NOVEMBER 2012

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IN COMPLIANCE

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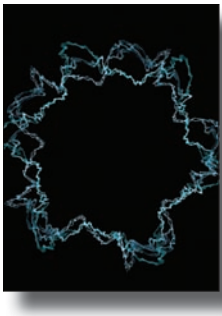
DEPARTMENTS

FEATURES



News in Compliance

FCC News

FCC Proposes $1 Million Fine for Slamming

The U.S. Federal Communications Commission (FCC) has proposed a fine of more than a $1 million against a Florida-based telecommunications firmed that allegedly changed the preferred long-distance telecommunications service of a group of consumers without authorization, a practice known as "slamming."

In a Notice of Apparent Liability for Forfeiture issued in August 2012, the Commission proposed a fine of $1,108,000 for LDC Telecommunications of Clearwater, FL for switching telephone service of 27 consumers without authorization. The Commission's action in this case caps a nearly four year process, during which the Commission's Consumer & Government Affairs Bureau sent LDC 44 separate complaints from consumers who claimed that their long-distance phone service was switched without their authorization.

Section 258 of the federal Communications Act prohibits carriers from changing a subscriber's selection of telephone service providers without their explicit permission. The Commission's forfeiture guidelines have established a base forfeiture amount of $40,000 for each instance of slamming, resulting in a proposed forfeiture of $1,080,000 for LDC. In addition, the Commission proposed an additional forfeiture of $28,000 for LDC's failure to respond to seven separate communications from the Commission related to individual slamming complaints that fell within the one year statute of limitations.

The complete text of the Commission's Notice of Apparent Liability for Forfeiture against LDC is available at incompliancemag.com/news/1211_01.

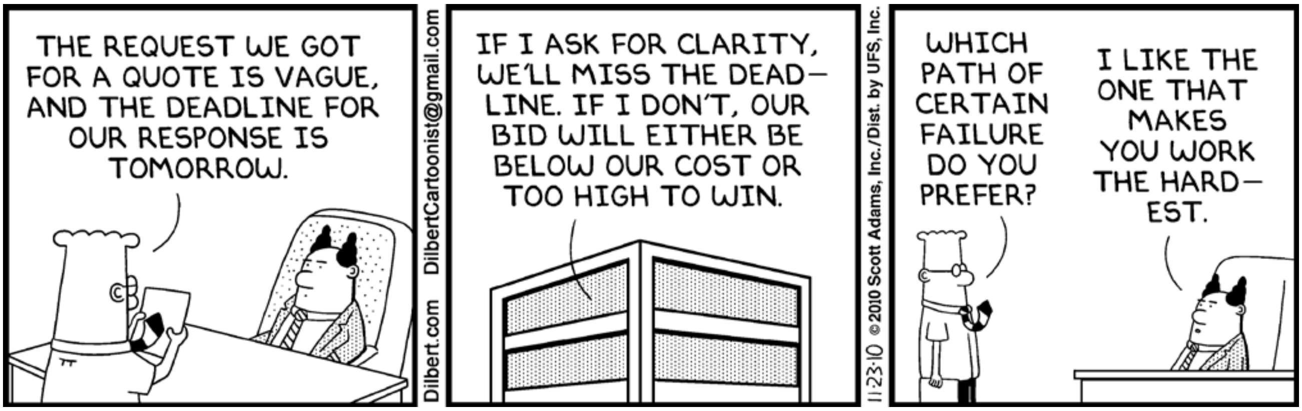
FCC Proposes $1.6 Million Fine for Unsolicited Faxes

The U.S. Federal Communications Commission (FCC) has proposed forfeiture penalties in the amount of nearly $1.6 million against a California company for delivering unsolicited advertisements to consumers via facsimile machine.

Issued in September 2012, the Notice of Apparent Liability for Forfeiture cites a myriad of companies operated for delivering unsolicited fax advertisements to consumers, beginning as far back as October 2010. The fax advertisements offered recipients various financial services, including "0% interest" on "restructured" credit card programs.

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

In this case, the Commission cited willful and repeated violations of its regulations, levying $16,000 in fines for each of 99 apparent violations, for a total of $1,584,000. The Commission noted that the proposed penalty was based on the number of apparent, willful, repeat violations involved, as well as' efforts to disguise culpability and evade responsibility for the violations, despite Commission warnings.



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News in Compliance

European Union News

EU Commission Updates List of Standards for Medical Device Directive

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

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

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

The revised list of standards for the EU's Medical Device Directive is available at incompliancemag.com/news/1211_03.

Updated Standards List for Active Implantable Medical Devices Issued by EU Commission

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 90/385/EEC, relating to active implantable medical devices.

According to the EU's Directive, "an 'active medical device' means any medical device relying for its functioning on a source of electrical energy or any source of power other than that directly generated by the human body or gravity."

Further, "an 'active implantable medical device' means any active medical device which is intended to be totally or partially introduced, surgically or medically, into the human body or by medical intervention into a natural orifice, and which is intended to remain after the procedure."

The updated list of CEN and Cenelec standards that can be used to support compliance with the Directive was published in the *Official Journal of the European Union* in August 2012, and replaces all previously published standards lists for the Directive.

The list can be viewed at incompliancemag.com/news/1211_04.

EU Commission Issues New Standards List for In Vitro Diagnostic Medical Devices Directive

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

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

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

The updated list of CEN and Cenelec standards that can be used to support compliance with the Directive was published in August 2012 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

> The Commission of the European Union has issued updated standards lists for the Medical Devices Directive, the Active Implantable Medical Devices Directive, and the the In Vitro Diagnostic Medical Devices Directive.

European Union News

The list is available at incompliancemag.com/news/1211_05.

EU Postpones Tighter Cadmium Restrictions Under REACH Regulations

The Commission of the European Union (EU) has issued regulations temporarily delaying the implementation of more restrictive requirements regarding the use of cadmium in certain plastic materials.

In May 2011, the Commission revised Annex XVII of the EU's requirements concerning the registration, evaluation, authorization and restriction of chemicals (REACH). Specifically, the revised Annex placed greater restrictions on the use of cadmium as a coloring agent in paints and polymers, as a stabilizer in polyvinyl chloride (PVC), in jewelry, and in brazing sticks and fillers used in jewelry-making.

However, following the adoption of these new requirements, the Commission determined that substitutes for some of the newly restricted plastic materials were not available and that a further assessment of the restrictions was warranted. Therefore, in a Regulation issued in September 2012, the Commission has reverted to the original list of plastic materials restricted under the REACH regulation, pending further review by the European Chemicals Agency.

The complete text of the Commission's regulation regarding cadmium is available at incompliancemag.com/news/1211_06.

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: editor@incompliancemag.com

News in Compliance

CPSC News

CPSC Initiates Rulemaking for High-Powered Magnets

The U.S. Consumer Product Safety Commission (CPSC) has issued a Notice of Proposed Rulemaking that could result in a new federal standard for small, high-powered magnet sets.

High-powered magnet sets are often marketed as sculptures, puzzles or stress relievers, and CPSC-required labeling makes clear that these magnet sets are not for use by children. However, when swallowed by a child, the magnets can link together inside of a child's intestines, leading to intestinal obstruction, perforations, sepsis and even death. Data collected by the CPSC indicates that small, high-power magnets were associated with 1700 emergency room visits between 2009 and 2011, with 70 percent of the emergencies involving children 4 to 12 years of age.

According to the CPSC, the proposed mandatory federal standard would set performance requirements for magnet sets based on their size and strength, and would restrict the sale of magnet sets that do not meet the established performance requirements.

The complete text of the CPSC's Notice of Proposed Rulemaking on high-powered magnets is available at incompliancemag.com/news/1211_07.

BatteriesPlus Recalls Battery Packs Due to Explosions

Retailer BatteriesPlus, LLC, of Hartland, WI has issued a second recall of certain Rayovac-brand replacement battery packs manufactured in China and used with cordless power tools.

The company has reported to the U.S. Consumer Product Safety Commission (CPSC) that the battery packs can unexpectedly explode, posing a risk of injury to consumers. BatteriesPlus issued its first recall of approximately 112,000 battery packs in December 2011. The second recall of more than 65,000 battery packs follows three additional reports of exploding batteries, including one report of a consumer injury.

The recalled battery packs were sold exclusively at BatteriesPlus retail stores and online at www.batteriesplus.com between June 2008 and July 2012 for between $60 and $70.

Additional details about this recall are available at incompliancemag.com/news/1211_08.

Power Strips Recalled Due to Electric Shock Hazard

Legrand Wiremold of West Hartford, CT has recalled about 14,000 under cabinet power and lighting power strips manufactured in China.

According to the company, the electrical wires are reversed on the receptacles on the power strips, posing a risk of electrical shock to consumers. Legrand Wiremold has received one report of an incident related to the recalled power strips, but no reports of injuries.

The recalled power strips were sold at retailers Ace Hardware, Do it Best, Home Depot USA, Sutherlands and True Value Hardware, as well as at Amazon.com, between February 2011 and August 2012 for about $40.

More information about this power strip recall is available at incompliancemag.com/news/1211_09.

Apes Love Apps (from our "You Can't Make This Up" File)

Forget about the new iPhone 5! What today's smart primate really wants is an iPad!

At 12 zoos located in the U.S. and Canada, zoologists are providing orangutans with access to iPads as part of their enrichment process. Under the program "Apps for Apes," orangutans are given access to the computing tablets twice weekly for 15 minutes to half an hour. The animals use apps such as Doodle Buddy for drawing, as well as certain memory games and communications applications.

Because the devices are fragile, zookeepers hold the iPads while the animals navigate the touch screen. However, the program is investigating ways to ruggedize the case so that the orangutans have complete control.

According to program organizers, the iPads are not meant to replace physical stimulation, but to expand the orangutans' access to broader intellectual experiences and aid in communications.

The Apps for Apes program is expected to expand to zoos in Australia, New Zealand, Japan and Europe, and depends on donated iPads. You can learn more about the project, and how to donate your unwanted iPad, at www.redapes.org.

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 698A: Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations
New Edition dated September 14, 2012

UL 710: Standard for Exhaust Hoods for Commercial Cooking Equipment
New Edition dated September 13, 2012

UL 746A: Standard for Polymeric Materials - Short Term Property Evaluations
New Edition dated September 6, 2012

UL 756: Standard for Coin and Currency Changers and Actuators
New Edition dated September 14, 2012

UL 1004-1: Standard for Rotating Electrical Machines - General Requirements
New Edition dated September 19, 2012

UL 1897: Standard for Uplift Tests for Roof Covering Systems
New Edition dated September 14, 2012

UL 2231-2: Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Particular Requirements for Protection Devices for Use in Charging Systems
New Edition dated September 7, 2012

UL 2231-1: Standard for Safety for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements
New Edition dated September 7, 2012

UL 2803: Standard for Sustainability for Printing Services
New Edition dated September 18, 2012

REVISIONS

UL 73: Standard for Motor-Operated Appliances
Revision dated September 18, 2012

UL 174: Standard for Household Electric Storage Tank Water Heaters
Revision dated September 21, 2012

UL 295: Standard for Commercial-Industrial Gas Burners
Revision dated September 21, 2012

UL 360: Standard for Liquid-Tight Flexible Steel Conduit
Revision dated September 20, 2012

UL 795: Standard for Commercial-Industrial Gas Heating Equipment
Revision dated September 21, 2012

UL 858A: Standard for Safety-Related Solid-State Controls for Household Electric Ranges
Revision dated September 25, 2012

UL 864: Standard for Control Units and Accessories for Fire Alarm Systems
Revision dated August 31, 2012

UL 1029: Standard for High-Intensity-Discharge Lamp Ballasts
Revision dated September 28, 2012

UL 1277: Standard for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members
Revision dated September 5, 2012

UL 1315: Standard for Metal Waste Paper Containers
Revision dated September 11, 2012

UL 1363: Standard for Relocatable Power Taps
Revision dated September 20, 2012

UL 1450: Standard for Motor-Operated Air Compressors, Vacuum Pumps, and Painting Equipment
Revision dated September 27, 2012

UL 1561: Standard for Dry-Type General Purpose and Power Transformers
Revision dated September 28, 2012

UL 2335: Standard for Fire Tests of Storage Pallets
Revision dated September 26, 2012

UL 2420: Belowground Reinforced Thermosetting Resin Conduit (RTRC) and Fittings
Revision dated September 21, 2012

UL 2515: Aboveground Reinforced Thermosetting Resin Conduit (RTRC) and Fittings
Revision dated September 21, 2012

UL 60065: Standard for Audio, Video and Similar Electronic Apparatus - Safety Requirements
Revision dated September 21, 2012

UL 60335-2-8: Standard for Safety for Household and Similar Electrical Appliances, Part 2: Particular Requirements for Shavers, Hair Clippers, and Similar Appliances
Revision dated September 26, 2012

UL 60745-2-22: Hand-Held Motor-Operated Electric Tools - Safety - Part 2-22: Particular Requirements For Cut-Off Machines
Revision dated September 6, 2012

iNARTE Informer

What's Next

BY BRIAN LAWRENCE

We would like to welcome Sal Agnello as the new RABQSA International Director of Business Development. Sal Agnello comes to RABQSA from ASQ, where he worked in Market Development and Services.

Sal's background is in marketing, sales, and business development. In the past he has worked with three major corporations, (Johnson Controls, WI Energy, and Invensys). He is a former US Army officer in the area of logistics and engineering. He has been a part time faculty member in marketing at the Milwaukee School of Engineering (MSOE), and at Marian University.

Departments having responsibility for iNARTE question pool maintenance, exam development and new program development will report to Sal.

LOOKING BACK ON THE ESDA SYMPOSIUM

Although attendance was a little below that of recent years, this event was supported enthusiastically by attendees and exhibitors, and the venue itself was worth the visit.

During the symposium we were able to renew our formal Agreement for mutual support and cooperation, but this time under our new identity as a Certification Brand of RABQSA. Members of the RABQSA psychometrics and examination development team were with us in Tucson and we had a very productive meeting with the ESDA Technical Committee who support the iNARTE certification program. In the near future RABQSA will be conducting a job analysis survey with the intent of determining if the current iNARTE examination subjects are appropriate in today's environment, and how changes to our exam structure might make it more appropriate as an evaluation of the knowledge mix that industry is looking for.

WHAT'S NEXT

If it's November it must be Product Safety month. Yes, we are just about at the end of the US symposium season, and this year the IEEE Product Safety Engineering Society holds its annual symposium in Portland, Oregon, another place that is worth a visit even without the symposium.

This society targets design professionals and design engineers interested in electrical product safety. The IEEE

One of the other symposium attendees seemed all charged up, but the bellman waved him in anyway.

Product Safety Engineering Society addresses safety engineering for equipment and devices used in the scientific, engineering, industrial, commercial and residential arenas. It is interesting to note that this year the symposium is focused on Product Compliance Engineering, and an EMC track is featured each day of the event.

If consumers were questioned about what is important to them when selecting a product having electrical or electronic components, the safety of that product would be quite high on their list. Safety is certainly one of the key marketing strategies for the automotive industry and is being featured more and more frequently in other fields. SO WHY ARE THERE NOT MORE PRODUCT SAFETY ENGINEERS? Since its foundation as a new professional society of the IEEE in June 2003, the PSES has struggled for existence. There is considerable support for the society from a number of sister groups within the IEEE, but actual membership has been slow to develop. iNARTE has been affiliated with the PSES since 2004, offering the credentialing of engineers and technicians in product safety disciplines. However, eight years later we have less than 350 current certificate holders, almost equally spread between Japan and the North Americas. There is just one certified engineer in China, one in Taiwan, one in Australia and one in Switzerland. Considering all the products we buy from China, that one guy must be really busy.

Maybe our understanding of the knowledge and experience requirements for Product Safety Engineers and Technicians is missing the mark for today's manufacturing environment. Maybe we need a better understanding of what a Product Safety professional does every day, and by so doing we could craft our credentialing requirements and our examination subjects to better match what industry expects of them. Such an understanding will add value to this certification for both employers and employees.

iNARTE Informer

Whether or not you hold an iNARTE certificate in any of our disciplines, if you are associated or concerned in any way with Product Safety from design through manufacturing to final test, please visit and complete our on line JOB ANALYSIS SURVEY at https://www.surveymonkey.com/s/PSiNARTE.

The results of this survey will be shared with the IEEE PSES in order that we can both be more responsive to industry needs and to the professionals that work in this discipline.

THE NEW WIRELESS DEVICE CERTIFICATION PROFESSIONAL, WDCP

The first applications and examinations for this new credential were featured during October at the Telecommunications Certification Body Council, (TCBC), workshops held at the Holiday Inn - Inner Harbor in Baltimore, Maryland. The TCBC workshops have great participation from the FCC through their continuing evolution of the Knowledge Database (KDB) documents, providing information and guidance on the testing of devices subject to the FCC Rules. The iNARTE WDCP examinations featured a number of questions related to the FCC KDB documents.

Congratulations to all our examinees who demonstrated their knowledge of EMC fundamentals and wireless device specifics, by passing this first iNARTE examination.

If you were not able to attend the TCBC workshops or the iNARTE examination, you can register for the examination at any time and at any of the Authorized Test Centers listed on our web site, www.narte.org.

Also remember that if you already hold an iNARTE certificate as an EMC engineer or technician, we will waive the Part 1 examination on EMC fundamentals and you can just take Part 2 on wireless device certification subjects.

(the author)

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

QUESTION OF THE MONTH

Last month we asked:

Let H and E be the Phasors corresponding to a plane wave at some point in space, and H* and E* are the complex conjugates of H and E. How would you calculate the average power density in this plane wave?

The answer choices were:

A) Real (E × H*)
B) Real (E × H*)/2
C) Real (E × E*).
D) Real (H × H*).
E) Real (E × E*)/2Z, (where Z is the impedance of the medium).

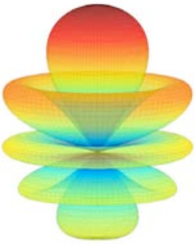
The correct answer is (B) Real (E × H*)/2

Since the Phasor is defined as a function of the peak value of a sinusoidal quantity, the correct answer is (B). Since E/Z = H, answer (E) is also correct, but only when Z is real. Thus, only (B) is always correct, making (B) the correct answer.

This month’s question is from the Product Safety pool:

Choose one of the following parts that is permitted to be in contact with a test finger in the accessibility test.

A) An uninsulated part of an ELV circuit.
B) An uninsulated part of an TNV circuit.
C) An uninsulated part of a limited-current circuit.
D) Any parts separated by functional insulation or basic insulation.



ACES
Applied Computational Electromagnetic Society

CALL FOR PAPERS

The 29th International Review of Progress in Applied Computational Electromagnetics (ACES 2013)
March 24 – 28, 2013 Embassy Suites Hotel, Monterey, California

The international ACES symposium serves as a forum for developers, analysts, and users of computational techniques applied to electromagnetic field problems at all frequency ranges. The symposium includes technical presentations, software demonstrations, vendor booths, short courses, and hands-on workshops.

Papers may address general issues in applied computational electromagnetics or may focus on specific applications, techniques, codes, or computational issues of potential interest to the ACES community. The following is a list of suggested topics, although contributions in all areas of computational electromagnetics are encouraged and will be considered.

SUGGESTED TOPICS

Integral Equation Methods
Differential Equation Methods
Fast and Efficient Methods
Hybrid and Multi-Physics Modeling
EM Modeling of Complex Mediums
Modeling Electrically Large Structures
Inverse Scattering and Imaging Techniques
Optimization Techniques for EM-Based Design
Asymptotic and High Frequency Techniques Low
Frequency Electromagnetics
Computational Bio-Electromagnetics
Printed and Conformal Antennas
Modeling and Performance of RFID Systems

Wideband and Multiband Antennas
Dielectric Resonator Antennas
Phased Array Antennas
Smart Antenna and Arrays
Nanotechnology Applications
EMC/EMI Applications
Propagation Analysis
Remote Sensing Applications
RF and Microwave Devices
TeraHertz Antennas
High Performance Computing
Parallel and GPU Computations
Sensors, RFID Integrated Sensors

All authors of accepted papers will be invited to submit an extended version of their paper(s) for publication, after review, in a special issue of the ACES Journal.

PAPER SUBMISSION PROCEDURE

No email, fax, or hard-copy paper submission will be accepted. Photo-ready finished papers are required, in Adobe Acrobat format (*.PDF) and must be submitted through the conference section of ACES web site. Successful submission will be acknowledged automatically by an email after completing all uploading procedures as specified on ACES web site. Notifications regarding paper submission, acceptance, and all other conference related issues will be directed to the corresponding author's email supplied during the paper upload process.

SUBMISSION DEADLINE AND REGISTRATION REQUIREMENT

The first version of all contributions must be uploaded to the ACES web site by **November 15, 2012.** This is a firm deadline for the initial version of all contributed and invited papers, including special session papers. Upon the completion of the review process, the acceptance notification along with the pre-registration information will be emailed to the corresponding author on or about **January 15, 2013.** Each corresponding author is required to complete the paid pre-registration, the execution of any required paper revisions, and upload the camera ready version by the firm deadline of **February 15, 2013** for final acceptance for presentation and inclusion in the symposium proceedings.

For more information, please visit ACES on-line at: ***http://aces.ee.olemiss.edu***.

MR. Static

Useful Static Electricity

BY NIELS JONASSEN, sponsored by the ESD Association

Most people are unaware of the important applications that are based on electrostatic principles.

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

The term *static electricity* most likely brings to people's minds such phenomena as nasty shocks, clinging clothes, dirty TV screens, exploding tankers, and, especially to the readers of this magazine, ruined electronic components and circuits (also known as ESD problems). And one must admit that when the talk in the electronics industry is about static electricity, it is rarely for its virtues, but rather because—almost without exception—it presents itself as a nuisance or sometimes even as a risk.

This is slightly unfair to static electricity, although understandable considering that most people know only of its negative characteristics. Most people are unaware that static electricity—or rather, electrostatic principles—are vital for painting the refrigerator, the quality of sandpaper, the functioning of the photocopier and, even more importantly, the cleaning of smoke from coal-fired power plants. These are only a few examples of important applications of static electricity.

It may at first sight seem funny that the cause of the apparently unpredictable and bothersome expressions of static may also be put to good use. But from a physicist's point of view, it is not surprising at all. Most applications of static electricity are related to the handling of particulates, whether airborne or suspended in liquid. The following characteristics are common to electrostatic processes:

- The force from an electric field on a small, charged particle may be much larger than gravity.
- It is very easy to monitor the electric force by monitoring the electric field.
- The electric forces acting upon airborne particles interfere insignificantly with the air and its movement.

In all electrostatics applications, some materials must be electrified, meaning they must be able to respond to an electric field. This can be done either by giving the materials a net charge or by exposing them to induction or polarization.[1,2] The three most significant electrification processes are corona electrification, contact and triboelectrification, and induction and polarization in an electric field. Precipitation uses corona electrification. Often, two or more electrification processes are active. For example:

- Separation uses both corona and triboelectrification.
- Surface treatment uses contact and triboelectrification and polarization.

This article focuses on examples of all three of these applications.

PRECIPITATION

The principle of electrostatic precipitation is the charging of airborne

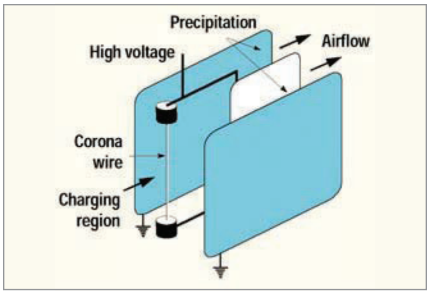


Figure 1: Overview of an electrofilter

(solid or liquid) particles with the same polarity, which consequently makes them move in the same direction in an electric field.

Many industrial processes produce airborne particulates to such an extent that it is necessary to clean the affected air before releasing it into the environment. A prime example is the production of fly ash in coal-fired electric power generation. A lot of other industries also produce particulate air pollution on a large scale.

Even everyday activities, such as cooking and cleaning (not to mention smoking) produce a particle concentration in the air, often at unacceptable levels. Although particulates can be removed from the air by mechanical filters, for industrial pollution, the world would be at a loss without electrostatic precipitation, usually in the form of the electrofilter.

The electrofilter is the oldest application of static electric principles to be put to industrial use, dating back to 1906 when Frederick Cottrell built his first precipitator. Figure 1 shows a simplified drawing of an electrofilter, and Figure 2 illustrates its working principles.

A single corona wire (or series of them) is kept at a high potential, which causes

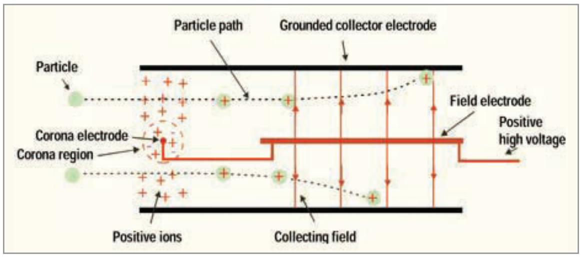


Figure 2: Electrofilter, working principle

MR. Static

The principle of electrostatic separation is the charging of components in particulate mixtures with opposite polarities (or leaving conductive materials uncharged) and subsequently separating the components by mutual repulsion.

Material A	Material B
Asbestos	Silicates
Coal	Pyrite
Coal	Shale
Copper ore	Silicates
Coke	Iron
Diamonds	Silicates
Feldspar	Quartz
Fly ash	Carbon
Iron	Silicates
Kaolin	Iron contamination
Limestone	Silicates
Nickel	Copper ore
Zirconium	Sand
Barley, rice	Rodent excrement
Cocoa beans	Shells
Cotton seeds	Stems
Grain	Garlic seeds
Nut meat	Shells
Photographic film	Paper
Polyvinyl	Polyester

Table 1: Electrostatically separable mixtures

positive and negative ions to be formed within a thin sheath around the wire. In the figure, the negative ions are attracted to the wire where they are neutralized. The positive ions, however, move toward the grounded electrodes, forming a highly concentrated region of positive ions. When the dirty air is drawn through this region, the ions will tend to attach to particles in the air.

The airflow carries the charged particles into the precipitation volume, where they move toward the collecting electrodes and where, eventually, they may plate out. Whether a particle will actually land on the collecting electrodes depends on many factors, including flow rate, particle size, particle charge, filter dimensions, and field strength.

Several methods can be used to remove the plated-out materials from the collecting electrodes. For industrial plants, big mechanical shakers may be needed for cleaning; for household electrofilters, it may be sufficient to place the filter unit in the dishwasher every other week to remove lingering particulates.

SEPARATION

The principle of electrostatic separation is the charging of components in particulate mixtures with opposite polarities (or leaving conductive materials uncharged) and subsequently separating the components by mutual repulsion or by an external electric field, possibly aided by gravity.

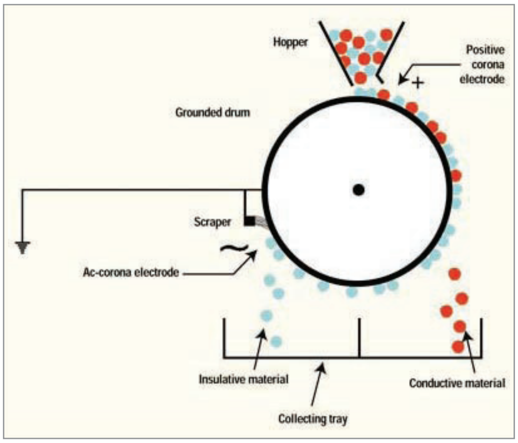


Figure 3: Electrostatic drum separator

Figure 3 depicts this process using a drum separator. A mixture of conductive and insulative particles is fed from a hopper onto a grounded drum, and all the particles are charged (positively in the case shown) by a corona discharge. When the particles leave the corona region, the conductive particles lose their charge to the drum and move away by gravity and “centrifugal” forces. The insulative particles stick to the drum until a brush or scraper, possibly assisted by an ac corona discharge, removes them.

The charging of the particles to be separated can be achieved using a variety of methods. Selecting the appropriate method depends on several factors, including the properties of the materials themselves, the state of their surfaces, and external parameters such as electric fields and temperature gradients across interfaces. Table 1 lists a few of the many material mixtures that in particle form can be separated electrostatically to produce a commercial benefit.

The three topics treated here are only a few of many useful applications of electrostatic principles. Equally valuable applications include electret microphones and filters, electrostatic motors, and the vital field of electrostatic image forming known as xerography.

COATING

Nearly all products manufactured today are coated in some way. This is true for the paper we write on, the clothes we wear, the cars we drive, and the furniture we sit on. For practical, economic, and environmental reasons, it is desirable that products be coated with only the necessary amount of material, and this consideration makes electrostatic coating superior to most other methods.

In an earlier column, we discussed spray painting as a method of surface treatment using electrostatics.[3] This section addresses a completely different type of coating used for manufacturing sandpaper. Figure 4 illustrates the principle used in this coating process.

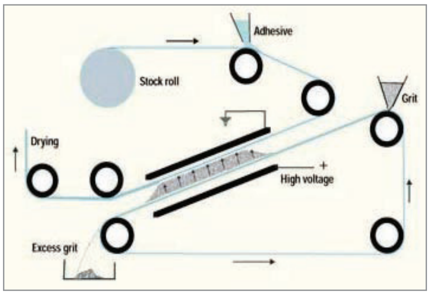


Figure 4: Manufacturing of sandpaper

Two plane electrodes—one grounded while the other is connected to a high-voltage supply—are used to establish an electric field. A continuous belt of a suitable semiconductive material passes through the field in contact with the lower electrode. The paper or textile for the sandpaper backing is fed from a stock roll through the field, in contact with the upper electrode. Before the paper enters the field, a layer of adhesive is applied to the side of the paper that will eventually face downward.

An abrasive such as ground agate is fed from a hopper onto the lower belt outside the field. When the abrasive enters the field, the polarized grains will be charged directly with the same polarity as the lower electrode.

The grains will align their longest axes with the field, and when the field strength is high enough, they will move toward the upper electrode and embed themselves in the adhesive with a sharp tail protruding. If a grain hits a point already occupied by another grain, the late arriver is neutralized, charged with the opposite polarity, and repelled. It will then fall to the lower belt, repeating the process.

When the grit-covered face leaves the field, a shaker removes loose material and a drier sets the adhesive. The electrostatic deposition of the abrasive provides a more uniform distribution and a more beneficial orientation of the single grains than is possible by a purely mechanical process.

CONCLUSION

The three topics treated here are only a few of many useful applications of electrostatic principles. Equally valuable applications include electret microphones and filters, electrostatic motors, and the vital field of electrostatic image forming known as xerography, without which we wouldn't have photocopies. The purpose of this short survey is to provide an overview of the possibilities of electrostatics. Perhaps the next time you are frustrated by an ESD problem, you might even remember that static electricity can also be looked at as a good thing.

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(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.

Symbol Standardization: There's No Need to Reinvent the Wheel

BY GEOFFREY PECKHAM

In this column, we'll explore the need for standardized elements and components in symbols in order to effectively communicate safety.

As a professional in the engineering field, a primary concern you're faced with is effectively communicating safety. Often that involves the customization of safety labels and markings for the products you design or manufacture. To communicate your specific safety or hazard information, graphical symbols are critical. Why? Well drawn symbols have the ability to command attention and engage viewers in a way that words alone simply cannot match – and they do so in a way that globally communicates your message across language barriers.

When you see a symbol, whether it's a notice in a public setting or a warning on a product, at first glance it looks simple. That's because, when a symbol is well-designed, its end result *should* look simple; it should be easy to understand either due to its clear representational elements, or because you "learned" to recognize it through its consistent use and through repeated exposure.

But, when it comes to how a standardized symbol is created, how it came to have its precise appearance and design elements, it's anything but a simple process. It is not a process characterized by expert designers each doing their own thing to invent new symbols. Standardized elements and components must be used in order to yield symbols that are consistent in their construction and readily understood. And, that's what this column is about. There's a science behind symbol design. It involves the careful application and consideration of three important factors: 1) an understanding of the latest global safety standards, 2) a high regard for best practice symbol design principles, and 3) as complete a knowledge as possible of the symbols that have been standardized to date.

Graphical symbols are standardized worldwide by two global groups, ISO and IEC. When it comes to safety symbols, ISO is the one to watch, in particular, ISO Technical Committee 145 committee. In my work in chairing

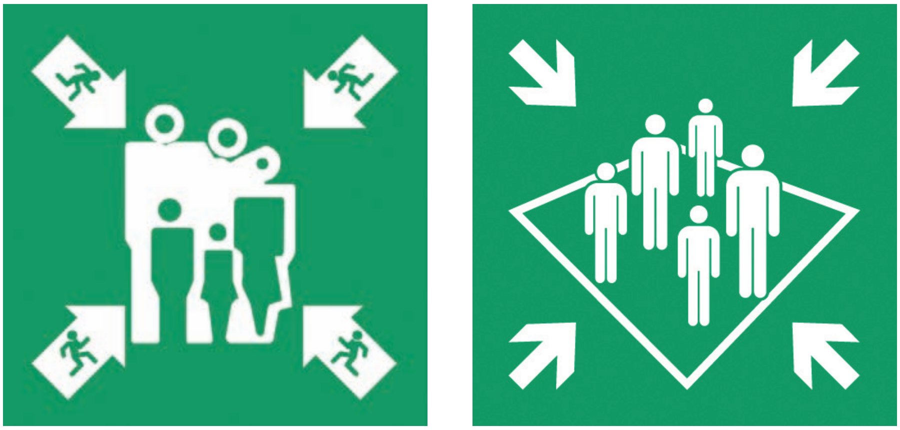

Figure 1: Old (at left) and new (at right) images of the shipboard assembly point symbol.

Figure 1 shows an old and new version of an assembly point symbol, the icon used to guide a ship's passengers to the location of assembly stations. The older version is too visually complex for quick understanding by a first-time viewer, and it fails to use the latest ISO design principles for the human figure and arrow elements.

the U.S. Technical Advisory Group to *ISO/TC 145 – Graphical Symbols*, I've been involved in an effort to define best practices for shipboard safety sign systems. This is part of a nearly 3-year-long project that will usher in a new era of visual safety communication onboard ships. (See the April 2012 *On Your Mark* column, which refers to the overturned Costa Concordia cruise ship, for more information on safety sign systems onboard ships.) The goal of the specific committee that I'm working with is to reevaluate symbols currently in use onboard ships, with the intention of modernizing them in line with ISO/TC 145 graphical design principles. To illustrate the importance of using standardized elements and components in symbols, let's look at a few examples of these shipboard safety symbols, which are now in their final stages of development.

Figure 1 shows an old and new version of an assembly point symbol, the icon used to guide a ship's passengers to

ON Your Mark

Figure 3 shows an old and new version of a radiotelephone symbol, the icon used to guide a ship's crew to the location of a two-way VHF radiotelephone apparatus. The older version does not use the latest ISO design element for "waves," as shown in the non-ionizing radiation symbol in Figure 4.

the location of assembly stations. The older version is too visually complex for quick understanding by a first-time viewer, and it fails to use the latest ISO design principles for the human figure and arrow elements. In contrast, in the new version, the design has been simplified to be visually 'legible' from a greater distance, and it has been updated to use human figures and arrows that comply with ISO symbol design principles, principles that have been used to create an entire vocabulary of new symbols, including those shown in Figure 2.

Figure 3 shows an old and new version of a radiotelephone symbol, the icon used to guide a ship's crew to the location of a two-way VHF radiotelephone apparatus. The older version does not use the latest ISO design element for "waves," as shown in the non-ionizing radiation symbol in Figure 4. The new version utilizes this wave pattern, using the same line thickness and shape consistent with this

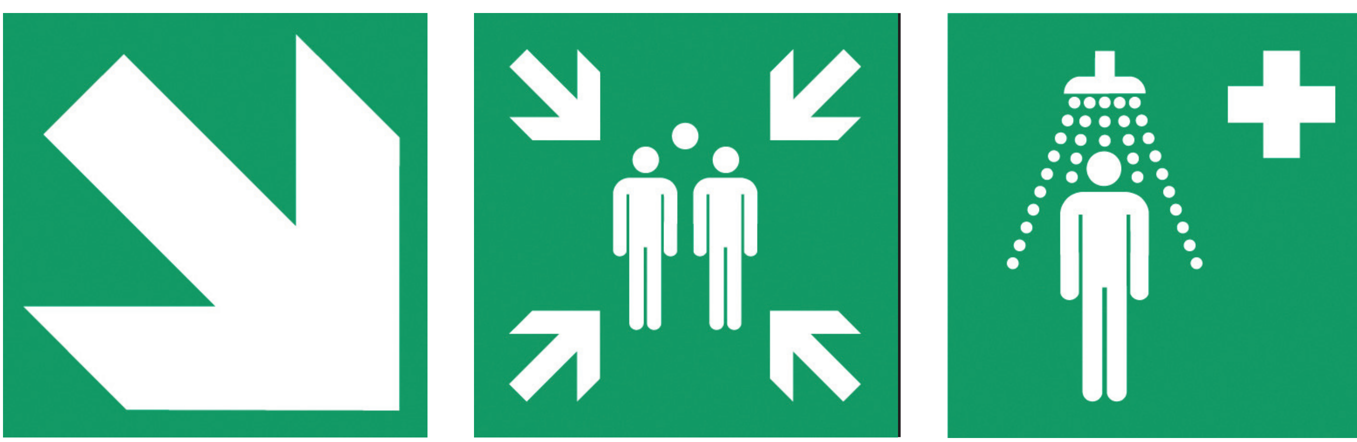

Figure 2: A selection of ISO symbols that share common design features with the new assembly point symbol.

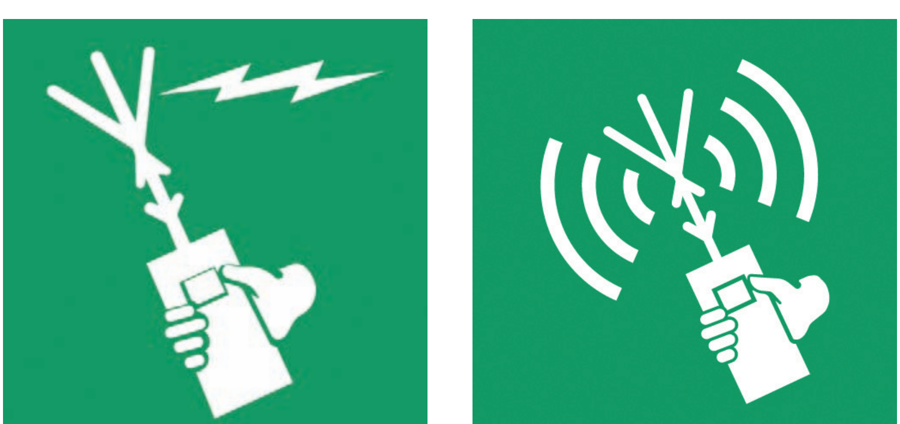

Figure 3: Old (at left) and new (at right) images of the radiotelephone symbol.

Figure 4: The ISO symbol for non-ionizing radiation.

When it comes to properly creating new symbols, you don't need to – and shouldn't – reinvent the wheel. No matter what type of hazard message or safety information you need to convey, you should use what's been done before in symbol standardization to guide your efforts if and when a new symbol needs to be created.

element as its been visually represented in other recent ISO symbols.

Now, how can this help to guide your product safety labels? When it comes to properly creating new symbols, you don't need to – and shouldn't – reinvent the wheel. No matter what type of hazard message or safety information you need to convey, you should use what's been done before in symbol standardization to guide your efforts if and when a new symbol needs to be created. Figure 5 shows a wide range of symbols that Clarion has created as part of its work in helping companies to better communicate safety so risk is reduced and people are better protected from harm.

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

(the author)

GEOFFREY PECKHAM

is CEO of Clarion Safety Systems and chair of both the ANSI Z535 Committee and the U.S. Technical Advisory Group to ISO Technical Committee 145 - Graphical Symbols. Over the past two decades he has played a pivotal role in the harmonization of U.S. and international standards dealing with safety signs, colors, formats and symbols. This article is courtesy of Clarion Safety Systems © 2012. All rights reserved. Clarion strongly protects its intellectual property rights, including sign designs.

Figure 5: Clarion-created safety symbols, crafted with ISO design principles to aid in noticeability and comprehension.
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Applied Safety Science and Engineering Techniques (ASSET™)

Taking HBSE to the next level

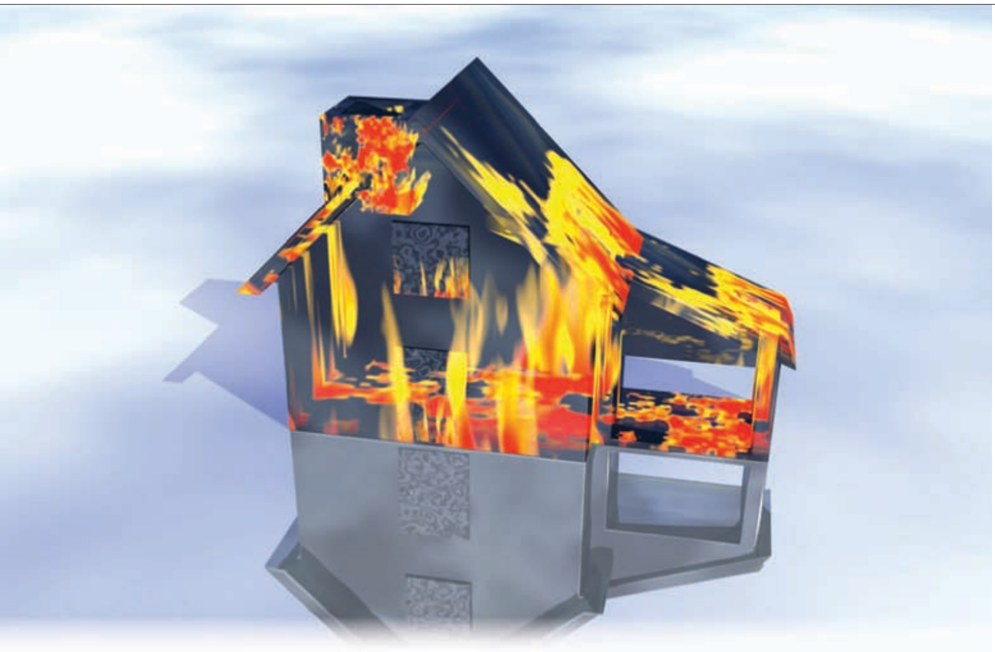
BY THOMAS LANZISERO

Hazard Based Safety Engineering (HBSE) principles have been used to better understand product safety and to help guide the design and evaluation of appropriate safeguards through analysis of sources, causes and mechanisms of harm. UL Applied Safety Science and Engineering Techniques (ASSET™) takes HBSE to the next level. ASSET leverages the strength of HBSE principles by expanding and integrating them with other established safety science and engineering techniques, including elements of risk management, systems and reliability engineering, functional safety and human factors. This paper outlines the expansion and integration of these principles and techniques, and demonstrates the potential of taking HBSE to the next level.

ASSET addresses diverse forms of harm, hazardous sources and objects of harm (persons, property, environment, critical operations), across a broad range of products, systems, services and applications, based on safety science. An asset in any organization is an item of value, a resource that provides advantage, such as a product realization design process that achieves safety by design. The design and evaluation of safety requires a systematic, methodical process. The effective use of a complete set of suitable, consistent design and evaluation techniques can help demonstrate that reasonable care and due diligence was exercised in the safety of a design.

The HBSE concepts initially conceived by engineers at HP/Agilent targeted


Safety



Safety and protection address the risk of harm. Harm can include unwanted effects or consequences, including injury or damage to health of persons (or animals including livestock and pets), damage to property or the environment, or interruption in essential commercial operations.

typical types of hazards and forms of injury involving electronics products, such as information technology and office equipment. The HBSE concepts and tools have been further developed and applied with the support of research engineers at Underwriters Laboratories. UL University has been serving as the principal instructional organization for HBSE workshops. UL uses HBSE and applied safety science and engineering techniques in many facets of its work, such as research, development and interpretation of standards, and risk assessment with hazard and failure analysis of new and emerging products, applications and technologies. Applied safety science and engineering techniques will be briefly introduced in the context of safety and risk, and outlined in the context of other technical and managerial processes.

SAFETY

Safety and protection address the risk of harm. Safety has many meanings, applications, levels and contexts. Generally speaking, we can consider safety as freedom from unacceptable risk of harm. (IEC/ISO Guide 51). But let's consider the qualifiers in this statement.

Harm can include unwanted effects or consequences, including injury or damage to health of persons (or animals including livestock and pets), damage to property or the environment, or interruption in essential commercial operations. This harm may be the result of a variety of factors, independently or in combination or sequence, involving hazardous situations and circumstances. Risk of harm is based on probability and severity, that is, the likelihood of harm occurring and the severity of its consequences if it occurs.

Unacceptable risk of harm is a level that is not tolerated. The degree of tolerance varies in accordance with many factors, including specific applications, situations and circumstances of product use, misuse and exposure. Risk attitudes and appetites vary among individuals, companies, industries, cultures, etc. Levels of unacceptable risk may be defined, for example, by regulatory bodies, authorities having jurisdiction, standards development bodies, etc., with input from others involved or affected.

Freedom from unacceptable risk of harm is a beneficial condition. But like many other freedoms that we enjoy, this freedom also comes at a cost. To achieve safety is no small task. It requires comprehensive, systematic review of all potential harm from hazards, and the prioritization of mitigating safeguards throughout the entire product lifecycle, considering all manners of exposure. Safety is relative, posing a challenge in product realization to balance with other design requirements, factors and constraints. This balance may be addressed, for example, by risk-benefit analysis, cost-benefit analysis or other techniques.

Safety is not without any risk, but with risk reduced to an acceptable level – by design, analysis and validation, including evaluation and testing for certification. It is said that safety is no accident. It is the practical manifestation of suitable design concepts, applied consciously and conscientiously.

Risk Management

There are a variety of means to assess, reduce and manage risk of harm. Risk analysis involves hazard identification and risk estimation in terms of likelihood of the occurrence of harm

Many publications address various aspects and applications of risk management, including international guides, standards and series published by organizations such as the IEC (International Electrotechnical Commission) and ISO (International Standardization Organization).

and the severity of its consequences should it occur. Risk evaluation involves judgment of acceptability of risk. This leads to analysis of options to accept or reduce this risk, and then maintain or control it at an acceptable level. In some cases, this risk level may be considered to be As Low As Reasonably Practicable (ALARP), typically used in risk-benefit analysis for medical devices having health benefits to balance the risk of harm

But risk is not necessarily a simple or straightforward combination of probability and severity rankings. Weighting factors may be applied to rankings, and scales may be nonlinear or contain discontinuities. Other factors may also need consideration, such as frequency, exposure, vulnerability, etc. In estimating and evaluating risk, it is important to consider that when the severity of consequences is very high (serious harm, death), then the likelihood must be demonstrated or known to be reliably low. This approach would be more conservative (safe) than an initial assumption of very low probabilities, resulting in trivializing (even unintentionally) the importance of potentially severe consequences.

Risk Management Publications

Many publications address various aspects and applications of risk management, including international guides, standards and series published by organizations such as the IEC (International Electrotechnical Commission) and ISO (International Standardization Organization), ranging from general-use to industry-, product-, hazard-, harm- and safeguard-specific categories. Basic references, some with very recent publications, include ISO IEC Guide 51 (Safety aspects), ISO 31000 (Risk management — Principles and guidelines), IEC/ISO 31010 (Risk management – Risk assessment techniques), IEC Guide 116, Guidelines for safety related risk assessment and risk reduction for low voltage equipment, IEC 60300-3-9 (Dependability management), and Risk Assessment Guidelines for Consumer Products (in Official Journal of the European Union, referencing GPSD, General Product Safety Directive and RAPEX, Community Rapid Information System).

Additional IEC and/or ISO Guides cover more specialized aspects such as terminology (73), vulnerability (50, 71), applications (37, 63, 78, 110, 112), environment (64, 106, 114), and procedural matters (2, 75, 104, 108).

Certain industries, such as medical devices and machinery have developed a tiered structure of risk publications. Publications covering medical devices range from guides on safety aspects (ISO Guide 51) and drafting of safety standards (ISO/IEC Guide 63) to risk management for medical devices (EN ISO 14971), quality management systems for regulatory purposes (ISO 13485), to more specific standards on basic safety and essential performance (IEC 60601-1), followed by a series of collateral standards (IEC 60601-1-1 to IEC 60601-112), particular standards (IEC 60601-2-1 to IEC 60601-2-54) and essential performance requirements (IEC 60601-3 (-1)). Likewise, publications covering machinery range from guides on safety aspects (ISO Guide 51) and drafting of safety standards (ISO Guide 78) to general standards on risk assessment principles (EN/ISO 14121-1), practical guidance and examples (-2), to more specific standards on design concepts with terminology, methodology (EN/ISO 12100-1) and technical principles (-2), and electrical equipment of machines (EN 60204-1).

ASSET integrates the current IEC/ISO body of knowledge on risk management, and addresses specific aspects including appropriate risk and hazard identification, risk reduction and risk control.

ASSET and Risk Management

ASSET integrates the current IEC/ISO body of knowledge on risk management, and addresses specific aspects including appropriate risk and hazard identification, risk reduction and risk control. For example, guidelines are provided for a suitable assessment of the scope of the analysis, including general characteristics, intended use and users, environment, installation, operation, maintenance, repair, shipping, storage, and reasonably foreseeable unintended use and misuse conditions. Then for hazard identification, additional steps help identify sources and possible conditions for harm. Risk estimation is supplemented with guidance to estimate and express risk. Risk evaluation is aided by steps to define and apply tolerable risk criteria for decisions. Risk reduction is guided by steps to analyze protective measures that reduce and/or control risk via safeguard attributes. Reassessment of residual risk is supplemented by steps to monitor and apply field data.

Strategies are presented to identify, prioritize and validate appropriate safeguards that are suited to any product, including usage scenarios and exposure conditions. Such strategies help identify essential safeguard characteristics: those safety-critical functions relied upon under all conditions, including duress, throughout the product life. Relevant analysis techniques include Fault Tree Analysis (FTA) and Failure Modes and Effects Analysis (FMEA), which address failures and other conditions that may lead to system faults, as well as the need for, and the effects of, suitable protective mechanisms.

Safety Engineering Management Processes

Technical processes include the expansion and adaptation of HBSE, hazard analysis and risk assessment concepts, as well as application of techniques such as FTA and FMEA. Managerial processes include risk management, but the more overarching common element is "management" itself. Safety engineering management not only involves risk management, but also asset-, enterprise-, quality systems- (incl. quality assurance and continuous improvement), process- (design, mfg), document-, decision-, systems engineering- and system safety-, product safety-, project- and project risk-, design-, concurrent engineering-, design review-, configuration-, change control-, supply chain-, dependability-, life cycle model-, data(records), information security-, knowledge-, learning-, incident/recall- and disaster/emergency- management. As for risk management, these additional safety engineering management aspects are also addressed in many IEC, ISO and other publications. Document references are available upon request.

Safety Strategy

The strategy to meet safety objectives begins with applied safety science and engineering techniques. This helps to identify and prioritize research, and apply these findings to develop safety requirements and test methodologies that are appropriate, proactive, focused and consistent. This can then lead to safety attributes that are properly identified, validated and controlled for all scenarios, conditions, and lifecycle stages, both up and down the supply chain. The result is a demonstrated degree of safety and improvement.

Hazard Based Requirements

Hazard-based safety standards can offer clear safety objectives and various means to meet them. A hazard-based approach serves to reduce risk of harm by addressing each hazard. This approach would determine which undesirable effects are to be avoided, the susceptibility to them, their conditions and causes, and appropriate protection against them. A hazard-based standard would identify the objectives of protecting against each specific undesirable effect, and directly relate them to appropriate protection requirements and limits. HBSE principles have also formed the foundation of hazard-based requirements in product standards such as IEC 62368-1, Audio/video, information and communication technology equipment – Part 1: Safety requirements.

ASSET EXPANSION OF HBSE CONCEPTS AND TOOLS

ASSET expands the basic HBSE concepts and analysis tools in ways that include the following, as shown in Figure 1.

HBSE Premise

The HBSE Premise for Injury is a 3-block model based on energy transfer, which outlines the 1) hazardous source and 2) transfer mechanism to 3) a body/part that is subject to injury. Injury can occur when the magnitude and duration of energy transfer exceeds the body/part susceptibility, or its inability to withstand it.

The HBSE Premise for Injury is a 3-block model based on energy transfer, which outlines the 1) hazardous source and 2) transfer mechanism to 3) a body / part that is subject to injury.

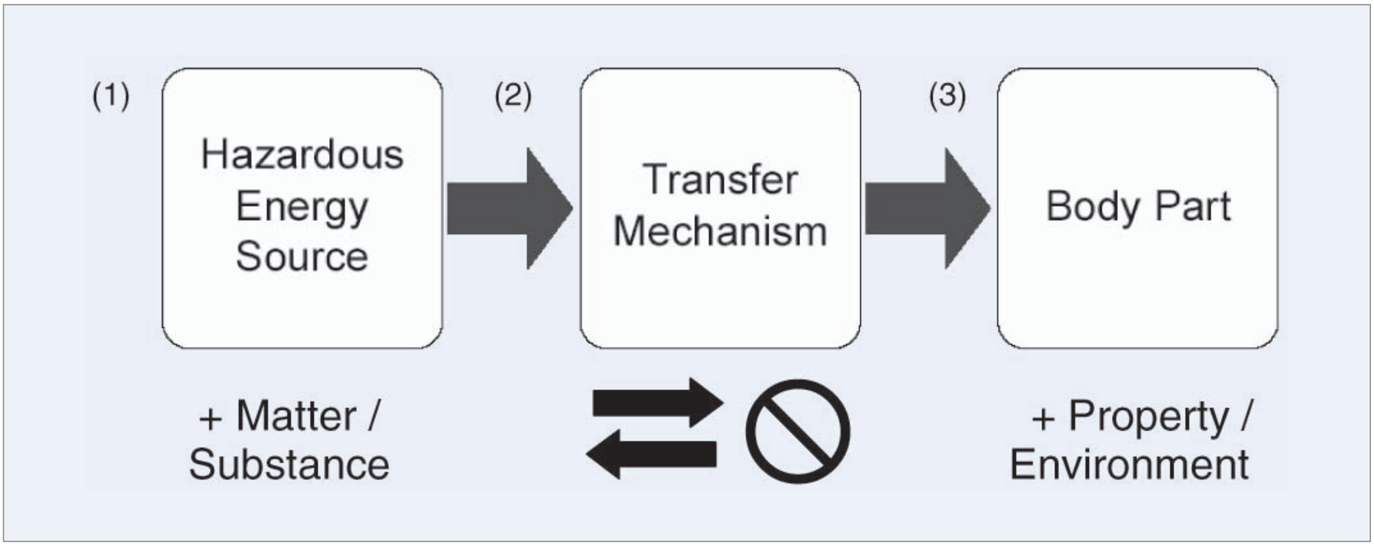


Figure 1: HBSE Premise, 3-block energy transfer model for injury, expanded

Examples include mechanical forms of energy that may cause various types of physical injury; thermal energy (heat) that may cause skin burn injury; electrical energy that may cause "electric shock" or unwanted physiological (including lethal) effects; and electrically caused fire that may cause injury and property damage. This model can forewarn of injury if its elements can be quantified, in terms of the characteristics of the energy source and rate and degree of transfer (delivered and received), and the inability of a body/part to withstand it (susceptibility).

However, this simple model can be expanded in a variety of ways, adapted to address other types of hazards, transfers and harm. For example, the hazardous source (1) can involve other forms of energy, including acoustic noise, pressure (sonic/ultrasonic/fluid/gas), explosion/implosion, arc flash/blast, radiation (visible, UV, IR, ionizing (gamma)/non-ionizing (laser)), vibration, fields (electric/magnetic/electromagnetic), unintended motion or activation, as well as potential energy (suspended masses, support failures) or stored energy (springs, capacitors) that may be converted to other forms.

In addition, the hazardous source (1) can also be in the form of matter. This could include an object (person contributes to transfer), involving a sharp edge (laceration) or small part (choking) or long part (strangulation), where other factors of the harm mechanism need also be considered. This could also include a harmful substance, such as chemical (toxic/carcinogenic) or biological (bacteria) material. Recall the RoHS (Restriction of Hazardous Substances) directive that curtails the use of materials such as lead, mercury, cadmium, hexavalent chromium, PBB and PBDE to infinitesimal levels (parts per million). The transfer mechanism (2) can cause harm in a direction to the body (e.g., applied force), as well as away from it (e.g., extracted heat), or even involve a reduction or restriction of transfer (energy or substance) that is needed to maintain health (e.g., air restriction due to small-part choking hazard).

And in addition to injury to persons (3), other forms and objects of harm can be addressed. Such harm may also involve damage to health or welfare of persons, injury to animals (livestock, pets), and damage to property, the environment or essential commercial operations.

Other factors must also be considered. For example regarding environmental harm, lifecycle issues of electrical and electronic products raise additional safety concerns. With concern for PBTs (Persistent Bioaccumulative Toxins), is the hazard persistent, taking a relatively long time to break down in the environment? Is it bioaccumulative, whereby substances collect in living organisms and ultimately end up in the food chain and persons? Is it toxic, with known potential for harm, whether acute (immediate) or chronic (longer-term)? By what means is it transferred, and in what amounts and durations, and to what degree?

Other functional aspects such as incorrect outputs can also lead to harm, involving energy or substance, due to hardware, software or human interface factors, resulting from incorrect control, timing, duration, sequence, etc. These aspects are more closely associated with functional safety, addressed separately.

HBSE Process

The HBSE Process is a flow diagram that considers all sources (hazardous energy) associated with a product, how they may cause harm by transfer, and how this transfer can be reduced to protect against injury. It helps us to analyze specific protective mechanisms (safeguards) having features and properties that are needed to protect against specific harm mechanisms.

This simple model can also be expanded in a variety of ways. For the first HBSE Process step (1), "Identify Energy Source", consideration is needed for all sources (energy/substance) that are supplied to, contained within, converted by, used by or associated with the product.

For the next step (2), "Is Source Hazardous", consideration is needed for whether the source is capable of causing harm. These steps need to conducted for each type of source, transfer means/mechanism, potential for harm and entity subject to harm. Is the source hazardous with respect to the product function, application, environment, uses, users and others involved, exposed, having access, or otherwise affected?

Is this an unacceptable risk of harm? How is an acceptable level of risk determined? What factors may this depend on (use, users, environment, values, etc.)? What conditions make the source hazardous or its transfer harmful? Can this occur in normal operation and intended, normal use? Or does it require an abnormal or unintended condition? Must other unwanted or fault conditions have occurred in the past or exist in the present?

Are these conditions of omission (inaction) or commission (action/reaction)? Do they involve hardware, software and external influences (environment, human interaction and error, etc.)? Are these conditions reasonably foreseeable? It's been said that all conditions are foreseeable (which may not necessarily require action), but following an incident a jury may decide what is reasonable (what actions should have been taken).

The product may have been evaluated to perform all design functions as intended (do what intended). But have all reasonably foreseeable conditions been anticipated? Has the product been evaluated to suitably and safely respond to all these conditions, combinations and sequences and at least fail-safe (NOT do what NOT intended)? Has this performance been validated by test? Have the safeguards, and their specific properties, relied on for this performance been evaluated and controlled?

For the next step (3), "Identify Means by which Energy can be Transferred to a Body Part", consideration is also needed for direction and/or restriction of transfer, whether to, from, or blocked (if needed) from the person (body part) or other object of harm (property, environment, etc.).

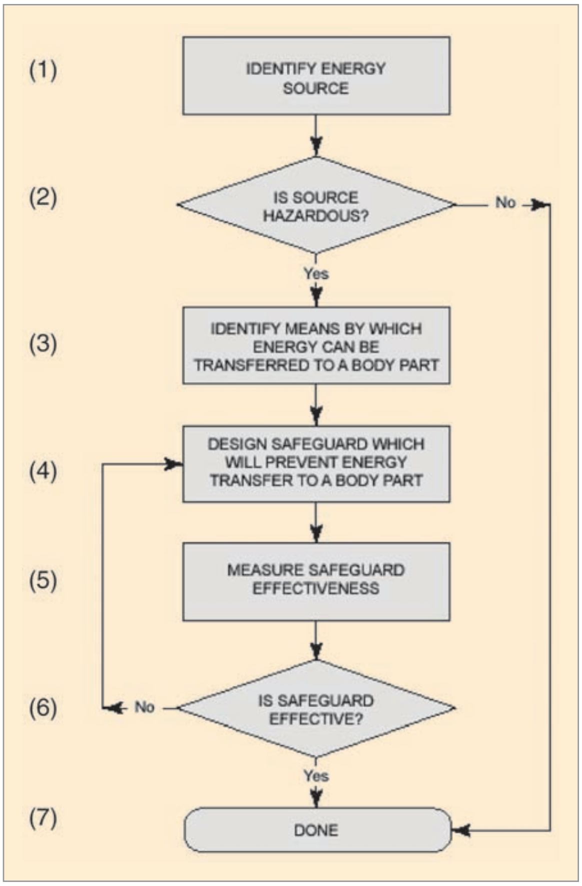


Figure 2: HBSE Process with expansion notes

For the next step (4), "Design Safeguard Which Will Prevent Energy Transfer to a Body Part", consideration is also needed for preventive safeguards that reduce, control or eliminate the source (total amount), as well as mitigating safeguards that reduce, control or eliminate the transfer (transferred rate, duration and amount). The hierarchy of protection should be to first eliminate the hazard (design it out), then guard against the hazard (reduce the source and then the transfer), then warn about the hazard (relying on personal responsibility and other factors for avoidance). In some cases it may also be possible to reduce susceptibility to a hazard by increasing the resistance to the source, such as through material properties including resistance to ignition.

For the next steps (5), "Measure Safeguard Effectiveness" and (6) "Is Safeguard Effective", much additional consideration is needed to properly understand and apply this "effectiveness" measure, which involves safeguard attributes. Which specific properties of safeguards are relied upon for each protective function? Under what conditions must they function effectively? What conditions may tend to degrade this performance or render it ineffective? How well do these attributes hold up under each of these conditions, including combinations and sequences? Just as in evaluating risk, when the severity of consequences is high (i.e., safeguard failure), the likelihood must be demonstrated or known to be reliably low.

Safeguards attributes are properties of protective features and mechanisms, which need to be specifically identified, evaluated and validation tested under all reasonably anticipated conditions, and controlled in design and manufacturing. These attributes can be summarized in the descriptive term DURESS (Durability, Usability, Reliability, Efficacy, Suitability, Scalability), which helps describe the needed characteristics:

Durability – protective characteristics should be able to withstand, and not be adversely affected by conditions, circumstances and scenarios of use (reasonably foreseeable use, unintended use, misuse or abuse)

Usability – protection should function as needed, without interfering with normal, intended product functions (so as not to invite defeating of safeguards)

Reliability – protection should maintain its essential performance throughout its entire design life, in all conditions and stages of the product lifecycle (cradle-to-grave)

Efficacy – protection should be able to effectively perform the needed safety function, without introducing or increasing other hazards (fix one problem but create another)

Suitability – protection should be provided to a degree appropriate for the application, based on the level of risk with a suitable safety factor that demonstrates the degree to which tested performance limits exceed minimum thresholds of harm

Scalability – protection should perform as needed in the intended scale of use, properly interacting with other materials, components, systems and environments (small-scale properties appropriate for large-scale applications and conditions)

HBSE Fault Tree for Injury

Fault Tree Analysis (FTA), a deductive, graphical, top-down analytical method in which the top event is a fault, such as harm or other undesirable event. It outlines the necessary and sufficient conditions and logical relationships for this harm to occur, in order to determine the most likely contributors

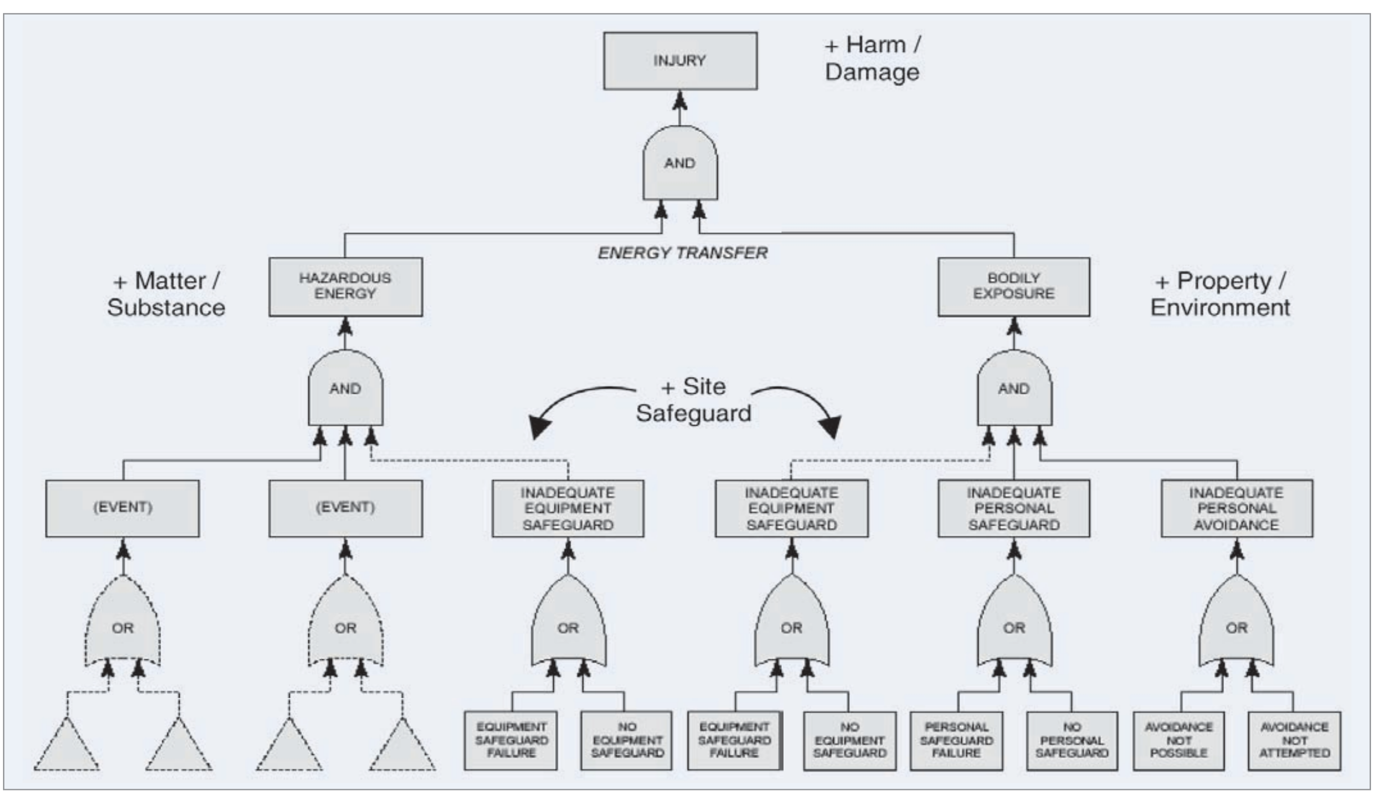


Figure 3: HBSE Fault Tree for Injury, expanded

ASSET integrates these elements to leverage the strengths of HBSE, risk management, and other techniques, to optimize the value of our resources and assets: our individual and collective safety knowledge, experience and expertise.

(root causes on critical paths) and the most effective safeguard strategies.

The HBSE fault tree for injury outlines conditions leading to the injury top event, with initial necessary and sufficient conditions of hazardous energy and exposure of (for transfer to) a susceptible body part. This fault tree model can be expanded to include other types of hazards and harm. It can also depict the order of priority for safeguards, to eliminate, guard or warn about the hazard. Such FTA models have been successfully used in analysis of fire scenarios, including those caused by lithium ion batteries.

FTA AND FMEA/FMECA

To complement the deductive, top-down FTA, one can use an inductive, bottom-up analysis method such as Failure Modes and Effects Analysis (FMEA) or Failure Modes and Effects Criticality Analysis (FMECA), which more directly considers the effect of severity and risk rankings. This method begins at the "bottom", with individual items (components, materials) and their functions (in each operating mode). Failure modes, effects, severities, likelihoods and other factors are determined, and then potential causes, recommended actions, and resulting effects are analyzed methodically. Integrated FTA/FMECA techniques have also been successfully applied to fire risk involving lithium ion batteries, as we presented at the latest NASA Aerospace Battery Workshop (2009).

SYSTEMS ENGINEERING

Elements of the systems engineering approach address scope and context, from concept through all product lifecycle stages (cradle-to-grave), from design through prototyping, manufacturing, assembly, packaging, transport, storage, installation, commissioning, operation, maintenance, repair, decommissioning, reuse to disposal.

Specific properties of materials and components, including hardware, software and human elements, need to be compatible with the needs, influences and interfaces of subsystems and the overall system, including external systems and the environment (micro and macro). Functions, characteristics and properties need to be considered for materials, components, devices, circuits, subsystems, systems and processes, as contributing to harm or to protection.

RELIABILITY ENGINEERING

Reliability engineering elements address the criticality of safety-critical functions and features, and the conditions under which they must continue to perform effectively. Reliability approaches such as probability of failure, circuit redundancy and fail-safe modes are also used in techniques such as FTA and FMEA, and addressed by a number of related disciplines, including system safety and dependability management.

FUNCTIONAL SAFETY

Functional safety is a special field that specifically addresses electrical, electronic and programmable systems. Similar to other types of safeguards, reliance is placed on specific functions or characteristics of a product, requiring certain attributes. But a safeguard in functional safety is considered to be the essential performance of hardware and software controls that manage safety-critical functions. Some functional safety aspects may be directly protective by design (life safety). Functional safety aspects in other applications address functions for which failure may lead to increased risk of harm (immediate or imminent), loss of a required level of protection, or other reduced ability to protect against harm. In "single-fault" analysis, the conditions that rely upon protective mechanisms to operate should be considered as given conditions, and any failure or inadequacy of this protection would be considered as the fault condition.

HUMAN FACTORS

Elements of human factors address many aspects, including anthropometry, physiological responses and susceptibility to energy and substance transfer, behavior (product use, misuse, abuse or hazard avoidance), human error, interaction, and other human characteristics including performance, limitations, etc. related to aspects of a product or system, such as design, manufacturing, operation, maintenance, etc.

SUMMARY

ASSET integrates these elements to leverage the strengths of HBSE, risk management, and other techniques, to optimize the value of our resources and assets: our individual and collective safety knowledge, experience and expertise. The application of safety science and engineering techniques to any hazard is based on examining the types and mechanisms of harm in order to consider appropriate

The application of safety science and engineering techniques to any hazard is based on examining the types and mechanisms of harm in order to consider appropriate mechanisms for protection.

mechanisms for protection. This analysis includes the conditions and circumstances that must be present, first for harm to occur, and then for protection against it. It's a basic but robust approach, in which simple tools can be applied, with appropriate subject matter expertise, to simple or complex scenarios in a consistent, repeatable manner, an asset to any organization.

"The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hard substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judge like the lawyers. He cannot, like the architects, cover his failures with trees and vines. He cannot, like the politicians, screen his shortcomings by blaming his opponents and hope the people will forget. The engineer simply cannot deny he did it. If his works do not work, he is damned." - Herbert Hoover (1874 - 1964).

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"ASSET: The Evolution of Hazard Based Safety Engineering into the Framework of a Safety Management Process" coming in the December 2012 issue.

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ASSET and HBSE workshops are available through UL.

(the author)

THOMAS LANZISERO
is a Sr. Research Engineer and Distinguished Member of Technical Staff at UL LLC (Underwriters Laboratories, Melville, NY) with nearly 30 years of applied practice in safety engineering. He is a registered Professional Engineer (P.E.) and principal instructor and practitioner of Hazard Based Safety Engineering (HBSE). He has led development of Applied Safety Science and Engineering Techniques (ASSET™), including the ASSET Safety Management Process for informed decisions to achieve, maintain and continuously improve safety as a design objective. This work has recently been recognized with a 2011 IEEE Region 1 Award for Technological Innovation.

This and related hazard analysis and risk assessment work has been extensively published and presented, including keynote presentation on the safety of consumer electronics into the future at the 2012 International Conference on Consumer Electronics (ICCE) by the IEEE CES, 2012 Advanced Product Safety Management course at St. Louis University, 2010 and 2011 International Symposium on Product Compliance Engineering by the IEEE Product Safety Engineering Society, 2011 IEEE Chicago Argonne National Laboratories Technical Conference, International Consumer Product Health and Safety Organization (ICPHSO 2011), Association of Southeast Asian Nations (ASEAN), Asia Pacific Economic Cooperation - Joint Regulatory Advisory Council (APEC JRAC Risk Assessment Workshop), American Society of Safety Engineers (ASSE) and NASA (2009 NASA Aerospace Battery Workshop).

An IEEE Senior Member, Tom is Founding Chair of the Long Island, NY Chapter of the IEEE Product Safety Engineering Society (PSES) and Vice Chair of the IEEE Risk Assessment Technical Committee (RATC). He serves as technical expert in committees for electric shock protection and risk management, including US National Committee Technical Advisory Groups (USNC TAGs), the International Electrotechnical Commission (IEC TC64 MT4) and the International Organization for Standardization (ISO 31000 / ANSI Z690). He can be contacted at +1.631.546.2464 or thomas.p.lanzisero@us.ul.com.

Occupational Hazards of the Safety Engineer

OSHA meets UL

BY TED ECKERT

The job of the product safety engineer is to reduce the risks associated with a product to an acceptably low level. The product safety engineer is interested in protecting the life and health of the customer who will use the product. However, the testing involved in safety engineering can entail some risks of its own. The environment for safety testing itself needs to be designed to provide an adequate level of safety for the person performing the test. This requires appropriate test equipment, properly designed environment, well documented procedures, personal protective equipment, training and monitoring of personnel who have access to the test lab.

There are numerous potential risks in the safety test lab, and these typically are similar to the potential risks we test for in our products. There are electrical hazards including shock and arc blast. There are thermal hazards including burns and the risk of flame. Mechanical hazards include risks from hazardous moving parts or from heavy objects crushing body parts. High energy lasers can be exposed in testing, and electrical arcs will generate significant amounts of UV light creating a risk of cataract formation in the eye. Medical products may generate ionizing radiation. There are even chemical exposure hazards for some testing. All of these potential risks need to be properly addressed and mitigated.

INJURY STATISTICS

It is difficult to find statistics for injuries in the product safety testing profession. As a profession, the number of practitioners is small and it doesn't warrant its own category by the U.S. Bureau of Labor Statistics (BLS). However, the BLS does record injuries as a rate per 100 workers, and it is reasonable to put product safety engineering in the same category as electrical manufacturing. For the most part, the types of hazards are similar. While the time spent at a desk will lessen the product safety engineer's total exposure time to hazards, it also reduces their experience and practice. An analogous situation would be comparing a professional carpenter versus a weekend woodworker. The professional may be exposed to the risk of injury for 40 hours a week, but this gives them the practice and experience to do the work right. The weekend woodworker may spend only 4 hours a week with a table saw, but their lack of experience significantly raises the risk of injury.

The BLS keeps records of reportable injuries, which are injuries severe

Product safety testing laboratories must comply with the applicable occupational health and safety regulations of the jurisdiction in which they are located. The governing authority in the United States is the Occupational Safety and Health Administration (OSHA) under the Department of Labor. The OSHA rules apply to almost all employees in the private sector.

enough to require medical treatment. The most recent BLS statistics are for 2009 where there were 3.5 reportable injuries per 100 workers in the electrical equipment, appliance and component manufacturing industry [1]. This is the most appropriate recorded category to extrapolate for product safety engineering and it shows a real risk of injury. Product safety testing is too small of an industry to be broken out separately by BLS, and it is likely that many injuries sustained during safety testing are not reported as worker compensation claims.

The rate of fatalities is a harder to extrapolate as the total number is lower and doesn't allow the BLS to categorize fatalities by narrow industry sectors. The total for 2009 in the United States was 4,551 out of approximately 130 million workers [2]. The fatality rate for the manufacturing sector was only about two thirds the overall rate for private industry, and this represents about one fatality per 1500 injuries in the electrical manufacturing sector. I do not have sufficiently specific data and I will not extrapolate to the product safety testing industry.

APPLICABLE REGULATIONS

Product safety testing laboratories must comply with the applicable occupational health and safety regulations of the jurisdiction in which they are located. The general principles of regulations are generally similar between North America and Europe. The application of these principles and the level of enforcement may be more variable in other jurisdictions, but I will address The United States and Canada specifically and Europe in general.

The governing authority in the United States is the Occupational Safety and Health Administration (OSHA) under the Department of Labor [3]. The OSHA rules apply to almost all employees in the private sector. Although there is a common belief that small employers are exempt from OSHA rules, this is a misunderstanding. The enforcement procedures may differ depending on the employer's size, and although OSHA will rarely audit a company with ten or fewer workers, these companies are still subject to the regulations. The OSHA regulations cover general work practices and some specific work situations. However, the requirements are NFPA and ANSI standards which are incorporated into OSHA regulations by reference [4]. The OSHA directly covers requirements for training, monitoring and reporting of injuries along with safety practices common among different work environments.

While OSHA is reviewing and adoption NFPA 70E for electrical safety, it is currently a reference document not carrying mandatory requirements. Following NFPA 70E will demonstrate due diligence should an OSHA inspector arrive at a facility. NFPA 70E is not to be confused with NFPA 70. Whereas NFPA 70 covers the rules for the installation of electrical equipment, NFPA 70E covers the rules for safe work practices around exposed hazardous voltages. Additional applicable standards referenced by OSHA are numerous and include, but are not limited to, ANSI standards such as ANSI Z87.1-89 for eye protection, ANSI Z87.2 for respiratory protection and ANSI A14.2-56 for metal ladder use. Additional regulations will apply for specific risks such as laser and X-ray testing.

The regulations for Canada are similar in their technical requirements. The regulations are governed by Health Canada under the Canada Occupational Health and Safety Regulations [5][6]. Many specific requirements are covered by referenced standards including the Food and Drugs Act, Hazardous Products Act, Nuclear Safety and Control Act, Radiation Emitting Devices Act and Controlled Products Regulations [7-11]. The Controlled Products Regulation for example specifically covers the marking and warning requirements for chemicals and hazardous materials. The specific requirements are very similar to those called out by OSHA in the United States.

European requirements will vary from country to country. The European Union does set some standards since the EU is intended to allow the movement of workers across borders without problems. The body setting policy at the European Union level

is the European Agency for Safety at Work [12]. As with product safety regulations, there are EU Directives regarding occupational safety that member bodies are required to incorporate into national law. The framework is established in Directive 89/391 with additional Directives written to cover physical hazards, noise, radiation exposure, personal protective equipment, hazardous material handling and marking and many more potential hazards [13][14]. These Directives in turn may have specific applicable standards. For example, EN 50191 covers the installation and use of electrical test equipment and EN 60825-4 covers guarding and protection when there is exposure to Class 3 or Class 4 lasers. Each country must adopt these regulations as a minimum standard, but individual countries may choose to enact stricter regulations. The policy regarding the enforcement of regulations is handled at the national level and is not determined by the European Commission.

BASIC PRINCIPLES

Many product safety engineers will groan when they think about OSHA looking at their lab, but the general approach espoused by Environmental Health and Safety (EH&S) professionals can be implemented with minimal hassle and significant benefits. A six step approach can be used; eliminate the risk, provide adequate guarding and protection, use proper personal protective equipment (PPE), provide proper hazard marking and warning, train the affected employees and use continuous improvement. Although the final item isn't always included in some safety programs, it is important. Proper analysis is required whenever there is an injury or even a "near miss". Continuous improvement allows you to better focus a general safety program to the narrow field of hazards and issues found in safety certification testing. These issues are determined by systematic causal analysis of incidents that have occurred.

ELIMINATING RISK

Product safety testing involves abusing products to make sure that they fail in a safe manner. This may mean that the product safety engineer will be exposed to hazards, but the exposure can be controlled through the use of safe work practices. For example, measurements of hazardous voltages can be made without exposing personnel to those voltages by applying test probes using clip-on leads while the equipment under test (EUT) is disconnected from power. The test engineer should use enough test leads and meters to simultaneously record necessary voltages at once. Power can then be applied after all test leads are secured. This eliminates the risk of electrical shock by placing the hands close to hazardous voltages, and it reduces the risk of an arc flash from a test probe accidentally shorting out terminals as it is inserted into live equipment. Another example of risk reduction is the addition of outriggers during the stability testing of large, heavy equipment. The outriggers will stop the fall of equipment if it should start to tip over when subjected to the test force. Alternately, a large test jig can be used that will arrest the fall of equipment when it reaches a tilt of 12¡, allowing a 10¡ tip test without the risk of equipment falling over onto personnel. Consider requiring more than one person be present in the laboratory when any potentially hazardous testing is performed. The second person should be clear of the area where the test is being performed so that they will not be put at risk should something go wrong with the test.

PHYSICAL LABORATORY DESIGN

The test laboratory should be designed with the assumption that problems may occur and will need to be addressed. Safety test laboratories should have two means of egress where possible, with the two doorways placed at opposite ends of the room. Security and other design concerns will typically result in doors that swing into the laboratory. If possible have one door that opens out and that has panic hardware that allows the door to be opened without the use of hands, such as a push-bar across the door. Each test area should have an egress route at least 1.25 meters wide. Practice good housekeeping to keep these aisles clear of test equipment and storage boxes. The laboratory should have adequate lighting, exit signage and emergency lighting. Make sure the lab has adequate cooling to handle the heat load that will be generated by the EUT. I once tested a 12 kW load in a room with 4 kW of cooling, and the room temperature finally stabilized at 46° C. This would have been an unacceptable environment had somebody been required to work in the room constantly during the testing. Eyewash stations and showers may be required depending on the chemicals that are used in the laboratory.

GUARDING AND PROTECTION

The next step is to provide adequate guarding and protection. Flammability testing should be done in a fume hood that will safely extract the combustion gasses from the room. The same fume hood can be used for other tests where volatile chemicals may be used or testing where there may be toxic gasses released into the air. The room itself should have a sprinkler system to protect in the event that a fire does start and get out of control. Hand-held fire suppression equipment should be available should materials ignite during fault testing. Sand or fire blankets can be used for small fires allowing for an easier cleanup. Special fire suppression equipment may be needed depending on the materials being tested, particularly with alkali metals such as lithium.

Some fault testing can result in flying debris, such as testing fuses at high fault currents. Current limiting devices can fail catastrophically when exposed to currents beyond their interrupt ratings. Plexiglas guards can be used to provide a barrier between equipment and personnel during fault testing if there is a risk of debris flying.

Flammable chemicals should be stored in an approved flammable storage cabinet. Chemicals should be stored in their original containers. If smaller volumes of chemicals are moved to another container, that container must be properly marked with the appropriate chemical properties.

If the EUT generates radiation, shields against that radiation need to be provided for the test engineer. This applies for both ionizing radiation and nonionizing radiation such as a laser. Wearable monitors may be required depending on the type of radiation.

Additional equipment may depend on the type of testing being performed. If your laboratory staff must work with tall equipment, consider providing personnel with a rolling platform ladder (Figure 1). This will provide a large and stable work surface for working above ground level and is preferable to a step ladder. Provide lifting equipment and hoists if personnel must handle heavy equipment or components. The personnel who use this equipment must be trained in its use. (See section entitled “Training”.)

Figure 1: Rolling platform ladder

ELECTRICAL DESIGN

The safety laboratory needs to be designed with the proper electrical connections for the type of equipment to be tested. This may mean providing a variety of outlets of different ratings. One technique is to provide a higher current multi-phase outlet, and then to use adapter boxes that provide specific outlets, each with the proper overcurrent protection. Consider installing an Emergency Power Off (EPO) button that shuts off selected power in the room. The EUT gets connected to a protected outlet, and if there is a problem of such severity that the test engineer cannot easily disconnect power, the EPO can be used to shut off power to the EUT. The EPO can also be used to disable the door lock via an electronic strike plate, allowing entry by emergency responders should there be a situation in the lab requiring fire or medical personnel. In such cases, an indicator light should be placed outside the door to the laboratory to indicate that the EPO has been activated. Please note that the EPO should not turn off lights in the laboratory.

Additional equipment may depend on the type of testing being performed. If your laboratory staff must work with tall equipment, consider providing personnel with a rolling platform ladder. This will provide a large and stable work surface for working above ground level and is preferable to a step ladder.

Ground Fault Circuit Interrupters (GFCIs) are required for outlets in close proximity to sources of water. However, GFCI should not be used in other locations for supplementary protection. GFCIs are susceptible to nuisance tripping due to the leakage current of ITE, and they can be impractical in the laboratory environment. Safe work practices are required to reduce the risk of exposing personnel to fault current. AFCIs are susceptible to tripping during abnormal condition testing and could terminate testing prematurely. Arc Fault Circuit Interrupters (AFCIs) also should not be used in a safety laboratory to provide supplementary protection. AFCI’s intended purpose is to shut off power when arcing can go undetected in a residential environment where there are lots of flammable materials. AFCIs are not used in commercial environments in general and would provide few benefits in the safety laboratory.

If you perform fault testing that will result in tripping a branch circuit breaker, you need to take additional precautions. Circuit breakers are not designed for repeated tripping. Their detents and internal components will weaken slightly with each trip. Ground faults are especially hard on circuit breakers and significantly shorten their operating lives. Instead of depending on the branch circuit breaker to terminate a test, insert overcurrent protection between the EUT and the branch circuit breaker. This supplementary overcurrent protection must be of a type and rating such that it will open before the branch breaker, and it should be installed in such a way that it can be easily and safely replaced. The supplementary protector can be replaced as it degrades preventing the need to replace circuit breakers in an

All personnel who use the lab need to be issued the proper personal protective equipment (PPE) for the type of work that they do. The type of PPE should be based on the testing performed and the risks to which the personnel will be exposed. Protective gloves may be required for some types of tests. Different gloves may be needed for protection against thermal burns, sharp edges or chemical hazards.

Figure 2: Electrical gloves

electrical panel. This protection can be installed in the previously mentioned adapter boxes. The box can then be unplugged and safely disassembled to replace the supplementary protector.

PERSONAL PROTECTIVE EQUIPMENT

All personnel who use the lab need to be issued the proper personal protective equipment (PPE) for the type of work that they do. The type of PPE should be based on the testing performed and the risks to which the personnel will be exposed. It is also important to note that "personal" is part of PPE. Each employee who works in the laboratory should be issued their own PPE. It is not to be shared among employees. PPE needs to be chosen in the correct size and type for the employee and they need to be trained in its proper use. Employees need to understand that if they don't have the proper PPE, they should forego the test until it can be done safely.

Safety glasses should be worn in almost any safety test laboratory as they will be recommended for many types of tests. Physical tests, ranging from drop tests to impact tests, may result in flying debris. Abnormal condition tests can have unpredictable results that can also result in flying debris. In the United States, NFPA 70E requires safety glasses be worn whenever working around exposed hazardous voltages. Electrical arcs generate intense ultraviolet light which can contribute to cataract growth in the eyes, so the glasses should provide UV protection in additional to impact protection.

PPE will be needed as physical protection for a number of risks possible in the test laboratory. Hearing protection may be required if testing will involve loud equipment. Safety shoes should be worn when working with heavy equipment to protect feet from crush injuries. These shoes should also have electrically insulating soles to reduce the shock hazard. Protective gloves may be required for some types of tests (Figure 2). Different gloves may be needed for protection against thermal burns, sharp edges or chemical hazards. Chemical exposure may also dictate the use of respirators. If so, the respirators need to be fitted properly, the filters need to be selected based on the hazard and the employee needs to be medically evaluated and well trained in the use of the respirator.

NFPA 70E imposes fairly strict requirements for PPE for working with exposed hazardous voltages, so it is best to eliminate the need for the test engineer to place their hands in the equipment while it is live. If this must be done, NFPA 70E will require differing levels of protection depending on the voltages present. This protection includes electrical gloves with leather protectors, safety glasses, face shields and flame resistant clothing. The PPE required for testing a 120 V hand mixer may be simple, but much more would be required for testing a 250 kW, 480 V uninterruptible power supply. Do not rely on the practice of keeping one hand in your pocket. This may reduce the risk of hazardous current running through your heart, but you still run the risk of creating an accidental short circuit. This could still allow hazardous current to run through your hand resulting in significant burns. In higher power equipment, it can result in an arc flash or arc blast that can do even more damage.

Make it easy for employees to keep their PPE in or adjacent to the laboratory. Even if the employee's office isn't far away, there can be the temptation to just run a quick test even if they forgot to bring their PPE. Lockers or cubbies allow easy storage of safety glasses, lab coats, safety shoes, ear protection and other PPE. Provide additional PPE if you have regular visitors to the laboratory. Safety glasses and ear plug dispensers can easily be placed immediately outside the laboratory area allowing the quick outfitting of visitors when needed.

MARKING AND WARNING

Marking and warning should be used where hazards cannot be eliminated, guarded or controlled below safe levels. Chemicals should be properly marked where they must be used and the Material Safety Data Sheets (MSDS) must be available to personnel to provide them with the proper warnings, PPE requirements and information (Figure 3). Mark areas where there will be exposed hazardous voltages. The test engineer may be aware of the exposed voltages, but there may also be a possibility of others entering the lab without such knowledge. These people need to be able to see the proper

Figure 3: MSDS station

Marking and warning should be used where hazards cannot be eliminated, guarded or controlled below safe levels. Chemicals should be properly marked where they must be used and the Material Safety Data Sheets (MSDS) must be available to personnel to provide them with the proper warnings, PPE requirements and information.

warning signs to know the hazard is present. Similar marking should be used for hot surfaces or exposed hazardous moving parts. The National Electrical Code prohibits placing any object in front of an electrical panel, so mark the proper exclusion area around the panel. Use floor marking for areas used for storage of large items to clearly delineate storage areas from aisles.

Certain hazards will require additional marking. There will need to be marking on the door into the laboratory if there are radiation hazards, whether they are ionizing or nonionizing. Specific information about lasers in the laboratory will need to be marked including the laser class and the wavelength. Signs on the door should indicate the required PPE if there is ongoing testing dictating specific PPE be used at all times.

TRAINING

All affected employees need the proper training to reduce their risk of injuries. Affected employees include not only those performing the testing, but those with access to the laboratory area while testing is being performed. Personnel unfamiliar with specific testing may enter the lab and these people need the training to be able to assess and handle the risks present. It is important to document which employees have been trained and what hazards they have been trained to handle. An employee not trained to handle a specific hazard should not be permitted to perform testing where that hazard may be present. Training needs to be repeated periodically both as a refresher and to ensure new standards and requirements are well communicated.

The various regulating agencies, such as OSHA, mandate the training. Employees must be trained in the use of PPE before they can perform the tasks that require the PPE. If special equipment is required to perform a task, the affected employees must be trained to use the equipment. Employees must be trained in proper ergonomics, lifting techniques and use of hoists if their job requires them to lift heavy loads.

Training on its own has a limited benefit if there isn't enforcement of the rules. Enforcement need not be draconian, but it does need to provide an incentive to follow safe work practices. Laboratory safety needs to be part of the corporate culture, and the laboratory manager is responsible for the safety of the employees in the lab. It is important that the managers cultivate a culture of safety so that they can act as guides, not policemen.

CONTINUOUS IMPROVEMENT

Any laboratories safety program should include continuous improvement. Work practices may need to be tailored to the specific testing performed. If there is an incident, update the workplace practices for the laboratory to address appropriate corrective actions for the issue. Look for near misses and use them as an opportunity for improving work practices. Work with your employer's Environmental Health and Safety group to help minimize risks in the laboratory.

Continuous improvement should not be just a top-down program. All of the laboratory personnel should be involved. Suggestions that come from the workers in the lab are more likely to be easy to implement than programs dictated from management alone. Track incidents to determine if changes are having the intended effect.

CONCLUSION

The risk of injury in the safety test laboratory may seem low, but there are real hazards that do result in injuries and even a risk of death. The proper

The risk of injury in the safety test laboratory may seem low, but there are real hazards that do result in injuries and even a risk of death. The proper design of the laboratory along with good training and the proper use of protective equipment can significantly reduce the risk of injuries.

design of the laboratory along with good training and the proper use of protective equipment can significantly reduce the risk of injuries. The implementation of proper safety can be done cost effectively if designed into a laboratory program. These costs can pay for themselves by eliminating possible higher expenses ranging from noncompliance fines from the Occupational Safety and Health authority, withdrawal of an occupancy permit for unsafe condition, lost time from injured workers and increased workers compensation costs.

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(the author)

TED ECKERT
is currently a compliance engineer for Microsoft Corporation where he is responsible for products including video game systems and tablet computers and where he serves as Microsoft's representative to the U.S. National Committee for TC108. Previously, he was a Staff Compliance Engineer at APC-MGE, a division of Schneider Electric. Over his career as a product safety engineer, Ted has tested industrial electronics, power distribution products, air conditioners, information technology equipment and toys.

Inductance: The Misconceptions, Myths, and Truth (Size Matters)

BY BRUCE ARCHAMBEAULT, SAM CONNOR AND MARK STEFFKA

Inductance is one of the most misunderstood and misused concepts in electrical engineering. While in school, we learn about *inductors*, small components we can hold in our hands and lumped elements we can put in a SPICE circuit, but we seldom learn about *inductance*.

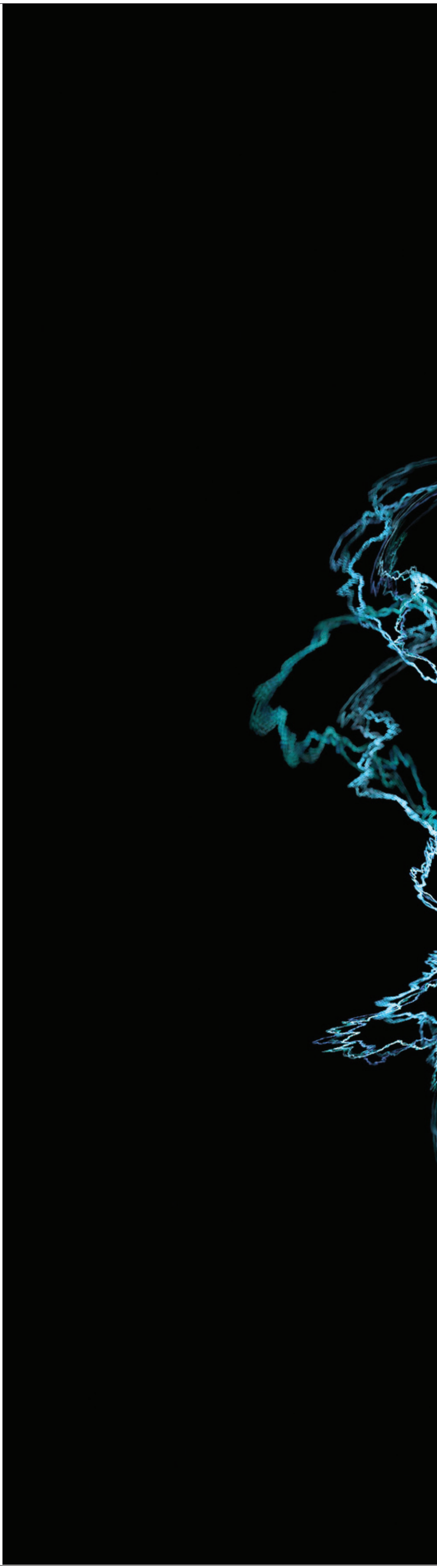
We also learned that "inductors" have a property that causes their impedance to increase as frequency increases (Equation 1) and that, when combined with capacitors, they produce resonant circuits. While inductors certainly have inductance (when used in a circuit), we do not need a physical inductor to have inductance!

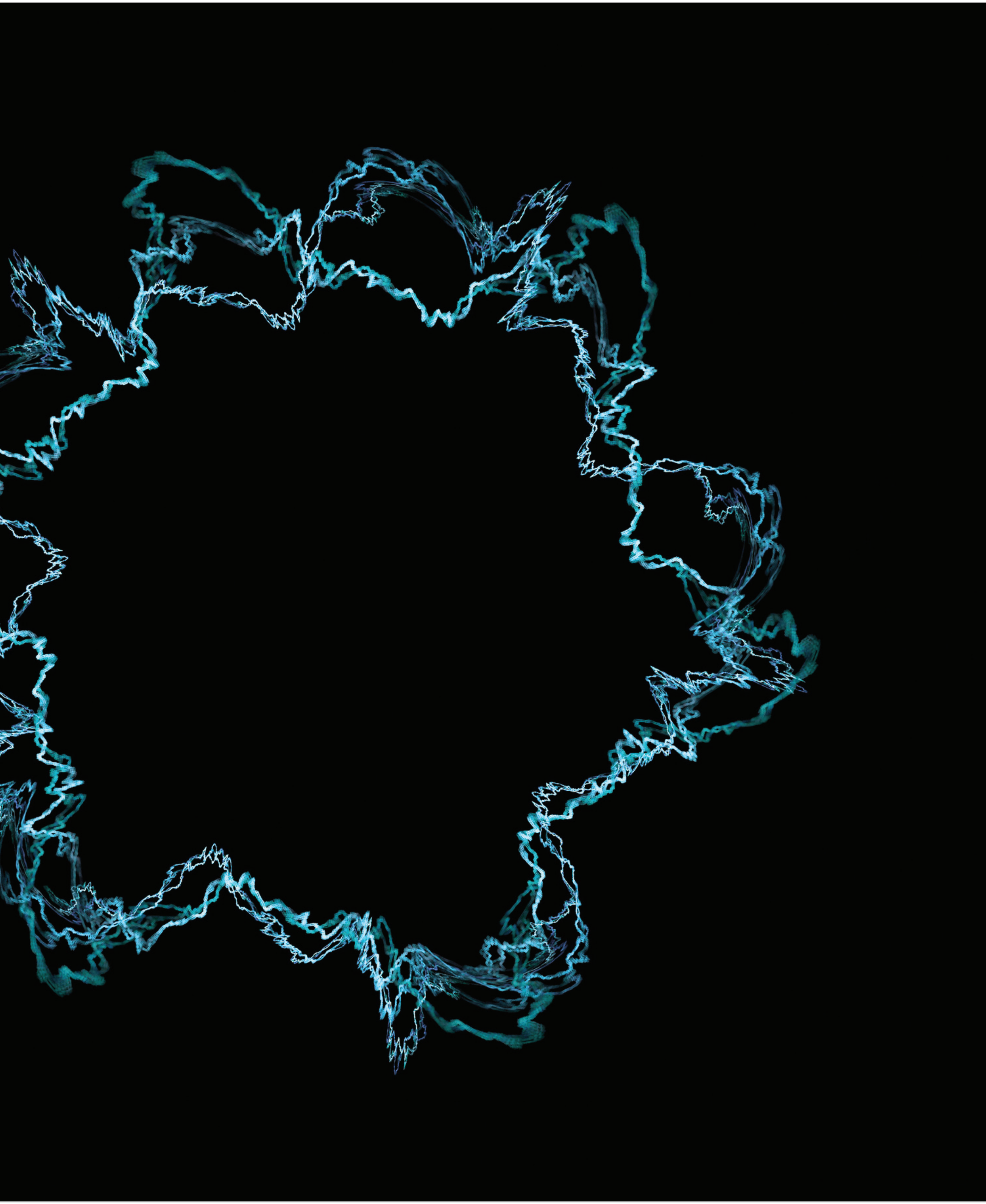
$$X_L = 2\pi fL \quad (1)$$

Where:
X_L is the inductive impedance
f is the frequency
L is the inductance

WHY IS THIS IMPORTANT?

We are constantly exposed to products and components which claim to have low inductance. *This is one of the main causes of the misunderstandings surrounding inductance.*





> The fundamental fact is that the only time we have inductance is when there is a loop of current. Without the current loop, we cannot have inductance. As soon as there is current, the current must return to its source, so there will always be a current loop whenever there is current.

The fundamental fact is that the only time we have inductance is when there is a loop of current. Without the current loop, we cannot have inductance. Of course, as soon as there is current, the current must return to its source, so there will always be a current loop whenever there is current. This is a fundamental fact of physics. The goal of this article is to try to dispel some of the misconceptions surrounding inductance and to encourage engineers to think more clearly about these physics.

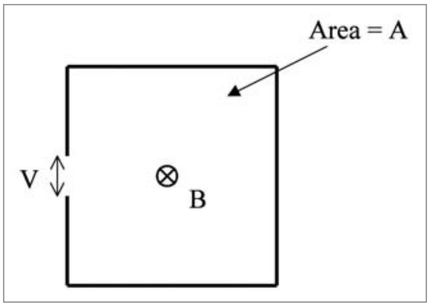


Figure 1: Simplified geometry for Faraday's Law

DEFINITION OF INDUCTANCE

The definition of inductance comes from Faraday's Law (Equation 2). If we dissect this equation, and relate it to Figure 1, we see that both sides of the equation require a loop. The left hand side is the integral (or simply the summation) around a closed loop of the electric field multiplied by the length (which is simply the voltage).

The voltage around the loop is the same as the voltage across a small gap, as shown in Figure 1. The point being that a loop is required creating the loop inductance.

$$\oint \overline{E} \cdot dl = -\iint \frac{\partial \overline{B}}{\partial t} \cdot d\overline{S} \qquad (2)$$

When we look carefully at the right-hand side of Faraday's Law, we see that there is a double integral (area of a surface) where the amount of time-varying magnetic flux density within the surface area is summed. Since there is a surface, there must be a defined perimeter, again forming a loop.

The standard unit of inductance is the henry. It is a derived unit that relates the amount of negative voltage created by a time varying current. If the rate of change of the current is 1 ampere/second, then one henry will induce a voltage across the gap (with a magnitude of negative one volt) to resist the change in current.

If the time-varying magnetic field within the surface area is not changing with position (an electrically small loop, for example), then Faraday's Law reduces to Equation 3.

$$V = -A\frac{\partial B}{\partial t} \qquad (3)$$

If we now induce a time-varying current in this loop, there will be a time-varying magnetic flux within the loop. Equation 3

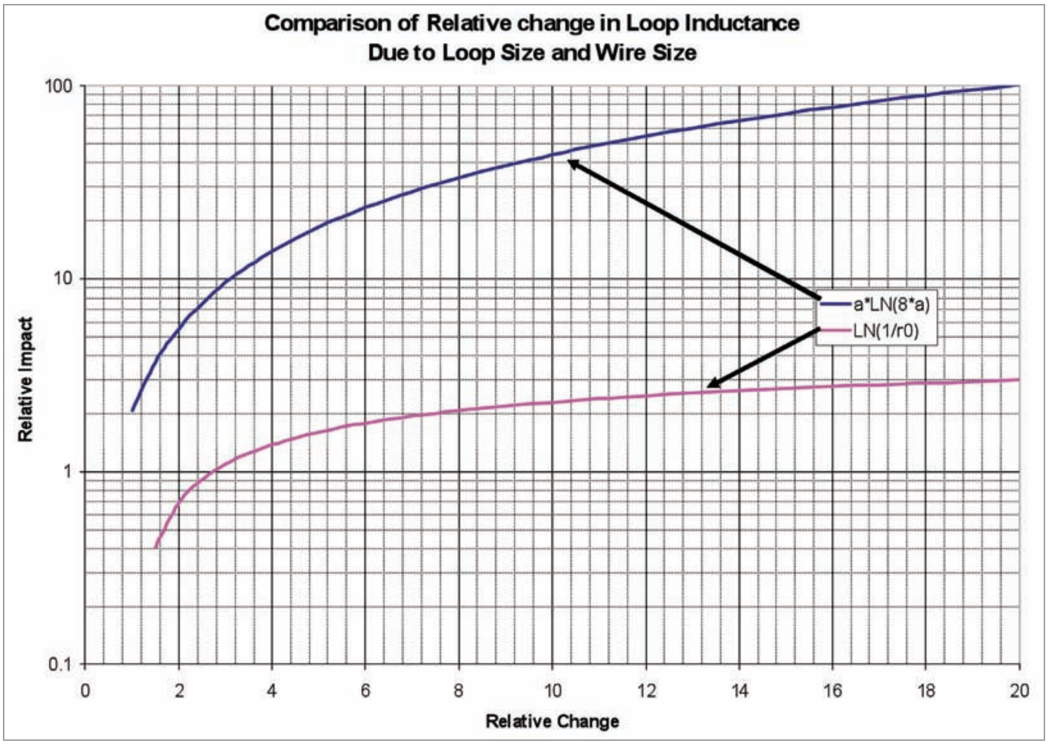


Figure 2: Relative impact on loop inductance from Equation 3

The bottom line is that a loop must be defined before the term 'inductance' has any meaning. A simple, straight wire, a braided ground strap, and a surface-mounted capacitor do NOT have inductance by themselves!

shows us that there will be a *negative* voltage induced in the loop, effectively impeding the initial flow of current. Clearly, as the size of the loop area becomes larger, the amount of negative voltage (inductive impedance) will increase. The loop area is the primary physical effect that controls the amount of inductance a current will experience.

It is common for someone to expect the inductance of a circuit will be reduced by increasing the conductor size. This will be examined a little later, but it is worth the time to look at a simple formula for finding the inductance of a simple isolated loop. Equation 4 allows us to calculate the inductance of a wire loop [1].

$$L \approx \mu_0 a \ln\left(\frac{8a}{r_0} - 2\right) \qquad (4)$$

Where:

L = loop inductance

a = loop radius

r_0 = wire radius

The size of the loop is determined by a, the radius of the loop. This radius is both outside the natural log function and inside the function. The radius of the wire, r_0, is only within the log function, and so the inductance varies much more slowly with the radius of the wire. Figure 2 shows the relative change in total loop inductance as either the loop radius or the wire radius changes. It is clear that the loop area has a much more significant impact on loop inductance.[1]

1. The relative impact of the wire size was so small compared to the loop area that a log scale was required to see the effect of wire radius change!

The bottom line is that a loop must be defined before the term 'inductance' has any meaning. A simple, straight wire, a braided ground strap, and a surface-mounted capacitor do NOT have inductance by themselves! We could discuss the partial inductance[2] of those items, but until the loop is defined, the inductance is not defined.

When a vendor discusses the inductance of a braided ground strap, how the inductance is determined should be understood so that the user can determine if the braided strap will or will not perform in a similar fashion in his or her application. Similarly, a surface-mounted capacitor often has a specification for an equivalent series inductance (ESL). How is this possible without defining the loop where the current will flow? Again, we need to understand the measurement process. The vendor simply places the capacitor over a very thin insulator with a ground plane beneath it. A voltage is applied between the capacitor's port #1 and ground-reference, the current flows through the capacitor and returns directly below in the ground plane, forming as small a loop as possible. Of course, when the capacitor is used in a real-world printed circuit board and connects to internal PCB layers, the amount of actual inductance is much greater than in the ideal ESL.

2. Partial inductance will be briefly explained in a later section.

DECOUPLING CAPACITOR CONNECTION INDUCTANCE

As mentioned in the above section, the actual inductance of a decoupling capacitor mounted on a PCB is much higher than the vendor's reported ESL. The connection inductance depends on the distance between the vias and the distance from the top (or bottom) mounting location to the planes that are to be decoupled[3]. Figure 3 shows a side view of a typical decoupling capacitor mounting on a PCB.

It is obvious that if the vias are placed close together and the planes to be decoupled are near the top of the PCB (when the capacitor is mounted on the top of the PCB), the connection inductance, represented by the loop, will be minimized. However, there are limits to how close the vias can be placed due to manufacturing issues. There are also limits to how close to the top surface the power/ground-reference planes can be located. So it is important to understand how the mounting will

3. Connection inductance is considered to be 'above the planes' only and does not consider the separation between the power and ground planes, nor the distance from the capacitor to the observation point.

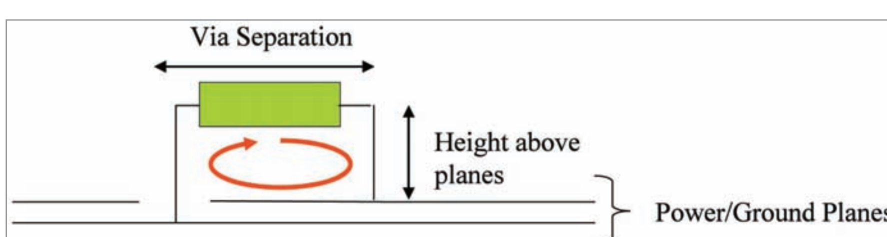


Figure 3: Typical surface-mounted decoupling capacitor loop inductance

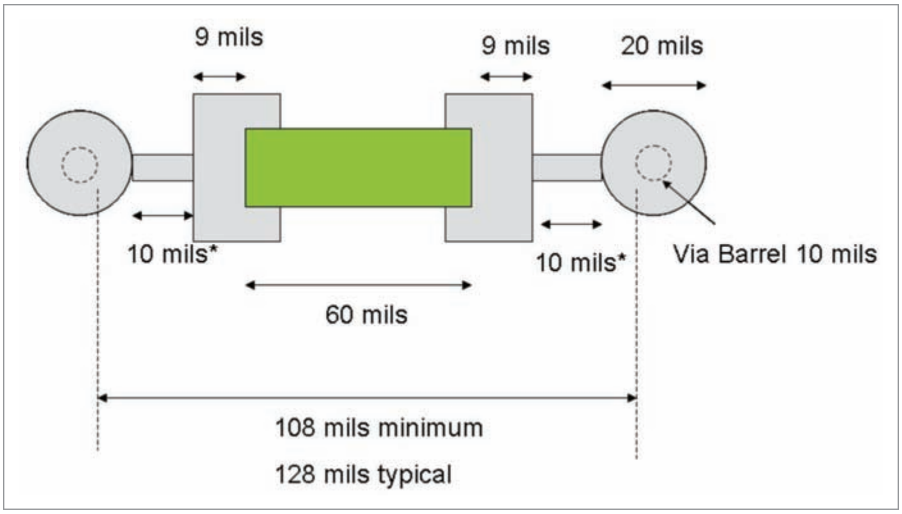


Figure 4: Typical minimum 0603 capacitor mounting dimensions

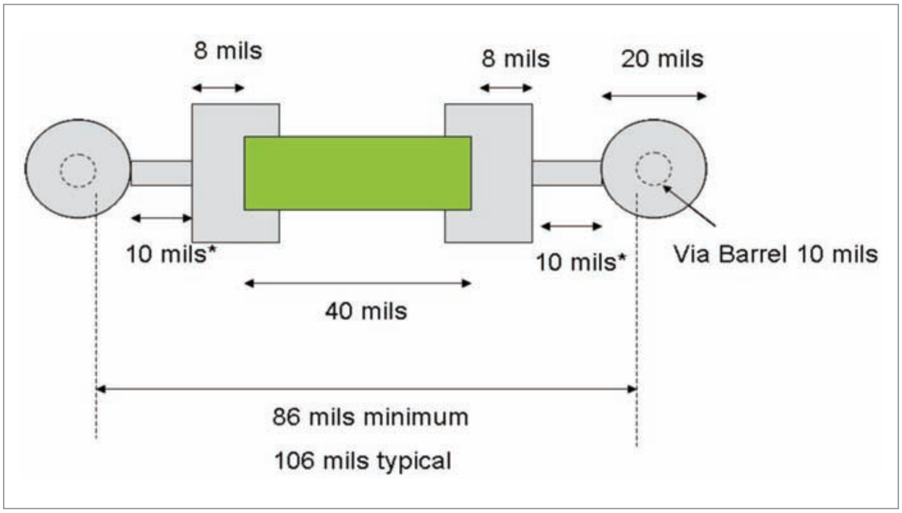


Figure 5: Typical minimum 0402 capacitor mounting dimensions

affect the performance of the capacitor and the connection inductance [2].

Connection inductance alone does not tell the complete story. The inductance associated with the spacing between the power/ground-plane pair, as well as any inductance associated with the distance between the IC and the decoupling capacitor, is not included in the connection inductance calculations.

Figures 4 and 5 show common mounting configurations for capacitors of size 0603 and 0402, respectively, for typical manufacturing limits. Table 1 shows some calculated[4] connection inductances (without ESL) for 0805, 0603, and 0402 size SMT capacitors for different depths to the power/ground-reference plane pairs [3-4].

These values are calculated with the example of 7-8 mils from capacitor-to-mounting-pad-edge, 20 mils from capacitor-mounting-pad-edge-to-via-pad, via pad diameter of 20 mils, via barrel size of 10 mils, and trace width equal to 20 mils. The absolute minimum distance from via pad to capacitor mounting pad edge is reported to be 10 mils, but typically 20 mils is used to be safe.

4. See references for details on the formula used for this calculation.

Distance from board to planes (mils)	0805 typical/minimum (148 mils between via barrels)	0603 typical/minimum (128 mils between via barrels)	0402 typical/minimum (106 mils between via barrels)
10	1.2 nH	1.1 nH	0.9 nH
20	1.8 nH	1.6 nH	1.3 nH
30	2.2 nH	1.9 nH	1.6 nH
40	2.5 nH	2.2 nH	1.9 nH
50	2.8 nH	2.5 nH	2.1 nH
60	3.1 nH	2.7 nH	2.3 nH
70	3.4 nH	3.0 nH	2.6 nH
80	3.6 nH	3.2 nH	2.8 nH
90	3.9 nH	3.5 nH	3.0 nH
100	4.2 nH	3.7 nH	3.2 nH

Table 1: Connection inductance for typical capacitor configurations

The distance between the via pad and the capacitor mounting pad was kept to a small value in the above calculations. If this distance is increased slightly to 50 mils, the connection inductance increases to the values in Table 2.

The connection inductance plays a much greater role in the performance of decoupling capacitors than the typical ESL of these components. Connection inductance values of 1 to 3 nanohenries are typical with the most common surface-mount capacitor sizes and manufacturing technologies. Using the tables, engineers can decide if a decoupling capacitor is better placed on the top or bottom surface of the PCB in order to provide charge to the power/ground-reference plane pairs.

MUTUAL INDUCTANCE

Mutual inductance is a measure of the current induced in a second loop, due to the flux from the first loop (Figure 6). As described above, a time-varying current in the first loop will create time-varying magnetic flux. If a second loop is close to the first loop, a significant portion of this magnetic field flux will penetrate the second loop, inducing a time-varying current in the second loop.

Figure 6 shows the two loops in a co-planar orientation. If they are oriented perpendicularly to each other, then the lines of flux from Loop 1 will not penetrate Loop 2, and there will be no mutual inductance[5]. If one of the loops is made much smaller, then the amount of flux is reduced, again reducing the mutual inductance. And finally, as the loops are moved further apart, the magnetic flux penetrating the second loop decreases rapidly, which also reduces mutual inductance.

5. This is approximate. There would be a small amount of flux lines within the conductors, creating a small amount of mutual inductance.

PARTIAL INDUCTANCE

The definition of inductance requires a current flowing in a loop. *Without a complete loop, there cannot be inductance*. Practical considerations, however, lead us to discuss the inductance of a part of the overall current loop, such as the inductance of a capacitor. This idea of discussing the inductance of only a portion of the overall loop is called partial inductance [4]. Partial inductances can be combined to find the overall inductance. For the simple case of a rectangular loop of wire where sides

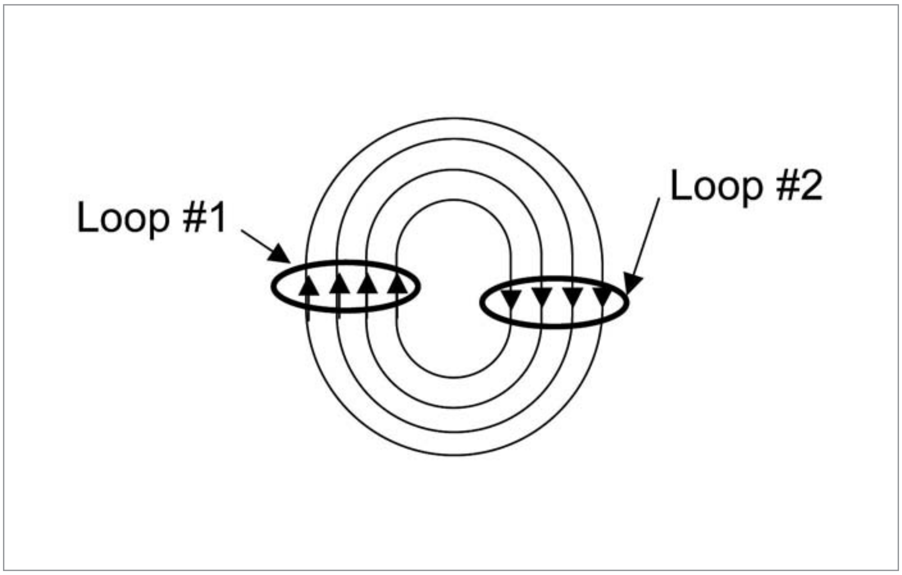


Figure 6: Mutual inductance from current in one loop creating flux in second loop

Distance from board to planes (mils)	0805 (208 mils between via barrels)	0603 (188 mils between via barrels)	0402 (166 mils between via barrels)
10	1.7 nH	1.6 nH	1.4 nH
20	2.5 nH	2.3 nH	2.0 nH
30	3.0 nH	2.8 nH	2.5 nH
40	3.5 nH	3.2 nH	2.8 nH
50	3.9 nH	3.5 nH	3.1 nH
60	4.2 nH	3.9 nH	3.5 nH
70	4.5 nH	4.2 nH	3.7 nH
80	4.9 nH	4.5 nH	4.0 nH
90	5.2 nH	4.7 nH	4.3 nH
100	5.5 nH	5.0 nH	4.6 nH

Table 2: Connection inductance for typical capacitor configurations with 50 mils from capacitor pad to via pad

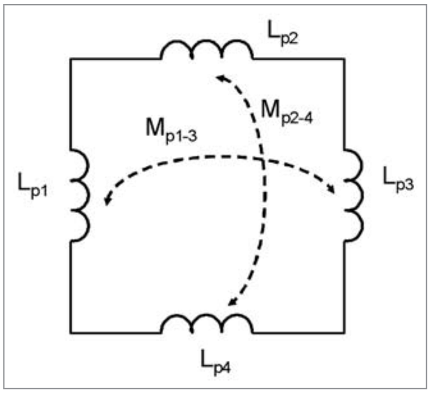


Figure 7: Partial inductance components of simple rectangular loop

1 and 3 are parallel to each other and so are sides 2 and 4 (see Figure 7), Equation 5 can be used to calculate the total inductance from the partial inductances.

$$L_{total} = L_{p1} + L_{p2} + L_{p3} + L_{p4} - M_{p13} - M_{p24} \tag{5}$$

Figure 7 shows this distributed inductance concept and relates back to Equation 5. In each portion of the loop we assign a partial inductance value as well as partial mutual inductance between all parts of the loop.[6] Though the conductors may have different sizes, it is not a problem to calculate the partial inductance values. Naturally, if the current follows a more complex path, additional partial inductances and partial mutual inductances will be needed.

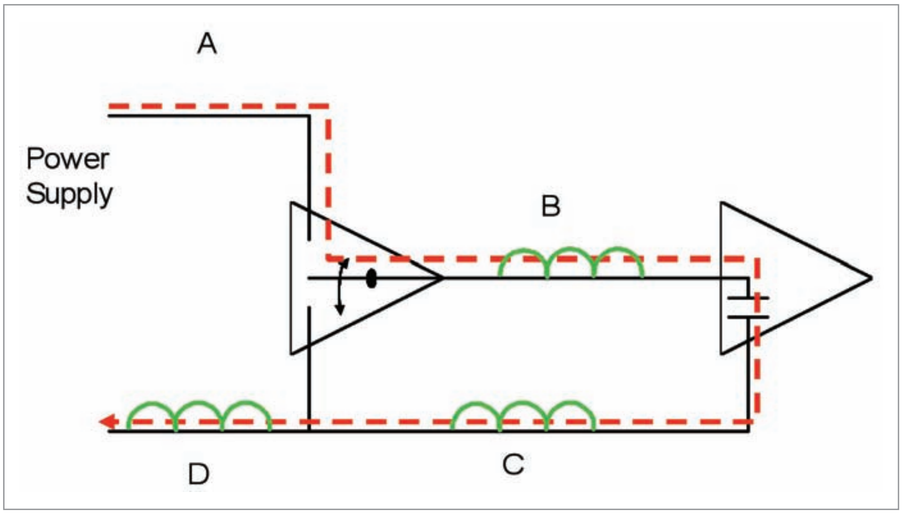


Figure 8: Current path for data through IC gates

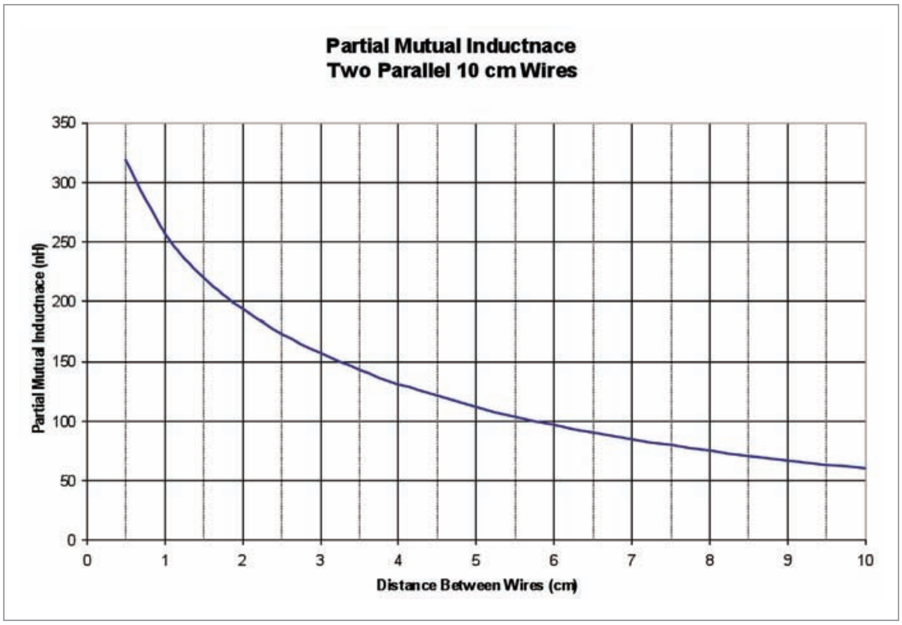


Figure 9: Example of partial mutual inductance of a pair of parallel wires

The concept of partial inductance is especially useful when the physical geometry is complex and it is difficult to assign the loop inductance to any one location around the loop. For example, Figure 8 shows current flow from the power plane in a PCB through the output driver of an IC, through a trace to the IC load, and finally through the ground-reference plane back to the power supply source. Since there is a closed loop of current, there is an inductance associated with that current path … but where could we place the loop inductance in this circuit? First of all, since the various conductors have different sizes, it would be impossible to find a formula to find the loop inductance. However, since we know this inductance exists (even if we cannot calculate it easily), where would we place the inductance? If we choose location 'A', then we ignore any voltage drop in the other conductors due to inductive impedance. The same is true for the other locations (B, C, and D). The inductance is actually a distributed quantity and must be considered to be throughout the loop. The concept of partial inductance allows us to do this.

The partial inductance for a length of wire is given by (6), and the partial mutual inductance between a pair of parallel wires is given in (7).

$$L_{pi} = \frac{\mu_0}{2\pi} l \left[\log\left(\frac{l}{r} + \sqrt{\left(\frac{l}{r}\right)^2 + 1} \right) + \frac{r}{l} - \sqrt{\left(\frac{r}{l}\right)^2 + 1} \right] \tag{6}$$

6. In this case, we only show the partial mutual inductance of the parallel sections, since perfectly perpendicular conductors will not have any mutual inductance.

$$M_{p_{12}} = \frac{\mu_0}{2\pi} l \left[\log\left(\frac{l}{d} + \sqrt{\left(\frac{l}{d}\right)^2 + 1} \right) + \frac{d}{l} - \sqrt{\left(\frac{d}{l}\right)^2 + 1} \right] \quad (7)$$

Where:

l = length of wire

r = radius of wire

d = distance between parallel wires

Figure 9 shows the partial mutual inductance for two parallel 10 cm long wires. Note that when the wires are close together, the partial mutual inductance is very high. Referring back to (5), we see that when the partial mutual inductance is high, the total inductance is low (because it is subtracted). When the wires are close, the loop area would be smaller, resulting in a lower inductance, as expected. Calculations for more complex geometries can be found in [5].

SUMMARY

The basic principle that inductance requires current to flow in a loop is an important concept to understand. This is not unreasonable since current *must* flow in a loop. The size of the current loop determines the amount of inductance.

Inductance is a basic building block in electronic circuits. That is, as soon as metal conductors are used and current flows through them, inductance exists. This inductance becomes the limiting factor in all high-frequency circuits. When capacitors are used as filter elements, the natural inductance associated with the current flowing though the capacitor limits the frequency range where the capacitor is an effective filter component.

Partial inductance is a useful concept, since with partial inductances one can discuss the contribution of a single part of the loop to the total inductance. An example is the via connecting between different layers on the PC board, the metal stand-off post between the PC board and the chassis, and traces on the PC board connecting filter components. Each of these metal structures can be analyzed to find their partial inductances, and the results can then be combined to find the total inductance.

This has been a very brief introduction to inductance. A much more complete study of this subject is available in the references.

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Dr. Bruce Archambeault and Sam Connor bring their experience at IBM to the issue of inductance and EMC, while Mark Steffka shares his expertise developed at General Motors.

(the authors)

DR. BRUCE ARCHAMBEAULT

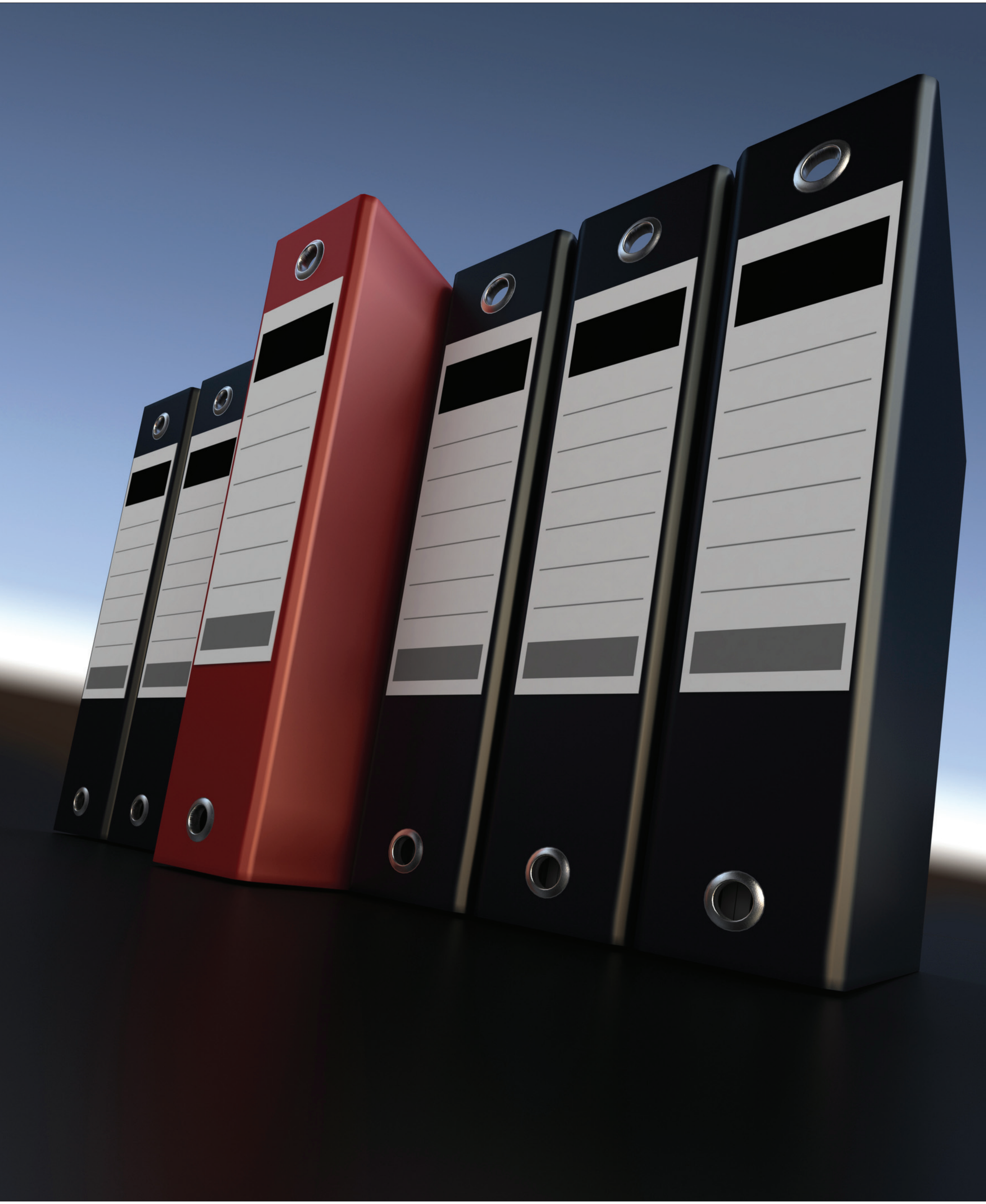
is an IBM Distinguished Engineer at IBM in Research Triangle Park, NC and an IEEE Fellow. He received his B.S.E.E degree from the University of New Hampshire in 1977 and his M.S.E.E degree from Northeastern University in 1981. He received his Ph. D. from the University of New Hampshire in 1997. His doctoral research was in the area of computational electromagnetics applied to real-world EMC problems. He is the author of the book "PCB Design for Real-World EMI Control" and the lead author of the book titled "EMI/EMC Computational Modeling Handbook".

SAM CONNOR

is a Senior Technical Staff Member at IBM and is responsible for the development of EMC and SI analysis tools/applications. Mr. Connor's current work activities and research interests also include electromagnetic modeling and simulation in support of power distribution and link path design for printed circuit boards. He has co-authored more than 20 papers in computational electromagnetics, mostly applied to decoupling and high-speed signaling issues in PCB designs. He is a Senior Member of the IEEE and is currently the Chair for the TC-9 subcommittee of the IEEE EMC Society.

MARK STEFFKA, B.S.E., M.S.

is a Lecturer (at the University of Michigan - Dearborn), an Adjunct Professor (at the University of Detroit – Mercy) and an automotive company Electromagnetic Compatibility (EMC) Technical Specialist. His university experience includes teaching undergraduate, graduate, and professional development courses on EMC, antennas, and electronic communications. His extensive industry background consists of over 30 years' experience with military and aerospace communications, industrial electronics, and automotive systems. Mr. Steffka is the author and/or co-author of numerous technical papers and publications on EMC presented at various Institute of Electrical and Electronics Engineers (IEEE) and Society of Automotive Engineers (SAE) conferences. He has also written about and has been an invited conference speaker on topics related to effective methods in university engineering education. He is an IEEE member, has served as a technical session chair for SAE and IEEE conferences and has served as an IEEE EMC Society Distinguished Lecturer. He holds a radio communications license issued by the United States' Federal Communication Commission (FCC) and holds the call sign WW8MS.



Administrative Compliance Your Achilles Heel?

BY NICK WAINWRIGHT

This article outlines the administrative obligations contained in the European EMC Directive, 2004/108/EC, with particular reference to the Declaration of Conformity (DoC). It considers the mounting evidence, including that resulting from European market surveillance campaigns, that insufficient attention is paid to ensuring that the supporting documentation is not only in place, but also up to date.

The requirements of the EMC Directive, like all New Approach directives, can be broadly split into two;

- the technical requirements and
- the administrative requirements

Compliance with the technical requirements is demonstrated (in most cases) by assessing a product against the relevant harmonised European standards and compliance with the administrative requirements is demonstrated by ensuring that the requisite documents and paperwork are available and up to date. In the case of the EMC Directive, the requisite paperwork is normally Technical Documentation and a valid DoC.

Only by meeting both the technical and the administrative obligations should the CE Marking be affixed to a product and the product placed on the market.

ADMINISTRATIVE REQUIREMENTS

Whilst concerns regarding the number (or suspected number) of non-compliant products on the market is nothing new, historically many of these concerns have tended to relate to the technical aspects of compliance.

Deficiencies in administrative compliance have, with the exception of market surveillance activities, only tended to come to light when a DoC has been requested by a potential customer and the manufacturer has been unable to supply one in a reasonable time frame.

Under both 89/336/EEC and 2004/108/EC, there is a stated requirement to produce a valid DoC and the minimum requirements of what it should contain are clearly stated as follows:

- reference to the Directive
- identification of the apparatus to which it refers
- name and address of the manufacturer and, where applicable, the name and address of his authorized representative in the Community

Deficiencies in administrative compliance have, with the exception of market surveillance activities, only tended to come to light when a DoC has been requested by a potential customer and the manufacturer has been unable to supply one in a reasonable time frame.

- dated reference to the specifications under which conformity is declared to ensure the conformity of the apparatus with the provisions of this Directive
- date of the declaration
- identity and signature of the person empowered to bind the manufacturer or his authorized representative

MARKET SURVEILLANCE ACTIVITIES

The EMC Administrative Co-operation Working Group (ADCO) carried out the 4th EMC Market Surveillance Campaign during 2011.

The primary purpose of the campaign was to assess the compliance of a range of LED lighting products with the administrative and technical requirements of the EMC Directive. Administrative compliance included checking of the DoC.

The results of the surveillance activities were published towards the end of 2011 [1]. The overall administrative compliance was found to be only 28.8% with the main deficiencies relating to the CE marking and the DoC.

Declarations of Conformity were available for only 74.4% of the assessed LED lighting equipment, meaning that 1 in 4 assessed products did not have a DoC available. It is possible that some of those products may have been technically compliant, however as they were not administratively compliant, they did not meet the requirements of the EMC Directive.

Almost half of DoCs presented had major deficiencies including:

- missing reference to the Directive
- incorrect Directive referenced
- inadequate identification of the product
- incorrect standards
- not issued by the manufacturer and/ or authorised representative

Overall, only 39.9% of the assessed products were presented with an acceptable Declaration of Conformity. In other words 61.1% of the assessed products were not presented with an acceptable Declaration of Conformity, either because one did not exist or because it had major deficiencies.

Previous EMC Market Surveillance Campaigns raised similar concerns about compliance levels generally and administrative compliance specifically.

FURTHER EVIDENCE

The ADCO market surveillance results of 2011 reflect the compliance position of the LED market; a fast growing and fast changing industry.

Are the deficiencies identified in DoCs for LED lighting products representative of those commonly found elsewhere?

At York EMC Services (YES) we see a significant number of DoCs each year, either via our DoC Checking Service or as part of our wider consultancy work and therefore an answer to the question above is readily available.

And that answer is an emphatic “yes”; all the issues identified in the market surveillance activities for LED lighting are commonly observed by YES across a wide range of different industry sectors.

Probably less than 10% of DoCs that arrive at YES for assessment could be classed as being anywhere approaching correct with the other 90% containing a range of deficiencies, many of which would be considered as major.

Given the copious number of sources of information for what should be included on a DoC; specialist training providers, consultants, industry websites and even the EMC Directive itself this is a disappointing state of affairs.

As regards deficiencies, there are a number of recurring themes, of which the top 3 are:

1. The standards are incorrectly applied, out of date or undated
2. The reference to the Directive is incorrect
3. Identification of the apparatus covered by the DoC is inadequate

Each of these will now be considered in turn including typical examples of where and how the requirements have not been met.

STANDARDS

The most common issues, by some distance, relate to the presentation of standards on a DoC. These issues break down into a number of subcategories which will be considered in more detail.

Perhaps to start off on a positive note, it is worth stating that it unusual to see a DoC where the manufacturer has selected completely incorrect product specific or generic standards. No doubt these do exist but, it seems, not in significant numbers.

Listing basic standards

It is relatively common to see a DoC which lists basic standards as opposed to product specific or generic standards. Figure 1 shows a typical example.

CE Marking is based on the correct application of harmonised European standards which includes product specific and generic standards. In lay terms, basic standards, which contain details of the test methods, are the support acts to product specific and generic standards. They are not "CE Marking" standards and are not listed in the OJ. A DoC should be made against product specific and/or generic standards as appropriate.

In relation to Figure 1, there are several questions that the DoC does not answer:

- Against which standards is the product being declared for EMC? The answer to this question is that we simply don't know. EN61000-4-X immunity standards are referenced by virtually every product specific and generic standard published in recent years. Conspicuous by its absence is reference to EN61000-4-3 for radiated immunity.
- What about emissions? There are no emission standards listed at all.
- Against which standards is the product being declared for electrical safety? The Low Voltage Directive is listed on the DoC but it contains no safety standards, so again the answer is that we simply don't know.

Correct versions of standards

By far the most common issue relating to standards occurs when the product has been correctly assessed against a particular version of a standard, but that standard has subsequently been updated and either an amendment and/or a new version has been published. The transition period has then passed and as a result the DoC has become invalid.

Two examples of recently reviewed DoCs are shown In Figures 2 and 3. There is plenty of other potential discussion relating to the information contained in both Figures 2 and 3.

More specifically, and what can't be seen from the snippet used in Figure 3, is that the DoC was signed in 2003. Therefore all of the standards listed were considerably out of date even at the time the DoC was signed!

Directives Complied with:	Low Voltage Directive 2006/95/EEC Electro Magnetic Compatibility Directive 2004/108/EEC
References to Harmonised Standards used:	All equipment contained within the system satisfies the requirements when installed and operated according to the supplied instructions: EN6100-4-2 – ESD EN6100-4-4 – Electrical Fast Transients / Burst EN6100-4-5 – Voltage Surges EN6100-4-6 – Conducted RF Fields EN6100-4-11 – Voltage Dips and Interruptions

Figure 1: References to basic standards are commonplace

BS EN 50081-1 : 1994	Electromagnetic Compatibility Generic Emission Standard Part 2: Industrial Environment
BS EN 50082-2 : 1995	Electromagnetic Compatibility Generic Immunity Standard Part 2: Industrial Environment

to demonstrate compliance with Council Directive 89/336/EEC (amendments 92/31/EEC and 93/68/EEC).

Figure 2: References to old generic standards are still commonplace

Electromagnetic Compatibility Directive 89/336/EEC
in accordance with:

EN 55022 : 1994 Class B
IEC801-2 : 1991 Level 3
IEC801-3 : 1984 Level 2
IEC801-4 : 1988 Level 2
(Through testing by an independent UKAS approved body).

Low Voltage Directive 73/23/EEC in accordance with:

BS EN 60335-2-63:1993 Commercial electric water boilers and liquid heaters. (Through testing by an independent NAMAS approved body).

Figure 3: References to IEC801-X standards still exist but are fortunately not that commonplace

Relevant EC Directives:	Low Voltage Directive 73/23/EEC EMC Directive 89/336/EEC
Harmonized Standards:	EN 61010-1 EN 61010-1:1990+A1 EN 61010-1:1990/A2 EN 61010-2-051
	EN 50081-1 EN 50081-2 EN 50082-1:1992 EN 50082-2 EN 55011:1991 EN 5514-1 EN 5514-1/A1 EN5514-2 EN 55022:1994 EN61000-3-2 EN61000-3-3 EN61000-6-2

Figure 4: Keeping options open!

The range of conforms to the CE marking directive 93/68/EEC through compliance with the following standards:

Figure 5: The statement "a range of" on a DoC is far too commonplace

Product family	Detector and ancillaries
Product description	Part Number
Optical Smoke Detector	55000-600
EMC Optical Smoke Detector	55000-620
Optical Detector	55000-660
Heat Detector	55000-400
EMC Heat Detector	55000-420
High Temperature Heat Detector	55000-401
Ionisation Smoke detector	55000-500
EMC Ionisation Smoke detector	55000-520
Ionisation Smoke detector	55000-560
Multisensor Detector	55000-885
Isolating Base	45681-284
Isolator	55000-720
Intelligent Low Power Relay Base	45681-242
MiniDisc Remote Indicator	53832-070

Figure 6: Robust identification of the products covered by a DoC

Undated standards

All standards change on a regular basis either by amendment or publication of a new version. The newer standard may contain different tests or test limits/levels or other changes that affect how the product is assessed.

A standard listed on a DoC without an associated date means that is not possible to identify the precise version of the standard to which the product is being declared and by association the actual test requirements that have been met. Figure 4 shows an example of where undated standards have been included on the DoC.

In addition (and leaving aside the fact that most of the standards are undated) Figure 4 shows a DoC for a product meeting an impressively long list of EMC standards.

This must certainly be an interesting product; a cross between Information Technology Equipment (ITE) and a household appliance which is also Industrial, Scientific and Medical (ISM) Equipment and used in an industrial environment!

Upon further investigation, it transpired that the product covered by this DoC was in fact a piece of measurement equipment falling within the scope of EN61326-1; which isn't actually listed!

REFERENCE TO THE DIRECTIVE

When doing presentations on the subject of DoCs I have often found myself anecdotally stating that I am as likely to review a DoC which references 89/336/EEC on as I am one which references 2004/108/EC. Several years since the passing of 89/336/EEC this still seems to be the case.

When researching for this paper, I picked 10 of the most recently assessed DoCs to check the frequency at which 89/336/EEC still appeared. Sure enough the 10 DoCs were split exactly 50/50; 5 referring to 89/336/EEC and 5 referring to 2004/108/EC.

Most of the examples used in this paper to illustrate other issues also make reference to 89/336/EEC.

DESCRIPTION OF THE APPARATUS

One of the key information requirements for a DoC is that the product(s) included should be able to be clearly identified. For manufacturers having a large number of products this can be a challenge but an important one to undertake. It should be possible to uniquely trace each product to a DoC; without ambiguity.

A DoC should be a living document that is regularly reviewed to ensure that it accurately reflects the state of compliance of the product to which it refers. There should be a valid DoC for each day that the product is placed on the market.

Figure 5 illustrates a common issue where the manufacturer is inadequately describing the scope of the DoC.

The phrase "a range of" only defines the scope of the DoC in general terms. What products, types, models and/or variants are included in this range? The answer is that it is impossible to tell without additional information and furthermore it is highly likely that "the range" will change over time further reducing the traceability.

Figure 6 shows a good example of how to identify products within the scope of the DoC. In this example the actual product numbers can be identified clearly and unambiguously.

CONCLUSION

There is clear evidence that many products placed on the market are not compliant with the administrative requirements of the EMC Directive and therefore not compliant with the EMC Directive.

A recurring theme, when assessing DoCs, is that many were clearly valid when issued but have become invalid over time through not being maintained. This is demonstrated by the number of out of date standards that are often encountered.

What this reveals is that the issuing of a DoC is perceived by many manufacturers to be a one-off, isolated event rather than part of a compliance process.

In practice, issuing a DoC is simply one event in a whole series of events that when brought together form the compliance process for the product from concept to retirement from sale.

Ensuring on-going compliance (both technical and administrative) after the product is placed on the market is one phase of this process and the one that includes maintenance of the DoC.

A DoC should be a living document that is regularly reviewed to ensure that it accurately reflects the state of compliance of the product to which it refers. There should be a valid DoC for each day that the product is placed on the market.

Often an invalid DoC is just the tip of the iceberg and inevitably raises other questions about the technical compliance of the product.

- Is it simply the case that the DoC hasn't been updated or is there more to it?
- Is it also the case that the changes to the standards have not been assessed for their technical significance to the product in question?
- If the DoC is invalid, what is the likelihood that the Technical Documentation is also invalid?
- If the DoC hasn't been updated for several years, is it also the case that the product has changed in the meantime and that an EMC assessment carried out previously is no longer valid?

In other words could an invalid DoC be an indication that the product is actually neither administratively nor technically compliant….?

REFERENCE

1. 4th EMC Market Surveillance Campaign, EMC Administrative Co-operation Working Group, 2011

(the author)

NICK WAINWRIGHT

Nick has been involved with EMC all his working life, starting as an EMC test engineer in the telecommunications industry before moving into commercial testing.

He joined York Electronics Centre, the predecessor to York EMC Services, in 1990 as an EMC Test Engineer and worked his way up the organization until this year he was given the task of running the 40 strong company as Chief Operating Officer.

Nick takes a very hands-on approach to the roles he undertakes and has specified and designed EMC test facilities and implemented quality systems within laboratories to enable them to achieve accreditation to ISO17025.

Nick is a regular speaker at EMC conferences, courses and workshops on subjects ranging from CE Marking and standards to testing, ISO17025 and measurement uncertainty.

EMC Education

The View from the Chalkboard

BY MARK STEFFKA

I am pleased to be writing this first edition on what we plan will be a periodic column on the topic of formal EMC educational opportunities offered by colleges and universities around the world. I have met many of you in my years of work in both industry and teaching EMC. I look forward to meeting many more of you as a result of being asked this year by the EMC Society to serve as the new chair of the Education and Student Activities Committee (ESAC), which I gladly accepted!

The origin of this column goes back a few years when I was asked by the staff of *In Compliance* if I'd like to contribute to their publication. I was very much honored by that invitation and had replied that I would consider it when I had a topic that I felt was worth the valuable time of the readership of the publication. Earlier this year, in my discussions with Lorie Nichols, the question of "Who's doing what in EMC Education?" came up and I realized that was "the topic"! My passion for EMC Education is no secret to those of you who know me. And it's a frequent topic in my discussions with many of my undergraduate and graduate level

Course Title
Introduction to EMC (Undergraduate course)
Advanced Topics in EMC (Graduate Course)
Electromagnetic Compatibility (Undergraduate/graduate class)
Your EMC Course

students wanting to continue their studies in EMC. The questions from these students are typically to the effect of “Where can I further my education in EMC?” Or “What universities offer formal courses in EMC?”

Perhaps you may have read a paper that Dr. Thomas Jerse (Emeritus Professor – *The Citadel*) and I wrote for the *2007 IEEE International Symposium on EMC* – “Establishing EMC Education: The Ten-Year Contribution of the University Grant Program“. In that paper we reviewed the EMC educational grants that had been awarded by the EMC Society – and the formal courses that resulted from those grants. In addition, there are a few universities that I personally know that have had an extensive contribution to EMC education for many years – most notably, *Missouri University of Science and Technology* (MST), in Rolla, Missouri (USA), and *Politecnico Di Torino*, in Turin, Italy. I know there are many more and that is part of the purpose of this column, to identify other universities and what they offer.

What I’d like to be able to do in these pages that *In Compliance* has allowed me to use is to identify the formal university-linked EMC educational opportunities around the world - from undergraduate to doctoral level, “live” (on campus), or distance learning (DL) formats, as part of a regular curriculum or professional development.

So – here’s where I’d like to begin. If you know of (or are involved) in a university EMC course – a regular semester or professional development, I’d love to hear from you. As time goes on, I’d like to be able to provide *In Compliance* readers a readily usable resource to easily identify those EMC educational opportunities.

I’d like to compile a matrix to identify these opportunities – including contact information and look forward to updating it as the months go by. So – as they say “Keep those cards and letters coming in!”

(the author)

MARK STEFFKA, B.S.E., M.S.
is a Lecturer (at the University of Michigan - Dearborn), an Adjunct Professor (at the University of Detroit – Mercy) and an automotive company Electromagnetic Compatibility (EMC) Technical Specialist. His university experience includes teaching undergraduate, graduate, and professional development courses on EMC, antennas, and electronic communications. His extensive industry background consists of over 30 years’ experience with military and aerospace communications, industrial electronics, and automotive systems.

Mr. Steffka is the author and/or co-author of numerous technical papers and publications on EMC presented at various Institute of Electrical and Electronics Engineers (IEEE) and Society of Automotive Engineers (SAE) conferences. He has also written about and has been an invited conference speaker on topics related to effective methods in university engineering education. He is an IEEE member, has served as a technical session chair for SAE and IEEE conferences and has served as an IEEE EMC Society Distinguished Lecturer. He holds a radio communications license issued by the United States’ Federal Communication Commission (FCC) and holds the call sign WW8MS.

Send your university EMC courses to be included in the matrix to Mark Steffka at msteffka@umich.edu

Location	When	Delivery Method	Contact
University of Michigan - Dearborn	Fall semester (typically)	On campus class with lab	Mark Steffka msteffka@umich.edu
University of Michigan - Dearborn	Winter semester (typically)	On campus with distance learning available	Mark Steffka msteffka@umich.edu
University of Detroit - Mercy	Once every 2 to 3 years	On campus	Mark Steffka steffkma@udmercy.edu
University name	***When it’s taught***	***Method***	***Contact information***

TECHNICAL Tidbits

Electromagnetic Interference (EMI) Effects on Measurement Equipment

ESD Effects on Oscilloscopes

BY DOUGLAS C. SMITH

When debugging designs or making electrical measurements of noise, especially ESD, we often assume the only equipment in the room that works perfectly is our measurement equipment. This assumption can be wrong and when it is, the bad data that results can add significantly to the time needed to get to the cause of a design problem. Examples of ESD interference to oscilloscopes are described and one innovative approach to minimizing EMI induced error is shown.

Figure 1 shows an attempt to measure a waveform associated with an ESD event using a high bandwidth analog scope many years ago. Almost every engineer or technician trying to make such a measurement in that time frame obtained a plot like Figure 1. The plot was taken using a 1 GHz bandwidth Tektronix 7104 analog scope with a camera mounted on the scope to capture the waveform. The 7104 was the last of the analog scopes in general use just before digital scopes became fast enough to take over most lab measurements.

In the plot of Figure 1, time appears to go backwards! What really happened was that the very strong fields generated by the ESD simulator interacted directly with the electron beam in the oscilloscope, overriding what the scope deflection systems were trying to do. The result drove the electron beam all over the screen, resulting in the strange waveform in the figure. People quickly learned to put these scopes in a Faraday Cage when making ESD measurements. The Faraday Cage shielded the scope from the ESD generated fields, and the desired waveform was obtained.

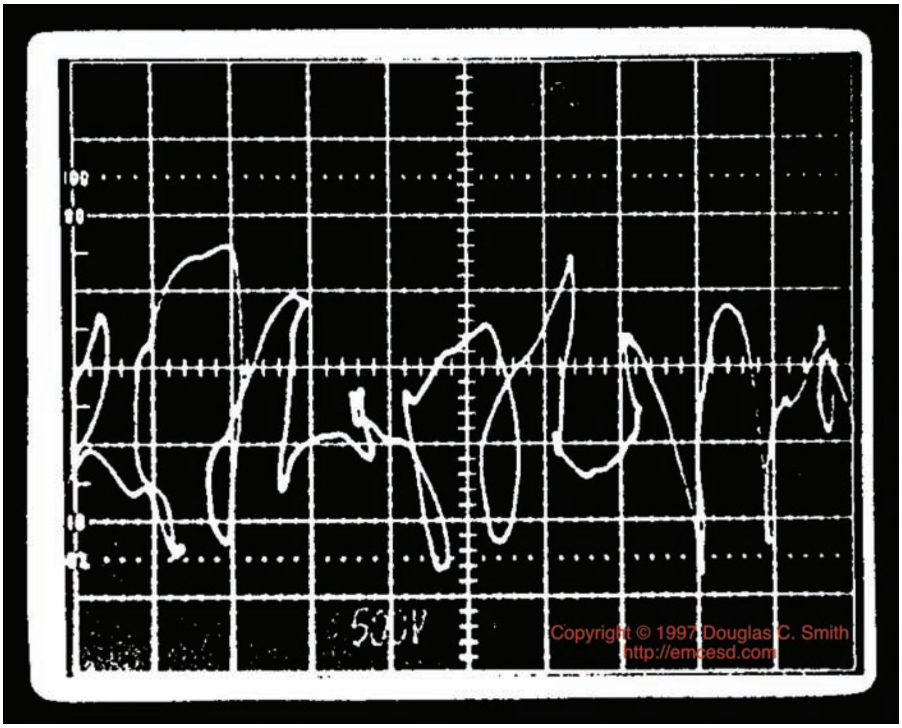


Figure 1: Example of ESD Induced Error in an Analog Oscilloscope

These days we use digital scopes with solid state displays that don't use electron beams the way analog scopes did, but it is still possible to get EMI induced error in scope measurements. One example can be seen in my Technical Tidbit article September 2004, "Mobile Phone Response to EMI from Small Metal ESD." One of the figures from that article is reproduced in Figure 2.

The plot in Figure 2 was the voltage induced into a small dipole antenna tuned to about 1800 MHz in response to jingling coins in a plastic bag. The desired signal is the tall spike in the middle of the plot. But notice the "hash" noise starting about 10 ns before the spike. This noise traveled over the direct path through the air from the ESD events into the scope electronics. The hash starts earlier because the

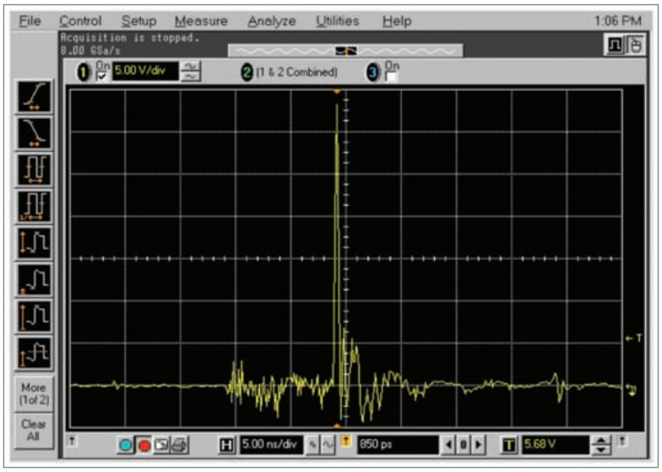


Figure 2: Example of ESD Induced Error in a Digital Oscilloscope (Vertical scale = 5 Volts/div, Horizontal scale = 5 ns/div)

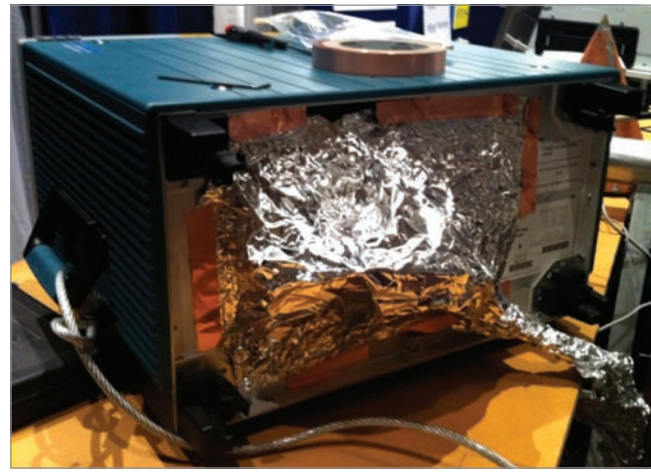


Figure 3: Makeshift Shield to Prevent ESD Induced Measurement Error

propagation time is faster for the air path than through several feet of coax cable the desired signal had to travel through. To fix this and similar problems one can use a Faraday Cage around the scope or simply move the scope further away from the source of the EMI, jingling coins in this case.

Figure 3 shows one solution by a friend of mine, Jon Barth of Barth Electronics in Boulder City, NV, to the problem of ESD interference to his scope and PC while trying to measure the calibration waveform of an ESD simulator. ESD noise was getting into the connection between his PC and the scope, making data acquisition nearly impossible. The copper tape and aluminum foil shield did the job for him and is much simpler to implement quickly than a Faraday Cage.

EMI can manifest itself in other ways as well including crosstalk between scope channels when trying to measure a high amplitude signal and a small one on different channels at the same time. I have even seen, back in the early 1990s, a scope change its state because its control circuits were not immune to the effects of ESD. The results of this problem were quite evident though so there is little danger of bad data from this cause.

The effects of EMI on analog and digital scopes are quite different, but in both cases, significant measurement error can occur if care is not taken.

Don't assume your measurement equipment is working perfectly, especially around ESD. Be on the lookout for error creeping into your measurements.

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

(the author)

DOUGLAS C. SMITH

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

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

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

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

BUSINESS News

Aeroflex Adds 4x2 MIMO Support to 7100 Digital Radio Test Set

Aeroflex Ltd. announced added support for the 4x2 multi-input multi-output (MIMO) to the 7100 digital radio test set for the R&D testing of LTE user equipment being designed with this feature. 4x2 MIMO is used adaptively to offer improved throughput in good signal conditions and improved resilience in poor signal conditions.

For more information, contact your local Aeroflex office in the US at 800-835-2352 or email info-test@aeroflex.com.

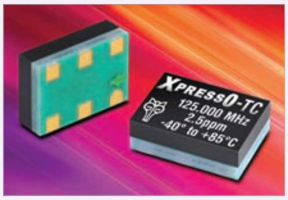
Cascade TEK's Colorado Testing Lab Now Offering HALT/HASS Testing

Cascade TEK has announced its Colorado Lab now offers HALT/HASS testing. The HALT (Highly Accelerated Life Test) and HASS (Highly Accelerated Stress Screen) testing methods are an excellent tool to quickly uncover latent weaknesses in a product, by putting products through random vibration combined with very rapid temperature transitions – subjecting the product to increasing amounts of stress and fatigue. Charlie Felkins, a 20 year vetern in HALT testing will be running Cascade TEK's HALT/HASS test program.

For more information about Cascade TEK, visit www.cascadetek.com.

Fox Electronics' Xpress TCXOs Provide Custom Frequencies up to 250 MHz with Quick Delivery

Fox Electronics has announced their enhanced line of XpressO low jitter configurable oscillators with the new TXCO version, XpressO-TC. This new line provides custom



frequencies up to 250 MHz and offers a significant advantage over traditional TCXOs with a typical maximum frequency of 50 to 60 MHz. These new devices are ideal for applications requiring high precision and extremely low jitter.

Visit www.foxonline.com or call 888-GET-2-FOX for more information.

LCR Electronics Inc. Now Offers Filters for MIL-STD-461 DC and AC Single and Three Phase Applications

LCR Electronics has announced a new line of filters for MIL-STD-461 DC and AC single and three phase (delta or Wye) applications. These filters are designed to mitigate conducted emissions from 10 kHz to 30 MHz. The feed through capacitors (line to ground) incorporated in the filters maintain attenuation to 1 GHz

and above when installed with additional shielding and isolation between input and output terminations.

For more information, visit www.lcr-inc.com or contact LCR directly at sales@lcr-inc.com.

Leader Tech is the World's Only MIL-SPEC Approved and Certified Manufacturer of 12 Conductive Elastomer Compounds

Leader Tech has announced that their newly expanded line of TechSIL Conductive Elastomer compounds recently received QPL certification by the Defense Logistics Agency. This certification designates Leader Tech as the only MIL-SPEC approved and certified manufacturer of all 12 conductive elastomer formulations.

This prestigious designation authorizes the company to formulate, extrude and mold conductive elastomers to stringent MIL-DTL-83528D specifications.

Leader Tech's new TechSIL 5000 Conductive Elastomers provide engineers with a highly customizable gasketing solution that delivers a shielding effectiveness of up to 110 dB across wide temperature variations and environmental conditions. An applications engineer is also available to help formulate materials to meet your custom requirements.

For more information on these products, visit www.leadertechinc.com or email sales@leadertechinc.com.

MEN Micro's New PCI Express Mini Carrier Card Brings SIM Power to CompactPCI

MEN Micro Inc. has announced the release of a robust PCI Express (PCIe) mini card carrier board

that features 2 PCIe mini car slots as standard with USB and PCI Express connections as well as 2 SIM card slots. Model F223 is a 3U compact PCI board that can be used virtually with all wireless applications from GPS, WLAN and WMTS to GSM and HSDPA and is expandable to 18 SIM slots.

For more information, contact Stephen Cunha at 215-542-9575 or stephen.cunha@menmicro.com.

BUSINESS News

Northwest Nazarene University Receives Grant from The Micron Foundation

Northwest Nazarene University in Nampa, Idaho has been awarded a $200,000 grant from the Micron Foundation to assist the University's new bachelor of science in engineering program. The grant will support the engineering program's pursuit of accreditation upon its first graduating class in 2014. NNU President David Alexander said "We are grateful to the Micron Foundation for their investment in the future of NNU's engineering students."

For more information about The Micron Foundation, visit www.micron.com/foundation.

Panashield Selected as North American Partner for Dutch Microwave Absorber Solutions (DMAS)

Dutch Microwave Absorber Solutions (DMAS) has announced that Panashield has been selected as its North American Partner for exclusive distributor of their high quality absorbers products in the USA, Canada and Mexico. Panashield provides facility solutions for global EMC by creating controlled electromagnetic environments necessary for testing electronic devices. DMAS products include high performance polystyrene microwave absorbers suited for (semi) anechoic chambers.

For more information, visit DMAS at www.dmas.eu or Panashield at www.panashield.com.

SolaHD Introduces Next Generation of SHP Series Modular Power Supplies with Increased Power and Flexibility

SolaHD has announced their next generation SHP Series of heavy-duty power supplies featuring an enhanced modular design that allows customers to configure up to 24 output voltage combinations ranging from 2Vdc to 60Vdc. These new power supplies also feature a maximum 4,920 watts of increase power capability per case and intelligent modules that allow customers to choose between I2C and CANBUS/RS485 communications to monitor and control many attributes of the power supply.

Call 877-999-7652 or email egseg.customerservice@emerson.com for more information.

New Line of Amplifiers Designed for Wireless Testing Requirements

MILMEGA, now a part of Teseq, offers a new line of amplifiers designed to meet wireless test requirements from 700 MHz to 2.8 GHz. The AS0728 family is available in from 25 to 170 watts P1 dB power levels and are ideal in the wireless communications industry where high reliability, excellent linearity, power density and leading performance are required. These amplifiers are a standard 3U high and can be combined in rack mounted form to build higher power amplifiers.

For more information on this line of amplifiers, visit www.teseq.com.

Joslyn Surge Protection Devices Now Available with Steel Enclosures

Thomas & Betts announced their line of Joslyn® AC surge protection devices (SPDs) are now available with stainless steel enclosures for corrosive applications. They are suitable for protecting single, split and three-phase applications ranging from 120V to 600V Delta and are capable of handling high-surge energy from 20 kA to 400 kA per phase. Joslyn® SPDs protect operations from the damaging effects of electrical power surges, transients and noise from the service entrance to the equipment level.

For more information, visit www.tnbpowersoluations.com or call 800-816-7809.

Energy Micro, Linear Technology and Würth Elektronik Enables Fast Designs of Battery Less Products with the "Energy Harvesting Solution To Go"-Kit

The "Energy Harvesting Solution to go"-kit provides easy access to energy harvesting technologies which help developers to apply them in future battery less products.

The two basic parts of the kit are an energy harvesting board and the Giant Gecko starter kit.

For more information, visit www.we-online.com/harvest.

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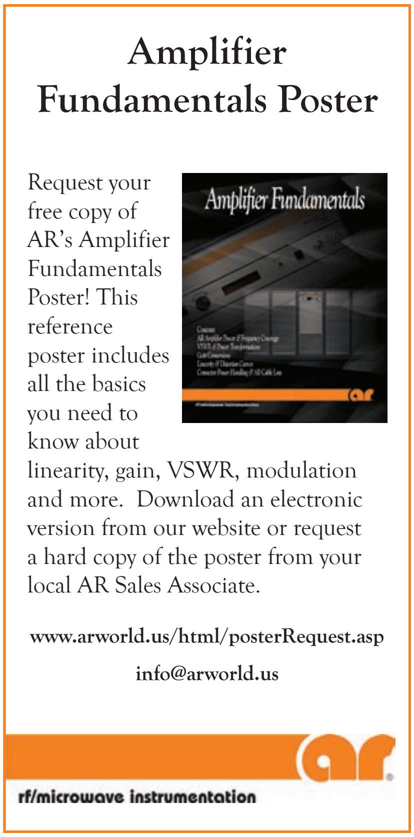

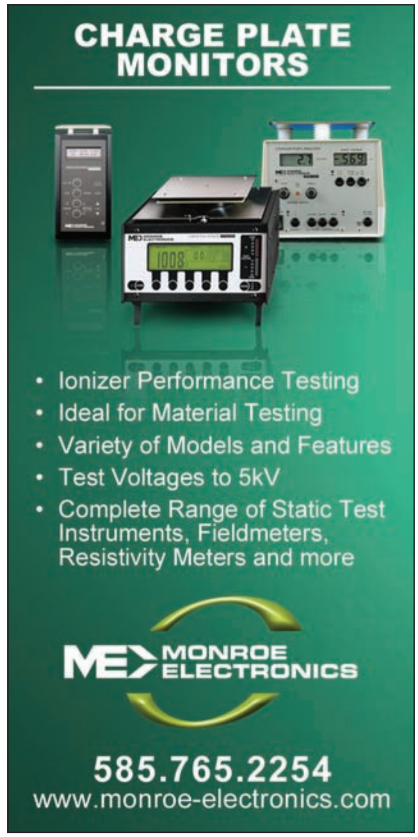

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(Authors)

BRUCE ARCHAMBEAULT
is an IBM Distinguished Engineer at IBM in Research Triangle Park, NC and an IEEE Fellow. He received his B.S.E.E degree from the University of New Hampshire in 1977 and his M.S.E.E degree from Northeastern University in 1981. For Bruce's full bio, please visit page 51.

SAM CONNOR
is a Senior Technical Staff Member at IBM and is responsible for the development of EMC and SI analysis tools/applications. His activities and research interests also include electromagnetic modeling and simulation in support of power distribution and link path design for printed circuit boards. For Sam's full bio, please visit page 51.

TED ECKERT
is currently a compliance engineer for Microsoft Corporation where he is responsible for products including video game systems and tablet computers and where he serves as Microsoft's representative to the U.S. National Committee for TC108. For his full bio, please visit page 43.

NIELS JONASSEN, MSC, DSC,
worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. Mr. Jonassen passed away in 2006. For Mr. Jonassen's full bio, please visit page 21.

THOMAS LANZISERO
is a Sr. Research Engineer and Distinguished Member of Technical Staff at UL LLC with nearly 30 years of applied practice in safety engineering. He is a registered Professional Engineer and principal instructor and practitioner of Hazard Based Safety Engineering. For Tom's full bio, please visit page 35.

BRIAN LAWRENCE
began his career in electromagnetics at Plessey Research Labs, designing "Stealth" materials for the British armed services. In 1973 he moved to the USA and established a new manufacturing plant for Plessey to provide these materials to the US Navy. For Brian's full bio, please visit page 16.

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 visit page 25.

DOUGLAS C. SMITH
Mr. Smith held an FCC First Class Radiotelephone license by age 16 and a General Class amateur radio license at age 12. He received a B.E.E. degree from Vanderbilt University in 1969 and an M.S.E.E. degree from the California Institute of Technology in 1970. For his full bio, please visit page 61.

MARK STEFFKA
is a Lecturer (at the University of Michigan - Dearborn), an Adjunct Professor (at the University of Detroit – Mercy) and an automotive company Electromagnetic Compatibility (EMC) Technical Specialist. For Mark's full bio, please visit pages 51 and 59.

NICK WAINWRIGHT
Nick has been involved with EMC all his working life, starting as an EMC test engineer in the telecommunications industry before moving into commercial testing. He is Chief Operating Officer of York EMC Services. For Nick's full bio, please visit page 57.

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