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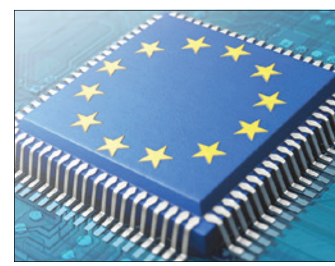

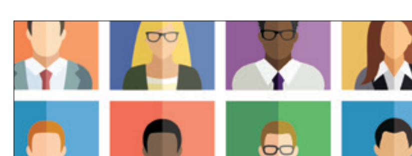

FCC Overhauls 5.9 GHz Band for Wi-Fi and Auto Safety

The U.S. Federal Communications Commission (FCC) has redesignated a portion of the 5.9 GHz band for Wi-Fi, automotive safety-specific technologies, and other currently unlicensed uses.

According to a Report and Order issued by the Commission in mid-November, the lower 45 megahertz (5.850-5.895 GHz) will now be designated for use by Wi-Fi and other unlicensed uses, while the upper 30 megahertz (5.895-5.925 GHz) will be designated for cellular vehicle-to-everything (C-V2X) technologies to enhance automotive safety.

Full-power indoor unlicensed operations in the lower 45 megahertz portion are permitted with immediate effect, and intelligent transportation services (ITS) services currently using that portion of the spectrum will have one year to transition to the upper portion of the spectrum. At the same time, the FCC's action designates C-V2X as the next generation technology standard for safety-related transportation and vehicular communications, signaling the transition away from legacy dedicated short-range communications (DSRC) technology.

The FCC says that the new spectrum designations will provide additional connectivity for Wi-Fi services while reducing the burden on cellular networks and while also speeding the deployment of ITS technologies that will improve automotive safety.

ARRL Seeks Waiver of Proposed FCC Amateur Application Fees

The ARRL, the national association for amateur radio, has requested that the U.S. Federal Communications Commission (FCC) waive its recently proposed fee for amateur radio applications.

The ARRL's waiver request was filed in response to the Notice of Proposed Rulemaking issued last month by the FCC, in which the agency proposed a fee of $50 for amateur radio applications to help recover the cost of processing those applications.

According to the ARRL, fees for amateur licenses have been excluded from the agency's fee collection schedule since 1985. The ARRL further argues that "unlike other FCC services, the Amateur Radio Service is all volunteer and largely self-governing with examination preparation, administration, and grading handled by volunteers, who submit licensing paperwork to the FCC."

"These volunteer services lessen the regulatory burden…on the Commission's resources and budget in ways that licensees in other services do not," the ARRL contends.

FDA Releases Guidance on EMC of Medical Devices

The U.S. Food and Drug Administration (FDA) has issued a guidance document for medical device manufacturers on the recommended information that should be provided in premarket submissions filed with the agency to demonstrate electromagnetic compatibility (EMC) for electrically powered medical devices or devices with electrical or electronic functions.

Posted to the FDA website, the guidance document embraces the "all-hazard approach" to device safety and encourages device manufacturers to provide EMC-related information in a number of specific areas. The FDA's draft guidance document replaces the agency's former guidance on the subject issued in July 2016.

U.S. Department of Defense Unveils Electromagnetic Spectrum Strategy

In a significant development, the U.S. Department of Defense has announced the release of its plan to maintain military superiority across the electromagnetic spectrum.

Released at the end of October, the "2020 Department of Defense Electromagnetic Spectrum Superiority Strategy" details the Department's plan to ensure its continued, unfettered and secure access to spectrum essential to the use of GPS, radio, satellite, and cellphone communications essential to our country's defense.

According to Frederick D. Moorefield, the deputy chief information officer for command, control, and communications, the Defense Department "is, perhaps the biggest user of spectrum in the United States." "DoD uses spectrum for almost everything wireless," he says. "Everything from tactical radios that the soldier uses in the field, or in operations, to satellite communications, to radar that we use to track objects and devices."

The strategy document details five separate goals for securing the electromagnetic spectrum (EMS), including: 1) develop superior EMS capabilities; 2) evolve into an agile and fully integrated EMC structure; 3) pursue total force readiness in the EMS; 4) securing enduring partnership for EMS advantage; and 5 establish effective EMS governance.

The Department's electromagnetic spectrum strategy was mandated by Congress as part of the 2019 National Defense Authorization Act, according to an article posted to the website of National Defense Magazine. The article also notes that the strategy could have "a wide-ranging impact on the acquisition enterprise including research and development and upgrades to legacy systems."

Defense Department officials are expected to release a detailed roadmap and implementation plan for its electromagnetic spectrum strategy next March.

CONTINUING YOUR PROFESSIONAL EDUCATION IN 2021

Compiled by the *In Compliance Magazine* Staff

The year past has brought unprecedented challenges to all of us. But often, times of overwhelming uncertainty also provide incredible opportunities to view the world through a different lens and bring innovative solutions to seemingly insurmountable problems.

This is certainly the case when we look at the landscape for professional development activities that emerged in 2020. While many scheduled in-person trainings and workshops were postponed or canceled altogether, training providers also embraced the potential of platforms like Microsoft Teams and Zoom and quickly revamped their offerings for virtual presentation. And, without having to incur travel expenses or spend time commuting to in-person training locations, participation in virtual learning offerings, including seminars, workshops, and symposia, has surpassed almost everyone's expectations.

Virtual offerings have their limitations and don't provide us with the same kind of engagement with presenters, instructors, and other participants as in-person events do. But the 2020 experiments with virtual learning have led to a dramatic broadening of professional development opportunities for industry professionals regardless of their location. And 2021 will no doubt see the widespread adoption of a variety of options for learners everywhere.

So, as 2021 begins, we've once again we've queried the training resources throughout our industry to provide you with an overview of free or affordable solutions to meet your training goals in the new year. In this article, you'll find sources of compliance-related seminars, workshops, and other types of training, offered live, including both virtual and in-person options, as well as pre-recorded webinars and on-demand training offerings.

The information that follows is current as we go to press (early December 2021). But please note that dates for live in-person seminars, workshops, and symposia provided here are subject to change. So check the listed websites for the most up-to-date information on scheduling. Finally, we invite you to submit updates and corrections as well as suggestions for additional listings for our Events section. Please send your comments to us at editor@incompliancemag.com.

LIVE VIRTUAL AND IN-PERSON SEMINARS AND WORKSHOPS

The **American Council of Independent Laboratories (ACIL)** hosts occasional live virtual webinars related to the Council's wide range of activities, including technical subjects, ACIL Committee activities, and laboratory business practices. For more information, go to https://www.acil.org/default.aspx and click on the word "Education" at the top of the page. (Also see listing under "Recorded Webinars and On-Demand Training")

The **American Association for Laboratory Accreditation (A2LA)** WorkPlace Training portal now offers virtual classroom trainings featuring live instructor-led sessions. Currently, there are more than 25 separate virtual training offerings, covering areas including international standards, management systems, technical subjects, and soft skills. As always, course instructors are subject matter experts with many years of professional training experience. 2021 dates for many A2LA trainings are now available. Additional details are available at http://www.a2lawpt.org. (Also see listings under "In-House/Custom Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

Keith Armstrong of **Cherry Clough Consultants Ltd.** will be the featured presenter at the EMC & Compliance International 2021 program in Newbury, Berkshire (United Kingdom) on May 19-20, 2021.

Over two days, Keith will present the following sessions:

- The Physics of SI, PI, and EMC Without Maths
- Circuit Design for Cost-Effective SI, PI, and EMC
- Shielding for Cost-Effective SI, PI, and EMC
- Filtering for Cost-Effective SI, PI, and EMC
- Essential PCB Design and Layout for Cost-Effective SI, PI, and EMC
- Advanced PCB Design and Layout for Cost-Effective SI, PI, and EMC

For more information, or to register, go to https://www.emcuk.co.uk/workshops-information. (Also see listings under "In-House/Customer Seminars and Workshops" and "Recorded Webinars and On-Demand Training)

This year, **Dangelmayer Associates** will virtually host and present its annual ESD workshop, "ESD Best Practices for Technology Change." The workshop will be held the week of July 19, 2021. Additional details and registration information is available at http://www.dangelmayer.com/training-workshops.php. Dangelmayer Associates will also present its multi-day ESD Auditor Certification Training in a virtual format. Go to https://dangelmayer.com/auditor-certification-course.php for more information.

Doug Smith of **D.C. Smith Consultants** will host virtual presentations of workshop "Lab Techniques, Robust Design, and Troubleshooting" in several four half-day sessions throughout 2021. Visit his website at https://emcesd.com/bcsem_hfmeasv.htm for the most up-to-date information and the 2021 schedule. Doug also continues to co-host the EMC Week in Boulder City, Nevada (U.S.), dedicated to helping participants to learn everything they need to know about EMC design and testing. This year's virtual event is scheduled for April 5-9. Find additional details for EMC Week at http://emcesd.com/bcsem_emcweek.htm.

Equipment Reliability Institute offers several live, in-person public classes throughout the year, including courses on "Military Standard 810 Testing" and "Fundamentals of Random Vibration and Shock Testing." For complete information and 2021 training dates, go to https://equipment-reliability.com/open-courses. (Also see listing under "In-House/Custom Seminars and Workshops")

The **ESD Association** offers access to a wide variety of live virtual and in-person educational opportunities throughout the year to provide engineers with the knowledge and tools needed to meet the challenges of ESD in their companies. The Association co-sponsors regional tutorials with local chapters, conducts a national tutorial and education seminar in conjunction with the annual EOS/ESD Symposium, and publishes and distributes numerous educational materials on ESD. For full details and their current schedule, visit the ESD Association's website at http://www.esda.org/training-and-education. (Also see listing under "Recorded Webinars and On-Demand Training")

ETS-Lindgren offers virtual training courses throughout the year. Courses planned for 2021 include:

- EMC Design and Antenna Test Implications for Today's Modern Vehicles – An Intensive 2.5 Day Workshop
- TILE!™ – Speed Trainings on Automated EMC Test Software for Novice to Advanced Users
- EMQuest™ – Antenna Pattern Measurement Software Tools and Tips to Make Your Testing Faster and More Efficient

For information about specific course dates and other course details, go to http://www.ets-lindgren.com/services/education-training. (Also see listings under "In-House/Custom Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

Eurofins York offers classroom compliance training throughout the year at various locations in the United Kingdom. Find out more at https://www.yorkemc.com/services/training. (Also see listings under "In-House/Custom Seminars and Workshops")

Dr. Bogdan Adamczyk of **Grand Valley State University** will offer his live in-person, two-day certificate course for the industry on "Principles of Electromagnetic Compatibility" on April 22-23, 2021, in Grand Rapids, Michigan. Course participants will perform numerous hands-on measurements in small groups to reinforce the course topics. The course is intended for both the practicing professionals and the new engineers entering the field. For additional details, go to http://www.gvsu.edu/emccenter.

Intertek offers live virtual and in-person public seminars and workshops throughout the year at various locations in the U.S. and around the world. Additional information is available at the company's "Knowledge and Education" portal at https://www.intertek.com/knowledge-education. (Also see listing under "Recorded Webinars and On-Demand Training")

Dr. Todd Hubing of **LearnEMC** will present two live virtual courses in the spring of 2021 ("Electronic System Design for EMC Compliance" and "Computer Modeling Tools for Electromagnetic Compatibility") and two in the fall ("Fundamentals of Electromagnetic Compatibility" and "Advanced Design for EMC Compliance"). These courses focus on fundamental concepts and tools that EMC engineers can utilize to avoid electromagnetic compatibility and signal integrity problems. For dates and additional details, go to https://learnemc.com.

Silent Solutions offers live in-person public workshops for design engineers interested in a practical, hands-on approach to EMC design, troubleshooting, and the special field concerned with circuit-to-circuit interference. Engineers working for manufacturers whose products target commercial and industrial environments will find this training extraordinarily useful. Visit http://www.silent-solutions.com/education/courses-and-events to learn more. (Also see listing under "In-House/Custom Seminars and Workshops")

TÜV SÜD America offers live virtual public training courses that are enhanced by the real-life experiences of its auditing and testing teams, offering years of experience in the worldwide international standards arena. These courses can help prepare you for the most challenging compliance issues. Visit their website at https://www.tuvsud.com/en-us/services/training/e-learning-courses to see the current offerings. (Also see listing under "Recorded Webinars and On-Demand Training")

UL is currently offering live digital events, webinars, and other forms of virtual training in the U.S. and locations around the world. The world's most progressive and safety-conscious companies rely on UL's educational programs for the expertise and tools required to design and install safer products, increase efficiency, realize improved speed to market, and ultimately advance their approach to prevention and compliance. A current listing of 2021 programs and dates is available at https://www.ul.com/events. (Also see listing under "Recorded Webinars and On-Demand Training")

Wyatt Technical Services, LLC is an independent consulting firm specializing in EMC design, troubleshooting, and training services to commercial and industrial manufacturers with global distribution in the consumer, computer, network and telecommunications, industrial, and scientific industries. Ken Wyatt will also be participating in the 2021 EMC Week in Boulder City, NV (U.S.). For further information, visit http://www.emc-seminars.com/page6/Schedule.html.

IN-HOUSE/CUSTOM SEMINARS AND WORKSHOPS

Many experts and training organizations offer standard and/or customized workshops and seminars and workshops on an in-house basis. These training programs offer companies an opportunity to train multiple compliance personnel with a specialized approach designed for their needs. Following is a list of organizations and trainers that offer both virtual and in-person seminars and workshops for in-house presentation.

The **American Association for Laboratory Accreditation (A2LA)** also offers customized laboratory staff training on a number of topics. Go to https://www.a2lawpt.org/contract for more information. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

Vladimir Kraz of **Best ESD Technical Services** offers in-house classes on all aspects of managing and mitigating ESD, EOS, and EMI issues in today's manufacturing environment. Classes include electrical overstress in electronic manufacturing and the application of SEMI E176 and E33 in semiconductor manufacturing. Classes are focused on specific processes and technologies employed by the participants. For additional information, go to http://www.bestesd.com.

Keith Armstrong of **Cherry Clough Consultants Ltd.** also offers an array of live, in-house seminars on a virtual basis, covering a wide range of topics from his extensive training portfolio. Customized or more specialized virtual training for up to 1000 attendees is also available on request. For more information, go to https://www.cherryclough.com/Custom-Training-Courses. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

ETS-Lindgren offers customized trainings on various test and measurement topics for your engineers and test technicians. From standards updates to how to perform an Acoustic, 5G, or EMC test and more, ask how we can increase the productivity of your team. Go to http://www.ets-lindgren.com/services/education-training for more information. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

Equipment Reliability Institute also provides on-site training on a broad range of testing and design topics. For more information, go to http://www.equipment-reliability.com/onsite-courses. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

Eurofins York also offers customized, in-house training offerings in addition to their comprehensive schedule of public training programs. For additional details on their "bespoke" training options, go to https://www.yorkemc.com/services/training/on-site-training. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

Ikonix USA offers customized 1- or 2-day compliance training options at your site. For more information, go to https://www.ikonixusa.com/on-site-training-package.

Daryl Gerke of **Kimmel Gerke Associates, Ltd.** continues to offer in-house training on a virtual basis. His two-day course on "Design for EMC" focuses on EMC problems and how to identify, prevent, and fix more than 40 common EMI/EMC problems at the equipment level. His other virtual in-house course, "EMC in Military Systems," addresses issues stemming from four key EMC interfaces, grounding, shielding, power, and cables. For further details, visit http://www.emiguru.com/seminars.

Mark Montrose of **Montrose Compliance Services** offers customized, in-house training programs and workshops on achieving EMC compliance and EMC design fundamentals and techniques. For more information, go to https://montrosecompliance.com/emc-training-seminars/seminars_courses.

Silent Solutions (http://www.silent-solutions.com) offers many of its live public seminars and workshops for private, in-house delivery, and can also customize its offerings to address specific organizational needs and requirements. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

RECORDED WEBINARS AND ON-DEMAND TRAINING

Your time is valuable and your schedule doesn't always allow you to participate in live virtual and in-person presentations. But there are plenty of training options that you can take advantage of, right from the comfort of your daily workspace. Many organizations and training experts provide on-demand webinars, as well as books, podcasts, and e-learning programs. Here are a few options to get you started:

The **American Council of Independent Laboratories (ACIL)** also hosts an archive of previously recorded webinars that are available on-demand, covering EMC standards, key EMC committee meetings, and other EMC activity. Go to https://www.acil.org/page/ACIL_Webinars for more information. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops")

The **American Association for Laboratory Accreditation (A2LA)** offers a comprehensive suite of self-paced e-learning options through its WorkPlace Training portal. More than 30 different courses providing the equivalent of hundreds of hours of training are currently available, including online training on ISO/IEC 17025 compliance. For more information, visit http://www.a2lawpt.org/e-learning. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "In-House/Custom Seminars and Workshops")

Keith Armstrong of **Cherry Clough Consultants Ltd.** provides a wide range of training course modules for assembling customized in-house webinars for individual organizations, single-site or multi-site, worldwide. These are confidential, enabling detailed design discussions. PDF-formatted color course notes for these modules may be downloaded at https://www.emcstandards.co.uk/online-training. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops" and "In-House/Custom Seminars and Workshops")

EMC Fast Pass provides comprehensive online training courses and short courses to assist electronic engineers, compliance specialists, and hardware manufacturers design and test products that pass EMC and RF certifications the first time. Course offerings include:

- EMC Design for Compliance (Immunity)
- EMC Design for Compliance (Emissions)
- Intrinsically Safe Hardware Design
- EMC Troubleshooting and Pre-Compliance Testing
- EMC Testing Foundations
- FCC Wireless (RF) Pre-Compliance

Additional information is available at https://emcfastpass.com/training/index.php/course-listings.

The **ESD Association**, in addition to its live virtual and in-person public seminars and workshops, also hosts online classes and training videos through the ESDA Online Academy at https://www.esda.org/store/training-and-education. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

ETS-Lindgren also offers a number of previously recorded webinars that are available on-demand. Details are available at http://www.ets-lindgren.com/services/education-training. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "In-House/Custom Seminars and Workshops")

Intertek's extensive catalog of live and on-demand webinars complements the company's live virtual and in-person training options. Additional information is available at https://www.intertek.com/knowledge-education/webinars. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

NTS has launched its TESTalks series of free, on-demand webinars on MIL-STD 461G. This five-part series covers key aspects of this important standard, including conducted and radiated emissions and susceptibility considerations. For more information, go to https://www.nts.com/nts-testalk.

Rohde & Schwarz offers a complimentary, five-track, on-demand webinar series covering EMC essentials, testing essentials, RF fundamentals, RF testing, and digital testing. To access the complete webinar series, go to https://www.rohde-schwarz.com/us/campaigns/rsa/icr/everything-test-webinar-series_254047.html.

TÜV SÜD America offers on-demand webinars covering various topics in the areas of product safety, EMC, management systems, and competency assessments. Go to the TÜV SÜD Resource Center at https://www.tuvsud.com/en-us/resource-centre to learn more. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

UL also provides safety- and compliance-related training delivered via its extensive library of on-demand webinars. Topic areas include hazard-based safety engineering, global market access and global directives, code compliance, conformity assessment, sustainability, responsible sourcing and social auditing, and many more. For additional details, visit https://www.ul.com/events/on-demand-webinars. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

INDUSTRY SYMPOSIA, CONFERENCES AND EXHIBITS

Annual symposia are an excellent resource for extensive technical training, as well as the exchange of new ideas and technical concepts. The benefit of attending these events is that attendees can sample a vast array of workshops quickly and efficiently while connecting with colleagues and professionals with the same interests. (The symposia listed below are currently planned as live in-person events unless otherwise noted. Please check the listed website for up-to-date information on dates and locations.)

European Microwave Week 2020
January 10-15, 2021 – Jaarbeurs Utrecht, the Netherlands
https://www.eumweek.com

EuCAP 2021 – The 15th European Conference on Antennas and Propagation
March 22-26, 2021 – Dusseldorf, Germany
http://www.eucap2021.org

EMV 2021
March 23-25, 2021 – Stuttgart, Germany
https://emv.mesago.com/koeln/en.html

RF & Microwave 2021
March 31-April 1, 2021 – Paris, France
http://www.microwave-rf.com

2021 International Applied Computational Electromagnetics Society Symposium
Not yet scheduled. Check their website for current information at https://aces-society.org/conference/Monterey_2020.

DesignCon 2021
April 13-15, 2021 – San Jose, California (U.S.)
https://designcon.com

2021 IEEE International Symposium on Product Compliance Engineering (ISPCE)
Not yet scheduled. Check their website at http://2020.psessymposium.org for current information.

2021 IEEE International Instrumentation and Measurement Technology Conference (I^2MTC)
May 17-20, 2021 – Virtual
http://i2mtc2021.ieee-ims.org

EMC & Compliance International Exhibition & Workshops
May 19-20, 2021 – Newbury, Berkshire, United Kingdom
https://www.emcuk.co.uk

2021 Asia-Pacific International Symposium on Electromagnetic Compatibility
May 25-28, 2021 – Bali, Indonesia
https://apemc2021.org

IMS 2021 – 2021 International Microwave Symposium
June 6-11, 2021 – Atlanta, Georgia (U.S.)
https://ims-ieee.org/ims2021

Sensors Expo & Conference
June 28-30, 2021 – San Jose, California (U.S.)
https://www.sensorsexpo.com/cancellation-update

2021 Joint IEEE International Symposium on Electromagnetic Compatibility, Signal and Power Integrity, EMC Europe
July 30-August 6, 2021 – Virtual
https://www.emc2021.emcss.org

The Battery Show 2021, North America
Not yet scheduled. Check their website at https://thebatteryshow.com for current information.

43rd Annual Electrical Overstress/Electrostatic Discharge Symposium
September 20–October 1, 2021 – Tucson, Arizona (U.S.)
https://www.esda.org/events/43rd-annual-eosesd-symposium-and-exhibits

43rd Annual Symposium of the Antenna Measurement Techniques Association (AMTA)
October 24-29, 2021 – Daytona Beach, Florida (U.S.)
https://www.amta2021.org

IEEE EMC SOCIETY 2021 REGIONAL EVENTS

2021 Chicago IEEE EMC Mini Symposium
Not yet scheduled, Check their website at http://www.emcchicago.org for current information.

EMC Fest 2021
May 13, 2021 – Livonia, Michigan (U.S.)
https://www.emcsociety.org/wp/?page_id=35

2021 Minnesota EMC Event
September 23, 2021 – Bloomington, Minnesota (U.S.)
https://www.mnemcevent.com

We hope this list will help you meet your professional development goals in 2021. Many additional trainings and events will be planned throughout the year, so be sure to check our events calendar at https://incompliancemag.com/event-directory to find the most up-to-date information. Another way to brush up on the basics and delve deep into advanced topics is by visiting our online resource center, the *In Compliance* Electrical Engineering Resource Center (EERC) at https://incompliancemag.com/eerc.

THE EU CONFLICT MINERALS REGULATION

Implications for the Electronics Sector

Dr. Alex Martin is Principal Regulatory Consultant at RINA. Alex provides advice and compliance support on various regulations affecting electro-technical products, from EMCD, LVD, and RED through to environmental laws like RoHS, REACH, and WEEE. Alex can be reached at alex.martin@rina.org.

By Alex Martin

Over the last 10-15 years, supply chain management has increasingly entailed addressing environmental, social, and governance (ESG) issues alongside the likes of quality, cost, service, and delivery. This has been experienced in the electronics industry, but equally the likes of the textiles and apparel, jewelry, automotive, and aerospace and defense sectors. Corporate practices have changed in light of campaigning by political activists and non-governmental organizations, as has legislation and/or government-backed voluntary initiatives.

For those involved in the manufacture, distribution, and sale of electrical and electronic equipment, understanding "conflict minerals" – metals and minerals derived under duress and traded to keep armed groups funded – is likely best cast in terms of the wider identification, assessment, and management of ESG risks in supply chains (other risks might include, for example, child and forced labor, corruption and bribery, environmental pollution, etc.). While existing legislation may not apply to your business today, it might tomorrow.

Moreover, customers may have their own expectations and pressures can come from other actors like campaign groups and investors. This is emphasized early on in this article, specifically as the EU Conflict Minerals Regulation does not presently apply to electrical equipment manufacturers, although they are a target of an EU effort to encourage voluntary disclosure on conflict mineral uses (on which, more below).

BACKGROUND

Human history is littered with conflicts arising from natural resource access, so in one sense, the concept of a "conflict resource" or "conflict mineral" is nothing new. However, at any given time, some natural resources will likely prove more valuable than others. Over the last 30 years or so, demand for tin, tantalum, tungsten, and gold (the so-called "3TG" and what are presently considered "conflict minerals") has made controlling their extraction and processing lucrative. Table 1 lists 3TG uses in a variety of products, electrical and electronic equipment included.

Tin	• Used in alloys, tin plating, and solders for electronic circuits. • Used in car parts ranging from engine components through to gears, pumps, joints, and windshields. • Used as solder in buttons, zippers, and other fasteners as well as in jewelry. Composite material in rivets and eyes.
Tantalum	• Used mainly to produce tantalum capacitors, particularly for applications requiring high performance, small format and high reliability, such as hearing aids, pacemakers, global positioning systems (GPS), laptops, mobile phones, and games consoles.
Tungsten	• Used in metal wires, electrodes, contacts in lighting, and electronic, electrical and heating applications. Tools may incorporate tungsten, often when alloyed with steel.
Gold	• Present in some chemical compounds used in semiconductor and manufacturing processes. • Used as plating to produce the shine on zippers, fasteners, and other metal components. • Composite metal in or on jewelry and watches.

Table 1: 3TG uses

The last decade has been marked by governments, specifically in the developed world, increasingly recognizing and highlighting concerns to industry over the use of conflict minerals in the manufacture of products.

In turn, control of these resources and trade in them can become a political flashpoint and something fought over in civil wars. This was the case in the Democratic Republic of the Congo (D.R.C.) in the late 1990s and early 2000s, when the First and Second Congo Wars entailed both the Congolese national army and rebel groups seeking control over 3TG mining, which encompasses many artisanal and small-scale mines.

Conditions in such mines are tough. Miners are known to work up to 48 hours at a time and risk life and limb in an environment of mudslides and tunnel collapses. As well as the human cost associated with this type of mining, the wars in the D.R.C. region have caused the deaths of more than five million people, many due to disease and starvation. Although progress has been made towards a lasting peace since the wars ended, armed groups retain control over some mines, and the trade in conflict minerals persists.

U.S. AND EU REGULATORY RESPONSES

The last decade has been marked by governments, specifically in the developed world, increasingly recognizing and highlighting concerns to industry over the use of conflict minerals in the manufacture of products. This has led to legislation, with the earliest adopter being the U.S. with the Dodd-Frank Act of 2010. Section 1502 of this particular law sets requirements for companies whose products incorporate 3TGs derived from the D.R.C. and neighboring countries.

Provisions of the Dodd-Frank Act were implemented through inclusion within the general rules and regulations of the Securities Exchange Act of 1934, specifically Section 240.13p-1. This requires "issuers" – major stock market-listed companies required to make regular Securities and Exchange Commission (SEC) filings – to report on efforts to eliminate conflict-implicated 3TGs from supply chains if they are used in their products. Companies covered by Section 240.13p-1 must take the following steps:

- Determine applicability;
- Conduct country of origin inquiry;
- Establish a due diligence process;
- Determine status; and
- File a report.

The Dodd-Frank Act does not prescribe a due diligence process, but the Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas,[1] published by the Organization for Economic Co-Operation and Development (OECD), is cited as a suitable reference. At the core of the OECD's Due Diligence Guidance is a five-step framework, as summarized in Table 2.

In 2017, the EU adopted its own law concerning conflict minerals, Regulation (EU) 2017/821.

Regulation (EU) 2017/821 applies to EU-based importers of 3T ores and concentrates as well as gold above certain defined thresholds, as detailed in the Regulation's Annex I. For in-scope importers, obligations span establishing suitable management systems, assessing and managing relevant supply chain risks, conducting third-party audits, and information disclosure.

It is worth highlighting that the EU law is quite different from the Dodd-Frank Act, with the following summarizing specific points of difference:

- The EU Regulation does not impose any obligations upon "downstream users" of 3TGs, i.e., manufacturers of components or finished products, unless they also happen to be importing 3TGs into the EU. By comparison, U.S. legislation does apply in the downstream, with publicly listed companies that manufacture or contract to manufacture products that contain 3TG falling within the scope of the legislation.

- Unlike Dodd-Frank, the EU Regulation exempts small volume importers of 3TG. No such exemption exists under the U.S. legislation.
- The EU Regulation is more specific in defining what 3TG ores, concentrates and metals come within its scope. The Regulation's Annex I gives a lot of detail, including combined nomenclature codes.
- Geographically, the EU Regulation is non-specific. Rather, the law concerns itself with 3TG sourced from conflict-affected and high-risk areas (CAHRAs) that might exist in the world. The U.S. legislation is specific though, applying only to conflict minerals sourced from the D.R.C. and its nine neighboring states.

As such, electrical equipment manufacturers are not directly affected by the EU Regulation in the way that they otherwise might fall within the scope of the Dodd-Frank Act if publicly listed in the U.S. (e.g., as the likes of many of the largest consumer electronics companies are). However, this is not to say that EU policy-makers had not given thought to the EU Regulation applying to downstream users of 3TGs, including businesses in the electronics sector. They had, and for those interested in the discussions that took place and what compromise was reached before the Regulation was adopted, a partial record exists within minutes of the European Commission's "Member State Expert Group on responsible sourcing of tin, tantalum, tungsten, and gold" that are available online.[2]

Minutes from the 9 March 2018 meeting of this Group reveals that the compromise which saw Regulation (EU) 2017/821 "based on only importers of metals and minerals being covered by the legal requirements of the Regulation" entailed an expectation that "a series of measures also should be taken to retain the focus on and validity of efforts taken by downstream companies." What, then, of these measures?

THE EU'S "TRANSPARENCY PLATFORM FOR DOWNSTREAM COMPANIES"

At the time of writing, the measure of most prominence and greatest significance for

	Step	Practice
1	Establish strong management systems	• Adopt and commit to a supply chain policy for conflict minerals. • Establish a system that allows the identification of the smelters in the company's mineral supply chain. • Maintain records (preferably electronic) for at least five years. • Incorporate policies and traceability into supplier agreements and contracts. • Establish mechanisms for grievances and whistle-blowers.
2	Identify and assess risks	• Identify smelters/refiners in supply chain. • Assess due diligence practice of smelters.
3	Respond to risks	• Report findings to senior management. • Exercise leverage over suppliers that can work most effectively to mitigate risks further back in the chain. • Monitor, track, adapt, and adjust risk mitigation efforts.
4	Audit	• Carry out an independent third-party audit of smelter's/refiner's due diligence program.
5	Publicly report	• Report – preferably in annual sustainability or corporate social responsibility reports – on the due diligence program, such as: the company policy, responsible management, steps taken to identify and assess smelters/refiners.

Table 2: The five-step framework of the OECD Due Diligence Guidance

manufacturers, importers and distributors of components and finished products (including but not limited to items of electrical and electronic equipment) is the proposed transparency platform. Detail related to this can be found within minutes of the above-mentioned Member State Expert Group, but the author was fortunate enough to get an insight from a European Commission policy officer first-hand when she presented on conflict minerals at the RINA Electrical and Electronic Equipment and the Environment Conference in November 2019. This presentation revealed that the platform is to take the name of "ReMIS," the Responsible Minerals Information System.

REMIS: WHAT WE KNOW SO FAR

The European Commission describes[3] it as an "information system that aims to support downstream companies, in particular, to share and publish – on a voluntary basis – information regarding their due diligence practices and exchange best practices in this regard." The European Commission has also outlined how the system will likely work, with company-submitted registration information initially being reviewed and "validated" by the Competent Authority appointed under Regulation (EU) 2017/821 of the EU Member State in which the company is legally based.

To register, business information including name and address, supply chain position (upstream/downstream), industry sector(s) in which the business is active, metals and minerals handled, and a summary account of due diligence practice appears to be anticipated. It would then seem that any more detailed information a company wished to share for online publication on ReMIS would be reviewed by a designated European Commission service desk. What this review would entail is, however, currently unclear.

A prototype version of ReMIS has been tested, with at least some industry stakeholders involved in this testing. This is reported upon in the 5 June 2019 minutes of the responsible sourcing Member State Expert Group, which notes that "the Commission received positive feedback on the usability and functionalities of the system." However, it seems that safeguarding personal data is a concern, as is managing both European Commission and Member State Competent Authority compliance with requirements under the EU General Data Protection Regulation (GDPR). Concerning this, the Commission has prepared an initial draft of a GDPR-required "joint controllership agreement," but it is not known whether this has been accepted at the time of writing.

IMPLICATIONS FOR ELECTRICAL EQUIPMENT MANUFACTURERS

It is likely that, in the years ahead, the European Commission's ReMIS platform will result in various businesses that use 3TGs in their components and products publicly reporting upon this, as well as the efforts they are taking to assure themselves that 3TGs are responsibly sourced. Demand for information may come from the investment community, particularly to help the community become better informed – and so able to assess – ESG risks within business supply chains.

How, then, to prepare for this?

Many large, consumer-facing electronics companies whose products incorporate 3TGs have already taken significant strides in their management practices. Among them are Apple, Dell, HP Inc., and Intel. The way these companies have responded provides insight into how to manage and report upon conflict mineral uses in electronics supply chains.

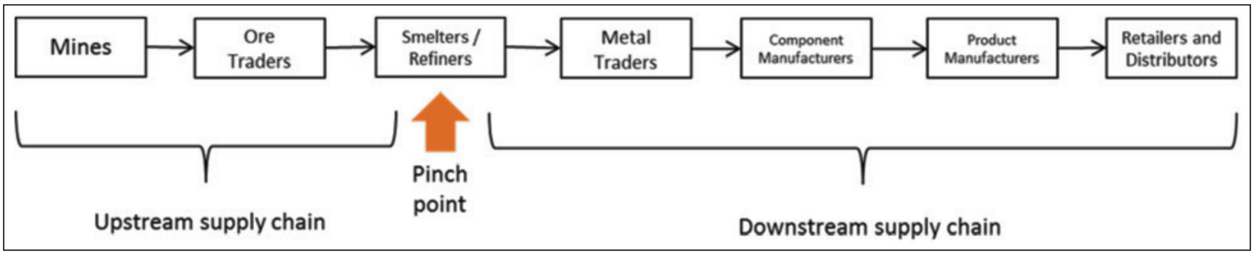

Figure 1: Actors in a minerals supply chain

Many large, consumer-facing electronics companies whose products incorporate 3TGs have already taken significant strides in their management practices. Among them are Apple, Dell, HP Inc., and Intel.

There is overlap in practice, which includes policy- and goal-setting, surveying suppliers, determining smelters in use, comparing smelters with those on approved lists (e.g., as published by the U.S.-based Responsible Minerals Initiative, "RMI"[4]), arranging smelter audits, and running awareness-raising training events. It is worth explaining the emphasis placed upon smelters here, and this is simply because they are perceived to constitute the "pinch point" in minerals supply chains (see Figure 1[5]).

For practitioners, the following steps are advisable:

- Understand and scale the challenge facing your company. This is likely to include determining possible 3TG uses in products, then determining which suppliers you are going to engage with and how you are going to do this (e.g., by working up your own survey or making use of, say, the RMI Conflict Minerals Reporting Template[6]).
- Frame the company response, either with a new program of work or by expanding existing ones (e.g., programs for managing substance restrictions found in, for example, the EU RoHS Directive and/or EU REACH Regulation). Initially, this will be a top-level exercise anticipated to entail achieving senior management buy-in, securing a budget, documenting key policies and procedures, and determining roles and responsibilities for the likes of contacting suppliers and the collection, collation, and analysis of data. Cross-functional work is expected, so even if the program is owned and led by an Environmental or Corporate Responsibility Manager, the support of personnel from, for example, Procurement, Finance, and IT, should be considered, approved, and documented early on.
- Consider the optimal IT solution. This will depend on how many products and suppliers you are dealing with. If a large number, this will result in a lot of data, making a more automated (and sophisticated) solution desirable.
- Document as you go, including scoping decisions and other such judgements. This is good practice with regard to due diligence, constituting a record of key decision-making and reasoning deployed.
- Phase the program in, monitoring as you proceed. This provides scope for identifying problems and making corrections for better implementation overall.

Fostering a perspective that goes "beyond compliance" will be beneficial. To see conflict minerals as something to be complied with is to miss potential opportunities like reducing supply-side ESG risk and enhancing relationships with preferred suppliers and customers. It is something the investment world is also likely to use to assess company performance in the future, so getting ahead with respect to practice and disclosure may offer a competitive advantage.

ENDNOTES

1. http://www.oecd.org/corporate/mne/mining.htm
2. Accessible through the "Meetings" tab on the webpage of https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3256
3. Information comes from the presentation "The EU Regulation on responsible sourcing of minerals ("Conflict Minerals"): progress on implementation" given by Zora Mincheva, DG TRADE Policy Officer, to the RINA EEE & the Environment Conference on 14 November 2019.
4. http://www.responsiblemineralsinitiative.org/smelters-refiners-lists
5. Adapted from ChainLink Research, "Turning conflict minerals law compliance into a competitive advantage," September 2013.
6. https://www.conflict-minerals.com/solution/cmrt-512

STANDARDS PLAY A KEY ROLE IN ENABLING INNOVATION

Why standards-based conformity assessment is critical and how companies can get involved

Innovative new technologies typically come from individual companies rather than from standards bodies. Even so, standards play a critical role in making those brand-new technologies something that enterprises and other end-users feel comfortable buying. Put simply, standards enable new technologies to go mainstream and allow customers to choose best solutions from multiple vendors.

Vendors often start selling a new technology years before relevant standards are published. They know that consumers and businesses want the latest and greatest technologies, so they frequently ship pre-standard versions to meet that demand. If they don't, they could be at a competitive disadvantage.

This practice raises a host of questions – some philosophical, some practical – about the role that standards play for vendors, their customers, and the challenges they face when trying to get the latest technology implemented to gain competitive advantage. Some of these questions include:

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By Ravi Subramaniam

- Should early adopters delay the launch of pre-standard products or accept the associated risk? Analysts often advise enterprises to wait until a standard has been ratified.
- Vendors typically layer on additional, proprietary features to help differentiate their products. However, if these features are not based on an approved standard, there is a possibility that the features may not be interoperable with systems built on the approved standard.
- Standards can be interpreted in different ways. Vendors need documentation of what requirements must be met to claim conformance so that differences in interpretations are minimized. So how much can enterprises and other end-users rely on standards for enabling multi-vendor environments?

Vendors have a vested interest in helping the industry as a whole address these challenges. For example, some enterprises might be reluctant to buy new gear – pre-standard or not – because they don't want the expense of resolving interoperability issues. That means lost or delayed revenue for vendors.

Some enterprises are willing to buy pre-standard solutions, but only on the condition that their vendors provide warranties and other assurances that they will bear responsibility for resolving any interoperability issues. Vendors also have costs associated with helping customers resolve interoperability issues, such as staffing up to field those inquiries, investigating them, and offering solutions. Those support costs may significantly increase.

TESTING FOR THE COMMON GOOD

Now for some good news. The same organization behind most major technology standards – the IEEE – also provides multiple opportunities for vendors to overcome these challenges. In the process, vendors also can play a key role in ensuring that standards anticipate their needs and the needs of their customers. That involvement keeps standards ahead of the curve, not behind it.

To understand how to consider the example of synchrophasors. They're a key part of the power grid and provide utility operators with time-synchronized data about the current, voltage, and frequency at each location.[1] That information helps operators avoid blackouts and brownouts by pinpointing where to upgrade infrastructure to maximize capacity and reliability. In fact, synchrophasors are so important for smart grids that the U.S. American Recovery and Reinvestment Act of 2009 helped fund more than 1000 of them, worth over $328 million.

Synchrophasors also provide a cautionary tale that highlights the importance of independent technology certification—not only for utilities but for just about every other industry too. In 2014, the National Institute of Standards and Technology (NIST) tested a variety of phasor measurement units (PMUs)[2] using the IEEE C37.118.1-2011 Standard for Synchrophasors for Power Systems[3] and found that 80 percent of the units tested weren't compliant. Many of the vendors whose PMUs failed subsequently made changes, resubmitted them, and then passed.

The moral of this story is that vendors—in any industry—can avoid the time, expense, and negative PR of re-engineering their products by participating in independent certification *before* bringing them to market. This also helps them avoid developing a reputation for recalling products due to non-compliance, as well as the expense of reimbursing customers whose operations are disrupted.

It's important to note that a standard outlining requirements for a new technology may not address all aspects of implementation for that technology. Some of those aspects aren't immediately obvious to vendors and end-users. Hence, the importance of testing and certification, which can help identify those shortcomings, misunderstandings, and other gaps, thus contributing to improvements in the standard's quality and value. In the process, testing/certification can accelerate the adoption of new technologies by helping to validate interoperability. In the case of the synchrophasor testing performed by NIST, for example, the lessons learned from the testing subsequently led IEEE SA to publish a revision in 2014 to address some ambiguities in the standard and to adjust some performance limits.

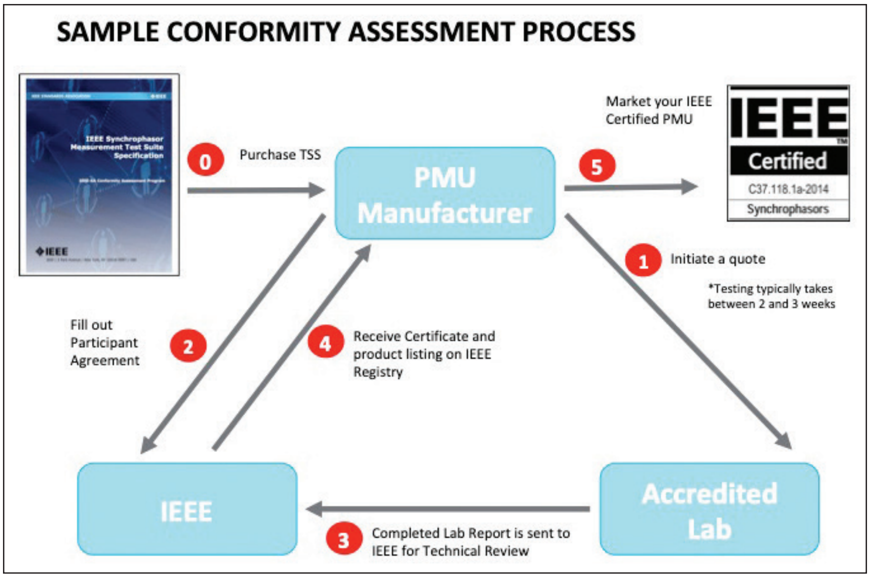

Figure 1: How the conformity assessment process works

HOW IEEE CONFORMITY ASSESSMENT PROGRAMS WORK

Numerous vendors, consultants, and other companies worldwide participate in IEEE Conformity Assessment Programs (ICAP),[4] which use a steering committee format to holistically develop conformity assessment programs around specific standards. ICAP helps IEEE working groups navigate through the conformity assessment ecosystem, which may encompass conformance testing, commissioning, interoperability, inspection, and laboratory recognition, as well as the development of test suite specifications or plans.

ICAP partners with expert test labs around the world to provide the right level of testing and field evaluation support. One example is the University of New Hampshire InterOperability Lab (UNH-IOL),[5] whose capabilities include testing to the IEEE 1588 ™ Precision Time Protocol for Power Applications. Consumers Energy Laboratory Services[6] became the first lab recognized by ICAP to perform testing of the phasor measurement units based on the IEEE C37.118 standard. ICAP worked collaboratively with NIST and other key players to ensure the right test tools and methodologies were utilized in the testing process.

Figure 1 illustrates how the conformity assessment process works, using synchrophasor PMUs as an example.

ICAP provides the marketplace with several benefits:

- Manufacturers get a proven method of demonstrating compliance with requirements.
- A trustworthy public registry of certified products gives enterprises and other end-users a convenient, credible way to verify which products have successfully completed conformity testing and certification, including addressing software/firmware modifications and product changes.
- As an independent resource, ICAP empowers end-users to reduce risk by making more informed purchasing decisions. For example, the IEEE certification mark gives them peace of mind that their new products will be more likely to interoperate with other certified products.
- New technologies establish themselves in the market with stable and robust products. This also helps the market grow quickly because customers don't postpone purchases for fear of being de facto beta testers.
- Manufacturers, systems integrators, and the rest of a technology's ecosystem have a shared resource for testing and certification. That cooperation significantly reduces their individual costs and upkeep compared to doing testing entirely on their own.

ICAP PORTFOLIO SPANS MULTIPLE INDUSTRIES

In addition to synchrophasors, the ICAP portfolio[7] spans a wide variety of verticals and technologies, including drones/UAVs, time-sensitive networking for industrial automation, cybersecurity, blockchain, federated learning, autonomous vehicles, medical devices, sensors, and the Internet of Things:

Smartphone Cameras

IEEE 1858™[8] provides image-quality standards for mobile camera videos and images, including those used in smartphones. Participants such as mobile operators, operating system vendors, handset manufacturers, chipset vendors, software providers, and test labs use these standards to enable "apples-to-apples" comparisons between different products. This overcomes the challenges that occur when everyone uses their own methodology for spatial frequency response, chroma level, color uniformity, texture blur, and other key metrics.

Electric Vehicles

Over 3.7 million electric vehicles (EVs) were sold worldwide over the past two years. That's an impressive number, considering that consumers and businesses are concerned about running out of power before they can get to a charging station, how long charging takes, and whether a public charging station will be compatible with their EV model. Meanwhile, electric utilities are concerned about the grid's ability to support the exponential increase in EVs each year.

To help the EV ecosystem address these and other market-limiting concerns, the IEEE 2030.1.1™ DC Quick Charging Test Suite Specification provides a wide variety of test cases, which each participating lab uses to ensure that its methodology is consistent. For example, one test case checks whether a charger meets the standard's voltage resistance properties. Another assesses whether a charging panel designed for indoor use has a minimum rating of IP 41, which protects against water intrusion.

IEEE is currently revising the IEEE 2030.1.1 standard to include bi-directional charging and ultra-rapid charging up to 400 kW. The existing certification program will also be updated to ensure testability and certification of those chargers. These super-fast chargers are key for addressing EV buyers' concerns about being able to charge quickly. Fast charging also enables each station to support more EVs because they're in and out in less time.

Precision Timing for Energy Infrastructure

Electrical utilities and other members of the energy industry rely on the IEEE 1588 Precision Time Protocol (PTP) standard to ensure that their infrastructure is tightly synchronized down to the sub-microsecond range. ICAP worked with NIST and other industry stakeholders to create a test suite specification (TSS) that provides a common approach to verifying a clock's performance with the requirements of IEEE 1588.

The IEEE 1588 Power Profile Certification program was critical for addressing challenges that many utilities encountered. For example, one said, "We crudely simulated a time spoofing incident and found devices did not follow the time when step changes were introduced." According to another, "We've seen devices update the timestamp/correction-field in the incorrect location."

Figure 2 on page 26 summarizes the key benefits that ICAP provides for vendors and end-users.

HOW TO GET INVOLVED

Beyond conformity assessment activities, there is a benefit for vendors, end-users, and others in participating in IEEE working groups so they can be involved in the standards-development process. This is an opportunity to influence new standards and get a valuable insider's perspective into the future. IEEE working groups also provide a convenient, invaluable opportunity to network with other industry leaders. Even if a vendor or end-user doesn't have the time or the resources to participate in working groups, another option is to share their expertise about what an ICAP program should assess for new standards. Some vendors, end-users, test laboratories, and others choose to participate in both working groups and ICAP programs.

The IEEE recently initiated the development of a credentialing program for the IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems, which is key for supporting and enabling the rapidly growing use of renewable energy sources such as wind, solar, and energy storage. In fact, some states have adopted it as a standard in their statewide interconnection regulations.

When launched, the new credentialing program is expected to address the impending need for a trained and knowledgeable workforce, who may be part of engineering and consulting firms, electrical contractors, and other implementers of IEEE 1547. The expectation is that this new program will help expand the use of renewable energy worldwide.

CONCLUSION

Vendors and everyone else in a particular ecosystem – whether it's wireless technology, drones, or EVs – benefits when conformity-assessment work is done in parallel with standards development because both can be available simultaneously. Otherwise, implementation of a new technology could be delayed until after the conformity-assessment work is done. That delay doesn't benefit vendors that are eager to provide customers with cutting-edge technology solutions.

But by working together, vendors can implement their new, standards-based technologies successfully. That's a future we all can look forward to.

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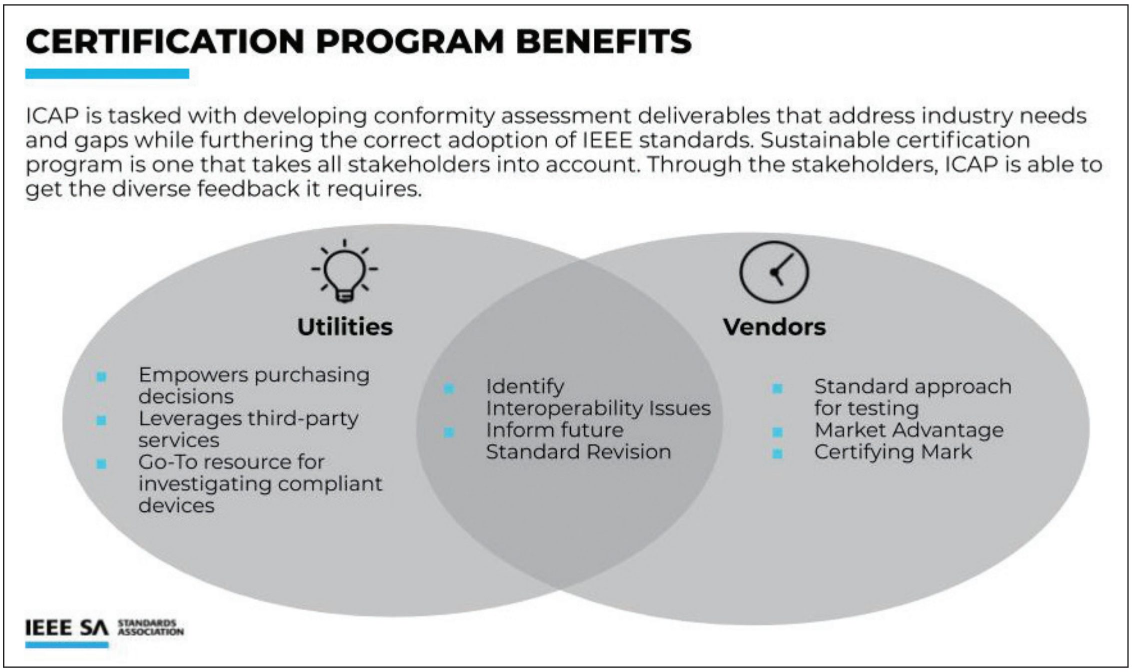
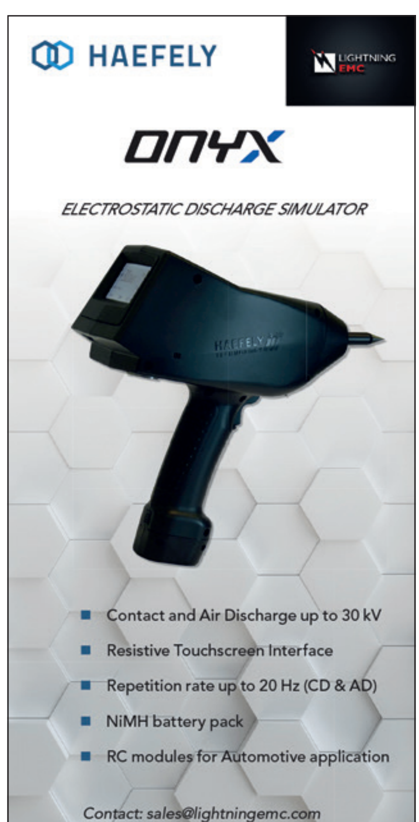
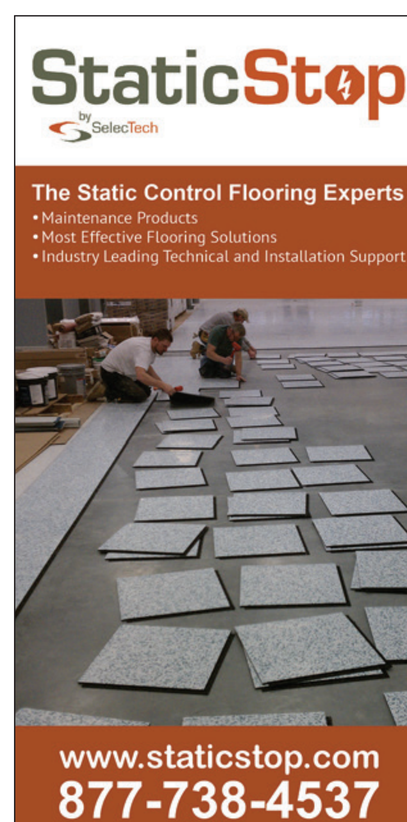


Figure 2: How ICAP benefits vendors and end-users

PRODUCT Showcase





ROBOTS AND ROBOTICS

Assessing Hazards and Testing to Global Standards

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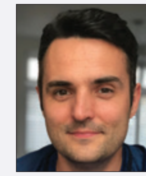

By Pierrick Balaire

Robotics is a rapidly growing field with applications in multiple industries and taking many shapes and forms in today's world. Examples include collaborative robots (cobots), industrial mobile robots (IMRs), automatic guided vehicles (AGVs), automated mobile platforms (AMPs), smart mining, autonomous mobile storage for the retail industry, medical robots, and robotic personal assistants.

As these devices become more prevalent, it is important to understand the hazards and testing options for these innovative devices, as well as the various global standards and requirements with which manufacturers and developers will need to comply.

HAZARDS

There are several hazards that need to be assessed and addressed for robots and robotic devices. The main hazards to consider for robotics are:

- Mechanical: Hazards originating from moving, overspeed, falling, sharp edges, etc., that are caused by the design and function of the system itself must be considered and assessed.
- Electrical: The overall safety and performance of electrical components, including insulation, thermal effect, and shock hazard within the device and its peripherals should be considered, particularly in regard to electrical safety standards.
- Ergonomic: These are potential ergonomic concerns related to the design and comfort of the device or system.
- Thermal: Products must be assessed for the potential to overheat, which could result in fire/explosion, burns, or other damage.
- Acoustical/Noise: Operational issues resulting in unwanted or loud noises could arise as a product performs its intended task or function.
- Vibration: Mechanical issues that lead to unwanted or excessive vibration during use. This, in turn, can produce noise and potential damage to the product.
- Radiation: Electromagnetic emissions from the system and its components must fall within a range that is considered safe and acceptable.
- Material/substance: Hazards related to the components within the robot, such as wiring, metals, liquid, etc., must be considered and assessed.
- Environmental: Hazards associated with the specific environment related to the machine's intended use. For example, in a healthcare environment, potential interference hazards associated with other medical devices and their critical functions.

In addition to individual hazards, it is common to see combinations of hazards, such as vibration and noise (vibration issues will create concerns around noise), electrical and thermal (poor electrical quality leading to overheating), or chemical and radiation. It is important to keep these potential combinations in mind when developing products, so you can mitigate risk in the product design and test appropriately when assessing the device.

TESTING OPTIONS

To assess the hazards associated with robotics, there are several testing areas that may apply. Depending on the hazard(s), you will need to consider:

- Hazardous locations assessments: Products used in hazardous locations or explosive atmospheres must be assessed to specific, stringent requirements in place for these environments.
- Functional safety evaluation: To ensure a device's fail-safe mechanisms are operating correctly and risks are reduced to as low as reasonably predictable, these assessments are vital to qualify or quantify the safety integrity level of safety functions.

In addition to understanding potential hazards and testing options, it is critical to know the standards for robots applicable in the region or market in which a device will be marketed or sold.

- Process evaluations: This may include things like risk management, programmable electrical medical systems, and usability. Process assessments will depend on the individual products, their intended use, and potential environments.
- Mechanical safety testing: These are evaluations that assess machinery and mechanics for performance and safety. These tests should assess potential risks and may also identify some that must be prevented and/or corrected.
- Electrical safety testing: These assessments will help to ensure safe operating standards in relation to the product's use of electricity. They also illustrate compliance with electrical safety standards required in a given market.
- Performance testing: Assesses attachments like manipulators, visual detection, and acoustical devices for overall performance and endurance to ensure consistency with use.
- Environmental testing: Assessing hazards related to the intended environment to ensure product performance and safety is important. Products used outdoors, for example, will need to be evaluated for components like weather and climate concerns. Products used in industrial settings will need higher endurance factors than those used in homes.
- Electromagnetic compatibility (EMC) & electromagnetic interference (EMI): These tests help to ensure a product continues to function when in use around other devices emitting electromagnetic energy, as well as making sure that a device does not interfere with the operations and function of other nearby products. As more products in use emit EMI, these assessments are increasingly important.
- Wireless and cybersecurity testing: Ensure wireless products meet requirements for connectivity, function, and data protection. As the world becomes more connected, it is more important than ever to ensure the security of any product.

GLOBAL STANDARDS

In addition to understanding potential hazards and testing options, it is critical to know the standards for robots applicable in the region or market in which a device will be marketed or sold. Often these standards address all or some of the hazards identified and outline testing requirements as well. What is required does vary by market, however, so it's important to know which standards apply to a given project.

A global standard, ISO 10218-1: Robots and robotic devices, addresses the safety requirements for industrial robots, systems, and integration. This ISO standard has been harmonized and adopted by many countries and regions; however, there are other standards that may apply to robotics in a given area.

European Union

Robots in the European Union (EU) are regulated based on their application. Industrial robots fall into the scope of the Machinery and EMC Directives. Manufacturers should follow existing EN and ISO standards on robotic devices. Several of these standards are harmonized under the Machinery Directive and include the following:

- EN 12100: Safety of machinery – General principles for design – Risk assessment and risk reduction
- ISO 13849-1: Safety of machinery – Safety related parts of control systems Part 1: General principles for design
- EN ISO 10218-1: Robots and robotic devices – Safety requirements for industrial robots
- EN ISO 10218-2: Robots and robotic devices – Safety requirements for industrial robots; robot systems and integration
- EN ISO 13482: Robots and robotic devices – Safety requirements for personal care robots

For robots used in hazardous locations or potentially explosive environments, the ATEX Directive, 2014/34/EU must be considered. If the safety of machinery is governed by safety distance, then EN 13857 applies.

- ISO/TS 15066: Robots and robotic devices – Collaborative robots
- EN 61000-6-2: Electromagnetic compatibility (EMC) Part 6-2: Generic standards – Immunity standard for industrial environments
- EN 61000-6-4: Electromagnetic compatibility (EMC) Part 6-4: Generic standards – Emission standard for industrial environments
- ISO 9283:1998: Manipulating industrial robots – Performance criteria and related test methods
- ISO 13850: Safety of machinery – Emergency stop – Principles for design
- IEC 60204-1: Safety of machinery – Electrical equipment of machines – Part 1: General requirements
- IEC 62061:2005: Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
- EN 1525: Safety of industrial trucks. Driverless trucks and their systems
- EN1526: Safety of industrial trucks. Additional requirements for automated functions on trucks
- ISO 3691-4: Driverless industrial trucks and their systems

In the EU, medical robots must adhere to IEC 60601-1 ED3+AMD1. This general standard must be applied in conjunction with new standards in development, such as:

- IEC 80601-2-77: Particular requirements for the basic safety and essential performance of robotically assisted surgical equipment
- IEC 80601-2-78: Particular requirements for the basic safety and essential performance of medical robots for rehabilitation, assessment, compensation or alleviation

For robots used in hazardous locations or potentially explosive environments, the ATEX Directive, 2014/34/EU must be considered. If the safety of machinery is governed by safety distance, then EN 13857 applies. Other machinery standards may also be applicable. Finally, some robots will need to comply with the EU's Radio Equipment Directive (RED), 2014/53/EU, which establishes safety and EMC requirements for equipment using the radio spectrum.

North America

A series of standards have been developed for the North American market, which, together with existing international standards, ensure a high degree of safety evaluation.

- ANSI/RIA R15.06: American national standard for industrial robots and robot systems safety requirements (originated from ISO 10218 series)
- ANSI/RIA R15.08: Mobile Robot Safety (in development)
- ANSI/UL 1740: Standard for robots and robotic equipment
- CAN/CSA Z434: Industrial robots and robot systems (originated from ISO 10218 series)
- ISO 10218-1: Robots and robotic devices – Safety requirements for industrial robots
- ISO 10218-2: Robots and robotic devices – Safety requirements for industrial robots; robot systems and integration
- ISO 13849-1: Safety of machinery – Safety related parts of control systems Part 1: General principles for design
- ISO 13482: Robots and robotic devices – Safety requirements for personal care robots
- IEC 61508-1: Functional safety of electrical/ electronic/ programmable electronic safety-related systems; Part 1: General requirements

- IEC 61508-2: Functional safety of electrical/electronic/programmable electronic safety-related systems. Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems
- IEC 61508-3: Functional safety of electrical/electronic/programmable electronic safety-related systems. Part 3: Requirements for software.
- IEC 62061: Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
- UL 3100: Outline of Investigation for Automated Mobile Platforms (AMPs)

Asia

In Asia, many countries have standards for robots that are harmonized with ISO 10218-1. There are also some standards to address risk management, in addition to standards for general electrical safety. Here are some examples of Asian robotics standards:

China

- GB 11291: Robots and robotic devices. Safety requirements for industrial robots
- GB 11291.2-2013: Robots and robotic devices. Safety requirements for industrial robots. Part 2: Robot systems and integration
- GB/T 15706-2012: Safety of machinery. General principles for design. Risk assessment and risk reduction

Japan

- JIS B9700:2013: Safety of Machinery – General Principles for Design – Risk assessment and risk reduction
- JIS 8433-1: Robots and robotic devices – Safety requirements for industrial robots Part 1
- JIS TS B0033: Robots and robotic devices – Collaborative robots

South Korea

- KS B ISO 10218-1: Robots and robotic devices – Safety requirements for industrial robots
- KS B ISO 10218-2: Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration

Taiwan

- CNS 14490-1 B8013-1: Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots and robotic devices
- CNS 14490-2 B8013-2 Robots and Robotics – Safety Requirements for Industrial Robots – Part 2: Robot Systems and Whole Combined

Singapore

- SS ISO 10218-1:2016: Robots and robotic devices – Safety requirements for industrial robots
- SS ISO 10218-2:2016: Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration

BEST PRACTICES

As the use and prevalence of robots continue to evolve, manufacturers and developers can prepare their products for various markets in several ways. First, it is important to know the standards and requirements for the market you are looking to enter. Along these lines, stay informed on updates and changes in each market, which are inevitable in a rapidly changing field. Additionally, keep up-to-date on changes in technology and its applications, as they may impact standards and requirements.

Identify any overlaps in the testing and assessment requirements of the market(s) you wish to enter. This may help streamline your approach, which, in turn, can get products to market more quickly and at a reduced cost.

Work with a trusted and knowledgeable partner who knows the standards and the best ways to illustrate compliance. Such a partner can help to build a comprehensive test plan to get products to market, one that includes assessments for quality and safety to help ensure a product's success.

Robots and robotics offer many possibilities to so many different industries, and many manufacturers wish to explore the opportunities with these products. Knowledge of the standards and requirements can not only ensure a safer, better performing product, it can allow you to get your products to market quickly and efficiently.

2021 FACES IN COMPLIANCE

TRAINING AND EDUCATION

Dr. Bogdan Adamczyk

GRAND VALLEY STATE UNIVERSITY

DR. BOGDAN ADAMCZYK is professor and director of the Grand Valley State University (GVSU) Electromagnetic Compatibility Center where he regularly teaches college-level EMC courses and EMC certificate courses for industry. He is an iNARTE certified EMC Master Design Engineer. He was a founding member and chair (2011-2020) of the IEEE EMC Chapter of West Michigan.

In 2012 he established the GVSU EMC Center and became its director. The EMC Center is a unique facility where GVSU collaborates with EMC practitioners from the community. This collaboration provides GVSU students with the opportunity to co-op and gain hands-on experience in the field of regulatory testing for EMC pre-compliance. The Center supports the local industrial community with design/re-design assistance and pre-compliance testing for products during the development cycle.

The joint EMC research between GVSU and its industrial partner, E3 Compliance LLC, has provided rich educational material that has been widely disseminated and incorporated in the EMC courses for both the GVSU students and industry.

Prof. Adamczyk authored or co-authored over 60 papers on EMC education, measurement, and testing. He is the author of the textbook “Foundations of Electromagnetic Compatibility with Practical Applications” (Wiley, 2017) and the upcoming textbook “Principles of Electromagnetic Compatibility with Laboratory Exercises” (Wiley 2022).

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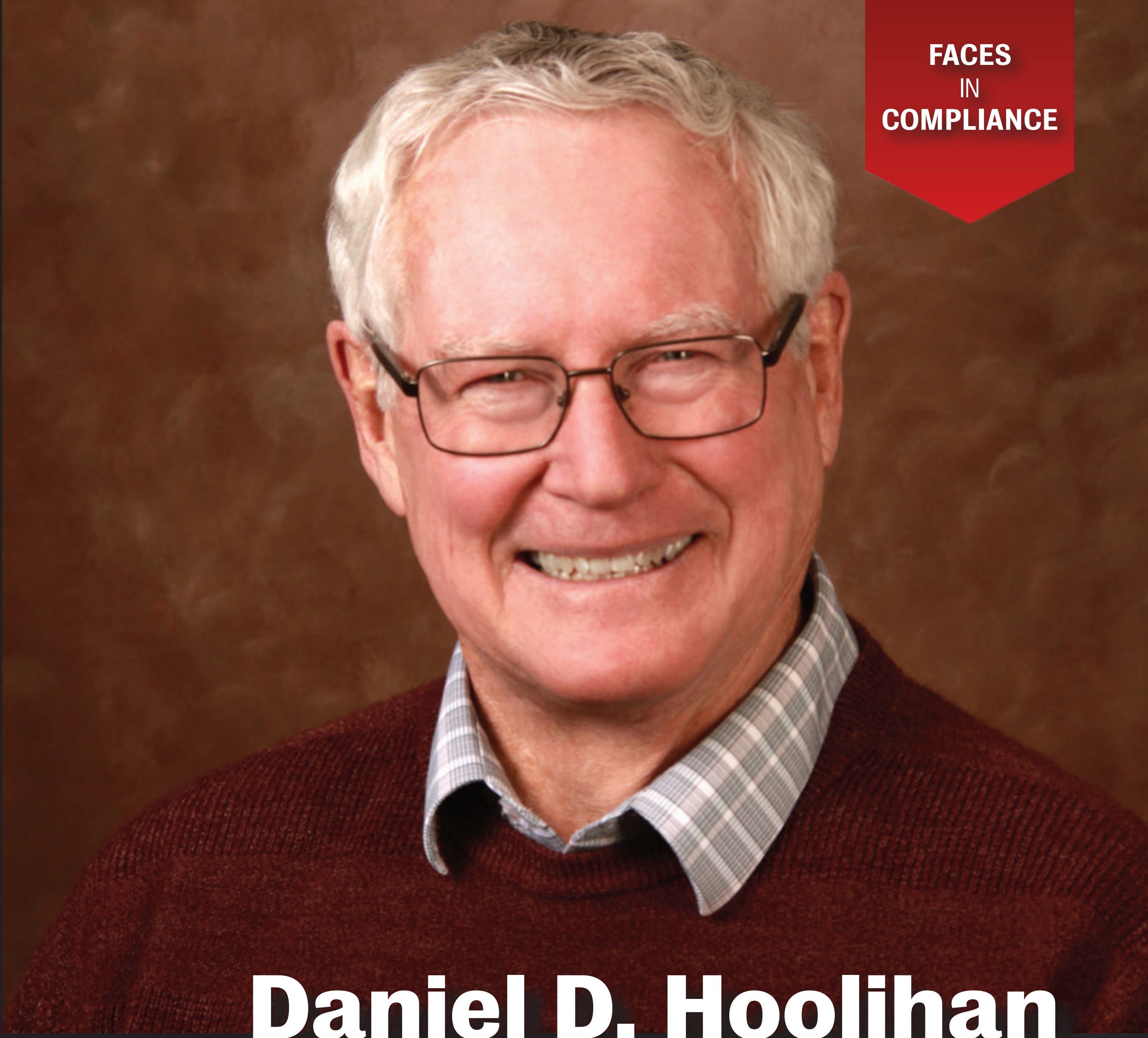

Daniel D. Hoolihan

HOOLIHAN EMC CONSULTING

DAN HOOLIHAN is the Founder and President of Hoolihan EMC Consulting; a 20-year old EMC-Engineering consulting firm. He specializes in EMC Laboratory Accreditation; EMC Standards Development, and EMC Education.

He has been assessing EMC Laboratories to International Standards for over 30 years. His major emphasis has been on laboratories involved in the United States Department of Commerce's National Institute of Standards and Technology (NIST) National Voluntary Laboratory Accreditation Program (NVLAP) relative to ISO/IEC 17025:2017 – General Requirements for the Competence of Testing and Calibration Laboratories.

Presently, he is Chairman of the ANSI-associated C63-Committee, which develops EMC standards for ANSI and IEEE. Some of the approximately twenty C63-standards are "adopted by reference" by United States Government Agencies to be used by manufacturers to show compliance to regulatory requirements.

With over fifty (50) years of experience, Hoolihan teaches courses in EMC Engineering in conjunction with ETS-Lindgren, the IEEE-EMC Society, and the C63-Committee.

Hoolihan is Past-President of the IEEE-EMC Society (1998-1999) and is presently Chairing the History Committee of the EMC Society.

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Raymond EMC Enclosures Ltd.

RAYMOND EMC is a Canadian company dedicated to providing quality state-of-the-art EMC Chamber solutions. Acquired by President Bruce Alexander in 2012, their core values of excellence, adaptability, integrity, and fun are truly a reflection of their team.

Jason Harrison, Head of Engineering, says: "Every project has its unique challenges and obstacles as each project is tailored towards the unique requirements of our customers. I am constantly learning new things about not just our industry, but those of our clients."

José Burgos, Shop Technician, added "After hearing about the company's mission, vision, and goals for the future, it made me want to be a part of it. In the short time I've been working here, we've grown so much, and it's only the beginning."

"Being in a supportive and collaborative environment with everyone moving towards the same goal of excellence is something that I appreciate daily." says Eric Wanamaker, Head Project Manager.

"Our supportive and welcoming work environment has made my time here equally as enjoyable as educational. It is this attitude and dedication that makes REMC standout not only as a leader in product quality, but in customer satisfaction." adds Malika Goodman, Engineering Student.

Overall what makes Raymond EMC successful is their people, and one needs simply to read the above to believe it.

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FACES IN COMPLIANCE

EMI SHIELDING GASKETS

George M. Kunkel

SPIRA MANUFACTURING CORP.

GEORGE M. KUNKEL, EMI shielding expert, inventor, and author, has been an EMC design engineer for over 50 years of his life. George is the inventor of Spira's unique, patented spiral EMI gasket. Known as the gold standard in the industry for over 40 years, the entire family of EMI products–including EMI/RFI shielding gaskets, shielded honeycomb filters, and other products–are expertly crafted and designed to last the life of a system.

With B.S. and M.S. degrees in engineering from UCLA, George served as Chairman of the Technical Committee on Interference control for 18 years, and Chairman of a Shielding Theory and Practice working group of the EMC Society of the IEEE for 6 years. He also taught courses on EMC System Design at UCLA extension.

Last year, George's groundbreaking new book on EMI Shielding was published: Shielding of Electromagnetic Waves–Theory and Practice. This book is the culmination of practical and theoretical research over the course of his career. It provides a new, more accurate and efficient way for design engineers to understand electromagnetic theory and practice as it relates to the shielding of electronical and electronic equipment.

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TRANSMISSION LINE REFLECTIONS AT THE RL AND RC LOADS

By Bogdan Adamczyk

This article discusses the reflections on a transmission line terminated with either an *RL* or an *RC* load. The detailed analytical derivations are verified through the HyperLynx simulations and laboratory measurements.

Dr. Bogdan Adamczyk is professor and director of the EMC Center at Grand Valley State University (http://www.gvsu.edu/emccenter) where he regularly teaches EMC certificate courses for industry. He is an iNARTE certified EMC Master Design Engineer. Prof. Adamczyk is the author of the textbook "Foundations of Electromagnetic Compatibility with Practical Applications" (Wiley, 2017) and the upcoming textbook "Principles of Electromagnetic Compatibility with Laboratory Exercises" (Wiley 2022). He can be reached at adamczyb@gvsu.edu.

1.1 REFLECTIONS AT THE RL LOAD - ANALYSIS

Consider the circuit shown in Figure 1.1, where the transmission line of length d is terminated by an *RL* load. (Reflections at the purely inductive load are discussed in [1]).

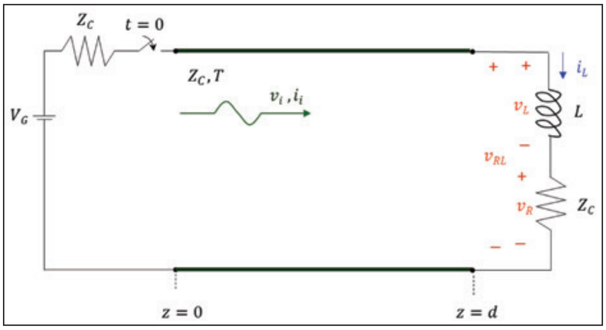

Figure 1.1: *RL* termination of a transmission line

Note that the load resistor value is equal to the characteristic impedance of the transmission line; it is also assumed that the initial current through the inductor is zero, $i_L(0^-) = 0$.

When the switch closes at $t = 0$, a wave originates at $z = 0$, [2], with

$$v_i = \frac{V_G}{2} \tag{1.1a}$$

$$i_i = \frac{V_G}{2Z_C} \tag{1.1b}$$

and travels towards the load. When this wave arrives at the load, (at the time $t = T$), the reflected waves, v_r and i_r are created. This is shown in Figure 1.2.

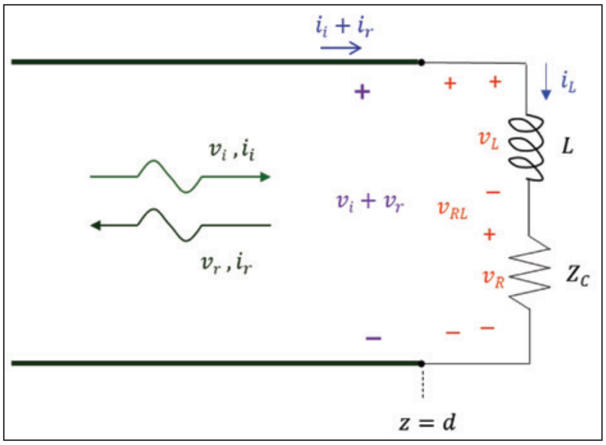

Figure 1.2: Incident and reflected waves at the *RL* load

The reflected current wave is related to the reflected voltage wave by

$$i_r(t) = -\frac{v_r(t)}{Z_C} \tag{1.1c}$$

KVL and KCL at the load produce

$$v_i + v_r(t) = v_L(t) + v_R(t) \tag{1.2a}$$

$$i_i + i_r(t) = i_L(t) \tag{1.2b}$$

Our initial goal is to determine the reflected voltage $v_r(t)$ at the location $z = d$, i.e., $v_r(d,t)$. The ultimate goal is to determine the total voltage at the load, $v_{RL}(d,t)$. From Eq. (1.2a) we obtain the inductor voltage as

$$v_L(t) = v_i + v_r(t) - v_R(t) \tag{1.3}$$

The load resistor voltage can be obtained from

$$v_R(t) = Z_C i_L(t) \tag{1.4}$$

Using Eqns. (1.1a) and (1.4) in Eq. (1.3) produces

$$v_L(t) = \frac{V_G}{2} + v_r(t) - Z_C i_L(t) \tag{1.5}$$

The differential v-i relationship for the inductor is

$$v_L(t) = L\frac{di_L(t)}{dt} \tag{1.6}$$

Utilizing Eqns. (1.2b) and (1.6) in Eq. (1.5) we get

$$\frac{V_G}{2} + v_r(t) - Z_C[i_i + i_r(t)] = L\frac{d}{dt}[i_i + i_r(t)] \tag{1.7}$$

Using Eq. (1.1b) and (1.1c) in Eq. (1.7) we have

$$\frac{V_G}{2} + v_r(t) - Z_C\left[\frac{V_G}{2Z_C} - \frac{v_r(t)}{Z_C}\right] = L\frac{d}{dt}\left[\frac{V_G}{2Z_C} - \frac{v_r(t)}{Z_C}\right] \tag{1.8}$$

Since V_G and Z_C are constant Eq. (1.8) reduces to

$$\frac{L}{2Z_C}\frac{dv_r(t)}{dt} + v_r(t) = 0 \tag{1.9}$$

This differential equation needs to be solved for $v_r(t)$, for $t > T$, subject to the initial condition $v_r(t = T)$. Let's determine this initial condition. Using Eqns. (1.1a) and (1.1c) in (1.2b) gives

$$\frac{V_G}{2Z_C} - \frac{v_r(t)}{Z_C} = i_L(t) \tag{1.10}$$

Evaluating it at $t = T$, we get

$$\frac{V_G}{2Z_C} - \frac{v_r(T)}{Z_C} = i_L(T) \tag{1.11}$$

Since the current through the inductor cannot change instantaneously, we have $i_L(T)$, and thus

$$v_r(T) = \frac{V_G}{2} \tag{1.12}$$

Now we are ready to solve Eq. (1.9), subject to the initial condition in Eq. (1.12):

$$\frac{L}{2Z_C}\frac{dv_r(t)}{dt} + v_r(t) = 0, \ \ v_r(T) = \frac{V_G}{2}, \ \ t > T \tag{1.13}$$

First, let's rewrite this equation in a standard form:

$$\frac{dv_r(t)}{dt} + \frac{v_r(t)}{L/2Z_C} = 0 \tag{1.14}$$

or

$$\frac{dv_r}{dt} + \frac{v_r}{\tau} = K \tag{1.15}$$

where

$$\tau = \frac{L}{2Z_C}, \ \ K = 0 \tag{1.16}$$

The solution of Eq. (1.16) was derived in [3] as

$$v_r(t) = K\tau + [v_r(T) - K\tau]e^{-\frac{1}{\tau}(t-T)} \tag{1.17}$$

Utilizing Eqns. (1.12) and (1.16) in Eq. (1.17), we obtain

$$v_r(d,t) = \frac{V_G}{2}e^{-\frac{2Z_C}{L}(t-T)}, \ \ t \ge T \tag{1.18}$$

The total voltage across the RL load is

$$v_{RL}(d,t) = v_i + v_r(d,t) = \frac{V_G}{2} + v_r(d,t) \tag{1.19a}$$

or

$$v_{RL}(d,t) = \frac{V_G}{2} + \frac{V_G}{2}e^{-\frac{2Z_C}{L}(t-T)}, \ \ t \ge T \tag{1.19b}$$

Equation (1.19b) predicts that at $t = T$, the voltage at the load rises from zero to V_G, and then decays exponentially to $V_G/2$. Let's verify these observations through simulations and measurements.

1.2 REFLECTIONS AT THE RL LOAD - SIMULATION

Figure 1.3 on page 42 shows the HyperLynx schematic of the transmission line terminated in an RL load.

The simulation results are shown in Figure 1.4.

1.3 REFLECTIONS AT THE RL LOAD - MEASUREMENTS

The measurement setup and the results are shown in Figure 1.5.

The measurement results are shown in Figure 1.6.

Note that the measurement results verify the simulation and the analytical results.

2.1 REFLECTIONS AT THE RC LOAD - ANALYSIS

Consider the circuit shown in Figure 2.1 where the transmission line of length d is terminated by an RC load. (Reflections at the purely capacitive load are discussed in [1]).

Note that the load resistor value is equal to the characteristic impedance of the transmission line; it is also assumed that the initial voltage across the capacitor is zero, $v_C(0^-) = 0$.

When the switch closes at $t = 0$, a wave originates at $z = 0$, with the initial voltage and current values given by Eqns. (1.1a) and (1.1b); this wave travels towards the load. When the wave arrives at the load, (at the time $t = T$), the reflected waves, v_r and i_r are created. This is shown in Figure 2.2.

The reflected current wave is related to the reflected voltage wave by Eq. (1.1c). KVL and KCL at the load produce

$$v_i + v_r(t) = v_C(t) \tag{2.1a}$$

$$i_i + i_r(t) = i_R(t) + i_C(t) \tag{2.1b}$$

Our initial goal is to determine the reflected voltage $v_r(t)$ at the location $z = d$, i.e., $v_r(d, t)$. The ultimate goal is to determine the voltage at the load, $v_C(d, t)$.

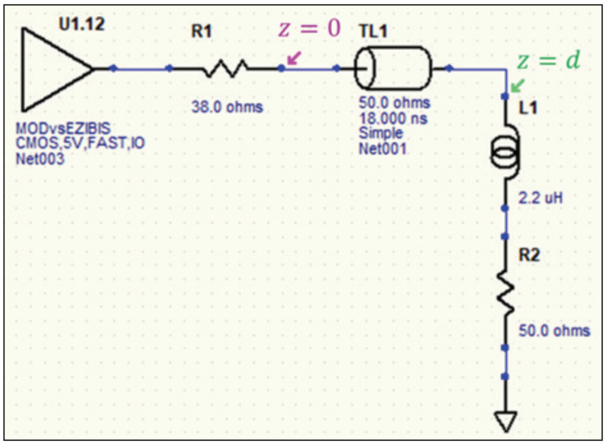

Figure 1.3: *RL* load - HyperLynx schematic

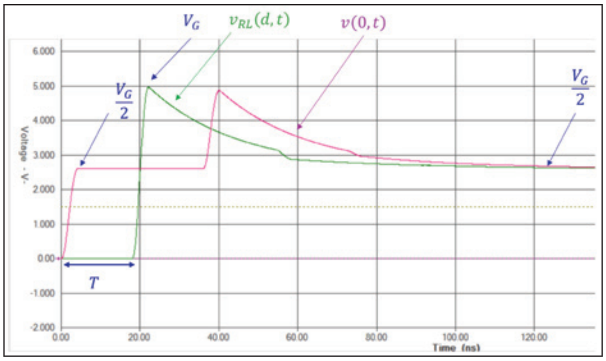

Figure 1.4: *RL* load - Voltages at the source ($z = 0$) and the load ($z = d$)

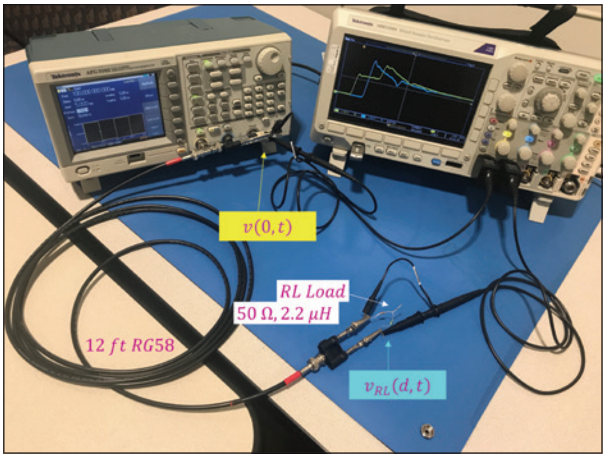

Figure 1.5: *RL* load – Measurement setup

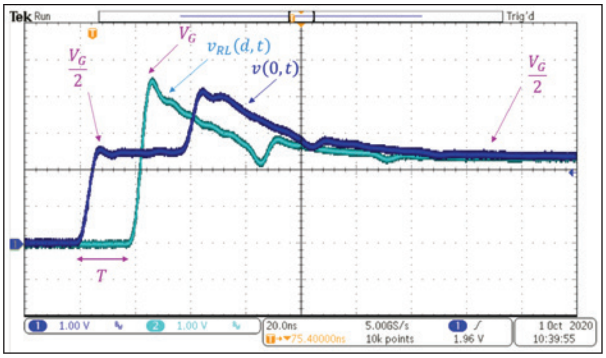

Figure 1.6: *RL* load – Measurement results

From Eq. (2.1b) we obtain the capacitor current as

$$i_C(t) = i_i + i_r(t) - i_R(t) \tag{2.2}$$

The load resistor current can be obtained from

$$i_R(t) = \frac{v_i + v_r(t)}{Z_C} \tag{2.3}$$

Using Eqns. (1.1b), (1.1c) and (2.3) in Eq. (2.2) produces

$$i_C(t) = \frac{V_G}{2Z_C} - \frac{v_r(t)}{Z_C} - \frac{v_i + v_r(t)}{Z_C} \tag{2.4}$$

The differential v–i relationship for the capacitor is

$$i_C(t) = C\frac{dv_C(t)}{dt} \tag{2.5}$$

Utilizing Eqns. (1.1a) and (2.4) in Eq. (2.5) we get

$$\frac{V_G}{2Z_C} - \frac{v_r(t)}{Z_C} - \frac{V_G}{2Z_C} - \frac{v_r(t)}{Z_C} = C\frac{d}{dt}\left[\frac{V_G}{2} + v_r(t)\right] \tag{2.6}$$

Since V_G is constant Eq. (2.6) reduces to

$$\frac{Z_C C}{2}\frac{dv_r(t)}{dt} + v_r(t) = 0 \tag{2.7}$$

This differential equation needs to be solved for $v_r(t)$, for $t > T$, subject to the initial condition $v_r(t = T)$. Let's determine this initial condition. Using Eq. (1.1a) in (2.1a) gives

$$\frac{V_G}{2} + v_r(t) = v_C(t) \tag{2.8}$$

Evaluating it at $t = T$, we get

$$\frac{V_G}{2} + v_r(T) = v_C(0) \tag{2.9}$$

Since the voltage across the capacitor cannot change instantaneously, we have $v_C(T) = 0$, and thus

$$v_r(T) = -\frac{V_G}{2} \tag{2.10}$$

Now we are ready to solve Eq. (2.7), subject to the initial condition in Eq. (2.10):

$$\frac{CZ_C}{2}\frac{dv_r(t)}{dt} + v_r(t) = 0, \quad v_r(T) = -\frac{V_G}{2}, \quad t > T \tag{2.11}$$

First, let's rewrite this equation in a standard form:

$$\frac{dv_r(t)}{dt} + \frac{v_r(t)}{CZ_C/2} = 0 \tag{2.12}$$

This equation is in the form of Eq. (1.15), with

$$\tau = \frac{CZ_C}{2}, \qquad K = 0 \tag{2.13}$$

The solution of Eq. (2.13) is of the form presented in Eq. (1.17). Utilizing Eqns. (2.10) and (2.13) in Eq. (1.17) we obtain

$$v_r(d,t) = -\frac{V_G}{2}e^{-\frac{2}{CZ_C}(t-T)}, \quad t \geq T \tag{2.14}$$

The total voltage across the RC load is

$$v_C(d,t) = v_i + v_r(d,t) = \frac{V_G}{2} + v_r(d,t) \tag{2.15a}$$

or

$$v_C(d,t) = \frac{V_G}{2} - \frac{V_G}{2}e^{-\frac{2}{CZ_C}(t-T)}, \quad t \geq T \tag{2.15b}$$

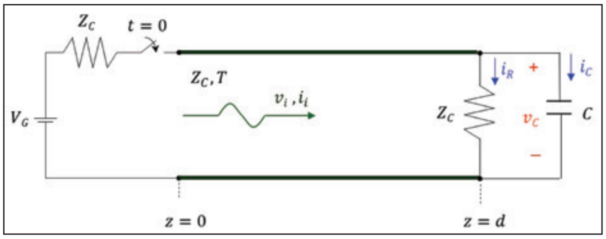

Figure 2.1: *RC* termination of a transmission line

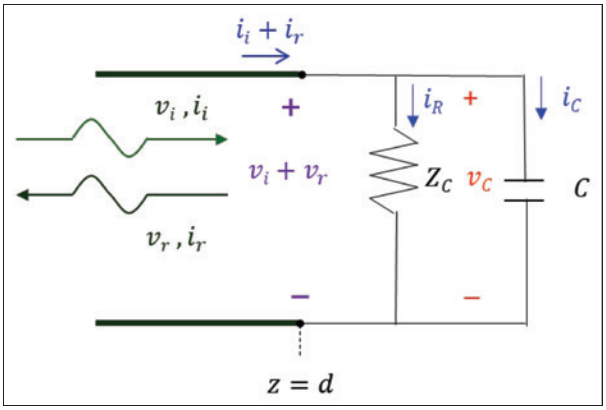

Figure 2.2: Incident and reflected waves at the *RC* load

Equation (2.15b) predicts that at $t = T$, the voltage at the load is zero and increases exponentially to $V_G/2$. Let's verify these observations through simulations and measurements.

2.2 REFLECTIONS AT THE RC LOAD - SIMULATION

Figure 2.3 shows the HyperLynx schematic of the transmission line terminated in an *RC* load.

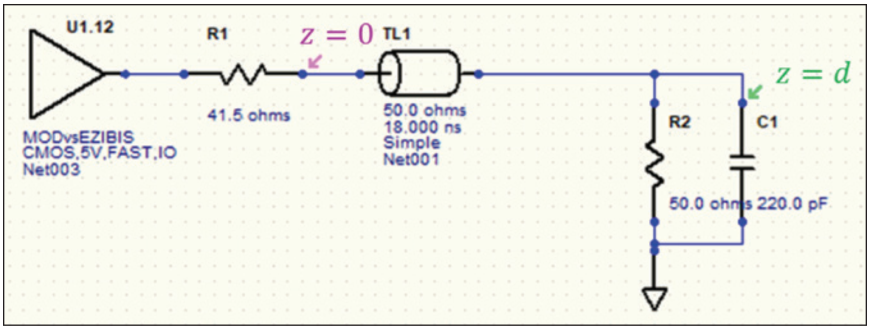

Figure 2.3: *RC* Load - HyperLynx schematic

The simulation results are shown in Figure 2.4.

2.3 REFLECTIONS AT THE RC LOAD - MEASUREMENTS

The measurement setup and the results are shown in Figure 2.5.

The measurement results are shown in Figure 2.6.

Note that the measurement results verify the simulation and the analytical results.

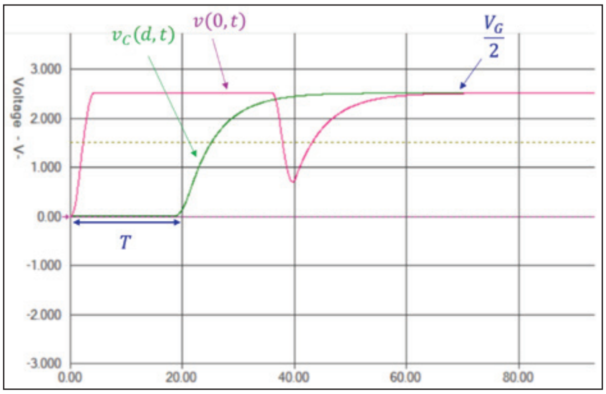

Figure 2.4: *RC* load - Voltages at the source ($z = 0$) and the load ($z = d$)

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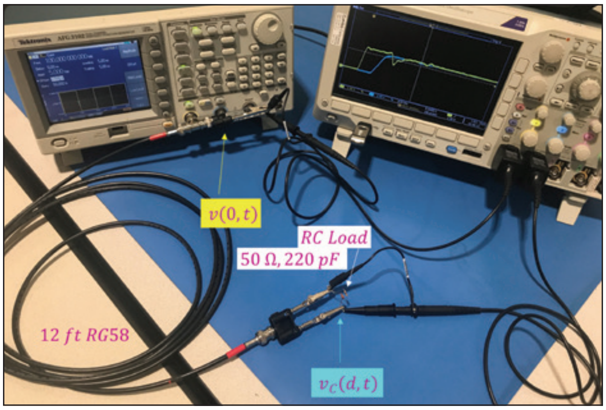

Figure 2.5: *RC* load – Measurement setup

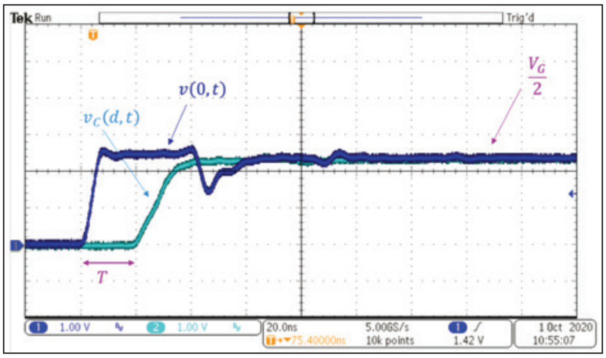

Figure 2.6: *RC* load – Measurement results

TWO-PIN HBM TESTING: A NEW OPTION?

By Robert Ashton for EOS/ESD Association, Inc.

Human Body Model (HBM) is the original ESD test method for semiconductor devices and is still the most widely used ESD test [1]. This article will discuss the old, but now new two-pin HBM tester. Not only are the new two-pin testers not subject to one of the drawbacks of today's high pin count testers, they provide additional testing convenience and diagnostic options not available in traditional HBM testers.

Robert Ashton is the Chief Scientist at Minotaur Labs. He received his BS and PhD degrees in Physics from the University of Rhode Island. Robert is an active member of ESDA working groups for device testing standards and the JEDEC latch-up working group. He has been a regular member of the EOS/ESD Symposium technical program committee.

Founded in 1982, EOS/ESD Association, Inc. is a not for profit, professional organization, dedicated to education and furthering the technology Electrostatic Discharge (ESD) control and prevention. EOS/ESD Association, Inc. sponsors educational programs, develops ESD control and measurement standards, holds international technical symposiums, workshops, tutorials, and foster the exchange of technical information among its members and others.

BACKGROUND

The basic HBM circuit diagram is shown in Figure 1. A 100-pF capacitor is charged to a voltage and then discharged across the device through a series 1500-ohm resistor. This produces the classic HBM waveform, a rapid rise in current followed by a 150 ns exponential decay, with a nominal peak current of about V_{HBM}/1500 ohms. Developing an HBM tester based on Figure 1 is not as straightforward as it might seem. Details of the high voltage relay to initiate the pulse have led to unintended consequences and false failures which have been documented in the literature. Ionized gas in the relay after the pulse created sustained low currents after the main pulse [2] and rapidly changing relay capacitance created voltages before the pulse [3]. These artifacts have been rectified with simple modifications of the pulse source.

Delivering the pulse to the device under test (DUT) can also be a challenge. The very earliest HBM tester was undoubtedly a very simple RCL circuit with a pair of clip leads, a Two Pin Tester. As integrated circuits became more complicated, the test method evolved. To save test time, pin combinations were developed in which a number of pins were ganged together on the low side of the pulse source, while a single pin was stressed on the high side of the pulse source. These are the traditional pin combinations, now in Table 2B of JS-001. [4] To accommodate these pin combinations HBM testers were designed to facilitate the pin combinations in both manual and automated, relay-matrix based, configurations. Relay matrix-based testers have been the mainstay of HBM testing of high pin count for some time, but there have occasionally been issues related to parasitic circuit elements within the matrix, which have resulted in false failures. The next section will discuss how parasitics can lead to distorted waveforms. We will then discuss how a new generation of the two-pin testers has come on the market, such as the Grund Technical Solutions Pure Pulse HBM system and HPPI's HBM option for their Transmission Line Pulse (TLP) systems. These systems are insensitive to tester parasitics but have a number of other advantages that will be discussed.

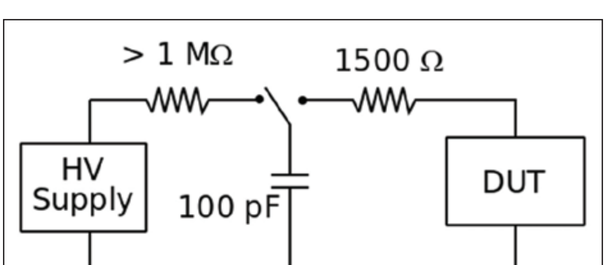

Figure 1: Basic HBM circuit model where DUT is the device under test, conventionally an IC package

TESTER PARASITICS

Relay matrix-based testers have been found to have significant parasitic circuit elements, particularly the capacitance across open relays [5,6]. An example is shown in Figure 2 on page 46. If the stressed pin is a supply group with many pins, or an Input or Output with diodes to a power rail, many open relays with parasitic capacitance will be stressed. The result can be that the actual waveform exiting the DUT can be significantly distorted, as shown in Figure 3. The resulting stress waveforms to the ESD protection structures can be very different from the waveform they were designed for and any waveform they would see during handling, which can result in false failures during testing.

THE NEW TWO-PIN TESTERS

The new two-pin testers deliver the HBM pulse to the DUT using wafer probes, as shown in Figure 4. The Pure Pulse system from Grund Technical Solutions (GTS) system [7] uses RF probes, providing a controlled impedance down to a few mm from the DUT. The HPPI systems, HBM-S1-B and HBM-TS10-A [8], place the pulse source close to the DUT, permitting more conventional cables. By applying the HBM stress directly between two pins on the DUT there are no unintended circuit elements to distort the stress waveform. This ensures that the DUT receives the intended stress. This is, however, not the only advantage of two-pin testers.

The use of wafer probes for pulse delivery has obvious advantages. HBM testing can be done conveniently at both wafer and package level. At the package level, there is no need for a socket, eliminating the cost, design effort, and time delays that are often associated with HBM testing.

Leakage or curve trace measurements before and after HBM stress to quickly detect a signature of device damage has long been a feature of HBM test systems, and two-pin testers include that capability. The two-pin testers go beyond that capability by measuring voltage across the DUT and current through the DUT DURING the HBM pulse. This creates an entirely new level of diagnostic capability for HBM [9].

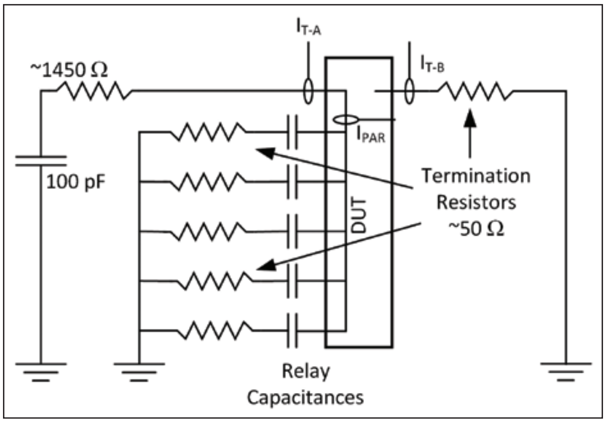

Figure 2: Circuit diagram showing how a relay matrix based HBM tester can have unexpected parasitic capacitance.

Figure 5 shows an example of the current through, and voltage across, a high voltage device with snapback, stressed with a 750 V HBM pulse. On first inspection, the current pulse looks very much like a standard HBM current pulse through a short. The decay, however, doesn't quite look like an exponential decay with a 150 ns time constant. At about 420 ns the current drops significantly and is essentially zero by 500 ns. The voltage across the device gives insight into the device's behavior. At the beginning of the voltage pulse, the voltage rises rapidly, as would be expected for a high voltage device. The voltage rise also starts a few ns before the current. This suggests that there is a delay in current,until the voltage reaches the device turn on above 25 V. The voltage then drops rapidly as

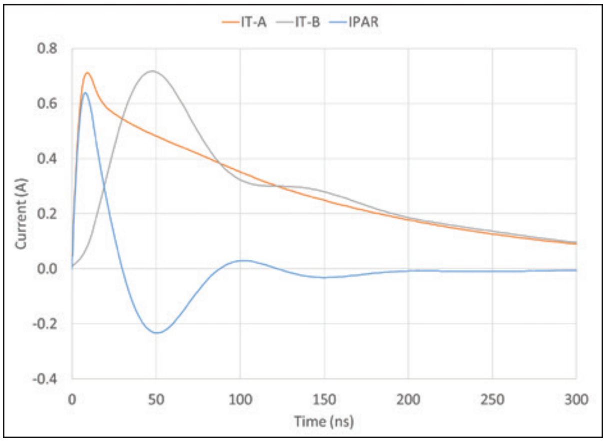

Figure 3: Simulation showing that the current waveform out of the DUT, IT-B, may look very different than the input waveform, IT-A due to unintended currents within the device, IPAR, due to parasitic capacitance of relays within the matrix. Refer to Figure 2 where these currents are monitored.

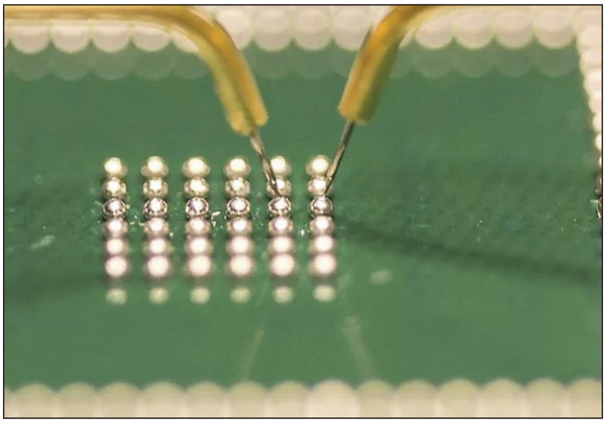

Figure 4: 50-ohm wafer probe needles as part of a two-pin HBM tester.

the device goes into snapback, and the current starts to behave as an HBM pulse. Voltage reaches a minimum at around 200 ns, rising slowly until 420 ns. At 420 ns the voltage begins to increase rapidly, reaching a peak of 26 V around 550 ns. The rise in voltage corresponds to when the current significantly drops. This indicates when the device leaves snapback and the voltage returns to above its breakdown voltage.

Measuring voltage across a DUT during the pulse also makes it possible to capture the exact time of failure. Device failure is often accompanied by an abrupt drop in voltage across the DUT.

There has been occasional criticism of the GTS Pure Pulse system that it is not a true 1500-ohm source impedance but is a 50-ohm source delivering an HBM current waveform. This is not valid. The waveform is formed using an RCL network similar to those used in a matrix-based tester, which is then delivered over a short 50-ohm line. The situation is actually the same in a matrix-based tester. The pulse is formed with an RLC circuit but is then delivered to the DUT over a series of traces and connections which all have characteristic impedances that are certainly not 1500 ohms but are not as well controlled as using RF probes.

The single area where two-pin testers create a challenge for the test engineer is the implementation of the pin combinations in JS-001 for a two-pin tester. That could be the topic of a future article.

SUMMARY

The new two-pin testers provide an interesting option for HBM testing. They can perform HBM testing at both package and wafer level, and with robotic probe holders, they can perform automated testing. In addition to measuring leakage currents before and after stress, the new testers can measure voltage and current during the HBM stress itself, giving new insight into device performance during an HBM stress. Matrix-based HBM testers have served the industry well and will continue to be a major tool for years to come. They have the advantage of being able to directly use the pin combinations in JS-001's Table 2A and Table 2B. It is very advantageous, however, to have another option for performing HBM testing without the cost and time required for designing custom boards, as well as a method that is essentially free of the issues of tester parasitics.

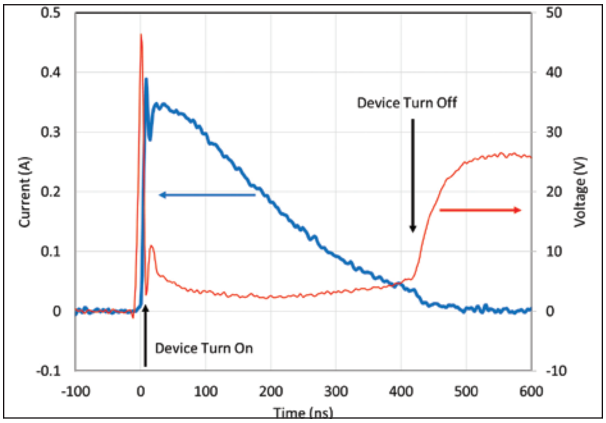

Figure 5: High voltage device with snapback stressed with a 750 V HBM pulse

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Banana Skins

307 Poor power quality makes cooker switch itself on

Typically, regular voltage quality spot checks are made throughout a local distribution system with additional measurements taken when a customer asks; is there a voltage problem? Indeed, this was the initial question that prompted an investigation into the cause of a modern electric cooker switching itself on.

Initial discussions between the local Distribution Network Operator (DNO) and customer revealed that this phenomenon first took place at Easter, then July and was experienced repeatedly throughout the summer months. However, the problem did not then re-occur until late September.

Standard voltage quality analysis – to BS EN 50160 'Characteristics of voltage supply in public electric power supply networks' – simply showed an increased level of flicker, only slightly above normal levels. However, investigations did reveal that a cable-car was located some distance away from the residential area. This cable-car comprised a double lift installation, having a 65kW lift with slipring motor compensated with 20kVAr capacitor power, as well as a 75kW lift with a B6-circuit rectifier drive. Although electrically distant from the local distribution substation, the cable-car was supplied from the substation by a two-core 2´95mm^2 copper cable, approximately 400m long.

Further investigations indicated that the oven malfunction seemed to coincide with periods of increased cable car use, normally at peak periods in the summer. A half-day network analysis at the lift equipment connection point in the local distribution system was carried out. Oscillograms were captured when the envelope trigger or transient level trigger varied by 20% of the voltage fundamental peak, or at least 65V between the cable and earth. Results showed that these limits were exceeded by a factor of two, by commutation spikes caused by the operation of the B-6 rectifier drive of the 75kW lift when it was the only lift in use.

Going back to the cooker manufacturer revealed that the cooker's electronic oven controls initiated switching commands via pulses. It was possible that the commutation spikes – with their steep slopes and zero-crossings – were being mistaken as switch-on commands.

(Adapted from "Power Detectives", *by Stephanie Horton, Engineering Manager at LEM UK Ltd, in the IEE Power Engineer Journal, October/November 2004 Issues, pages 40-41, http://www.theiet.org.)*

(Editor's note: Keith Armstrong reports that in private communications with an officer enforcing product safety laws in a mainland European country, the officer said that they had experienced several instances of household appliances turning themselves on by mistake. This includes appliances such as saunas, and fire safety was a significant concern. Interference was regarded as the likely culprit.)

308 Darth Vader toy switched on by low-level interference

What is electromagnetic noise and why is it proclaimed dangerous and unwanted? This extract from Ministry of Commerce's Field Offices newsletter is a graphic example of EM noise and interference (EMI) it may cause. "… A not so long time ago in a distract not so far away, a certain Technical Officer's son received a Darth Vader remote control toy for Christmas. The parents noted that this toy displayed the renowned C-Tick mark for EM Compatibility (EMC)! The children played Star Wars games until the sun set.

And that's when the real story began. You see, once the children were in bed at night, the parents could hear the occasional synthesised sound of "you underestimate the power of the dark side!". A quick check revealed all children asleep and the remote control untouched. Once a number of these occurrences had been heard, an "interference investigation" was launched.

The Technical Officer called himself back on duty and quickly found that the darned toy operated at 27.120 MHz and responded to electrical noise! This EMI could be generated from such simple things as light switches being turned off, and washing machine pumps switching during normal wash cycles…"

(Taken from "The Back Page" *of the EMC Society of Australia's Newsletter, September 2004 Issue Number 27, http://www.emcsa.org.au.)*

309 Computer company learns that EMC compliance pays

In its formative years, a major US PC manufacturer felt that FCC certification was not a barrier to marketing. Standard operating procedure was to sell while the authorisation process was in process. Then the FCC arrived to shut down the factory. The VP of Engineering met with the FCC in Washington at the last minute and worked out an agreement that kept the factory running. After that point, FCC certification and other agency approvals became a requirement before shipment was authorised. Today, that company has a world class compliance operation and I am proud to have taken part in that process.

(Richard Woods, in a correspondence on the IEEE's emc-pstc list server, 15 July 1998.)

310 Interference before World War I

The US Military first encountered

Radio Frequency Interference (RFI) some time prior to World War I when a radio was first installed on a vehicle.

(Warren Kesselman and Herbert Mertel, writing in the "EMC Standards Activities" section of the IEEE EMC Society Newsletter, Summer 2000 Issue, http://www.ewh.ieee.org/soc/emcs.)

311 New vacuum cleaner crashes car manufacturer's computer

A cleaner in the offices of a major UK car manufacturer started to use a new vacuum cleaner, plugging it into the sockets in a corridor outside the room where their stock control computer lived. Unfortunately, the mains sockets in the corridor were connected to the same branch of the power distribution as the computer, and the conducted noise from the vacuum cleaner crashed the computer. This happened ever day for some time, costing the company a great deal of money, until someone realised the vacuum cleaner was the cause of the problem.

(Anonymous, private conversation August 1994.)

312 Mains transients cause switch-on of toaster, burns gas station down

Transients in the mains supply of a gas station in the USA (called a petrol station in the UK) caused the spurious switch-on a microprocessor-controlled toaster one night after the staff had all gone home. Since the microprocessor wasn't in its normal programme, it didn't switch the toaster off.

The manufacturer of the toaster had omitted to include a thermal fuse, so the gas station caught on fire and burnt down. The PCB had been designed by a UK company, and its designers were later questioned intensely by a team of US lawyers for several hours.

(Anonymous, private conversation, August 1994.)

313 Radar interference anecdotes

Our purchasing manager has a penchant for (expensive) cars. He had a '92 Peugeot 605, and whenever he drove past the military airbase at Lyneham its air bag indicator would light. This was attributed to the site's radar interfering with the car's front wheel sensors. In addition the semi-automatic gearbox would drop into sports mode… The '93 model he now has appears to be immune.

I myself suffered TV interference from ground radar when living 10 miles from Gatwick airport – bars would roll down the screen as the sweep went through.

(From Chris James, private communication, 7th July 1998.)

Banana Skins numbered 314–315 describe interference events that we might not be too surprised to hear about in or after 2015.

314 2015: CE does not stand for 'China Export'

A major electronics manufacturer has been ordered to suspend all sales in the EU while it fixes EMI problems with its products. Enforcement officials impounded products in warehouses throughout the EU. The average time to fix a product's EMI problem is expected to be one month, but they have so many products that they expect it will be two years before they finish. They had argued that they thought the CE mark stood for 'China Export', said no-one had actually told them they had to comply with the EMC Directive, and that they were only doing what many of their competitors were doing anyway. The enforcement agents found these arguments unpersuasive.

(Possible electronic industry trade journal news item in 2015, or in fact in any year.)

315 2015: Plasma beam weapon interferes with COTS

Western military forces have come to rely (unofficially) on the widespread use of consumer ('COTS') electronics such as GPS navigation, cellphones, and palmtop computers with wireless datacomms. Every soldier, sailor or pilot seems to own at least one of each, and they take them everywhere with them, including military exercises and operations. Some enterprising junior officers have even created their own 'command and control' nets, some of which seem to be much more effective than official ones.

But during a recent NATO exercise based around the new SHIVA particle-beam anti-missile tactical battlefield man-pack systems, a large proportion of this COTS equipment failed to work and the unofficial methods that had grown up around them fell apart, causing great confusion. It had not been realised by how much these facilities had come to be relied upon. As a result, the 'attacking' forces easily won the exercise, despite being on foot, armed only with weapons of Afghan war vintage, and communicating by shouting loudly.

(Possible article in Jane's Defence Weekly in 2015, http://www.janes.com.)

The regular "Banana Skins" column was published in the EMC Journal, starting in January 1998. Alan E. Hutley, a prominent member of the electronics community, distinguished publisher of the EMC Journal, founder of the EMCIA EMC Industry Association and the EMCUK Exhibition & Conference, has graciously given his permission for In Compliance to republish this reader-favorite column. The Banana Skin columns were compiled by Keith Armstrong, of Cherry Clough Consultants Ltd, from items he found in various publications, and anecdotes and links sent in by the many fans of the column. All of the EMC Journal columns are available at: https://www.emcstandards.co.uk/emi-stories, indexed both by application and type of EM disturbance, and new ones have recently begun being added. Keith has also given his permission for these stories to be shared through In Compliance as a service to the worldwide EMC community. We are proud to carry on the tradition of sharing Banana Skins for the purpose of promoting education for EMI/EMC engineers.

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