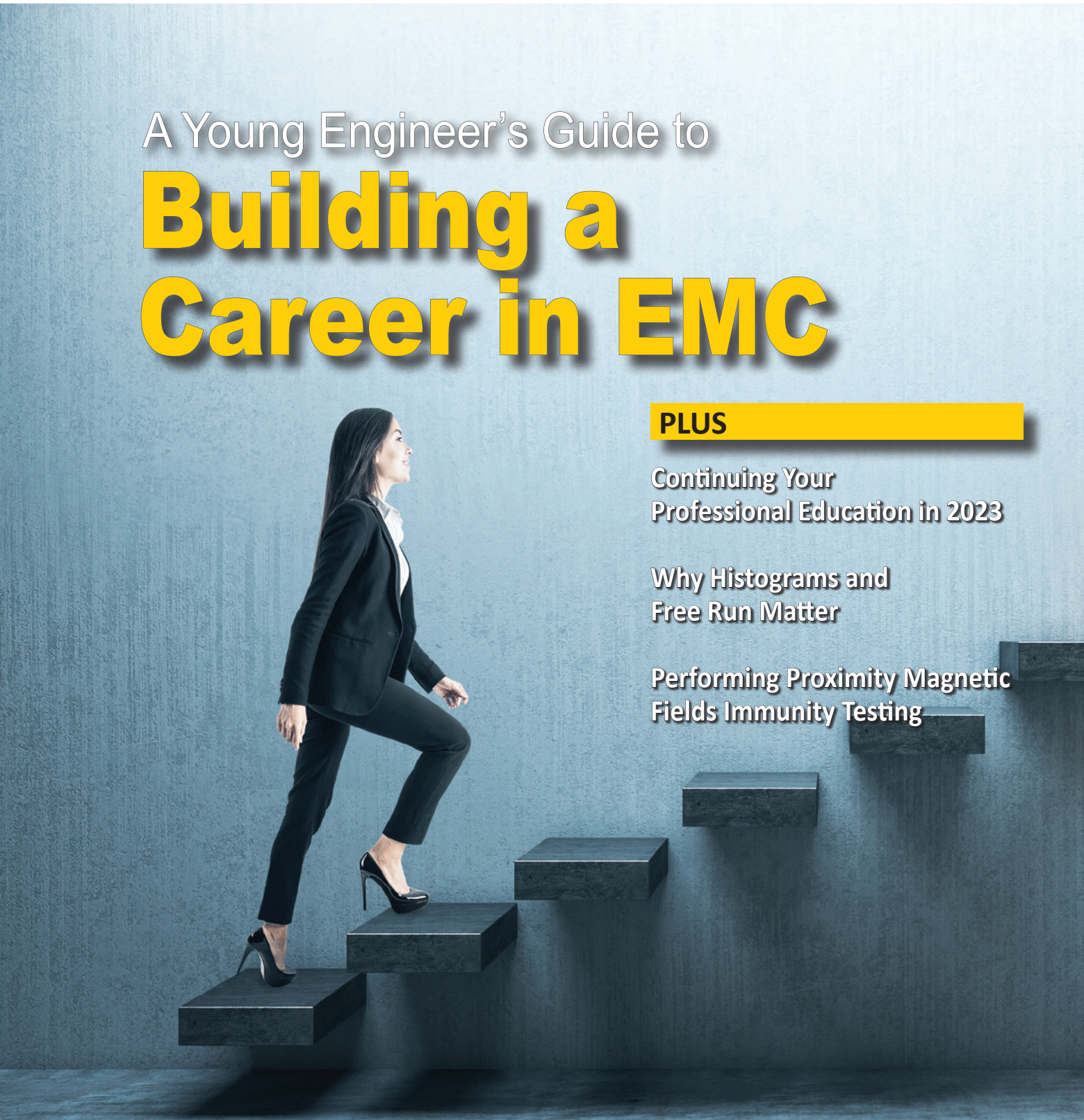
JANUARY 2023

IN COMPLIANCE™

THE COMPLIANCE INFORMATION RESOURCE FOR ELECTRICAL ENGINEERS

A Young Engineer's Guide to

Building a Career in EMC



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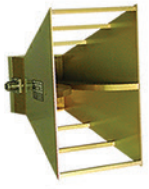

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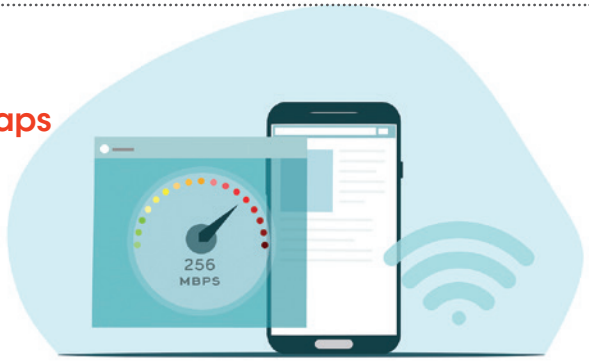
FCC Releases New National Broadband Maps



The U.S. Federal Communications Commission (FCC) has recently released a preliminary version of its new national broadband map, part of its ongoing effort to make broadband services available to all.

The new interactive map displays specific location-level information about broadband services available throughout the country. Consumers can enter their address to see detailed information about the fixed and mobile services that service providers report as being available at that location and can file challenges directly with the FCC if services are not available as reported.

Consumers and other interested parties can access the Commission's new broadband maps at https://broadbandmap.fcc.gov.

In addition, the FCC has launched an updated version of the FCC's Speed Test Application that enables users to compare the actual performance and coverage of their mobile networks with that reported by their service provider. The updated Speed Test App is available through both the Apple App Store and the Google Play Store.

EU Commission Update Lists of Harmonized Standards for RED

The Commission of the European Union (EU) has amended the Annexes of the EU's Radio Equipment Directive (2014/53/EU, also known as the RED) that detail harmonized standards that can be used to demonstrate conformity with the Directive's essential requirements.

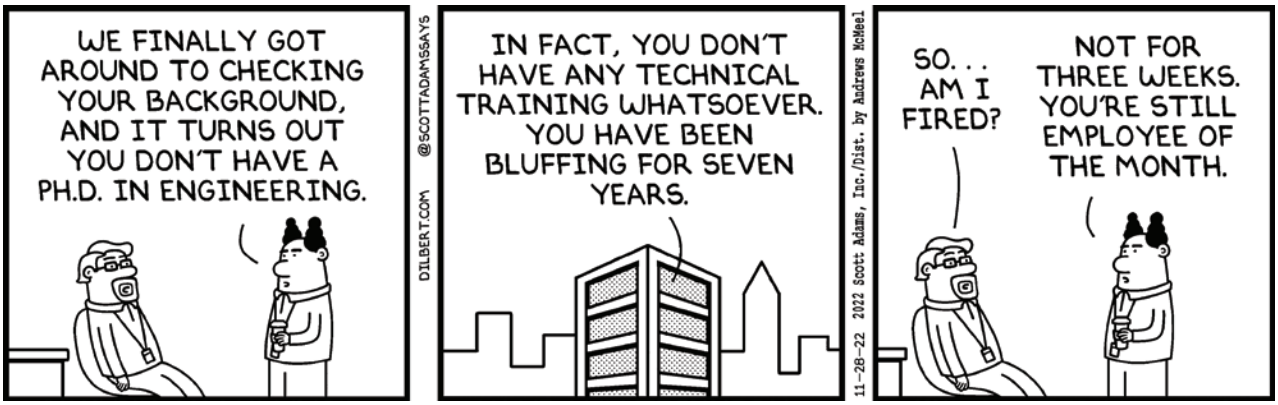
Published in the *Official Journal of the European Union*, Commission Implementing Decision (EU) 2020/167 revises Annexes I and II of the Directive, thereby verifying the use of 167 additional ETSI drafted harmonized standards in support of RED. The Commission's Decision also includes a revised Annex III, which stipulates dates of withdrawal of more than 20 additional standards.

FAA Says 5G May Have Been Source of In-Flight Avionic Failures

As the deployment of 5G technologies gains traction around the world, some aviation experts are expressing concerns regarding potential connections between 5G cellular networks and unexplained interferences with critical avionic flight systems.

According to an article published on the Flight Global website, the U.S. Federal Aviation Administration (FAA) suspects that new 5G cellular installations may have been the source of approximately 80 separate instances of aircraft system interference this year. The FAA reportedly told Flight Global that "none of these (cases) resulted in safety-related effects, and none affected a direct aircraft control input such as autothrottle or speed breaks/spoilers"

But the FAA has also continued to call for changes to current regulations regarding the deployment and use of technologies operating in the 5G C-band environment, insisting that the U.S. Federal Communications Commission (FCC) should "codify certain additional operating limits" on 5G operations to avoid future compromises to aviation safety.



FCC Amends Equipment Authorization Rules to Increase Security

Continuing its efforts to protect the U.S. communications networks from security threats, the U.S. Federal Communications Commission (FCC) has announced additional changes to its equipment authorization rules.

In an exhaustive Report and Order, Order, and Further Notice of Proposed Rulemaking, the Commission has adopted a number of revisions to its part 2 rules concerning equipment authorization processes under either equipment certification procedures through Telecommunications Certification Bodies (TCBs) or Supplier's Declaration of Conformity (SDoC) procedures. The revisions include:

- All applicants must now attest in their applications that the equipment for which they seek certification is not "covered" equipment under the Commission's Covered List;
- Entities that have been identified on the Covered List as producing "covered" equipment are now prohibited from obtaining equipment authorization through the Commission's SDoC procedures;
- Applicants for equipment certification must now designate a U.S. agent for services of process, regardless of whether the applicant is domestic- or foreign-based;
- Provisions that allow the FCC to use streamlined procedures for revoking equipment authorizations if the application includes false statements or representations related to "covered" equipment; and
- Strict prohibition against the authorization of all telecommunications and video surveillance equipment produced by Huawei and ZTE, including their subsidiaries and affiliates.

The Commission is also seeking comment on further revisions to the equipment authorization program, including whether component parts should be considered in the Commission's prohibition on the authorization of "covered" equipment, and whether all applicants seeking equipment certification have a U.S-based responsible party to help ensure compliance with the Commission's equipment authorization program rules.

FCC Approves Changes to Improve Wi-Fi

The Office of Engineering and Technology (OET) of the U.S. Federal Communications Commission (FCC) has granted conditional approval to a small group of companies working to finalize the development of technologies that would support expanded spectrum access for Wi-Fi networked systems.

According to a Public Notice, the OET conditionally approved 13 entities to operate automated frequency coordination (AFC) systems, which can be used to manage access to the 6 GHz spectrum band for standard-power unlicensed devices. Such devices will use the AFC systems to adjust operating parameters to protect microwave links that operated in the 6 GHz band from harmful interference.

The 13 entities receiving conditional approval include Broadcom, Google, Sony, Nokia, Qualcomm, and the Wi-Fi Alliance. The OET's action paves the way for these entities to work toward finalizing their AFC systems for full commercial operations, subject to final testing by the OET.

FCC Requires Broadband Providers to Display Consumer Info Labels

The U.S. Federal Communications Commission (FCC) has issued new labeling rules for broadband equipment and services to help consumers more fully understand and compare the feature and costs of comparable offerings.

Under the scope of a Report and Order and Further Notice of Proposed Rulemaking issued by the Commission, broadband service providers will now be required to display key information, such as speeds, data allowances, prices, and other fees, at the point of sale of both wireless and wired services. The Report and Order also includes a template of the required label, which is similar to the widely used nutrition labels for food products.

Broadband service providers will be required to display the label in close proximity to any advertisement for broadband services, as well as on their online account portal. Service providers will also be required to provide the label to an existing customer upon request.

The effective date of the FCC's new labeling requirement for broadband services is pending.

You Can't Make This Stuff Up: Scientists Build Circuit Boards Based on Mushrooms

Dealing with the burgeoning problem of electronic waste (e-waste) continues to perplex both environmentalists and engineers. But an accidental discovery by scientists working with mushrooms may pave the way toward more biodegradable electronic devices and components in the near future.

Researchers at the Johannes Kepler University in Linz, Austria were investigating the use of mushroom skins in home insulation systems. What they found during the course of their research was that the mycelium-covering skins of reishi mushrooms were "robust, flexible, and heat resistant" when shielded from ultraviolet light, and were able to stay intact even when exposed to temperatures as high as 500 degrees Fahrenheit.

That surprising finding led the researchers to consider whether mycelium-based materials could serve as the substrate material to which components in computers and other electronic components are attached. Substrates currently used in electronic technologies are generally made of non-recyclable plastics and are difficult to separate from the electronic components attached to them.

> Mycelium-based materials could simply be placed in soil where they would biodegrade, giving easy access to the formerly implanted components.

The researchers' preliminary findings into the potential of what they call myceliotronics was recently published in a paper posted to the ScienceAdvances website.

FDA Clarifies Definition of "Device"

The FD&C Act has been amended to help avoid confusion about the difference between "device" and "counterfeit device."

The U.S. Food and Drug Administration (FDA) recently issued a guidance document to clarify the agency's use of the term "device" in its regulations.

The guidance, titled "Referencing the Definition of 'Device' in the Federal Food, Drug, and Cosmetic Act in Guidance, Regulatory Documents, Communications, and Other Public Documents," is intended to clarify recent amendments to the Federal Food, Drug, and Cosmetic (FD&C) Act prompted by the enactment of the 2021 Federal Safeguarding Therapeutics Act.

In brief, the Safeguarding Therapeutics Act defined a new term, "counterfeit device," applicable to any device that uses proprietary names, markings, or manufacturing processes without prior authorization. Devices deemed counterfeit devices are subject to refusal of admission into the U.S., and the Act also empowers the FDA to destroy any such devices that have been unlawfully admitted.

To help avoid potential confusion about the difference between "device" and "counterfeit device," the FDA amended the FD&C Act to include a new definition for counterfeit devices consistent with the Safeguarding Therapeutics Act. The amended FD&C Act also clarifies the FDA's use of the terms "device" and "counterfeit device" in its regulatory documents and other FDA communications. The FDA's guidance serves to explain these changes to facilitate compliance efforts by device manufacturers.

Guidance documents issued by the FDA represent only the current thinking of the agency and do not establish legally enforceable requirements or responsibilities.

A YOUNG ENGINEER'S GUIDE TO BUILDING A CAREER IN EMC

Some Suggestions for Making the Most of Your Professional Journey

Nika Amralah is a Radio Frequency Applications Engineer. She obtained her BEng and MEng in Aerospace Engineering from Carleton University in Ottawa, Canada. Nika can be reached at nikaamralah@gmail.com.

By Nika Amralah

For young engineers and new technical professionals entering the field of electromagnetic compatibility (EMC) engineering, the journey of building a successful and lasting career can seem overwhelming. This article discusses common challenges of starting a career in EMC and offers practical advice based on my personal experience in the industry.

For EMC specifically, the public is often not aware that this industry exists. Even engineers in different disciplines can pass through much of their careers without considering the impact of EMC in their work. Despite this disconnect, ensuring the compatibility of electronics in the modern world is imperative. Many young engineers overlook a career in EMC, perhaps simply because they have not yet been exposed to it. The EMC industry continues to grow with advancements in technology and requires an influx of new technical professionals to keep up with the demand. This dynamic brings with it great opportunities for growth and career development.

USING EXPLORATION AND QUESTIONS AS TOOLS FOR LEARNING

As many EMC engineers will attest, most of your learning is done on the job. Universities equip engineers with the fundamental knowledge they need to succeed, but more importantly, with the ability to think critically and solve problems. When these skills are applied to real-life scenarios and projects, practical knowledge is gained. Over time, this compounds into experience and expertise in a specific field.

A new professional's first technical role represents a unique opportunity to bridge the gap between theoretical learning from their university education to the real-life practices of the working world. This experience may come in the form of an internship, volunteer role, or first engineering position after graduating. I pursued an undergraduate degree in Aerospace Engineering at Carleton University in Ottawa, Canada which included a cooperative education program. This is how I was first introduced to the field of EMC and learned the fundamentals of electromagnetic shielding and RF chamber design.

One of my biggest lessons from this experience was learning to have the courage to ask questions. Asking questions is one of the greatest tools for young engineers to master. There is value in doing independent research and being resourceful in answering your own curiosities, but often asking a question in a meeting will be the fastest way to resolve your uncertainty. Asking questions does not demonstrate a lack of understanding. Instead, asking questions should be seen as a commendable active effort toward cultivating expertise.

It is also valid to join meetings simply to listen and learn until you reach a point of feeling comfortable enough to participate. Take time to reflect on discussions and follow up with an email or conversation when you have remaining thoughts or queries. Leaving questions unanswered will also leave unnecessary lingering doubt. Your coworkers are likely more willing to help you than you may expect.

Experience comes with time and ultimately leads to confidence. Put yourself in situations from which you can learn. For example, offer to assist with tasks outside of your usual role. This includes interacting with technicians, project managers, and other business professionals and support staff outside of the realm of engineering. Exploring a wide scope of work will help you become a well-rounded engineer and can also help you to uncover new professional interests. All experiences are valuable, so expose

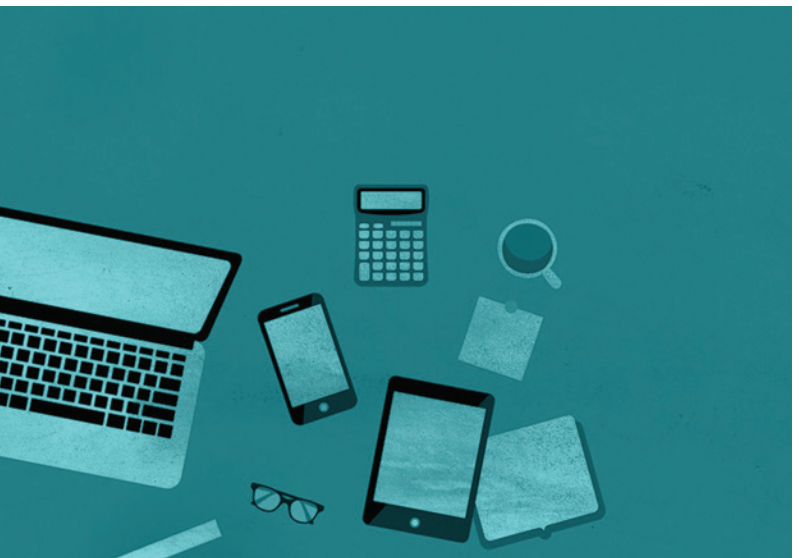
Have confidence in sharing your opinions and remember that a diversity of perspectives will always be a benefit to the end product of engineering.

yourself to as many new situations as possible. One day in the future, you may find yourself relying on that previous experience to solve current challenges. Having a wealth of experiences to draw upon will serve you throughout your career.

HAVING CONFIDENCE IN YOUR TECHNICAL ABILITIES

For young engineers, a common limiting belief is thinking that you do not have enough experience to contribute to technical discussions. I challenge this idea by suggesting that young engineers have the special advantage of being able to see situations from a new perspective and bring fresh ideas. The longer you work in an industry and become settled in familiar approaches, the harder it is to consider new ways of thinking. Have confidence in sharing your opinions and remember that a diversity of perspectives will always be a benefit to the end product of engineering. New ways of thinking can lead to fruitful conversations, design changes, or technical improvements.

When starting a career, especially in a field as specialized as EMC, you are not expected to know everything or be a technical expert from day one. Your managers and other engineers in positions of leadership have gone through a similar journey themselves and will help you build up your knowledge. The most important qualities for success are a willingness to learn and the ability to demonstrate initiative. These two characteristics will guide you through the initial learning curve and set you up for long-term professional growth. In fact, learning is a life-long pursuit since it is important to keep up to date with the industry and its technological advancements.



As a woman in engineering, I found myself falling into this misconception that I did not have enough experience to participate in meetings at the start of my career. If you are in a similar situation, I recommend that you think back to your engineering degree and remember that this is clear evidence of your technical merit. You have demonstrated your understanding and resilience by completing a rigorous academic curriculum. Graduating from a university engineering program is no small feat! As you accumulate work experience from internships, your first job after graduation, and all subsequent positions, your self-confidence and technical knowledge will continue to grow.

THE IMPORTANCE OF MENTORSHIP

Some of the best resources for young engineers starting in the EMC industry are the senior engineers who have been working in this field for decades. Unfortunately, as many senior engineers begin to retire, their wealth of knowledge leaves with them. This is the reason why it is critical to help engineers with different levels of experience to learn from each other.

Connecting with senior EMC engineers can result in developing a mentoring relationship. This starts with networking either within your place of employment, at a university, or while attending external networking events. Managers, professors, and leaders in the field are good examples of potential mentors. Mentors can

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Attending technical events or meetings on a regular basis where you can expect to interact with the same group of people is a great way to meet new professionals.

be considered as your professional board of directors. These are individuals with career experience that you can rely on for guidance and advice. Strive to build meaningful connections and give back to your mentors whenever possible. Remember to prioritize quality over quantity because it will always be more fulfilling to invest in fewer mentors that will champion you rather than maintaining many mentoring relationships with less depth.

Personally, attending relevant conferences like the IEEE International Symposium on Electromagnetic Compatibility, Signal & Power Integrity, or the Annual Meeting and Symposium of the Antenna Measurement Techniques Association (AMTA) have been great places to connect with mentors. Volunteering in technical committees within the IEEE EMC Society has also been an effective method for finding mentors with similar professional interests.

For example, I am currently an Officer-at-Large with Technical Committee 8 (TC8) on Aeronautics and Space EMC. I first got involved with TC8 in 2019 by attending an "Ask the Experts" panel in New Orleans and asking the panelists how I could be further involved in the EMC industry as a recent graduate. I followed their recommendation to attend TC8 meetings and have held a position in the committee ever since. Because of my background in aerospace engineering, I have found that this committee aligns with my interests and allows me to connect with fellow committee members over shared passions.

Attending technical events or meetings on a regular basis where you can expect to interact with the same group of people is a great way to meet new professionals. Active participation helps other people to get to know you until you ultimately develop a relationship. Show initiative in reaching out on LinkedIn or by email and express appreciation for any support you receive. My mentors have been an integral part of my career development and I am very grateful to have had their help over the years.

Another benefit of staying involved in the EMC industry is developing skills that are complementary to your technical knowledge. Attending industry events or meetings are opportunities for networking, building conversational skills, and connecting with peers. These settings cultivate soft skills that are critical for a successful career in engineering. The ability to communicate your ideas clearly will directly affect how your technical suggestions are received in the workplace. Without proper delivery, your contributions may be neglected due to a lack of confidence and justification. The best ideas cannot materialize unless they are effectively communicated to decision-makers.

From societal expectations to biases in the workplace, women in engineering face additional challenges when starting their careers. The lack of representation in the EMC industry can be discouraging, but the situation is improved with every woman who decides to pursue the field. Finding a woman in the workplace in a position of leadership to be your mentor can be a great resource to keep you motivated. Even if it is not possible to find another woman in engineering to be your mentor, I would suggest that any woman in

When starting your career, you are not expected to know everything. Instead, demonstrate a willingness to learn and an active effort in participating.

a position of leadership can be an inspiration and a valuable source of advice. There are many challenges that women face in the workplace that are common among different disciplines.

TOP 3 KEY TAKEAWAYS FOR YOUNG ENGINEERS

A summary of the key lessons described throughout this article is listed below. This advice can help guide professional growth for new engineers in EMC.

1. Have the courage to put yourself in new situations with the goal of learning from them. Try expanding the scope of your role to discover your professional interests and preferences. Offer to assist other teams or volunteer your time and skills outside of work in technical committees like with the IEEE EMC Society. Ask questions, stay curious, and always continue learning.
2. Have confidence in your technical skills and your ability to contribute, even if you are the least experienced member of a team. You bring a fresh perspective that is valuable to consider. When starting your career, you are not expected to know everything. Instead, demonstrate a willingness to learn and an active effort to participate. Showing initiative for your own learning will expedite professional growth.
3. Invest in meaningful mentoring relationships and learn from senior EMC engineers. Look within your existing network to find potential mentors or expand your network by attending relevant conferences or events. Find mentors that will champion you and support your career progression. Treat mentors as your professional board of directors and rely on them for guidance.

I wish you the best of luck in your professional journey in the field of EMC. The opportunities for you are endless as long as you have the confidence, drive, and courage to pursue them.

CONTINUING YOUR PROFESSIONAL EDUCATION IN 2023

Compiled by the *In Compliance Magazine* Staff

The Covid pandemic that has dominated our lives over the past three years has now begun to fade into the background. In its place, we now live with the ongoing military conflict in Ukraine, increasing nuclear threats from North Korea, seemingly untamable economic inflation, massive layoffs in the technology world, the collapse of cryptocurrency, and a constantly changing political landscape. Continued uncertainty seems to be the only constant in our world today.

But regardless of the current environment, your ongoing efforts to refresh or expand your technical knowledge and professional skills are essential to your continued personal growth and success. So, as 2023 begins, we've once again queried training resources throughout our industry to provide you with an overview of free or affordable solutions to meet your training goals and to help you on your journey to becoming your best self 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. We've also included a list of industry symposia, conferences, and exhibitions to be held in both the U.S. and around the world.

The information that follows is current as we go to press (early December 2022). 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 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 offers both in-person and virtual classroom training featuring live instructor-led sessions. Currently, there are more than fifteen separate training offerings, covering areas including international standards, management systems, technical subjects, and soft skills. Course instructors are subject matter experts with many years of professional training experience. Additional details are available at https://www.a2lawpt.org/training. (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 a featured presenter at the EMC & Compliance International 2023 program in Newbury, Berkshire (United Kingdom) on May 16-17, 2023, and will conduct the following workshops:

- Quickly Designing Cost-Effective EMC Filtering
- Quickly Designing Cost-Effective EMC Shielding, Part 1
- Quickly Designing Cost-Effective EMC Shielding, Part 2

For more information, or to register, go to https://www.emcandci.com.

Keith will also be conducting his updated EMC Design Courses in both Melbourne and Sydney Australia in March 2023. Topics include:

- Essential & Advance SI, PI, and EMC Design for Cost-Effective PCBs in 2023
- Design for EMC in 2023
- Complying with Edition 4 of IEC 60601-1-2 + A1, A2, Medical EMC for Basic Safety and Performance
- The Safe Design of Electrical Equipment in 2023

Additional information about these programs is available at https://www.emctech.com.au/keith-armstrong-design-compliance-emc-safety-2023. (Also see listings under "In-House/Customer Seminars and Workshops" and "Recorded Webinars and On-Demand Training)

This year, **Dangelmayer Associates** will host and present in person its annual ESD workshop, "ESD Best Practices for Technology Change." The workshop will be held the week of July 24, 2023. Additional details and registration information is available at https://www.dangelmayer.com/training-workshops.php. Dangelmayer Associates will also present its multi-day ESD Auditor Certification Training in person in 2023. Visit to https://dangelmayer.com/auditor-certification-course.php for more information. (Also see listing under "Recorded Webinars and On-Demand Training)

Doug Smith of **D.C. Smith Consultants** will host virtual presentations of his workshop "Lab Techniques, Robust Design, and Troubleshooting" in four half-day sessions throughout 2023. Doug will also conduct in-person his 3-day workshop "Lab Techniques, Robust Design, and Troubleshooting" and his workshop on "ESD Simulator Characterization" during the year. Visit his website at https://emcesd.com for the most up-to-date information and his 2023 schedule.

The **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 2023 training dates, go to https://equipment-reliability.com. (Also see listing under "In-House/Custom Seminars and Workshops")

The **EOS/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 https://www.esda.org/training-and-education. (Also see listing under "Recorded Webinars and On-Demand Training")

ETS-Lindgren offers in-person and virtual training courses throughout the year as part of their popular ETS-U program. For information about course details and dates, visit https://www.ets-lindgren.com/about-us/news-events. (Also see listings under "In-House/Custom Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

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

Dr. Bogdan Adamczyk of **Grand Valley State University** (GVSU) will offer his two-day certificate course for industry on "Principles of Electromagnetic Compatibility" on April 6-7, 2023, and October 5-6, 2023 at the GVSU EMC Center in Grand Rapids, Michigan. Numerous measurements and demonstrations 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 https://www.gvsu.edu/emccenter.

The **IEEE EMC Society** offers access to a number of live webinars on a variety of EMC-related subjects. Go to https://www.emcs.org/virtual-and-webinar-events.html for more information. (Also see listings under "Recorded Webinars and On-Demand Training" and "Industry Symposia, Conferences, and Exhibits")

Intertek offers live virtual and in-person public seminars and workshops throughout the year at

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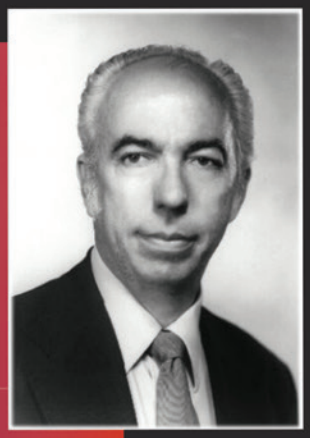

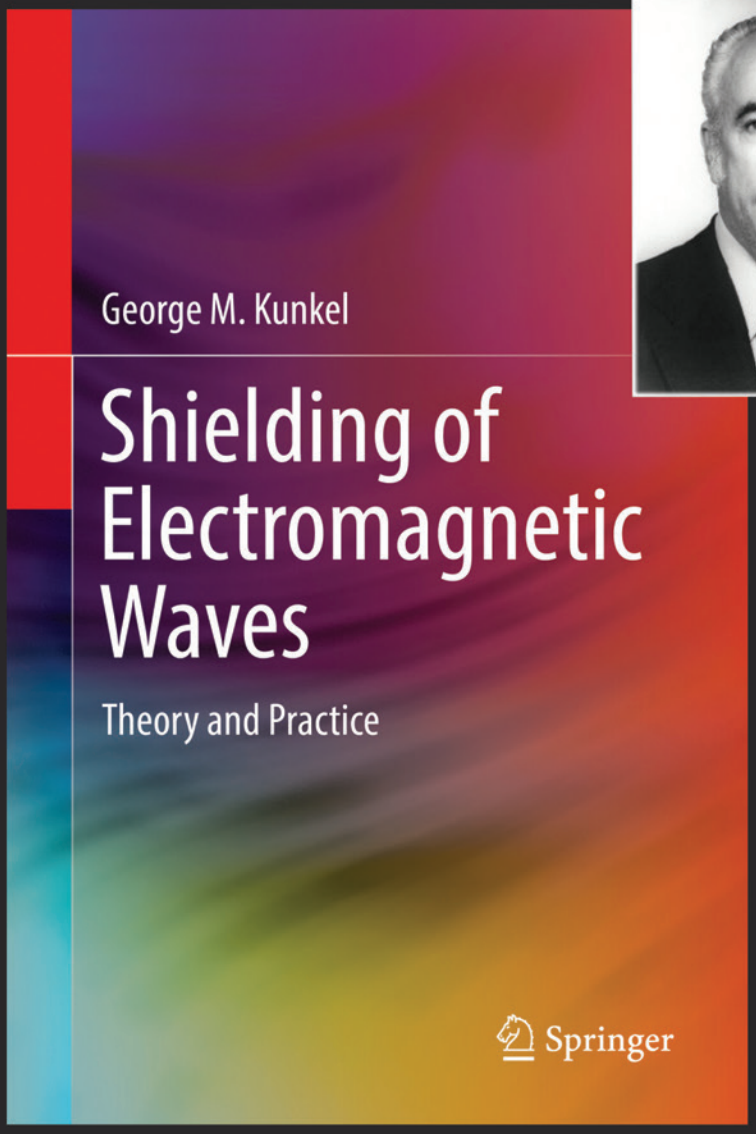

George Kunkel discovered a critical error in electromagnetic shielding theory in 1970: the accepted theory of shielding *violates* the basic laws of physics.

This book is the culmination of over 50 years of practical and theoretical research. It provides a new, more accurate and efficient way for design engineers to apply electromagnetic theory in the shielding of electrical and electronic equipment.

More information is available at **www.spira-emi.com/book**

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various locations in the U.S. and around the world. Visit https://www.intertek.com/knowledge-education, the company's "Knowledge and Education" portal, for additional information. (Also see listing under "Recorded Webinars and On-Demand Training")

Daryl Gerke of **Kimmel Gerke Associates, Ltd.** continues to offer his popular EMC trainings on a synchronous virtual basis. His three-day course on "Design for EMC" focuses on EMC problems and how to identify, prevent, and fix more than forty common EMI/EMC problems at the equipment level. His other course, "EMC in Military Systems," addresses issues stemming from four key EMC interfaces, grounding, shielding, power, and cables. For further details on these trainings, go to https://www.emiguru.com/seminars, or visit the website of the Applied Technology Institute (https://aticourses.com). (Also see listing under "In-House/Custom Seminars and Workshops")

Dr. Todd Hubing of **LearnEMC** will present a live virtual course on "Printed Circuit Board Design for EMC and Signal Integrity" in late March 2023. This course consists of eight consecutive 90-minute sessions conducted from Monday, March 20, 2023 through Thursday, March 30, 2023. The course will enable participants to make effective decisions regarding component selection, component placement, and trace routing. For additional details, go to https://learnemc.com. (Also see listing under "Recorded Webinars and On-Demand Training")

Min Zhang of **Mach One Design** will be a featured presenter at the EMC & Compliance International 2023 program in Newbury, Berkshire (United Kingdom) on May 16-17, 2023, and will conduct the following workshops:

- Intersystem and Intrasystem EMC (Huh? What?)
- Structure Resonances: Live Demo

For more information, or to register, go to https://www.emcandci.com.

Silent Solutions will offer several EMC courses during the first half of 2023. The in-person EMC courses, "Applying Practical EMI Design and Troubleshooting Techniques," "Advanced PCB Design for EMC & SI, and "Mechanical Design for EMC," will be presented at Oxford University, Oxford (United Kingdom) May 15-19th. To learn more visit https://www.silent-solutions.com.

TÜV SÜD America offers live virtual public and private training courses and webinars 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 advance their approach to prevention and compliance. A current listing of 2023 programs and dates is available at https://www.ul.com/events. (Also see listing under "Recorded Webinars and On-Demand Training")

Kenneth Wyatt of **Wyatt Technical Services, LLC** is an independent consultant 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. Visit http://www.emc-seminars.com/page6/Schedule.html for further information on his public seminar schedule for 2023. (Also see listing under "Recorded Webinars and On-Demand Training")

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 in both English and Spanish. Go to https://www.a2lawpt.org/training 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 **BestESD Technical Services** provides customer-oriented classes and workshops on practical aspects of managing EMI, EOS, and ESD within the factory environment, using a results-based approach to provide participants with a fuller understanding of managed parameters. Classes and workshops are conducted on the customer premises and can include hands-on demonstration and training on actual tools and processes in production. Specifics include overview and compliance with SEMI E.176 standard and current ESDA work on EOS. Visit https://www.bestesd.com for more information.

Keith Armstrong and his Associates at **Cherry Clough Consultants Ltd.** offer an array of workshops and seminars, both in-person or virtual, for up to one thousand people at a time. Their extensive training portfolios cover a wide range of topics and customized or more specialized training is also available. For more information, go to https://www.cherryclough.com. (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 and software education to how to perform an acoustic, 5G, or EMC test and more, our customized offerings can help increase the knowledge and productivity of your team. These customized trainings can be held at your facility, or at ETS-Lindgren's headquarters facility where the lectures are complemented by hands-on demonstrations in or R&D test chambers. For more information and a custom training quote, contact sales@ets-lindgren.com. (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. Go to https://www.equipment-reliability.com for more information. (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 1–4-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.** also offers his synchronous virtual courses, "Design for EMC" and "EMC in Military Systems" on an in-house basis. Visit https://www.emiguru.com/seminars for further details. (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. For more information, go to https://www.acil.org and click on the word "Education" at the top of the page. (Also see listing 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 thirty different courses providing the equivalent of hundreds of hours of training are currently available, including online training on ISO/IEC 17025 compliance. More information is available at https://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 and his Associates at **Cherry Clough Consultants Ltd.** provide a wide range of training course modules for in-house webinars, and their PDF-formatted color course notes are available for immediate download at https://www.emcstandards.co.uk/emcacademy. A number of new on-demand training webinars are now being made available at https://emcstandards-shop.fedevel.education/index.html. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "In-House/Custom Seminars and Workshops")

Dangelmayer Associates presents complimentary live webinars throughout the year. Visit their site at https://dangelmayer.com/webinar-videos.php to view complimentary recordings of the webinars. There are also excellent complimentary ESD demonstration videos on their site https://dangelmayer.com/esd-videos.php. (Also see listing under "Live Virtual and In-Person 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 (IS) Hardware Design
- FCC Wireless (RF) Pre-Compliance
- EMC Technician Training

Visit https://emcfastpass.com for more information.

The **EOS/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/training-and-education. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "Industry Symposia, Conferences, and Exhibits")

Dr. Todd Hubing of **LearnEMC** also provides access to his on-demand online course "Computer Modeling Tools for Electromagnetic Compatibility." This course reviews the latest computer modeling tools and techniques that can help engineers design products that are EMC compliant. For additional details, go to https://learnemc.com. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops" and "In-House/Custom Seminars and Workshops")

ETS-Lindgren also offers a number of previously recorded webinars that are available on-demand covering topics such as EMC testing, wireless/5G testing, automotive testing (including e-motor and autonomous vehicles), ANSC C63® standards updates, and electro-magnetic protection. Additional details about our on-demand offerings 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")

The **IEEE EMC Society** also provides access to several on-demand recordings of recent presentations at Society and Chapter events. Further information is available at https://www.emcs.org/virtual-and-webinar-events.html. (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "Industry Symposia, Conferences, and Exhibits")

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 TESTalks provides access to free, on-demand videos on several aerospace and defense-related standards, including RTCA/DO-160, MIL-STD-810H, and MIL-STD-461G. The five-part video series on MIL-STD-461G 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 comprehensive selection of webinars, virtual demonstrations, and other remote learning options covering a wide variety of technical subjects. Learn more by accessing their Knowledge Center at https://www.rohde-schwarz.com/us/knowledge-center/new-resources/overview_253060.html.

StaticWorx offers a collection of nearly 50 brief videos about static electricity that answer commonly asked questions, explain confusing technical terms, and help you to mitigate the effects of static electricity. Visit the company's YouTube channel to access their video library at https://www.youtube.com/c/staticworx.

TÜV SÜD America also 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/services/training/e-learning-courses 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")

Kenneth Wyatt of **Wyatt Technical Services, LLC** offers several webinar- and video-based trainings. For more information, visit http://www.emc-seminars.com/page6/Schedule.html. (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 planned as live in-person events unless otherwise noted. Please check the listed website for up-to-date information on dates and locations.)

DesignCon 2023
January 31-February 2, 2023 – Santa Clara, California (U.S.)
https://designcon.com

EuCAP 2023 – The 17th European Conference on Antennas and Propagation
March 23-31, 2023 – Florence, Italy
http://www.eucap2023.org

2023 International Applied Computational Electromagnetics Society (ACES) Symposium
March 26-30, 2023 – Monterey, California (U.S.)
http://www.aces-society.org

EMV 2023
March 28-30, 2023 – Stuttgart, Germany
https://emv.mesago.com/koeln/en.html

A2LA Annual Conference 2023
April 16-19, 2023—Tuscon, Arizona (U.S.)
https://a2la.org/2022-tech-forum

2023 IEEE International Symposium on Product Compliance Engineering (ISPCE)
May 1-3, 2023 – Dallas, Texas (U.S.)
http://2023.psessymposium.org

EMC & Compliance International Exhibition & Workshops
May 16-17, 2023 – Newbury, Berkshire, United Kingdom
https://www.emcandci.com

2023 Joint Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC) and International Conference on Electromagnetic Interference and Compatibility (INCEMIC)
May 22-25, 2023 – Bengaluru, India
https://apemc-incemic-2023.org

2023 IEEE International Instrumentation and Measurement Technology Conference (I²MTC)
May 22-25, 2023 – Kuala Lumpur, Malaysia
http://i2mtc2023.ieee-ims.org

IMS 2023 – IEEE International Microwave Symposium
June 11-16, 2023 – San Diego, California (U.S.)
https://ims-ieee.org/ims2023

Sensors Expo & Conference
June 20-22, 2023 – Santa Clara, California (U.S.)
https://www.sensorsexpo.com

IEEE International Symposium on Antennas and Propagation & USNC-URSI Radio Science Meeting
July 23-28, 2023 – Portland, Oregon (U.S.)
https://2023.apsursi.org

2023 IEEE International Symposium on Electromagnetic Compatibility, Signal and Power Integrity
July 31-August 4, 2023 – Grand Rapids, Michigan (U.S.)
https://www.emc2023.emcss.org

EMC Europe 2023
September 4-8, 2023 – Krakow, Poland
https://www.emceurope2023.org

The Battery Show 2023, North America
September 12-14, 2023 – Novi, Michigan (U.S.)
https://thebatteryshow.com

European Microwave Week 2023
September 17-22, 2023 – Messe Berlin HUB 27, Berlin, German
https://www.eumweek.com

45th Annual Electrical Overstress/Electrostatic Discharge Symposium
October 1-6, 2023 – Riverside, California (U.S.)
https://www.esda.org/events/45th-annual-eosesd-symposium-and-exhibits

45th Annual Meeting and Symposium of the Antenna Measurement Techniques Association (AMTA)
October 8-13, 2023 – Seattle, Washington (U.S.)
https://2023.amta.org

RF & Microwave 2023
Not yet scheduled. For current information check their website at http://www.microwave-rf.com.

IEEE EMC SOCIETY 2023 REGIONAL EVENTS

2022 Chicago IEEE EMC Mini Symposium
May 23, 2023 – Schaumburg, Illinois (U.S.)
http://www.emcchicago.org/sectfiles/events.htm

Michigan EMC Fest 2022
May 25, 2023 – Livonia, Michigan (U.S.)
https://www.emcsociety.org/wp/?page_id=35

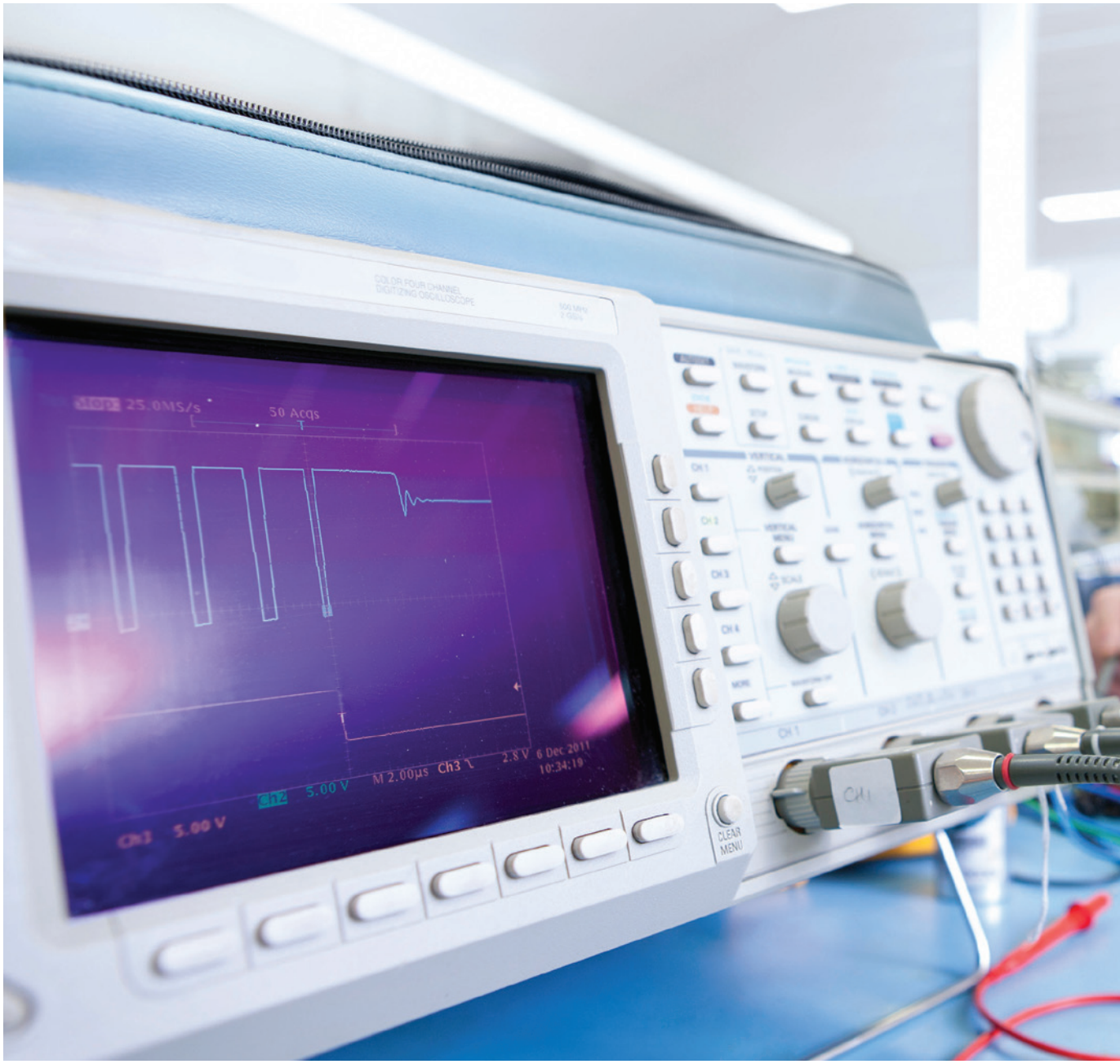
2023 Minnesota EMC Event
September 21, 2023 – Bloomington, Minnesota (U.S.)
https://www.mnemcevent.com

We hope this list will help you meet your professional development goals in 2023. Many additional trainings and events will be planned throughout the year, so be sure to check our events calendar at http://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 http://incompliancemag.com/eerc.

In the meantime, we hope that the year ahead brings only good health and happiness to you and your loved ones!

WHY HISTOGRAMS AND FREE RUN MATTER

A New Method for Oscilloscope-Based Power Integrity Testing



Joel Woodward has 33 years of experience in the test and measurement industry and is currently involved in product roadmap planning for Rohde & Schwarz oscilloscopes. He holds a degree in Electrical and Computer Engineering from Brigham Young University, and an MBA from Regis University, as well as an FPGA debug patent. Woodward can be reached at joel.woodward@rsa.rohde-schwarz.com.

By Joel Woodward

With the continual decrease in power rail DC voltages and tolerances, oscilloscopes remain a key tool for development teams tasked with power integrity measurements. The continual trend to lower voltages and tolerances has driven the proliferation of power rail probe usage with oscilloscopes. The question of "should we purchase our first power rail probe" has changed to "what's the best measurement technique". Initial techniques have been refined as users and oscilloscope manufacturers collaborate and share insights and experiences.

A relatively unknown yet superior technique emerged from experts making power integrity measurements. This approach involving histograms and free-run trigger mode offers three key improvements compared to the traditional approach:

- By using a waveform histogram, users can visually and statistically compile power rail attributes;
- By using a single histogram measurement across all acquired waveforms instead of a measurement on each waveform, speed-of-test is accelerated, and with great accuracy; and
- By using free trigger mode, users get increased real-time power rail coverage versus instrument dead time when the instrument is blind to power rail signal activity.

All major oscilloscope manufacturers offer power rail probes, and these probes incorporate several attributes that make them superior for highly accurate measurement of small voltages with tight tolerances. Lots of material is available on the benefits of using power rails. This includes the probes' minimal DC loading impact on the power rail, built-in offset to enable users to take advantage of small vertical scaling, and a 1:1 attenuation ratio to minimize noise. The relatively new histogram approach to power rail measurements accelerates test time by more than 50 times while providing more accurate measurement results.

TRADITIONAL APPROACH

The long-used approach for measuring power rail tolerance is to have the oscilloscope use a voltage peak-to-peak measurement to determine the overall amplitude from noise, ripple, and periodic disturbances (see Figure 1).

Oscilloscope users agree that a key issue with this traditional approach continues to be oscilloscope blind time. All oscilloscopes are subject to blind time between acquisitions. During this time, the

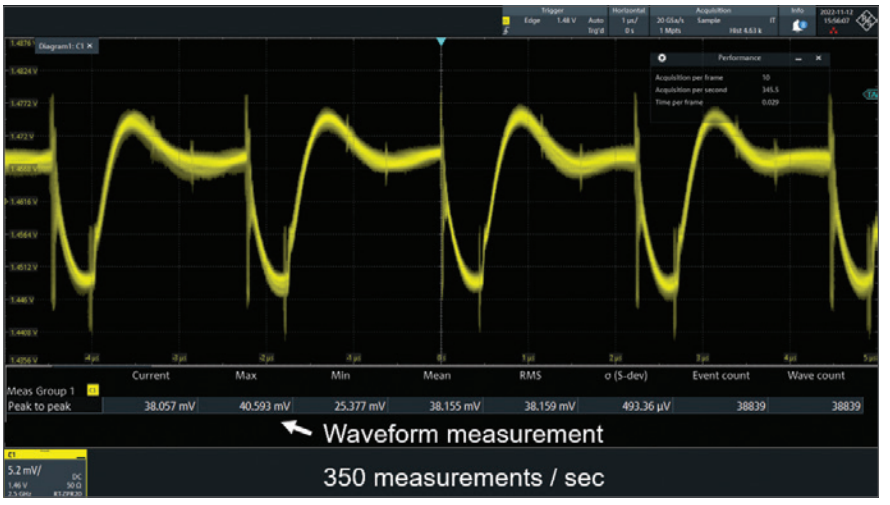


Figure 1: Making a measurement on each acquired oscilloscope waveform slows the update rate and increases blind time when the oscilloscope is not seeing or measuring power rail signal activity.

oscilloscope is processing the last acquisition and cannot perform any new acquisitions until the previous one has been processed. While engineers are generally aware of this, many are not aware that the ratio between blind time and real-time signal acquisition can be extremely large. It is not uncommon to have 1000 times the amount of blind time compared to acquisition time.

Several attributes related to testing power rails lead to additional undesired blind time. Oscilloscope users never achieve the faster update rate needed for better testing and hence are only able to test snippets of time, while missing large amounts of rail signal activity between acquisitions.

Oscilloscope manufacturers communicate a waveform update rate (wfms/s) for specific oscilloscope families. This value describes the maximum speed at which the instrument can acquire and display signals. The fastest oscilloscopes in the world have a waveform update rate in excess of one million waveforms per second, while slower ones will have an update rate in the tens of waveforms per second. Waveform update rate describes a maximum value, but this value is not typical for power integrity measurements.

Maximum update rates occur at a specific time base setting, with the fastest sample rate, and without any measurements turned on. However, this is not descriptive of a power integrity test setup. At time bases of 1 uS/ and slower that are typically used for power rail measurements, blind time increases.

Testing power rails varies from other types of testing in that a trigger signal is not always readily available. Most oscilloscopes require a minimum voltage swing for detecting a trigger event. Power rails often do not have enough signal swing and hence users choose auto-trigger, which means if the oscilloscope does not find a suitable trigger it will table an acquisition after a predefined period of waiting, typically a few mS. This triggering issue also contributes to users missing significant time when the oscilloscope is not acquiring power rail activity. Alternatively, in normal mode when the oscilloscope is triggering on the signal, it still needs to re-arm the trigger after each acquisition, which in turn slows down the waveform update rate.

Lastly, turning on measurements on all oscilloscopes reduces the instrument's acquisition rate. An oscilloscope that acquires 1 M waveforms per second without any measurements on might have a reduction to 350 acquisitions per second when measurements are turned on. An oscilloscope that normally acquires 50 waveforms per second might be slowed down to 5 acquisitions per second when a measurement is enabled. The need to process a measurement results

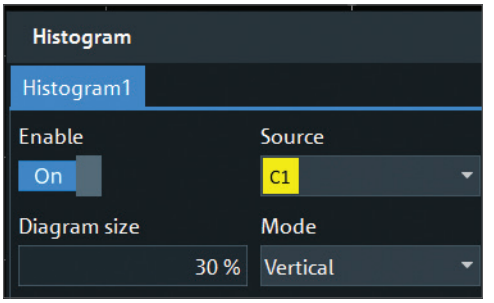


Figure 2: Turning on an oscilloscope waveform histogram creates a compressed statistical model of all vertical waveform values across all past acquisitions that the oscilloscope can quickly measure.

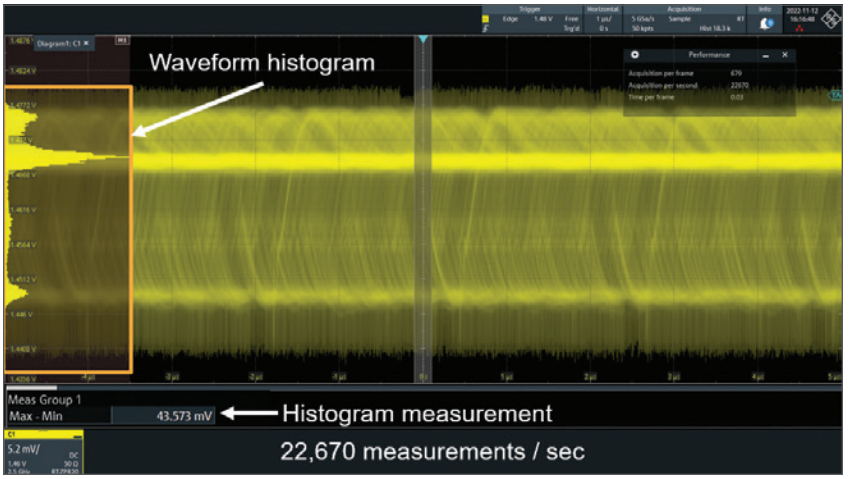


Figure 3: For some advanced oscilloscopes, a max peak-to-peak histogram measurement with free run trigger mode can yield nearly 23,000 power rail measurements per second. This is a >60X improvement over the traditional method, allowing users to see and measure over 20% of real-time rail signal activity.

in additional time during which the instrument is not actively acquiring power rail activity.

How much power rail activity do oscilloscopes miss? It is not uncommon for an oscilloscope with a fast update rate, a time base setting of 1 uS/div, and a single waveform measurement to have an update rate of 300 to 400 measurements per second. Is this fast? This update rate and time base combination means the oscilloscope is missing 99.6% of real-time power rail activity. Any anomalies that occur on the power rail during this blind time will not be recognized or measured by the oscilloscope. This processing speed tops other oscilloscopes where the update rate is just a few measurements per second, resulting in missing > 99% of power rail signal behavior.

Peak-to-peak voltage measurements are made on each individual waveform with results accumulated across multiple acquisitions. This provides a peak-to-peak range for each individual waveform, but it does not incorporate the largest maximum value versus the smallest minimum value that is acquired over successive acquisitions. What is needed is a peak-to-peak measurement that encompasses all acquisitions and updates as the oscilloscope acquires new power rail signal activity.

A SUPERIOR APPROACH

Several modifications to the traditional approach enable users to dramatically increase test time coverage and achieve more accurate measurements. The improved measurement techniques build on less frequently used oscilloscope settings that have existed for a long time, but that have not been exploited collectively for a specific application. Power integrity happens to be the key application where these capabilities combine to produce a result far better than the traditional power integrity measurement approach used by most engineers today.

1. Use Waveform Histogram

A number of currently available oscilloscopes offer a less commonly known feature called waveform histogram (see Figure 2). The instrument computes all waveform values and produces a corresponding histogram that shows what vertical values the waveform had, and what percentage of acquisition samples were at a specific amplitude. In a sense, histograms are very compact representations of waveform amplitude values at each sampled point. The histogram does not retain the detail related to the shape of each waveform, but rather just the vertical values. This is exactly what is needed for power integrity measurements.

Figure 3 shows a waveform histogram of a power rail. From the histogram, the user can quickly determine how much of the time the signal under test spends on each level. The histogram incorporates information from all acquired samples in each acquisition and builds up with each successive acquisition.

Why use a waveform histogram? For voltage tolerance testing, the shape of the waveform is not important. What is important are the minimum and maximum values. Rather, ripple, noise, and disturbances present themselves as anomalies that exceed voltage tolerance levels. A histogram is a great visualization tool to see if tolerance levels have been violated.

For many oscilloscopes, waveform histogram processing is done in hardware, and the oscilloscope experiences little to no drop in the maximum waveform update rate. With waveform histograms, such instruments can measure 20 times more acquisitions per second versus using a V_{pp} measurement on each acquisition. Such oscilloscopes capture as much as 20 times more real-time signal activity on the rail.

2. *Make the Peak-to-Peak Voltage Measurement (V_{pp}) on the Histogram*

Apply V_{pp}, min, or max measurement to the waveform histogram instead of measuring each individual waveform. Why is applying a V_{pp} measurement to a waveform histogram better than applying to individual waveforms? Since the waveform histogram contains power rail waveform information from all past acquisitions, the measurement applies to all acquisitions. For example, if a histogram is composed of 1000 repetitive acquisitions, a single peak-to-peak measurement on the histogram covers the composite information from all 1000 acquisitions. But the oscilloscope only needs to make a single measurement, instead of 1000 measurements, meaning the oscilloscope's update rate stays faster.

In addition to the speed increase, the peak-to-peak measurement on the histogram is made across all acquired data. It constitutes the true max peak-to-peak voltage from the highest value versus the smallest value. This provides the correct overall peak-to-peak value overall acquired data, versus the less accurate traditional approach that measures just the worst-case single acquisition that may not include the highest maximum voltage and the lowest minimum voltage of all acquisitions.

3. *Use Free Run Trigger Instead of Auto or Norm Trigger*

The third technique to achieve a more comprehensive, hence more accurate, power integrity test on power rails includes a change in how engineers trigger their oscilloscope. For testing rail voltage tolerances, triggering on a specific part of the waveform is not required. In fact, in many cases, oscilloscopes require larger voltage swings than occur on power rails. Because of this, testing of power rails is often done with the oscilloscope set to the default auto-trigger mode. If the oscilloscope does not find a trigger within a short period of time, typically a few mS, it goes ahead and acquires. The auto trigger mode inherently slows down the oscilloscope acquisition rate, meaning testing includes a small portion of the power rail real-time signal activity. Switching the trigger mode to norm yields a similar update rate as the auto trigger.

For power integrity tolerance testing, a trigger on a specific part of the waveform is not critical. Many oscilloscopes incorporate a less common trigger mode known as free run (see Figure 4). With the trigger set to free run, the oscilloscope captures data, processes

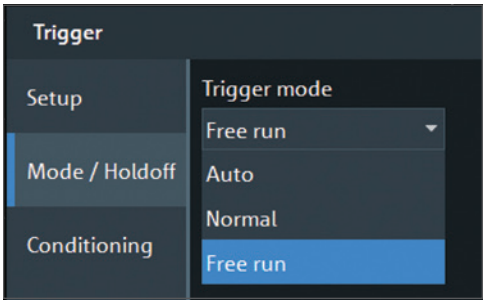


Figure 4: Setting the oscilloscope trigger mode to Free run matches power integrity test needs and maximizes the instrument's ability to see and measure the maximum amount of real-time rail signal activity.

	R&S RTO6 Oscilloscope time base = 1 uS/, SR = 5 Gsa/s			
Trigger setup	auto	norm	**free run**	
Measurement	none	Vpp on waveform	none	**Vpp on histogram**
Acqusitions/s	500	350	22.6 K	22.6 K
Time to measure 50K acqusitions	NA	143 sec	NA	2 sec
% of real-time rail activity captured	0.35%		22.6%	
% rail signal activity missed	99.65%		77.4%	
Vpp max	NA	40.6 mV	NA	42.7 mV
Improvement		1X		65X

Table 1: Comparison of traditional one measurement per acquisition approach, versus the superior histogram with free run trigger approach. The latter method enables the user to see and measure >60X more real-time power rail signal activity.

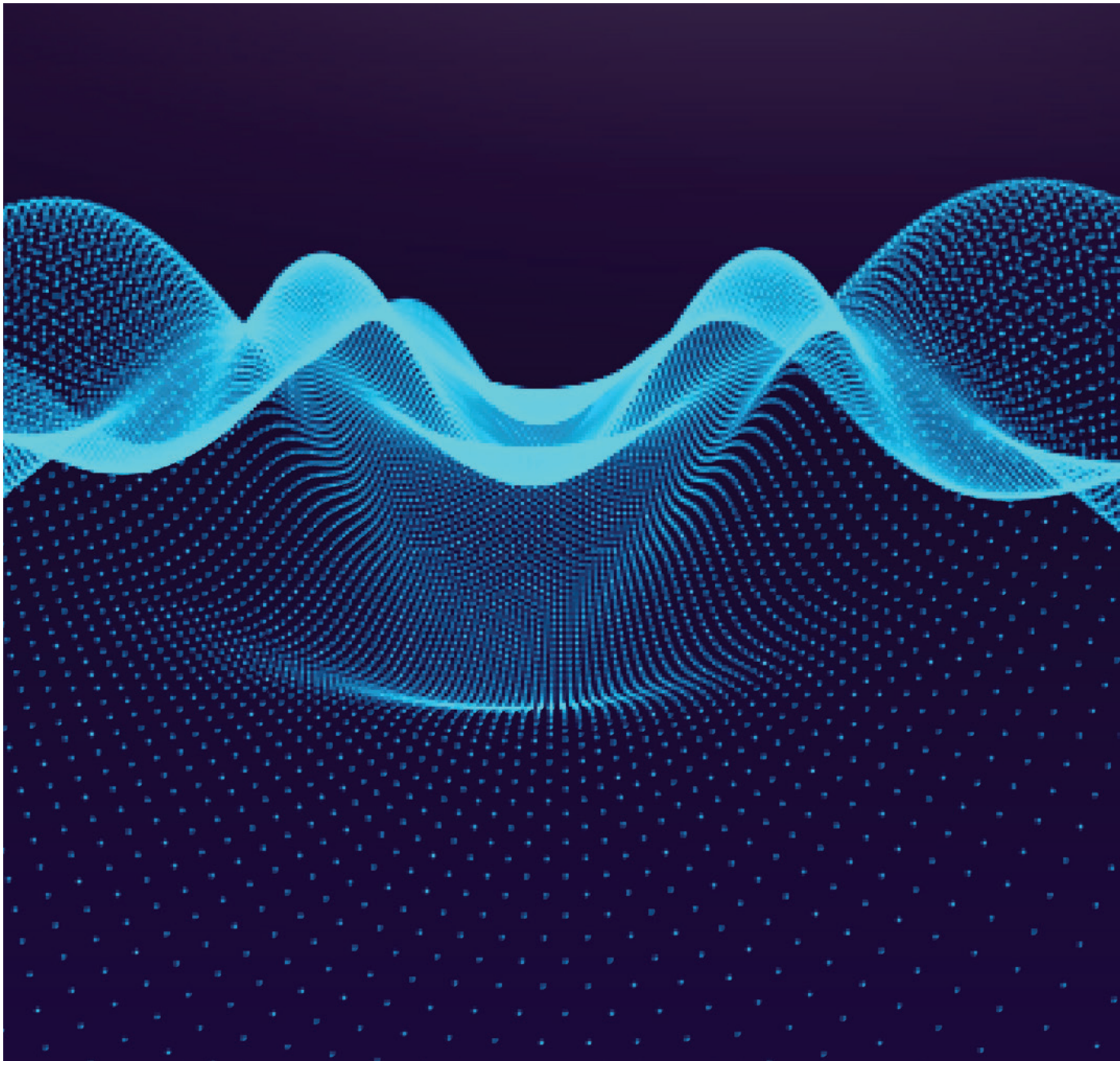
the data, and then captures the next acquisition without having to look for or wait for a trigger event. The tradeoff is that the trigger does not occur at the same point of the waveform each time. For power integrity tolerance testing, triggering on the same part of the signal each time is not needed and there are benefits in asynchronous triggering. Free run mode yields a waveform update rate dramatically faster than in auto or normal trigger modes. For example, on a specific oscilloscope tested with a time base setting of 1 uS/, in auto trigger mode the capture rate is 1,200 wfms/s while in free run the acquisition rate increases to 22.7 K wfms, almost 20 times better.

Table 1 shows the difference between the traditional measurement-per-waveform approach, versus the refined histogram combined with free-run trigger mode. (An R&S model RTO6 oscilloscope was used to highlight the differences between the two approaches.)

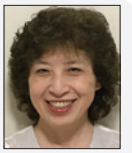
Like many approaches, combining multiple techniques yields significant advantages. For power rail testing with oscilloscopes, using waveform histograms, plus measurement on histograms, plus free run trigger mode enables users to capture and analyze a significantly higher percentage of rail activity than the traditional method of making peak-to-peak voltage measurements on individual waveforms with the oscilloscope's trigger set to auto or normal mode.

PERFORMING PROXIMITY MAGNETIC FIELDS IMMUNITY TESTING

How to Conduct Testing in Accordance with IEC 60601-1-2:2014 Amendment 1:2020



Grace Lin is a Regulatory Compliance Engineer at HYTORC. Prior to joining HYTORC, she was an EMC staff engineer and a TCB reviewer at Intertek. Lin can be reached at glin@hytorc.com.



Brian Lackey is an EMC engineer and member of the technical staff at Intertek in Lexington, Kentucky. He is a member of the TCB Council, an organization responsible for directly interfacing with the FCC, and is developing standards with the IEEE for statistical process control. Lackey can be reached at brian.lackey@intertek.com.

By Grace Lin and Brian Lackey

IEC 60601-1-2 is the international standard on electromagnetic disturbances to medical electrical equipment and is used in support of worldwide regulatory approvals for medical electrical equipment. The latest edition of the IEC 60601-1-2 standard, IEC 60601-1-2:2014 Amendment 1:2020 (referenced as Edition 4.1 hereafter), was published September 1, 2020. This latest edition includes the following significant technical changes with respect to its previous edition (IEC 60601-1-2 Edition 4.0 2014-02, referenced as Edition 4.0 hereafter):

- Normative references—As listed in Table 1, standard versions of eleven normative references are updated. In addition, ISO 7137:1995 is deleted and IEC 61000-4-39:2017 is added.
- Power input voltages—Power input voltage requirements for the following tests have been clarified: conducted disturbances (CISPR 11), voltage dips immunity (IEC 61000-4-11), and voltage short interruptions and voltage variations immunity (IEC 61000-4-11).

  For conducted disturbances and voltage dips immunity measurements, testing shall be performed at both minimum and maximum rated voltages. If the difference between the minimum and the maximum rated input voltages is less than 25% of the highest rated input voltage, the tests may be performed at any one rated voltage. Please note each economy/region may have its own requirements. For example, South Korea requires that testing be performed at 220 V.

  Testing of voltage short interruptions and voltage variations immunity shall be performed at any one voltage. Again, each economy/region may have its own requirements.
- Conducted immunity to SIP/SOPS (IEC 61000-4-6)—This test is now applicable to SIP/SOPS on cables equal to or greater than 1 m in length (versus 3 m from Edition 4.0).

IEC 60601-1-2:2014	IEC 60601-1-2:2014 Amendment 1:2020
IEC 60601-1:2005 Amendment 1:2012	IEC 60601-1:2005 Amendment 1:2012 Amendment 2:2020
IEC 60601-1-8:2006 Amendment 1:2012	IEC 60601-1-8:2006 Amendment 1:2012 Amendment 2:2020
IEC 60601-1-11:2010	IEC 60601-1-11:2015 Amendment 1:2020
IEC 60601-1-12	IEC 60601-1-12:2014 Amendment 1:2020
IEC 61000-4-5:2005	IEC 61000-4-5:2014 Amendment 1:2017
IEC 61000-4-11:2004	IEC 61000-4-11:2004 Amendment 1:2017
CISPR 11:2009 Amendment 1:2010	CISPR 11:2015 Amendment 1:2016 Amendment 2:2019
CISPR 14-1:2005	CISPR 14-1:2016
CISPR 16-1-2:2003 Amendment 1:2004 Amendment 2:2006	CISPR 16-1-2:2014 Amendment 1:2017
CISPR 32:2012	CISPR 32:2015
ISO 7137:1995	(Delete)
ISO 14971:2007	ISO 14971:2019
-	IEC 61000-4-39:2017

Table 1: Normative references

- Immunity to proximity magnetic fields—This is a newly added requirement stipulated in Subclause 8.11 of Edition 4.1 with the title of "Immunity to proximity magnetic fields in the frequency range 9 kHz to 13.56 MHz." It applies to medical electrical equipment or systems that contain magnetically sensitive components or circuitry with a less than 0.15 m separation distance from the field sources of 30 kHz, 134.2 kHz, and 13.56 MHz.
- Annex F—Annex F, an informative annex, has been replaced by a new one. The title of the annex has been changed from "RISK MANAGEMENT for BASIC SAFETY and ESSENTIAL PERFORMANCE with regard to ELECTROMAGNETIC DISTURBANCES," to "Guidance on the application of RISK MANAGEMENT with regard to ELECTROMAGNETIC DISTURBANCES in this collateral standard."

The following sections describe the proximity magnetic fields immunity test, and the key technical changes.

TEST REQUIREMENTS

Proximity magnetic fields immunity test requires three frequencies to be tested: 30 kHz, 134.2 kHz, and 13.56 MHz. Test frequencies, test signal modulation, and test levels are listed in Table 2.

Test levels listed in Table 2 are the amplitude of unmodulated carrier signal (i.e., continuous wave, CW). For testing at the frequencies of 134.2 kHz and 13.56 MHz, the carrier signals are pulse-modulated using a 50% duty cycle square wave signal and with specified modulation frequencies.

Frequency	Modulation	Immunity Test Level @ 50 mm (A/m)
30 kHz	Continuous Wave (CW)	8
134.2 kHz	Pulse Modulation 2.1 kHz	65
13.56 MHz	Pulse Modulation 50 kHz	7.5

Table 2: Test frequency, modulation, and test levels

TEST EQUIPMENT

Test equipment includes a generator, an optional compensation network, a radiating loop antenna, a monitoring loop antenna, and an electromagnetic interference (EMI) receiver or spectrum analyzer.

The generator must have the capability of generating the desired test levels. It includes a signal generator and a power amplifier. A signal generator must be capable of generating a carrier signal for the frequencies of interest and be equipped with pulse modulation capability internally or externally.

Based on experience using radiating loop antennas from two manufacturers, an 80 watts power amplifier should be able to generate the desired test levels. Manufacturers of radiating loop antennas typically provide drive power information for its radiating loop antennas. It is important to ensure the power amplifier is not saturated and the EMI receiver or spectrum analyzer is not overloaded.

A test laboratory with IEC 61000-4-6 10 V_{emf} test capability may use the same signal generator and power amplifier from its IEC 61000-4-6 test equipment if the signal generator and power amplifier cover frequencies of 30 kHz and 134.2 kHz. Though IEC 61000-4-6 specifies the test frequency range from 150 kHz to 80 MHz (not covering 30 kHz and 134.2 kHz), a power amplifier may work for frequencies below 150 kHz even if its specification starts at 150 kHz.

A matching network (compensation network) is used to better match the voltage standing wave ratio (VSWR) in the system to reduce needed power and to prevent damage to the power amplifier from reverse power. If a matching network is used, it connects directly to a radiating loop or through a specially designed cable. At the time of this writing, a 13.36 MHz matching network is commercially available, but a matching network can be made in-house with all the required components typically costing less than $100. A vector network analyzer (VNA) is used to tune the matching network.

A radiating loop antenna is a field-generating device. A monitoring loop antenna is a magnetic field sensor

Type of Loop Antenna	Frequency	Loop Diameter (mm)	No. of Turns	Wire Diameter
Radiating Loop	9 kHz – 150 kHz	120 ± 10	20	~ 2.0 mm (AWG 12)
Monitoring Loop	9 kHz – 150 kHz	40 ± 2	51	~ 0.07 mm (7 Stand 41 AWG)
Radiating Loop	150 kHz – 26 MHz	100 ± 10	3	~ 1.0 mm
Monitoring Loop	150 kHz – 26 MHz	40 ± 2	1	~ 0.5 mm

Table 3: Loop antenna specifications

loop. Specifications for these loop antennas are listed in Table 3.

Both radiating and monitoring loop antennas are commercially available. Equipment manufacturers offer loop antennas as individual parts or as kits. Kits typically come with 50 mm fixtures.

Radiating loop antennas can also be made in-house. Step-by-step instructions are provided below to construct a 134.2 kHz radiating loop antenna:

1. Find a cylindrical form 120 ±10 mm in diameter, and 100 mm in height. The cardboard center of a wire spool of about 120 mm should work for the purpose.
2. Wrap 20 turns of AWG 12 wire around the center of the form, leaving a few feet free on either end.
3. Create a compensation network using a piece of prototyping board or other material with a coaxial connection for the amplifier on one side and terminals for the loop on the other. An optional step-down transformer may be used to increase the impedance as recorded by the amplifier and to produce the necessary drive current in the loop. The transformer must be rated for the test frequency and drive current.
4. Connect the loop and the compensation network to a calibrated VNA and measure the impedance at the design frequency (e.g., 134.2 kHz).
5. Add series capacitance to the compensation network to move the impedance to the Re(Y)=1 circle, Im(Y) < 0.
6. Add parallel capacitance to the compensation network to move the impedance to the center (match).

Build up the capacitors on a breadboard first, then solder them on a prototyping board, and place the board in an enclosure with dual banana jacks. A TESEQ NSG 4070 conducted immunity system is used to power the loop antenna and obtain the required 65 A/m with less than 10 watts of power.

ESTABLISHING TEST LEVELS

Figure 1 shows the test setup to establish test levels.

The monitoring loop antenna is positioned on the center axis of the radiating loop antenna and at a distance of 50 mm. Loop antenna manufacturers offer fixtures to keep the monitoring loop antenna at a distance of 50 mm from the radiating loop antenna.

The monitoring loop antenna is connected to an EMI receiver or a spectrum analyzer. The magnetic field strength (in dBμA/m) at the distance of 50 mm is calculated as the sum of the measured voltage level (in dBμV) and the conversion factor (in dB/Ωm) of the monitoring loop antenna. The conversion factor is used to convert the monitoring loop antenna voltage to magnetic intensity. The relevant conversion factor

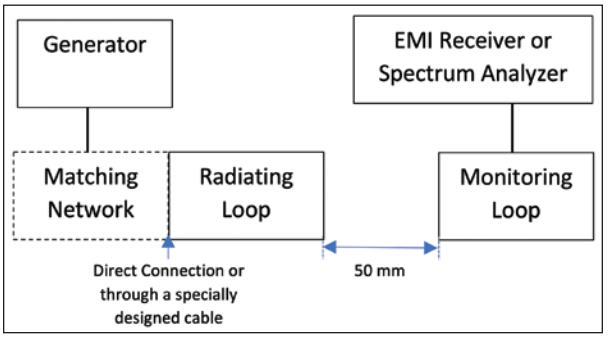


Figure 1: Test setup—Establish test levels

can be found in the datasheet of the monitoring loop antenna. The measured field strength must be within ± 10 %. of the specified test level.

To achieve the desired magnetic field strength (for example, 7.5 A/m (137.5 dBµA/m) at 13.35 MHz), increase the power of the generator at the input of the radiating loop antenna (or the input of the matching network if a matching network is used) until the measured voltage at the output of the monitoring loop antenna is reached. For a conversion factor of 18.3 dB/Ωm, the measured voltage is 119.2 dBµV. No modulation signal is applied while establishing test levels. Record the signal generator output levels for testing.

Once the measured voltage is reached, switch on the modulation of the test signal to verify the correct modulation of the test signal. To verify the modulation, set the span of an EMI receiver (in spectrum mode) or a spectrum analyzer to zero, as shown in Figure 2. A pulse frequency of 50 kHz is equivalent to a pulse period of 20 µs.

EXECUTING TEST

Figure 3 shows the test setup to execute the test.

Test methods are specified in IEC 61000-4-39:2017. The test is performed by exposing the equipment under test (EUT) to the test signals at 30 kHz, 134.2 kHz, and 13.56 MHz. Place the radiating loop antenna at the test distance of 50 mm from a test point on the EUT. Orient the plane of the radiating loop antenna parallel to the EUT's faces. Set the signal generator's output level to the level recorded from established test levels.

The dwell time must be long enough for the EUT to adequately respond to the test signal. The minimum dwell time is 2 seconds.

CONCLUSION

IEC 60601-1-2 Edition 4.1 2020-09 CONSOLIDATED VERSION supersedes IEC 60601-1-2 Edition 4.0 2014-02. Each economy/region sets its own transition period. In the U.S., the Food and Drug Administration (FDA) will no longer accept Edition 4.0 test reports after the end of the transition period of December 17, 2023.

Being prepared for the changes and requirements is important to your success. Table 4 lists a summary of tests required and specified in Edition 4.1, including the completely new proximity magnetic fields immunity test.

REFERENCES

- IEC 60601-1-2:2014 Amendment 1:2020, Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral Standard: Electromagnetic disturbances – Requirements and tests
- IEC 61000-4-39:2017, Electromagnetic compatibility (EMC) – Part 4-39: Testing and measurement techniques – Radiated fields in close proximity – Immunity test

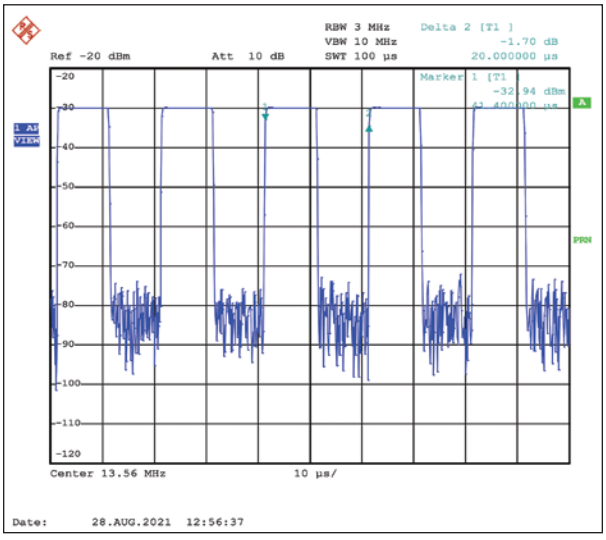


Figure 2: Screenshot—Verifying modulation

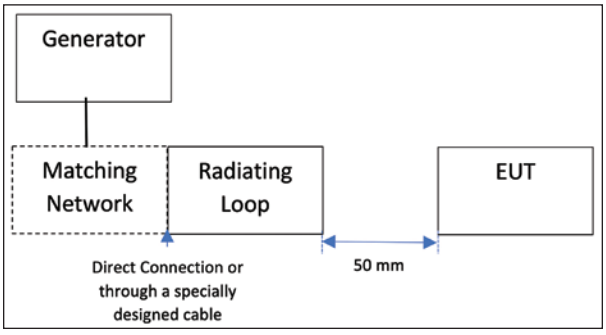


Figure 3: Test setup—Execute tests

- IEC 61000-4-6:2013, Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields
- Schwartzbeck FESP 5132 Datasheet http://schwarzbeck.de/Datenblatt/k5132.pdf
- AMETEK CTS LAS 6100 Datasheet https://www.ametek-cts.com
- AMETEK CTS LAS 6120 Datasheet https://www.ametek-cts.com

Test	Basic Standard	Applicable Ports
Electromagnetic radiation disturbance (Radiated Emissions)	CISPR 11:2015 A1:2016 A2:2019	enclosure
Conducted Disturbances (Conducted Emissions)	CISPR 11:2015 A1:2016 A2:2019	input a.c. power
Harmonic Current Emissions	IEC 61000-3-2:2005 A1:2008 A2:2009	input a.c. power
Voltage Changes, Voltage Fluctuations and Flicker Emissions	IEC 61000-3-3:2013	input a.c. power
Electrostatic Discharge Immunity	IEC 61000-4-2:2008	enclosure patient coupling signal input/output parts
Radiated RF Electromagnetic Field Immunity	IEC 61000-4-3:2006 A1:2007 A2:2010	enclosure
Proximity Fields from RF Wireless Communications Equipment	IEC 61000-4-3:2006 A1:2007 A2:2010	enclosure
Electrical Fast Transient/Burst Immunity	IEC 61000-4-4:2012	input a.c. power input d.c. power signal input/output parts
Surge Immunity	IEC 61000-4-5:2014 A1:2017	input a.c. power input d.c. power signal input/output parts
Immunity to Conducted Disturbances induced by RF Fields (Conducted RF Disturbance Immunity)	IEC 61000-4-6:2013	input a.c. power input d.c. power patient coupling signal input/output parts
Power Frequency Magnetic Field Immunity	IEC 61000-4-8:2009	enclosure
Voltage Dips Immunity	IEC 61000-4-11:2004 A1:2017	input a.c. power
Voltage Short Interruptions and Voltage Variations Immunity	IEC 61000-4-11:2004 A1:2017	input a.c. power
Proximity Magnetic Fields	IEC 61000-4-39:2017	enclosure
Electrical Transient Conduction Along Supply Lines	ISO 7637-2:2011	input d.c. power

Table 4: Summary of tests specified in IEC 60601-1-2 Edition 4.1

SINUSOIDAL STEADY STATE ANALYSIS OF TRANSMISSION LINES

Part I: Transmission Line Model, Equations and Their Solutions, and the Concept of the Input Impedance to the Line

By Bogdan Adamczyk

In the previous article, [1], a concept of the phasor was introduced. This tutorial article is a part of the three-article series devoted to the frequency-domain analysis of a lossless transmission line. First, a time-domain model of a lossless transmission line is shown and used to arrive at the time-domain equations describing it. Next, the time-domain solution is transformed into the phasor domain. Subsequently, the general solution for the voltage and current is presented and followed by the concept of the input impedance to the line.

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 2023). He can be reached at adamczyb@gvsu.edu.

1. TRANSMISSION LINE EQUATIONS

A lossless transmission line can be modeled as a distributed parameter circuit consisting of a series of small segments of length Δz as shown in Figure 1.

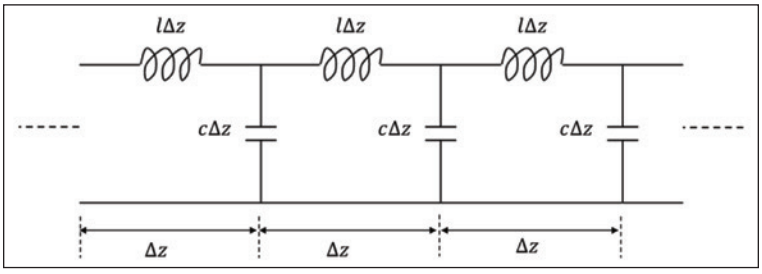


Figure 1: Distributed circuit model of a lossless transmission line

To obtain the transmission line equations, [2], let us consider a single segment of a lossless transmission line shown in Figure 2.

The distributed, per-unit-length parameters describing the transmission line are the inductance l in H/m and the capacitance c in F/m.

Writing Kirchhoff's voltage law around the outside loop results in

$$-V(z,t) + l\Delta z \frac{\partial I(z+\Delta z,t)}{\partial t} + V(z+\Delta z,t) = 0 \quad (1.1)$$

or

$$V(z+\Delta z,t) - V(z,t) = -l\Delta z \frac{\partial I(z+\Delta z,t)}{\partial t} \quad (1.2)$$

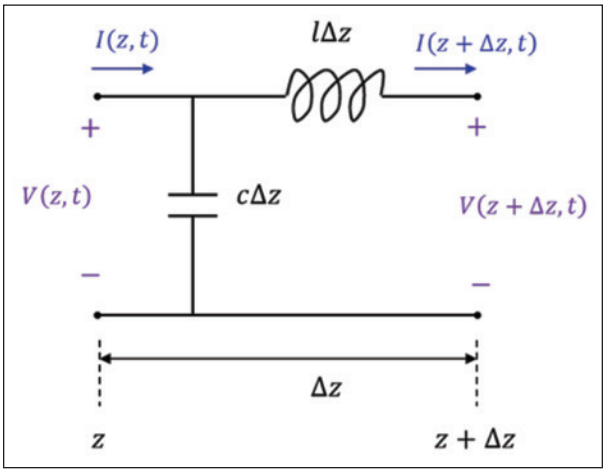


Figure 2: Single segment of a lossless transmission line

Dividing both sides by Δz and taking the limit gives

$$\lim_{\Delta z \to 0} \frac{V(z+\Delta z,t)-V(z,t)}{\Delta z} = -\lim_{\Delta z \to 0} l \frac{\partial I(z+\Delta z,t)}{\partial t} \tag{1.3}$$

or

$$\frac{\partial V(z,t)}{\partial z} = -l \frac{\partial I(z,t)}{\partial t} \tag{1.4}$$

Writing Kirchhoff's current law at the upper node of the capacitor results in

$$I(z,t) = c\Delta z \frac{\partial V(z,t)}{\partial t} + I(z+\Delta z,t) \tag{1.5}$$

or

$$I(z+\Delta z,t) - I(z,t) = -c\Delta z \frac{\partial V(z,t)}{\partial t} \tag{1.6}$$

Dividing both sides by Δz and taking the limit gives

$$\lim_{\Delta z \to 0} \frac{I(z+\Delta z,t)-I(z,t)}{\Delta z} = -\lim_{\Delta z \to 0} c \frac{\partial V(z,t)}{\partial t} \tag{1.7}$$

or

$$\frac{\partial I(z,t)}{\partial z} = -c \frac{\partial V(z,t)}{\partial t} \tag{1.8}$$

Equations (1.4) and (1.8) constitute a set of first order, coupled transmission line equations. These equations can be decoupled, [2], resulting in

$$\frac{\partial^2 V(z,t)}{\partial z^2} = lc \frac{\partial^2 V(z,t)}{\partial t^2} \tag{1.9a}$$

$$\frac{\partial^2 I(z,t)}{\partial z^2} = lc \frac{\partial^2 I(z,t)}{\partial t^2} \tag{1.9b}$$

In a sinusoidal steady state, the transmission line is driven by a sinusoid

$$v(t) = V\cos(\omega t + \theta) \tag{1.10}$$

which has a corresponding phasor, [1],

$$\hat{V} = Ve^{j\theta} \tag{1.11}$$

In phasor domain, the equations (1.9) become

$$\frac{\partial^2 \hat{V}(z)}{\partial z^2} = -\omega^2 lc\hat{V}(z) \tag{1.12a}$$

$$\frac{\partial^2 \hat{I}(z)}{\partial z^2} = -\omega^2 lc\hat{I}(z) \tag{1.12b}$$

Equations (1.12) describe a wave propagating with the velocity of

$$v = \frac{1}{\sqrt{lc}} \tag{1.13}$$

This velocity is related to frequency ω, and phase constant β by

$$v = \frac{\omega}{\beta} \tag{1.14}$$

From Eqns. (1.13) and (1.14) we obtain

$$\frac{1}{\sqrt{lc}} = \frac{\omega}{\beta} \tag{1.15}$$

and thus

$$\beta = \omega\sqrt{lc} \tag{1.16}$$

or

$$\beta^2 = \omega^2 lc \tag{1.17}$$

Therefore, Eqns. (1.12) can be expressed as

$$\frac{\partial^2 \hat{V}(z)}{\partial z^2} = -\beta^2 \hat{V}(z) \tag{1.18a}$$

$$\frac{\partial^2 \hat{I}(z)}{\partial z^2} = -\beta^2 \hat{I}(z) \tag{1.18b}$$

2. GENERAL SOLUTION OF THE TRANSMISSION LINE EQUATIONS

The general solution of Eqns. (1.18) is of the form

$$\hat{V}(z) = \hat{V}^+ e^{-j\beta z} + \hat{V}^- e^{j\beta z} \tag{2.1a}$$

$$\hat{I}(z) = \frac{\hat{V}^+}{Z_C} e^{-j\beta z} - \frac{\hat{V}^-}{Z_C} e^{j\beta z} \tag{2.1b}$$

where the *characteristic impedance* of the transmission line, Z_C, is given by

$$Z_C = \sqrt{\frac{l}{c}} \tag{2.2}$$

and the constants $\hat{V}^+$ and $\hat{V}^-$ are obtained from the knowledge of a complete transmission line model (as we will show in the next article).

Before proceeding any further, let us verify that the Eqns. (2.1) are indeed the solutions of Eqns. (1.18). First, let us demonstrate this for Eq. (2.1a).

Differentiating Eq. (2.1a) with respect to z gives

$$\frac{d\hat{V}(z)}{dz} = -j\beta\hat{V}^{+}e^{-j\beta z} + j\beta\hat{V}^{-}e^{j\beta z} \tag{2.3}$$

Differentiating once more produces

$$\frac{d^2\hat{V}(z)}{dz^2} = (-j\beta)(-j\beta)\hat{V}^{+}e^{-j\beta z} + (j\beta)(j\beta)\hat{V}^{-}e^{j\beta z} \tag{2.4a}$$

or

$$\frac{d^2V(z)}{dz^2} = -\beta^2\hat{V}^{+}e^{-j\beta z} - \beta^2\hat{V}^{-}e^{j\beta z} \tag{2.4b}$$

Thus

$$\frac{d^2\hat{V}(z)}{dz^2} = -\beta^2\left(\hat{V}^{+}e^{-j\beta z} + \hat{V}^{-}e^{j\beta z}\right) = -\beta^2\hat{V}(z) \tag{2.4c}$$

proving that Eq. (2.1a) is the solution of Eq. (1.18a). Next, let us look at the Eq. (2.1b).

Differentiating Eq. (2.1b) with respect to z gives

$$\frac{d\hat{I}(z)}{dz} = -j\beta\frac{\hat{V}^{+}}{Z_C}e^{-j\beta z} - j\beta\frac{\hat{V}^{-}}{Z_C}e^{j\beta z} \tag{2.5}$$

Differentiating once more produces

$$\frac{d^2\hat{I}(z)}{dz^2} = (-j\beta)(-j\beta)\frac{\hat{V}^{+}}{Z_C}e^{-j\beta z} - (j\beta)(j\beta)\frac{\hat{V}^{-}}{Z_C}e^{j\beta z} \tag{2.6a}$$

or

$$\frac{d^2\hat{I}(z)}{dz^2} = -\beta^2\frac{\hat{V}^{+}}{Z_C}e^{-j\beta z} + \beta^2\frac{\hat{V}^{-}}{Z_C}e^{j\beta z} \tag{2.6b}$$

Thus

$$\frac{d^2\hat{I}(z)}{dz^2} = -\beta^2\left(\frac{\hat{V}^{+}}{Z_C}e^{-j\beta z} - \frac{\hat{V}^{-}}{Z_C}e^{j\beta z}\right) = -\beta^2\hat{I}(z) \tag{2.6c}$$

proving that Eq. (2.1b) is the solution of Eq. (1.18b).

The solutions in Eqns. (2.1) consist of the forward- and backward-traveling waves, [3],

$$\hat{V}(z) = \hat{V}_f(z) + \hat{V}_b(z) \tag{2.7a}$$

$$\hat{I}(z) = \hat{I}_f(z) + \hat{I}_b(z) \tag{2.7b}$$

The forward-traveling waves are described by

$$\hat{V}_f(z) = \hat{V}^{+}e^{-j\beta z} \tag{2.8a}$$

$$\hat{I}_f(z) = \frac{\hat{V}^{+}}{Z_C}e^{-j\beta z} \tag{2.8b}$$

while the backward-traveling waves are given by

$$\hat{V}_b(z) = \hat{V}^{-}e^{j\beta z} \tag{2.9a}$$

$$\hat{I}_b(z) = -\frac{\hat{V}^{-}}{\hat{Z}_C}e^{j\beta z} \tag{2.9b}$$

3. THE COMPLETE CIRCUIT MODEL OF A TRANSMISSION LINE

To determine the voltages and currents along the transmission line we need to consider a complete circuit model consisting of the source, the transmission line, and the load, as shown in Figure 3.

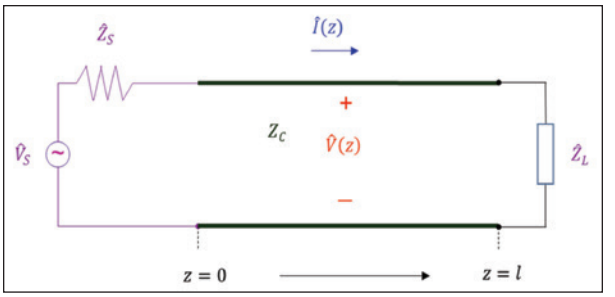


Figure 3: Model 1: Transmission line circuit with the source located at $z = 0$ and the load at $z = l$

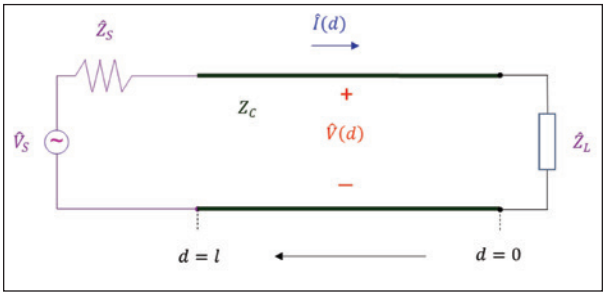


Figure 4: Model 2: Transmission line circuit with the load located at $d = 0$ and the source at $d = l$

In this model, we are moving from the source located at $z = 0$, towards the load located at $z = l$. It is often convenient to use an alternate circuit, shown in Figure 4.

In this alternate model, we are moving from the load located at $d = 0$, towards the source located at $d = l$.

4. CONCEPT OF THE INPUT IMPEDANCE TO THE TRANSMISSION LINE

Consider a transmission line circuit shown in Figure 5.

The input impedance to the line at any location z, $\hat{Z}_{in}(z)$, is always calculated looking towards the load, regardless whether we use Model 1 or Model 2. Figure 6 shows the equivalent circuit where the circuit to the right of nodes *AB* has been replaced with the input impedance to the line at that location, [4].

The input impedance can be calculated at any location, including $z = 0$, as shown in Figure 7.

We refer to this impedance as the input impedance to the line at the input to the line.

The next article will be devoted to the calculation of the input impedance at the input to the line and at any location between the source and the load.

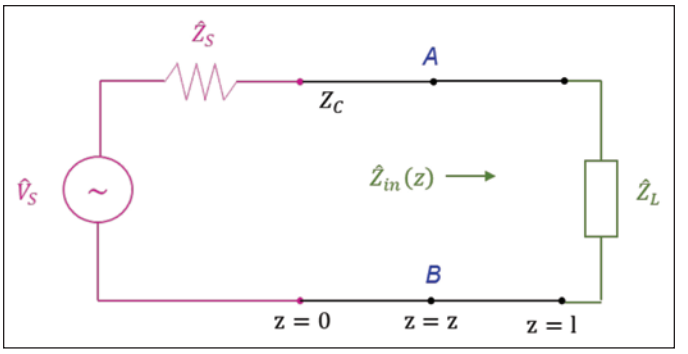


Figure 5: Input impedance to the line at any location z

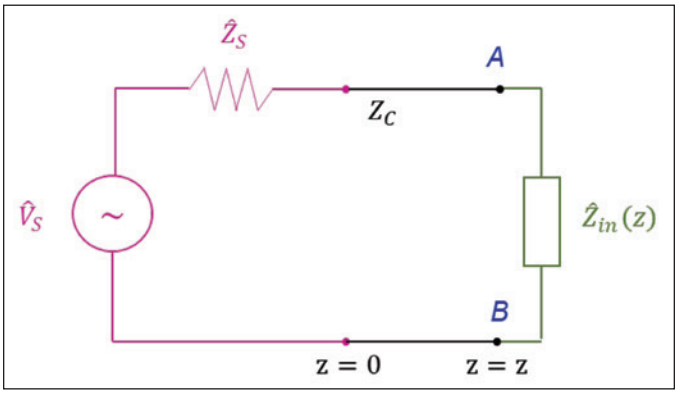


Figure 6: Equivalent circuit

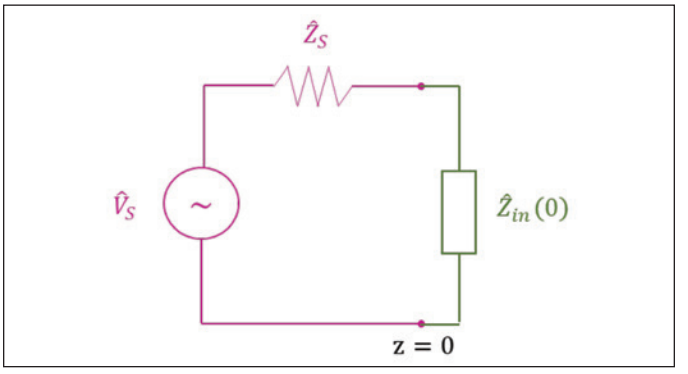


Figure 7: Input impedance to the line at the input to the line

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THE TRANSISTOR: AN INDISPENSABLE ESD PROTECTION DEVICE - PART 1

Use of Bipolar Transistor ESD Protection in RF Technologies

By Lorenzo Cerati, Dolphin Abessolo-Bidzo, Mirko Scholz, and Marko Simicic for EOS/ESD Association, Inc.

Since its invention in 1947 at Bell Labs by William Shockley, Walter Brattain, and John Bardeen, the bipolar transistor has been implemented in multiple key applications successfully. Nowadays in the semiconductors industry, the bipolar transistor is massively used for various functions in modern integrated circuits (ICs) products. For on-chip electrostatic discharge (ESD) protection solution, the bipolar junction transistor, represented in Figure 1, is a very effective and valuable ESD device. With high ESD performance, low leakage, low input capacitance, and compactness, it has a smaller footprint advantage compared to other ESD devices. Furthermore, modern bipolar devices are reaching record RF performance including but not limited to a high transition frequency f_T > 300GHz and minimum noise figure NF_{MIN} < 1dB.

Lorenzo Cerati is ESD Design Solutions Technical Director and Fellow of Technical Staff at STMicroelectronics.

Dr. Ir. Dolphin Abessolo-Bidzo is Senior Principal RF ESD & Latch-Up Design Engineer at NXP Semiconductors.

Dr. Mirko Scholz is a Principal Engineer ESD Development at Infineon Technologies AG in Neubiberg/Germany.

Marko Simicic is part of the ESD team in imec, Belgium, with the focus on researching ESD solutions for devices and circuits.

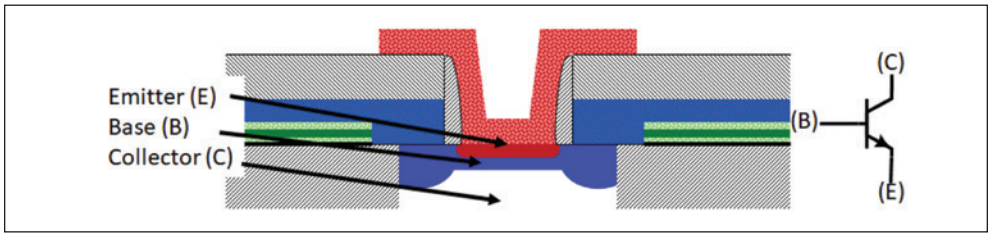

Figure 1: A simplified cross-section of the bipolar junction transistor. Inset is its electrical symbol [1]

Device Parameters		Triggering Parameters		Holding Parameters		Failure Parameters	
Device	R_{LB}[kΩ]	V_{T1}[V]	I_{T1}[mA]	V_{ON}[V]	R_{ON}[Ω]	V_{T2}[V]	I_{T2}[A]
NPN_Rlb_10k	10	8.9	1.0	3.4	2.3	6.1	1.1
NPN_ Rlb_100k	100	4.8	1.0	3.4	2.3	6.1	1.1
NPN_Rlb_1M	1000	4.4	1.0	3.4	2.3	6.1	1.1

Table 1: ESD parameters of an example standalone latch-back bipolar NPN transistor

The NPN device can be implemented as a very effective standalone primary ESD protection for pad-based ESD protected input/output in RF and high-speed applications especially. The trigger voltage of the latch-back silicon junction bipolar NPN transistor is very much dependent on the base-emitter discrete resistor R_{LB} value (Table 1). The latter must be chosen and tuned according to the device to be protected in the core of the integrated circuit and the so-called ESD design window.

In this example, the standalone latch-back bipolar NPN transistor can withstand up to 1.1A transmission line pulse (100ns-TLP), this is equivalent to about 2kV human body model (HBM) robustness in terms of energy content as shown in Figure 2.

USING MOS TRANSISTORS AS ESD PROTECTION CLAMPS IN CMOS CIRCUITS

Since the beginning of ESD protection design, MOSFET transistors are common ESD protection devices in CMOS circuits. The ESD current is discharged either through the MOS-channel in a power clamp or conducted by the parasitic bipolar transistor that is inherent in every MOS transistor. Figure 3 shows the simplified schematics for both ESD clamp concepts.

In a power clamp, a transient trigger circuit biases the gate of the "big MOS transistor" for the duration of the ESD current. The MOS-channel provides the low-ohmic path to ground. During normal operation, the trigger circuit keeps the gate closed and the ESD clamp off. In a grounded-gate configuration for a MOS transistor, a high value resistor connects gate, source and bulk. This prevents the biasing of the gate and opening of the MOS channel during ESD stress and normal operation. However, during ESD stress the *parasitic bipolar* transistor between drain and source (Figure 4 on page 44) turns on and provides a path to ground for the conduction of the ESD current.

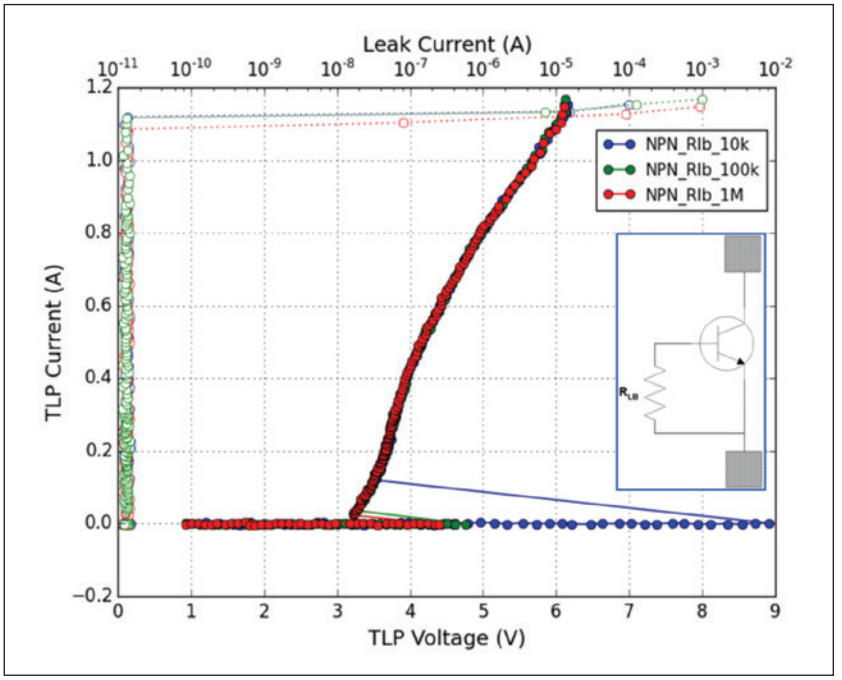

Figure 2: 100ns-TLP measurements of a latch-back bipolar NPN transistor. Inset shows its typical implementation between two pads.

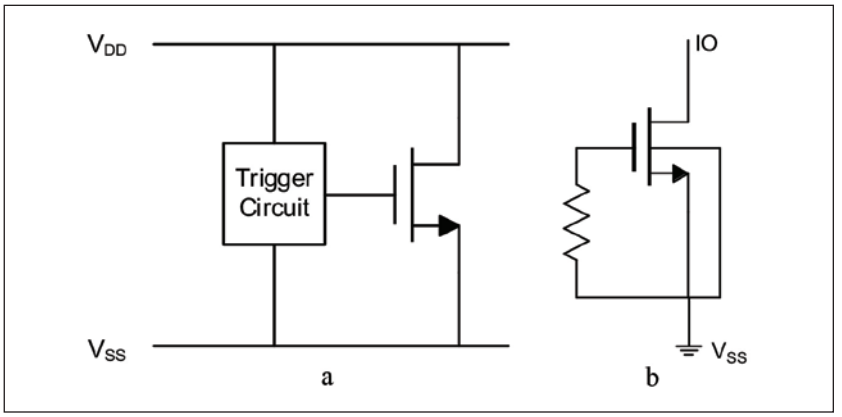

Figure 3: Use of MOS transistors as ESD clamps: principle schematics of a NMOS based power clamp (a) and grounded-gate NMOS based IO protection (b)

Continuous technology scaling increases the contact resistance. This led to the introduction of silicidation from the 0.35 µm CMOS process node. Silicides are low-ohmic films in the active areas of transistors. Because of the high currents during ESD stress, silicidation has a negative impact on the ESD robustness of MOS transistor based ESD clamps. Silicidation leads to a non-uniform current conduction in the drain and source areas. In fully silicided MOS devices, the ESD current concentrates close to the gate. This locally increases the current density and reduces the failure level of the device. A silicide-blocking mask between drain and gate (Figure 5) helps to reduce this "current crowding effect" and enables a uniform spread of the current. The ESD design measure enables a significant improvement of the failure current during ESD stress (Figure 6).

SUMMARY

As described in this article the invention of the bipolar transistor has seen the technology evolve into wide semiconductor applications. Both the bipolar transistor and MOS transistor continue to provide effective ESD protection options.

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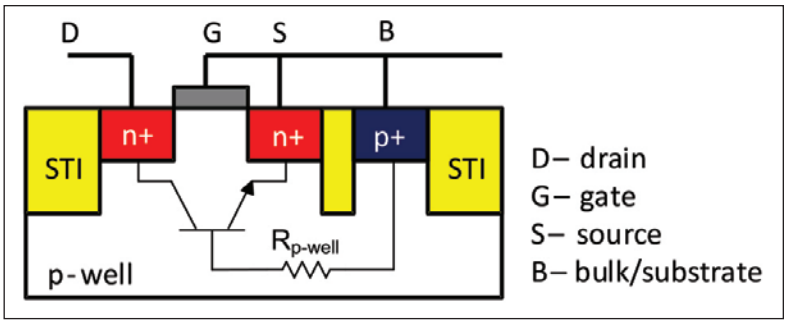

Figure 4: Cross-section of a NMOS transistor in grounded-gate configuration. The parasitic bipolar is here a NPN with the drain as collector, the source as emitter and the bulk as base.

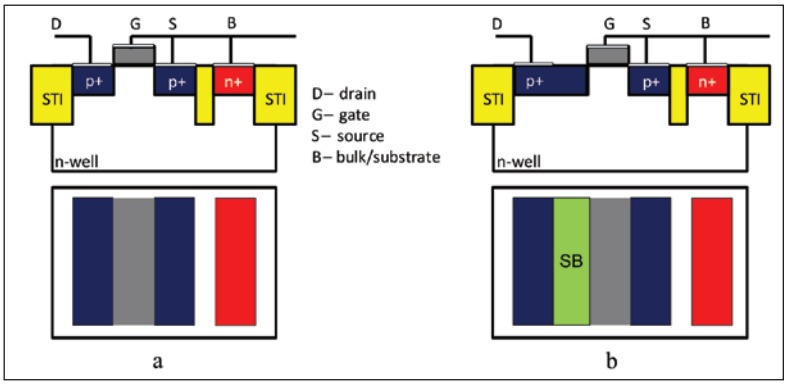

Figure 5: Device cross-section and simplified layout view of a fully silicide grounded-gate PMOS transistor (a) and a silicide block grounded-gate PMOS with silicide-blocking (SB) between drain and gate (b)

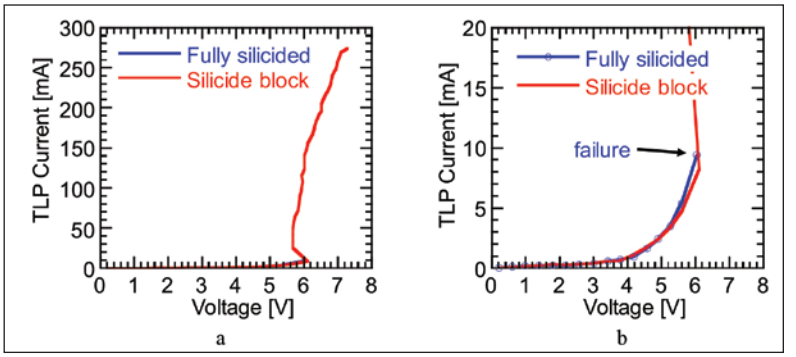

Figure 6: Comparison of 100ns TLP-IV curves of a fully silicide grounded-gate PMOS and a silicide block grounded-gate PMOS: complete TLP IV curves (a) and zoom-in to failure of the fully silicide device (b)

UNDERSTANDING SAFETY LABEL FORMAT AND SYMBOL OPTIONS

By Erin Earley

In our last 'On Your Mark' column, we explored the product liability and legal landscape, noting how product safety labels are an important part of keeping users safe and reducing liability risk – as well as how industry standards like ANSI Z535.4 (domestically) and ISO 3864-2 (internationally) can be effective starting points in helping you to develop adequate warnings. "Warnings and instructions should be front and center for manufacturers. Warnings can be the downfall of a product but also its salvation," trial attorney and product liability expert Cal Burnton told us.

When it comes to formatting options and symbol use in your labels, the current versions of these standards allow manufacturers to use a number of different options. So, how do you make the right decision for your products? "I recommend first understanding the standards-based options available to you, weighing the benefits and limitations, and then deciding which best conveys your safety message to your intended audience," says Angela Lambert, head of standards compliance at Clarion Safety Systems.

Read on for a quick guide to understanding the considerations of the main label and symbol format options available to you, including pros and cons, and whether they meet the U.S. ANSI Z535.4 standards, the international ISO 3864-2 standards, or both standards.

SYMBOL-ONLY LABEL FORMATS

This style of safety label uses only ISO-formatted symbols without a word message or an ANSI/ISO signal word panel. It meets both the ANSI Z535.4* and ISO 3864-2 standards. The benefits of this type of format are that it can communicate across language barriers without translations and that these symbols typically use less space than other types of formats. The limitations are that more than one symbol-only label may be needed to communicate the safety message, the severity of the hazard isn't defined, and that symbol comprehension testing or training may be needed.

Erin Earley, head of communications at Clarion Safety Systems, shares her company's passion for safer products and workplaces. She's written extensively about best practices for product safety labels and facility safety signs. Clarion is a member of the ANSI Z535 Committee for Safety Signs and Colors, the U.S. ANSI TAG to ISO/TC 145, and the U.S. ANSI TAG to ISO 45001. Erin can be reached at eearley@clarionsafety.com.

SYMBOL AND TEXT LABEL FORMATS

This type of safety label uses ISO-formatted symbols with an ANSI/ISO signal word panel and word message. This format meets ANSI Z535.4, and meets ISO 3864-2 as well, as long as at least one 'ISO-formatted' symbol (meaning the symbol uses a colored, surround shape consistent with the ISO standards) is used. The benefits of this type of format are that multiple symbols can reinforce the message, the signal word panel defines hazard severity level, and a word message provides information on hazard and how to avoid it. The limitations are that space may be an issue, translations may be necessary, and some symbol and text label options don't meet ISO 3864-2 (due to the ISO-formatted symbol requirement).

TEXT-ONLY ANSI LABEL FORMATS

These text-based safety labels use an ANSI/ISO signal word panel and a word message. This meets the ANSI Z535.4 standard. It does not, however, meet ISO 3864-2. That's because the ISO standard requires at least one ISO-formatted symbol to be used. A benefit of this type of format is that it requires

less space and may work well when space is an issue. A limitation, aside from not meeting international standards, is that translations may be necessary.

WORDLESS ISO LABEL FORMATS

This format of safety label uses an ISO wordless format with a hazard severity panel. It meets both ANSI Z535.4* and ISO 3864-2. Benefits of this type of format are that the hazard severity panel color-coding communicates the level of risk, and that the label communicates across language barriers without translations. The limitations are that the severity of the hazard is not defined in words, and that comprehension of both the symbols used and of the severity-level color-coding may vary.

MULTILINGUAL LABEL FORMATS

This style of safety label uses ISO-formatted symbols with an ANSI/ISO signal word panel and word message, accompanied by translated text. You may choose to use one combined, multilingual label, with English as well as another language on a single label, or you can use an 'add-on' label style, where you place a separate, translated version of the label beside the English version. Multilingual label formats meet both ANSI Z535.4 and ISO 3864-2. The benefits of this style are that translated text communicates to specific, target audiences. The limitations are that special care must be given to translations to ensure accuracy and that the translation matches with the intended audience, and that label installation prior to or after shipment must be taken into consideration.

The task of defining the proper content of your product's safety labels is one that's never finished. It's an ongoing process. As you periodically re-evaluate your labels, reviewing the ANSI and ISO standards-based format options available to you can help to ensure you're using today's best practices. It can also help you to make sure that your label program is as effective as possible – and may open up new communication tactics as well as opportunities like consolidating your warnings.

**Note:* *The ANSI Z535.4 standard does not specifically include this label format. However, ANSI allows manufacturers to use it by way of its section 3.1.1, which allows for the use of ISO formats.*

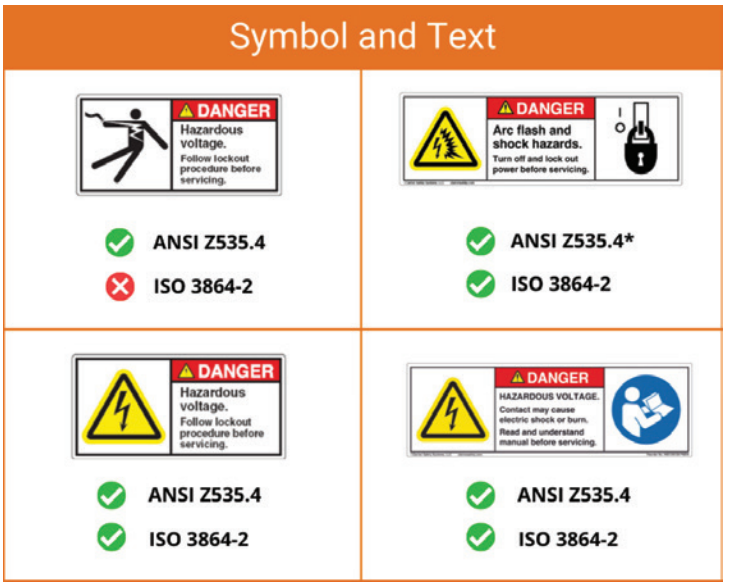

Figure 1: A look at various 'Symbol and Text' label format options and whether they meet ANSI Z535.4 standards, ISO 3864-2 standards, or both standards.

Figure 2: A look at various 'Wordless', 'Text Only', 'Multilingual', and whether they meet ANSI Z535.4 standards, ISO 3864-2 standards, or both standards.

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However, other promotional activities or sales should be conducted outside of the actual presentations.

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Important Dates

February 15, 2023
Formal Paper/Reviewable Presentation Submission Deadline

March 15, 2023
Acceptance Notification Deadline

April 1, 2023
Final Paper/ Presentation Submission Deadline

Conference Dates

May 1-3, 2023

Banana Skins

415 Interference with global navigation satellite systems (e.g. GPS)

A new consortium will investigate problems associated with interference, jamming, and multi-path activity affecting the integrity of GNSS applications. Chronos Technology, the National Physical Laboratory (NPL), and Bath University — all of the UK — have formed the Saturn Consortium to better understand the local availability and integrity of GNSS transmissions and the susceptibility or immunity of GNSS applications to external interference.

The Saturn consortium proposes to assess the susceptibility of GNSS applications to external interference and multi-path problems, which all three members have experienced. It aims to develop cost-effective techniques to assess local availability of GNSS transmissions, and to define new standards for Galileo integrity and availability at the point of use.

In a timing environment, local signal authentication will help to improve the efficiency of the new generation of telecommunications and wireless technologies such as TETRA, WCDMA, and Wi-Max, which require precise time synchronization for capacity and bandwidth optimization. Techniques developed by the consortium will be applicable to Galileo as the new system comes into service.

(Copied entire from: "Group Forms Over Interference", GPS World, February 1st, 2007, http://www.gpsworld.com.

According to https://www.jpl.nasa.gov, GNSS stands for Global Navigation Satellite System. Currently operating GNSS's are GPS (U.S.A.'s Global Positioning System) and GLONASS (Russia's Global Navigation Satellite System). Another GNSS planned for the future is Europe's Galileo.)

416 Alarming Microwave

Question: If we use our microwave oven for longer than about 30 seconds, our car's alarm goes off. Why? The car is at least 20 metres away through two walls. The inside of the microwave is a little corroded and the car has a remote central locking/ alarm system.

Reply #1: Certain car alarms, such as those fitted to recent Mazda 6, Toyota Rav4 and Mitsubishi Shogun models, transmit a continuous signal at 2.45 gigahertz at powers of up to 500 milliwatts. The microwaves are picked up by sensors inside the vehicle, which detect changes in intensity to signal the presence of intruders. Microwave ovens also operate at 2.45 GHz. While the power radiated within the oven is typically in the range 600 to 800 watts, the amount radiated outside the appliance will typically be less than a watt. When your oven is in operation, the microwaves reaching your car may be powerful enough to trigger the sensors inside it, which the alarm system interprets as a disturbance within the vehicle.

It is possible to set a car alarm so that the internal signal generator is disabled. You might also want to have your microwave oven serviced in case there is a serious leak of radiation. If your microwave has damaged shielding the radiated power could be higher than the values above. (From Joel Smith, Pateley Bridge, North Yorkshire, UK.)

Reply #2: It is odd that your microwave is leaking enough radiation to trigger the car's alarm, considering the legal limit - in the US, at least - for leaked radiation from a microwave oven is 1 milliwatt per square centimetre at a distance of 5 centimetres (*seems a little low – shouldn't that be 1W/sq cm? – Editor*).

Perhaps your microwave has a serious leak, or you have an unusually sensitive car. You could try parking the car in front of a friend's house and running their microwave oven to see what happens. If it appears to be solely your problem, consider getting the microwave replaced. (From Alex Reinhart, Boerne, Texas, US.)

(Copied entire from the 'Last Word', New Scientist, 3 Feb 2007, page 93, http://www.newscientist.com. Also see Banana Skin No. 35.)

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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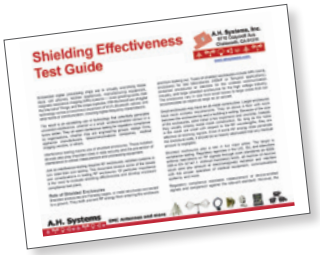

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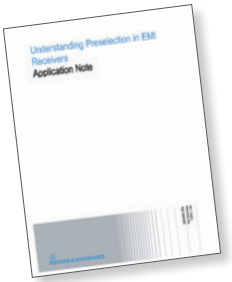

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