pattern of intensity for a radiating electric. The individual antennas comprising the receive array are visible at the bottom of the plot, with all dipoles aligned along the y axis. Those antennas in the plane of the plot clearly show interaction with the **E** field as a localized disturbance in the field intensity.

The responses shown are of the voltage produced by the detector, normalized to the incident **E** field intensity generated by the source dipole. Figure 12 (page 42) shows the result using a 40mm dipole probe (i.e. a pair of 20mm elements) with a 250kΩ diode detector, in isolation and in the presence of the probe array.

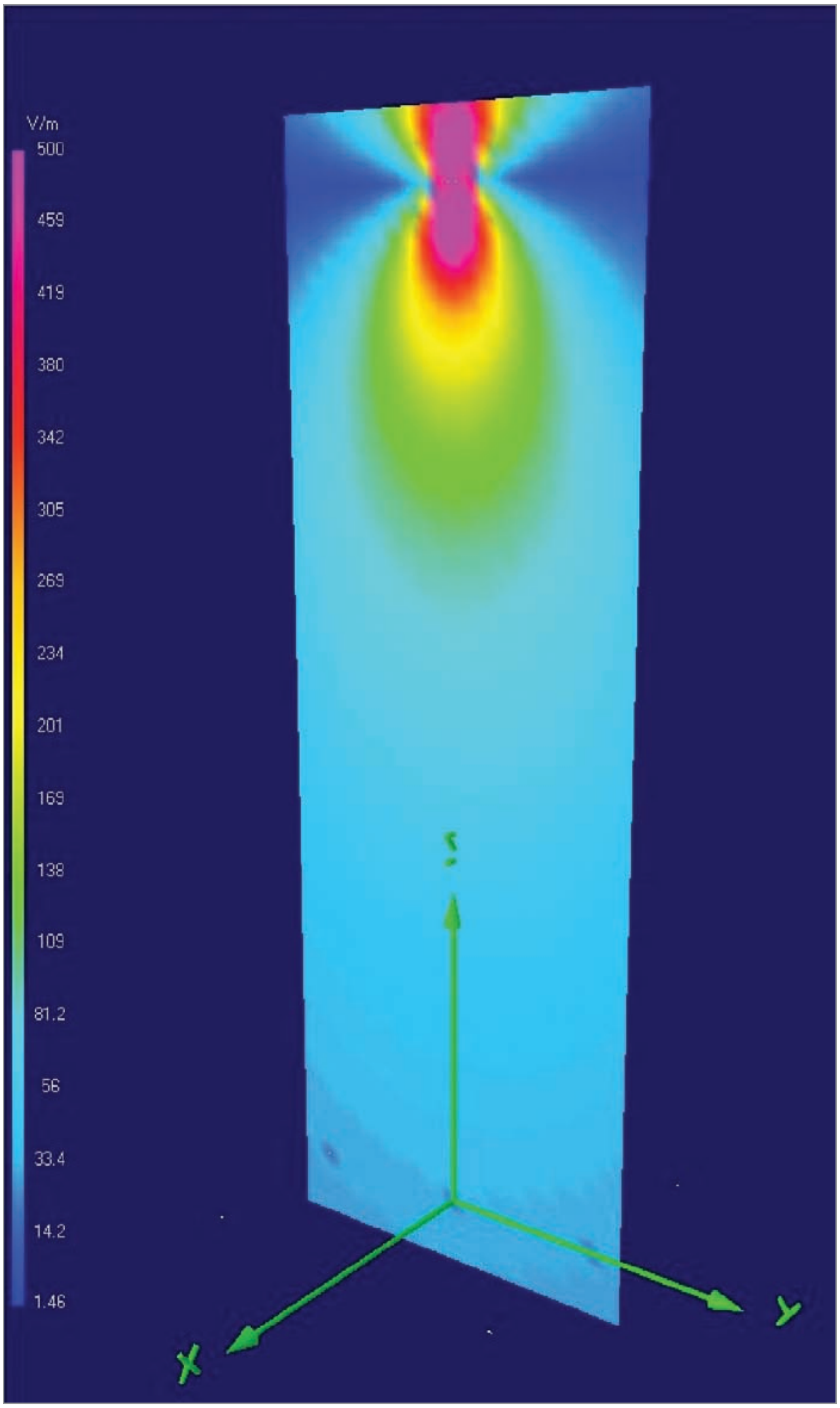


Figure 11: Plot of E field across the central plane of the dipole antenna array containing the source and central probe dipoles (Figure 8 for probe array geometry).

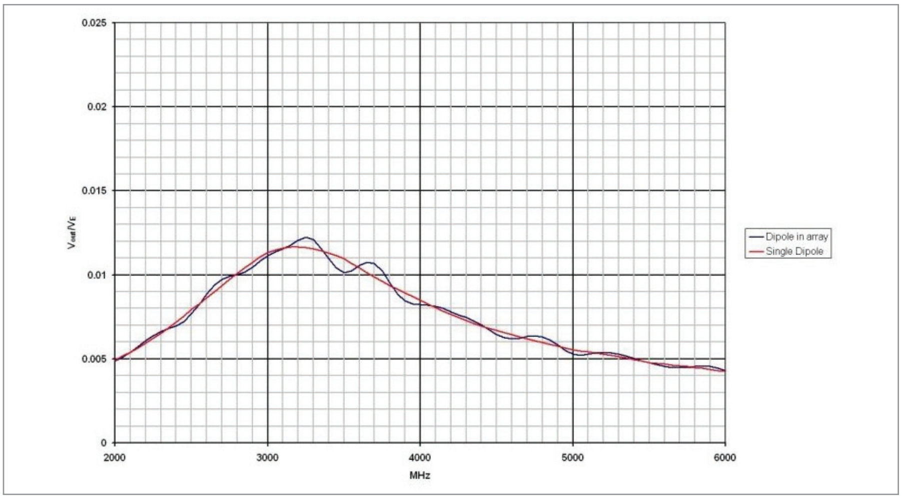


Figure 12: Normalized transfer function against frequency of the 40mm (two 20mm elements) dipole, with a 250kΩ detector diode model.

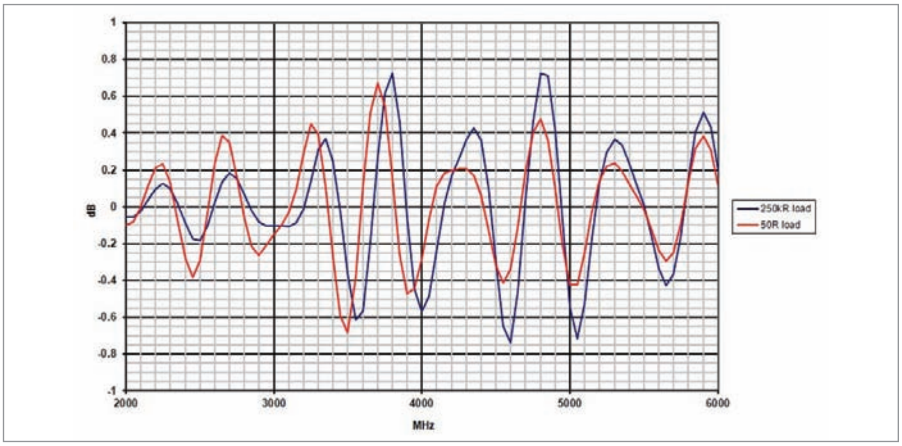


Figure 13: Deviation versus frequency due to the presence of the array of 40mm (two 20mm element) dipoles, with 50Ω and 250k Ω detector diode models.

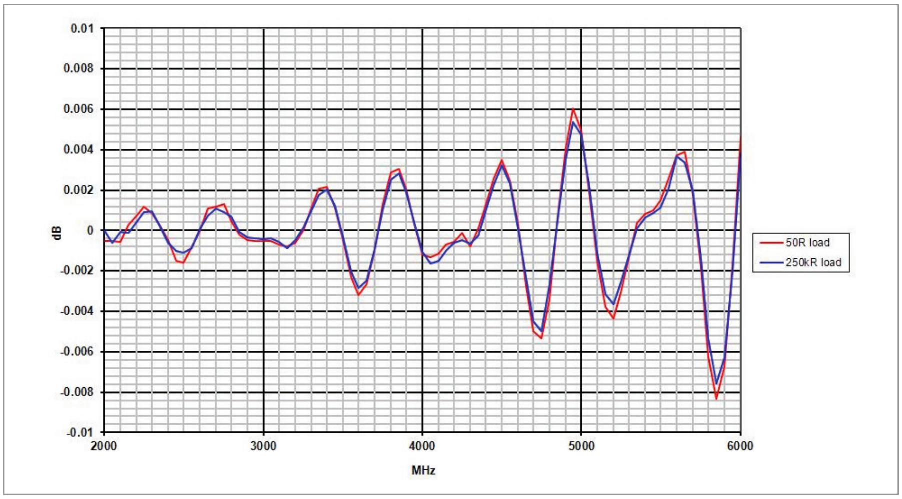


Figure 14: Deviation versus frequency due to the presence of the array, for 10mm (two 5mm element) dipoles, with 50Ω and 250k Ω diode models.

In Figure 13 the difference between the single probe and array responses for load resistance values of 50Ω and 250kΩ are plotted, and thus gives the array-measurement error value. This indicates that the array introduces a maximum error approaching +/-0.8dB around a frequency region close to the 40mm dipole's half-wave resonance (assuming effective dipole length is 0.9 of the actual length, λ/2 = 4.17GHz). From this, it can be seen that increasing detector load resistance does not significantly reduce the array error.

Field probe designs often employ electrically short antennas, which trade a flatter frequency response against lower sensitivity. At 6GHz, a 5mm antenna is still less than λ/10, thereby satisfying the criteria for an electrically short antenna. The simulation was repeated using a 10mm dipole (two 5mm elements) in place of the 40mm dipole.

Figure 14 shows the expanded difference between the single probe and array responses for both 50Ω and 250kΩ detector diode models, giving the array-measurement error. This indicates that the array now introduces a maximum error approaching +/-0.008dB, a significant improvement over the longer dipole model.

This improvement indicates a reduced degree of mutual coupling, as the shorter 10mm dipoles are less efficient receivers and transmitters than the 40mm dipoles, which are operating around their λ/2 point. The mutual coupling between them is greatly reduced and consequently the error introduced is also reduced.

The diode load impedance again does not appear to have much effect. This is because the 10mm dipoles remain electrically short across the frequency range examined and so exhibit very low antenna resistance R_r. As a result, increasing R_L beyond a few 10's of ohms does not significantly reduce the error due to the mutual impedance between the array antennas. The probe manufacturer's configuration of the detector circuit does not therefore appear to be significant in choosing probes to be used in the array. However the type of antenna used might be more significant, favoring those that remain electrically short across the full working frequency range.

CONCLUSIONS

This study has shown that it is possible to use an array of field probes to measure **E** field intensity at many points simultaneously, thereby significantly reducing the measurement time needed, whilst keeping the naturally resulting errors due to probe antenna coupling within acceptable levels for pre-test verification checks. With regards to EN 61000-4-3 test setup verification, careful selection of the probe size and antenna configuration can keep the errors to an order similar to the inherent accuracy of a typical commercially available probe.

Given the cost involved in such an array, and that the fully populated array of sixteen probes at 0.5m spacing would produce the largest errors due to scattering, a partial solution involving fewer probes could be an attractive compromise. For example, rotating four probes around the grid so as to keep 1m clearance between them would still significantly reduce the test time compared with a single probe, whilst lowering the error factor and implementation cost compared with the full sixteen probe solution.

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ESD Electronic Design Automation Checks

Part 2: Implementing ESD EDA Checks in Commercial Tools

BY MATTHEW HOGAN

Electrostatic discharge (ESD) design rules verification has grown in volume and complexity as integrated circuit (IC) designs have become more complex and added significantly more power domains. With each additional power domain, verification of the signals that cross these domains becomes more difficult (particularly in the identification of inadvertent paths), as well as the check of interactions between circuit blocks that may result in many potential ESD discharge current paths [1]. While not strictly related to ESD, designs that incorporate multiple power domain checks are particularly susceptible to subtle design errors that are difficult to identify in the simulation space or with traditional PV techniques. Often, these subtle reliability errors don't result in immediate part failure, but in performance degradation over time. Effects such as negative bias temperature instability (NBTI) can lead to the threshold voltage of the PMOS transistors increasing over time, resulting in reduced switching speeds for logic gates [2-4]. At the same time, hot carrier injection (HCI), which alters the threshold voltage of NMOS devices over time [5], and soft breakdown (SBD) [5] also contribute as time-dependent failure mechanisms, adding to the degradation effects of gate oxide breakdown.

ESD rules for ICs with multiple power domains, IP reuse, and system integration require greater complexity to avoid device damage. Design hierarchy also comes into play where some rules are applied on a top cell and/or top pads, but others are applied between internal blocks that cross multiple power domains. Tracking the rules and the nets to which they apply is by no means a trivial task when

ESD rules for ICs with multiple power domains, IP reuse, and system integration require greater complexity to avoid device damage.

performed manually. Automation is necessary to effectively and efficiently cope with these requirements.

As a result, multiple methods have been developed using modeling or simulation to perform chip-level ESD verification [6-8]. However, while simulation-based ESD verification methods, to verify compliance to human body model (HBM) and charged device model (CDM) requirements, are effective, they do not necessarily check all elements in the design for ESD violations. In particular, internal interfaces between different supply domains are not explicitly checked. Additionally, getting device models for simulation at these extreme conditions is often problematic.

Part 1 of this series, "Outlining the Essential requirements of the ESD Verification Flow", provided an overview of the essential requirements of an effective ESD EDA verification flow [14]. This article (Part 2) discusses a well-established topological methodology for checking ESD design rules. The ESDA Technical Report 18, "ESD Electronic Design Automation Checks" (TR18) [13], provides an overview of recommended ESD checks that should be performed to validate appropriate ESD protection structures within a design. We will focus our effort on TR18 rule 5.1.3, which applies to internal interfaces between power or ground domains, a requirement that has been recently highlighted [9-11]. Rather than modeling or simulating, the methodology uses the device netlist topology to check all domain crossing interfaces and associated ESD devices in the entire design, and is realized using the Calibre® PERC™ tool from Mentor Graphics. Although internal interfaces may span many levels in the design hierarchy, checking is done hierarchically by utilizing a novel technique for topology-aware verification. In addition to performing topology checking, at times there is the need to include both topology and physical information to create a more comprehensive checking environment. Such an environment is required to perform ESD layout verification checks [12].

The following sections cover the targeted ESD rules, the new hierarchical algorithm, ESD rule variations. and verification results.

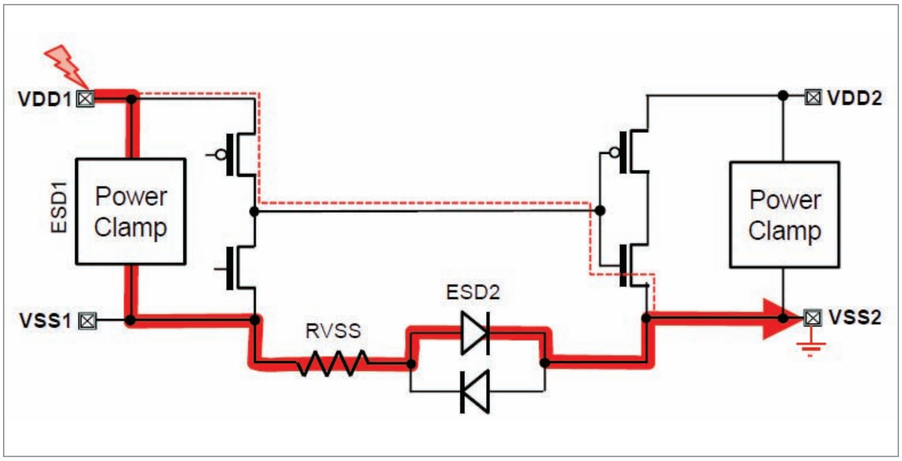

Figure 1: Typical signal cross-domain ESD issue *(source: EDA Tool Working Group (2011),* **from** *ESD Electronic Design Automation Checks (ESD TR18.0-01-11) [13]*

THE ESD RULE

Transistors' gates can be exposed to direct ESD events. This is particularly common in input receivers, although many other topologies can expose a gate oxide to an ESD discharge path. Since gate oxides (by virtue of their small capacitance) cannot shunt any significant amount of current, they have to be considered voltage pulse driven as far as their failure mechanism is concerned. It is irrelevant whether the gate oxide is connected to signal, ground, or supply. The failure criteria will depend on the actual combination exercised and whether a soft vs. hard oxide breakdown sets the failure limit (application-dependent) [13].

ESDA TR18, check 5.1.3 [13] is intended to verify presence of protections on signals that cross a power domain boundary. As shown in Figure 1, when the pad VDD1 is struck with respect to VSS2, a high voltage could be developed across the gate-source oxide of the NMOS in the VDD2 power domain.

To define our rule, we begin by identifying the ESD protection strategy; to protect this component we need to ensure that the voltage across it does not exceed the set failure level.
A simplified overview of the check that needs to be performed to ensure

Drivers and receivers are determined by net connectivity, as are the different power domains.

the gate oxide is adequately protected is as follows:

For each net in design,
IF net connects *driver* and *receiver*
THEN
check *power domains* of driver and receiver
IF different power domains
THEN
check for anti-parallel *diodes*
IF anti-parallel *diodes* do not exist
THEN
ESD error

Drivers and receivers are determined by net connectivity, as are the different power domains. Because this is an interface, the pieces of the circuit that must be checked are usually distributed between different levels of the design hierarchy, so it is not obvious how to check the rule independently on a cell-by-cell basis. However, using a flat approach does not provide sufficient capacity to run larger chips. For scalability reasons, it becomes necessary to develop a hierarchical topological approach to efficiently solve this issue. We present here such a method that performs hierarchical verification.

HIERARCHICAL VERIFICATION

Overview

The first requirement is a SPICE netlist, which can be either a schematic netlist or a netlist extracted from the layout. In the latter case, the LVS-like runset used for extraction must ensure that all ESD protection devices are extracted (Note: parasitics are not extracted, just intentional devices). While the netlist must contain the proper text names for device pins (so that power and ground domains can be established), in general, texting in the netlist is not used extensively for verification (see Figure 2).

The second input is an ESD rule deck. It specifies the ESD design rules to be checked, and the list of power and ground domain names. Power and ground names are not generated automatically; they must be specified in the rule deck per the design specification. This rule deck is essential for making the verification method generic. For ease of discussion, however, we will describe the method in the context of the ESD design rule formulated above.

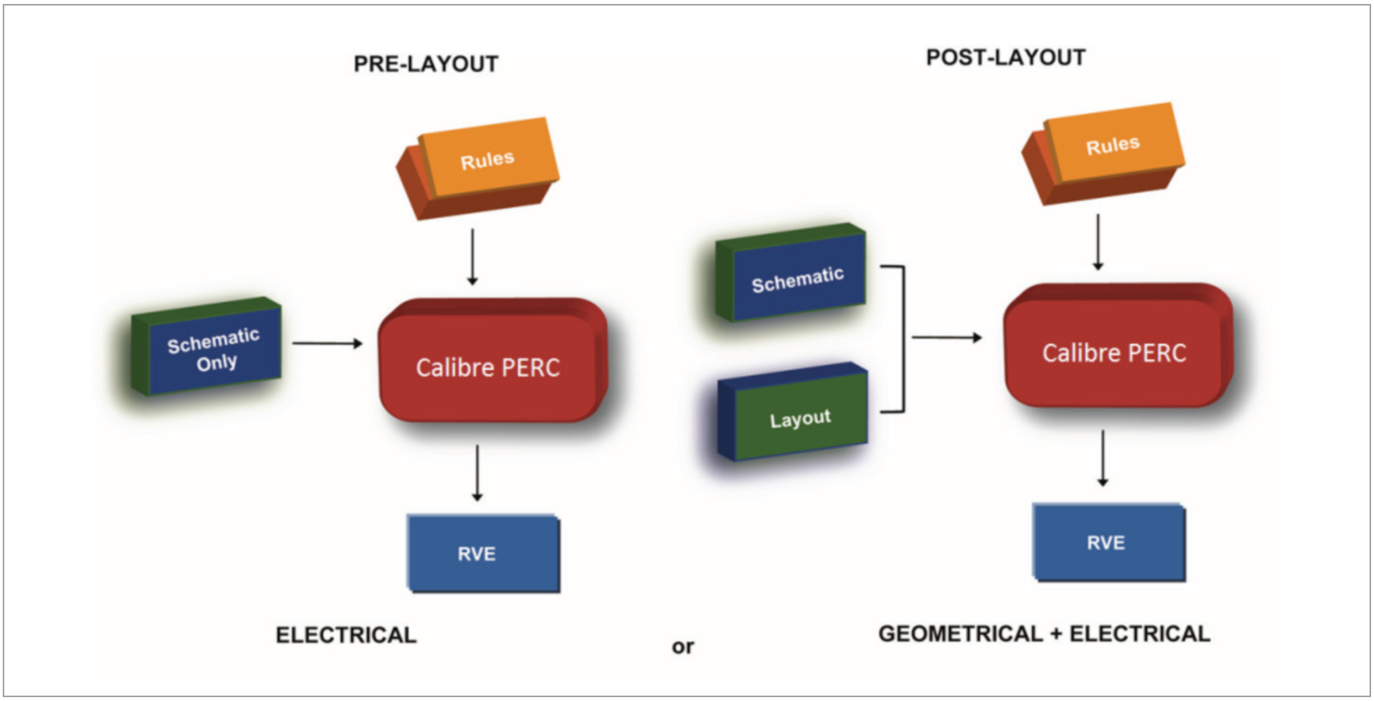

Figure 2: Hierarchical verification flow

Once net connectivity is defined, we can check the ESD design rule cell by cell. Since a net's path through devices is, in general, instance-dependent, we cannot just check each cell once.

Conceptually, the hierarchical algorithm runs in two steps: 1) initialization, and 2) rule-checking. In the initialization step, the algorithm gathers ESD-related topology information from each cell and propagates it throughout the design. In the second step, the algorithm checks ESD design rules independently, cell by cell, as each cell now has access to the entire ESD protection scheme propagated from all other cells.

ESD Rule-Checking

Once net connectivity is defined, we can check the ESD design rule cell by cell. Since a net's path through devices is, in general, instance-dependent, we cannot just check each cell once. Instead, we find a list of representative instances with unique net connectivity for each cell. Depending on the amount of regularity in the design, the list of instance representatives can be orders of magnitude smaller than the list of all instances for a cell. This greatly improves the speed of the tool compared to checking a flat netlist and is done while preserving any instance specific configurations.

Rule Deck Coding Considerations

Given the diversity in ESD rules, it is important to develop a robust rule deck that will not miss real violations. Within the framework of our method, there are two basic approaches: one is to code a new rule for each variation, and the other is to code a single general purpose rule that covers all variations. The tradeoff is speed vs. rule complexity. The first approach is simpler but slower, as each net will be checked multiple times (once for each rule). The second approach is faster but obviously more complex.

The rules should include checking of properties of the ESD protection devices, such as ESD components widths. Also, the rules should handle different protection types. For example, the ESD protection circuit in Figure 1 could be a dynamic or static clamp or diodes.

Similarly, the drivers and receivers in real circuits are not necessarily simple inverters. They can be NANDs, NORs, etc. However, this does not need special attention from the rule-writing point of view. The tool automatically handles different types of logic gates.

Moreover, the tool can recognize multiple drivers/receivers on an interface net—for instance, a driver with a fan-out to three inverters (in the same domain or in different domains). The rules should take advantage of this

In practice, designs with multiple power and ground domains often involve hundreds or thousands of crossings that need to be verified.

ability and report all drivers/receivers associated with a violation.

At the global level, a robust rule deck should also include other ESD checks. For example, the parameters used in the domain crossing interface check can be dependent on properties of the supply protections. As an example, in the case shown in Figure 1 where the driver and receiver have separate VDDs and VSSs, we are able to make a determination of the checks to be performed and determine the need for the specific protection circuit specified (in this case, anti-parallel diodes).

RESULTS

ESD rule decks have been written using this technique and have been verified in production design flows for both large blocks and complete chips. We will review the results in terms of functionality (How well did it identify real problems?) and reporting (How easy is it for users to manage and correct errors?).

Functionality

In practice, designs with multiple power and ground domains often involve hundreds or thousands of crossings that need to be verified. In addition to determining what signals require ESD clamps for protection, the crossing audit is also needed to determine which ground domains need interface protections.

In one example, for noise isolation purposes, a PLL was designed with separate ground domains for the core and 1.8V circuits. Traditionally, crossings between domains were checked manually to see if ESD clamps were present. However, crossings can be very difficult to find, since the connections may need to be traced through multiple schematics and there can be hundreds, if not thousands, of crossings. Using the PLL example, the hierarchical ESD audit identified all 133 crossings in just a few seconds. The crossing audit also successfully caught missed instances of clamps in the preliminary design.

Reporting

The output from the rule deck lists all the crossing nets and is organized by hierarchy (Figure 3). For each net, the MOSFETs on both sides of the interface, together with the associated grounds, are shown. This output can be customized as desired, and Calibre PERC provides a results viewing environment (Calibre RVE) to highlight devices in the schematic and/or layout when they are selected in the report. All 133 results are displayed in the graphical tree view shown in Figure 3. Analysis of these results will identify the specific details for each failure.

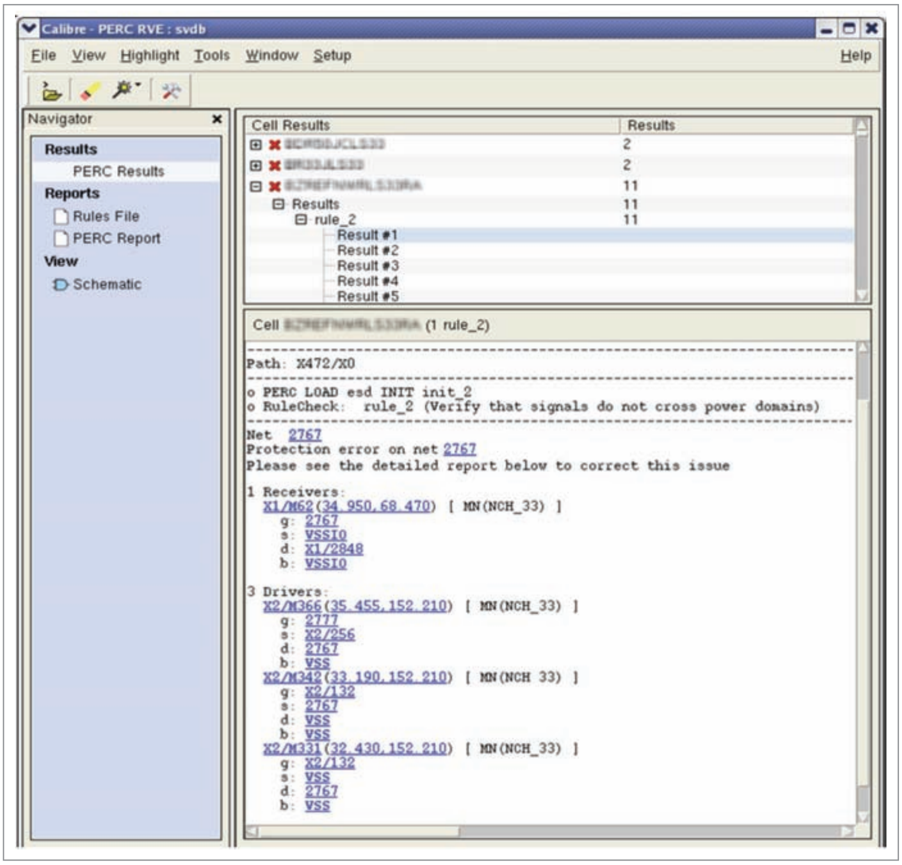

Figure 3: Results for an entire design showing an ESD protection error on net 2767, involving one receiver and three drivers

> Until now, there has been a clear gap in EDA solutions to address the demands of circuit and electrical verification.

The schematic representation in the results viewer can provide a different perspective of an error (Figure 4) This often provides a holistic view of the connectivity, enabling much easier debugging than the original schematic. Of course, as these results are displayed in Calibre RVE, highlighting back to the original schematic is also supported.

Because you can specify nets, devices, pins, etc., and create "groupings" for testing conditions, the tool can use these conditions to determine how to evaluate a design.

CONCLUSION

In this paper, we presented a well-established, topologically-driven hierarchical verification methodology that has been developed to automate ESD rule-checking. It can handle large ICs and check ESD protection rules on the original design without netlist reduction. The hierarchical algorithm uses a novel topology-aware concept, allowing for verification of chip-level ESD design rules. The presented method has been extensively verified and is being used in production to significantly improve ESD quality.

Until now, there has been a clear gap in EDA solutions to address the demands of circuit and electrical verification. The ability to use both netlist and layout (GDS) information simultaneously to perform electrical checks enables designers to address both reliability concerns arising from crossing multiple power domains and catastrophic failures from ESD that can have large effects on yield and reliability. In addition, this method can employ topological constraints to verify that the correct structures are in place wherever circuit design rules require them. An automated solution that verifies circuits at both the schematic and layout phase can reduce cost and time to market, while improving yield and device reliability.

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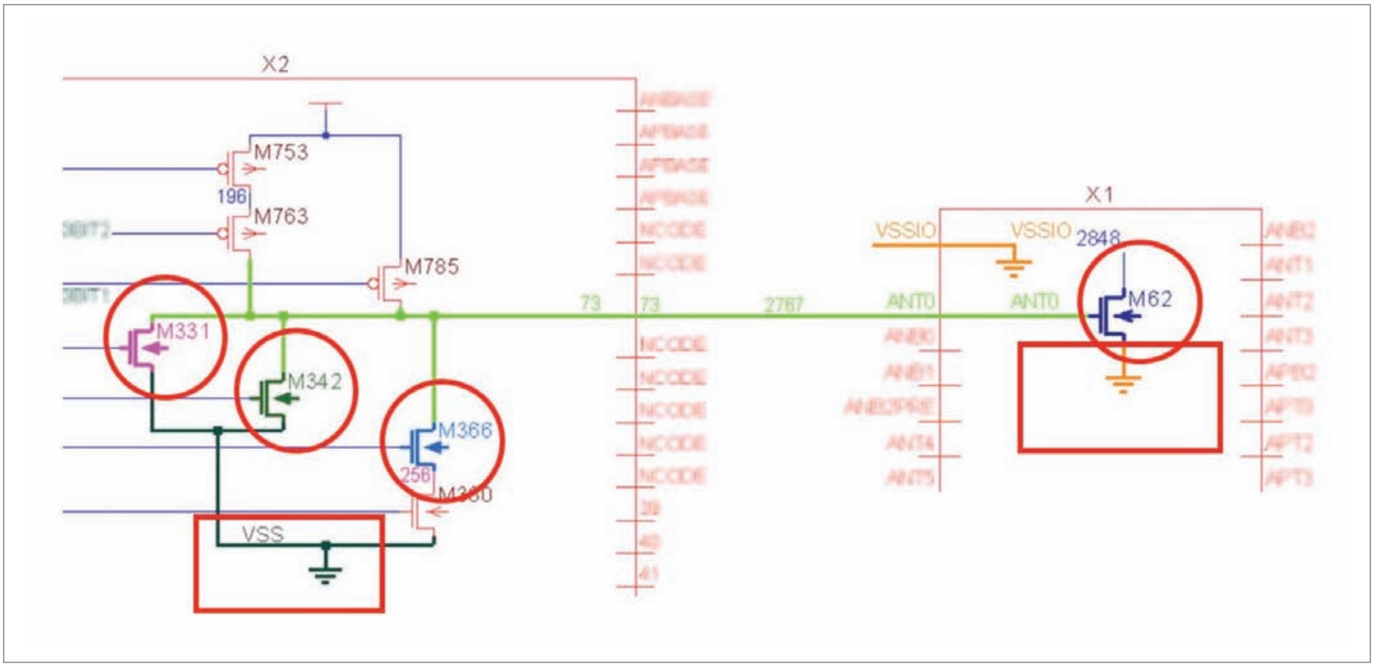

Figure 4: Schematic image from results viewing, identifying all the circuitry elements affected by the error: Net 2767, Receiver: X1/M62, Drivers: X2/M331, X2/M341, X2/M366, Ground nets VSS and VSSIO

An automated solution that verifies circuits at both the schematic and layout phase can reduce cost and time to market, while improving yield and device reliability.

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At the time of writing, the ESDA EDA Working Group consisted of the following members: Michael Khazhinsky (Silicon Labs), Fabrice Blanc (ARM), Gianluca Boselli (Texas Instruments), Shuqing (Victor) Cao (Global Foundries), Norman Chang (Ansys), Dan Clement (On Semiconductor), Rosario Consiglio (Impulse Semiconductor), Maxim Ershov (Silicon Frontline), Melanie Etherton (Freescale Semiconductor), Eleonora Gevinti (ST), Harald Gossner (Intel), Matthew Hogan (Mentor Graphics), Larry Horwitz (Synopsys), Kelvin Hsueh (ESD Consultant), Mujahid Muhammad (IBM), Louis Thiam (Cadence), Nitesh Trivedi (Infineon), Vesselin Vassilev (Novorell).

Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the Association has broadened its horizons to include areas such as textiles, plastics, web processing, cleanrooms and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness through standards development, educational programs, local chapters, publications, tutorials, certification and symposia.

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The Art of Spraying Electrically Conductive Paints

Non-conductive spray painting experience is not enough to ensure success

BY JESSE HAGAR

Electrically conductive coatings for plastic enclosure electromagnetic shielding are growing in popularity as concerns over weight increase for a variety of EMI applications in the military, aerospace, automotive, telecom, medical, and semiconductor marketplaces.

Conductive coatings are generally applied by spraying a layer of electrically conductive paint, which is heavily filled with a conductive metal such as silver, nickel, copper, or a variety of coated or specialty powders and flakes. When one first attempts to use a conductive paint, the results can be disastrous if he or she is unprepared for the task. Conductive paints cannot be handled or applied in the same manner as conventional paints. Using this medium is something of an art form that takes equipment modifications, proper up-front part design, personnel training, experience, and practice. However, by following these simple guidelines, one can prepare oneself for a successful startup to spraying conductive paints.

CONTINUOUS AGITATION

All conductive paints are loaded with heavy metal fillers, sometimes as high as a 4:1 ratio of metal to resin by weight. These heavy particles will settle quickly, like sand in water. Even the most well-formulated paint, designed to minimize settling, will experience the conductive filler falling out of suspension. This is the number one issue that affects one's ability to spray these paints properly.

Care must be taken that the paint is under constant agitation during use. An air-driven mixer for the paint pot or a recirculation loop (or both) will keep the paint constantly moving and prevent particles from settling out. This is the only way to ensure the paint remains homogeneous throughout the entire spray process. For hand-held spray guns, the operator will need to aggressively shake the spray cup and gun between passes. In addition, it is also important to avoid magnetic-driven mixers when the paint contains ferromagnetic filler.

If one does not have a continuous recirculation loop, the paint will settle in the spray lines. If the paint in the lines is allowed to sit for more than a few seconds, the lines must be fully purged before spraying can resume. In high-volume spray applications, it is sometimes less expensive to modify equipment with a recirculation loop than to purge and dispose of expensive conductive paint between each part.

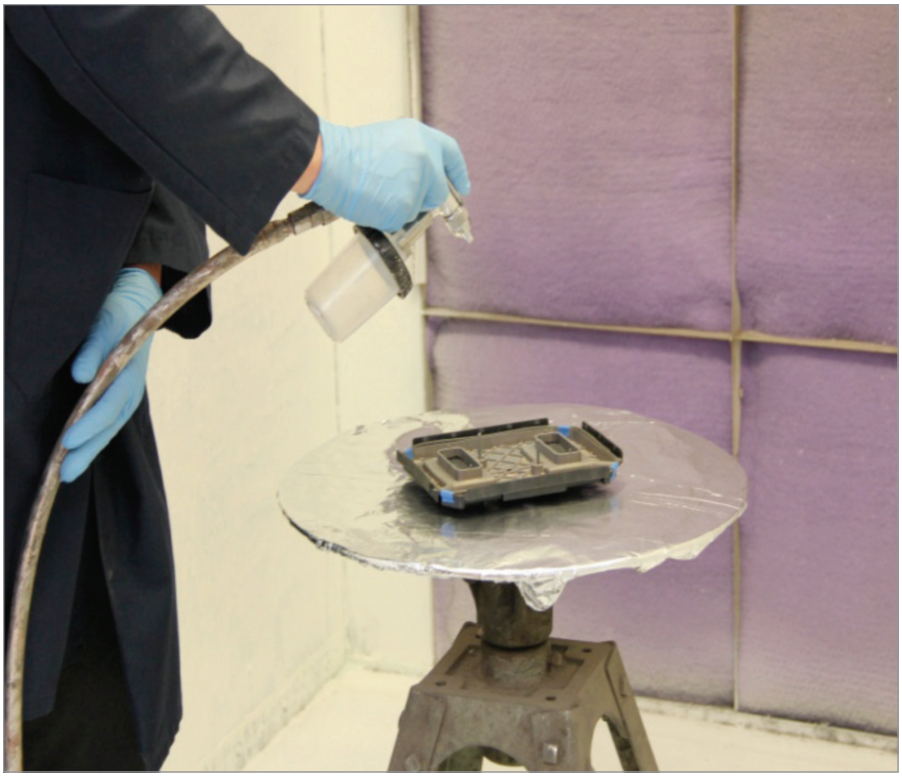

Figure 1: Prototype painting

> Conductive coatings are generally applied by spraying a layer of electrically conductive paint, which is heavily filled with a conductive metal such as silver, nickel, copper, or a variety of coated or specialty powders and flakes.

Storing conductive paints will cause the particles not only to settle but to also to hard-pack over time at the bottom of the container. Before each use, it is important to aggressively shake the container for several minutes. Also, always check to verify the paint is homogeneous by scraping a clean paint stirrer or spatula across the bottom of the container. If a viscous sludge of particles is found on the spatula, then the paint will require further mixing before use. See ASTM D869 (Standard Test Method for Evaluating Degree of Settling of Paint) for more direction on this procedure.

EQUIPMENT

Many hand-held, air-atomized spray guns will work for conductive paint application, including siphon-feed spray guns, gravity-feed guns, and high volume/lowpressure (HVLP) spray guns with pressure pots. Also, many manufacturers of automated high volume spray equipment are gaining experience with conductive paints and are now modifying their equipment with pot mixers and continuous recirculation to satisfy the growing demand.

One also has to consider the fluid nozzle diameter (Figure 2). For air-atomized spray guns, a fluid nozzle of 0.040” (1mm) or greater will work with most conductive paints. However, for smaller more detailed parts with automated equipment, one could possibly use a much smaller diameter. The equipment, particle size, and viscosity all play a factor. If the nozzle were undersized then clogging, spitting, resin rich or inconsistent spray can occur. One common fix when experiencing trouble spraying conductive paints is to increase your fluid nozzle diameter.

SOLVENT PACKAGE

Another issue in spraying conductive paints is “dry spray.” Dry spray occurs when the paint does not level correctly, causing particles to not lay down. The goal of a conductive paint is to maximize filler particle contact, which is achieved by coating the surface with metal filler particles that effectively cover the surface like leaves on the ground in the fall. However, dry spray causes the particles to position themselves more perpendicular to the substrate and not fully submerged in resin. This will cause an extremely rough surface, conductivity loss, and cohesion issues.

There are a few potential causes of dry spray. One is that the percentage of solids is too high and another is that too much solvent is evaporating between atomization and contact with the substrate. Despite the cause, one common and easy fix is to decrease the distance between the spray nozzle and the substrate. Another fix is the addition of solvent to the paint. Most well-formulated conductive paints will contain a proper mixture of fast, medium, and slow evaporating solvents. Therefore if considerable solvent addition is considered, contacting the paint's manufacture for recommendations is important. In fact, if equipment limitations require the need for a faster or slower solvent package for a spray application, most small or moderately sized paint manufacturers are willing to adjust the paint's formulation to fit a customer's needs.

THICKNESS

Coating thickness is also an important consideration when spraying conductive paints. The more conductive the filler, the thinner a coating required to achieve the paint's full shielding potential. For example, a very conductive filler such as silver only requires a 0.5 mil dry film thickness, whereas a significantly less conductive filler such as nickel requires as much as 3.0 mils. Moderately conductive fillers such as silver-coated copper fall somewhere in the middle.

It is a common misconception that if one significantly increases the paint's thickness, the shielding effectiveness also significantly increases.
Going above the manufacturers recommended thickness provides little to no additional shielding in reality. In fact, tests show that doubling the manufacturer's thickness recommendations, only results in a 3-6 dB increase in shielding. If everything was done correctly during the painting process (including complete coverage, correct thickness, and confirmed conductivity) and more shielding is still required, then a paint with a more conductive filler is needed.

Uniform thickness for a conductive coating is significantly more important than with a conventional paint. To ensure uniform thickness and complete coverage, there should be a 50% overlap between paint strokes and each subsequent coat should be sprayed perpendicular to the previous coat.

If you are considering painting the inside of a complicated part, such as the inside of a housing, it is important to take into account up-front part design. Any 90-degree, sharp corners will never receive the proper coating thickness and will therefore produce a significant EMI leakage. The more curvature that exists in the corners, the greater the opportunity is to build up the proper coating thickness. It is very expensive to fail shielding tests and consequently require redesign of a mold; if the use of a conductive coating potentially will be potentially considered, sharp corners must be avoided during the initial design phase.

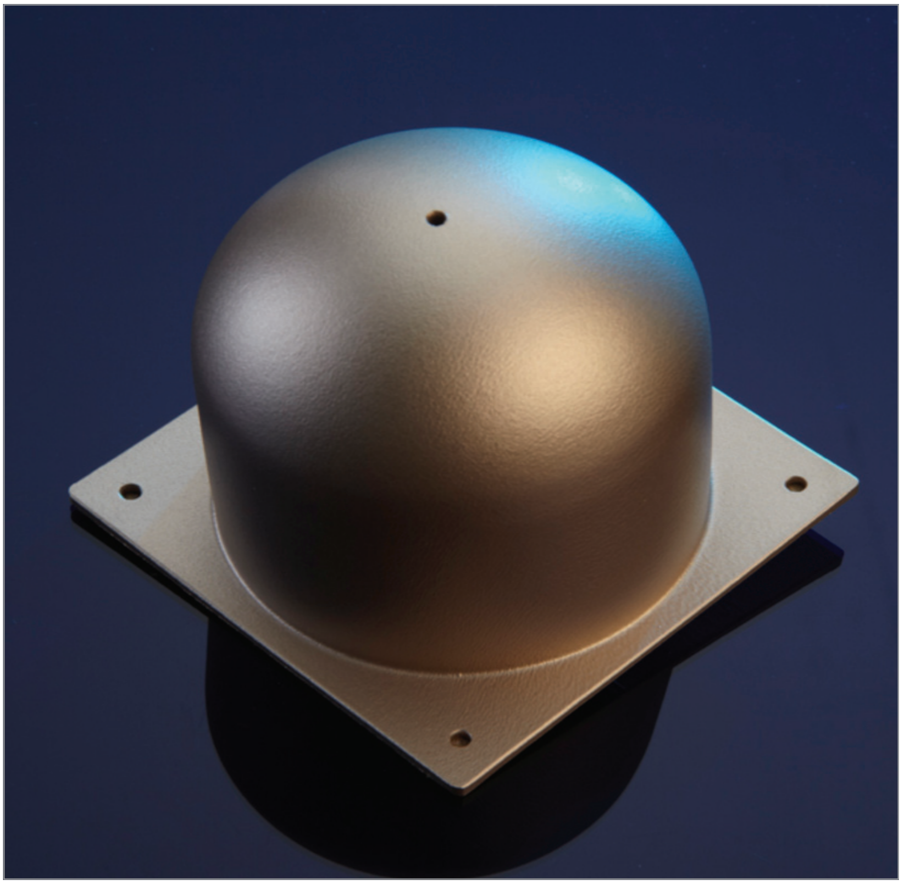

Figure 2: Commercial radome

FINAL THOUGHT

Spraying conductive paints for the first time can leave you frustrated by the wasting of plenty of time and money. However, with the proper preparation you can ensure a successful smooth transition into spraying conductive paints. There are many high-volume spray equipment manufacturers and paint manufacturers willing to work with potential customers to ensure success.

This article has not been reviewed by the ICM Editorial Advisory Board.

(the author)

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is a Produce Development Engineer at Parker Hannifin. For additional information, contact the Chomerics Division of Parker Hannifin Co., 77 Dragon Court, Woburn, MA 01801, call 781-935-4850, email chomailbox@parker.com, or visit www.chomerics.com.

35th Annual ELECTRICAL OVERSTRESS/ ELECTROSTATIC DISCHARGE SYMPOSIUM

September 8-13, 2013 | Rio All Suite Hotel | Las Vegas, Nevada, USA

CALL FOR PAPERS

About the EOS/ESD Symposium

The ESD Association, in cooperation with IEEE, is sponsoring the 35th Annual Symposium on Electrical Overstress (EOS) and Electrostatic Discharge (ESD) effects. The Symposium will be dedicated to the understanding of issues related to electrical transients and electrical overstress, and the application of this knowledge to the solution of problems in consumer, industrial and military applications, including electronic components and manufacturing, as well as in systems, subsystems and equipment.

Technical Papers

The Technical Program Committee solicits paper contributions, including data and analysis that advance the state-of-the-art knowledge, enhance or review the general knowledge, or discuss new topics related to EOS/ESD. Paper Presentations at the Symposium will be in electronic Power Point® format.

Abstracts

Authors must submit a 50-word abstract and 4-page (maximum) summary of their work. The summary must clearly state the purpose, results (e.g., data, diagrams, photographs, etc.), and conclusions of the work. Summaries must also include references to prior publications and state how the work enhances existing knowledge. Authors must designate the appropriate technical area related to their work and submission. See reverse for suggested, but not restricted, topic listings. **Authors are encouraged to use the abstract submission toolkit available on the ESD Association's website www.esda.org.**

Presentation of work at the International ESD Workshop (IEW) will not preclude an abstract submission, as long as the submission follows the EOS/ESD Symposium guidelines. If the IEW work is submitted to the EOS/ESD Symposium, it is required that the IEW work is expanded upon significantly (e.g. 50% increase of data graphs) in the abstract submission for the EOS/ESD Symposium in order to be considered for acceptance.

Electronic Submissions

Abstract submissions shall be made electronically via an emailed PDF file to **info@esda.org**. **One file for each submission is required.**

Paper Acceptance

The Technical Program Committee will accept unpublished papers for peer review with the understanding that the author will not publish elsewhere the work prior to presentation at the Symposium. Accepted papers published in any form prior to presentation at the Symposium may result in the paper being withdrawn from the Symposium Proceedings. Authors must obtain appropriate company and government clearances prior to submitting their abstracts.

Paper Awards and Recognition

Awards are presented annually for the Symposium Outstanding Paper (selected by Symposium attendees), the Best Paper (selected by the Technical Program Committee), and the Best Student Paper. The Best Paper is considered for presentation at the RCJ EOS/ESD Symposium in Japan. Eligible student contributions for the Best Student Paper Award should be marked as such by the authors at the time of abstract submission.

Deadlines

The submission deadline is Friday, January 11, 2013. Abstracts not meeting guidelines may not be accepted. The final submission deadline for the finished papers will be Friday, June 14, 2013. **ESDA reserves the right to withdraw any paper not meeting the guidelines, including deadlines. Your paper MUST be submitted by the deadline**. Final papers will be limited to a maximum of 10 pages - guidelines will be provided after acceptance of the paper.

Sponsored by the ESD Association in cooperation with the IEEE
Technically co-sponsored by the Electron Devices Society

For further information, please see contact details on the next page.

Papers are solicited in the following areas:

I. Component Level EOS/ESD

- On-Chip Protection Devices & Techniques
- IC Design and Layout Issues
- ESD & Latchup, or other Reliability Aspects
- ESD in Advanced Technologies (Multi-gate, SOI, SiGe, Compound Semiconductors, Carbon Nano-tubes, etc.)
- Transmission Line Pulse and Other Testing Methods
- EOS/ESD Failure Analysis
- Through-Silicon Via Protection
- Processing Issues and Effects
- New ESD Phenomena in MEMS (Microelectromechanical Systems)
- ESD Device and Circuit Simulation
- Modeling and Physics of EOS/ESD
- RF Devices and Circuits
- High Voltage, High Power Technologies (BiCMOS, HV CMOS)

II. System Level EOS/ESD

- Simulators, Calibration and Correlation
- Optical Networks ESD
- ESD Detection and Measurement Techniques
- ESD Electronic Design Automation (EDA)
- Case Studies, Reviews and Analysis
- Test Methods and Procedures
- Modeling and Simulation
- Transient ESD/EMI Induced Upset

III. EOS/ESD Factory Level and Materials Technology

- Packaging and Handling
- Test Methods and Procedures
- Air Ionization and Uses
- Facility Design
- ESD Control Materials
- Use of Antistatic Materials
- ESD in Die Stacking Technologies
- Case Studies, Reviews and Analysis
- Troubleshooting Techniques
- Management Issues (cost/benefit analyses, etc.)
- ESD Shunting Packaging Technology
- Chemistry

IV. Electrostatic Control

- Biomedical & Chemical Industry Electrostatic Control
- ESD Control in Explosives and Pyrotechnics
- Aircraft, Spacecraft and Avionics ESD
- Graphic Arts Electrostatic Control
- Oil/Petroleum Industry Electrostatic Control

V. Magnetic Recording Heads and Ultra Sensitive Devices

- Testing and Analysis
- Special Considerations for Extremely Sensitive Devices
- Protection Techniques
- Failure Analysis Techniques and Interpretations

VI. ESD Standards – Components, System, Factory & Materials

- Test Methods and Procedures
- Standards - Comparisons and Analysis
- Round-Robin Testing, Results and Analysis
- Case Studies

Accepted papers covering selected topics may be considered for review for invited publications in *IEEE Transactions on Device and Materials Reliability (TDMR), IEEE Transactions on Electron Devices, the Micro-Electronics Reliability Journal, the Journal of Electrostatics* or other appropriate publications.

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7th Annual International Electrostatic Discharge Workshop

IEW Call For Presentations

May 20-23, 2013, Airlie Conference Center, Warrenton, VA, USA
http://www.esda.org/iew.htm

The 7th International ESD Workshop (IEW) will be held at the Airlie Center, Warrenton, VA, USA. Founded as an "Island of Thought", Airlie Center's natural secluded setting, distinguished meeting rooms, commitment to sustainable and green initiatives, and its 50th anniversary as a world-renowned conference center promises to combine to produce a lasting ESD learning experience. IEW 2013 will include invited seminars, technical sessions, special interest groups (SIGs), discussion groups, and invited speakers. The IEW especially invites submission of late-breaking exciting new research to stimulate discussion and interaction around new ideas, encouraging new research topics.

To maintain the unique IEW experience and provide ample opportunity for informal discussions, the 2013 IEW will continue the successful workshop presentation format introduced in 2011 for all submissions: Technical sessions will begin with each author presenting a brief summary to highlight key findings, followed by an interactive poster-based discussion session among authors and attendees. The IEW is closely aligned with the EOS/ESD Symposium for collaborative conference activities.

Abstract Submission Deadline Nov. 19, 2012

Submission Instructions

Your abstract (two pages including reasonably sized figures) must clearly present the data and the significance of the results. Please e-mail your presentation abstract including title, author affiliation, and e-mail address to iew@esda.org by November 19, 2012 (Sunday) deadline. The submission format is a PDF® file (Adobe Acrobat®). Notification of acceptance will occur by December 17, 2012. Final, full presentations for the workshop in MS PowerPoint® format must be received by April 14, 2013. These MS PowerPoint® slides will be included in the presentation handout along with a CD-ROM that will be distributed during the workshop.

There will be no published proceedings of the workshop. Due to an agreed alignment through the ESD Association, the presentation of your work at the IEW will not preclude a subsequent, but more detailed submission (=> 50% increase of data graphs), to the EOS/ESD Symposium. For any questions please contact the Technical Program Chair, Junjun Li at junjunli@us.ibm.com. Please visit the IEW website at www.esda.org/iew.htm for a submission template.

Areas the IEW would like you to consider as abstract submission topics include:

System-Level ESD Issues/EOS

On- and off- chip IEC protection clamps, component/system ESD co-design case studies, cable discharge clamps, transient latch-up, design of system-level clamp circuits, system level ESD test issues and scan techniques, ESD-induced soft errors, and EOS field-failure case studies/histories/solutions.

Simulation and Tools

CAD work on process, device and circuit levels involving process models, device models, testing models, circuit simulation, and whole-chip verification techniques.

ESD Test Characterization, Methods, and Issues

TLP & vfTLP debug and device characterization methods, correlation between TLP & vfTLP tests with standard qualification tests, HBM and CDM tester artifacts, issues relating test qual levels to real-world exposure, test chip methodology, cable discharge test methods, and test standards issues.

Failure Analysis Techniques

Locating failure sites, in particular CDM, imaging techniques, correlating FA identified damage site with ESD stress, and unusual failure modes.

Novel On-Chip Protection Clamps and Circuit Configurations

New clamp devices and clamp configurations, methods to increase the failure threshold of protected devices, high voltage clamps for automotive and power amplifiers, out-of-the-ordinary chip protection concepts, and low-capacitance clamps for RF and SERDES. and technology scaling issues.

Anomalous ESD Issues

Random and unrepeatable ESD failures, Case Histories, ESD tester correlation issues, and ESD data statistics.

Technology Integration Issues

ESD sensitivity with technology transfers, 3D IC ESD design issues, qualification challenges for different fabs, unusual problems of process interaction with ESD, process monitor methods, and technology scaling issues.

EDA Tools

Tools to support ESD checking of the topological layout and netlist, point to point resistance, current density, simulation (SPICE), and macro integration.

Abstract Submission Deadline: Nov. 19, 2012

Please check our web page at http://www.esda.org/iew.htm for regular updates on the workshop. As it becomes available, we will post information on the full technical program including the seminar topics, the keynote speaker, the technical sessions, as well as the discussion group and special interest group topics. In addition to peer-reviewed presentations, attendees will also have the option to present non-peer-reviewed posters at the workshop. Please also go to the web page for information on workshop registration, the Airlie Center, and the Warrenton / Washington DC area.

The IEW encourages student submissions by providing a 50% discount in registration fees for a limited number of student presenters. Proof of student status must be submitted along with the abstract for the workshop presentation.

Lodging & Facilities

Airlie's accommodations comprise 150 tastefully appointed rooms equipped with private bath, high-speed Internet access, cable television, radio-alarm clock, in-room coffee service, iron & ironing board, hair dryer and magnetic lock. All accommodations are located in close proximity to Airlie House, the Center's hub. Guests can easily walk from any of the seven lodging buildings to anywhere on campus. For a fleeter alternative, borrow one of the "loaner bicycles" during your stay. The Center's campus provides a scenic backdrop for jogging, walking, biking, and fishing, with many trails and gardens for visitors to explore and enjoy. Airlie has a fully equipped exercise room, two outdoor pools, tennis courts, volleyball and a skeet range.

Lodging and all meals are included in the registration costs for the workshop. **Attendees are allowed to bring guests who will be charged separate fees.**

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ESD ASSOCIATION ®

TECHNICAL Tidbits

Measuring Breakdown Voltage with an ESD Simulator

Special simulator characteristics are needed

BY DOUGLAS C. SMITH

Measuring high voltage breakdown has many uses including tracking down the cause of equipment failure and ascertaining compliance to safety standards. Some ESD simulators can be used to measure DC breakdown voltage and have the advantage that they can measure breakdown to voltages in excess of 10,000 volts. Not all ESD simulators can do this and the special characteristics required are discussed and an example is given of how this method was used to track down an equipment problem.

DISCUSSION

Figure 1 shows the details of measuring the breakdown voltage of a small AC plug style transformer of the type often used with small electronic equipment. In this case, a Fischer F-65 current probe was used to measure the waveshape of the breakdown current, but this is not necessary to measure breakdown voltage.

Many ESD simulators work by charging up a storage capacitor, often on the order of 150 pF, to the desired high voltage and then switching the charged capacitor to the tip of the simulator. Unfortunately, ESD simulators that work this way cannot be used to measure breakdown voltage accurately and many of them have digital controls that also complicate matters. What is needed is a simulator that keeps the storage capacitor connected to the tip at all times and charged through a low current, high voltage power supply.

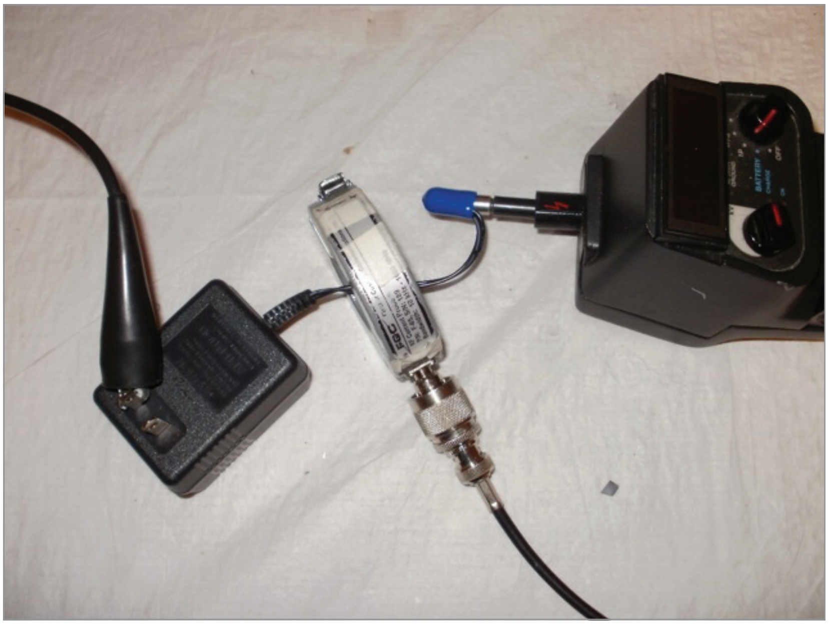


Figure 1: Test Setup for Measuring DC Voltage Breakdown of a Small AC Plug Style Transformer

The KeyTek MiniZap ESD simulator by Thermo Scientific is such a device. The storage capacitor is connected to the tip at all times and is charged by a low current, high voltage supply. The digital display is actually a voltmeter reading the tip voltage in real time. The MiniZap's analog controls (read that as "knobs") facilitate the breakdown voltage measurement.

The method is as follows:

1. Connect the two nodes for the breakdown measurement between the tip of the MiniZap and its ground cable.
2. Using air discharge mode, slowly raise the voltage setting of the MiniZap remembering that the display on the MiniZap is actually reading the DC voltage stress being applied to the circuit or device under test.
3. At some point, the MiniZap fires and turns off the high voltage supply, signaling that a breakdown has occurred.
4. The last reading on the display just before the MiniZap fired is the breakdown voltage of the circuit or device under test.

Figure 2 shows another example of a breakdown test on another small AC plug style transformer. It is probably best not to have your fingers on the circuit during the actual test, lest you measure **your** breakdown voltage.

Using an ESD simulator, like the KeyTek MiniZap, one can measure breakdown voltage up to 15,000 Volts. If you don't have an outright breakdown but just a leaky path, you will notice the device will load down the reading on the MiniZap, possibly making it impossible to reach the desired voltage.

Here is an example of how measuring breakdown voltage this way proved useful and time saving. I was working on a small embedded controller that used an electromechanical relay to operate a 240 VAC 60 Hz motor that rotated a sizable drum. The problem was that when the equipment was subjected to a 6 kV ringwave lightning surge test, the processor IC was often destroyed (burnt to a crisp).

The processor IC controlled a discrete transistor that operated the electromechanical relay which in turn applied the 240 VAC mains to the motor, so I suspected breakdown of the relay. I connected a MiniZap, on the test bench, from the contacts of a relay to its coil and slowly raised the voltage. The relay was rated at 6 kV, but at 5200 to 5400 Volts breakdown occurred between the coil and contacts! So the relay was not meeting its published specifications and was allowing the lightning surge to be applied directly to the processor circuit with predicable results.

SUMMARY

Some, but not most, ESD simulators can be used to measure high voltage breakdown in circuits and devices. The KeyTek MiniZap is one such device.

The MiniZap will measure breakdown voltages to 15,000 Volts, probably more than most uses require.

Equipment used in this Technical Tidbit:
Thermo Scientific KeyTek MiniZap Electrostatic Discharge Simulator

For more Technical Tidbits, *please visit Doug's site,* http://emesd.com.

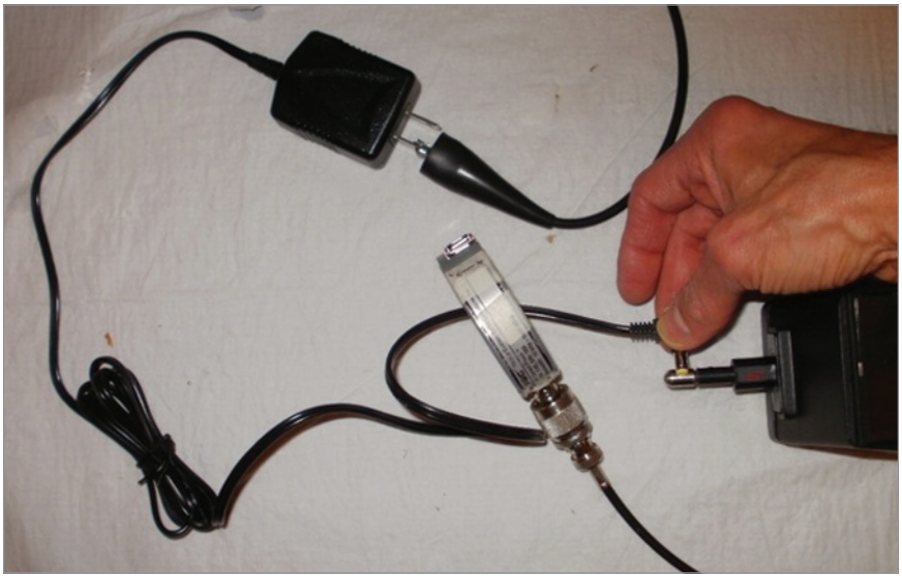


Figure 2: Test Setup for Measuring DC Voltage Breakdown of a Second Small AC Plug Style Transformer

(the author)

DOUGLAS C. SMITH

Mr. Smith held an FCC First Class Radiotelephone license by age 16 and a General Class amateur radio license at age 12. He received a B.E.E.E. degree from Vanderbilt University in 1969 and an M.S.E.E. degree from the California Institute of Technology in 1970. In 1970, he joined AT&T Bell Laboratories as a Member of Technical Staff. He retired in 1996 as a Distinguished Member of Technical Staff. From February 1996 to April 2000 he was Manager of EMC Development and Test at Auspex Systems in Santa Clara, CA. Mr. Smith currently is an independent consultant specializing in high frequency measurements, circuit/system design and verification, switching power supply noise and specifications, EMC, and immunity to transient noise. He is a Senior Member of the IEEE and a former member of the IEEE EMC Society Board of Directors.

His technical interests include high frequency effects in electronic circuits, including topics such as Electromagnetic Compatibility (EMC), Electrostatic Discharge (ESD), Electrical Fast Transients (EFT), and other forms of pulsed electromagnetic interference. He also has been involved with FCC Part 68 testing and design, telephone system analog and digital design, IC design, and computer simulation of circuits. He has been granted over 15 patents, several on measurement apparatus.

Mr. Smith has lectured at Oxford University, The University of California Santa Barbara, The University of California Berkeley, Vanderbilt University, AT&T Bell Labs, and internationally at many public and private seminars on high frequency measurements, circuit design, ESD, and EMC. He is author of the book High Frequency Measurements and Noise in Electronic Circuits. His very popular website, http://emcesd.com (www.dsmith.org), draws many thousands of visitors each month to see over 150 technical articles as well as other features.

He also provides consulting services in general design, EMC, and transient immunity (such as ESD and EFT), and switching power supply noise. His specialty is solving difficult problems quickly, usually within a couple of days. His work has included digital and analog circuits in everything from large diesel powered machinery to IC chip level circuits. His large client base includes many well known large electronic and industrial companies as well as medium sized companies and start-up companies.

BUSINESS News

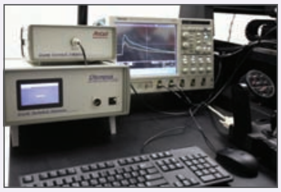
Robotic Scanners Identify Circuits Affected by ESD/EMC Events

Amber Precision Instruments has announced a series of robotic scanners designed to identify circuits likely to be affected by ESD and other EMC events. SmartScan provides a complete, precise picture of sensitive components and structures. Software control and analysis programs allow 3 dimensional plots to be developed to display sensitive areas superimposed on the actual circuit being tested.

The SmartScan system allows engineers to quickly identify and correct problems at a prototype stage and provides a means for EMC engineers to diagnose problems rapidly. For more information, contact API at sales@amberpi.com or (408) 752 0199.

ESD Compliance Test Equipment Offers New Measurement Capabilities

GTS has introduced the 'all-in-one' Olympus family of pulsed stress testers. This tester family can be configured as a low cost manual tester or high speed automatic tester. GTS equipment provides innovations such as recording device under test (DUT) currents and voltages during each stress pulse.



GTS provides custom and semi-custom ESD test solutions. The Olympus test solution can be tailored to meet your current needs and expanded in the future. For additional information visit www.GrundTech.com.

iNARTE Merges into RABQSA International, Inc.

The International Association for Radio, Telecommunications and Electromagnetics, Inc (iNARTE) and, RABQSA International, Inc., have executed official Articles of Merger, whereby the surviving organization, RABQSA International will absorb the operations of iNARTE. iNARTE will function in the future as a brand of RABQSA International.

iNARTE's operations are moving into RABQSA facilities located in Milwaukee, Wisconsin. RABQSA will continue to honor the iNARTE branding and uphold the tenet of iNARTE's values. The merger promises innovative approaches to certification products and services, with an industry focus and international recognition at its heart. For additional information or inquiries on the merger, please contact Peter Holtmann, President and CEO, by emailing pholtmann@rabqsa.com.

Northwest EMC Prepares to Open a New Testing Lab in Bothell, Washington

Northwest EMC will open it's fifth testing lab in Bothell, Washington. This new lab will provide full EMC and EMI testing services to help serve the greater Seattle region, including Wireless EMC testing, RTCA DO-160, and MIL-STD 461. The opening of the new Bothell location is scheduled for fall 2012.

Partnership to Address North American EMC Market

Rohde & Schwarz has announced that it will take over the sales of anechoic chambers and shielded rooms from the Albatross Projects Group in the USA and Canada, effective immediately. Production, sales and service of complete EMC systems are now available from a single source.

Rohde & Schwarz and Albatross Projects Group, a German supplier of EMC test setups, have globally collaborated for more than 20 years on turnkey solutions and EMC test systems for CISPR, IEC, automotive and military standards. Visit www.rohde-schwarz.us for more information.

New High Performance Compact Fuse Rated 500 VAC

Schurter has announced the new series SHT 6.3x32 mm compact fuse. The series provides overcurrent protection up to 500 VAC. The high breaking capacity of 1500A at rated voltage safeguards electronic systems and operators in the event of a catastrophic short circuit incident. The compact size of the fuse, combined with its high ratings and performance, makes it suitable for a much broader range of applications than a typical 6.3x32 mm fuse. For sales and product information, contact Cora Umlauf at (800) 848-2600 or info@schurterinc.com.

Teseq Offers New 3-Phase Burst Pulse CDN for EFT Testing

Teseq Inc. now offers a 200 A, 3-phase burst pulse coupling/decoupling network (CDN) for electrical fast transient (EFT) and burst testing. The new CDN 3083-B200 handles high inrush currents and pulse-shaped peak currents, and the company reports it is ideal for testing high current and high power equipment such as large machines, appliances and smart grid applications.

Compliant with IEC 61000-4-4, Teseq's CDN 3083-B200 is compatible with all brands of burst generators. The new system is compact, lightweight and easy to handle Contact Teseq USA directly for pricing or to find out about renting Teseq products.

PRODUCT Showcase

Your Source for Product and Service Solutions

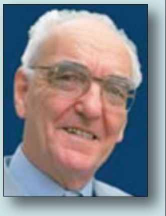
(Authors)

DAVE CULLEN
Dave Cullen is the Test Instrumentation Manager of York EMC Services Ltd. and holds BEng (Hons) and MSc degrees in electronic engineering and product development respectively. For Dave's full bio, please visit page 43.

GERARD EDWARDS
Gerard Edwards is a Senior Lecturer in Electrical and Electronic Engineering at University of Bolton, UK and has taken many courses in physics/computing/electronics from undergraduate to MSc level.
For Gerard's full bio, please visit page 43.

GENE FELDER
is the Corporate Product Manager at Desco Industries. Before joining Desco, he was general manager of BW/IP International SR Engineering. For Gene's full bio, please visit page 33.

NIELS JONASSEN, MSC, DSC,
worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate.
Mr. Jonassen passed away in 2006.
For Mr. Jonassen's full bio, please visit page 23.



JESSE HAGAR
is a Produce Development Engineer at Parker Hannifin. For Jesse's full bio, please visit page 55.

MATTHEW HOGAN
is a Calibre Marketing Engineer for Mentor Graphics, with over 15 years of design and field experience. He is an active member of the ESD Association involved with the EDA working group and Symposium technical program committee.
For Matthew's full bio, please visit page 51.

BRIAN LAWRENCE
began his career in electromagnetics at Plessey Research Labs, designing "Stealth" materials for the British armed services. In 1973 he moved to the USA and established a new manufacturing plant for Plessey to provide these materials to the US Navy. For Brian's full bio, please visit page 17.

ANDY MARVIN
Andy Marvin is Technical Director of York EMC Services Ltd and Professor of Applied Electromagnetics, leading the Physical Layer Research Group at the University of York Department of Electronics. For Andy's full bio, please visit page 43.

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For Geoff's full bio, please visit page 25.

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We wish to thank our community of knowledgeable authors, indeed, experts in their field - who come together to bring you each issue of *In Compliance*. Their contributions of informative articles continue to move technology forward.

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