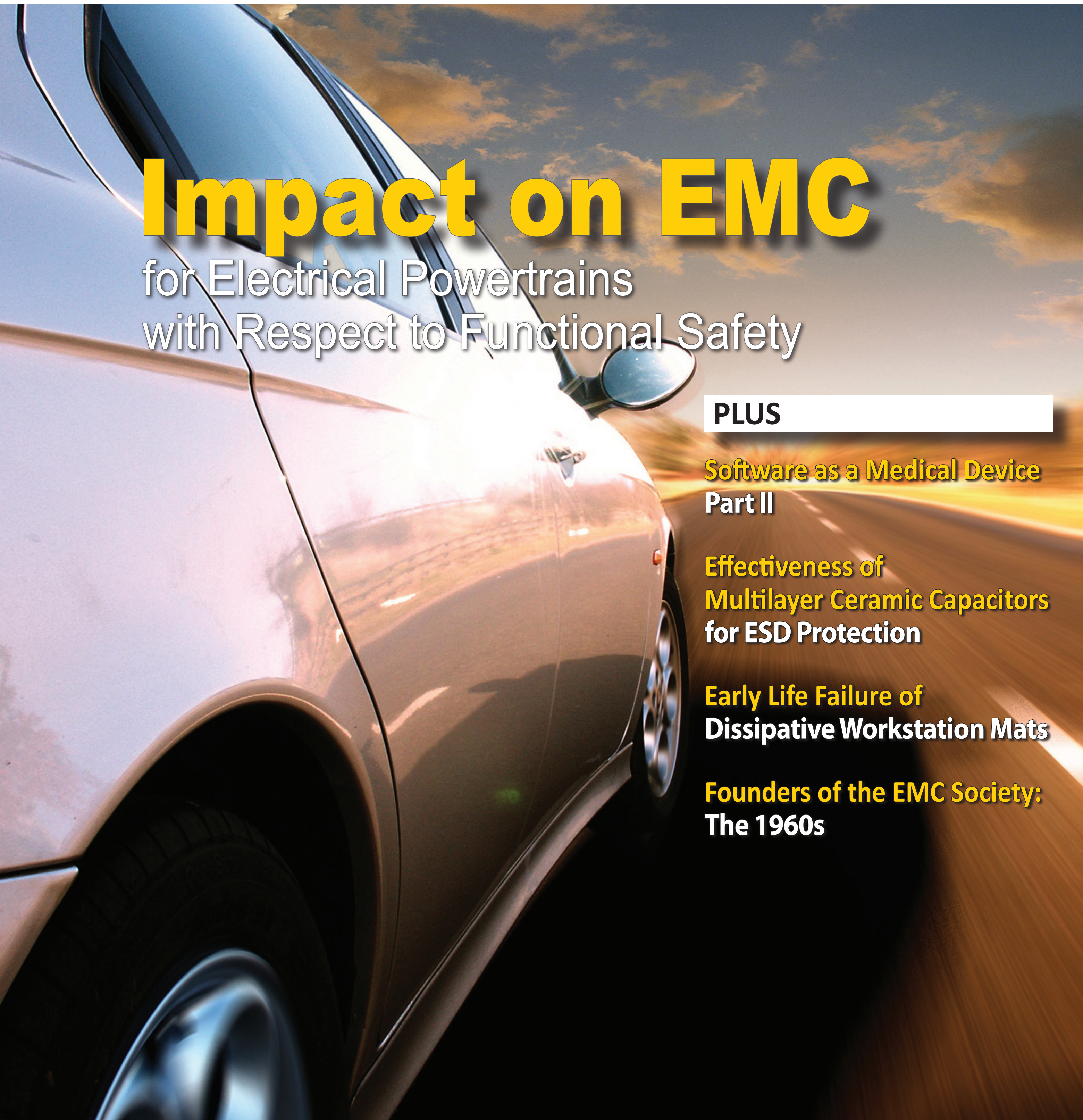
MAY 2012

IN COMPLIANCE™

THE COMPLIANCE INFORMATION RESOURCE FOR ELECTRICAL ENGINEERS



Impact on EMC

for Electrical Powertrains with Respect to Functional Safety

PLUS

Software as a Medical Device Part II

Effectiveness of Multilayer Ceramic Capacitors for ESD Protection

Early Life Failure of Dissipative Workstation Mats

Founders of the EMC Society: The 1960s

IN COMPLIANCE

In Compliance Magazine
ISSN 1948-8254 (print)
ISSN 1948-8262 (online)
is published by

Same Page Publishing Inc.
P.O. Box 235
Hopedale, MA 01747
tel: (508) 488-6274
fax: (508) 488-6114

editorial staff

editor/publisher Lorie Nichols
lorie.nichols@incompliancemag.com
(978) 873-7777

production director Erin Feeney
erin.feeney@incompliancemag.com
(978) 873-7756

copy editor Mary Ann Kahl
maryann.kahl@incompliancemag.com

publishing staff

director of sales Sharon Smith
sharon.smith@incompliancemag.com
(978) 873-7722

national sales manager Shellie Johnson
shellie.johnson@incompliancemag.com
(404) 991-8695

subscriptions

In Compliance Magazine subscriptions are free to qualified subscribers in North America.

Subscriptions outside North America are $129 for 12 issues. The digital edition is free.

Please contact our circulation department at circulation@incompliancemag.com

advertising

For information about advertising contact:
Sharon Smith at 978-873-7722
sharon.smith@incompliancemag.com

CONTENTS

May 2012
Volume 4 • Number 5

News in Compliance

FCC News

FCC Seeks Comment on Intentional Wireless Service Interruptions

The U.S. Federal Communications Commission (FCC) is seeking comment from the public and other interested parties on concerns and issues related to intentional interruptions of wireless services by government authorities for public safety-related reasons.

In a Public Notice issued in March 2012, the Commission staunchly reaffirmed its commitment to preserve the availability and openness of communication networks, as well as the constitutional rights of the citizenry. However, it also noted a number of unique public safety circumstances in which the temporary and localized interruption of wireless services might be considered by authorities.

According to the Commission, such circumstances could include the potential wireless detonation of an explosive device, or the organizing of potentially violent public activities by a so-called "flash mob." Indeed, the Commission cites an actual incident in August 2011, in which transit officials in the San Francisco area temporarily suspended wireless services in selected Bay Area Rapid Transit (BART) stations to deter protesters from organizing.

The Commission says that "there has been insufficient discussion, analysis, and consideration of the questions raised by intentional interruptions of wireless service by government authorities," and that a period of public comment is warranted to explore the legal constraints and policy considerations of the issue.

The complete text of the Commission's Public Notice on wireless service interruptions is available at incompliancemag.com/news/1205_01.

> In a Public Notice, the Commission staunchly reaffirmed its commitment to preserve the availability and openness of communication networks, as well as the constitutional rights of the citizenry.

FCC Releases Enforcement Advisory Against Jammers

The U.S. Federal Communications Commission (FCC) has issued an advisory warning to consumers about the use of various jamming devices to block cellphone and GPS communications.

Issued in March 2012, the Commission's Enforcement Advisory references recent publicized instances of people using cellphone jammers to create "quiet zones" on buses and trains, and reminds consumers that the use of such devices is illegal. Violations of the Commission's rules carry monetary penalties of up to $112,500 per any single incident, as well as potential criminal sanctions, including imprisonment.

In addition to banning the use of jamming devices by individuals, FCC rules also prohibit the importation, advertising or selling of such devices.

Although jamming devices can interfere with public cellphone conversations that may be annoying to some, they can also block all radio communication within the affected area, including 911 emergency system calls made from cellphones and urgent communications by public safety officials.

The complete text of the Commission's Enforcement Advisory regarding jamming devices is available at incompliancemag.com/news/1205_02.

FCC Proposes Additional 40 MHz for Mobile Broadband Operations

The Federal Communications Commission (FCC) has proposed increasing the spectrum available for mobile broadband operations by removing certain restrictions on the use of 40 MHz currently allocated for mobile satellite services (MSSs).

MSS is a radiocommunication service involving transmission between mobile earth stations and one or more space stations, and is intended

FCC News

to provide communications in areas where coverage via terrestrial base stations is difficult or impossible. The Commission initially allocated 70 MHz of spectrum for MSS use in 1997, but reduced the allocation to 40 MHz in 2003 due to lack of progress in the deployment of MSS services.

In a Notice of Proposed Rulemaking issued in March 2012, the Commission proposed to carry out a recommendation in its *National Broadband Plan* to enable the provision of stand-alone terrestrial services in this spectrum. This step would provide for more flexibility in the provision of MSS services, and support the expansion of broadband deployment in the 2 GHz band. The Commission's Notice also seeks public comments on other methods for freeing up additional spectrum.

The complete text of the Commission's Notice of Proposed Rulemaking is available at incompliancemag.com/news/1205_03.

Do you have news that you'd like to share with your colleagues in the compliance industry? We welcome your suggestions and contributions.

Send news items to the editor:

In Compliance Magazine
P.O. Box 235
Hopedale, MA
(508) 488-6274
editor@incompliancemag.com

News in Compliance

European Union News

Updated List of Standards Released for EU's Directive on General Product Safety

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 2001/95/EC, related to general product safety.

The EU's General Product Safety Directive covers "any product… which is intended for consumers or likely, under reasonably foreseeable conditions, to be used by consumers even if not intended for them, and is supplied or made available, whether for consideration or not, in the course of a commercial activity, and whether new, used or reconditioned." The Directive is intended to ensure the general safety of products beyond those specific safety issues addressed in other product directives, such as the Machinery Directive, the EMC Directive, or the R&TTE Directive.

The list of CEN standards was published in February 2012 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards is available at incompliancemag.com/news/1205_04.

> The Commission of the European Union has updated standards lists for the Directives on General Product Safety, Machinery and Electrical Safety. The Commission has also approved use of electronic instructions for certain medical devices.

New List of Standards for EU's Machinery Directive

The Commission of the European Union (EU) has issued an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 2006/42/EC, also known as the Machinery Directive.

The EU's Machinery Directive defines the essential health and safety requirements for a wide range of products, including: machinery and partly completed machinery; lifting accessories; chains, ropes and webbing; interchangeable equipment; removable mechanical transmission devices; and safety components.

The Directive's scope specifically excludes electrical and electronic products covered under Directive 2006/95/EC (the EU's so-called Electrical Safety Directive), including household appliances, audio and video equipment, informational technology equipment and ordinary office machinery.

News in Compliance

European Union News

The extensive list of CEN and Cenelec standards for the Machinery Directive was published in March 2012 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards can be viewed at incompliancemag.com/news/1205_05.

Updated Standards List Published for the EU's Electrical Safety Directive

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the essential requirements of its directive relating to electrical equipment designed for use within certain voltage limits (2006/95/EC).

The Directive defines 'electrical equipment' as any device designed for use with a voltage rating of between 50 and 1000 V for alternating current, and between 75 and 1500 V for direct current.

The updated list of standards that can be used to demonstrate compliance with the Directive was published in February 2012 in the *Official Journal of the European Union*, and replaces all previously published standards lists. The complete list of standards can be viewed at incompliancemag.com/news/1205_06. (Note that the list runs 93 pages!)

EU Commission Approves Use of Electronic Instructions for Certain Medical Devices

The Commission of the European Union (EU) has approved the use of electronic forms of instructions with

European Union News

certain medical devices intended for use exclusively by medical professionals.

Under the terms of a Commission Regulation issued in March 2012 and published in the *Official Journal of the European Union*, manufacturers of active implantable medical devices, implantable medical devices, fixed installed medical devices and medical devices fitted with visual display systems will be able to provide in electronic form use instructions previously provided on paper. Such devices are intended for use exclusively by medical professionals, and not by consumers.

> Manufacturers opting to provide electronic instructions will be required to include notices on product packaging on how to access the electronic forms of instruction, or provide supplementary printed instructions on how to access electronic instructions.

Manufacturers opting to provide electronic instructions will be required to include notices on product packaging on how to access the electronic forms of instruction, or provide supplementary printed instructions on how to access electronic instructions.

The Regulation regarding the use of electronic instructions applies as of March 1, 2013, and is available at incompliancemag.com/news/1205_07.

News in Compliance

UL Standards Updates

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

STANDARDS

UL 102: Standard for Sustainability for Door Leafs
New Edition dated March 22, 2012

UL 110: Standard for Sustainability for Mobile Phones
New Edition dated March 14, 2012

UL 498: Standard for Attachment Plugs and Receptacles
New Edition dated March 30, 2012

UL 635: Standard for Insulating Bushings
New Edition dated March 8, 2012

UL 1008A: Standard for Medium-Voltage Transfer Switches
New Edition dated March 30, 2012

UL 1567: Standard for Receptacles and Switches Intended for Use with Aluminum Wire
New Edition dated March 16, 2012

UL 1642: Standard for Lithium Batteries
New Edition dated March 13, 2012

UL 1691: Single Pole Locking-Type Separable Connectors
New Edition dated February 29, 2012

UL 1815: Standard for Nonducted Heat Recovery Ventilators
New Edition dated February 29, 2012

UL 2797: Standard for Sustainability for RV and/or Marine Holding Tank Additives: Biologically-based
New Edition dated March 30, 2012

UL 2798: Standard for Sustainability for Biological Digestion Additives for Cleaning and Odour Control
New Edition dated March 30, 2012

UL 60745-2-5: Hand-Held Motor-Operated Electric Tools - Safety - Part 2-5: Particular Requirements for Circular Saws
New Edition dated March 20, 2012

REVISIONS

UL 48: Standard for Electric Signs
Revision dated March 13, 2012

UL 471: Standard for Commercial Refrigerators and Freezers
Revision dated March 23, 2012

UL 626: Water Fire Extinguishers
Revision dated March 30, 2012

UL 651: Standard for Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings
Revision dated March 30, 2012

UL 705: Standard for Power Ventilators
Revision dated March 13, 2012

UL 746C: Standard for Polymeric Materials - Use in Electrical Equipment Evaluations
Revision dated March 7, 2012

UL 796F: Standard for Flexible Materials Interconnect Constructions
Revision dated March 15, 2012

UL 814: Gas-Tube-Sign Cable
Revision dated March 1, 2012

UL 827: Standard for Central-Station Alarm Services
Revision dated March 21, 2012

UL 916: Standard for Energy Management Equipment
Revision dated March 12, 2012

UL 1063: Standard for Machine-Tool Wires and Cables
Revision dated March 7, 2012

UL 1241: Standard for Junction Boxes for Swimming Pool Luminaires
Revision dated March 30, 2012

UL 1431: Standard for Personal Hygiene and Health Care Appliances
Revision dated February 28, 2012

UL 1517: Standard for Hybrid Personal Flotation Devices
Revision dated March 19, 2012

UL 1803: Standard for Factory Follow-Up on Third Party Certified Portable Fire Extinguishers
Revision dated March 13, 2012

UL 2129: Halocarbon Clean Agent Fire Extinguishers
Revision dated March 30, 2012

UL 2196: Standard for Tests for Fire Resistive Cables
Revision dated March 30, 2012

UL 2238: Standard for Cable Assemblies and Fittings for Industrial Control and Signal Distribution
Revision dated March 21, 2012

UL 2586: Standard for Hose Nozzle Valves
Revision dated March 15, 2012

UL 60730-2-2: Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Thermal Motor Protectors
Revision dated March 28, 2012

UL 62368-1: Audio/Video, Information and Communication Technology Equipment - Part 1: Safety Requirements
Revision dated March 8, 2012

CPSC News

LED Night Lights Recalled Due to Fire and Burn Hazards

American Tack & Hardware Company, Inc., of Saddle River, NJ is recalling about 227,000 LED night lights manufactured in China.

The company reports that an electrical short circuit in the night light can cause it to overheat and smolder or melt, thereby posing a fire and burn hazard to consumers. American Tack & Hardware says that it has received 25 reports of the night lights smoking, burning, melting and charring, but no reports of injuries.

The recalled LED night lights were sold at hardware stores, home centers and lighting showrooms from March 2009 through October 2010 for about $6.

Additional details about this recall are available at incompliancemag.com/news/1205_08.

Lenovo Recalls Desktop Computers

Lenovo of Morrisville, NC has recalled about 50,000 of its ThinkCenter-brand desktop computers manufactured in Mexico.

According to the company, a defect in an internal component in the power supply can overheat, and pose a fire hazard to consumers. Lenovo has received reports of one fire incident and one smoke incident, but no reports of injuries.

The recalled computers were sold online at the Lenovo website and through Lenovo authorized distributors nationwide from May 2010 through January 2012, for between $500 and $800, depending on the model.

More information about this recall is available at incompliancemag.com/news/1205_09.

Ceiling Fans Recalled Due to Shock Hazard

Westinghouse Lighting Corporation of Philadelphia, PA has announced the recall of about 7000 ceiling fans manufactured in China.

Westinghouse has reported to the U.S. Consumer Product Safety Commission (CPSC) that the fans include two 60-watt light bulbs that exceed the fan's maximum wattage. This condition can cause the fans to overheat or fail, posing fire and shock hazards to consumers. The company has not received any reports of incidents related to the defective ceiling fans, but has initiated the recall to minimize the risk of future incidents.

The ceiling fans were sold through home improvement and hardware stores, home centers, and electrical product suppliers nationwide, as well as through Amazon.com, from January 2011 through January 2012 for between $135 and $160.

Additional information about this recall is available at incompliancemag.com/news/1205_10.

iNARTE and RABQSA

BY BRIAN LAWRENCE

In April 2011, we reported that iNARTE had signed an agreement to become affiliated with RABQSA. Now, one year later, I am pleased to announce that effective May 6, 2012, iNARTE will merge into the RABQSA organization.

As a result, iNARTE will now become a part of the world's largest, multi-million dollar, Personal Certification organization, having principal offices in Milwaukee, WI, Sydney, Australia and Seoul, Korea, with eleven other international offices across Asia, Europe, Africa and South America.

SO WHO IS RABQSA?

RABQSA is a non-profit certification agency whose controlling member is the American Society for Quality, (ASQ). ASQ is is a knowledge-based global community of quality control experts, with nearly 85,000 members dedicated to the promotion and advancement of quality tools, principles, and practices. RABQSA offices in the USA are within the ASQ building in Milwaukee.

ASQ had its beginnings in 1946 when quality experts and manufacturers sought ways to sustain the many quality-improvement techniques used during wartime. As the ASQ interests and activities expanded, and in order to maintain separation between these activities, several independent subsidiaries were created under the ASQ umbrella. The ASQ accreditation activities moved to the ANSI-ASQ National Accreditation Board, ANAB. Much of the personal certification activities moved to the Registrar Accreditation Board, RAB, while ASQ itself retained its global membership and many of the quality related personal certification activities.

RABQSA was created in 2004 through the merger of the personnel certification activities of the US based Registrar Accreditation Board (RAB), by the Australia-based Quality Society of Australasia (QSA).

RABQSA International offers personal certification in more than 30 different disciplines, based on combinations of knowledge, skills, personal attributes and qualifications specific to the scheme and/or scope of certification. RABQSA also certifies training programs based on a series of criteria which allows training providers to offer either certified training courses that have gained industry recognition, and also to certify their own courses.

RABQSA personnel certification programs are accredited to ISO/IEC 17024 by JAS ANZ, Inmetro, and ANSI.

Today, RABQSA has more than 10,000 certified personnel and more than 80 certified training providers. Following the iNARTE/RABQSA merger on May 6, the number of certified personnel in the new organization will swell to almost 15,000.

With few exceptions, the RABQSA personnel certification schemes focus on recognizing the competencies and qualifications of auditors working in a wide variety of industry sectors. iNARTE certifications have been reserved for professional engineers and technicians working in Radio, Telecommunications and other fields involving RF and Electromagnetic disciplines. As a result there is no overlap or competition between RABQSA and iNARTE. In the future, the new organization we will have the industry recognition, support and opportunity to introduce the iNARTE brand certification to the practitioners who work in the sectors currently served by RABQSA's certified auditors.

Learn more about RABQSA at http://www.rabqsa.com.

The RABQSA 2011Annual Report is available at http://rabqsa.com/docs/rabqsa-annual-report-fy2011.pdf.

IEEE EMCS 2012

The first of the symposia at which iNARTE will be offering examinations in 2012 is the EMCS 2012 in Pittsburgh, PA. Our exam day is Friday, August 10. As usual any and all of the iNARTE certification examinations will be on offer, but for anyone intending to take other than an EMC or EMC Design Engineer examination, we do ask that you register in advance by visiting http://www.narte.org/h/examregform.asp.

That way we will be sure to have your examination ready on the day. EMC candidates can register with us any time before or during the symposium. We will be at Booth #300 that week to take care of you and answer your questions.

Don't forget, this year you can become certified as an **EMC Design Engineer**, in addition to being certified as either an **EMC Engineer or Technician**. Our traditional EMC Certification programs for Engineers and Technicians has been offered for more than 20 years, and is based on a general knowledge of EMC fundamentals but with an emphasis on EMC testing and troubleshooting. The new EMC Design Engineer program introduced in 2011, requires a similar knowledge of the fundamentals, but has an emphasis on electronic design and the incorporation of EMC principles when designing for compliance.

Many of you will know as regular readers of, "The iNARTE Informer", that more than 50% of our EMC certificate holders are in Japan. Last year for the first EMC Design Engineer examinations in Japan, more than 50% of the candidates were already holders of the traditional iNARTE certification. As electronic manufacturing has moved offshore, together with the test labs and test personnel, more and more EMC Engineers are directing their skills to the design and development disciplines. This added personal certification of those special skills is now much in demand by the electronics industries..

Remember, this new EMC Design Engineer certificate is issued for life. Unlike the traditional EMC certificate, which has to be renewed annually as evidence of currency in the technology, this new certificate is intended to test your knowledge in the application of EMC principles to electronic design. As such it is a closed book examination, you can bring just a calculator and a small self made notebook to the exam room, no reference books and no laptops, (remember those days from college?).

The EMC Design Engineer examination is in two Parts. Part 1 consists of 30 questions and all should be attempted. Part 2 is 40 questions, of which 30 should be attempted. Each Part must be completed in 3 hours. Subject matter is generally distributed as follows:

Part 1

Basic Principles
Countermeasures
Design and Design Review
Simulation and Rule Check
Signal Integrity and Power Integrity
Electromagnetics and Shielding

Part 2

Electronic Circuits and Power Electronics
Electrical Circuit Theory
Measurement and Analysis
Specifications and Standards
Mathematics
Terminology

QUESTION OF THE MONTH

Last month we asked:

An ideal dummy load for use in a 50 Ω system should have:

A) 50 ohm reactance, zero resistance
B) 50 ohm resistance, zero reactance
C) 50 ohm inductive reactance
D) 50 ohm capacitive reactance
E) None of the above

The correct answer is B), 50 ohm resistance, zero reactance

This month's question is:

For proper operation, what should the pass band impedance of a low-pass filter be as compared to the impedance of the transmission line into which it is inserted?

A) Substantially higher
B) About the same
C) Substantially lower
D) Twice the transmission-line impedance

(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.

MR. Static

Environmental ESD, Part 2

Thunderstorms and Lightning Discharges

BY NIELS JONASSEN, sponsored by the ESD Association

The properties of thunderstorms and lightning discharges as related to the atmospheric electric circuit are discussed.

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

Reprinted with permission from:
Compliance Engineering Magazine,
Mr. Static Column

A thunderstorm can be considered an electric generator in which positive and negative charges are separated and stored in different regions of the cloud. As the charges are separated, the field will grow between opposite charges in the same cloud or in different clouds, or between a cloud and the ground. When the breakdown field strength is exceeded, an electric discharge will take place, sometimes in the form of a lightning flash. As further charges are separated, the process is repeated but normally at different places.

The mechanism of a thunderstorm is, in principle, very simple. But in spite of this and the many years of thunderstorm research, a detailed knowledge of the processes responsible for the charge separation and the discharges is still not at hand. There are, however, a series of known processes that actually do take place in thunderstorms and that may cause charges to separate.

To evaluate if a given process may play a role in the electrification of a thundercloud, it is necessary to determine not only if the process is able to separate charges and distribute the polarities in a way corresponding to what is measured in actual clouds but also if the rate of charge separation can explain the time variations observed in, for instance, the intervals between lightning flashes.

Direct observations from aircraft as well as radar measurements have shown that a thundercloud consists of one or more active cells with high vertical velocities. Rain and hailstones, as well as lightning activity, are formed in the cells. A particular cell may have a total lifetime of about an hour, whereas the precipitation and lightning activity may last only 15–20 minutes. A fully developed cell may have a horizontal extension of 2–10 km and a height of some 10 km, with the base of the cloud at maybe 3 km above ground (see Figure 1). The vertical velocities are typically in the order of 5–10 $m \cdot s^{-1}$. In special cases, however, velocities of 30–40 $m \cdot s^{-1}$ have been measured.

The temperature in a thundercloud varies from about 0°C at the base of the cloud to about –40°C in the upper layers. At the top of the cloud is a region with predominantly positive charge, whereas the negative-charge region is located at the base. Often, a smaller region with positive charge is also found at the base.

A thundercloud can be considered a vertical dipole (often double), and a lightning discharge can partly be described as a change in the dipole moment. The magnitude of this change is in the order of 100 C·km, corresponding to a charge of 20–30 C. As an average thunderstorm produces a lightning flash every 10–20 seconds, a charging current of about 1–2 A is required. The first lightning flash is

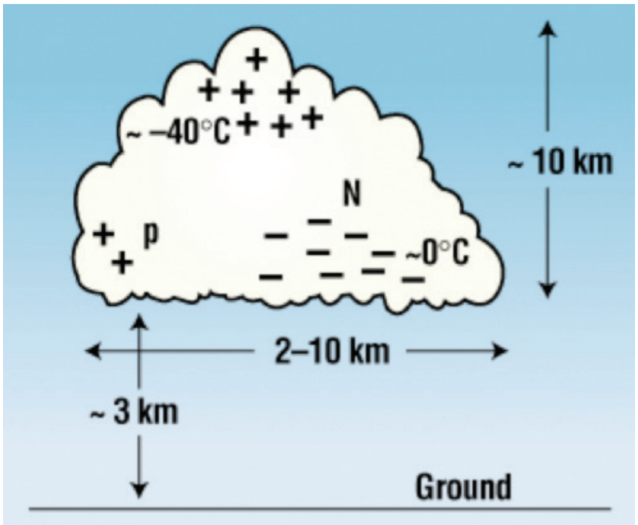


Figure 1: Typical thundercloud

normally registered about 20 minutes after the precipitation has started. Assuming that the precipitation is necessary for the electrical activity, a rough estimate of the charge that has to be separated in a volume of about 50 km^3 in about 20 minutes (i.e., with a rate of about 1 $C/(km^3 \cdot min)$) would be approximately ± 1000 C. It should be mentioned that some thunderstorm specialists claim that, instead of precipitation, convective activity is the prerequisite for charge separation.

Turning to the actual mechanisms of charging, several processes may be responsible for the charge separation. It has been shown that regions with temperatures below 0°C are often the seat for the most active charging processes. However, it has also been shown that considerable charge separation may take place in warm clouds.

In the thundercloud, there are big ice particles in the form of hailstones formed by glazing, that is, the freezing of subcooled water by contact with a cold body. The ice formed is amorphous and glassy and has the same content of impurities as the cloud particles from which it is formed. The glazing process can take place only in the temperature interval from 0° to −15°C. At lower temperatures, the water vapor freezes out and forms pure ice crystals. In addition, the hailstones will have a somewhat higher temperature than the ice crystals, partly because of the latent heat released by the freezing of the water. If a hailstone and an ice crystal happen to come into frictional contact with each other, the more conductive, impure hailstone will become positive and the pure ice crystal will become negative. Calculations and measurements (laboratory and field) both seem to show that this process might give charging rates in the order of 10 C/(km^3·min), which should be sufficient to cause lightning activity.

A similar process takes place when subcooled water drops hit ice particles. The drops will partly freeze onto the ice particles in a glazing process. Because of the released latent heat, part of the water will stay liquid, moving away with a positive charge and leaving the heavier ice particles negatively charged. The collisions between ice particles and subcooled water drops may also result in the expulsion of light ice splinters, again leaving the ice particles with a negative charge. The charging rate of these processes seems to be about 1 C/(km^3·min), the estimated critical value for lightning activity.

Other possible charging processes are inductive charging in an inhomogeneous field of solid or liquid particles that come in contact with each other and are subsequently separated by gravity, and thermoelectric charging by asymmetric friction or other causes. A common feature of these theories is that they all assume the presence of precipitation elements and that the processes typically take place in a temperature region below 0°C.

According to another theory, the strong vertical air movements in the thunderclouds may play a vital role in the charging process. The theory maintains that, in the lower atmosphere, the air has a small excess of positive ions and that a cloud formed in this region will therefore initially be positively charged and attract negative ions from the upper atmosphere. The negative ions may be caught by a downdraft and on their way attach themselves to droplets or other elements of precipitation. In this way, a negative charge is formed at the cloud base, and the resulting field may be strong enough to cause corona discharges at sharp points on the ground. Positive ions will be attracted to the cloud but may be caught by an outside updraft and carried to the top of the cloud, increasing the field so that more negative ions are attracted from the upper atmosphere, thereby amplifying the charging process until lightning activity starts.

It is not possible to point to one of these theories (or others) as being mainly responsible for the charge separation in thunderclouds. Probably the charging is a result of more than one and not always the same processes.

CURRENT BALANCE IN THE ATMOSPHERE

It has already been mentioned that the fair-weather current and the charge brought to ground by elements of precipitation account for a positive current density of about $4 \cdot 10^{-12}$ A·m^{-2}. To evaluate whether this can be balanced by the effect of thunderstorms, the contributions from lightning discharges and from the current induced by the fields below and above the thunderstorms must be looked at separately.

As far as the lightning discharges are concerned, it is estimated that about 1800 thunderstorms are active at any one moment. Each of these storms produces about 60 lightning flashes per hour, each carrying about 20 C, with approximately 80% of the flashes bringing negative charge to the ground. This will then correspond to a total current of about $-1.3 \cdot 10^{6}$ C/hr, or −360 A, which corresponds to $-0.7 \cdot 10^{-12}$ A·m^{-2}.

The current caused by the fields below and above the thunderclouds can be estimated in two different ways. The current below a thundercloud has been measured at -10^{-8} A·m^{-2}. With about 1800 simultaneously active storms, each with an approximate horizontal dimension of 50–60 km^2, this corresponds to an average current density for the earth as a whole of $-2.3 \cdot 10^{-12}$ A·m^{-2}. It should be mentioned that it is extremely difficult with any degree of accuracy to measure the vertical current density during a thunderstorm. In another method, the current above the thunderclouds is measured to have an average of about −0.8 A per thunderstorm. Using the same assumptions as in the previous argument, this corresponds to an average current density of about $-2.8 \cdot 10^{-12}$ A·m^{-2}.

The contributions from the various processes can be summarized as shown in Figure 2. It appears that about $-0.7 \cdot 10^{-12}$ A·m^{-2} is lacking in order to make the current budget balance. It should, however, be kept in mind that the calculation of the two negative contributions is based on very uncertain estimates of the number of active thunderstorms and the average lightning rate. It has, for instance, been suggested that the number of thunderstorms active at any one moment might be closer to 3000 than the figure of 1800 used above, but this higher figure could also include

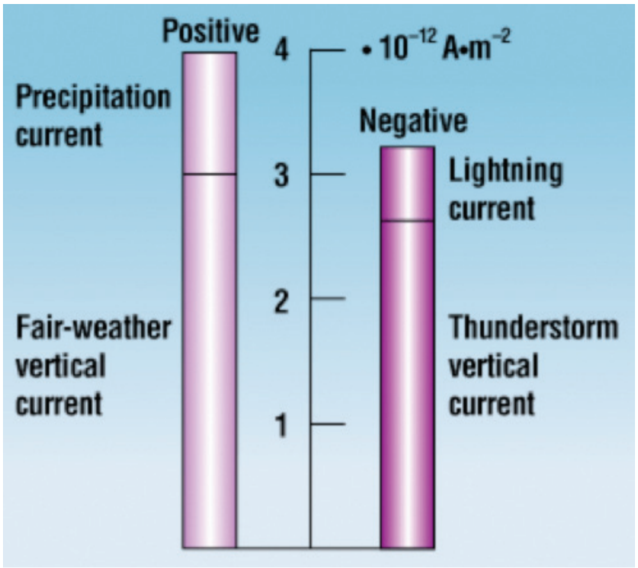


Figure 2: Atmospheric current balance

a number of weaker systems with lower lightning rates and possibly weaker fields. Despite the uncertainties, the estimated values of the atmospheric electric parameters seem to fit the circuit reasonably well.

LIGHTNING DISCHARGES

Although lightning discharges contribute rather modestly to the current balance in the atmosphere, these same discharges have such violent (direct and indirect) effects and properties that a short survey of this phenomenon would be appropriate.

A lightning discharge is a transient current of high intensity spanning several kilometers. Lightning may be produced by sandstorms and snowstorms or by erupting volcanoes, but the most common cause is the activity in cumulonimbus clouds (thunderclouds). Although the most common type of lightning discharge takes place entirely within the cloud (intracloud strokes), the discussion will be limited to the discharges between a cloud and the ground.

MR. Static

Any cloud-to-ground discharge is made up of a series of partial discharges separated in time by 40–50 milliseconds and lasting about 200 milliseconds for the total flash. Figure 3 shows some of the characteristic features of a cloud-to-ground stroke as it would appear on a streak-camera photograph.

The Stepped Leader. Each lightning discharge starts with a predischarge or leader that propagates from the cloud to the ground in weakly luminous steps. The predischarge may start as a local discharge between the N and p regions in the base of the thundercloud (see Figure 1), converting part of the negative charge bound in the base into highly mobile electrons, which will be carried to ground in a negatively charged column. The column appears to move in luminous steps about 50 m in length, with a time between steps of about 50 microseconds, during which time the intensity of the steps is too weak to be observed.

The predischarge moves with a velocity of about 1.5·105 $m{\cdot}s^{-1}$ (>500,000 km/hr), and because the base of a thundercloud is typically at an altitude of 3 km, it takes about 20 milliseconds for the predischarge to reach the ground. The negative charge in a predischarge is about 5 C, and the average current is therefore approximately 100 A. The diameter of the discharge has been measured photographically to be between 1 and 10 m, but it is assumed that the actual charge transport takes place in a narrow core surrounded by a luminous corona sheath, which is what is actually observed.

The Main Stroke. When the predischarge brings the negative charge at high potential close to the ground, the field strength at ground level may be high enough to cause ionization and make the discharge move from the ground to the leader. When the two discharges meet, the leader is effectively grounded and its conductive channel will support a very luminous main or return stroke.

The return stroke differs in many ways from the leader stroke. The strongly ionized wave front moves with a velocity of about one-tenth of the speed of light, covering the distance from the ground to the base of the thundercloud in about 70 microseconds.

The region between the wave front and the ground is traversed by strong currents that bring the excess negative charge in the leader channel to the ground. Measurements at ground level have shown currents in the main discharge of 10–20 kA during the first few microseconds, falling off to half the initial value in 20–60 microseconds, but with currents of hundreds of amperes to flow for several more milliseconds.

During the main stroke, considerable amounts of energy are dissipated in the discharge channel, and the temperature will be higher than during the predischarge. Because the gas density cannot change instantaneously, the pressure in the channel will be higher than in the surroundings, and the channel will expand supersonically, producing a shockwave that gives rise to the sound of thunder. The shockwave phase lasts about 5–10 microseconds, during which time the gas density in the channel behind the shockwave will decrease until a state of equilibrium is reached between the channel with high temperature and low density and the surrounding air with low temperature and high density. In this state, the discharge channel has a diameter of a few centimeters.

The Dart Leader. The lightning discharge is not necessarily finished even if the current in the main discharge has decreased to zero. The main discharge has provided a conductive trail, and if extra charge from the N region is available less than some 100 milliseconds after the main stroke, this charge may move through the channel as a continuous discharge or dart leader. The dart leader appears as a luminous section of the channel about 50 m long moving toward the ground with a velocity of about $2{\cdot}10^6\ m{\cdot}s^{-1}$, or about 10 times as fast as the stepped predischarge. The dart leader reaches the ground in about 1 millisecond and carries a charge of about 1 C. During this charge transfer, the ionization of the channel

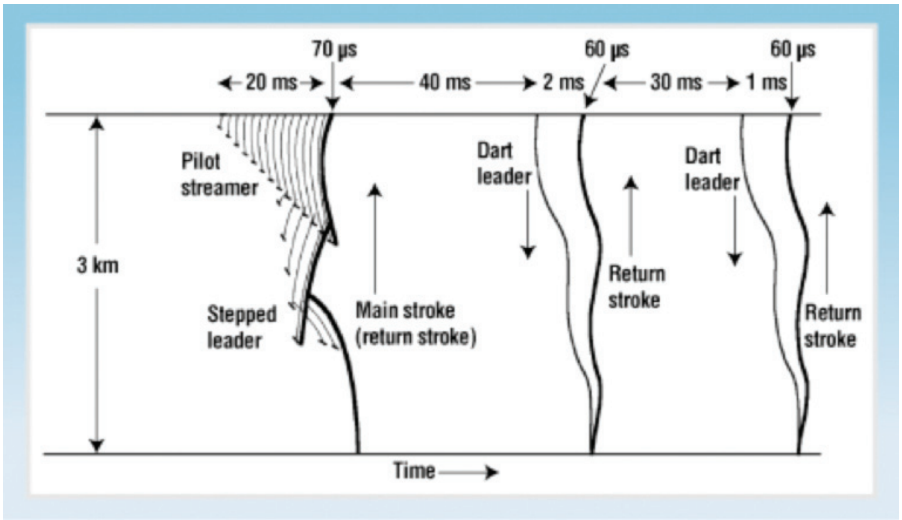


Figure 3: Typical lightning flash

It naturally follows that a relatively short review such as this one has to be rather summary. A series of relationships between the various elements have therefore been bypassed or only mentioned superficially, which may give the impression that the atmospheric electric circuit is a simpler phenomenon than is actually the case.

has increased and a new main stroke is possible. This process may be repeated (normally about 3–4 times), but much larger numbers (up to 26) of return strokes have also been observed.

The first return stroke, the actual main discharge, is strongly branched downward as in the preceding stepped leader. The subsequent return strokes, following the dart leaders, are only slightly branched. The first return stroke transfers more charge than do later return strokes, but because a more or less continuous current is flowing in the time between the two return strokes, the total charge transferred by a lightning flash is about twice that of a single-stroke flash.

Positive Strokes. Occasionally, stepped leaders bringing positive charges to the ground have been observed, but in such cases, the leader current is carried by negative charges (electrons) flowing out of the top of the leader into the positive region of the cloud and thereby charging the channel positively. The charge transferred by positive strokes may be about three times that of negative strokes, with maximum values of about 300 C. Positive strokes rarely have more than one return stroke.

Upward Leaders. If the field strength at ground level is particularly high (e.g., at very high structures or mountain tops), the ionization may start here, with the leader developing upward.

Charge Balance in Thunderstorms. As the majority of lightning flashes from a thundercloud to the ground carry a negative charge, it is expected that a thundercloud would eventually get an excess positive charge, reducing the possibility of bringing further negative charge to the ground. However, this tendency is counterbalanced both by positive discharges from the top of the cloud to the surrounding air and by the vertical current above the cloud often being greater than that below the cloud.

EFFECTS OF LIGHTNING DISCHARGES

This article primarily addresses the electrical phenomena and processes taking place in the atmosphere, but it does seem appropriate to briefly mention the effects on buildings, installations, and human beings brought about by the lightning discharges.

If the lightning strikes a conductor, an amount of heat approximately proportional to the charge is dissipated in a relatively small volume around the point of impact. The material may melt and be thrown around because of magnetic and pressure forces. Furthermore, the lightning current will dissipate heat and create magnetic forces on any conductor through which the charge is led to ground.

The lightning may also create overvoltages in installations and even along the ground. These overvoltages may appear in the medium itself because of resistive coupling or, in conductive surroundings, because of inductive coupling through the magnetic field or capacitive coupling through the electric field.

Finally, humans may be fatally injured and suffer brain damage by being hit directly by lightning strokes. Burns and damage to organs are rather rare because the discharge normally runs on the surface of the body, leaving lightning figures on the skin. However, nearby strokes may create overvoltages dangerous to human beings up to about 100 m from the point of impact.

CONCLUSION

It naturally follows that a relatively short review such as this one has to be rather summary. A series of relationships between the various elements have therefore been bypassed or only mentioned superficially, which may give the impression that the atmospheric electric circuit is a simpler phenomenon than is actually the case.

(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.

Tornados and Product Safety

BY GEOFFREY PECKHAM

In this column, we'll explore the similarity between the new tornado warnings that are starting to be tested in select parts of the country and the warnings that belong on your products.

Risk communication is the topic and it turns out that both you and the National Weather Service (NWS) have an identical task: to effectively communicate risk in a way that will *impact* people's behavior, motivating them to take the necessary actions to avoid potential injury and death. The word "impact" is key here, so please read on as we take a more detailed look at what is involved.

In an article published on April 1, 2012 titled, "New, Impact-Based Tornado Warnings Aim to Scare," Bill Draper of the Associated Press reported that the NWS will start to have radio and TV announcers use much stronger language when a tornado warning is issued. In the article, Draper quotes Ken Harding, a weather service official in Kansas City, who says, "We'd like to think that as soon as we say there is a tornado warning, everyone would run to the basement. That's not how it is. They will channel flip, look out the window or call neighbors. A lot of times people don't react until they see it." The result is that more and more often when a tornado warning is issued and the sirens go off, people ignore them. Why? Because in their experience, three out of four times it turns out to be a false alarm. So when a tornado does strike, lives are lost as a result of inaction because people have become jaundiced and desensitized to the alarms.

The challenge is how to motivate people to comply when warnings need to be given. The NWS has improved its technology so Doppler radar can better detect tornadic activity, including whether or not a storm is picking up debris. Their solution now involves giving a new type of warning to people living in the study area in Kansas and Missouri so that if a Joplin, Missouri-sized tornado approaches, residents

Figure 1: New tornado warnings are being tested in several states, with a hope that more explicit messages will better communicate the urgency of the situation and risk involved. Safety messages – whether in the form of warnings on severe weather or labels on your products – must be forceful in order to motivate the proper responses needed to stay safe.

Figure 2: The use of graphical symbols and clear language on signs and labels are critical to ensure that warnings stand out and are effective. These images demonstrate best practices with ANSI and ISO-formatted safety labels, courtesy of Clarion Safety Systems © 2012.

listening to the radio or TV will hear something similar to:

“THIS IS AN EXTREMELY DANGEROUS TORNADO WITH COMPLETE DEVASTATION LIKELY. ... SEEK SHELTER NOW! ... MOBILE HOMES AND OUTBUILDINGS WILL OFFER NO SHELTER FROM THIS TORNADO — ABANDON THEM IMMEDIATELY.”

This type of explicit, motivational warning is far more impactful than the lackluster ones that were given previously. The hope is to see a marked decline in the number of tornado-related deaths in the study area because of increased compliance with the new warnings.

Here is the takeaway for you: in the same way that the public now needs to be goaded into action when a tornado warning is given, the people who use your products need to be motivated to take notice of and comply with your on-product warnings. This is true now more than ever because we suffer from information overload in our culture, making it difficult for warnings to stand out among all of the signs and advertisements and other visual messages that we see on a daily basis.

Bottom line – your warnings must stand out and be heeded. How can this be achieved? By applying the latest ANSI and ISO standards, best practices, and semiotics (the science of signs and symbols) in the graphics and word messages in your warnings. When you have a pinch point or entanglement hazard, use graphical symbols that show interaction with the hazard. When a person could be crushed by a falling load, use the standardized human figure graphic and show him being struck with a directional force. Use lightning bolts for electricity, heat waves for hot surfaces, and laser blasts for lasers. (See examples of each of these labels in Figure 2). You get the idea; use symbols to increase the effectiveness of your warnings. Then, if you choose, reinforce the symbols with words that explain the hazard and how to avoid it. And don’t mince words! It is better to be direct than to be unclear. When it comes to safety communication, the difference between clear and confusing warnings can be the difference between life and death.

Without a doubt, constructing effective warnings is an art. Putting your best efforts into your safety labels and signs is so important because, similar to an approaching tornado, lives are on the line. And people need to be called to action – to be given clear and true warnings in order to motivate the proper response needed to stay safe. IN

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

(the author)

GEOFFREY PECKHAM is president of Clarion Safety Systems and chair of both the ANSI Z535 Committee on Safety Signs and Colors 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.

FUTURE of EMC Engineering

Figure 1: Bionic leg (photo courtesy Tibion)

Robotics and EMC Engineering

BY MARK I. MONTROSE

I learned about a new robot from Boston Dynamics through IEEE Spectrum called Petman[1]. Is this the future of humanity?

It got me thinking about how both EMC and product safety is a critical aspect of robotic engineering to prevent a real "Terminator" from becoming deployed by those seeking harm to others. Robotic engineering is a sub-field of mechanical engineering. To develop a robot, a combination of computer science, mechanical/robotic designers, industrial control and sensor development, EMC and safety engineers must work as a team, not as an individual specialist but with a wide skill set and knowledge in more than one area of engineering.

Robotic engineers design tools for a specific application. We currently find robots mainly in manufacturing such as the automotive industry, but in recent years there has been rapid expansion of research and engineering in agricultural production, mining, nuclear power-plant maintenance, household support and a variety of other uses. Applications include medical and military in addition to vehicles capable of piloting themselves on other planets. Twenty years from now, robots will be employed in a vast range of new activities, some of which we have yet to define. Engineers who best anticipate the needs of humanity related to robotic engineering will be extremely successful. The key to success is being able to work in teams with each team member having specialized skills. This includes both EMC and safety.

The key item to remember when designing robots in the future, as they become a greater part of our lives, is ensuring that electromagnetic transients from high-power communication systems (radios), a fast transient/burst or surge event that could cause functional disruption, component failure that prevents a robot from shutting down, software glitches, plus functional safety needs to be addressed ahead of time should an abnormal condition develop that could cause harm or death to those in the vicinity of the robot.

In the future, robots will have a high level of intelligence, such as feeling and emotions, or the ability to make a rational decision on their own. To minimize weight and cost, construction material is moving toward composites that do not provide shielding related to emissions and immunity. This poses a problem for EMC compliance. If the robot catches on fire will it be able to self-extinguish the fire before causing a major situation to develop? The manner in which we integrate EMC and product safety may override functionality. The Bionic Leg from Tibion (Figure 1) used to help stroke victims learn to walk again during physical therapy must never malfunction under a transient event.

The future of robotic engineering is exciting, especially for EMC and product safety engineers.

REFERENCE

1. http://www.bostondynamics.com/robot_petman.html

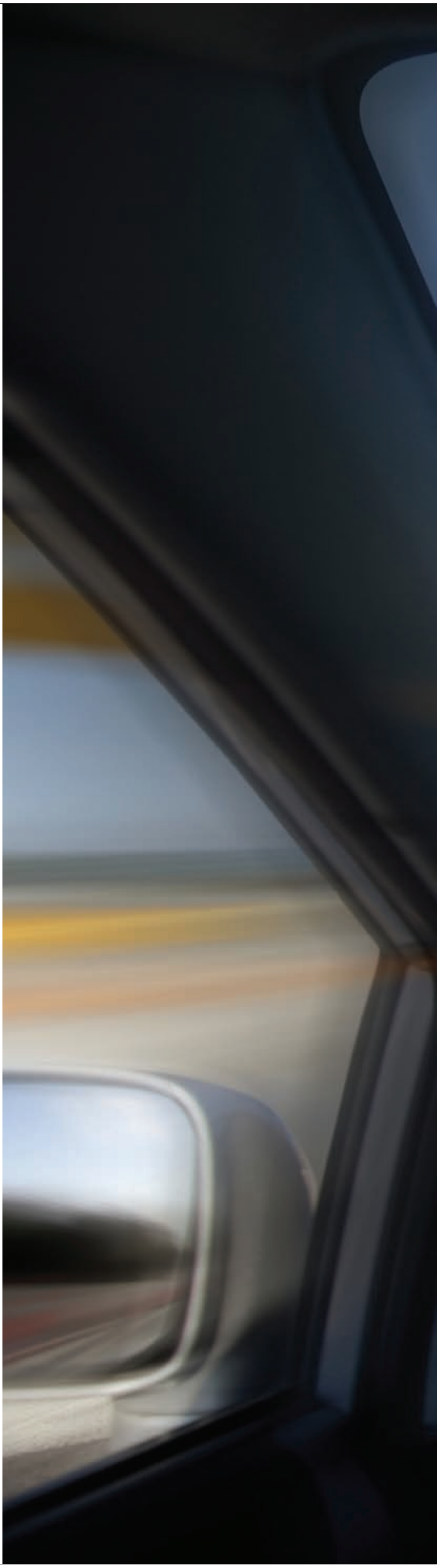
(the author)

MARK I. MONTROSE is an EMC consultant with Montrose Compliance Services, Inc. having 30 years of applied EMC experience. He currently sits on the Board of Directors of the IEEE (Division VI Director) and is a long term past member of the IEEE EMC Society Board of Directors as well as Champion and first President of the IEEE Product Safety Engineering Society. He provides professional consulting and training seminars worldwide and can be reached at mark@montrosecompliance.com.

Impact on EMC for Electrical Powertrains with Respect to Functional Safety: ISO 26262

BY JODY J. NELSON, WILLIAM TAYLOR AND ROBERT KADO

Due to increasing concerns with petroleum usage and the increasing federal fuel economy regulations, electric powertrains have become more accepted by automotive manufacturers and can be found in production and within numerous development programs.



Although electric propulsion vehicles were first built over 100 years ago, such vehicles are not commonplace in today's automotive market. As with any "new" technology, concerns arise regarding safety and reliability of such vehicles. The functional safety standard ISO 26262, introduced in final draft in 2011, provides crucial safety-related requirements for passenger vehicles including those employing electrical propulsion. Although the standard has already had a large influence on automobile manufacturers and suppliers, it's implications for EMC have not previously been fully clarified.

The objectives of the paper are firstly to compare and contrast present electromagnetic compatibility (EMC) vehicular and component requirements and processes to those suggested by the recently released functional safety standard, ISO 26262 [1]. Secondly, the paper analyzes other state-of-the-art standards and guidelines for EMC and functional safety that are not directly referenced by ISO 26262. Thirdly, the paper discusses environmental concerns and covers a real case study of a safety critical E/E component after real ageing effects. Finally, the paper provides suggestions on methods to improve EMC processes for electric powertrains to allow for greater acceptance to ISO 26262. The discussion within the paper is aimed specifically at electrical components involved with an electric powertrain.

ISO 26262 COMPARED TO PRESENT AUTOMOTIVE EMC REQUIREMENTS

ISO 26262 Coverage of EMC

EMC or Electrostatic Discharge (ESD) is referenced in 5 of the 10 total parts of ISO 26262, as illustrated in Table 1. As is seen in Table 1, besides the testing requirements of Part 5, there is a great focus on failures that can be caused by EMC within the analysis and design of the hardware component. In the development of production vehicles, recognizing and correcting issues early in the development are critical for cost effective and reliable products. EMC becomes just one of the numerous considerations that are required in the effective safety analysis required by ISO 26262.

Another key feature of ISO 26262 is the hazard analysis and risk assessment described in Part 3. EMC is not explicitly referenced in this section because it is only one of many potential causes to a hazard. These potential causes to a hazard should be identified in a Failure Mode and Effects Analysis (FMEA) and should include EMC effects. Part 3 determines the Automotive Safety Integrity Level (ASIL) for each function, which then sets the minimum requirements to reduce the probability of a failure to cause an unreasonable risk [1]. There are a total of four ASIL, with ASIL D having the most stringent requirements and ASIL A the least stringent. Additionally, there is a quality management (QM) class that signifies that it has no requirement to comply with ISO 26262.

It is not possible to assign an ASIL only to an immunity event; however, there could be a specific hazard identified which only EMC could cause. Unlike the many EMC requirements where limit lines are established with pass/fail criteria, there is no one defined threshold determining if the specific component or system complies with the intent of ISO 26262. A hazard analysis and risk assessment must be conducted for each component on each vehicle to determine the appropriate ASIL level, as shown in Table 2. It is an important task of the safety manager and the responsible EMC team to provide the input of any EMC related cause of hazards to the appropriate group conducting the hazard analysis and risk assessment. This is a brainstorming activity to see if any immunity event could cause a unique hazard not already identified by other potential failure modes. As will be shown later in the paper, nearly all immunity effects are already identified by the most common failure modes of an electronic signal. An example of an exception could be an ESD event. The voltage level and pulse characteristics are very unique to this specific ESD effect and could cause a hazard not previously considered.

Consider the example of an ESD event causing a unique hazard, such as degradation of a safety critical signal in the vehicle wiring harness during service. If the safety critical signal is from a powertrain E/E component function that has an influence on acceleration, it could have a severity of S3 (life-threatening injury) and a controllability of C3 (difficult to control). However, a hazard caused by an ESD event may only be an E2 (<1% of average operating time) or E1 (occurs less often than once a year for the great majority of drivers). This then establishes the highest possible requirements for that function according to an ASIL B or ASIL A.

Part	Description
3	Impact analysis
4	Test goals and test methods for both system and vehicle testing
5	Specification of hardware safety requirements
5	Hardware architectural design and hardware detailed design
5	Hardware integration and testing
5	Example calculation of hardware architectural metrics
9	Analysis of dependent failures
10	Relationship between faults, errors and failures
10	Example of dependent failures analysis

Table 1: References to EMC or ESD in ISO 26262 [1]

ISO 26262 EMC Testing Requirements

Table 3 highlights the required immunity tests as specified by ISO 26262. It is noted that ISO 7637-3 has been added in the final draft, recently published at the time of this paper, in comparison to the 2009 draft of ISO 26262 [1,2]. All ISO tests, numbers 1 through 6, are common tests required currently by OEMs or by an equivalent test. Additionally, the tests called out within the four tables of IEC 61000-6-1 are generally covered under internal OEM requirements and are often exceeded in field strengths and frequency coverage. The fourth table of IEC 61000-6-1 is specific to high voltage (HV) components with an interface to ac power, such as the HV battery charger connection to the power grid. Item number 8, IEC 61508, is the general functional safety requirement for any electronic or electrical system without regards to the specifics of the automotive industry [3]. It does not have any specific requirements for passenger vehicles dealing with EMC; however it does reference IEC 61000-1-2, a general standard on EMC and functional safety [4].

IEC 61000-1-2 will be discussed later in the paper. It is noted that it does not provide additional types of immunity testing, but rather suggests increasing the test severity of some general standards.

To verify the standard testing requirements from the OEMs, the EMC requirements from Ford Motor Company (Ford), General Motors Company (GM), and Chrysler Group LLC (Chrysler) were reviewed and compared against ISO 26262 requirements [5-7]. Tests numbered 1-6 of Table 3 are all required by the reviewed OEMs with the exception of ISO 7637-3 by Ford. Ford requires some of the transient tests of ISO 7637-3, but also includes several other pulses not captured in the specification based on experience with their vehicle testing. Both tests numbered 7 and 8 of Table 3 are not specific to passenger vehicle requirements. However, specified tests and test levels of IEC 61000-6-1 are already covered under the OEM EMC requirements. For the case of RF immunity, the frequency range is expanded to cover from 1 MHz up to greater than 3 GHz on a component level, rather than the 80 MHz to 2.7 GHz as specified by ISO 61000-6-1. Ford and GM do, however, stop their vehicle testing at 2 GHz. Additionally, the power levels are increased significantly from 3 V/m to standard levels of 70 and 100 V/m with high RF bands tested as high as 600 V/m. The requirement IEC 61508 is in some sense a circular requirement, since ISO 26262 covers the functional safety requirements specific to passenger vehicles whereas IEC 61508 is generic for E/E components in all industries. Notwithstanding, the reviewed OEMs have additional requirements and guidelines for immunity in comparison to the ISO 26262, including, but not limited to: IEC 61000-4-21 (reverberation chamber test methods), ISO 11452-1 (general immunity guidelines), ISO 11452-8 (immunity to magnetic fields), ISO 11452-9 (test methods for electrical disturbances from narrowband radiated EM energy), ISO 7637-1 (definitions from conducted and coupling tests), CISPR 12 and 25, and military standards such as MIL-STD-461E. All mentioned requirements apply to vehicles with an electric powertrain as well, not to mention that many OEMs have additional internal requirements specific to HV components.

Severity Class	Probability Class	Controllability Class		
		C1	C2	**C3**
S1	E1	**QM**	**QM**	**QM**
	E2	**QM**	**QM**	**QM**
E3		**QM**	**QM**	**A**
E4		**QM**	**A**	**B**
S2	E1	**QM**	**QM**	**QM**
E2		**QM**	**QM**	**A**
E3		**QM**	**A**	**B**
E4		**A**	**B**	**C**
S3	E1	**QM**	**QM**	**A**
E2		**QM**	**A**	**B**
E3		**A**	**B**	**C**
E4		**B**	**C**	**D**

Table 2: ASIL determination table from ISO 26262 with ASIL ratings shown in bold for each combination of severity, probability, and controllability [1]

As has been shown, OEM EMC requirements meet or exceed the immunity and electrostatic discharge (ESD) testing requirements as specified by ISO 26262 in most cases. In some particular cases there are gaps between the reviewed OEM EMC requirements and ISO 26262 requirements. Each OEM should evaluate their requirements according to ISO 26262 to confirm compliance.

EMC and ESD testing is only one of 10 possible integration tests to verify the robustness of the hardware under external stresses according to the tables with ASIL requirements in Part 5 of the standard [1]. EMC and ESD requirements are highly recommended for all ASIL levels, ASIL A to ASIL D.

ISO 26262 deals with the specifics of the close handling of functional safety critical circuits and safety mechanisms allowing the vehicle to go into a safe state, even under faulted conditions. These failures, and the mechanisms which provide safety during failures, may or may not be related to EMC in a given case. The challenge is to understand the features of ISO 26262, and apply them efficiently to EMC-related processes in the automotive industry.

For example, ISO 26262 mandates that the planning and definition of safety critical activities are handled by the safety manager for both the supplier and OEM portions of the development life cycle. In practice this requires proper coordination between the safety manager and the EMC testing groups. Based on safety and impact analysis, additional orientations or devices under test (DUT) could be requested. Such determination is made on a case-by-case basis. Additionally, the safety manager has the responsibility of communicating to the EMC testing groups on the monitoring and focus

No.	Standard	Title
1	ISO 7637-2	Electrical transient conduction along supply lines only
2	ISO 7637-3	Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines
3	ISO 10605	Road vehicles — Test methods for electrical disturbances from electrostatic discharge
4	ISO 11452-2	Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 2: Absorber-lined shielded enclosure
5	ISO 11452-4	Road vehicles —Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)
6	ISO 16750-2	Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads
7	IEC 61000-6-1	Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments
8	IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems

Table 3: Immunity tests as required by ISO 26262 [1]

of safety critical signals. The safety manager must take an active role in the creation of test plans and must review the results. The safety manager has an overall view of the safety of the particular component and can provide the best direction to ensure the tests are conducted properly, with the guidance from the EMC test group, for the particular component.

Automotive EMC Lessons Learned

One measure, defined in Part 5 of ISO 26262 to prevent common design faults, is the usage of lessons learned. EMC considerations for the automotive industry have been established since the 1980s, when automotive EMC design and test standards were first developed. The automotive EMC community has traditionally played an active role in the development of standards and has followed the recommendations of many international organizations such as International Organization for Standardization (ISO), Comité International Spécial des Perturbations Radioélectriques (CISPR), European Committee for Electrotechnical Standardization (CENLEC), Society of Automotive Engineers (SAE), Automotive EMC Laboratory Recognition Program (AEMCLRP), and International Commission on Non-Ionizing Radiation Protection (ICNIRP). The automotive industry participates annually at ISO and CISPR meetings, sending delegates from each representing country. Internal Original Equipment Manufacturer (OEM) requirements exceed Federal regulations and, in some cases, exceed the testing requirements of the previously mentioned organizations. Additionally, within a number of countries, the OEM EMC community has taken actions together to harmonize with other OEMs and to share the lessons learned from their own experience. This is apparent within the United States by the SAE automotive EMC working committee that is open to both OEMs and suppliers. This knowledge sharing is uncommon in many areas within the development of passenger vehicles due to the competitive nature of the automobile industry.

The lessons learned by the EMC community have grown and extends to knowledge gained over 30 years of experience on mass production vehicles. Electric powertrains introduce new components to the traditional vehicle. However, the handling of failures due to EMC on electric powertrains with respect to functional safety is similar to electronic throttle controls or other drive-by-wire technologies, where the industry has gained valuable insights over time since its inception in the 1980s. Both the controllers for electrical propulsion and electronic throttle control have similar functional safety concerns due to their direct impact on acceleration and braking. A consortium of German OEMs and suppliers established a set of guidelines for functional safety of electric throttle controllers starting in the late 1990s [8]. The contents of these requirements are often tailored to also consider electrical powertrain requirements. In many cases the functional safety relevant items will be the same; such as torque monitoring considerations, loss of CAN strategies, enabling a safe operating state, and reduced torque operating strategies.

In summary, the specific immunity tests required by ISO 26262 are already in practice in industry, with some small exceptions that require further evaluation from the OEM. In part, this reflects the efforts of industry over the past several decades to update and refine their methodologies regarding EMC. It is also a reminder of the nature of ISO 26262, which requires more than a set list of tests, as will be shown in future sections of this paper.

STATE-OF-THE-ART: FUNCTIONAL SAFETY FOR EMC

The requirements for hardware development, according to ISO 26262, are adapted to the state-of-the-art for the automotive industry. This then implies the usage of state-of-the-art standards for EMC with respect to functional safety. However, currently there exists no document specific to the automotive industry. A general industry standard, IEC 61000-1-2, does exist and will be evaluated among other technical papers here with reference to the specifics of automotive and electric powertrains. IEC 61000-1-2 is a supplement to IEC 61508; to provide guidance to achieve adequate immunity to EMC for safety-related systems and equipment.

IEC 61000-1-2 begins the validation requirements stating that there is no practical means to test a component to immunity under all environmental conditions in all operating modes. Since IEC 61000-1-2 is generic to all electrical systems in all industries, it can only provide example test methods and generic testing levels. It heavily relies on developing testing parameters based on knowledge and experience with the particular product within its most probable environments. As stated in the previous section, the automotive EMC industry in general works together to harmonize standards based on experience over a large quantity of vehicles. The Bureau of Transportation Statistics reports that 8-15 million vehicles are sold yearly in the U.S. alone [9]. Unlike many other industries, the standards derived by the automotive industry include a significant amount of field experience. It is justifiable that the internal OEM test levels and test methods comply with the requirements stated in IEC 61000-1-2. All suggested immunity test parameters of IEC 61000-1-2 are already commonly performed in the automotive industry, with the exception of environmental factors and ageing.

The inclusion of environmental factors, such as temperature and humidity, during immunity testing is non-trivial. Often, EMC test chambers and equipment are not suitable for testing across the full temperature range required by automotive environments. However, environmental effects cannot be ignored when evaluating electric powertrains during a field immunity event. Notwithstanding, it is important to note that, by standard automotive testing, automotive components endure extreme environmental conditions and must functionally operate across the complete environmental testing spectrum. The following two sections provide further details on how to consider environmental effects with respect to EMC.

The component itself is tested rigorously for functionality under extreme operating and environmental conditions. ISO 26262 requires that all safety relevant signals are also fully functional in these conditions. Additionally, ISO 26262 aids in filling in these temperature gaps through the evaluation of safety goal violations that can occur due to random hardware failures and by evaluating the hardware architecture. Immunity events causing a failure can be addressed using probabilistic metrics to analyze random failures and minimize their effects. Additionally, single-point, residual, and latent faults from the hardware architecture should be evaluated.

ISO 26262 provides two methods to evaluate random failures; a probabilistic approach, such as a Failure Modes Effects and Diagnostic Analysis (FMEDA), and a cut-set analysis, such as a Fault Tree Analysis (FTA). These methods must prove that a random hardware failure cannot cause a violation of the safety goals within a defined probability based on the ASIL rating of the system under consideration.

Generally, ISO 26262 will require a safety-critical system to address single-point, residual, and latent faults by either redundancy, moving the fault to a multiple-point fault, or by a high enough diagnostic coverage. The results of the FMEDA can be used to establish requirements for testing faults. This provides a systematic approach at recognizing and developing test cases.

Multiple-point faults require fault injection testing to verify that safety critical mechanisms remain in a safe state. Fault injection testing introduces faults to the hardware and studies the response. A list of common signal failure modes that are evaluated and tested are shown in Table 4. As can be seen, the failure modes considered during fault injection testing are also

No.	Failure Mode
1	Signal missing when required
2	Signal present when not expected
3	Signal too high of a value (short to battery voltage)
4	Signal too low of a value (short to ground)
5	Open circuit (lost connection)
6	Signal stuck
7	Oscillating signal value (random signal value)
8	Signal delayed
9	Signal drifts within normal operating region

Table 4: Common signal failure modes

failure modes of a potential immunity event. These tests then support EMC activities. The advantage of fault injection testing is that it isolates a potential immunity threat and verifies that the component allows for operation to a safe state if a failure occurs. This approach gets to the root of the impact to a failure, ensuring a safe outcome, and is independent of the source of the failure. As an example, the root cause of a signal being pulled low could be a cut circuit trace or an immunity event causing a dip in the voltage. Regardless, the fault injection test addresses the failure mode and verifies the proper reaction.

Many articles have been written with concerns on the lack of attention paid to immunity with respect to functional safety [10-12]. However, the guidelines provided by ISO 26262, when strictly enforced, alleviate many of the uncertainties raised in these articles. Before developing complex and impractical processes to analyze the risks to functional safety associated with EMC, ISO 26262 should be thoroughly reviewed and considered since it will be commonplace in the automotive industry.

ANALYSIS: TEMPERATURE EFFECTS

When evaluating electronic systems according to ISO 26262, it is important to understand the nuances of environmental exposure. Low-temperature conditions provide a useful example. For many power electronic components in electric powertrains, such as an inverter, true low-temperature conditions are only prevalent at start-up conditions after a cold-soak (e.g., overnight in a cold garage). Even very efficient electrical powertrains incur thousands of watts of losses, which are manifested as heat within the electronic components. Due to this heat generation, the time interval in which electrical powertrain component remain at the ambient low temperature is very short in comparison to the entire drive cycle. This effect has a substantial impact on the exposure of electronic components to the worst-case low temperature condition.

Average daily operation	60 minutes
Average daily drive cycles	2
Minimum capacitor temperature for unrestricted performance	15° C
Rate of capacitor temperature increase during operation	4.5° C/minute
Total time capacitor in restricted performance (in a year)	3150 minutes
Total yearly operating time	21,600 minutes
Exposure to external immunity event during operation	<1%
Probability of using emergency signal	<1%

Table 5: Parameters used for cold temperature example

To illustrate this dynamic, a test was conducted with a pure EV powertrain at -20° C ambient temperature. A load of 3 kW was applied, which is relatively small in comparison to real propulsion loads. Due to the effect of losses, the inverter's IGBT heated up to 45° C at a rate of 30° C/minute. The coolant temperature increased at a rate of 4.5° C/minute. Based on this, even at -40° C the inverter will heat to above ambient temperature within minutes and the entire cooling system in less than 15 minutes. Taking into consideration the frequency of a component's exposure to such extreme temperature conditions, the risk of exposure to an immunity event becomes very small considering the probability of the injection during this small time window of the vehicle's operation. All of these factors must be taken into consideration when conducting the hazard analysis and risk assessment.

For the first time, ISO 26262 provides a standardized risk analysis framework to account for all of these factors in an automotive production and development setting.

To elaborate further on the condition of low temperatures, consider the following example. A powertrain controller has an external emergency signal used to place the controller into a safe state in the event an unintentional acceleration event occurs. A decoupling capacitor between the signal and reference is used to secure the line from external immunity field events and is compliant to all EMC immunity requirements, assuming the capacitor maintains its specified capacitance. Consider a worst-case environment such as the region of Jokkmokk, Sweden in Lapland. This area is commonly used by a number of OEMs for winter testing. It resides along the Arctic Circle and has a yearly average temperature of approximately 0 degrees Celsius. Assuming the parameters illustrated in Table 5 and the average minimum temperatures of Jokkmokk, the capacitance of the capacitor could be below the necessary capacitance for 15% of the vehicle's operating time. However, the risk of exposure to an external immunity field is less than 1% and the probability of needing the emergency signal is also less than 1%. Therefore the exposure for this particular example becomes an E0 (extremely unusual) of E1 (occurs less often than once a year for the great majority of drivers). According to Part 3 of ISO 26262, this particular scenario of cold temperature operation may be a QM or ASIL A.

Environmental extremes on the other end of the spectrum must also be considered. A similar analysis should be conducted as was shown in the cold temperature case. In the case of hot temperatures, elevated temperatures are naturally tested on a vehicle (system) level since the duration of vehicle EMC testing is sufficiently long enough that the entire powertrain will heat up to a point where the vehicle's cooling system will be activated. Temperatures in the cooling system beyond a specified region, for example 90° C, would indicate a failure in the cooling system and would therefore produce a warning indication to the operator. A warning lamp already indicates to the operator that the continuation of driving must be taken with caution. When temperatures get too high, the powertrain will be reduced to zero torque. When considering these factors, the actual gaps in testing become small.

A full hazard analysis and risk assessment and FMEA should be conducted before over specifying immunity testing and requirements for a component. If the outcome proves that further testing is required, then the specific tests should be arranged between the safety manager and responsible EMC team. An example test could be conductive immunity testing beyond the operating temperatures of the component as detailed in SAE J2628 [13].

CASE STUDY: AGEING EFFECTS

Electrical components typically degrade in performance over time and after considerable usage. It is difficult to evaluate the impact of ageing with respect to EMC and functional safety due to the numerous parameters that must be considered and the lack of specific ageing data of each part within a component. Therefore the hazard analysis and risk assessment do not properly cover the risks involved with ageing, and actual testing is required.

As a case study, two air bag control modules from field vehicles were testing against the full immunity requirements after being subjected to major water intrusion and corrosion. The DUT was previously tested during the development phase and met all immunity requirements. The first module was from a vehicle over five years old with over 80,000 miles. The second module was from a vehicle over three years old with over 35,000 miles. Both modules displayed similar corrosion damage. In this test case, both modules passed the OEM's immunity tests as shown in Table 6.

The impact of component and vehicle ageing can and should be addressed to ensure functional safety. All components and vehicles undergo numerous accelerated lifetime and durability testing. Following these ageing tests, the vehicle should be tested again during development

CISPR 25 conducted RF emissions – (voltage on supply lines)	Both sets of DUTs meet requirements; less than 3dB variance between aged parts and non-aged parts
CISPR 25 conducted RF emissions – (current on all lines)	Both sets of DUTs meet requirements; less than 3dB variance between aged parts and non-aged parts
CISPR 25 radiated RF emissions	Both sets of DUTs meet requirements; less than 3dB variance between aged parts and non-aged parts
Bulk current injection	Both sets of DUTs meet requirements
ALSE with a ground plane (radiated immunity)	Both sets of DUTs meet requirements
Magnetic field immunity	Both sets of DUTs meet requirements
Transient disturbances conducted along supply lines	Both sets of DUTs meet requirements including parametric check posttest
Transient disturbances conducted along I/O lines	Both sets of DUTs meet requirements including parametric check posttest
Electrostatic discharge handling test	Both sets of DUTs meet requirements including parametric check posttest
Electrostatic discharge operating test	Both sets of DUTs meet requirements including parametric check posttest
Various EE tests; including supply voltage range (with hot/cold soak), voltage variations (dips, drops), load dump, short circuit, reverse battery, and overvoltage conditions	Both sets of DUTs meet requirements including parametric check posttest

Table 6: Immunity test performed on pre- and post-ageing DUT

against the immunity requirements with specific focus on functional safety items and verification of the properly functioning safe state mechanism. Currently, immunity testing of vehicle durability is not commonplace across the industry. It is recommended to improve the lessons learned by establishing a shared and open testing forum for vehicles' durability immunity testing among the OEMs. In addition to testing durability and field components, conducting tests beyond the operating temperature ranges, as specified in SAE J2628, can also simulate some effects of ageing components.

CONSIDERATIONS TO EMS FOR FUNCTIONAL SAFETY

Electric powertrains are generally assigned a high ASIL rating due to the high severity and probability of a hazardous event relating to their direct impact on vehicle propulsion. Some critical signals for immunity testing include the speed sensor, current and voltage sensors, torque relevant messages, and signals related to the safe shutdown of the powertrain in faulted conditions. Other aspects of the powertrain need to also be considered, such as the type of electric motor. Permanent magnet (PM) motors can add additional risks due to the back emf created by the rotating magnets. A high braking torque due to high current flow can be produced when the back emf voltage is greater than the high voltage (HV) battery if the shutdown of the electric powertrain is not properly performed with PM motors. Not only do the critical signals have to be monitored during immunity testing, but also the vehicle's safe reaction to a failure. All such potential hazards should be defined and identified during the hazard analysis and risk assessment and FMEA. These potential hazards should be included in the safety concept of the component or system.

EMC, to some degree, needs to be considered as one of many possible causes of failure. When this approach is taken, many of the risks associated with an immunity event are naturally covered through the normal ISO 26262 process. It is believed that ISO 26262 does not introduce revolutionary changes to the current OEM EMC process; however additional activities are still required. The following items are proposed to bring the current EMC processes into ISO 26262 compliance:

1. Align safety critical activities between the EMC test and development engineers and the safety manager. A kick-off meeting prior to development is required, along with continual update meetings.

2. Support the hazard analysis and risk assessment by providing feedback on failure modes due to immunity and ESD events. Verify that the proposed fault injection tests also cover failures associated with EMC. In particular, common-cause failures should be identified. Analyze each safety function against environmental conditions, such as extreme temperatures, to determine if additional measures and testing are required.

3. Create a test plan to specifically monitor and test the functional safety relevant signals and functions. When higher levels are allowed by the EMC specification, they should be used on functional safety items. Any redundancy design for safety mechanisms allowing the vehicle to go to a safe state must be emphasized.

Description	Typical Present EMC Processes	New EMC Processes, including ISO 26262
Safety analysis	FMEA	FMEA, FMEDA, FTA, Hazard Analysis, Risk Assessment, Common Cause Failures
Responsibility	Release engineer, EMC team	Release engineer, EMC team, Safety Manager
Tests	Standard automotive tests based on CISPR, ISO, etc.	Standard automotive tests based on CISPR, ISO, etc., specified ISO and IEC tests, fault injection tests (if not already considered)
Test conditions	Standard conditions	Standard conditions, additional orientations*, additional operating conditions*, durability components*, environmental conditions*
Documentation	Standard templates	Standard templates, traceability to safety case

Table 7: Comparison of present EMC processes and new proccesses to include ISO 26262 requirements

***Additional tests that could be required as an outcome of the hazard analysis and risk assessment.**

Additional orientations or test cases may be required based on the safety analysis.

4. Develop a plan for documentation and traceability of EMC related documents, including test reports and analysis. The safety manager should always be informed of any non-compliance issues.

5. Add in ageing immunity testing during development. Establish a shared and open forum with other OEMs and suppliers to increase the lessons learned in the effects of ageing and immunity events.

6. Evaluate internal component and vehicle requirements to confirm compliance to all EMC and ESD tests required by ISO 26262, shown in Table 3.

Table 7 provides a comparative summary between present EMC processes and updated processes to consider ISO 26262 requirements. Not everything shown in the new EMC processes is necessarily required for every component and system. Every company must evaluate the necessary changes to their processes based on the specific product. Companies working together can further align the activities and reduce the required effort.

CONCLUSION

ISO 26262 allows for a common automotive systematic approach to analyzing and evaluating risks for functional safety associated with EMC events. The standard process defined by ISO 26262 inherently addresses a number of risks associated with EMC and considers EMC as one of numerous possible failure modes. Today's standard automotive EMC processes and standards follow the majority of ISO 26262 requirements. However, additional processes and activities are required to gain compliance with the standard's overall requirements. These include assignment of a safety manager who can oversee the activities related to safety-critical functions, structured hazard analysis and risk assessment, inductive and deductive safety analysis, and required fault injection testing. The standard also points to some potential shifts in validation processes, such as additional environmental testing if required as an outcome of the safety analysis.

REFERENCES

1. ISO DIS 26262:2011, "Road vehicles - Functional safety," *International Organisation for Standardisation, vol. 43*.040.10, 26262, under publication.
2. ISO DIS 26262:2009, "Road vehicles - Functional safety," *International Organisation for Standardisation, vol. 43*.040.10, 26262, approval stage.
3. IEC 61508:2010, "Functional safety of electrical/electronic/programmable electronic safety-related systems," *International Electrotechnical Commission, ed. 2.0*.
4. IEC 61000-1-2:2008, "General – Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena," *International Electrotechnical Commission, ed. 2.0*.
5. EMC-CS-2009.1, "Electromagnetic Compatibility Specification For Electrical/Electronic Components and Subsystems," *Ford Motor Company website*, available: http://www.fordemc.com.
6. GMW3097, "General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility," *General Motors Corporation internal document*.
7. CS-11979, "Chrysler/Fiat Electrical and EMC Performance Requirements – E/E Components," *Chrysler Group LLC internal document*.
8. "Standardized E-Gas Monitoring Concept for Engine Management Systems of Gasoline and Diesel Engines," *Work Group EGAS, version 4.0*, 2007.
9. National Transportation Statistics, "The Transportation System," *US Bureau of Transporation Statitstics website*, available: http://www.bts.gov.
10. K. Armstrong, "EMC for the Functional Safety of Automobiles – Why EMC Testing is Insufficient, and What is Necessary," *2008 IEEE International Symposium on Electromagetic Compatibility*, Detroit, MI, August 18-22, 2008.
11. W. Grommes and K. Armstrong, "Developing Immunity Testing to Cover Intermodulation," *2011 IEEE International Symposium on Electromagetic Compatibility*, Long Beach, CA, August 14-19, 2011.
12. S. Wang, "Improve Vehicle's Functional Safety with an Approach Investigating Vehicle's Electromagnetic Interference with its Functional Safety," *2011 IEEE Vehicle Power and Propulsion Conference*, Chicago, IL, September 6-9, 2011.
13. SAE J2628, "Characerization, Conducted Immunity," *Society of Automotive Engineers International*, June, 2007.

(the authors)

JODY J. NELSON and WILLIAM TAYLOR
work at kVA LLC in Greenville, SC, USA and can be contacted at jody.nelson@kvausa.com and bill.taylor@kvausa.com, respectively.

ROBERT KADO
works with the Chrysler Group LLC in Auburn Hills, MI USA and can be contacted at rk381@chrysler.com.

Software as a Medical Device Part II

BY BRIAN McAULIFFE

An overview of EU Commission guidelines for developers of standalone software

Since the 2007 amendment to the Medical Devices Directive (93/42/EC)[1] aimed at clarifying its scope in relation to standalone software, there has been much debate on what types of standalone software should be qualified as medical devices and, subsequently, how they should be classified. An article titled 'Software as a Medical Device', published in the December 2011 issue of *In Compliance*, referred to a guideline document that was being worked on by the EU Commission for this purpose. This guideline was finally published in January 2012 as MEDDEV 2.1/6[2].

MEDDEVs are guidelines aimed at promoting a common approach by manufacturers and notified bodies involved in the conformity assessment procedures, and by the competent authorities of the member states charged with safeguarding public health.

Our purpose here is to provide an overview of what the Commission guidance really means for developers and suppliers of standalone software for use in a healthcare setting. A future article will provide an overview of the standards development activity as it relates to standalone software and healthcare IT solutions in general.

This article does not cover how the guidance should be interpreted in relation to the In Vitro Diagnostic Medical Devices Directive 98/79/EC.

The guidelines are not legally binding, and it is recognised by the Commission that under given circumstances (for example, as a result of scientific developments) an alternative approach may be possible or appropriate to comply with legal requirements.

SO WHAT IS "STAND ALONE" SOFTWARE?

Before drilling down into the content of the guidance, it is important to first define what we mean by standalone software. In the context of Medical Devices Directive (93/42/EC) (MDD) and this guidance, standalone software 'means software which is not incorporated in a medical device at the time of its placing on the market or its making available'. Any software that is embedded in a medical device, at firmware or application level, is assessed as part of the medical device and is therefore outside the scope of MEDDEV 2.1/6. The meaning of the term 'placing on the market' and other terms used in this article are as defined in MEDDEV 2.1/6.

Meeting the criterion of not being incorporated in a medical device is only one consideration - the standalone software must also meet the definition of a medical device to be qualified. For example, an enterprise resource planning (ERP) billing software application is not considered to be a medical device, as it does not have a medical purpose although used in a healthcare setting.

The **intended purpose** of the standalone software is also relevant – if the use for which the device is intended according to the manufacturers documentation is not for a medical purpose, then the standalone software is not to be qualified as a medical device.

It should also be noted that standalone software that does not meet the definition of a medical device but is intended to be used as an accessory to a medical device, is not in scope for MEDDEV 2.1/6 but is covered by the MDD.

QUALIFICATION CRITERIA

The qualification criteria to be applied in the process of deciding whether or not standalone software is a medical device are varied and complex. In addition to the medical purpose and 'used as intended' criteria, considerations such as the function performed by the standalone software being for the benefit of an individual patient or for the analysis of population data must be factored in.

In an attempt to model the decision framework, the guidance document contains a **decision tree diagram** which, if applied properly, should help in achieving a consistent application of the guidance by all stakeholders. The diagram, copied in Figure 1, guides the reader through a series of six decision steps.

Some key points:

- Only the intended purpose as described by the manufacturer of the product is relevant.
- If the software is not a computer program (e.g., a DICOM clinical image file), it is not a medical device (Decision Step 1). But the PACS system that manages DICOM files may be a medical device.
- If the software is incorporated in a medical device, it must be assessed as part of the process for that medical device and not as a standalone software (Decision Step 2).
- Decision Step 3 will be a key consideration for many suppliers of software systems - if the software does not perform an action on data, or performs an action limited to storage, archival, communication, simple search or lossless compression, it is not a medical device. However, where the software alters the representation of data for a medical purpose or where a search function provides interpretative results, it could be considered a medical device.
- The software must be used for the benefit of individual patients to be considered a medical device; i.e., software used to analyze population data, or provide generic treatment pathways is not a medical device (Decision Step 4).

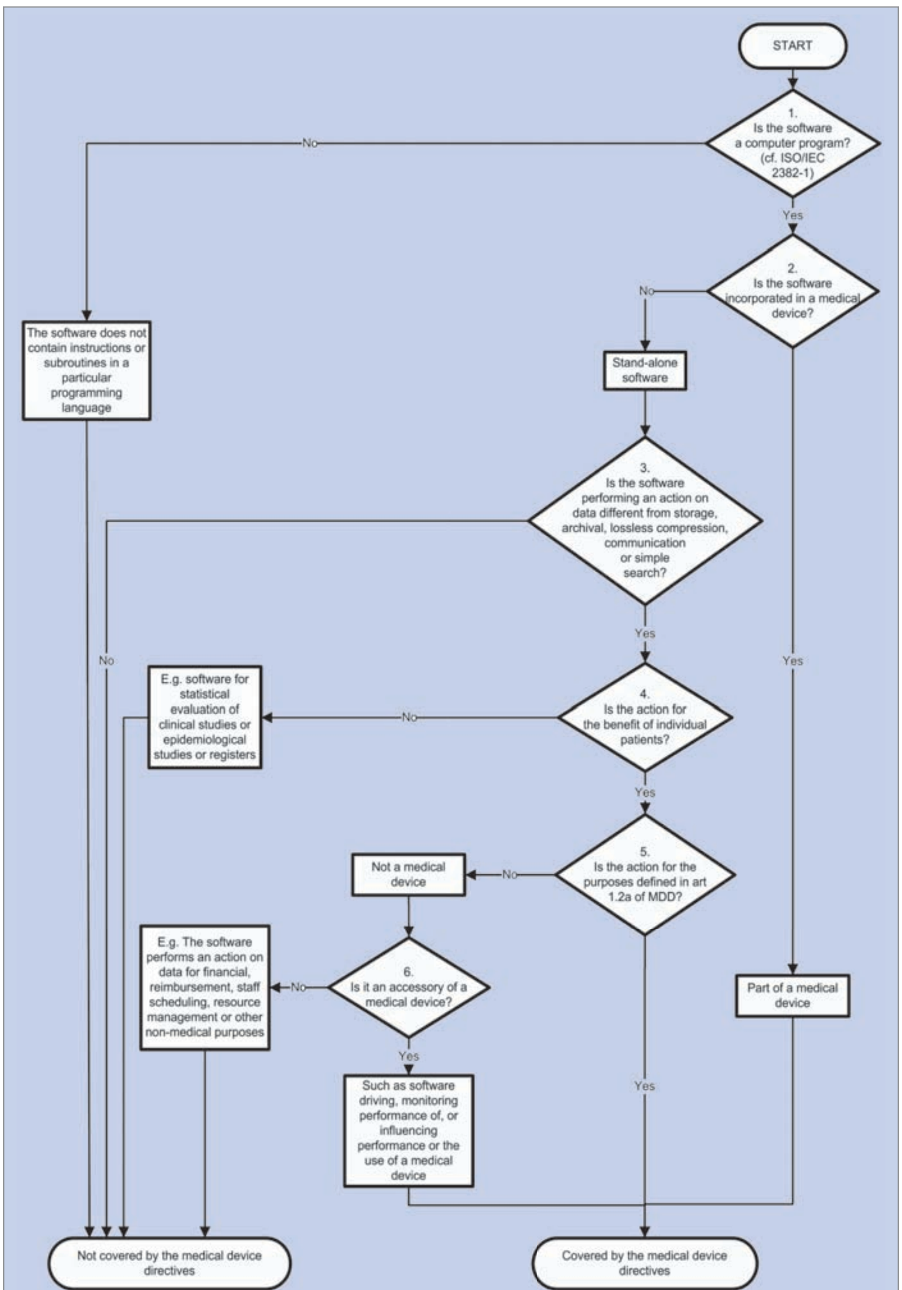


Figure 1: A decision diagram to assist qualification of software as a medical device.

- The software must have a medical purpose as defined in the MDD Article 1(2)a. Software for staff planning/rostering or invoicing in a healthcare environment are not to be considered as a medical device (Decision Step 5).
- If the software is an accessory to a medical device (e.g., it drives, monitors, or influences the performance or the use of a medical device), it is not itself a medical device but is covered by the MDD (Decision Step 6).

Annex 1 of the guidance contains some examples of qualification of software used in a healthcare setting, a selection of which are included in Table 1.

The types of applications listed in Table 1 are representative of recent advances in information technologies, and the healthcare IT or eHealth sector is currently experiencing rapid growth in both the bringing to market of innovative solutions and their increasing adoption by providers and other stakeholders into the delivery of healthcare services.

The EU Commission acknowledges this fact, and indeed are a key player in driving its development. Consequently it is the intention that MEDDEV 2.1/6 and the *Manual on Borderline and Classification in the Community Regulatory Framework for Medical Devices*[3] will be 'living' documents, updated as necessary in line with advances in the state of the art in relation to standalone software.

CLASSIFICATION OF STANDALONE SOFTWARE

Once a standalone software is qualified as a medical device by applying the logic outlined in Figure 1, the next question to be answered is into what classification it should fall.

The MDD defines possible classes for medical devices as being either Class I, IIa, IIb or III and provides a set of rules for deciding on the appropriate classification for a device. These rules, called implementing rules, are contained in Annex IX of the MDD.

Section 1.4 of Annex IX states clearly that 'standalone software is considered to be an **active medical device'**:

"Any medical device operation of which depends on a source of electrical energy or any source of power other than that directly generated by the human body or gravity and which acts by converting this energy. Medical devices intended to transmit energy, substances or other elements between an active medical device and the patient, without any significant change, are not considered to be active medical devices. Stand alone software is considered *to be an active medical device."*

This means that implementing rules 9, 10, 11 and 12 may apply, depending on the function and purpose of the stand alone software.

Generic Application	Description	Qualification as a medical device?
Hospital Information Systems	Systems supporting process of patient management – admission, scheduling, billing	No(*)
Decision support software	Radiotherapy treatment planning systems; Drug planning systems; Computer-aided detection systems	Yes (steps 3, 4, 5 of Figure 1)
Information systems	Electronic health record systems; RIS; Clinical information systems	No(*)
Communication systems	Email/mobile/video conference/paging – to transfer messages such as prescriptions/referrals/patient records	No(*)
	Software communicating alarms based on state of patient vital signs	Yes
Telemedicine systems	Telesurgery	Yes
	Remote video appointment software	No
	Home care monitoring	Telecom infrastructure is not but monitoring application could be

(*) see section on modular/multi-function software later in this article

Table 1

To assist suppliers of standalone software in interpreting these rules and to ultimately decide on the appropriate classification, the guidance document contains in Section 3 examples of how some typical standalone software applications should be classified in the context of implementing rules 9 through 12. Table 2 contains a selection of these examples.

MULTI-FUNCTION OR MODULAR SOFTWARE

In a healthcare setting, users will employ software applications for a mixture of purposes, some medical and others not – for example, admission and discharge of patients, electronic prescription, email communications with insurance providers, clinical decision support. Increasingly, vendors of software applications will market suites of software that include many of these functions in one software package. Each of the functions provided by the suite can be considered as a 'module'.

This mixture of medical and non-medical purpose in the functionality of the software suite makes it more difficult for suppliers of software systems to decide on how to approach conformity assessment and CE Marking of the software.

The guidance document offers the following advice:

- The modules (functionality) that have a medical purpose and are defined as a medical device must comply with the requirements of the MDD and be CE Marked.
- Non-medical modules are not subject to the MDD.
- The boundaries and interfaces of the various modules must be identified by the manufacturer during design and development, based on intended use.

Where it gets further complicated is that some medical purpose modules will interface with other non-medical purpose modules and/or equipment. Essential requirement 9.1 of the MDD (copied below) requires that the overall combination must not impair the safety and performance of the medical purpose modules:

"If the device is intended for use in combination with other devices or equipment, the whole combination, including the connection system must be safe and must not impair the specified performances of the devices. Any restrictions on use must be indicated on the label or in the instructions for use."

STANDARDS - DEMONSTRATING CONFORMITY

As with other directives under the EUs New Legislative Framework (NLF) the most accepted method of demonstrating conformity with the essential requirements of the MDD is through the application of harmonized standards published in the Official Journal of the European Union (OJEU). This will also be the most favored route chosen by manufacturers of standalone software, once the standards are published.

WHICH STANDARDS APPLY TO STANDALONE SOFTWARE ?

Once a standalone software is qualified as a medical device, then the design, development and maintenance of that software becomes subject to a similar conformity assessment regime as is applied to hardware medical devices. The purpose of this regime is to ensure that such software, when used as intended, will protect the safety of patients.

Considerations during the development process will need to address items such as risk management, software development

Stand alone software application	Relevant rule	Classification
Radiotherapy planning system used to calculate ionizing radiation dosage	Rule 9 (active therapeutic device)	Class IIb
Software for presentation of heart rate during routine check up	Rule 10 (active diagnosis device)	Class IIa
Software for presentation of heart rate during intensive care monitoring	Rule 10	Class IIb
Software intended to control the administering of medication	Rule 11	Class IIa or Class IIb (if potentially hazardous substances, or depending on body part)
All other stand alone software applications	Rule 12	Class I

Table 2

As we see the beginning of a market developing for healthcare related apps, it will be interesting to see how many of these standards the suppliers of the apps will be included on the Declaration of Conformity with the MDD

life-cycle processes, test and validation addressing implementation, use, and decommissioning phases of such software (systems).

As reported in a draft technical report issued in May 2011 by the International Standards Organization (ISO)[4], e-Health systems (in which software plays a major role) 'have the potential to play a key role in eliminating or mitigating documented threats to patient safety and quality of care ...' The report goes on to identify a number of international standards which already exist, and further standards that are under development, aimed at addressing safety in health software:

- ISO TS 25238:2007 Health informatics – Classification of safety risks from health software
- ISO 14971:2007 Medical devices – Application of risk management to medical devices
- IEC 62304:2006 Medical device software – Software lifecycle processes
- IEC 80001-1:2010 Application of risk management for IT networks incorporating medical devices, Part 1 – Roles, responsibilities and activities

The IEC 80001 series of standards represent an interesting departure from the typical design/development pre-market considerations relevant for manufacturers, in that it stipulates requirements to be considered when adding or removing a medical device (including software that is a medical device) into a network, wired or wireless, within a healthcare delivery organization (HDO). HDOs will be responsible for continued safe operation of the HDO network and will in turn place stringent requirements on suppliers of network and medical devices to demonstrate application of adequate levels of risk assessment/ mitigation during development.[5]

While this is an ISO report to be developed in conjunction with the International Electrotechnical Commission (IEC), its recommendations will most likely be adopted by the European standards development organizations CEN and CENELEC. Once adopted, these standards will more than likely be ratified by the EU Commission and published in the OJEU for use by manufacturers to demonstrate conformity with the MDD.

As we see the beginning of a market developing for healthcare related apps[6], it will be interesting to observe how many of these standards the suppliers of the apps will be included on the Declaration of Conformity with the MDD.

NOTES

1. Directive 2007/47/EC of the European Parliament and of the Council of 5 September 2007 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1993L0042:20071011:EN:PDF
2. MEDDEV 2.1/6 – Medical Devices: Guidance document – Qualification and Classification of stand alone software, http://ec.europa.eu/health/medical-devices/files/meddev/2_1_6_ol_en.pdf
3. http://ec.europa.eu/health/medical-devices/files/wg_minutes_member_lists/borderline_manual_ol_en.pdf
4. ISO/TC 215 / SC WG4 N856 Health Informatics – Guidance on standards for enabling safety in health software
5. A future article will cover in detail the current and future standards framework for medical software, including standalone software qualified as a medical device.
6. http://www.ehi.co.uk/insight/analysis/848/is-there-a-regulation-for-that_tcq

(the author)

BRIAN McAULIFFE

is currently employed as a Senior Engineer with Dell Inc. based in Ireland and working in the Global Regulations & Standards group. Brian has worked in compliance for 20 years with compliance testing laboratories and a number of product development companies in the telecoms and ITE sectors. He is active in the standards development process being an expert member of CENELEC and IEC technical committees and has been Chairperson of TechAmerica Europe Standards & Certification working group since 2009. Brian is currently studying part time for an M.Sc. in Health Informatics from the University of Limerick (www.ul.ie). These materials are not offered as and do not constitute legal advice or opinions. Seek independent legal advice with respect to compliance or any particular issue. The content of this document reflects the opinions of the individual author and may not reflect the opinions of Dell Inc.

Effectiveness of Multilayer Ceramic Capacitors for Electrostatic Discharge Protection

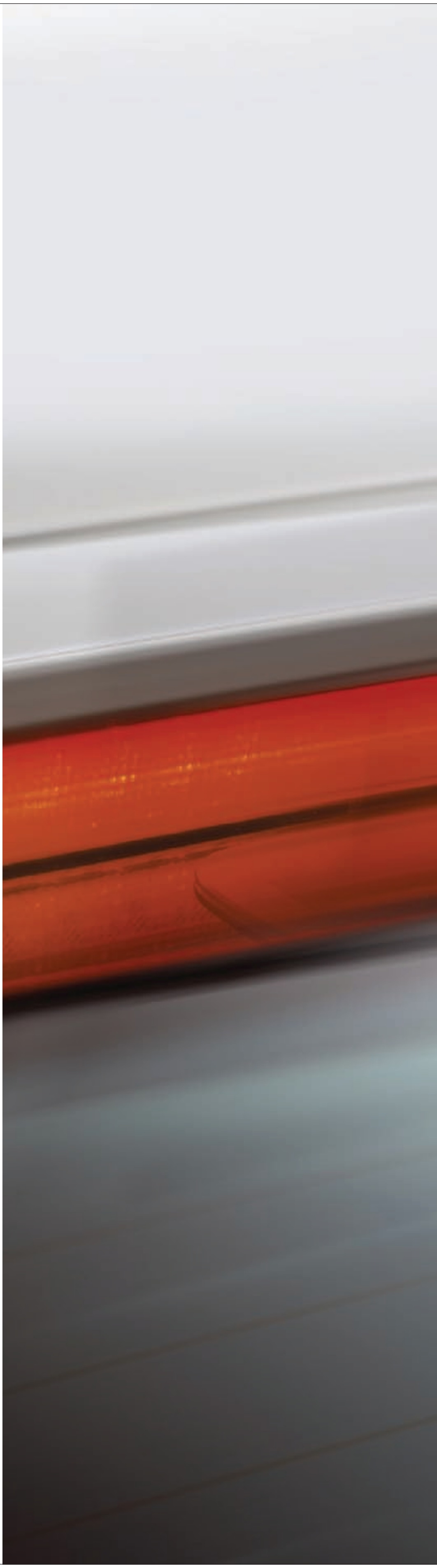
BY CYROUS ROSTAMZADEH, FLAVIO CANAVERO, FERAYDUNE KASHEFI AND MEHDI DARBANDI

A simple technique to deal with ESD can be achieved by mounting multilayer ceramic capacitors (MLCC) at the PCB I/O connector pins that is the ESD entry point.

EMC engineers recommend using 0603 MLCC's placed at close proximity to each connector pin, mandating low-inductance mounting strategy associated with the PCB traces and vias. When selecting surface-mount techonology (SMT) MLCC for ESD protection of I/O pins, engineers specify the ESD capacitor value, its DC voltage rating, and a choice of technology (X7R or C0G). MLCC, as an ESD bypass or shunt device, is used to divert the ESD current to ground. ESD protection devices should perform ESD mitigation and should not exhibit degradation, while maintaining ESD robustness throughout the life span of a product. Nevertheless, post-ESD examination of small foot-print 0603 MLCC's reveals serious structural damage, manifesting itself electrically in a dramatic change in the impedance characteristics. This is a major departure from a pre-ESD capacitor, thus resulting in excessive low frequency leakage and functional misbehavior.

BACKGROUND

Electrostatic discharge (ESD) is one of the most important reliability problems in the electronic circuit industry. Typically in the integrated circuit (IC) industry, one-third to one-half of all field failures (customer returns) are due to ESD. As ESD damage has become more prevalent in newer technologies due to the higher susceptibility of smaller circuit components, there has been a corresponding increase in efforts to understand ESD failures through modeling and analysis. Manufacturers of integrated circuits provide ESD test



information. However, the ESD data on IC level standards (human body model (HBM), charged device model (CDM), machine model (MM) and latch-up-to-the-system testing) is often confusing.

Design of robust ESD circuits remains challenging because ESD failure mechanisms become more acute as critical circuit dimensions continue to shrink. Circuit board designers are further constrained by the ability to design highly congested PCB's and meet ESD requirements. HBM provides much insight into device behavior during an ESD event [1,2].

An ESD event is the transfer of energy between two bodies at different electrostatic potentials, either through contact or via an ionized ambient discharge (a spark). This transfer has been modeled in various standard circuit models for testing the compliance of device targets. The models typically use a capacitor charged to a given voltage and then some form of current-limiting resistor (or ambient air condition) to transfer the energy pulse to the target.

In order to meet the module level ESD tests, various methods and techniques on printed circuit boards have been implemented and investigated. One effective technique is to add discrete noise-decoupling components or filters into complex CMOS based IC products to decouple, bypass, or absorb the electrical transient voltage (energy) under the system-level ESD test [3]. Various types of noise filter networks can be employed to improve system-level ESD stress tests, including capacitor filters, ferrite bead, transient voltage suppressor (TVS), metal oxide varistor (MOV), and 2nd order LC filter or 3rd order π-section filters.

Multilayer ceramic capacitors (MLCC) are employed as an ESD bypass mechanism at the connector pins of electronic control modules. An automotive control module may require the use of a single high-density connector with pin density in excess of 200. In a typical application, a connector may present the designer with a matrix of 4 x 50 (4 rows of 50 pins at each row) in a tightly congested PCB real estate. To accommodate the ESD protection for each and every I/O pin at the connector of highly congested PCB real estate, design engineers recommend the use of 0603 style MLC capacitors. In most applications, MLC capacitors used for ESD protection are rated for 100 V stress level. However, post-ESD characteristics of MLCC's are often ignored or misunderstood. In reality, MLCC's exposed to ESD stress exhibit a dramatic shift in characteristic impedance behavior. Careful examination of MLCC's reveals permanent structural damage resulting in excessive low frequency leakage. Post-ESD behavior of MLCC's results in a functional deviation for the control module, and it is fundamentally unsafe to use the product for its intended application. It is suggested that low profile 0603 capacitors should not be used for ESD protection, as reported in this paper. Alternative solutions can be met by the use of low profile transient voltage suppressors (TVS) or fast metal oxide varistors (MOV). However, 0805 style MLCCs with high value capacitance (> 47 nF) provide a good solution and are safe to be used as an ESD bypass element.

MLCCs used as a protective device or mechanism should consider the voltage, peak power and energy as the key components of an ESD threat. It is thus necessary to fully characterize the amplitude and timing of ESD components. Therefore, protection structure should reduce the voltage, peak power and energy threats by shunting the stress currents away from fragile portions of the microcontrollers and other ICs [4].

To solve ESD problems, MLC capacitors employed as ESD bypass or filter component on printed circuit boards (PCB), must shunt the ESD transient current safely to ground. It is important that MLC capacitors, employed as bypass components, absorb the ESD voltage and current safely and protect the device under test with no degradation. In addition, the MLC capacitor must remain within its parametric tolerance for it to be considered a reliable protection mechanism.

> Multilayer ceramic capacitors (MLCC) are employed as an ESD bypass mechanism at the connector pins of electronic control modules.

MLC CAPACITOR AS AN ESD PROTECTION DEVICE

Multilayer ceramic capacitors are designed for use where a small physical size with comparatively large electrical capacitance and high insulation resistance is required. The general purpose 0603 (1.6 mm x 0.5 mm) class II, type X7R (-55°C to +125 °C) is a popular choice for automotive electronic control module design. Therefore, it is a common practice to apply X7R MLCC's as an ESD protection component at all I/O pins.

Figure 1 illustrates a horizontal grind of the 0603 MLCC (magnification X 100) with plates spaced at 21 μm apart for a 10 nF, X7R type II capacitor. A higher value capacitor is designed with an increased number of plates. This will result in a narrow dielectric thickness, a possible drawback for high voltage transients. At the present time (May 2012), capacitor values for a type II X7R 0603 (100 V) range from 180 pF to a maximum value of 39 nF. However, the capacitor value range for the same technology but with larger physical size (0805) varies from 220 pF to a maximum value of 120 nF. This can be an important factor if ESD protection capacitor value is determined to exceed the maximum value of 39 nF available in 0603 package.

Figure 2 illustrates two different styles of MLCC technology with respect to the design of conductive plates. Capacitor manufacturers recognize the over-voltage stress concern and have provided an ESD-enhanced MLCC product. Close examination of Figure 2 demonstrates the style B MLCC is an ESD-enhanced design.

Figure 3 illustrates a horizontal grind of an ESD-enhanced MLCC at x100 magnification. Comparison with Figure 1 demonstrates the differences in plate geometry design.

Printed circuit board designers with fundamental EMC training are required to ascertain the optimum mounting strategy for ESD capacitors. EMC engineers verify a "Y-connection" topology for all of ESD capacitors at every I/O pin of the connector. MLCC must be placed in close proximity to the I/O pin (< 1cm) with a short trace (< 1cm) to the PCB return plane. In this manner, added PCB parasitic trace inductance and its degradation effect on the effectiveness of the ESD bypass capacitor is minimized. The general concern is to limit the added inductance due to PCB mounting inductance, and thus provide a low-impedance path for ESD current flow to return plane.

Another limitation would be to use the lowest value capacitor available, where it is most effective at higher frequencies. ESD would result in an RF current with a bandwidth in excess of 330 MHz. The choice between a 1 nF and 680 pF would easily be reduced to the latter one. However, ESD HBM consists of a 150 pF capacitance, thus a higher value MLC capacitor is preferred. A voltage divider network is established by the combination of HBM capacitor and MLCC. The voltage developed across a larger value MLCC, would lower the voltage developed across an integrated circuit, as indicated in Equation 1.

$$V_{MLCC} = \frac{C_{HBM}}{C_{HBM} + C_{MLCC}} V_{ESD} \qquad \text{Eq. 1}$$

Therefore, where $V_{MLCC} << V_{ESD}$, it is required that $C_{MLCC} >> C_{HBM}$.

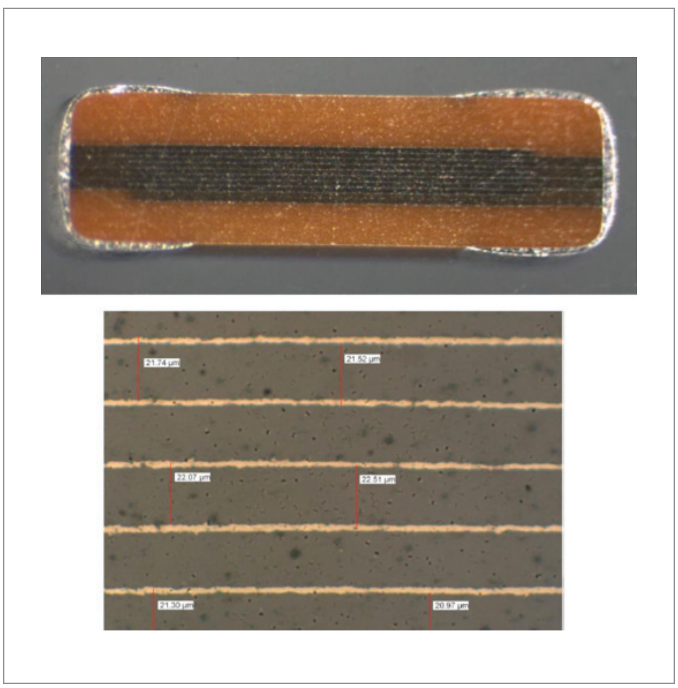


Figure 1: Standard 0603 MLCC (magnification x100)

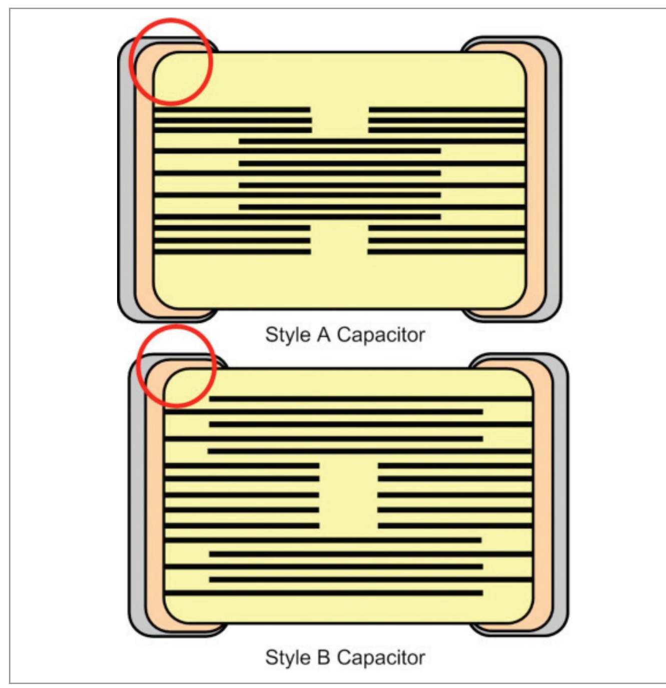


Figure 2: 'Standard' vs. 'ESD-enhanced' 0603 MLCC

Several electrical models of capacitors are available in textbooks and RF publications used by the EMC/RF community to describe the electrical behavior of MLC capacitors.

MLC CAPACITOR ELECTRICAL MODEL

Several electrical models of capacitors are available in textbooks and RF publications used by the EMC/RF community to describe the electrical behavior of MLC capacitors. A simple series RLC network is commonly used to provide accurate behavior for most applications. However, simple RLC model fails to provide the additional technical insight required for analysis of MLCC's exposed to ESD pulse. The modified model presented in Figure 1 has additional elements to describe the behavior of MLC capacitors exposed to ESD stress. In fact, the model described here is an accurate electrical description, necessary to account for the various physical attributes found within a capacitor.

1. L_1 is the series parasitic inductance associated with plate connections.
2. L_2 is the equivalent series inductance. It is also known as L_{ESL}.
3. R_1 is the equivalent series resistance (also known as R_{ESR}) and represents the actual ohmic resistance of the plates. This value is typically very low. It causes a power loss of I^2R_1. Its contribution to the total dissipation factor is $D_1 = 1/(\omega R_1C_1)$.
4. C_1 is the nominal capacitance.
5. R_2, the dielectric loss, is a parallel resistance arising from two phenomena; molecular polarization and interfacial polarization (dielectric absorption). Dielectric loss is a complex phenomenon that can change with frequency in most any manner that is not abrupt. Its contribution to the total dissipation factor can be approximated by $D_3 \sim 1/(\omega R_2C_2)$.
6. C_2 is the parallel dielectric absorption capacitor.
7. R_3, the leakage resistance or insulation resistance, is a parallel resistance due to leakage current in the capacitor. This value is typically very high. It causes a power loss of V^2/R_3. Its contribution to the total dissipation factor is $D_2 = 1/(\omega R_3C_1)$.

The impedance characteristics of type II (0603, X7R MLC) capacitors for a 680 pF and 10 nF is illustrated in Figure 5.

ESD is a high frequency pulse with a rise time of less than one nano second, resulting in spectral content in excess

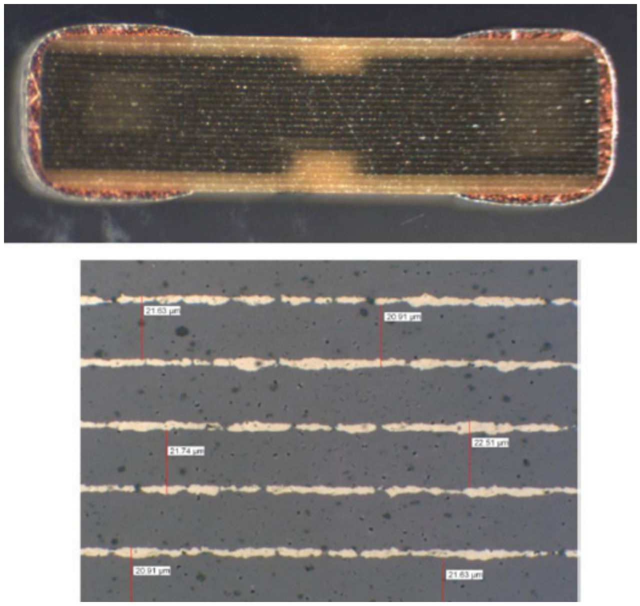


Figure 3: ESD-enhanced 0603 MLCC

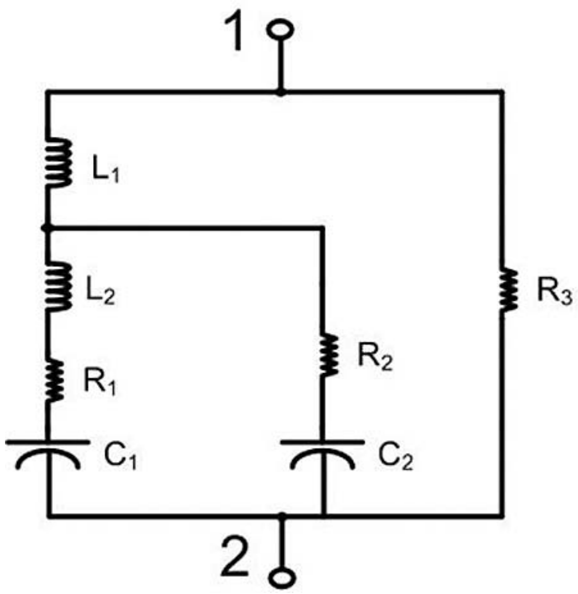


Figure 4: Improved electrical model of MLC capacitors

The requirements of a lower value ESD capacitor, as in the previous paragraph, may suggest the use of the lowest value MLCC available to the industry.

of 330 MHz. Hence, the choice of ESD capacitor is reduced to a smaller value MLCC, as seen in Figure 2. Closer examination of Figure 2 reveals a lower impedance for a 680 pF (1.71 Ω at f = 330 MHz) compared with a 10 nF (3.97 Ω at f = 330 MHz). Another consideration may be the result of capacitive loading of certain I/O signals, i.e., CAN bus, where a limited capacitance can be added to the communication bus.

The requirements of a lower value ESD capacitor, as in the previous paragraph, may suggest the use of the lowest value MLCC available to the industry. In addition, there is a third factor that is outlined in Table 1; R3 (insulation resistance) that may add additional incentive for the use of the lowest value MLCC. However, further insight is required to distinguish the apparent easy choice.

In Table 1, all nominal and parasitic elements for both capacitors are listed as per MLCC supplier A.

It is important to note that the insulation resistor R3 is an order of magnitude higher in value for smaller value capacitor (Table 1). As more plates are stacked up to accommodate higher value capacitance in the same physical volume of the 0603-style package, the dielectric thickness is reduced by a factor of 14.7. Therefore, as a consequence of thinner dielectric material between the capacitor plates, the insulation resistor for higher value capacitor is reduced by the same ratio (capacitor ratio: 10 nF/680 pF = 14.7, insulation resistor ratio: 0.1 x 10^{12} Ω/ 14.7 x 10^{12} Ω = 1/147. It is clear that a higher value capacitor will sustain a dielectric breakdown in lower ESD voltages. It was suggested by this argument, for ESD applications, only necessary to consider lower-value capacitors with higher insulation resistance in order to protect for dielectric breakdown, i.e., 680 pF vs. 10 nF. Further investigation was required to address the accuracy of aforementioned statement.

If a smaller capacitor presents a higher insulation resistance as shown above, it is important to examine the behavior of the insulation resistance after ESD tests. For further insight, it is important to evaluate the impact of ESD stress on 680 pF and 10 nF capacitors by characteristic impedance of post-ESD capacitors.

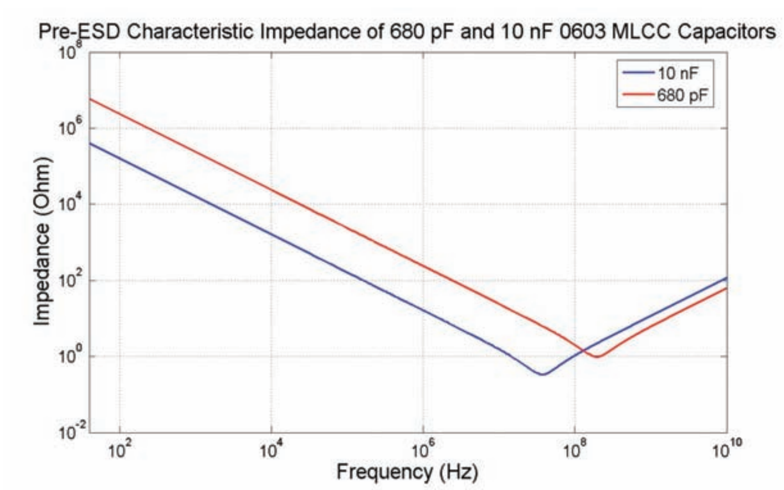


Figure 5: Pre-ESD impedance characteristics

Nominal Value @ 1 kHz	680 pF	10 nF
L1	49 pH	91 pH
L2	931 pH	1.730 nH
C1	680 pF	10 nF
C2	4.10 pF	4.10 pF
R1	5.15 kΩ	0.329 kΩ
R2	753.73 Ω	34.57 Ω
R3	1.471 x 10^{12}Ω	.01 x 10^{12}Ω

Table 1: MLCC 0603 capacitor model components

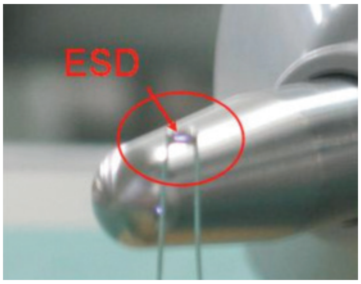


Figure 6: ESD air-discharge to 0603 MLCC

HUMAN BODY ESD TEST

ESD tests for automotive applications are derived and based on a human body model specified by original equipment manufacturers (OEM) [5,6,7,8,9].

A typical HBM discharge network consists of a 150 pF capacitor with a 2 kΩ resistor. The HBM capacitor can be charged up to 25 kV for an air-discharge test. The static charge accumulated on the 150 pF discharge network capacitor (charged to 25 kV) would amount to 3.75 µC. ESD is a high-frequency, high-voltage and high current event that can deposit 46.875 mJ of energy in the protection device in a relatively short time duration.

HBM provides much insight into device behavior during an ESD event. Although the HBM stress is characterized by a certain charging voltage, V_{HBM}, the 2 kΩ series resistor of the circuit is usually much larger than the impedance of the device under test, so we think of the HBM tester as current sources, with the peak HBM current equal to 12.5 A. (V_{HBM} = 25 kV, air-discharge).

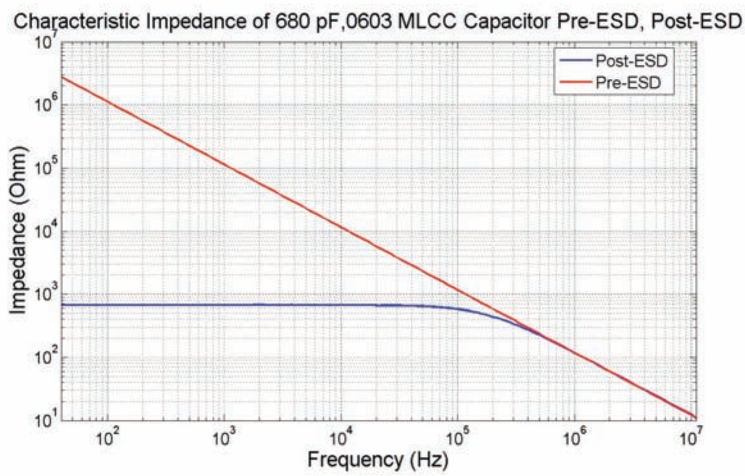


Figure 7: Measured pre-ESD and post-ESD (MLCC 680 pF)

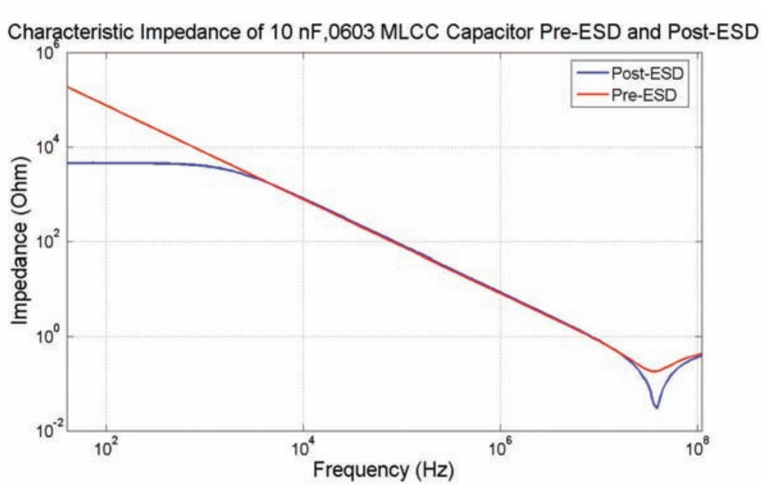


Figure 8: Measured pre-ESD and post-ESD (MLCC 10 nF)

PRE-ESD AND POST-ESD MEASUREMENTS

In order to evaluate the impact of ESD stress on 0603 MLCCs, two different types of tests were performed. Since a populated electronic control module is the intention of a realistic test, it is important to evaluate the impact of ESD stress per OEM ESD test techniques. In another method, a 0603 MLCC network was prepared, as shown in Figure 6, with two short wires (< 1 cm) at each end. Terminal 1 was connected to a ground plane where an ESD gun return wire would normally be connected. The ESD discharge tip was slowly approached to the floating terminal until an air discharge was achieved.

Pre-ESD and post-ESD characteristics of the 0603 capacitor were recorded using an Agilent 4294A impedance analyzer (40 Hz – 110 MHz) with the help of an Agilent 16034G test fixture. Capacitors were removed from test PCB or ESD network wires, and mounted inside the 16034G test fixture for impedance characterization.

It was decided to apply an ESD pulse to a fully populated automotive electronic control module as designed with

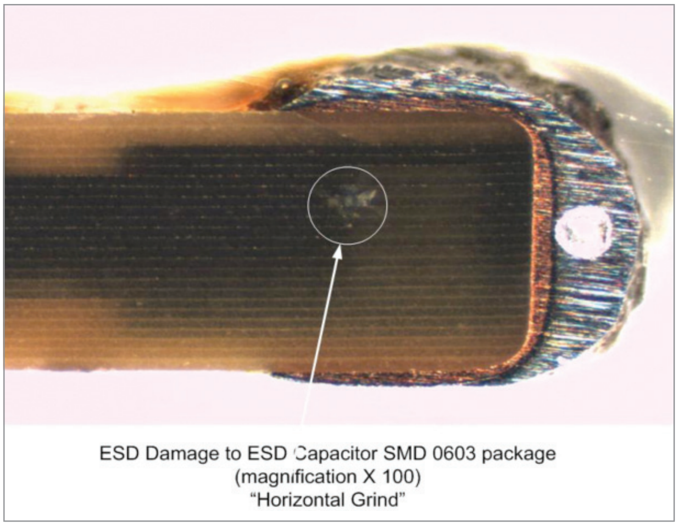


Figure 9: Dielectric damage for post-ESD MLCC

Post-ESD capacitor dielectric damage is illustrated in Figures 9 through 11 (horizontal grind) on a magnification scale of 100. The physical damage to X7R and C0G technologies are shown.

Figure 10: Dielectric damage for post-ESD X7R MLCC

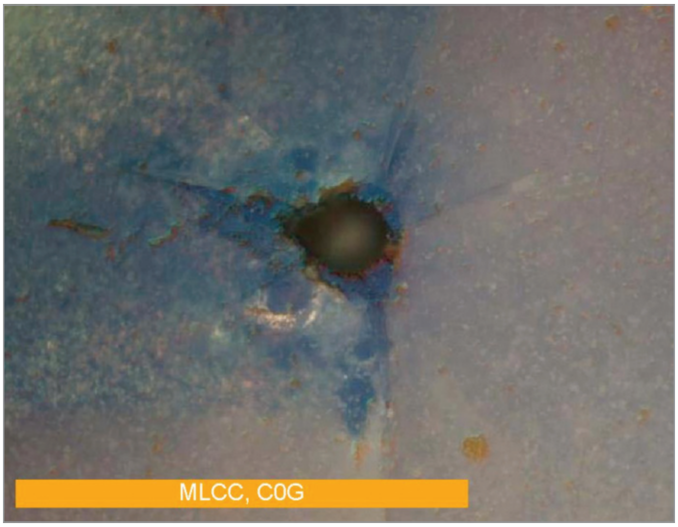


Figure 11: Dielectric damage for post-ESD C0G MLCC

rigorous EMC guidelines. As OEM ESD requirements provides guidelines [7,8,9] for remote I/O access ESD stress tests. An HBM model with discharge network as outlined in section IV was calibrated and ESD voltage levels from +/- 4 kV up to +/- 25 kV were applied in successive order. After each discharge, the MLCC was removed and analyzed on an impedance analyzer as per the previous method.

Figure 7 illustrates the impact of the ESD pulse at +/-15kV level for the 680 pF capacitor.

Figure 8 illustrates the impact of the ESD pulse at +/-15kV level for a 10 nF capacitor.

Post-ESD capacitor dielectric damage is illustrated in Figures 9 through 11 (horizontal grind) on a magnification scale of 100. The physical damage to X7R and C0G technologies are shown.

In Figure 12, a modified electrical model represented as per Figure 4, was used to illustrate post-ESD effects on both capacitors. In the electrical model per Table 1, R3 was replaced with a 500 Ω resistor to represent the nominal pre-ESD value provided by MLCC manufactures in Table 1 (14.7 x 10^{12} Ω).

It is important to note that the 10 nF capacitor developed severe leakage from 40 Hz up to 20 kHz, and for 680 pF the upper frequency is approximately 200 kHz. The impedance of both capacitors registers a 500 Ω resistive value in the aforementioned frequency range. It is thus concluded that ESD has caused non-recoverable, permanent damage to the MLCCs. Post-ESD behavior suggests physical

This study shows that permanent damage to dielectric material resulted for ESD voltages in excess of 15 kV.

damage to dielectric material due to metallization of capacitor plates. In reference to Figure 4, it is clear that R3 has shifted from its pre-ESD nominal value as per Table 1 (for 680 pF, R3 = 1.471 x $10^{12}\Omega$, or for a 10 nF, R3 = 0.1 x $10^{12}\Omega$ to an extremely low value of 500 Ω).

The issue of why the 680 pF MLCC has a 500 Ω leakage up to 200 kHz, whereas 10 nF shows the ill-effect only up to 20 kHz, can be explained as follows: the circuit of Figure 4 simplifies to the parallel of C1 and R3 at low frequencies, and the knee of the impedance curve appears for f ~ 1/2π R_3C_1. For post-ESD, the 680 pF MLCC is dominated by R3 from DC to ~ 300 kHz, whereas R3 contributes only up to 20 kHz for the 10 nF capacitor. Figure 13 illustrates the post-ESD leakage resistance degradation.

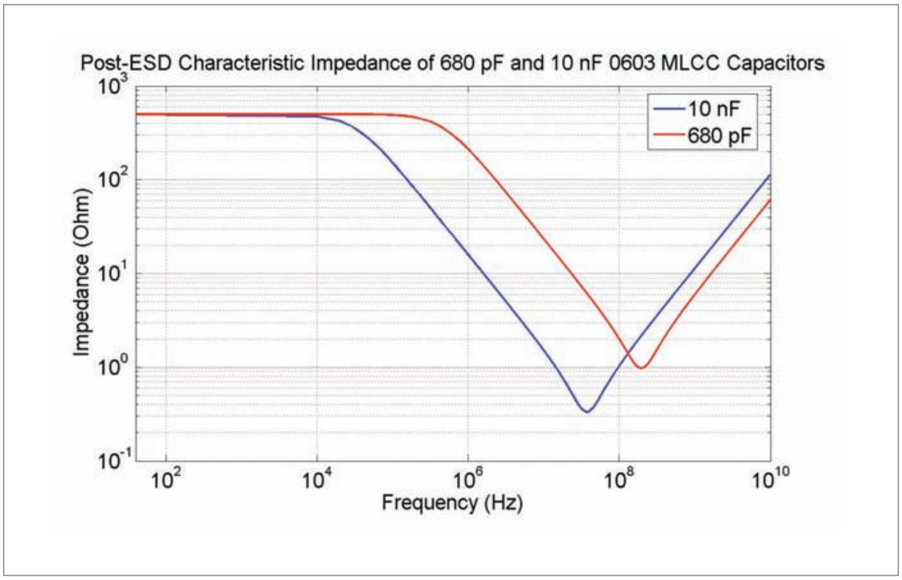


Figure 12: Simulated post-ESD impedance characteristics, R3 = 500 Ω

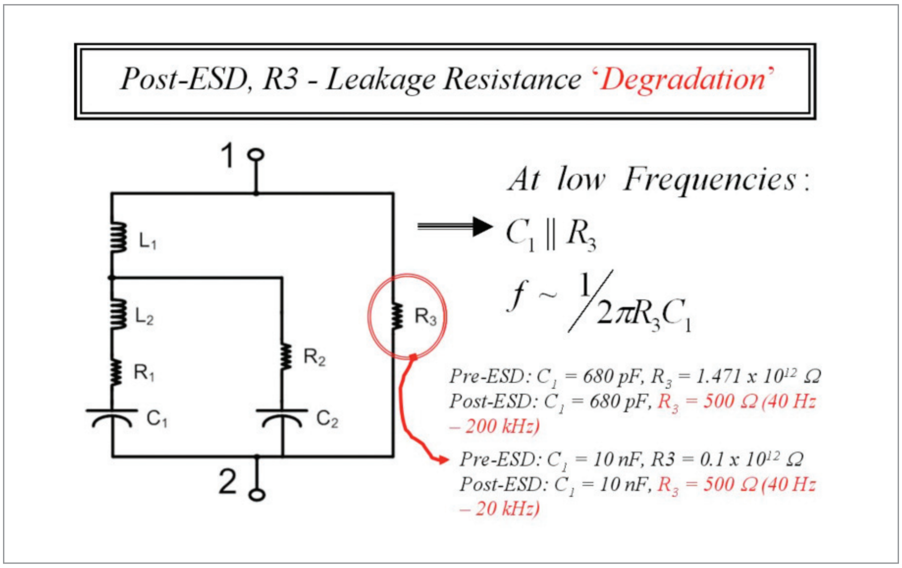


Figure 13: Post-ESD impedance behavior

It is clear that smaller size MLCC will suffer extreme leakage to a much higher frequency range. Use of higher value MLCCs is recommended, in contradiction to previous recommendations.

As an extension to exposure of 0603 MLC capacitors to ESD stress, additional ESD tests were performed on modules populated with larger 0805 MLC capacitors. Figure 14 illustrates the impact of +/- 25 kV HBM ESD stress on a 4.7 nF capacitor. It is clear that a 4.7nF 0805 capacitor would fail the ESD requirements. However, extending the capacitor size (value) in an 0805 package to 10 nF results in ESD compliance.

CONCLUSION

This study is an examination of the physical damage to the 0603 MLC capacitors exposed to ESD transients. It shows that permanent damage to dielectric material resulted for ESD voltages in excess of 15 kV. The use of 0603 MLC capacitors for I/O connector pins, as an ESD bypass mechanism, is not recommended and should be avoided. However, in larger footprints, 0805 MLCCs will meet the ESD stress for 25 kV requirements, provided the capacitor size exceeds 10 nF, and

The ESD capacitors provide a bypass element for the induced RF currents on the module harness due to impinging electromagnetic fields.

is rated for 100 V applications. A preferred ESD bypass solution would use a low capacitance transient voltage suppressor (TVS, C_{TVS} < 100 pF) or a fast metal oxide varistor (MOV).

However, I/O pin ESD capacitors in the range of 1 nF to 100 nF are often utilized as an input RF filter at the connector pins. The ESD capacitors provide a bypass element for the induced RF currents on the module harness due to impinging electromagnetic fields. Low value TVS capacitance is insufficient to provide the required filter across the 1 MHz – 200 MHz frequency bandwidth. Use of a TVS in parallel with a 0603 capacitor (10 nF – 100 nF) is recommended, where permissible.

REFERENCES

1. Y. Fukuda, et al., "ESD Protection Network Evaluation by HBM and CDM (Charge packaged Method)", *EOS/ESD Symposium Proceedings*, pp. 193 – 199, 1986.
2. Warren Boxleitner, Peter Richman, Geoff Well, "Characterizing the Stress applied to ICs by different ESD Testers", *EOS/ESD Symposium Proceedings*, 1990.
3. Ming-Dou Ker, Cheng-Cheng Yen, Pi-Chia Shih, "On-Chip Transient Detection Circuit for System-Level ESD Protection in CMOS Integrated Circuits to Meet Electromagnetic Compatibility Regulation", *IEEE Transactions on Electromagnetic Compatibility*, Vol. 50, No. 1, pp. 13 – 21, 2008.
4. Warren Boxleitner, "ESD Stress on PCB Mounted ICs Caused by Charged Boards and Personnel", *EOS/ESD Symposium Proceedings*, 1990.
5. ISO10605:2008, *Road Vehicles Test Method for Electrical Disturbances from Electrostatic Discharge*, February 2008.
6. IEC61000-4-2, "Electromagnetic Compatibility (EMC) – part 4-2: Testing and Measurement Techniques – Electrostatic Discharge Immunity Test", *EN 61000-4-2:1995, Amendment 1: 1998, Amendment 2:200*, 1995.
7. Ford Motor Company, *EMC-CS-2009*, September 2009.
8. General Motors Corporation, *GMW3097 Rev. 5*, May 2006.
9. Chrysler/Fiat Group LLC, *CS-11979*, April 2010.

(the authors)

CYROUS ROSTAMZADEH
Senior IEEE Member
Senior EMC Technical Specialist,
Robert Bosch LLC, Plymouth, MI, USA
Cyrous.Rostamzadeh@us.bosch.com

PROFESSOR FLAVIO CANAVERO
IEEE Fellow
Politcnico di Torino, Italy
Flavio.canavero@polito.it

PROFESSOR FERAYDUNE KASHEFI
IEEE Member
Department of Electrical Engineering at Azad University, Shabestar, Iran
fred.kashefi@gmail.com

MEHDI DARBANDI
School of Electrical & Computer Engineering, Tehran University,
Irandarbandimahdi@gmail.com

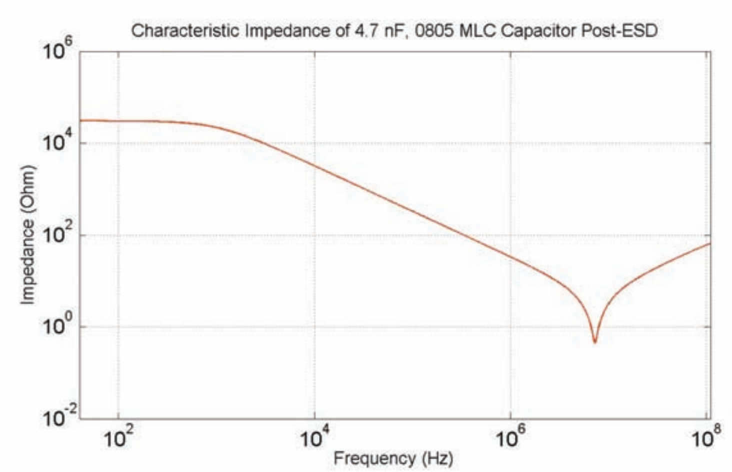


Figure 14: Measured post-ESD for a 4.7 nF 0805 capacitor

Early Life Failure of Dissipative Workstation Mats

Effects of accelerated exposure to fluorescent lighting

BY SAM THEABO AND BRIAN RETZLAFF

Routine compliance verification testing can reveal degradation of a workstation mat's electrical dissipative properties over time. Chronic failures occurring sooner than expected warrant root-cause investigation. This article describes a different approach taken to identify the cause of this elusive problem.

PROBLEM BACKGROUND

Early life failure rates of ESD workstation mats prompted an in-depth investigation at one of our manufacturing facilities. "Failure" in this case refers to a mat's electrical resistance drifting to $1x10^9$ ohms or above and therefore not meeting the work surface limit requirement of ANSI/ESD S20.20, using the test procedure in ESD TR53. Our ESD control program compliance verification testing revealed that the resistance measurements were changing in some mats, however not consistently as one would expect. The resistance drift in the affected mats occurred over six to nine months, spanning several audit cycles.

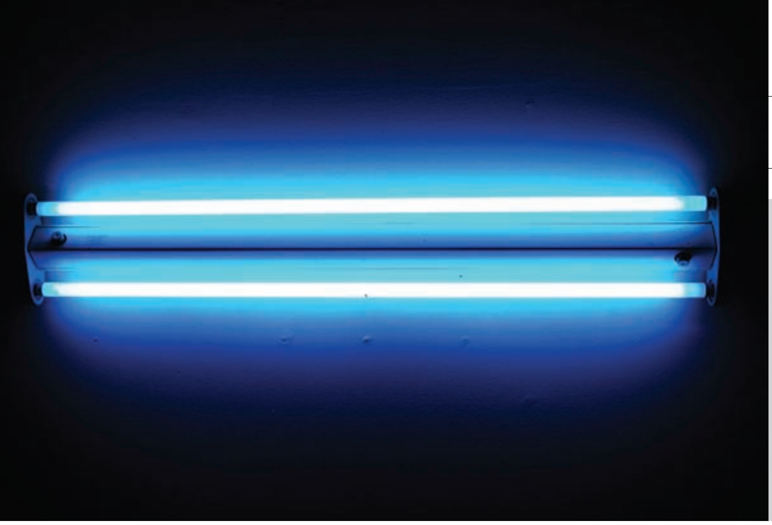
This was elusive and frustrating for two reasons:

- Not all of the 2-layer rubber mats shifted in resistance; only some did.
- Since the matting we used at that time did not contain a manufacturing date or lot number printed on the mat, it was difficult to identify exactly how old the mat material was and if the resistance shifting was a lot problem or completely random.

We somewhat assumed that all 2-layer rubber ESD matting was pretty much the same, mainly because the electrical specifications from various manufacturers are typically the same: $1.0 X 10^6$ to $<1.0 x 10^9$ ohms.

FIRST CONSIDERATIONS

Initially we turned to our suppliers for assistance in solving our problem. The first (and logical) question an ESD mat manufacturer asks when confronted with a high resistance mat reading is, "How was it cleaned?" The use of common household kitchen cleaners, which often contain silicone to achieve a glossy finish, can leave an insulative layer on ESD dissipative matting. This could lead to high resistance readings. Other unapproved cleaning products contain ammonia or citric acid, which can "attack" the rubber in the mat and cause degradation. A review of our ESD mat cleaner inventory showed that we were indeed using only approved products, thereby eliminating the suspected root-cause of improper mat cleaning.



Our test set up would use standard light fixtures positioned very close to mat samples in order to accelerate any affect that the fluorescent light might have.

A NEW THEORY

What other factor could there be that would reduce the effective life of the mats? Environmental conditions such as temperature and humidity were in good control, relative humidity typically being held to 40% (+/- 10%) in the manufacturing area year round. Air quality was consistent with all EH&S standards for industry. The only other variable that we could think of was the factory lighting. Could it be that normal factory fluorescent lighting was affecting the mat material, causing it to degrade prematurely over time? Since all fluorescent lights emit some ultraviolet (UV) radiation, might this be affecting the ESD mats?

We decided to stage an experiment to test this theory. Our test set up would use standard light fixtures positioned very close to mat samples in order to accelerate any affect that the fluorescent light might have. Periodic measurements would track each mat's performance over time.

MATERIAL SELECTION

Our factories primarily use 2-layer rubber matting because of its high-temperature resistance and ability to clean better than vinyl. For comparative purposes, it was decided that a variety of mat materials from different manufacturers would be included in the experiment.

The following mat types were obtained:

2-layer rubber: 6 different P/N's
2-layer vinyl: 1 P/N
3-layer vinyl: 1 P/N

All of the mat materials were supplied new from the manufacturers. There was no treatment such as pre-cleaning done to them.

TEST SET-UP

Several work benches were set up off-site, with 48-inch standard fluorescent light fixtures mounted four inches from the work surface of each bench (see Figure 1). As stated previously, this close distance was intended to

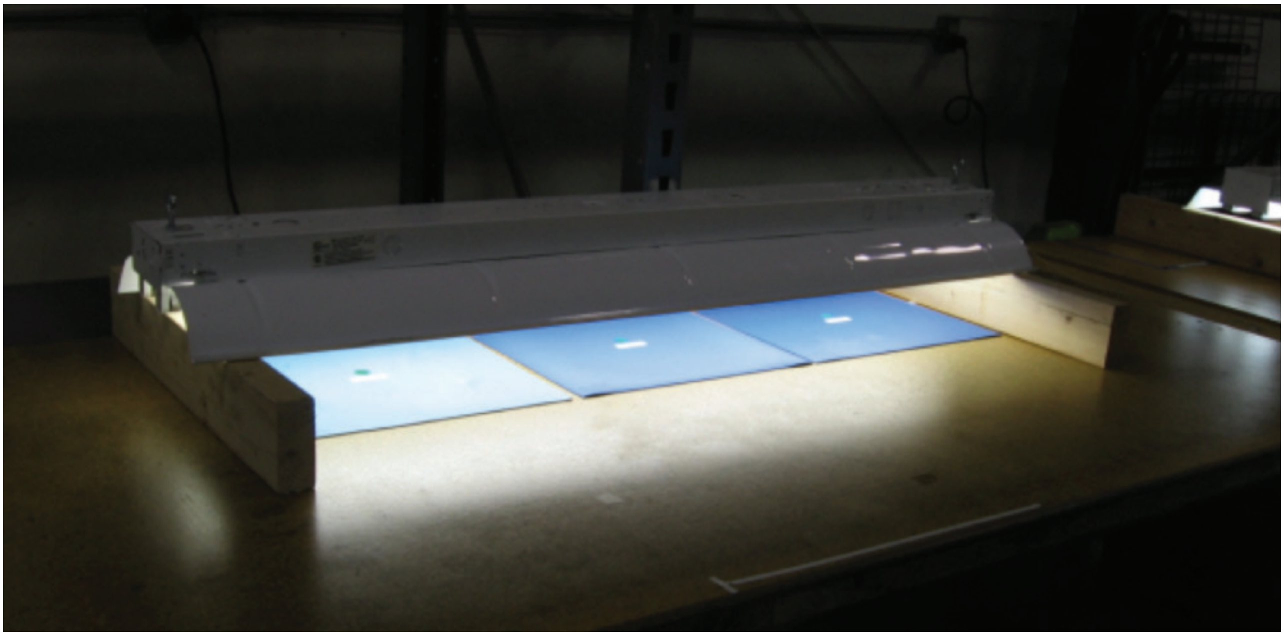


Figure 1: Fluorescent light test set-up (one of three)

Periodic resistance measurements were taken over time, with the same test procedure used as in the test set-up.

accelerate any effects that the lighting might have on the mats. In the factory, we typically experienced mat resistance shifting over six to nine months. If the lighting is truly a factor, any shift in resistance should be seen more quickly in this set-up.

A 14” by 14” square was cut from each mat roll to use as a sample. Each sample was marked with an ID number in the corner for tracking. The resistance of each sample was then measured point-to-point, as described in ESD S4.1. Two such measurements were taken for each mat; first with the probes placed on opposite diagonal corners, and then again on the other pair of opposite corners. Both measurements and their average were recorded on a data collection tracker. The mat samples were then placed next to each other beneath the light fixtures. (Note: The temperature beneath the lights measured between 75°F - 80°F, so extreme heat was not a factor.)

MONITORING AND COLLECTING THE DATA

Periodic resistance measurements were taken over time (see Figure 2), with the same test procedure used as in the test set-up. The intervals began at one week to start, then were extended (for logistical reasons) as the study progressed. The samples’ positions were shifted between each measurement session, in order to assure similar exposure conditions for all the samples.

ESD Dissipative Mat Study - Exposure to Fluorescent Lighting

BEGIN EXPERIMENT

			11/5/2009 (41% RH / 71F)			11/12/2009 (39% RH / 72F)			11/18/2009 (42% RH / 72F)			11/24/09 (35% RH / 74F)		
Mat ID #	Mfg	Mat Description	Test #1	Test #2	Average	Test #1	Test #2	Average	Test #1	Test #2	Average	Test #1	Test #2	Average
1	A	2-layer rubber	9.8E+06	1.1E+07	1.0E+07	3.8E+07	3.8E+07	3.8E+07	8.1E+07	7.9E+07	8.0E+07	3.2E+07	3.9E+07	3.6E+07
2	B	2-layer rubber	1.1E+07	1.0E+07	1.1E+07	2.4E+07	2.2E+07	2.3E+07	6.7E+07	5.7E+07	6.2E+07	6.5E+07	4.6E+07	5.6E+07
3	C	2-layer vinyl	7.1E+06	8.3E+06	7.7E+06	9.2E+06	9.5E+06	9.4E+06	1.2E+07	1.1E+07	1.2E+07	7.4E+06	7.1E+06	7.3E+06
4	D	2-layer rubber	3.7E+08	2.1E+08	2.9E+08	1.7E+08	1.2E+08	1.5E+08	1.1E+08	1.1E+08	1.1E+08	3.6E+07	4.4E+07	4.0E+07
5	E	3-layer vinyl	9.5E+07	3.3E+07	6.4E+07	1.5E+08	1.3E+08	1.4E+08	7.8E+07	6.7E+07	7.3E+07	2.7E+07	6.6E+07	4.7E+07
6	F	2-layer rubber	1.8E+07	1.5E+07	1.7E+07	5.3E+09	1.5E+10	1.0E+10	1.3E+11	9.2E+10	1.1E+11	8.7E+10	1.1E+11	9.9E+10
7	G	2-layer rubber	4.5E+07	7.3E+07	5.9E+07	2.5E+07	2.5E+07	2.5E+07	2.3E+08	2.1E+08	2.2E+08	6.7E+08	6.9E+08	6.8E+08
8	H	2-layer rubber	1.5E+07	1.5E+07	1.5E+07	1.6E+07	2.0E+07	1.8E+07	8.7E+07	8.5E+07	8.6E+07	9.8E+07	1.0E+08	9.9E+07

CONTINUE →

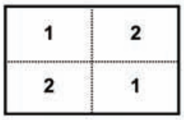
Samples removed from light on 1/13/10, tested 24 hours later

			12/18/09 (27% RH / 69F)			12/30/09 (17% RH / 68F)			1/14/10 (22% RH / 75F)		
Mat ID #	Mfg	Mat Description	Test #1	Test #2	Average	Test #1	Test #2	Average	Test #1	Test #2	Average
1	A	2-layer rubber	8.7E+08	1.0E+09	9.4E+08	5.4E+09	7.9E+09	6.7E+09	7.7E+09	1.2E+10	9.9E+09
2	B	2-layer rubber	1.1E+10	1.1E+10	1.1E+10	3.4E+10	3.2E+10	3.3E+10	3.2E+10	3.5E+10	3.4E+10
3	C	2-layer vinyl	9.1E+06	9.0E+06	9.1E+06	1.3E+07	1.2E+07	1.3E+07	1.3E+07	1.0E+07	1.2E+07
4	D	2-layer rubber	8.8E+07	8.0E+07	8.4E+07	1.1E+08	1.4E+08	1.3E+08	6.5E+07	8.1E+07	7.3E+07
5	E	3-layer vinyl	5.4E+07	8.8E+07	7.1E+07	3.1E+07	1.0E+08	6.6E+07	1.3E+08	3.4E+07	8.2E+07
6	F	2-layer rubber	1.2E+11	1.3E+11	1.3E+11	1.2E+11	1.9E+11	1.6E+11	1.4E+11	1.8E+11	1.6E+11
7	G	2-layer rubber	1.2E+10	1.2E+10	1.2E+10	3.4E+10	3.8E+10	3.6E+10	5.8E+10	1.0E+10	3.4E+10
8	H	2-layer rubber	9.2E+09	1.2E+10	1.1E+10	2.8E+10	3.6E+10	3.2E+10	1.9E+10	4.8E+10	3.4E+10

Assumption: Mat samples are representative of all lots from the supplier

TEST EQUIPMENT AND PARAMETERS

1. Meter used: ProStat PRS-801 (digital) w/ 5 pound probes
2. Light source: 4' reflector hood w/ 2 T8 35W each
3. Light source distance from mats: 4 inches
4. Mat samples: 14" x 14" cut from new rolls from pkg
5. Mat preparation: None, and no cleaner used during study



5 lb Probe Test Pattern

(orange) = Fails <1 x 10^9

Figure 2: Data collected over the 10-week test of fluorescent lighting on our eight mat samples

- Compliance verification periodic testing with data collection is a critical part of an ESD control program.
- Likely from ultraviolet radiation, fluorescent lighting can have a measurable effect on the electrical properties of 2-layer rubber ESD dissipative mats over time.
- Different mats in the sample tolerated the effects of fluorescent lighting by varying degrees.
- Interestingly, neither vinyl mat tested showed any significant change to their resistive properties.

Ambient temperature and relative humidity percentage were recorded for each set of measurements taken.

RESULTS

- There was significant variation in the different mats' tolerance to fluorescent light exposure relative to their ability to retain specified electrical properties (see Figure 3).
- Both vinyl mat samples appeared to be unaffected by the extended exposure.
- Only one, Manufacturer #4, out of the six rubber mat samples retained its electrical resistance properties throughout the duration of the experiment.
- The final measurement session was taken after removing all the mats from the light source for 24 hours, to see if there was a rebound effect. The data

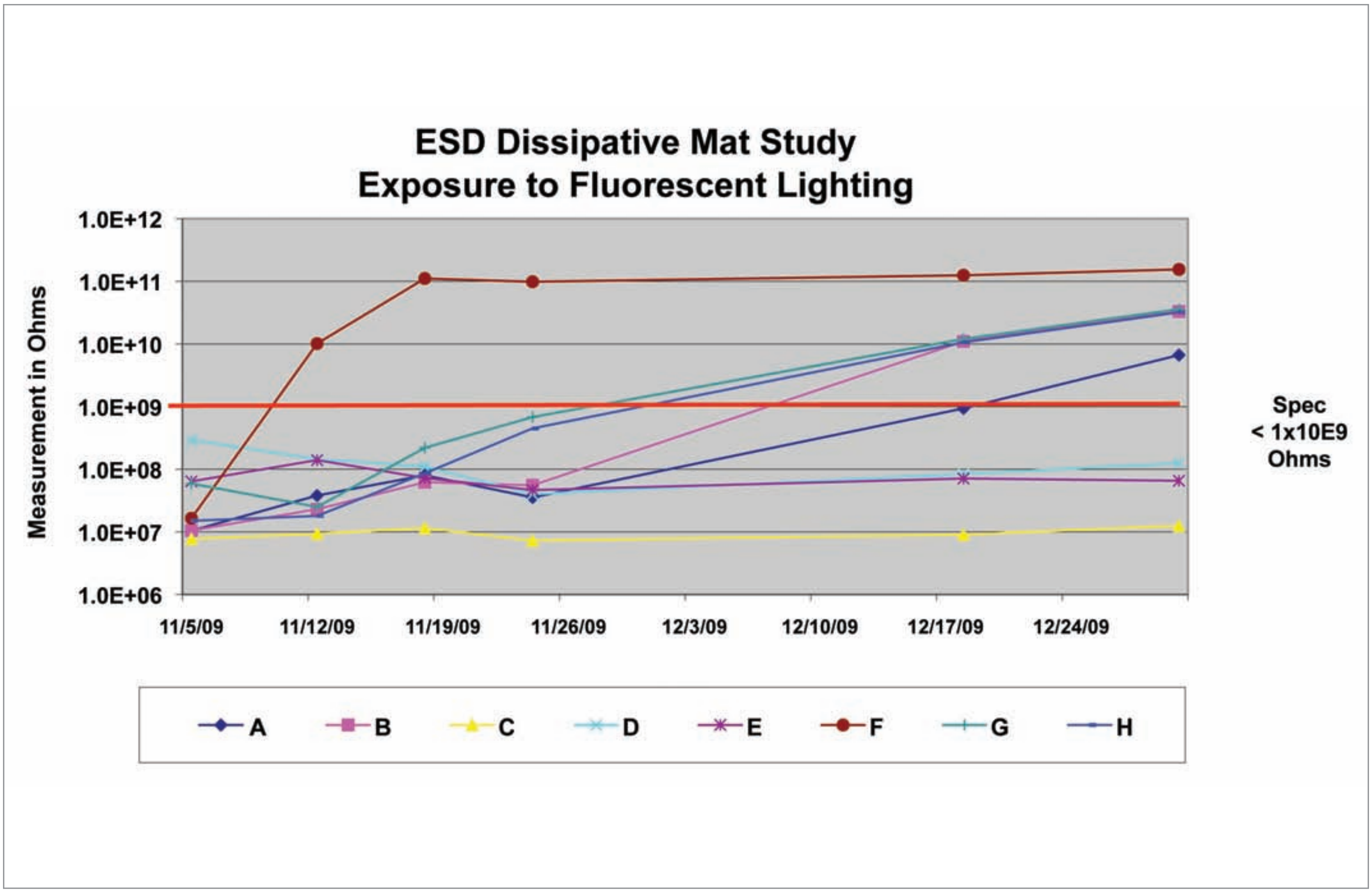


Figure 3: Graph depicting results of our workstation mat test

shows that the failed mats did not recover their original properties; their degradation appeared permanent.

CONCLUSIONS

- Compliance verification periodic testing with data collection is a critical part of an ESD control program.
- Likely from ultraviolet (UV) radiation, fluorescent lighting can have a measurable effect on the electrical properties of 2-layer rubber ESD dissipative mats over time.
- Different mats in the sample tolerated the effects of fluorescent lighting by varying degrees.
- Interestingly, neither vinyl mat tested showed any significant change to their resistive properties.
- Since this experiment did not take into account lot to lot variation at the supplier for each mat P/N, future mats purchased will require lot traceability information to be stamped on the bottom of the roll, every 3 feet minimum.
- The ESD Association technical report ESD TR4.0-01-02 Worksurfaces and Grounding Survey committee should deliberate on whether to add ultraviolet light immunity as a property to consider in the Worksurface Selection Guide.

The manufacturer of Mat ID #4 stated that the 2-layer rubber material composition is proprietary, but they advise us that their formula includes UV stabilizers. They were originally added to the rubber to stabilize color retention, ensure ESD performance over time, and eliminate surface-layer deterioration that results in cracking when the product is flexed.

(the authors)

SAM THEABO

is a staff Quality Engineer and corporate ESD Coordinator at Plexus Global Headquarters in Neenah, Wisconsin, with 24 years of career service. Previously, Sam was a Quality Assurance Engineer at AT&T – Western Electric in Lisle, IL, supporting the manufacture of ESS telephone switching systems. Theabo is ASQ-CQA and CQT certified.

BRIAN RETZLAFF

is a Process Engineer and ESD Subject Matter Expert at Plexus Manufacturing Solutions - Neenah Operations in Neenah, Wisconsin. He has 20 years of career service with Plexus. Since 2006, Brian has been an active member of the ESD Association, where he serves as a committee member and volunteer.

Founders of the EMC Society: The 1960s

BY DANIEL D. HOOLIHAN

In a previous edition of this magazine, we covered the contributions of some of the original members who helped create the EMC Society. In this article, we would like to introduce you to a few more founders important to the Society in its early years as the Professional Group on Radio Frequency Interference, part of the Institute of Radio Engineers (IRE) organization. These gentlemen were dominant in the organization of the EMC Society in the 1960s.

Vince Mancino

Vince Mancino was an early signer of the petition to form the Professional Group on Radio Frequency Interference (PGRFI), and he remained active in the "group" during the 1960s.

He graduated from Rutgers with a BSEE in 1951 and joined RCA as an Engineering Trainee. In 1960, Vince transferred to Cornell-Dubilier Electronics in Massachusetts and became the Chief Engineer of their Filter Division. After several years, he returned to RCA and became involved with weather satellites. At that time, weather satellites only took pictures of cloud coverage during daylight hours.

Vince tells the following story:
"When directly overhead, the satellite transmitted the data directly to a ground station in the local area, but, when the satellite was beyond the horizon, it would record the data on a tape recorder and then transmit it to earth from the tape recorder with a more powerful data transmitter. RCA Astro-Electronics Division had built a weather satellite for the U. S. Air Force, and it was undergoing final simulation tests. This required the recording of weather data on the tape recorder and then playing it back to the transmitter, which would simulate transmission to an earth ground station. Well, each time the data transmitter was turned on, the tape recorder output was turned to unintelligible gibberish. RCA had a high-powered managerial team frantically trying to solve the problem because there were schedule constraints and they were not making any progress.

And then someone remembered that I had previous EMC expertise. With the help of a mechanical

design engineer assigned to me at my insistence, we designed an add-on external box with compartments, which could be attached to the tape recorder. This was feasible because the tape recorder was located within a sealed housing. All wiring entering or exiting the tape recorder had to pass through this 'add-on external box'. This permitted (and required) signal lines to be isolated from the command and control lines, and then both groups to be isolated from the power lines. It also required miniature radio frequency (RF) suppression feed-through capacitors to be mounted inside the box on the outside wall, away from the wall mating with the tape recorder. All tape recorder external wiring had to pass through the filtering devices inside this add-on box. This approach worked, and the successful test of the 'RF-fix' was both dramatic and emotional.

The rules and principles that I laid down on this weather satellite became standard operating procedures for many years on all RCA-built weather satellites, as well as other satellites. I received, in February 1967, an RCA 'Engineering Excellence Achievement Award' for the satellite design 'RF-fix'. "

Vince attended the 50th Anniversary of the EMC Society celebration in Hawaii in 2007.

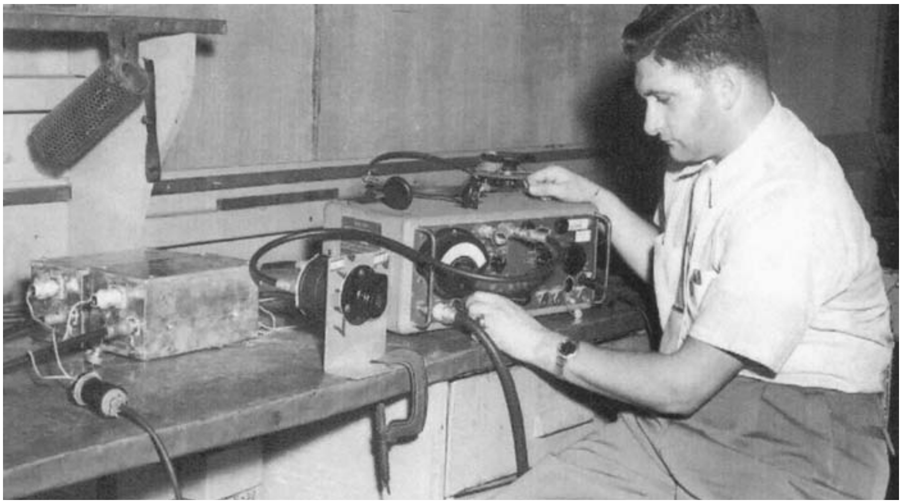
Fred Nichols (1917 – 1990)

Mr. Nichols was the speaker at the Third Conference on Radio Frequency Interference (RFI) Reduction sponsored by the Armour Research Foundation in Chicago in 1957, where he suggested starting a National Professional Group on RFI. At the time Fred was the Vice-Chairman of the Radio Interference Technical Committee (this was an engineering group in the Los Angeles area that was meeting on an irregular basis to to discuss radio frequency interference). His talk inspired some East Coast RFI engineers to start a petition, which resulted in the formation of the Professional Group on RFI as part of the Institute of Radio Engineers.

Early in his career, Mr. Nichols was president of Genistron, Inc. and was instrumental in evaluating security standards that required the use of shielded rooms. He then left Genistron and started his own company, LectroMagnetic Incorporated (LMI). Mr. Nichols served the EMC Society in many roles and was President of the EMC Society in 1969. He was the "official" photographer for the EMC Society for over 20 years, and gave pictures away to anyone and everyone he captured on film at Symposiums and local IEEE Meetings. Fred worked on the B-1 bomber, as well as many other military programs involving EMC. Of course, we must mention that his daughter, Janet Nichols O'Neil, has been the Secretary of the EMCS Board of Directors for over 25 years. She is also the current editor of the EMCS Newsletter/Magazine, and is doing an outstanding job of continuing the EMC legacies of her father.

Rexford Daniels (1898 – 1997)

Rexford "Rex" Daniels was the Newsletter editor of Quasies and Peaks. This was a newsletter that existed for radio frequency experts in the USA before the start of the PGRFI in 1957 (the predecessor to the EMC Society of the IEEE). He then became the editor of the PGRFI/EMCS



Vince Mancino working at his electronic bench, using a Stoddart RFI receiver

Early force in EMC Society development, Fred Nichols

Honored founder, Rex Daniels

Newsletter from 1958 to 1968. When Robert Goldblum took over for Rex as editor of the IEEE EMC Group Newsletter, he wrote the following on the cover page of the July 1968 issue:

Many of us who have delved into the discipline of EMI/EMC over the past thirteen years remember the first publication of a Newsletter devoted to electromagnetic interference. At that time, it was titled 'Quasies and Peaks' and was published and edited by a gentleman named Rex Daniels. Rex continued this publication as his personal contribution to the Society until after the formation of the PGRFI organization within the IRE. After Milton Kant edited the first issue of the IRE PGRFI Newsletter on January 2, 1958, Rex assumed the reins as Editor for the ensuing years. Now, at his own request, Rex has retired as Editor, but certainly not as an active participant and contributor in the EMC community. Because of his never tiring endeavors to bring us informative and timely Newsletters, he has been referred to as the Father of EMC by many persons. I would like to take this opportunity to applaud Rex for his unselfish sacrifices as Editor over the past thirteen years, and to wish him well in his continuing effort to advance man's knowledge in the field of EMC.

Rex also served on the PGRFI Administrative Committee from 1960-1962 and from 1964-1966. He was elected Vice-Chairman of the Admin Committee in 1962. He was the first recipient of the Certificate of Appreciation (1962), the first recipient of the Certificate of Recognition (1968), and the first recipient of the Honorary Life Member of the EMC Society (1970). He was a Fellow of the IEEE and was internationally recognized for over thirty years of outstanding contributions to the technical aspects of EMC, instrumentation for EMC testing, and EMC effects.

Donald R. J. White

Don White was the sixth President of the PGRFI, from 1963 to 1964. He was also the chairman of the Third National Symposium on EMC in 1961. A copy of the letter written by Dr. Ralph M. Showers (Chairman of the PGRFI in 1960-61) to Don was republished in the August 1961 IRE PGRFI Newsletter, as follows:

"On behalf of the officers and members of the PGRFI, I would like to express my thanks and sincere appreciation for the effort which you personally devoted to the conduct of the 3rd National Symposium on Radio Frequency Interference. Without question, this symposium was the best of the three that were held from the point of view of not only attendance but quality and general interest.

I would also like you to extend to the other members of your committee our appreciation for their contributions. The Symposium was certainly conducted with an unusual degree of smoothness for this type of affair. With best personal regards,"

Mr. White began his working career at the Naval Research Laboratory, followed by stints at ACF and AMF. In 1959, he accepted a position of Vice-President and Director of Research for Frederick Research Corporation. In 1961 he formed White Electromagnetics, Inc. and was the acting president. During the 1960s and 1970s, his firms were famous for teaching Don White Courses on EMC all over the world. He also developed and was Chief Editor of the EMC Encyclopedia, authored five books on EMC, wrote many articles for trade journals, and wrote and presented over 70 papers at symposiums and seminars.

Donald White (right) conferring with Major-General James Dreyfus at the Third National Symposium on EMC

Harold E. Dinger (1905 – 1975)

Mr. Dinger's first interest in radio was "sparked" by the sinking of the Titanic in 1912, when radio interference issues reduced the number of rescue ships and resulting survivors. His first direct activity in radio interference occurred during the early days of radio when electric utilities hired him to track down cases of interference and to prove the utilities were not the guilty party. In 1940, he joined the Naval Research Laboratory in Washington, DC, where he made substantial contributions in the fields of radio propagation, radio interference

Fourth Chair of PGRFI, Harold E. Dinger

reduction, frequency management, and geomagnetics. He authored numerous reports and published papers in the above fields. Mr. Dinger was delegated by the Department of State to represent the United States at conferences of the International Radio Consultative Committee (CCIR). He also represented the USA at Plenary Meetings of CISPR in 1947, 1950, and 1961. In 1947, Harold received the Meritorious Civilian Service Award from the Navy.

Harold was the Fourth Chairman of the PGRFI's Administrative Committee in 1961-1962 and served on the Administrative Committee from 1958 – 1963. He also was the Awards Chairperson of the PGRFI Administrative Committee in 1960.

Herman Garlan (1907 – 1997)

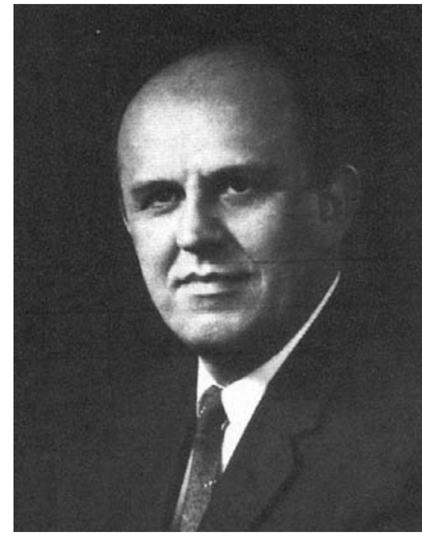
Herman Garlan was associated with the United States Federal Communications Commission (FCC) from 1940 through the 1970s. He started as a Field Engineer at the Chicago office, where he was an expert on radio station inspections and enforcement matters. In 1945, he transferred to Washington, DC where he began working on regulatory matters with land mobile communications services, including frequency allocations and promulgation of technical standards. Herman transferred to the Office of Chief Engineer in 1953, and became Chief of the RF Devices Branch in 1954. For many years, he was responsible for Part 15 and Part 18 of the FCC Rules.

Mr. Garlan is remembered for his service to the EMC Society, included being Fifth Chair of the Administrative Committee of the PGRFI from 1962 to 1963. He was also a member of the Administrative Committee from 1961 to 1963 and 1968 to 1970, and served as its Treasurer in 1961. In addition, he served as Vice-Chair of the Second and Third National Symposiums of the PGRFI.

Zigmund Grobowski

Mr. Grobowski was the Seventh Chair of the PGRFI, 1964 to 1965. He actually took over for Mr. Donald White in early 1964, since Mr. White had to resign due to business pressures. Mr. Grobowski was on the Administrative Committee from 1961 to 1967 and was Secretary from 1961 to 1962. He was also the Chair of Chapter Activities from 1960 to 1961 and assisted at several National Symposiums in an advisory position.

Mr. Grobowski was a consulting engineer and headed the firm of Grobowski and Associates in Washington, DC, after starting his career with Jansky and Bailey. He was a specialist in radio frequency



Seventh Chairman, Zigmund V. Grobowski

interference of missiles and rockets, and was influential in the EMC design of the Atlas and Titan missiles and, later, the Manned Space Flight Program. Mr. Grobowski enjoyed spending professional design time on antennas and educational television systems.

Aaron H. Sullivan, Jr. (1915 – 1985)

Aaron Sullivan, known as Sully, was a Life Fellow of the IEEE and a member since 1940. He was a Founding Member of the Washington Chapter of the EMC

Herman Garlan with participants at the Third National Symposium on PGRFI
Edward F. Mischler, National Engineering Service, Public Relations; Herman Garlan, FCC, Vice-Chairman; Fred Morris, Electro-Mechanics, Inc., Speaker; Joseph Berliner, NASA, Washington, D.C., Speaker; and Jack M. Carter, Jansky & Bailey, Inc., Hospitality

Aaron Sullivan, aka Sully

Society, served as secretary of the Chapter in 1961 and 1962, vice-chairman in 1962 and 1963, and chairman in 1962 and 1963. He also served on each of the Washington EMC Committees hosting the International EMC Symposia. Sully was Secretary in 1960 and 1961, and Chair of the Technical Program Committee in 1967. He started as Vice-Chair of the 1976 Symposium and ended up running the Symposium when the Chair had to take a temporary assignment outside of the country. Again, in 1983, he was the Chair of the Symposium in DC, which happened to be the Silver Anniversary of the EMC Society. He was on the EMC Society Board of Directors from 1964 to 1969 and from 1973 to 1975, was the eighth Chair of the Society, and served the longest term of any chairman, from 1 July 1965 to 31 December 1967 (30 months) due to a change in the Society's year-end from 30 June to 31 December. He was also the first editor of the PGRFI Transactions from 1962 to 1968, and edited the four-volume Handbook on Radio Frequency Interference, published in 1962.

The EMC Society honored him with a Certificate of Appreciation in 1966, an Honorary Life Member of the EMCS Award in 1976, and a Certificate of Acknowledgement in 1983.

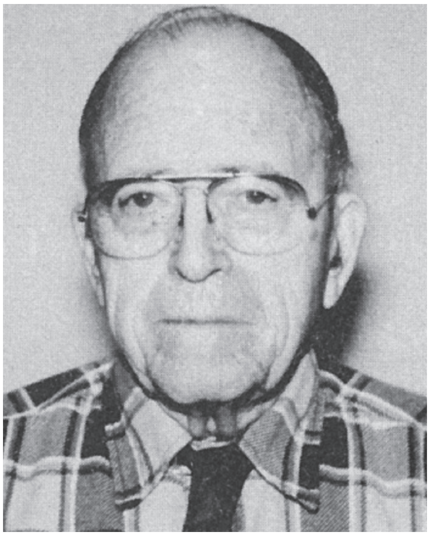
Sully received his electrical engineering degree from Cornell University and then became manager of the Washington Office of HRB-Singer, Inc. He was also a vice-president of Frederick Research Corporation in Wheaton, MD. During World War II, as an expert on the compatibility issues of various Allied radars and communication systems, he was in charge of radar and ECM planning for the Allied invasion at Normandy.

Leonard Thomas, Sr. (1910 – 2007)

Mr. Thomas lived to be 97 years old and was instrumental to the success of the Society in the early years of its formation. His daughter called him the 1920s equivalent of a modern day nerd. He built radio sets as a youngster and discovered his vocation of electrical engineering in high school. After graduating from college, he got a job repairing Philco radios and installing radios in cars. He then joined a radio station, where he "manned the station" and changed the records. In 1939, he moved to Washington, DC and worked as an engineer at the CBS radio station WJSV. He was the engineer for radio appearances of a number of famous entertainers, including talk-show host Arthur Godfrey. Mr. Thomas recalled that sometimes Mr. Godfrey would run late "and he would fly low coming in his car every morning, and if he was not on time, I would just play a record until he got there."

He left WJSV in 1942 and joined the war effort by becoming a radio engineer with the Bureau of Ships, a component of the Department of Navy. There he specialized in transmitter and receiver interference problems. He was instrumental in reducing electronic interference in small boats and this was a key factor in the success of PT-boat landings in North Africa during World War II.

After the war, Leonard became the first US representative to the International Special Committee on Radio Interference (CISPR), and in 1960 he joined the Electromagnetic Compatibility Analysis Center in Annapolis. He then became very active in the IEEE EMC Society, including being Secretary of the Society's Board of Directors for many years. He received the Laurence G. Cumming Award from the Society for his service to the Board.



Radio "personality" Leonard Thomas

He was elected a Fellow of the IEEE for "leadership in electromagnetic compatibility and development of interference measurement instrumentation and standards". Mr. Thomas also contributed many technical papers to the field over the course of his career.

FOUNDERS OF THE 60s

The Founders of the 60s helped move the EMC Society from its origin in 1957 to its position of prominence in the 1970s. They dedicated many hours of their lives to the EMC Society and set the foundation for further growth over many years to come.

(the author)

DANIEL D. HOOLIHAN

is the Founder and Principal of Hoolihan EMC Consulting. He is a Past-President of the EMC Society of the IEEE and is presently serving on the Board of Directors. He is presently an assessor for the NIST NVLAP EMC and Telecom Lab Accreditation program. As of the first of this year, he is the Chair of the ANSI ASC-C63R committee on EMC.

EVENTS in Compliance

May 2012

14-17
6th Annual International Electrostatic Discharge Workshop (IEW)
Electrostatic Discharge Association (ESDA)
Oud-Turnhout, Belgium
www.incompliancemag.com/events/120514_1

14-18
2012 Annual Spring Engineering Workshops
Silent Solutions LLC
Chelmsford, MA
www.incompliancemag.com/events/120514_2

15-17
Laboratory, Measurement, & Control Equipment UL/CSA/EN/IEC61010-1
E. D. & D., Inc.
Research Triangle Park, NC
www.incompliancemag.com/events/120515

16
ESD Basics for the Program Manager
Electrostatic Discharge Association (ESDA)
Bloomington, MN
www.incompliancemag.com/events/120516_1

16
Hipot Testing Your Product
Associated Research
Webinar
www.incompliancemag.com/events/120516_2

17
Medical Device Regulatory Compliance
MET Laboratories
Austin, TX
www.incompliancemag.com/events/120517_1

17
How To's of In-Plant ESD Auditing and Evaluation Measurements
Electrostatic Discharge Association (ESDA)
Bloomington, MN
www.incompliancemag.com/events/120517_2

22-24
Fundamentals of EMC Compliance Testing
ETS-Lindgren
Austin, TX
www.incompliancemag.com/events/120522_1

22-25
Korea Regional Tutorial Program
Electrostatic Discharge Association (ESDA)
Seoul, Korea
www.incompliancemag.com/events/120522_2

28
IEEE EMC Society Washington DC/Northern Virginia Chapter Meeting
Herndon, VA
www.incompliancemag.com/events/120528

31
MIL-STD Testing Seminar
MET Laboratories
Baltimore, MD
www.incompliancemag.com/events/120531

June 2012

5
Understanding Ground Resistance Testing
AEMC Instruments
Cleveland, OH
www.incompliancemag.com/events/120605_1

5-8
MIL-STD-461F
Washington Laboratories Academy
Gaithersburg, MD
www.incompliancemag.com/events/120605_2

5-10
ESD Association Meeting Series
Electrostatic Discharge Association (ESDA)
Seattle, WA
www.incompliancemag.com/events/120605_3

June 2012 *continued*

6
IEC 60601-1 3rd Edition Seminar
TÜV Rheinland
San Diego, CA
www.incompliancemag.com/events/120606

7-8
Device Design Essentials
Electrostatic Discharge Association (ESDA)
Seattle, WA
www.incompliancemag.com/events/120607

8
iNARTE Examinations at Washington Laboratories Academy
Gaithersburg, MD
www.incompliancemag.com/events/120608

11-12
Ingress Protection EN/IEC60529 & UL/CSA/EN/IEC60950-22
E. D. & D., Inc.
Research Triangle Park, NC
www.incompliancemag.com/events/120611

12
Hazardous Location Product Safety Testing Seminar
MET Laboratories
Houston, TX
www.incompliancemag.com/events/120612

13
A Crash Course in Safety and Circuit Theory
Associated Research
Webinar
www.incompliancemag.com/events/120613

14
MIL-STD Testing Seminar
MET Laboratories
Santa Clara, CA
www.incompliancemag.com/events/120614

PRODUCT Showcase

Your Source for Product and Service Solutions

SAVE THE DATE

Tuesday
May 8, 2012

Chicago EMC
Mini-Symposium

The Chicago Section IEEE EMC Society is pleased to announce its annual EMC Mini-Symposium on Tuesday May 8th, 2012.

Our EMC Mini-Symposium offers engineers, managers and project supervisors an excellent opportunity to receive world-class EMC training locally and at a very reasonable cost. The Mini-Symposium is an all-day event with topics ranging from EMC design principles and regulations to test methods and test equipment.

For additional details, visit www.emcchicago.org

SAVE THE DATE

Thursday, September 13, 2012
Minnesota EMC Event

This Annual Event will be held at the Ramada Mall of America in Bloomington, MN – a major suburb of Minneapolis. The Hotel is located five minutes from the Minneapolis-St. Paul International Airport.

The Annual Event will have three technical tracks; EMC and Medical Devices, EMC Standards (commercial and military), and Test Labs for EMC. Interested speakers may contact Dan Hoolihan for more details at danhoolhanemc@aol.com.

A Vendors table-top show will be held in conjunction with the three technical tracks. For further details on exhibiting at the MN EMC Event, contact Gerry Zander at gzander@northporteng.com.

2012 Minnesota EMC Event

PSES
Product Safety Engineering Society

The IEEE Product Safety Engineering Society is pleased to announce the Call for Papers, Workshops, and Tutorials for the 2012 IEEE Symposium on Product Compliance Engineering to be held November 5-7, 2012 in Portland, OR.

The Symposium seeks original, unpublished papers, workshops and tutorials on all aspects of product safety and compliance engineering.

DEADLINES:

- Abstract/Draft Presentation Submission: May 15, 2012
- Acceptance Notification: June 15, 2012
- Final Manuscript Submission: August 15, 2012

www.psessymposium.org

(Authors)

PROFESSOR FLAVIO CANAVERO, IEEE Fellow
Politcnico di Torino, Italy, Flavio.canavero@polito.it

MEHDI DARBANDI
School of Electrical & Computer Engineering, Tehran University, Irandarbandimahdi@gmail.com

DANIEL D. HOOLIHAN
is the Founder and Principal of Hoolihan EMC Consulting. He is a Past-President of the EMC Society of the IEEE and is presently serving on the Board of Directors. For Dan's full bio, please see page 63.

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 see page 21.

ROBERT KADO
works with the Chrysler Group LLC in Auburn Hills, MI USA and can be contacted at rk381@chrysler.com

PROFESSOR FERAYDUNE KASHEFI, IEEE Member
Department of Electrical Engineering at Azad University, Shabestar, Iran, fred.kashefi@gmail.com

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. For Brian's full bio, please see page 15.

BRIAN McAULIFFE
is currently employed as a Senior Engineer with Dell Inc. based in Ireland and working in the Global Regulations & Standards group. Brian has worked in compliance for 20 years with compliance testing laboratories and a number of product development companies. For Brian's full bio, please see page 41.

MARK I. MONTROSE
is an EMC consultant with Montrose Compliance Services, Inc. having 30 years of applied EMC experience. He currently sits on the Board of Directors of the IEEE (Division VI Director). For Mark's full bio, please see page 24.

JODY J. NELSON
works at kVA LLC in Greenville, SC, USA and can be contacted at jody.nelson@kvausa.com.

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. For Geoff's full bio, please see page 23.

BRIAN RETZLAFF
is a Process Engineer and ESD Subject Matter Expert at Plexus Manufacturing Solutions - Neenah Operations in Neenah, Wisconsin. Since 2006, Brian has been an active member of the ESD Association. For Brian's full bio, please see page 57.

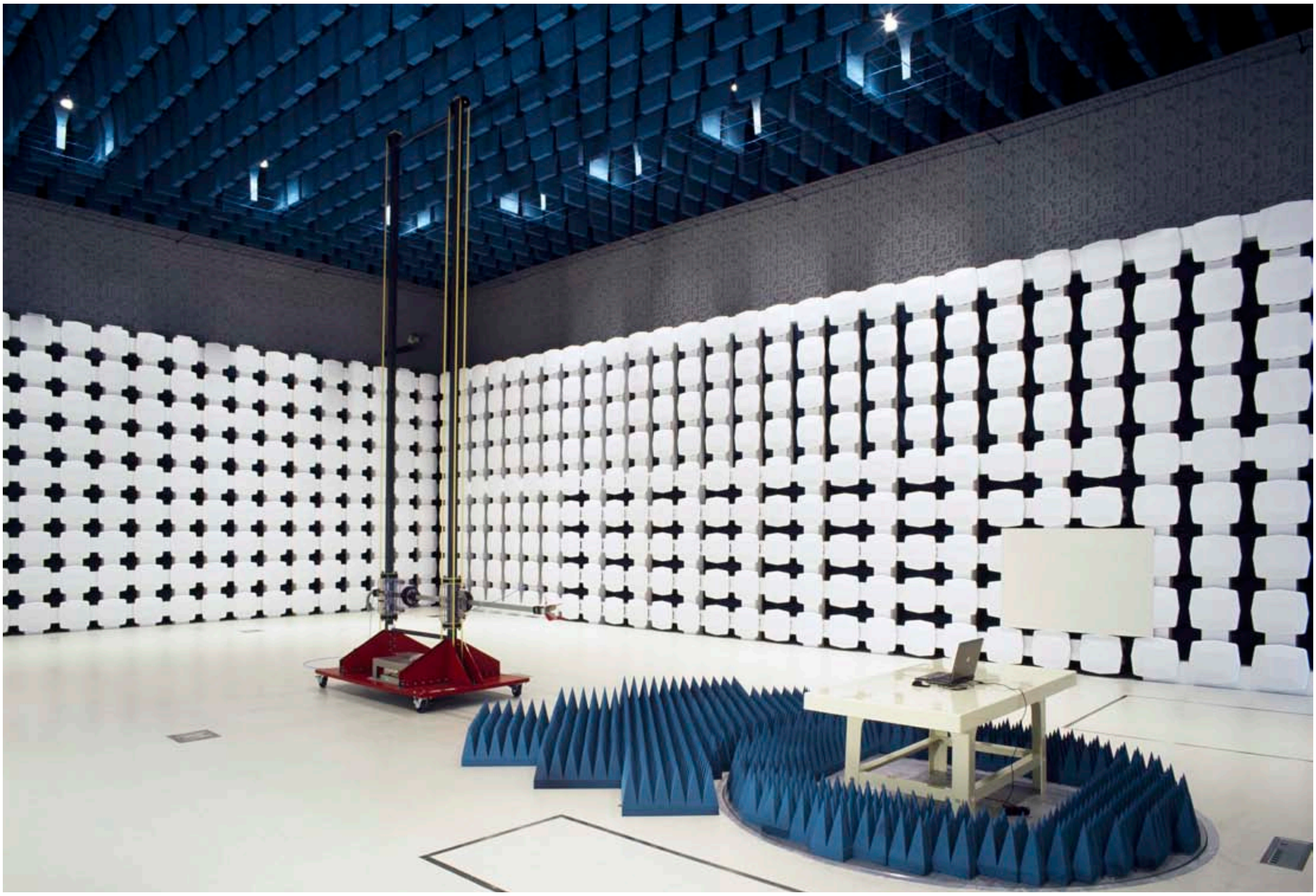
CYROUS ROSTAMZADEH, Senior IEEE Member
Senior EMC Technical Specialist, Robert Bosch LLC, Plymouth, MI, USA, Cyrous.Rostamzadeh@us.bosch.com

WILLIAM TAYLOR works at kVA LLC in Greenville, SC, USA and can be contacted at bill.taylor@kvausa.com.

SAM THEABO
is a staff Quality Engineer and corporate ESD Coordinator at Plexus Global Headquarters in Neenah, Wisconsin, with 24 years of career service. Theabo is ASQ-CQA and CQT certified. For Sam's full bio, please see page 57.

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.

(Advertisers)



TEST ON THE FAST TRACK –
NSG 5000 SERIES AUTOMOTIVE IMMUNITY SYSTEMS

Start your engines, keep your laboratory competitive: The NSG 5000 series of generators, compliant with every known international standard, is strengthening Teseq's reputation as the world leader in automotive EMC. The NSG 5500 with its unique built-in 100A transient coupler guarantees accurate, clean, compliant pulses at the EUT output. A wide selection of plug-in modules provides Pulse 1, 2a, 3a/b and Pulse 5 transients for every standard. The NSG 5600 is built from the ground up around the most powerful automotive-specific function generator in the world. Combine the NSG 5600 with a wide range of Teseq power amplifiers for Pulse 2b, Pulse 4 and other battery simulations. Additional modules for fast dropouts, ground shift and power magnetics tests ensure that the NSG 5600 fulfills more standards than anything in its class.

NSG 5500/NSG 5600 system highlights:

- **Clean, capacitive discharge pulses compliant to ISO 7637-2 Annex D and hundreds of international and manufacturers' standard tests**
- **Built-in 100 A coupler/battery switch**
- **Unique power magnetics functions**
- **Ground-shift and isolation transformer for SAE J1113-2 and more**
- **Powerful arbitrary waveform function generator**
- **Library with over 1000 tests from international and manufacturers' standards**

Teseq Inc. Edison, NJ USA
T+1 732 417 0501 F+1 732 417 0510
usasales@teseq.com www.tesequsa.com

MILMEGA
a TESEQ Company

TESEQ
Advanced Test Solutions for EMC