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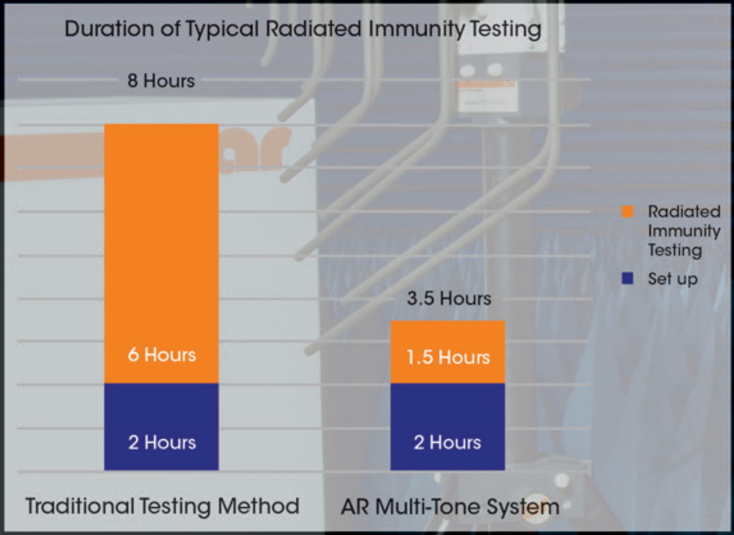
2023 PRODUCT RESOURCE GUIDE



Duration of Typical Radiated Immunity Testing
8 Hours
6 Hours
2 Hours
3.5 Hours
1.5 Hours
2 Hours
Radiated Immunity Testing
Set up
Traditional Testing Method
AR Multi-Tone System

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Scientists Invent a Paper Battery— Just Add Water

In the quest for battery power that's also environmentally friendly, a group of Swiss researchers has proposed a novel packaging approach that could help reduce metal and plastic waste associated with battery end-of-life processes.

According to a recent article posted on the website of Scientific American, researchers working at the Federal Laboratories for Materials Science and Technology in Switzerland have published a paper describing a water-activated paper battery made from environmentally friendly materials. The battery reportedly consists of the same key components as standard batteries, but the anode and cathode elements consist of inks that have been printed on the front and the back of a piece of paper.

The paper, which is infused with salt, is exposed to water and the resulting salt solution acts as the battery's electrolyte, producing approximately 1.2 volts of electricity until the paper dries out. Subsequently, rewetting the paper produces about 0.5 volts of electricity for over an hour.

The researchers believe that the greatest potential opportunity for using this water-activated paper battery is to embed them in low-power devices such as diagnostic tests and environmental sensors.

FDA Updates Recognized Standards List

The U.S. Food and Drug Administration (FDA) has updated its list of recognized international and national standards that can be used to demonstrate compliance with certain requirements for premarket review and authorization of medical devices.

In a Notice published in the Federal Register in mid-August, the agency announced more than 40 additions and modifications to the list of FDA Recognized Consensus Standards. Notable among the new standards added to the list is the addition of ISO 80601-2-87, which details safety and essential performance requirements for high-frequency ventilators, and IEC 62563-2, which addresses acceptance and constancy tests for medical image displays. Also newly added to the list of recognized standards is ISO 17664-2, which covers information to be provided by medical device manufacturers for the sterilization of non-critical medical devices.

EU Updates Standards Under Safety Regulation

The Commission of the European Union (EU) has amended its list of standards that can be used to demonstrate compliance with the essential requirements of its Directive on General Product Safety (2001/95/EC, also known as the GPSD).

According to an Implementing Decision (EU) 2022/1401 published in mid-August in the Official Journal of the European Union, the Commission has amended Annex 1 of the GPSD to add or replace 13 individual standards covering a wide range of products, including children's furniture and child use and care items, and gymnastic equipment.

The Implementing Decision also updates EN IEC 62368-1, which covers audio, video, information, and communications technology equipment, to reflect the 2020 amended version of the standard.

FCC Fines Electronics Marketer for Selling Non-Compliant Wireless Devices

The U.S. Federal Communications Commission (FCC) has levied a nearly $700k financial penalty against a New York-based electronics marketer for selling non-compliant wireless devices.

In a Forfeiture Order, the Commission cited the company Sound Around, a Brooklyn, NY seller of audio and video electronics and accessories, for marketing 32 non-compliant wireless microphones.

According to the Forfeiture Order, Sound Around had been receiving directives from the FCC since as far back as 2011, advising the company of the need to ensure that the devices it marketed have been properly authorized under Commission rules. Following ongoing complaints of non-compliance, the Commission issued a formal Letter of Inquiry in 2016, and a second Letter of Inquiry in 2019. However, in both cases, Sound Around never provided complete answers to the Commission's inquiry regarding the authorization of the wireless microphones it was marketing.

Ultimately, the Commission issued a Notice of Apparent Liability in April 2020 proposing a forfeiture of $685,338 for marketing 32 noncompliant models of wireless microphones within the prior 12 months. In response, Sound Around claimed that the Commission failed to prove that unlicensed wireless microphones were actually purchased and that the Commission's proposed fine was "excessive and unwarranted" and should be lowered.

In its Forfeiture Order, the Commission upheld its earlier assessment regarding Sound Around's practices in marketing unlicensed wireless microphones, laying out in exacting detail the basis for its rejection of the company's arguments against the proposed forfeiture, and even noting that the company "appears to be continuing to market some of the same noncompliant radio frequency devices issued in this Forfeiture Order."

THE 6G FUTURE:
HOW 6G WILL TRANSFORM OUR LIVES

Increased Bandwidth and Accelerating Speed Will Deepen Our Connection with the Digital World

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By Purva Rajkotia

With the global deployment of 5G networks still underway and many areas of the world still using older and less advanced communications networks, researchers and industry leaders are already looking ahead to 6G and its potential benefits. Following the 10-year development timelines of previous cellular technologies, we could expect 6G trials and deployments as early as 2030. But much work is ahead of us in these coming eight years to develop relevant standards that address the needs that are evident today and those that will reveal themselves in the coming years. To this end, the IEEE Standards Association (IEEE SA) is at the forefront of efforts to define 6G technology.

The high-level vision for 6G is to deepen the connection and integration between the digital, physical, and human worlds. While it's too early to know what final form 6G will take before it is standardized, we can speculate on the characteristics the next generation network will have, including the technologies that will be included and why they are important.

THE 6G NETWORK

As the name suggests, 6G is the successor to 5G communications technologies. Beyond supporting mobile, 6G will support technology like automated cars and smart-home networks, helping create seamless connectivity between the internet and everyday life.

Currently, 5G promises download speeds many times faster than 4G LTE networks and with significantly less latency. Naturally, we can expect 6G networks to use higher frequencies than 5G networks and provide substantially higher capacity and much lower latency. Current projections call for 6G to hit a maximum speed of one terabit per second (Tbps), which is 100-times faster than 5G. In terms of frequency,

6G wireless sensing solutions will impact government and industry approaches to public safety and critical asset protection, such as threat detection, health monitoring, and air quality measurements.

6G looks to elevate from 5G's frequency of 60 kilobits and reach 95 kilobits. 6G will use more advanced radio equipment and a greater volume and diversity of airwaves than 5G, including an extremely high frequency (EHF) spectrum that delivers ultra-high speeds and huge capacity over short distances. All 6G networks will have integrated mobile edge computing technology, not an add-on like current 5G, providing benefits such as improved access to AI capabilities and support for sophisticated mobile devices and systems.

Beyond amplifying applications for better connectivity and performance, tomorrow's 6G network design should use AI and machine learning (to improve assistance and efficiencies), support greater sustainability outcomes, increase security (to foster trust and reliability), and expand and improve connectivity with remote areas of the world.

The 6G network must be more efficient than 5G and consume less power. Energy efficiency achieved through digitization is critical for a more sustainable mobile industry because of the anticipated growth in data generation. The 6G network can power the applications needed to make this happen.

The network must be more than just secure. It must also be reliable. While privacy is an important component of security, consistent, reliable, and rapid, end-to-end data delivery, such as that needed to support the safe and efficient operation of driverless vehicles without concerns about potentially dangerous latency glitches, is essential.

The COVID-19 pandemic helped clarify the importance that future networks will need to emphasize societal and economic needs by focusing on expanded global access instead of just performance. Many areas worldwide, particularly rural and underprivileged areas, are without broadband access. Future networks will need to serve an ever-increasing number of users and their anticipated network use cost-effectively to achieve the goal of universal wireless communications access. 6G satellite technology, combined with intelligent surfaces capable of reflecting electromagnetic signals, can deliver low latency and multi-gigabit connectivity. This potential could be especially transformative in parts of the world where providing access to conventional mobile networks is too difficult, too expensive, or both. The advances provided by the open radio access network (Open RAN) should also help drive down network costs.

6G AND THE TRANSFORMATION OF SOCIETY

Like the evolution of all technologies, including faster networks and mobile, 6G will further transform how we do business, manage and operate our community infrastructures, and live. Key to the promise of 6G, sensing is the basis for all interaction with and emulation of the physical environment, and its potential extends to autonomous vehicles, smart factories, precision healthcare, and much more.

If 6G were available today, developers would most certainly be eager to leverage its anticipated attributes. 6G's exceptional data rates, low latency, secure reliability, agility, and dynamic insights will expand the scope of capabilities to support new and innovative applications in wireless connectivity, cognition, sensing, and imaging.

We can already feel the demand pull for 6G by examining the applications being deployed today. For example, technology trends seen with 5G, such as virtualized networks, are setting the stage for 6G by enabling things like specialized deployments. Operators have densified radio networks with more antennas. It is now easier to get a signal, especially indoors. Users now have close access to data storage and processing through cloud technologies and edge computing. Even at scale, latency is much lower.

> 6G will also enable immersive communication experiences through location and context-aware digital services, as well as sensory experiences, such as truly immersive extended reality and high-fidelity holograms.

The 5G platform already harnesses AI for optimization, dynamic resource allocation, and data processing. But extremely low latency of less than one millisecond and distributed architecture mean that 6G will be able to deliver global, integrated intelligence. 6G will propel the fourth industrial revolution, enabled largely by the industrial Internet of Things (IoT) services integrated with AI and machine learning.

6G wireless sensing solutions will impact government and industry approaches to public safety and critical asset protection, such as threat detection, health monitoring, and air quality measurements. We can anticipate greater decision-making capabilities using real-time information, improving the responsiveness of law enforcement officials and first responders.

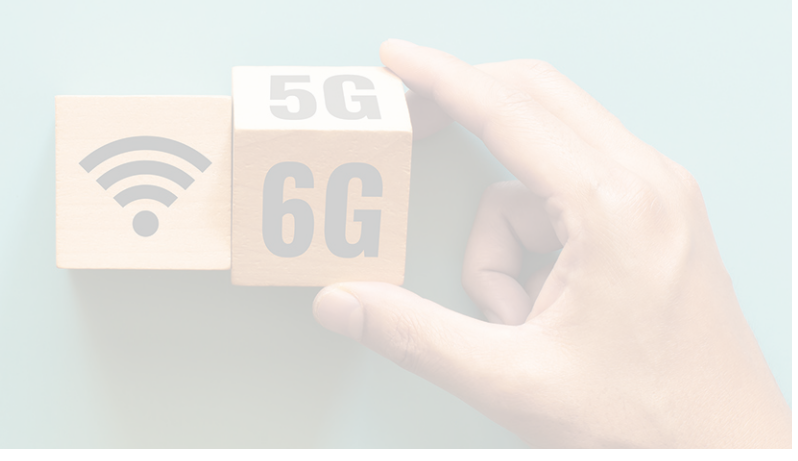
Autonomous driving is one of the main use cases in which 6G is expected to play a critical role by enabling greater accuracy and reliability. The recently released IEEE 2846, a new standard for autonomous vehicle (AV) safety, provides an important step in advancing

Autonomous driving is one of the main use cases in which 6G is expected to play a critical role by enabling greater accuracy and reliability.

the mass testing of AVs in the U.S. Looking further ahead, 6G and future networks will be needed to drive an AV society. For example, it's easy to understand that data speed with complete coverage will be required to enable thousands of AVs to navigate traffic in a geographical area. But it will also be needed for connection with a network of sensors that can direct the AV to an open parking spot close to the desired end of the route.

An essential part of AV navigation systems will be sophisticated maps, successors to GIS on the ground. The future includes the advent of real-time 4D maps, which everyone, including government organizations, will use to monitor, manage, and operate infrastructure, including traffic largely comprised of autonomous vehicles. A vast sensor network, aggregating data from ground and air inputs, will be used to map everything from traffic to weather conditions. With 4D mapping, we may see how we manage all space, including the air space above us.

6G will also enable immersive communication experiences through location and context-aware digital services, sensory experiences, such as truly immersive extended reality (XR), and high-fidelity holograms.



Look for virtual reality, which usually requires a cumbersome headset, to be replaced with augmented reality. Holographic technology will be integrated into many applications, including communication, telemedicine, architecture, interior design, and gaming. Instead of today's video conferences, it will be possible to speak to people in real-time in virtual reality (VR), using wearable sensors allowing users to have the physical sensation of being in the same room together.

Because 6G is more power-efficient than 5G, it may even be possible for low-power IoT devices to be charged over the network. This efficiency would transform the economics of mass deployments and aid sustainability. But beyond the network, 6G will also drive the technologies that can make our world more sustainable through global sensors measuring inputs from vast ecosystems, including forests, oceans, cities, and homes. At the most granular level, a smart home could pull intelligence from sensors inside and outside the home to learn from and adapt to your behaviors, such as when to turn on HVAC systems and when to put them on pause or shut them down.

We also can look forward to advances in precision healthcare, in which data science, analytics, and biomedicine are combined to create a learning system that conducts research in the context of clinical care while also optimizing tools and information to provide better outcomes for patients. Precision healthcare can include the use of tiny nodes that measure body functions tied to devices that can medicate and assist patients.

Leveraging satellite and other technologies, the 6G network has the potential to empower tremendous intelligence and limitless connectivity and connect all aspects of our physical and digital worlds – holistically, what some call the metaverse. The launch of 6G could fuel a massive increase in IoT adoption, allowing the transmission of data to update its digital representation, such as climate sensors in a factory or scattered throughout a city, in real time. With 6G, applications will be developed to observe and analyze events, provide more reliable predictions about likely outcomes, and automatically program response actions.

In a personal and relatable example for most everyone, 6G will provide terabit speeds that will inevitably make streaming more enjoyable and video calls less painful.

HOW IEEE SA SUPPORTS THE DEVELOPMENT AND LAUNCH OF 6G

Through our Connectivity & Telecom Practice, IEEE SA is building an ecosystem of interested stakeholders from across the globe to address the need for robust, responsible, and affordable wired/wireless platforms focused on providing improved and reliable connectivity to meet the ever-increasing data needs. The technologies and societal issues envisioned for 6G technology that are part of the focus of our efforts include virtualized RAN (Open RAN), universal connectivity, energy savings, cybersecurity, IoT, augmented reality, and a sustainable future. We welcome the involvement of participants from academia, government, and industry. For more information or to join the standards activity, please visit the Connectivity & Telecom Practice webpage[1].

ENDNOTE

1. https://standards.ieee.org/practices/connectivity-telecom

LATEST EU ECODESIGN AND ENERGY LABELING DEVELOPMENTS

The Proposed Sustainable Products Regulation and the 2022-2024 Working Plan

When it comes to energy-related products,[1] sustainable product policy in the European Union (EU) is largely implemented through the ecodesign and energy labeling legislative frameworks. Product-specific laws have been adopted under each framework. For example, various household appliances are the subject of individual EU Regulations concerning ecodesign[2] and energy labeling. In all, about 30 product groups are regulated through some 50 measures.

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By Alex Martin

While the legislative frameworks have been in place for many years, they have also been subject to periodic review and updating. For instance, the 2017 adoption of the EU Energy Labelling Framework Regulation came with the repeal of the 2010 Energy Labelling Framework Directive and the introduction of obligations associated with a product database – later known as the European Product Database for Energy Labelling (EPREL).

This article discusses the intention to update EU ecodesign legislation through the recent tabling of a proposal for a Sustainable Products Regulation. It is anticipated that this proposed EU Regulation will be adopted within the next two years. Meanwhile, a plan has been published for advancing existing EU policy concerning the sustainability of energy-related products between now and 2024. This is the European Commission's 2022-2024 Ecodesign & Energy Labelling Working Plan – something that this article also comments upon.

THE PROPOSED SUSTAINABLE PRODUCTS REGULATION

On 30 March 2022, the European Commission tabled a proposal for an EU Regulation establishing a framework for setting ecodesign requirements for sustainable products. The intent of this proposed Regulation is to replace the current Ecodesign Framework Directive (2009/125/EC). If adopted, the proposed Regulation would overhaul the existing EU ecodesign legislative framework.

In particular, the proposed Regulation would broaden the legislative scope such that any physical good placed on the EU market could be targeted (at present, the scope is confined to energy-related products), while more focus would be given to regulating product aspects other than energy performance (e.g., durability, reliability, reusability, upgradability, repairability, information requirements). Other things in contention include digital product passports, new obligations for fulfillment service providers, online marketplaces, and online search engines, and preventing the destruction of unsold consumer products.

Requirements for specific products or product groups would be set via delegated acts. It appears that the European Commission will soon consult on which products or product groups should be prioritized for regulation in the years ahead.

In the meantime, the proposed Regulation is subject to the EU's ordinary legislative procedure, meaning that the proposal will be scrutinized by the European Parliament (EP) and the Council of the EU in the coming months with tripartite meetings between Parliament, the Council, and the Commission also taking place. The ordinary legislative procedure is illustrated in Figure 1.

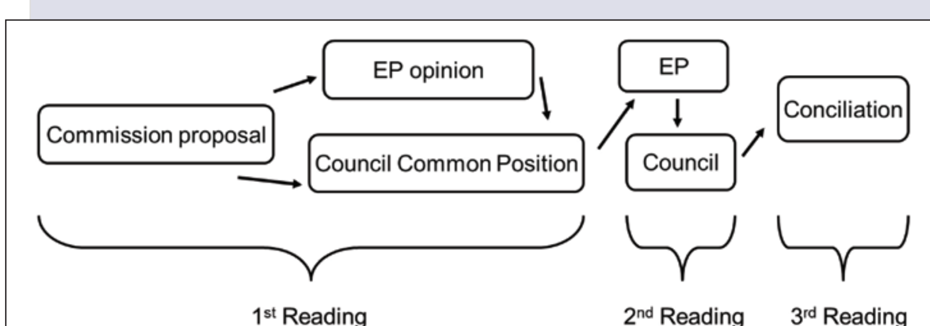

Figure 1: The ordinary legislative procedure

It will be interesting to see whether the proposed Regulation is adopted during a first reading or if it takes a second or third reading for the proposal to make its way into law. Come what may, the adoption of a new law is at least 18 months away, while it will still take longer for product-specific delegated acts to be drafted and adopted.

For the moment, those involved in the manufacture and supply of electrical and electronic equipment (and other products) should take heed of the proposal while noting that it is likely to be two years or more before anything substantive emerges in the form of new EU sustainable products legislation. In the meantime, all existing EU ecodesign legislation continues to apply, as do scheduled legislative reviews, completion of outstanding ecodesign preparatory studies, and so on.

For readers interested in the detail, Table 1 summarizes the main changes the proposed

Scope	The scope would be extended beyond energy-related products, so the new Regulation would apply to any physical good placed on the market, with a few exceptions, such as food, feed, medicinal, and veterinary products (Article 1(2)).
Ecodesign requirements	Products on the internal market would have to comply with ecodesign requirements, which would be set out later, in delegated acts, for each group of products separately (Article 3). Ecodesign requirements would aim to improve product durability, reliability, reusability, upgradability, reparability, possibility of maintenance and refurbishment, presence of substances of concern, energy use and energy efficiency, resource use or resource efficiency, recycled content, possibility of remanufacturing and recycling, possibility of recovery of materials, environmental impacts and expected generation of waste materials. Product groups would be prioritized based on their potential contribution to EU climate, environmental and energy efficiency goals, and their potential for improvement without disproportionate costs (Article 16). The ecodesign requirements would continue to be prepared by an expert group comprising Member State representatives and other interested parties, such as industry, small and medium-sized enterprises, trade unions, traders, retailers, and consumer and environmental organizations. The group would be renamed the Ecodesign Forum (Article 17).
Performance and information requirements	The Regulation distinguishes between performance requirements, such as durability and ease of repair (Article 6 and Annex I), and information requirements (Article 7). Information requirements should include at least requirements related to the product passport and to substances of concern. They could also include information on the performance of the product (with the Commission being required to determine classes of performance to enable consumers to compare products); information for consumers on installation, use, maintenance, and repair; and information on treatment facilities for disassembly, recycling, or disposal, etc. The required information would have to be provided on the product, on the product packaging, the product passport, a label, in a user manual, or on a website or application.
Misleading labels	The Commission would be empowered to adopt rules on labels indicating the performance of a particular group of products. For those products where no rules on labels are adopted by the Commission, using labels that mimic such labels and that could mislead or confuse consumers would be banned (Article 15).
Product passport	Delegated acts for specific product groups would require a product passport to be available for each product. The product passport could include information on performance and information requirements; information related to traceability of the product; the declaration of conformity; technical documentation; user manuals; and information about the manufacturer, importer, or authorized representative. The delegated acts would determine which information would be included and who would have access to what (e.g., consumers could have access to different information than manufacturers, importers, repairers, recyclers, or national authorities) and who would be allowed to update which information (Article 8). The information would be stored in a registry set up by the Commission (Article 12) and would be accessible via a data carrier (such as a barcode) on the product, its packaging or documentation (Article 9).
Self-regulation measures	Two or more economic operators would be able to submit a self-regulating measure establishing ecodesign requirements as an alternative to the adoption of a delegated act, provided that their market share in terms of volume is at least 80% of the units placed on the market (Article 18).

Table 1: Key changes envisaged within the proposed Sustainable Products Regulation

Regulation would bring into effect. The text in this table is reproduced from a European Parliamentary Research Service briefing paper on the proposed Regulation.[3]

THE 2022-2024 ECODESIGN & ENERGY LABELLING WORKING PLAN

Coinciding with its proposed Sustainable Products Regulation, the European Commission published its new Ecodesign Working Plan. Specific to the next two years, the Plan also outlines what is in the cards for energy labeling.[4]

Ecodesign Working Plans consider the potential for setting and/or furthering ecodesign requirements for different products. To date, the Commission has published three working plans, and it published its fourth in April of this year – although its scope has been broadened to also consider the potential for energy labeling this time round.

Destruction of unsold goods	Companies that discard unsold consumer products would be subject to transparency requirements and would have to publish, for instance, the number of discarded products, the reasons for discarding them, and how many of the discarded products were prepared for reuse, remanufacturing, recycling, energy recovery, and disposal. Companies would need to disclose the information on a publicly accessible website. The Commission would be empowered to ban the destruction of particular groups of products that have significant environmental impacts. In principle, these rules would not apply to SMEs, but a delegated act for a particular group of products could still specify otherwise (Article 20).
Incentives for sustainable products	Member States would be allowed to provide incentives for consumers to make sustainable choices, in particular when more sustainable products are not sufficiently affordable, by, for instance, introducing eco-vouchers and green taxation. The incentives would have to be targeted at products in the two highest classes of sustainability performance (Article 57).
Green public procurement	The Commission would be empowered to adopt delegated acts establishing ecodesign requirements applicable to public contracts, including mandatory technical specifications, selection criteria, award criteria, and contract performance clauses or targets (Article 58).
Obligations for online marketplaces	The Regulation would specify the obligations of online marketplaces concerning market surveillance. They would be required to cooperate with the market surveillance authorities to ensure effective market surveillance measures; inform the market surveillance authorities of any action taken in cases of non-compliant products; establish a regular exchange of information on offers that have been removed; and allow online tools operated by market surveillance authorities to access their interfaces in order to identify non-compliant products. Online marketplaces would be required to design and organize their online interfaces in a way that would enable dealers to comply with the requirements of the Digital Services Act regarding pre-contractual information and product safety information. Member States would be required to empower their market surveillance authorities to order an online marketplace to remove products that do not comply with the ecodesign requirements (Article 29).
Prevention of circumvention	Products that can detect if they are being tested in order to alter their performance and achieve a more favorable result would be banned (Article 33).
Market surveillance plans	Every two years, Member States would be required to draw up an action plan for market surveillance activities in relation to ecodesign and communicate these plans to the Commission and other Member States (Article 59). The Commission would be empowered to adopt delegated acts laying down the minimum number of checks by market surveillance authorities on specific products or specific requirements (Article 60).
Evaluation	The Commission would be required to carry out an evaluation of the Regulation eight years after its adoption (Article 69).
Entry into force	The Regulation would enter into force 20 days after its adoption and would be applicable immediately. However, since this would be a Framework Regulation, new ecodesign requirements would be applicable to specific groups of products only after the adoption of product-specific delegated acts.

Table 1: Key changes envisaged within the proposed Sustainable Products Regulation *continued*

Product Group	Energy Saving Potential 2030 (related to use phase or material efficiency)	Considerations
Low temperature emitters (radiators, convectors, etc.)	170 petajoule (PJ) (use phase)	Highest energy saving potential, important for Renovation Wave[7]/building decarbonization.
Professional laundry appliances	33 PJ (use phase)	Studied in the past and now considered more mature in view of progress in technical standardization.
Professional dishwashers	20 PJ (use phase)	
Universal External Power Supplies (EPS)	12-27 PJ (embedded)	Link to Common Charger initiative[8], will be done as part of the review of the existing EU External Power Supplies Ecodesign Regulation.
Electric vehicle chargers	11 PJ (use phase)	After 2030 the potential savings increase, to in 2050 almost 76 PJ annually. Hence, it is reasonable to consider setting requirements before large volumes of potentially inefficient chargers are installed.

Table 2: Product groups shortlisted for ecodesign preparatory studies

According to the Commission, the 2022-2024 Ecodesign & Energy Labelling Working Plan "strengthens the focus on the circularity aspects of ecodesign, following the example set in the previous Working Plan and in line with the Circular Economy Action Plan 2020." To this end, "new product-specific requirements on material efficiency aspects can and will be explored. This should result in further improved circularity and overall reduction of environmental and climate footprints of energy-related products, as well as stronger EU resilience."

Review Priorities

The Commission intends to prioritize the review of the following product groups:

- *Heating and cooling appliances*—This is based on the Council of the EU's request that the Commission "accelerate the ongoing work on heating and cooling appliances by rescaling energy labels as soon as possible." Meanwhile, the Commission affirms that the work will "be a critical contribution to the decarbonization of buildings and the Zero Pollution action plan as part of the overall Green Deal objectives, and these products are those with the highest energy consumption of all regulated products."
- *Other product groups with energy labels up for rescaling*—The EU energy label was subject to rescaling in 2020 and, in 2021, the provision and display of rescaled energy labels became a legal requirement in the case of household washing machines and washer-dryers, household dishwashers, electronic displays, refrigerating appliances, and light sources. The Commission is now keen to pursue the "timely rescaling and updating [of] the remaining 'old' energy labels… tak[ing] full advantage of the new features offered by EPREL." Among the other product groups likely to be targeted when it comes to the rescaling of existing energy labels are air conditioners, domestic ovens and cooker hoods, household tumble dryers, space heaters, residential ventilation units, solid fuel boilers, and more.
- *Other product groups with the potential for significant additional energy savings*—This includes product groups that represent significant additional savings potential in terms of energy or material savings, that are long overdue, or where particular circumstances imply a clear or urgent need for revision. For example, the Commission names water pumps, fans, and external power supplies.

Products Targeted for Future Ecodesign Preparatory Studies

The Working Plan explains that the Commission has identified 31 product groups that could be targeted for ecodesign and energy labeling. It advises that, together, these product groups present "new potential use phase savings in 2030 in the order of 1 000 PJ, or 278 TWh, i.e., circa 2% of EU primary energy use in 2020." However, given that the Commission must work within time and budgetary constraints, it has shortlisted five of the 31 product groups for which it "envisages initiating exploratory studies." These are identified in Table 2, which is a reproduction of what is found in the European Commission Communication that accompanied the publication of the Working Plan.[5]

Of further note is the Commission's stated wish to "further assess the possibility and appropriateness of establishing more product-specific requirements" when it comes to:

- Recycled content;
- Durability, firmware. and software; and
- Reducing or eliminating uses of scarce, environmentally relevant, and critical raw materials in energy-related products.

Here, the Commission states that "the requirements are theoretically applicable to all energy-related products; dedicated preparatory studies will be needed to help identifying the product categories that are most relevant for potential regulatory approaches."

The EPREL

The Commission states that "there are important functionalities that need to be addressed in 2022," all with a view to "operationalis[ing] several EU policies, including in relation to public incentives, sustainable private sector investments, green public procurement, and reduced VAT rates for certain energy-labeled products." The envisaged functionalities include:

- Introducing a dedicated web portal that will be the single access point, providing targeted information for citizens, national authorities, suppliers, dealers, and policymakers;

While the European Commission's proposed Sustainable Products Regulation will be subject to scrutiny and amendment by both the European Parliament and the Council of the EU in the months ahead, it will almost certainly be adopted.

- Improving the user interface and tools available to market surveillance authorities to better streamline their activities;
- Transforming the structure of the technical documentation to streamline registration activity by suppliers and facilitate analysis thereof by compliance authorities; and
- Starting the implementation of revised regulations for some product groups and possibly adding new ones (e.g., smartphones and tablets).

In addition, the Commission asserts that "it will be necessary to consider the conditions for, and modalities of, granting access to EPREL or some of its features to operators and possibly authorities from specific third countries, notably those that are part of the customs union or the Energy Community."

Market surveillance

Over the next two years, the Commission intends to step up its support to Member States "to contribute to a more effective and uniform application of market surveillance in the field of ecodesign and energy labeling." This effort is likely to include:

- Continuous improvement of IT tools such as the Information and Communication System for Market Surveillance (ICSMS) and EPREL;
- Giving technical and logistical support to Administrative Cooperation Groups (AdCos);
- Financing joint or concerted actions and campaigns;
- Engaging with the Member States on ways to improve market surveillance, including what resources they make available; and
- Proposing new legal provisions that will improve market surveillance.

The Commission will also continue to support economic operators' (e.g., product manufacturers) efforts to comply. Some examples of this effort cited by the Commission include the operation of functional mailboxes where questions can be addressed, and the publication of specific guidance documents, FAQs, and other information on the Commission website. It will also consider providing EU funding to set up an "industry-driven compliance support facility." Seemingly, the idea here is to increase outreach and provide more timely and targeted assistance to help suppliers and retailers more easily understand and meet their obligations.

The new Working Plan is an ambitious one, especially when one considers that it succeeds the Third Ecodesign Working Plan that was originally set to run until 2019 and, in the Commission's own words, "about 40% [of this Working Plan] is still ongoing and will be rolled over to the current planning period." So, there is much to do.

CONCLUSION

The EU's longstanding ecodesign legislative framework is on the cusp of change.

While the European Commission's proposed Sustainable Products Regulation will be subject to scrutiny and amendment by both the European Parliament and the Council of the EU in the months ahead, it will almost certainly be adopted. It is also highly likely that it will lead to the implementation of new measures relating to product durability, reliability, reusability, upgradability, and repairability. To this end, interested readers may find developments in European material efficiency standardization[6] something worth following.

Concerning the 2022-2024 Ecodesign & Energy Labelling Working Plan, it will be interesting to see what progress is made. If anything, the Commission's delivery fell short of its stated ambitions when it came to previous Working Plans. However, the Commission appears to have set itself both realistic and achievable goals for the next two years. We will have to wait and see what happens.

ENDNOTES

1. These are any goods or systems "with an impact on energy consumption during use which is placed on the market or put into service, including parts with an impact on energy consumption during use which are placed on the market or put into service for customers and that are intended to be incorporated into products."
2. Under the legislation, this is a term that refers to "the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle."
3. Šajn, N. (2022) *Ecodesign for Sustainable Products*, Brussels: EPRS. https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)733524
4. To obtain a copy of the Working Plan, please visit https://energy.ec.europa.eu/ecodesign-and-energy-labelling-working-plan-2022-2024_en
5. Accessible from https://energy.ec.europa.eu/ecodesign-and-energy-labelling-working-plan-2022-2024_en
6. A European Commission strategy that is intent upon renovating building stock to improve energy efficiency while driving a clean energy transition. It envisages the overhaul of 220 million buildings standing today by 2050. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
7. See https://ec.europa.eu/commission/presscorner/detail/en/IP_21_4613
8. CEN and CENELEC were mandated by the European Commission to develop general, wide-ranging standards on material efficiency aspects for ecodesign. CEN-CENELEC Joint Technical Committee 10 handled this, and it has developed and published various generic standards in the EN 4555X series. For example, EN 45552:2020 *General method for the assessment of the durability of energy-related products*.

DUTY TO WARN NON-ENGLISH SPEAKING AND READING PRODUCT USERS

When are Multilingual Warnings Appropriate

The duty to warn and instruct is a significant duty in the United States. Under U.S. product liability law, liability can result if a manufacturer or product seller fails to adequately communicate appropriate safety information to purchasers and users of its products.

Given the considerable number of languages spoken and read in the United States and the significant number of people who do not speak English or are illiterate, developing a method to effectively communicate safety information to readers of product labels and instruction manuals is an important consideration. Adequate safety communications that are not effectively communicated to foreseeable users may arguably be considered defective.

This article will describe the relevant law and the voluntary U.S. technical standards concerning the use of foreign languages in safety information and will provide recommendations to manufacturers about using multilingual labels and instructions, including the use of new technology to better transmit such information.

NON-ENGLISH READING OR SPEAKING RESIDENTS IN THE U.S.

According to the Census Bureau's 2020 census, the Hispanic population in the United States is close to sixty-two million. In addition, the Census Bureau estimated that 40.7 million U.S. residents five and older spoke Spanish at home in 2020, up from thirty-five million in 1990. And of those who spoke Spanish at home, the Census Bureau estimated that 16.2 million spoke English "not well."

In addition, forty-three million adults in the U.S. have low literacy skills, with 34% being Hispanic, 35% white, and 31% non-white. Thus, 66% of those with low literacy skills, or twenty-eight million people, do not read Spanish or English very well or at all.

Whatever the trends have been and will be in the future, millions of people are not proficient in speaking or

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By Kenneth Ross

writing English. And since they are not proficient in English or maybe any language, it will be challenging to communicate with them about how to use products properly and safely.

U.S. CASE LAW

With this as a backdrop, let us first consider what the courts say in this area. The two main ways to effectively communicate to illiterate or non-English reading product users are using their native language or commonly understood symbols. However, U.S. common law provides little guidance on when foreign languages or safety symbols are appropriate or required. Court rulings show the difficulty the courts have had on this issue.

Stanley Industries, Inc. v. W.M. Barr & Co., Inc.

In 1992, the U.S. District Court for the Southern District of Florida issued the *Stanley Industries* case.[1] In that case, the plaintiff alleged that a fire that occurred in the plaintiff's facility was caused by the spontaneous combustion of rags soaked in the defendant's linseed oil. The linseed oil was being used by two employees who were brothers from Nicaragua and whose primary language was Spanish.

The plaintiff sued the manufacturer of the linseed oil and the retailer, Home Depot, Inc., for negligent failure to warn, strict liability, and breach of warranty of fitness for a particular purpose. The defendant manufacturer filed a motion for summary judgment on negligent failure to warn.

The plaintiff's response to the defendant's motion for summary judgment argued that, because the language on the back of the product label was only in English and contained no symbols, it was inadequate. It further alleged that the label did not fairly, appropriately, and comprehensively warn Spanish-speaking, monolingual product users of the dangers likely to be encountered with the product's use.

The key fact in this case was that the defendants arranged to advertise, promote, and market products in the Miami area jointly and cooperatively. Home Depot regularly and actively advertised in the Miami market in Spanish on Hispanic television, radio, and in Hispanic newspapers. Home Depot also marketed a number of its products with bilingual instructions.

After reviewing the few prior cases discussing the subject of multilingual warnings or universally accepted symbols, the court denied the motion for summary judgment and held that it was for the jury to decide whether the defendants could have reasonably foreseen that the linseed oil would be used by persons such as the plaintiffs.

The court also held that the jury must decide whether a warning should at least contain universally accepted precautionary symbols. Lastly, the court held that it was for the jury to decide whether a warning, to be adequate, must contain words in a language other than English or must contain symbols.

In addition to denying the defendant's motion for summary judgment, the court added that it did not intend to advance any position on the merits of the case, nor did its decision foreclose affirmative defenses such as comparative negligence or intervening cause.

However, in a subsequent trial in November 1993, the jury returned a verdict in favor of Home Depot. Since the only defect claimed by the plaintiff was an inadequate warning, it can be assumed that the jury felt that it was unnecessary for the defendants to warn the plaintiff's employees in Spanish or by use of symbols, even if the defendant retailer advertised in Spanish.

Interestingly, many people have interpreted the judge's ruling in Stanley to mean that symbols and Spanish were necessary in this situation. That is not the holding of the court, and the fact that the jury subsequently ruled in favor of Home Depot supports the view that communications in Spanish were not considered necessary in this case.

Interestingly, three days before the jury verdict in 1993, Home Depot reportedly sent a letter to many of its suppliers asking that Spanish be included on all warning labels and instructions accompanying products sold to Home Depot. Presumably, Home Depot, as a preventive measure, decided that its suppliers should warn and instruct in Spanish regardless of the outcome of this case.

Ramirez v. Plough, Inc

In the second major opinion on this issue, the California Supreme Court ruled in 1993 that a manufacturer might not be held liable in tort for labeling a non-prescription drug solely in English. The court ruled on the adequacy of English-only warnings regarding Reye's syndrome on aspirin purchased by the plaintiff's mother, who could not read English but was literate in Spanish.

The pertinent facts this court considered were that the aspirin was advertised to and used by non-English-literate Hispanics and that the manufacturer presented no evidence as to the cost of Spanish-language labeling and the reasonableness of the manufacturer's conduct in not labeling in Spanish. The California Court of Appeals held that the adequacy of warnings was normally a fact issue for the jury, and the manufacturer appealed the case to the California Supreme Court.

The California Supreme Court reversed, dismissing the plaintiff's case against the manufacturer. The court held that the plaintiff's cause of action for inadequate warnings was preempted by federal and state regulations regarding warning requirements. Thus, the court held that, as a matter of law, a manufacturer could not be held liable for failure to include foreign language warnings when the product's warnings and labels complied with federal and state regulations.

The court relied on the lack of statutory authority from the California State Legislature requiring anything other than English labels on non-prescription drugs. It inferred that the Legislature had ". . . deliberately chosen not to require that manufacturers also include warnings in foreign languages." And they believed that requiring a language other than English "… is a matter of public policy for consideration by the appropriate legislative bodies and not by the Courts."

Medina v. Louisville Ladder and Home Depot, U.S.A., Inc.

More recently, the federal district court in Orlando considered the efficacy of the *Stanley* decision. Plaintiff argued that a ladder was defective because it lacked warnings and instructions in Spanish and that the defendants were negligent in failing to include them.[3] They relied on the *Stanley* case to support their allegations. Defendants filed a motion for summary judgment.

In June 2007, the court considered the *Stanley* opinion and declined to follow it. The court stated that *Stanley* is an "isolated precedent" and that in 15 years from the date of the opinion, no Florida case, state or federal, has concluded that bilingual warnings and instructions may be necessary under Florida law. The court said that there is no indication that Florida law imposes a duty to provide bilingual labels on consumer products and the court was unwilling to extend the law that far. On that basis, the court granted the defendant's motion for summary judgment and dismissed the plaintiff's case.

Farias v. Mr. Heater, Inc.

Lastly, in another Florida case, the plaintiff appealed from an adverse ruling on summary judgment against Mr. Heater, Enerco Group, and Home Depot on her claim of negligent failure to warn.[4] The appellate court found no error in the district court's conclusion that the warnings provided with the manufacturer's heater were adequate as a matter of law and therefore affirmed the granting of summary judgment.

The appellate court stated that a trial court can rule on warning adequacy as a matter of law if the warnings are objectively accurate, clear, and unambiguous. While the plaintiff did not challenge the trial court's ruling that Florida law does not automatically impose a duty to provide bilingual warnings on consumer products, she did argue, in part, that the question of the adequacy of the English-only warnings should be a jury question, citing the *Stanley* case.

The appellate court held that *Stanley* did not apply because there was no evidence that Enerco or Home Depot specifically marketed to Spanish-speaking customers through Hispanic media. And the fact that Home Depot requested its vendors to use bilingual packaging was not sufficient evidence of a targeted marketing campaign.

These cases are significant rulings since no defendant wants to have a jury decide such an issue but would prefer to have it decided by a judge in their favor as a matter of law.

Therefore, as of today, common law in general does not require a label to include a foreign language or even symbols for it to meet the duty to warn and instruct. And, if there is a direct marketing campaign to Spanish-speaking consumers, then it seems likely that, at least in Florida, the court would hold that the jury can decide whether Spanish should be required.

U.S. LABELING STANDARDS

The American National Standards Institute published voluntary consensus standards, referred to as ANSI Z535, concerning product safety labeling. ANSI Z535.4 (2011) provides guidelines for developing safety labels. This subpart provides, in an unofficial annex, acceptable formats for multilingual labels but does not provide any guidance on when to include foreign languages. On that issue, the standard says:

> *"The selection of additional languages for product safety signs is an extremely complex issue. Experts suggest that nearly 150 languages are spoken in the United States and millions of Americans speak a language other than English in their homes. If it is determined that additional languages are desired on a safety sign, the following formats should be considered. In all examples, the use of pictorials is strongly encouraged in order to better communicate the sign's hazard information across language barriers."*

Safety symbols are an optional part of the warnings developed in the ANSI Z535 standard, and the standard provides:

> *"Safety symbols may be used to clarify, supplement, or substitute for a portion or all of a word message found in the message panel. When used with a word message, safety symbols shall be compatible with the word message. A symbol may only be used to substitute for a portion or all of a word message if it has been demonstrated to be satisfactorily comprehended (e.g., Annex B of ANSI Z535.3) or there is a means (e.g., instructions, training materials, manuals, etc.) to inform people of the symbol's meaning."*[5]

Some courts have suggested, but never clearly ruled, that the manufacturer should have considered adding symbols to transmit the safety message. However, as a practical matter, it is risky to fully rely on a symbol in that it may not be understood by everyone or may not fully transmit the required safety message. Thus, it may be a good idea to add a safety symbol to a label with words to more clearly and forcefully transmit the message.

And lastly, a subpart, ANSI Z535.6, which provides guidelines on instructions, was issued in 2006 and reissued in 2011. This part of the standard does not contain any discussion of multilingual manuals.

Therefore, the main U.S. safety label standards do not require multilingual labels and provide no definitive guidance on when or where they may be appropriate.

RETAILER AND GOVERNMENT ACTIONS

Even though the common law and voluntary standards do not require foreign language safety labels or instructions, some manufacturers are including bilingual or even trilingual (English, Spanish, and French) labels and instructions with their products sold in North America. This may arise out of safety or liability concerns or is merely a reaction to sales patterns in North America or from customer demands such as Home Depot's.

Trilingual labels and other identification information would allow a manufacturer to sell anywhere in North America without changing its labeling. To the extent that this trend grows, the "state of the art" may be raised despite the lack of clear judicial, legislative, or voluntary standard guidance or requirements.

In addition, some government agencies have required manufacturers who fall under their jurisdiction to attach bilingual labels and symbols to some of their products. One example of government action is the California legislature's adoption of a law requiring 5-gallon buckets sold in California to have a bilingual label with a symbol. In addition, the U.S. Consumer Product Safety Commission mandated a number of years ago that charcoal used for grilling be in packaging that contains explicit warnings in English and Spanish along with several symbols.

There may be other specific examples of government agencies or even standards groups requiring or recommending foreign language labels, but it is limited and has not resulted in a broad legal or practical requirement. Therefore, most manufacturers and product sellers still have great flexibility as to how to meet their duty to warn and instruct.

PREVENTIVE TECHNIQUES

As discussed above, with a few narrow exceptions, neither U.S. law nor voluntary consensus technical standards specifically require that Spanish or any other foreign language be used on safety labels or instructions even when those products are clearly being sold in non-English speaking or reading areas in the United States.

Based on that, one could argue that there appears to be no duty to warn in any language other than English. However, having a good defense against a lawsuit may not be the best result when preventing accidents should be your primary goal. To provide a safer product for foreseeable non-English reading product users, a manufacturer or retailer may decide to exceed any enunciated or anticipated legal or technical requirements.

Before including foreign languages on labels on their products and in their instructions, however, manufacturers should think about this carefully. A manufacturer may run some risk of liability if it voluntarily chooses to include foreign languages or symbols on its products and these labels contain inadequate information or are not effectively communicated.

Likewise, a manufacturer who voluntarily chooses to include one foreign language on its label or in its instructions may be criticized for its failure to include other languages. If one foreign language is selected, another significant part of the user population that reads one of the over 150 other languages used in the United States may be neglected.

Another reason to be careful is that there is no assurance that product users in the U.S. will be able to read the foreign language. In fact, they may be illiterate in all languages. Also, including other languages on a safety label tends to clutter the label and could diminish the effectiveness of the entire label, especially the English message. And lastly, if the label is in a foreign language, there is a good argument that the manufacturer should also provide an instruction manual in the same foreign language.

If the manufacturer decides to add some Spanish but does not want to make it fully bilingual, one option is to have two signal words (e.g., WARNING in English and Spanish) and a pictorial on the label that at least clearly shows the hazard. The remainder of the label would be in English. Another option for products used in workplaces is to include one sentence in the foreign language describing the hazard and telling the reader to consult with their supervisor to find out how to avoid it.

In either case, the non-English reading or illiterate users could at least understand the type of hazard and possibly the consequences of not avoiding it. Then, if they are unable to read the English message on the label, they could ask someone who reads English to translate. Also, in this situation, the label could include a reference to the company website that includes safety information in a variety of foreign languages. Presumably, this safety information will already be translated for manuals shipped with products sold in foreign countries.

LEVERAGING TECHNOLOGY

New technology might also be useful in offering Spanish or other languages without having a full translation. There could be a label on the product with a sentence in English and Spanish about getting further information on their smartphone using QR codes which, when scanned, can portray a warning message on the screen or send the user to the company's website. This website can contain a link to the full English version of the instructions and to selected foreign language warnings and instructions.

A manufacturer's goal in this area is to adequately communicate safety information to foreseeable users, no matter where they are located. It is not too difficult to anticipate that people may not read or speak the English language.

In addition, there are companies that offer 3D interactive instructions that can be accessed from your smartphone (for example, see https://biltapp.com). These might be able to be programmed to offer information in English, Spanish, and other languages.

SHIFTING THE BURDEN

When the manufacturer does not know what foreign language may be appropriate for a given situation, it could provide English labels, including symbols, with the product and offer to provide labels in other languages to product sellers or employers. The practical burden (although probably not the legal burden) could be shifted to the product sellers or employers to decide if another language is required for the safe use of this product by customers or employees. These entities could then specifically request foreign language labels and manuals from the manufacturer. While this approach might be appropriate for some industrial equipment and other products used by workers, it is not practical for most consumer products.

One alternative is that manufacturers could offer to provide to retailers in areas with a substantial number of non-English speaking customers a pamphlet or leaflet providing safety information in the foreign language of the customers. Another alternative is to include a toll-free customer information number on the label of the product, informing the consumer that they can call the toll-free number to receive safety information in a foreign language.

Since the retailer or employer knows its customers or product users better than the manufacturer, maybe the decision as to the appropriate course of action properly resides with them. While it may not be possible as a legal matter to delegate the duty to warn to others, it may be appropriate to allow those more familiar with product users' language skills to assist in more effectively communicating the safety message to enhance safe product use.

CONCLUSION

The legal and technical requirements for providing adequate safety communications to those who do not read or speak English will evolve. Manufacturers who are creating safety communications for sales in the United States must keep track of these requirements and trends and try to comply with or exceed them as they exist today or might exist in the foreseeable 8future.

If the plaintiff is illiterate or only reads a foreign language and the safety information does not fully transmit the necessary information to that product user, there are risks no matter what course of action a manufacturer takes. Therefore, a manufacturer should assess the risk of different strategies that could be taken and try to predict whether they will be defensible if challenged.

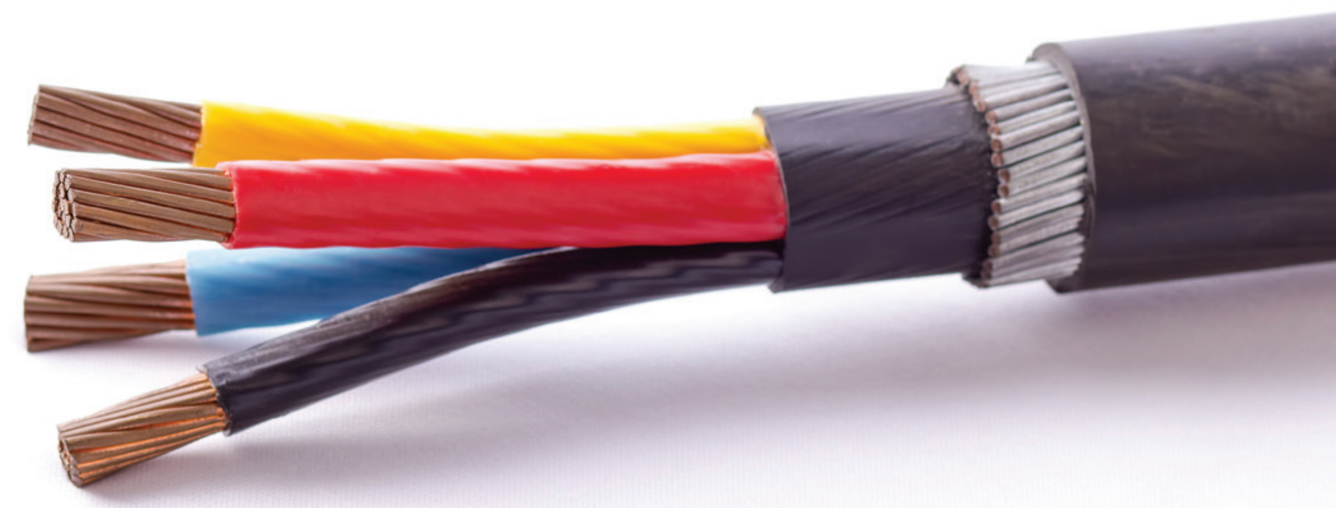
A manufacturer's goal in this area is to adequately communicate safety information to foreseeable users, no matter where they are located. It is not too difficult to anticipate that people may not read or speak the English language. It is much more difficult, if not impossible, to communicate all necessary safety information to all foreseeable product users. Nevertheless, attention to this issue can help minimize future liability in the United States as well as provide a better-quality product that is safer and easier to use.

ENDNOTES

1. *Stanley Industries, Inc. v. W.M. Barr & Co., Inc.*, 784 F. Supp 1570 (S.D. Fla. 1992)
2. *Ramirez v. Plough, Inc.*, 25 Cal. Reporter. 2d 97 (1993)
3. *Medina v. Louisville Ladder and Home Depot, U.S.A., Inc.*, 496 F. Supp.2d 1324 (2007)
4. *Farias v. Mr. Heater, Inc.*, 684 F. 3d (11th Cir. Fla. 2012)
5. ANSI Z535.4 (2011)

GETTING THE BEST EMC FROM SHIELDED CABLES UP TO 2.8 GHZ, PART 2

How to Terminate Multiple Shields in a Cable Bundle



In Part 1 of this article, I shared with you the origins of my journey to assess the shielding effectiveness (SE) of screened[1] cables and discussed some basic rules for terminating cable shields. In Part 2, I'll summarize the testing I recently conducted on various approaches to improving the shielding effectiveness of screened cables used in high-frequency applications and the results from that testing.

THE MEASURED CABLES

Note: all these cables' overbraids, whether single or double layers, used the same type of braid clamped to the backshells in the same way at both ends.

Cable 1: the "Null" cable for noise floor verification (see Figure 4)

A single overbraid on its own, to check that the noise floor of the test is low enough.

1. In the context of this article, the words: screened; screen, or screening may be replaced by shielded; shield, or shielding respectively, and vice-versa, without any changes in meanings.

Cable 2: the "Reference" unshielded TP cable (see Figure 4)

An unshielded twisted-pair (TP) cable on its own (actually, the single-braid-shielded TP cable used to assemble cables 3 to 6, with its outer plastic jacket and shield removed).

The measured results on this cable were used as the reference that was subtracted from the measured results of each of the other cable tests (i.e., cables 3 to 12) to determine their relative SE versus frequency.

Careful control of the entire test set-up tried to ensure that the RF coupling from the antenna to the cable and the room resonance effects were identical on every test so that they canceled out. The results showed that we were reasonably successful in this.

Cables 3, 4, and 5: single-braid-shielded TP cables with single overbraids (i.e., two shield layers in total) (See Figures 4, 10, and 11)

- Cable 3: Insulated single braid TP cable pigtailed to the backshells at both ends; plus a single overbraid 360° clamped to the backshells at both ends.

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- Cable 4: Same as Cable 3, but with the internal TP cable's braid now 360° soldered to the overbraid at the backshell at the CM measured end, but still pigtailed at the 120W end (see Figure 7).
- Cable 5: Same as Cable 3, but with the internal TP cable's braid now 360° soldered to the overbraid at the backshells at both ends (i.e., no pigtails at all).

Note: these cables, and Cables 6, 10, 11, and 12 below, all used the same type of single-shielded TP cable.

Cables 6, 10, 11, and 12: single-braid-shielded TP cables with double overbraids (i.e., three shield layers in total) (see Figures 5, 12, and 13)

- Cable 6: Same as Cable 3 (internal TP cable with an insulated single braid shield pigtailed to backshells at both ends), but now with double overbraids in direct electrical contact with each other along the entire cable length, and both overbraids 360° clamped together to the backshells at both ends.
- Cable 10: Same as Cable 6, but with the internal TP cable's braid 360° soldered to both overbraids at the backshell at the CM measured end while still pigtailed at the 120W end (see Figure 7).
- Cable 11: Same as Cable 6 but with the internal TP cable's braid 360° soldered to both overbraids at the backshells at both ends (i.e., no pigtails at all).

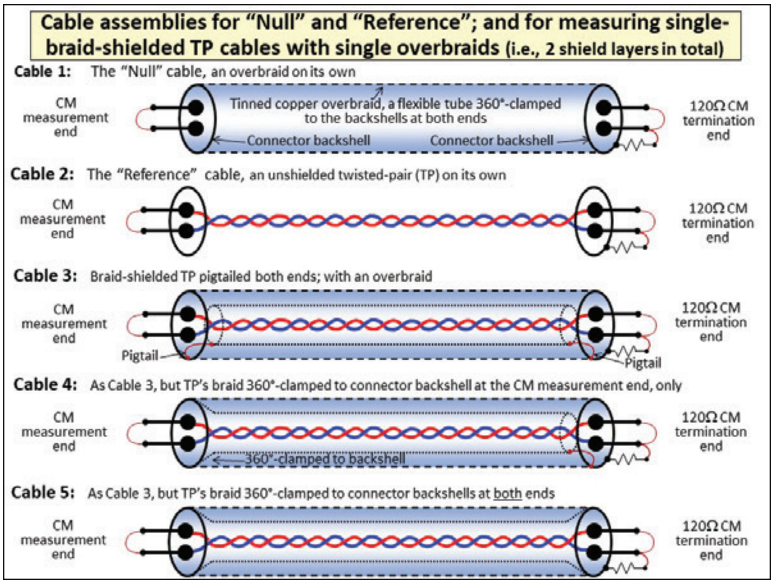

Figure 4: The cable assemblies for the reference measurements, and for the single-braid-shielded TP cables with single overbraids (i.e., two braid shield layers in total)

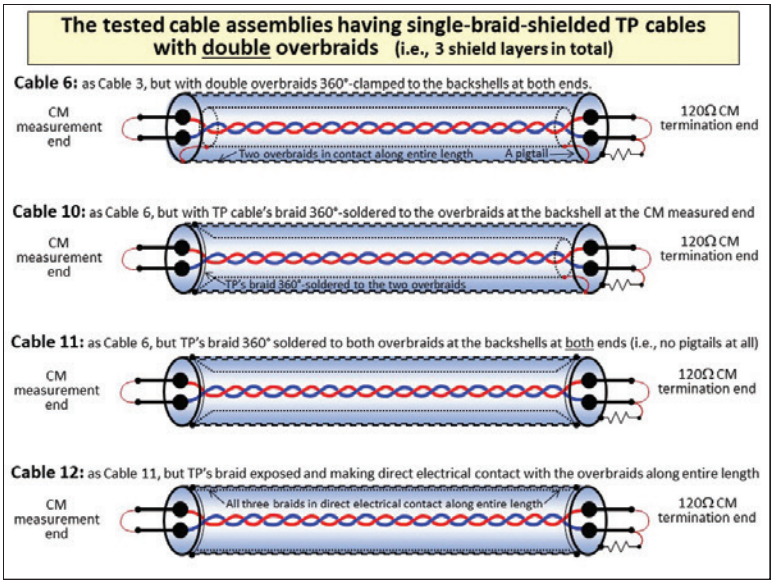

Figure 5: The cable assemblies having single-braid-shielded TP cables with double overbraids (i.e., three braided shield layers in total)

- Cable 12: Same as Cable 11, but internal TP cable's braid exposed and making direct electrical contact with the overbraids along the entire length of the cable. That is, all three braided shields are in direct electrical contact with each other along the entire length of the cable, and all are clamped together in 360° to the backshells at both ends. This cable was very stiff!

Note: these four cables, and Cables 3, 4, and 5 above, all used the same type of single-shielded TP cable.

Cables 7, 8, and 9: double-braid-shielded TP cables with double overbraids (i.e., four shield layers in total) (See Figures 6, 14, and 15)

- Cable 7: Same as Cable 6, but with the internal TP cable having double braid shielding in direct electrical contact with each other along its whole length, plus an overall layer of insulation, and pigtailed to the backshells at both ends. Cable 7 also has double overbraids in direct electrical contact with each other along the entire cable, and 360° clamped together to the backshells at both ends.
- Cable 8: Same as Cable 7 but with thin mylar film inserted between the two overbraids (except where they are clamped together to the backshells at both ends).

Note: these two cables both used the same type of double-braid-shielded TP cable.

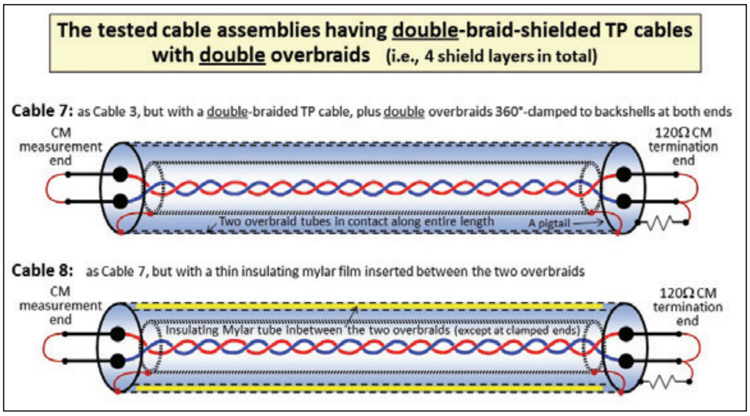

Figure 6: The cable assemblies having double-braid-shielded TP cables with double overbraids (i.e., four braided shield layers in all)

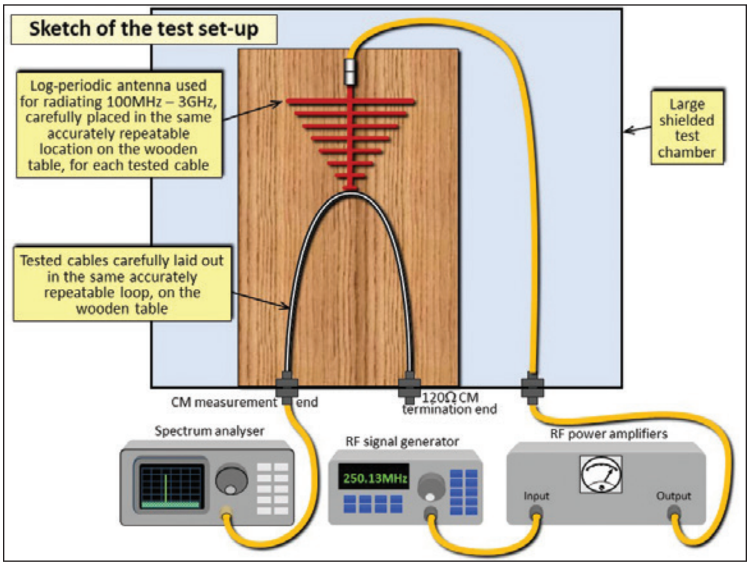

Figure 7: Sketch of the test set-up

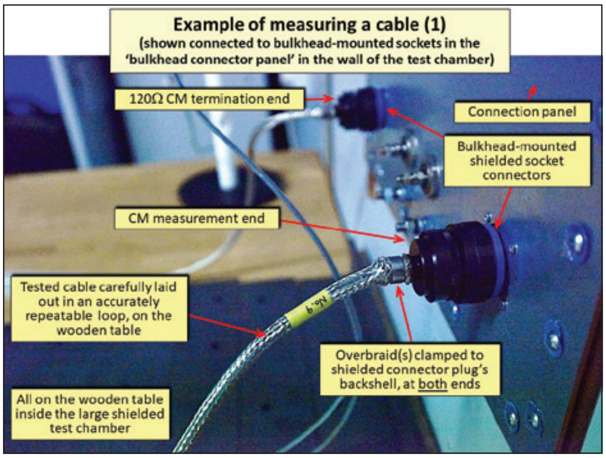

Figure 8: Example of measuring a cable, showing the connections to bulkhead-mounted connectors on the bulkhead connector panel in the wall of the test chamber

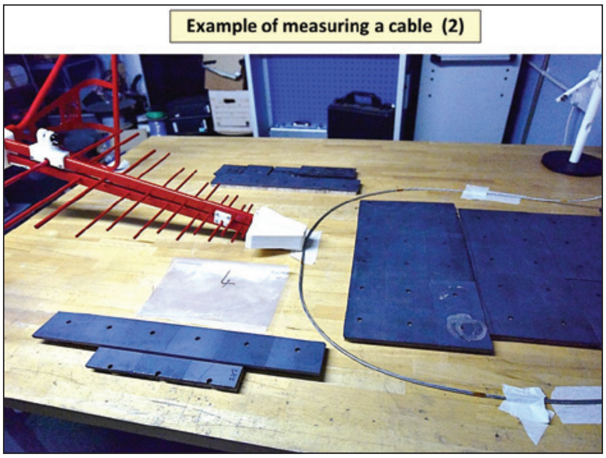

Figure 9: Example of measuring a cable, showing injecting RF into a cable

THE MEASUREMENT METHOD

There are many ways of testing the SE of cable assemblies (i.e., cables plus their connectors), and each should be expected to give different results even with identical cable assemblies. So, I chose a test method that best represented the situation I was most interested in and that was also the easiest and quickest to do with the facilities and resources I had available at the time (see Figures 7, 8, and 9).

The worst of the imperfections in this method were canceled out by careful control of consistency and repeatability, and by subtracting the measured results for each cable assembly from the measurements of the Reference unshielded TP cable, Cable 2 (see above, and Figure 4).

The test chamber had once been a large TEMPEST chamber for secure communications, but for a long time had been used as a storeroom.

With a spectrum analyzer, near-field RF probe effective up to 6GHz, and a Tek box TBCG1 radiating comb generator, 100MHz - 6GHz, it did not take long to identify the RF leakages and fix them (corroded spring fingers around the door, and a telephone wire that had been brought in without RF suppression). A connector panel (visible in Figure 8) was designed, fabricated, and affixed to a hole cut in the chamber wall and also checked for RF leaks up to 6GHz.

I would have preferred either an anechoic chamber or a mode-stirred chamber, but at least the metal racking and the stored equipment in the room broke up most of its major resonant modes! And a few scraps of left-over ferrite tiles from an anechoic EMC test chamber were enough to deal with the worst remaining standing waves.

I was not interested in absolute values of SE, only in which cable design/assembly methods were the best

for SE. In other words, their relative SE performances. I hoped to extract some general guidance rules for overbraid-shielded cables or cable bundles containing at least one individually shielded TP cable.

To help achieve this, with the imperfect test set-up briefly described above, a null cable (Cable 1, see Figure 4) was first measured. Being just an empty overbraid, the measurement identified any leakages from the antenna to the CM measurement pins of the bulkhead-mounted shielded connector, which included all chamber and panel leakages, and also the leakages inherent in the overbraid and its shield-bonding to the cable connectors, and from the cable connector to the bulkhead-mounted shielded connectors. This measurement showed that leakages were at or below the measurement noise floor for both frequency ranges.

Next, the Reference cable, Cable 2, was measured. This was an unshielded twisted-pair (TP) cable on its own, as shown in Figure 4, and previously described in detail.

Two different RF power amplifiers, one operating at 100MHz – 1GHz and a second at 800MHz – 2.8GHz, were used to cover the two frequency ranges reported in this article, with the above null and reference tests repeated for each amplifier.

To help achieve consistency between the different RF power amplifiers, a triaxial field probe with a fiber-optic cable passed through a waveguide-below-cutoff in the bulkhead connector panel was used to measure the field strengths around the antenna and the measured cables

External low-noise preamplifiers with good, flat frequency responses over the measured frequency ranges were used before the spectrum analyzer's input in cases where they would help reduce the noise floor.

All the other measured cables covered by this article consisted of the same null cable assembly used for Cable 1. Additional internal conductors and cables were made by the same very skilled cable assembler, in the same ways, with the same materials, and within a limited time span (a few days) so that we could assume consistency between them.

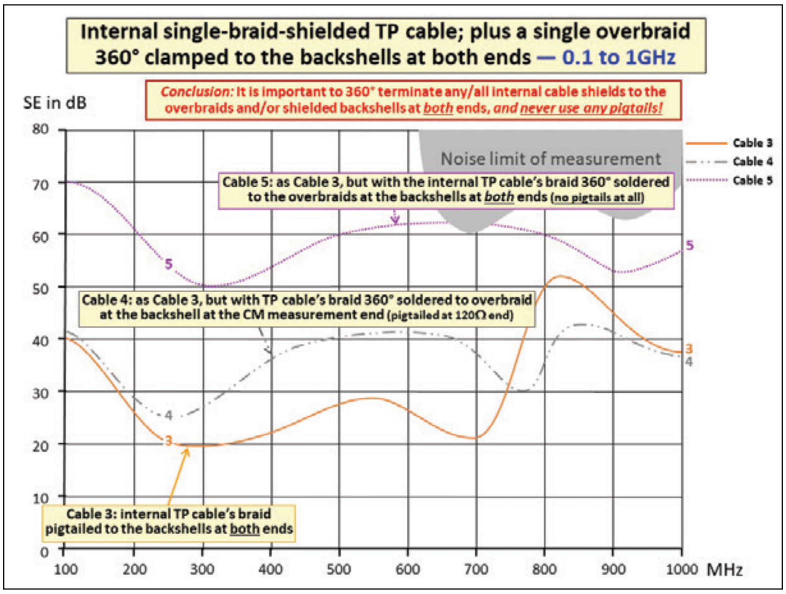

Figure 10: Results for internal single-braid-shielded TP cable, plus a single overbraid 360° clamped to the backshells at both ends — 0.1 to 1GHz

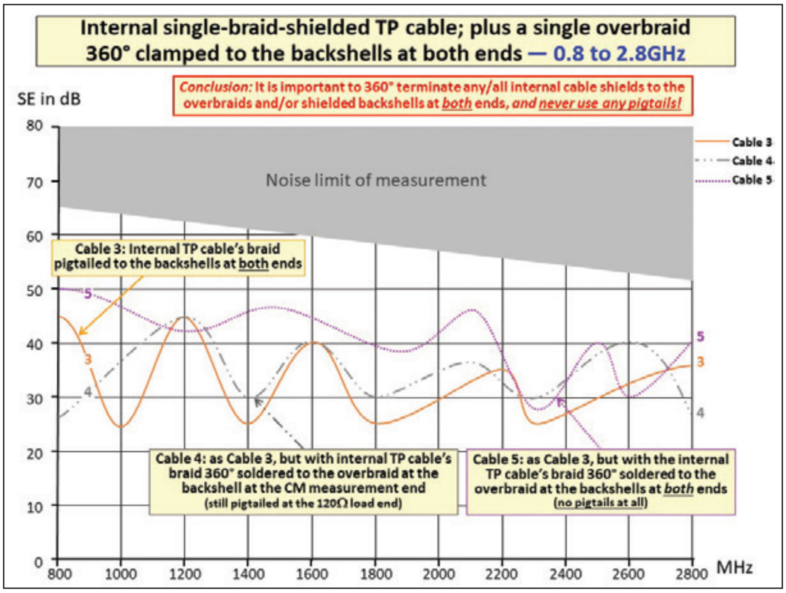

Figure 11: Results for internal single-braid-shielded TP cable, plus a single overbraid 360° clamped to the backshells at both ends — 0.8 to 2.8GHz

Given all the above and with the results from each amplifier, subtracting each cable's results from the reference result should have substantially reduced the effects of:

1. Frequency-related variations in the RF power output from each RF amplifier (see Figure 7);
2. Frequency-related variations in the antenna's response to the RF power from the power amplifiers;
3. Frequency-related variations in the coupling between the antenna and the measured cables (see Figure 9);
4. Frequency-related variations in the reflections from the shielded room (and the items stored in it);
5. Frequency-related variations due to RF impedance mismatches in the shielded connectors, and the resulting resonances caused by the length of the cable between them; and
6. There are many other possible causes of frequency-related variations in the measurements of the amplitudes of the CM noises picked up by the cables that are also reduced by the subtraction method described above, but they are all much smaller than the five listed above, so are not listed here.

This subtraction/cancellation approach was successful enough to draw conclusions on how best to terminate the shields of multiple shielded cables in an overall cable or bundle with overbraids, up to 2.8GHz. However, there were still some small errors that were deemed insignificant (see if you can spot them in the following figures!).

Results for Single-Braid-Shielded TP Cables with a Single Overbraid – Cables 3, 4, and 5

These are shown in Figure 10 for 100MHz – 1GHz, and Figure 11 for 800MHz – 2.8GHz.

Conclusions for Single-Braid-Shielded TP cables with a Single Overbraid – Cables 3, 4, and 5

A. Above 100MHz, the SE of these cables does not generally appear to continually degrade at the rate of 20dB/decade implied in Figure 1. Instead, they generally degrade more gradually and become more consistent as frequency increases.

   I don't know why this was the case and will not speculate here.

B. Fluctuations (frequency ripple) of up to ±12dB are seen on Cable 5, as predicted by the TRIAX BRAID curve in Figure 1, and I was pleased to have replicated it here.

   Apart from the UK defense standards referenced later, most of the other documents do not mention this effect at all. In my experience, this effect is much less widely known in real-world engineering than whether shields should be terminated at one end, the other end, or both ends.

   Ripples up to ±20dB are seen on Cables 4 and 3, which have pigtails at one or both ends, respectively.

C. It is important to 360°-terminate any/all internal cable shields to the overbraids and/or backshells at both ends – and *never use any pigtails*.

Results for Single-Braid-Shielded TP cables with <u>Double</u> Overbraids – Cables 6, 10, 11, and 12

These are shown in Figure 12 for 100MHz – 1GHz, and Figure 13 for 800MHz – 2.8GHz.

Conclusions for Single-Braid-Shielded TP Cables with <u>Double</u> Overbraids – Cables 6, 10, 11, and 12

D. Above 100MHz, the SE of these cables does not generally appear to continually degrade at the rate of 20dB/decade implied by Figure 1. The SE of Cables 10 and 6, which have pigtails at one or both ends, respectively, degrade more gradually than this as the frequency increases.

   However, Cables 11 and 12 (which have no pigtails) maintain a consistent SE up to 1GHz.

   Between 1GHz and 2.8GHz, Cable 11's SE degrades gradually as the frequency increases, but Cable 12's SE remained so good that it was in the

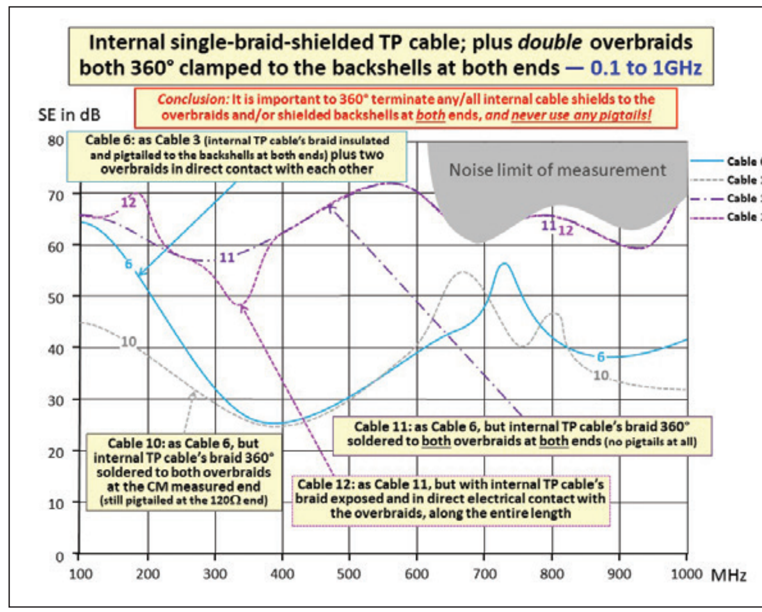

Figure 12: Results for internal single-braid-shielded TP cable, plus *double* overbraids both 360° clamped to the backshells at both ends — 0.1 to 1GHz

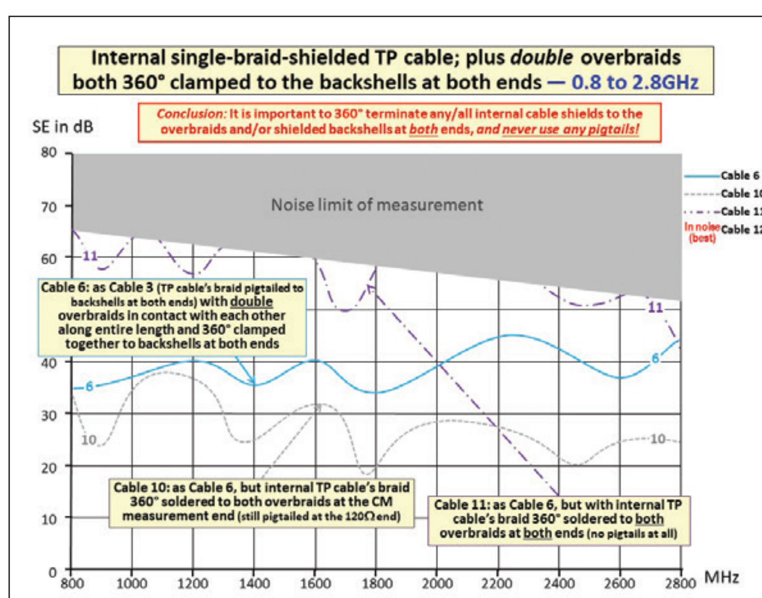

Figure 13: Results for internal single-braid-shielded TP cable, plus *double* overbraids both 360° clamped to the backshells at both ends — 0.8 to 2.8GHz

noise floor and we could not measure it with this test set-up in this frequency range.

E. Fluctuations (frequency ripple) of up to ±6dB are seen on Cable 11, a little worse than this for Cable 12.

Ripples up to ±20dB are seen on Cables 10 and 6, which have pigtails at one or both ends, respectively.

F. It is important to 360°-terminate any/all internal cable shields to the overbraids and/or backshells at both ends – and *never use any pigtails*.

Results for Double-Braid-Shielded TP Cables with Double Overbraids – Cables 7 and 8

These are shown in Figure 14 for 100MHz – 1GHz, and Figure 15 for 800MHz – 2.8GHz.

Conclusions for Double-Braid-Shielded TP Cables with Double Overbraids – Cables 7 and 8

Note: both of these cables use an internal TP cable with a double shield that is pigtailed at both ends.

G. Above 100MHz, the SE of these cables does not appear to continually degrade as fast as the rate of 20dB/decade implied by Figure 1.

H. Fluctuations (frequency ripples) of up to ±20dB are seen, which is fairly typical of all the cables that use pigtails, at one or both ends, in all these measurements.

I. Adding an insulating film between two overbraids makes SE *worse* (not up to 30dB better, as claimed in some of the later references).

It is much better for SE (although not for mechanical flexibility) for multiple overbraids to be in direct contact along their entire length.

J. Comparing the measurements of Cables 7 and 8 with those of the other cables discussed in this article, we see that their rate of fall in SE as frequency increases and their frequency ripples affirm the need to 360°-terminate any/all internal cable shields to the overbraids and/or backshells at both ends – and *never use any pigtails*.

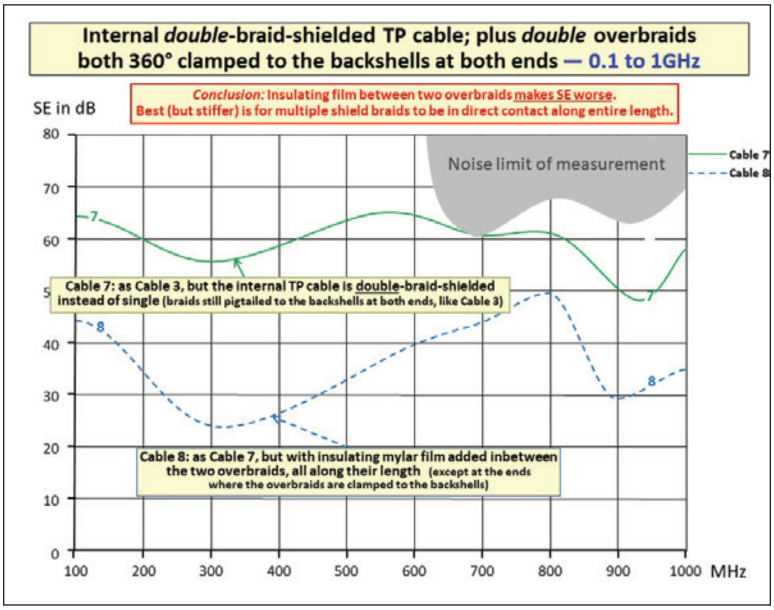

Figure 14: Results for internal *double*-braid-shielded TP cable, plus *double* overbraids both 360° clamped to the backshells at both ends — 0.1 to 1GHz

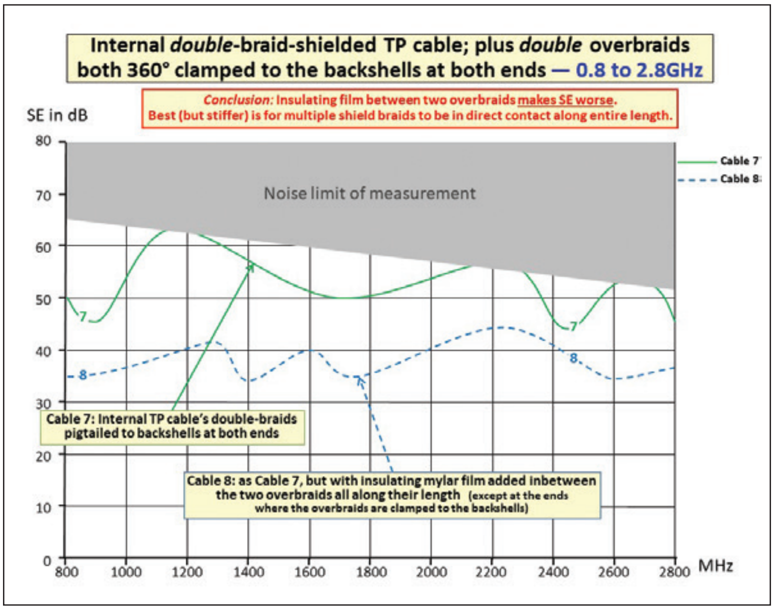

Figure 15: Results for internal *double*-braid-shielded TP cable, plus *double* overbraids both 360° clamped to the backshells at both ends — 0.8 to 2.8GHz

FINAL COMMENT

I would expect double-braid-shielded TP cables in an overall cable or bundle with double overbraids, with all shield layers 360° terminated to the overbraids and/or backshells at both ends *(and no pigtails at all)*, to give better results than any of the cables measured above. But we did not assemble or measure such a design.

BUT HOW TO TERMINATE THE SHIELDS OF INTERNAL CABLES WITHOUT USING PIGTAILS?

Few publications in the public domain (including mine) address how to terminate the shields of individually shielded cables within overbraided cables or cable bundles (ignoring those recommending pigtailing through connector pins!).

This is perhaps because it tends to be an issue for high-spec military or aerospace companies, whose internal design/assembly guides often seem to me to be specifying outdated or non-cost-effective practices, such as pigtailing via connector pins, or requiring a great deal of (costly!)

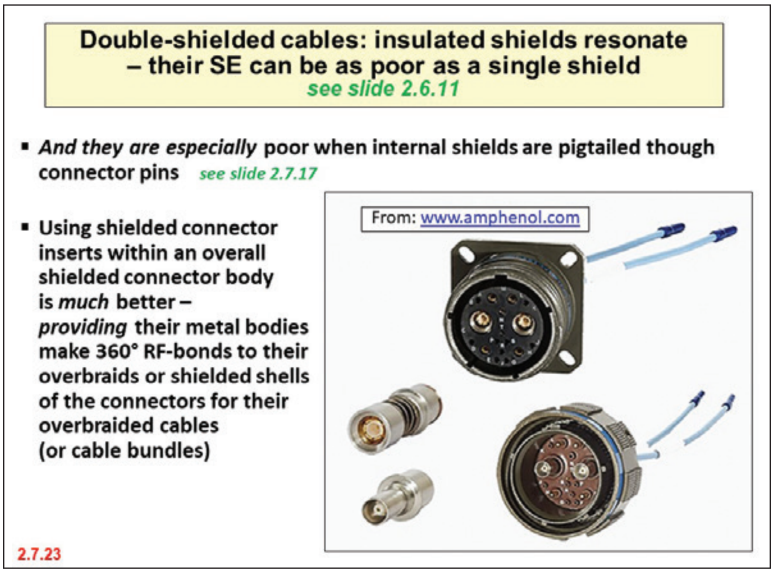

Figure 16: Slide 2.7.23 from [25]

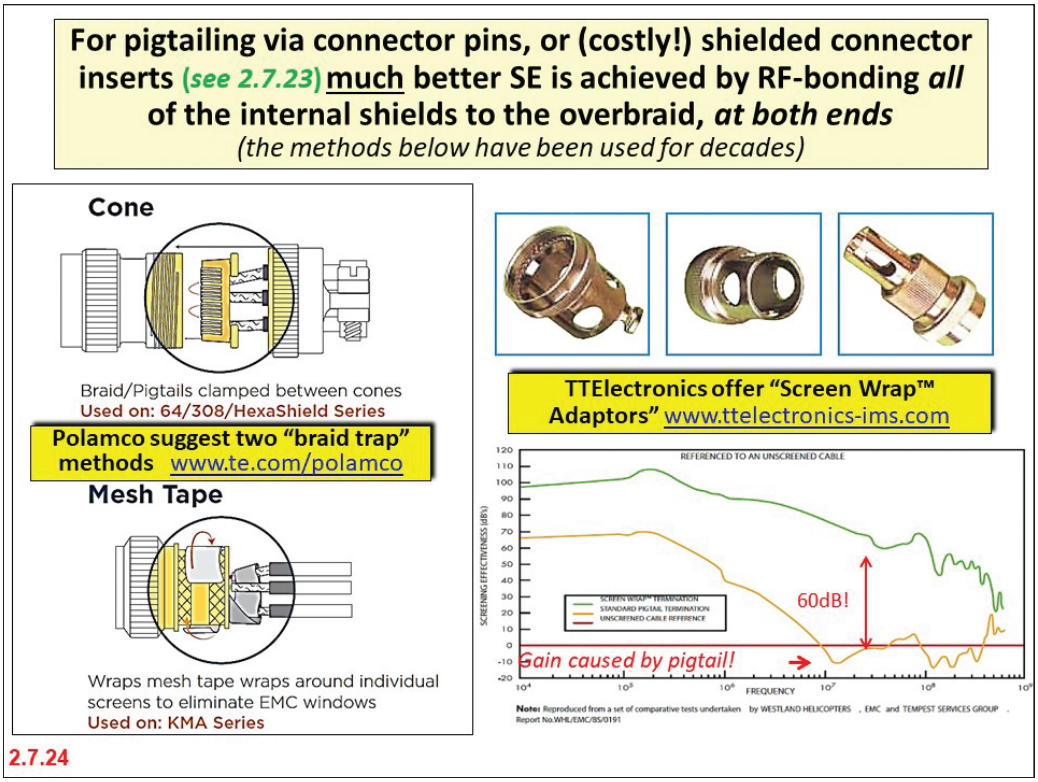

Figure 17: Slide 2.7.24 from [25]

manual assembly by skilled personnel (e.g., 360° soldering an internal braid to an overbraid).

How to cost-effectively terminate cable shields could, on its own, easily fill a whole article, but rather than extend this article by a few thousand words I've added Figures 16 to 18, taken from my training course on cable EMC [25], and hope they are sufficiently self-explanatory.

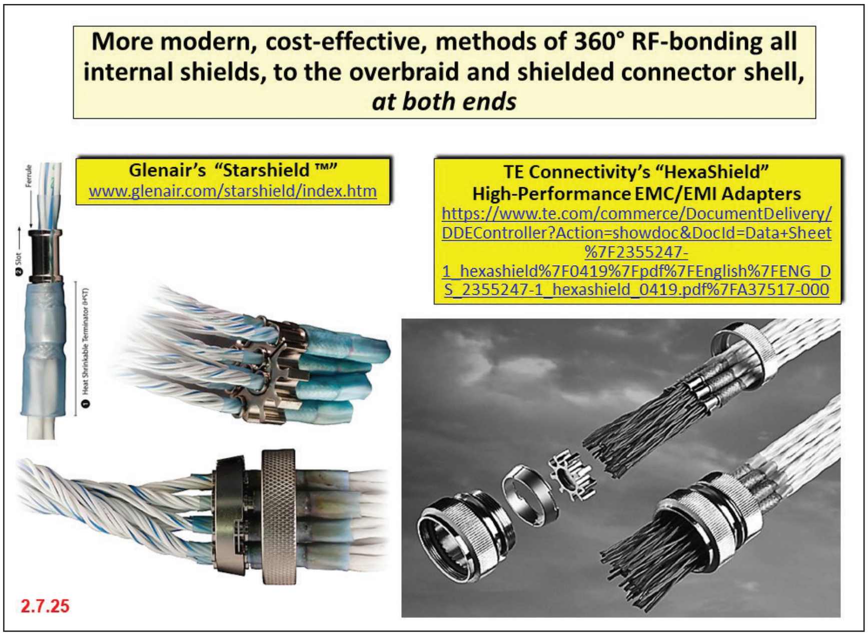

Figure 18: Slide 2.7.25 from [25]

ACKNOWLEDGMENTS

I would like to thank Lockheed Martin (UK) Ltd, near Ampthill, for the use of their facilities and for providing the test equipment used.

I would also like to thank the many people at LM(UK) who helped with these tests, particularly the following:

- Paul Moore (who made the resources available);
- Richard Clark (for helping convert his storeroom back into a shielded room);
- Chris Angove for his assistance with the shielded room and the measurements (including performing most of them and processing their data); and,
- Sean Tunn for his awesome knowledge and expertise in making shielded military cable assemblies.

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2023

Product Resource Guide

Contents

The process of making informed purchasing decisions can be quite complex. From absorbers to testing, today's compliance engineer must be knowledgeable and well-versed in what to look for when selecting products and services that will work best for your needs.

This is where the Product Resource Guide comes in. In this year's Guide, we highlight nine product categories—offer guidance on the use of these products—and selection tips on how to choose the right product or service for your applications.

So, whether you're simply looking to replace an old piece of equipment or are fully outfitting a brand-new lab, the Product Resource Guide is here to help.

We hope you'll find the 2023 Product Resource Guide an invaluable resource that you keep handy year 'round.

Lorie Nichols
Editor/Publisher

Contributing Author
Don MacArthur
Principal EMC Consultant
MacArthur Compliance Services, LLC.

ABSORBING MATERIALS

How to Select Absorbing Materials for Retrofitting

You're the compliance lead for your company's latest, newest, fanciest widget, just about to be released to production, with anticipated sales in the millions. The product has an extremely high profit margin and customers from all around the world are waiting in line to make a purchase.

The device is in the final stages of official compliance testing, and it must pass all compliance tests before it can be legally sold. On the last day of testing, one day before production release, it fails radiated emissions testing at 800 MHz, 3 dB over the Class B limit line. You contemplate certifying the device as Class A; however, this is legally not an option. It's a device that can be sold as residential, commercial, light-industrial in addition to the heavy-industrial environment, so it must pass Class B levels.

So, what are your next steps? The pressure is on high, full-throttle! The beads of sweat are starting to form on your forehead. What do you do to solve this problem in the shortest amount of time possible? Don't even think board spin. A board spin this late in the game will take too long and is therefore off the table as a solution.

Best Possible Option

You determine that you can likely suppress the 800 MHz offending emission emanating from a printed circuit board (PCB) using a flexible ferrite RF absorber sheet. The problem is that you need to find the right one and you don't have a lot of time to do it. The performance of various flexible absorber sheets is all over the map. A trial-and-error approach could take days and consume valuable resources before you find the right absorber to solve the problem. You know that most flexible absorber sheets work well in the single GHz and higher region, but your problem is just below a gig.

Luckily for you, you are smart and you've already thought through this problem well ahead of time. You had recently obtained sample flexible RF absorber sheets from several reputable vendors and characterized their performance (insertion-loss) following the method described by Ken Wyatt in Reference 1. You have this data neatly tucked away on the network, easy to find and use in case of an emergency just like this.

You look through the data you had collected for these sheets and locate the absorber material that provides the highest attenuation at around 800 MHz. You install the absorber onto the bottom of the PCB, re-test emissions on the product, and find out that you now have 6 dB of margin at 800 MHz. The product ships on time, having passed all required compliance tests! And, to top it off, you're now considered a big hero too! Management just loves you, and so do your customers. You saved the day. This is awesome!

Second Best Possible Option

The second-best option is similar to the best possible option identified above however, this time, you only ordered and received sample flexible RF absorber sheets from several reputable vendors. You have several sheets at your desk ready to go, but you have not yet characterized their performance. Other more pressing projects took the time you were going to use for this task. Fear not! The insertion-loss measurement described by Ken only takes about an hour. This is nothing in the big scheme of things, and soon you have the data you need to choose the correct RF absorber, install it, perform re-test of emissions, obtain passing results, and still become a hero, just only about an hour later than had you already collected the insertion-loss data.

Last Option

This option is not ideal. You don't already have data characterizing the insertion-loss flexible RF absorber sheets. In fact, you don't even have any flexible RF absorber sheets in-house. You ask around your company, and nobody else even knows what a flexible RF absorber sheet is. You have to perform an internet search, find what might look like acceptable material, order that material, wait for shipping (you'll probably want to pay for over-night shipping in this instance), get the material in, probably forego the simple insertion-loss measurement and go the trial-and-error route due to pressure from upper management. After several days of troubleshooting, trying to find the material that will squash the 800 MHz, you may or may not find a suitable material. You repeat this lengthy process until, by some EMC miracle, you happen to find a flexible RF absorber sheet that works. By this time, management is unhappy with you, customers have lost faith in your company's ability to deliver product on-time, and you have grown a few more grey hairs due to the extra stress involved. You kick yourself because you should have known better and gone with Best Possible Option route or even the Second-Best Option route.

Conclusion

If you think you're ever going to need to use flexible RF absorber sheets to help your product pass emissions, even at some later date, it might be a good idea to have already identified and obtained the material and have characterized its insertion-loss performance. By having a solution ready to go at a moment's notice, you may end up saving yourself and your company a lot in the long run. You may possibly even be considered a hero someday.

References and Further Reading

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Power Amplifier Linearity Requirements per IEC 61000-4-3

The 2020 edition of IEC 61000-4-3 contains several significant technical changes.

According to the forward of the standard, the specific changes are:

- a) *testing using multiple test signals has been described;*
- b) *additional information on EUT and cable layout has been added;*
- c) *the upper frequency limitation has been removed to take account of new services;*
- d) *the characterization of the field as well as the checking of power amplifier linearity of the immunity chain are specified.*

The focus of this article is the checking of the power amplifier linearity as pointed out in item d above.

Pro Tip: When IEC standards are published with revisions, the forward usually contains a short summary of the significant technical changes from the previous edition.

If you are responsible for monitoring and communicating updates to compliance standards as many compliance engineering professionals are, this information provides an excellent, short, easy-to-read summary, suitable for communication to key stakeholders located within your organization. First-line supervisors, engineering managers, engineering directors, and executives who do not have the want, need, or desire to read a more elaborate technical breakdown of the changes, will most certainly appreciate reading a clearer, concise, and most importantly brief, executive summary. The information contained in the forward of each standard is such a summary. Take advantage of its presence in the standard.

Power Amplifier Linearity

Power amplifier linearity is mentioned in many places with the IEC 61000-4-3 standard. IEC 61000-4-3 first mentions linearity as part of the level setting setup under clause 6.3.1 Characteristics of the UFA (Uniform Field Area). In this section of the standard, it states:

> *The actual test field strength ET can be different from the level setting field strength EL provided that the linearity of the system can be demonstrated (see 6.3.2 or 6.3.3 and Annex D).*

Further into the standard linearity is again mentioned:

> *It is required to ensure that the amplifiers can reproduce the modulation within the linearity requirements during testing (see 6.3.2 or 6.3.3 and Annex D).*

Clause 6.3.2 is the constant field strength level setting method, and 6.3.3 is the constant power level setting method. Note 3 of both of these two clauses state that Step 5 (Clause 6.3.2) or Step 7 (Clause 6.3.3) describe how to check if the amplifier used is sufficiently linear and that if more information is required to refer to Annex D. Annex D (informative) covers additional and very helpful information concerning amplifier compression and non-linearity.

Based on how many times and places the word "*linearity*" appears in IEC 61000-4-3, it is evident that the technical committee responsible for revision of the standard (SC 77B High frequency phenomena of IEC/TC 77 Electromagnetic compatibility) was more than likely very concerned about addressing the issue.

Amplifier Compression and Non-linearity (Annex D)

Annex D goes into the details and objectives of limiting amplifier distortion, the possible problems caused by harmonics and saturation, how to limit the harmonic content in the field, the effect of linearity characteristic on the immunity test, and the evaluation method of the linearity characteristic.

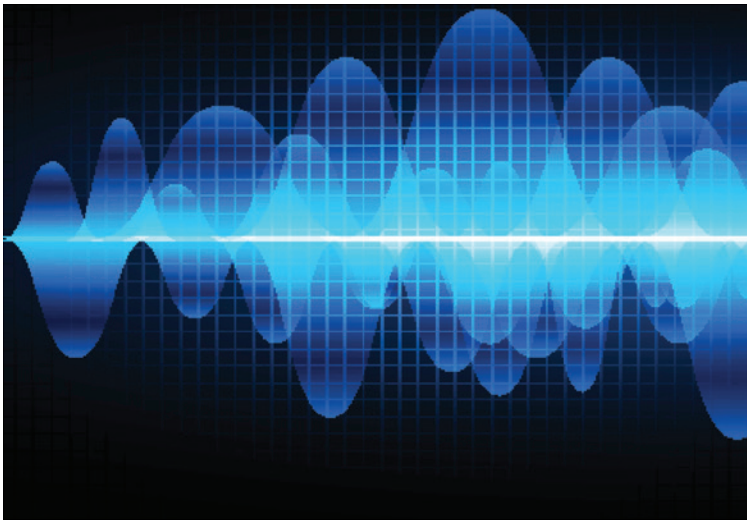
Pro-Tip: If 'you're involved in any way with IEC 61000-4-3 testing, then it would be a good idea for you to read Annex D.

According to the standard, Annex D is provided to assist test laboratories in understanding and limiting amplifier distortion, however, anyone involved in developing new electrical/electronic products and running them through radiated immunity testing should be interested in the potential issues caused by running an amplifier in saturation and harmonics that can be produced. Why should product developers and test laboratories be concerned about power amplifier linearity? The answer is "ownership" As product developers, we own getting the product out the door and into production as soon as possible. We 'can't always rely on the test facility to get everything right. People make mistakes. Sometimes there is a lack of training, lack of understanding, incorrect interpretation of the requirements, shortcuts taken, etc. If a product is failing a radiated immunity test, 'it's ok to ask the test facility to double-check amplifier linearity and that it 'isn't an issue. 'It's ok to ask them to back up their position with test data.

As noted in the standard:

> *Harmonics may cause an EUT failure where the EUT is robust at the intended fundamental frequency but not robust at the harmonic frequency. The false failure would be recorded incorrectly and may lead to an incorrect redesign.*

Product developers want to avoid making an unnecessary design change.



Under testing may also occur due to amplifier non-linearity and harmonics.

> *The harmonics may contribute significantly to the measured values taken during UFA measurement. The field strength at the intended frequency is incorrectly measured, as the broadband field probe will measure the fundamental and its harmonics.*

Linearity Measurement

Annex D provides a four-step procedure, example linearity curve and example gain deviation plots to determine linearity. The gain error over the level range of the measured amplifier output cannot exceed ±1 dB linearity. If this criterion cannot be met, Annex D provides guidance and a couple of methods that can be used to adjust forward power applied during the actual EUT test to achieve compliance. See Annex D for more details.

Summary

This was a quick run-through IEC 61000-4-3 power amplifier linearity requirements. For more information on this important subject, please see the following.

References and Further Reading

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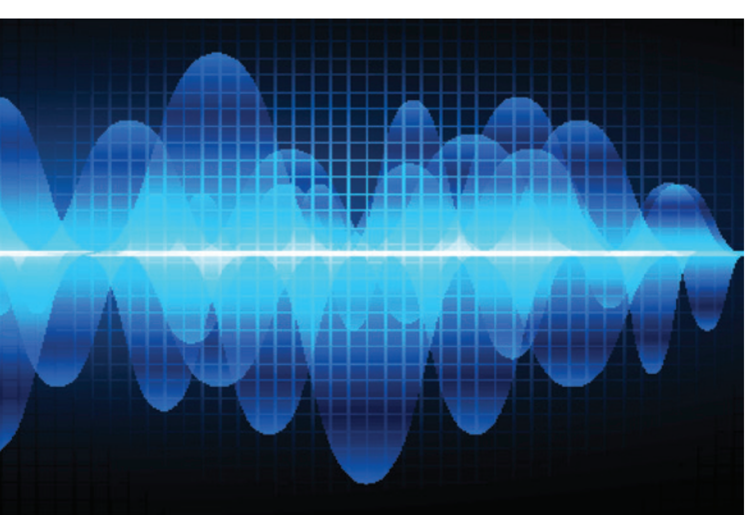


TIPS FOR SELECTING *Amplifiers*

1. Determine the frequency range of operation needed, sometimes more than one amplifier is required.
2. Determine if you need a Pulse or CW type of amplifier. Example: HIRF EMC applications require high power pulse amplifiers..
3. Determine the minimum acceptable linear or saturated power needed from the amplifier. Harmonics should be considered based on the frequency range. Example: As you go up in frequency antenna gain improves so a lower power amplifier may be acceptable but the higher gain of the antenna may affect the Harmonic Level.
4. Assess the system losses between the amplifier and the antenna/DUT. Example: If the test setup has 6dB of losses then the Amplifier power needs to be 6dBm higher.
5. Some modulations if required for the test application, would require a higher power amplifier. Example: When performing an 80% AM modulation test the amplifier needs to have 5.1dBm of margin to accommodate the peak.
6. Antennas, cables, DUTs, and rooms have cumulative VSWR, it is best to allocate for some power margin. Example: working into a 2:1 requires 12% more forward power.
7. Consider the application, is this a single test or will it be used repetitively?
8. Consider your desired RF connection types and locations to be optimal for your application.
9. Consider if automation will be used so the appropriate remote capability is included.

COMPLIANCE
SOLUTIONS

What to Do When Your Product Must Comply with Conflicting Requirements

As a compliance engineering professional, you may encounter situations when you must consider how multiple and often conflicting requirements apply to your product and how to deal with them effectively.

Things can get real confusing, real complicated, real fast. You may determine after a product has been released to production (when it is too late to make cost-effective design changes) that you may have missed a key requirement that your product should have met but does not because you overlooked it. Knowing all the requirements that apply to your product ahead of time will help you design the product to meet the harshest requirements and also design pre-compliance tests that represent the highest severity immunity test levels and lowest limit emissions levels you need to test the product against. This can be a big time saver because you can skip the formal full-compliance test setup, quickly determine pass/fail of the product, make design changes as necessary, then come back and run formal compliance tests knowing the product will likely pass. If you need to make design changes later, you can skip straight to running the harshest test levels to determine whether or not the change affected compliance.

Organization

The first step in dealing with conflicting requirements is to get organized. Think about all the various requirements the product has by type.

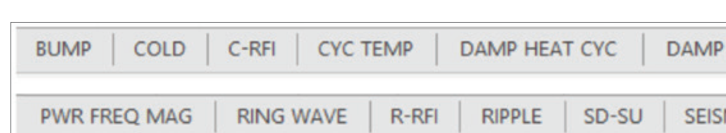


Figure 1

For electromagnetic compatibility (EMC) tests, the product probably has requirements for conducted RF immunity (C-RFI), electrostatic discharge (ESD), electrical fast transient burst (EFT), emissions, radiated RF immunity (R-RFI), surge, etc. For environmental tests, the product probably has requirements for temperature testing for Cold, Dry Heat, Damp heat Cyclic, and Damp Heat Steady State, etc. Vibration testing may include tests for Shock, Bump, Seismic, and others. Write all the various requirements down by name. I like to place them in alphabetical order. You can organize yours how you wish.

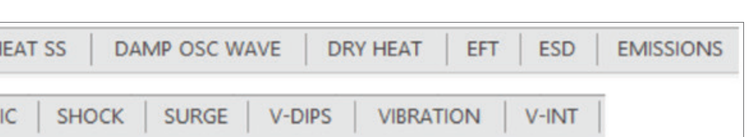
The next step of the process is to determine what tool you will use to keep track of the requirements. The two easiest choices for me are a word processing program or a spreadsheet program. I elected to organize my conflicting requirements using a spreadsheet program with each tab or worksheet containing the comparison of conflicting requirements for one of the areas identified in step one (ESD, for example).

Figure 1 is an example of the tabs used in my standards comparison spreadsheet.

Notice that I arranged the tabs in alphabetical order. You may elect to order the tabs by type, such as all EMC-related requirements are placed first, followed by vibration, then environmental. However you want to do it is up to you. The important thing is to be able to locate the information in a hurry when you need it. It is almost impossible to remember it all.

I have seen others use a word processing program where they inserted a table for each item they wanted to compare. Your organization may use some other requirements tracking program.

The third step is to start filling in details for each requirement. You will need a copy of each of the readily available standards you are interested in comparing.



TIPS FOR SELECTING *Chambers*

1. Selection of a chamber is determined by the standard being tested to. Some types of EMC Chambers are: Commercial, MIL STD/DO-160, CISPR 25 and Reverb.
2. Commercial chambers are used for IEC and CISPR standards for Emissions and Immunity testing. Typically, "Semi – Anechoic" and achieve CISPR16 (Emissions) and IEC 61000-4-3 (Immunity) chamber performance requirements.
3. Semi-Anechoic Chambers are strategically lined with absorber and ferrite to meet specifications without fully lining all surfaces.
4. Verification for CISPR 16 compliance is Normalized Site Attenuation (NSA) (26 MHz-1 GHz) and Site Voltage Standing Wave Ratio (sVSWR) (1-40 GHz). This verifies the chamber "Quiet Zone". Quiet zones are normally equal to the turntable diameter. EUT's can't be larger than the quiet zone.
5. For compliance, variations in the quiet zone performance cannot exceed +/-4db for NSA and 6dB for sVSWR.
6. Verification for IEC 61000-4-3 is a field uniformity test. Typically, a 1.5m x 1.5m vertical plane consisting of 16 points spaced 0.5 m apart is the measured area. At least 12 Points must vary by <6dB.
7. MIL STD and DO-160 chambers can be Semi-Anechoic or Fully Anechoic. Standards require the absorber have a minimum absorption of 6dB from 80MHz to 250MHz and 10dB above 250Mhz. A table with a conductive top is used for testing the EUT and is bonded the shield ground.
8. CISPR 25 chambers are fully lined on walls and ceiling, contain a similar table with metal lining on top, and must pass the Long Wire Test or the Reference Site Method test to meet the Standard.
9. Reverb chambers rely upon the reflectivity of the walls and an internal movable paddle to reflect generated signals and increase the value of V/m generated from the transmit antenna.
10. Information needed to design a reverb chamber is the lowest frequency, the test volume, maximum V/m, and standard to be tested to (MIL STD, DO, ISO).

These tips are presented by

Figure 2 is an example of the conflicting requirements I put together for emissions. I have filled in as much information as possible without overly complicating it with too much detail.

Figure 3 is an example of the conflicting requirements for ESD.

The examples in Figures 2 and 3 will give you a good idea of what information should be used to compare conflicting requirements.

	Operating Conditions	Conducted Emissions (MHz)
Relay Zone A Relay Zone B	Operational (Rated Values)	0.15 to 30
ANSI Meter	Operational (Rated V, I w/ spliced line/load conductors + tied to GND) (Note 1)	0.15 to 30
IEC Meter	Operational (Rated V, I w/ Linear Load)	0.15 to 30
IEC PMD	Operational (Influence Quantities)	0.15 to 30

Notes:
1) The ANSI test setup is much more complicated
2) FCC Part 15: Test to 5th harmonic of the highes

Figure 2

Criteria for Acceptance

You may have noticed that I have left out criteria for acceptance in the above conflicting requirements comparisons. This is because I wanted to keep things simple. By adding criteria for acceptance, each comparison would have been much harder and more confusing to read. This does not mean that knowing the criteria for acceptance is not important. It certainly is. The problem is that each standard has its own definitions about what defines pass/fail under various conditions. Some standards require only testing for correct functionality after the test has been performed. Other standards require all functions to continue showing no degradation during the test. I feel that the comparisons for the conflicts in criteria for acceptance are best left to a separate document.

Conclusion

Part of the job of a compliance engineering professional is to effectively communicate the regulatory requirements to all key stakeholders of the product currently in design or production. Often these requirements are conflicting. The best way I have found to perform this task effectively is to get organized and construct a conflicting requirements document that maps out where conflicts exist. Once constructed, this document becomes one of the most useful items found in a compliance professional's "bag of tricks."

Emissions

Radiated Emissions (MHz)	Class	Ports	Standards
30 to 6000	A	PS, Enclosure	IEC 60255-26 CISPR 11 CISPR 22
30 to 6000 (Note 2)	B	PS, Enclosure	ANSI C12.1 (Test No. 27) CFR 47, Part 15 A & B
30 to 6000	B	PS, Enclosure	IEC 62052-11 CISPR 22
30 to 6000	A / B	PS, Enclosure	IEC 61557-12 IEC 61326-1 CISPR 11

d than the IEC/CISPR test methods.
st frequency or 40 GHz, whichever is lower.

The examples in Figures 2 and 3 will give you a good idea of what information should be used to compare conflicting requirements.

Electrostatic Discharge Immunity

	Operating Conditions	Contact (kV)	Air (kV)	# of Discharges (+, -)	Interval (s)	Ports	Standards
Relay Zone A Relay Zone B	Operational (Rated Values)	2, 4, 6	2, 4, 8	10	1	Enclosure	IEC 60255-26 IEC 61000-4-2
ANSI Meter	Operational (Rated Values)	-	15	10	1	Enclosure	ANSI C12.1 (Test No. 28) IEC 61000-4-2
IEC Meter	Operational (Rated V, No I)	8	15	10 (Note 1)	1	Enclosure	IEC 62052-11 IEC 61000-4-2
IEC PMD	Operational (Influence Quantities)	4	8	10	1	Enclosure	IEC 61557-12 IEC 61326-1 IEC 61000-4-2

Notes:
1) Test using most sensitive polarity.

Figure 3

Use of Ferrites in PCB Reference Planes

Should the reference (i.e., ground) plane be split into two separate sections and a ferrite bead installed between them to prevent unwanted radio frequency emissions? Let's examine why this practice is not a good idea and should be avoided at all costs.

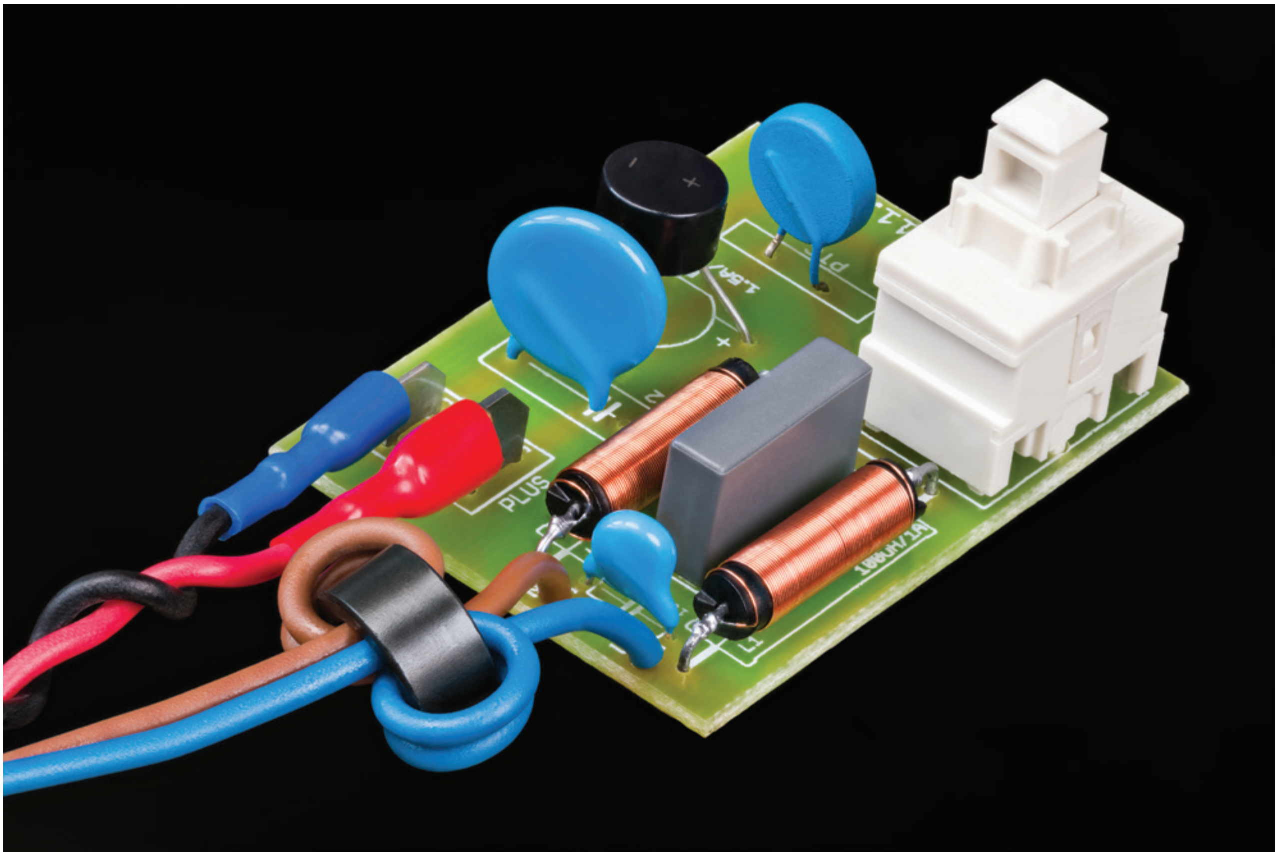
Splitting the Reference Plane

The 0V reference plane (sometimes mistakenly called a ground plane) is an essential element in electromagnetic compatibility (EMC) design of a PCB. Its proper design is more important than almost anything else that can be done to the board to achieve EMC compliance. DO NOT split the reference plane unless you know what you are doing (and maybe not even then).

Although it should be kept as one congruent element to achieve EMC compliance, beware that you will encounter EMC design guidelines and application notes for integrated circuits which still describe the old practice of splitting the reference plane between analog and digital sections, and then bridging them with a ferrite bead, as the best thing to do to achieve EMC compliance.

Don't let misguided application notes persuade you to split the reference plane into two. In contrast to the "old" guidelines, over the past several years, many electronic designers find that keeping the 0V reference plan intact will achieve better signal quality and EMC performance. Only under careful consideration should the 0V reference plane ever be split (i.e., specialty cases with low-frequency analog circuits).

In most cases, splitting the 0V reference plane and bridging the split with a ferrite is unnecessary. Splitting the reference plane, in fact, promotes bad routing practices because routing across the break alongside the ferrite establishes a significant loop antenna that not only emits radio frequency noise but also receives it nearly as well.



Adding a Capacitor

But, "What if I add a capacitor in addition to and parallel with the ferrite?"

Unfortunately, this circuit combination of ferrite and capacitor forms an LC resonant tank circuit that will ring intensely, making matters much worse! The spectrum of any digital signal found on the board will excite the LC resonance in that circuit after it crosses the gap across the reference plane. Even if an actual physical capacitor is not installed, stray capacitances on the board and within the system allow an LC resonant circuit to form with the ferrite causing electromagnetic interference.

What to Do Instead of Splitting Reference Planes

1. Ignore application notes that want you to provide isolation with split reference plans.
2. Practice proper layout and routing practices. This is the safest approach to provide separation and achieve EMC compliance for your design.

References and Further Reading

1. Armstrong, K., *EMC for Printed Circuit Boards*, Armstrong/Nutwood UK, 2010.
2. Altium, "How to Use a Ferrite Bead in Your Design to Reduce EMI," October 27, 2021.

CONSULTING AND TEST LABS

Signal Integrity Versus EMC

Two questions that often arise in and around engineering research and development cubicles, watercoolers, and office spaces are:

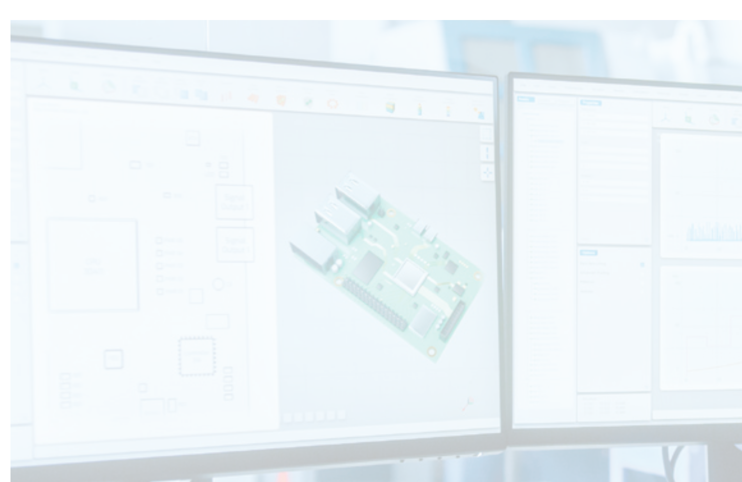
- How does signal integrity (SI) compare to electromagnetic compatibility (EMC) and vice versa? and
- Which of the two is the tougher design challenge (SI or EMC)?

The following article addresses these two very common questions involving two inter-related and specialized sub-fields within the realm of compliance engineering.

How Does SI Compare to EMC?

SI and EMC can be thought of as two different sides of the same coin, and there are some common design objectives between SI and EMC. However, a high-quality SI design does not automatically lead to a high-quality EMC design, and a high-quality EMC design cannot guarantee a high-quality SI design.

In short, SI is about maintaining signal quality from driver to receiver, and that crosstalk between two or more signals does not degrade the quality of the intended signal. SI involves ensuring timing margins are met, and signals do not exceed voltage thresholds that can damage or destroy both send and receive devices. There are no standards to be met, mandatory or otherwise. Just the requirement that the end-product function correctly in its intended application.



On the flip side, EMC is about properly designing products using rules of thumb and other well-established criteria to comply with governmental or market-driven emissions and immunity standards. EMC involves proper printed circuit board layout to limit the amount of unwanted common mode current allowed to flow out onto wires attached to the product. These currents are, in turn, measured by sophisticated test apparatus to determine if they fall under established limits. Recall that it only takes 5mA of common mode current flowing out onto wires to fail Class B radiated emissions limits.

Simulation is not that difficult or expensive in the SI world and is a very important part of developing products with good SI. Simulation brings several benefits, including reducing the risk of failure, enabling what-if analysis early in the design cycle, and providing information to justify design changes later in the design cycle, verifying their effectiveness, all while reducing time to market.

On the other hand, EMC simulation is currently not easy and currently not inexpensive. The best way to get the design right the first time is to design with EMC in mind and carefully layout circuit boards to achieve EMC. Early designs should be peer-reviewed before sending out for prototypes. It is best to obtain sample boards as soon as possible and test them using bench-top pre-compliance test methods or more official-like methods before attempting to pass official compliance tests.

Proper SI often involves the analysis and manipulation of what is found on the schematic, whereas proper EMC involves analysis and manipulation of the "hidden" schematic.

Other SI vs. EMC Considerations

Several other design layouts may or may not negatively impact SI but will most likely affect EMC. As a minimum, these important EMC (but not SI) design criteria include:

1. Placement of high-threat clock/high-speed circuitry next to I/O circuitry;
2. Routing of clock traces away from the edge of the board;
3. Placement of I/O connectors on opposite sides of the board;
4. Placement of high-speed traces between the I/O connector and I/O circuitry;
5. Use of ground floods on signal layers;
6. Routing of clock traces on surface layers;
7. Use of decoupling capacitors;
8. Proper heatsink grounding;
9. Proper grounding of PCB mounting holes; and
10. Overlapping clock harmonics and use of spread-spectrum clocks…

… to name a few.

SI vs. EMC Considerations Based on a Signal's Rise (Fall) Time or Frequency

Reference 1 states that for good SI, simulation techniques are recommended for all traces for which the bare-board t_p ³ $t_r/10$ or t_r ³ $1/10\pi f$ (where t_p is the signal propagation time, t_r is the signal's rise or fall-time [use whichever value is shorter of the two], and f is the highest frequency of concern. For good EMC, reference 1 recommends using simulation techniques when t_p ³ $t_r/40$ or t_r ³ $1/40\pi f$.

Basic Characteristics of SI versus EMC

SI	EMC
Time Domain	Frequency Domain
Voltage or Current Spectrum	Voltage Waveform
Radiated or Conducted	Not Relevant
High Threat Signals = Clock & I/O	High Threat Signals = All High-Speed Signals
Common Mode Noise: Great Concern	Common Mode Noise: Lesser Concern
Noise Levels of Concern = mA, mV	Noise Levels of Concern = mA, mV
Low Pass Filters Widely Applied to All High Threat Signals	Filters Judiciously Applied as Their Placement Can Negatively Impact SI Performance

Conclusion

The above discussion addressed the first question posed at the beginning of the article:

> *"How does signal integrity (SI) compare to electromagnetic compatibility (EMC) and vice versa?"*

To answer the second question:

> *"Which of the two is the tougher design challenge (SI or EMC)?*

I would say that given the ever-decreasing rise-fall times that components are now switching at in present day and the increasing pressures put on design engineering to design and ship products in shorter development times, both are equally challenging. However, based on some of the above information, one could easily conclude that EMC is the tougher design challenge.

References and Further Reading

1. Armstrong, K., *EMC for Printed Circuit Boards*, Armstrong/Nutwood UK, 2010.
2. Bogatin, E., *Signal and Power Integrity – Simplified, 2nd Edition*, Prentice Hall, 2010.
3. Syed, H., "Relationship Between Signal Integrity and EMC," Selectron USA, Inc., 2007.

Proper Heatsink Grounding

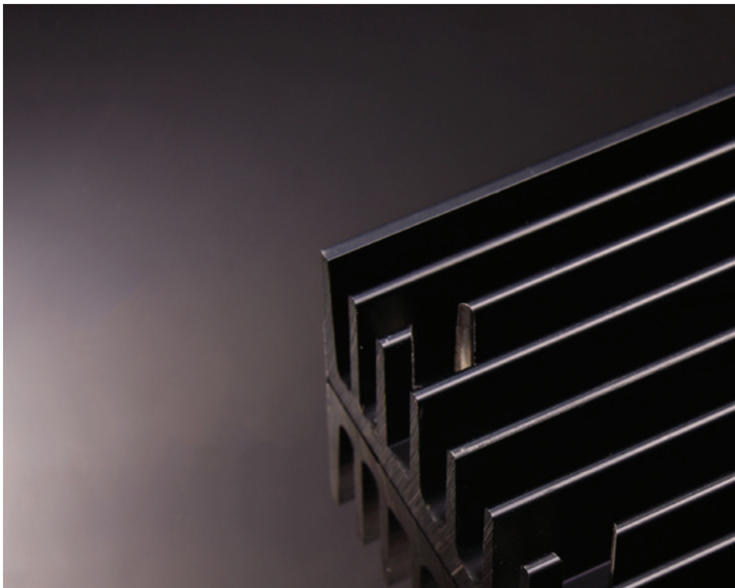
A common question in new product development is, "How do I properly ground the heatsink?"

As a practicing compliance professional, this is an important question to have at least an idea of how to respond. Other professionals on the development team look to the compliance staff for help in developing a solution that will perform well thermally (i.e., cool the integrated circuits they're attached to) and meet radiated emissions (RE) Class A or more stringent Class B requirements. The following summary of proper heatsink grounding is provided to better address this common issue. Let's first discuss common problems with heatsinks.

Common Issues with Heatsinks

Common practice is to place metal heatsinks on top of high-frequency (HF) integrated circuits (ICs) to help cool them. Because the heatsinks are mounted very close to the HF emitting function of the IC, unwanted internal currents can easily couple onto the heatsink. Due to its much larger physical and electrical size, the heatsink is a very efficient radiator compared to the much smaller IC and its tiny internal bond wires.

WARNING: This could spell disaster. I have witnessed first-hand where installing a heatsink (first believed to improve margin for RE) caused a product that initially passed Class B by a couple of dBs to fail Class A by over several dB! This likely occurred



because, with the installation of the metal heatsink, internal IC currents were allowed to parasitically couple onto the heatsink, and in turn, the heatsink performed just like an efficient antenna, radiating (or re-radiating, if you will) HF from the IC and allowing RE limits of the test to be exceeded.

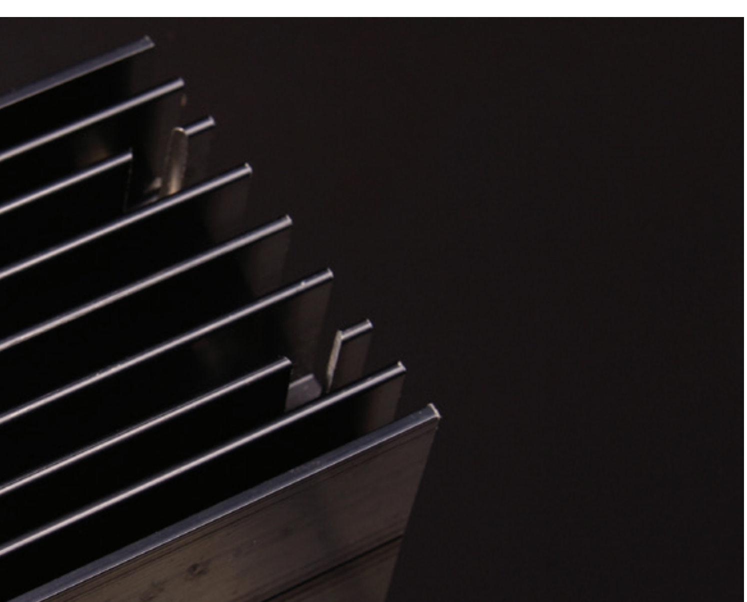
Where to Ground the Heatsink?

Another common practice is to "ground" the heatsink to the printed circuit board (PCB) ground-reference-pale (GRP). Doing so will reduce the voltage difference between the heatsink and the ground reference plane, thereby helping to reduce emissions.

How Many Ground Points are Required for the Heatsink and Where?

This is where the rubber meets the road, and a key to ensuring the metal heatsink performs more as a shield to HF from the IC and less like an efficient antenna that allows HF noise from the IC to be radiated into space.

Pro Tip: As technology progresses, the frequencies we're dealing with also increase. This means the heatsink size becomes electrically larger, resulting in a more efficient radiator. Carefully planned and designed heatsink grounding is mandatory if it is to be effective at shielding these higher frequencies.



Reference 1 describes measurements conducted from 100 MHz to 10 GHz with a common heatsink topology using several different grounding points. Ideally, we would like to have an infinite number of grounding points located around the heatsink to gain the lowest impedance path possible between the heatsink and the GRP. However, we must make a trade-off since we don't have an infinite amount of real estate surrounding the IC that we can consume. We will have to settle for a few grounding spots instead of an endless number of them. But how few can we get away with? At the other end of the extreme, if there aren't a sufficient number of grounding points, the emissions at some frequencies can increase. The table included below is intended to help the reader visualize published research results.

Conclusion

After reviewing Table 1, it becomes apparent that emissions levels are significantly impacted by the number of ground points installed between the heatsink and the GRP. Depending on the number of contact points, some emissions in specific frequency ranges go up, while at the same time, emissions go down in other ranges. The zero-, one- or two-point contact grounding scheme doesn't buy you much, and the eight-point method buys you quite a bit. All configurations have a primary resonance that can be moved around if it also falls on the first or second harmonic of the process clock frequency.

References and Further Reading

1. Archambeault, B.R., *PCB Design for Real-World EMI Control*, Kluwere Academic Publishers, 2002

Ground Contact Configuration[1]	Frequency (MHz)	~ Highest Electric Field (dBmV/m) Recorded	Comments
Zero Contacts	3750	183	All configurations resonant at this frequency
One Contact		183	
Two Contacts		186	
One Contact	300 - 800	183	Emissions increased
Zero Contacts	> 800	173	Emission the same regardless of the number of grounding contacts
One Contact			
Two Contacts			
Two Contacts	< 800	150 - 170	Low-frequency emissions improved
Two Contacts	800 - 2000	175 - 185	Emissions increased
Zero Contacts	> 2000	185	Emissions of the two contact configurations are ~ same as the configuration with no contacts
Two Contacts			
Four Corner Contact	< 1000	175	Emissions reduced
Four Corner Contact	1000 - 2000	185	Emissions drastically increased
Four Contacts – One Center of Each Side	< 1600	< 175	Emissions reduced
Four Contacts – One Center of Each Side	1600 - 2500	178 - 191	Emissions increased
Eight Contacts	< 2500	150 - 175	Emissions drastically reduced
Eight Contacts	> 2500	173 - 191	Emissions increased. Primary resonance ~ 2800 MHz

Note 1: Ground contact points are small metal posts (~ 25 mm x 25 mm) connected between ground plane and heatsink.

Table 1: Heatsink Grounding Configurations vs. Near Field Emission from Heatsink

FILTERS AND SHIELDING

The Synergy of Filtering and Shielding

In previous Product Insights articles (References 1 through 7), we've primarily addressed filtering and shielding topics separately. While the two are important foundational topics, it's time to take a deeper look into our roles as product developers toward the goal of achieving the most robust (lowest EMC emissions, high EMC immunity) product design possible at the highest frequency of concern in the system we're developing.

This article briefly describes the concept of the synergy of filtering and shielding and why knowing it is important.

Origin of the Synergy of Filtering and Shielding Concept

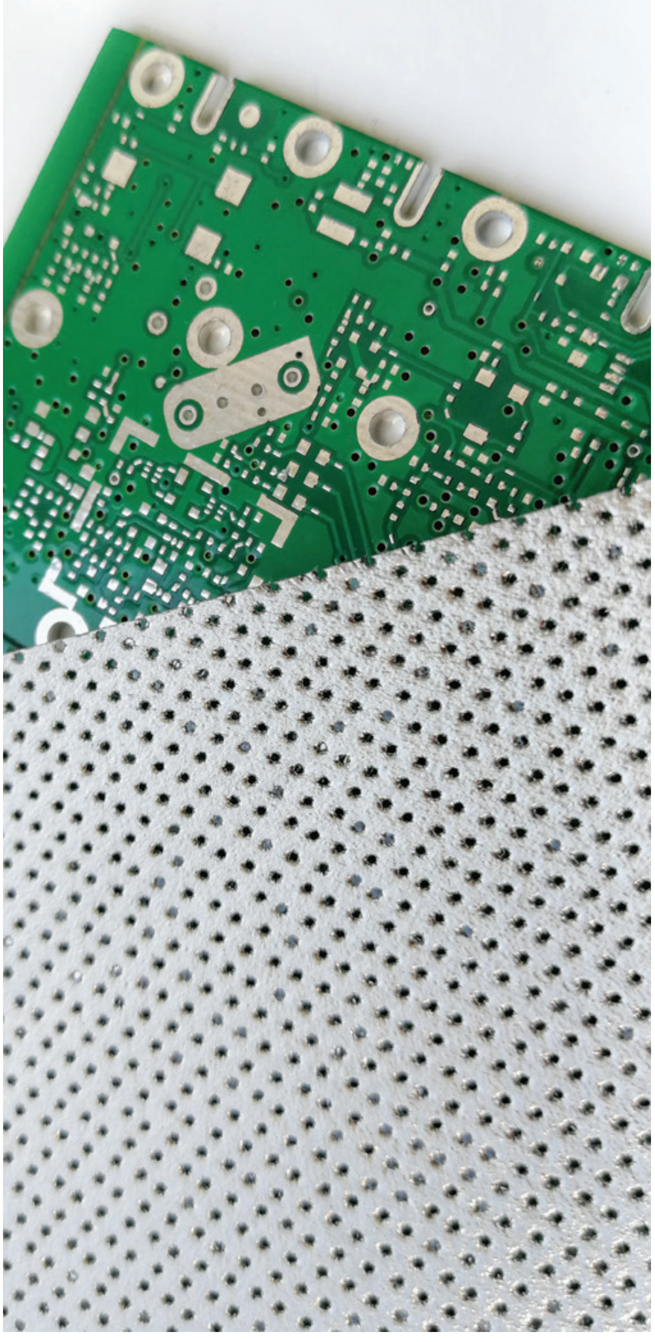
I've picked up on the concept of the synergy of filtering and shielding from world-renowned and UK-based EMC expert Keith Armstrong.
Keith describes the synergy of filtering (and much more) in two of his books on EMC (References 8 and 9).

Pro-Tip: If you don't already have Keith's books, you should seriously consider picking them up as soon as possible. They are chock full of very useful (and practical) EMC design concepts and are among the most useful books on EMC I've read.

The Essence of the Synergy of Filtering and Shielding

Mains filters and the like provide very little attenuation above ~30 MHz (highest frequency of the conducted emissions test) and permit radio-frequency (RF) emissions to emanate from accidental antennas (i.e., cables) attached to your device to cause both EMC emissions and immunity problems. Because the low-frequency (LF) filtering offered in this situation is less than ideal and much lower than required for the overall high-frequency (HF) shielded enclosure or shielding-can (if located on a printed circuit board), overall shielding effectiveness (SE) is severely degraded.

All unshielded cables that enter/exit the enclosure (mains included) must be filtered with good attenuation at the highest frequency of concern, if good HF shielding is required (often the case in today's environment of high-speed, high-frequency products and regulatory compliance requirements).



In short, the synergy of filtering and shielding means that filter attenuation versus frequency should match desired shielding performance.

How the Synergy of Filtering and Shielding is Accomplished

The synergy of filtering and shielding is best accomplished by what can be regarded as the belt and suspenders approach to EMC. Briefly, here are some ideas to consider:

- Utilize mains filters that specify their attenuation much greater than the typical 30 MHz, such as those filters specified as meeting military EMC requirements.
- Add additional HF filtering where needed.
- Utilize traditional high-performance, three-terminal feedthrough capacitors.
  - Use 360° electrical bond so internal and external surface currents stay separated of either side of the shield.
- For high-volume manufacturing utilizing shielding-cans on a PCB, use a surface-mount device (SMD) 3-terminal capacitor filters with the center terminal soldered to a guard trace with the filter's input and output terminals placed on opposite sides of the shielding-can's wall. Holes in the can straddle the SMD capacitors roughly at their center-point, one terminal of the SMD capacitor is located inside the shielding-can and the other terminal located on the outside. This is not as good as a 360° connection offered by using traditional types of feedthrough capacitors but is the best we can do in this situation.
- Utilize a dirty box/clean box method for mounting filters in the walls of shielded enclosures (see reference 8 for examples). This design technique helps isolate the noisy, bad RF signals from the good, clean ones. Along these same lines,
- Carefully route filter inputs and outputs, keeping the noisy input side wires or traces far away from the clean output wires or traces.
- Filter all unshielded signal or power cables entering/exiting the shield enclosure using 360° bonding.

- Other design techniques may be appropriate depending on the unique product design and can be developed using your own imagination and your own design for EMC prowess.

Summary

And there you have it, a quick run-through of the concept of the synergy of filtering and shielding and why it's an important concept to keep in mind. For more information, please see the following:

References and Further Reading

1. "How EMI Filters Are Specified for RF Performance," *In Compliance Product Insights*. November 2021.
2. "An Alternative Approach to Specifying an EMI Filter," *In Compliance Product Insights,* November 2020.
3. "How EMC Shielding is Defeated," *In Compliance Product Insights*, August 2020.
4. "Let's Talk About Why Filters Fail," *In Compliance Product Insights,* November 2019.
5. "Let's Talk About Shielding at the PCB Level," *In Compliance Product Insights,* August 2019.
6. "What Every Electronics Engineer Needs to Know About: Filters," *In Compliance Product Insights,* November 2018.
7. "What Every Electronics Engineer Needs to Know About: Shielding," *In Compliance Product Insights,* August 2018.
8. Armstrong, K., *EMC Design Techniques for Electronic Engineers*, Armstrong/Nutwood UK, 2010.
9. Armstrong, K., *EMC for Printed Circuit Boards*, Armstrong/Nutwood UK, 2010.

SAFETY

The Calculation of Creepage and Clearance Distances Using a Spacings Calculator

The calculation of creepage and clearance distances (spacings) is one of the most important activities a product safety/compliance engineer or technician performs throughout the product development process.

Conducting this activity sooner rather than later is key to releasing a product on time and within schedule and budget constraints. Waiting to calculate creepage and clearance distances until the prototype stage, when safety evaluation and testing have begun, is almost always a recipe for disaster. Correcting spacing miscalculations late in the product development cycle will assuredly add unnecessary redesign and retest efforts, increase the risk of delaying production release until the issue is addressed, or even releasing the product without the necessary product safety approvals.

If you work on a technically savvy design team, they will likely turn to you for help in determining the appropriate spacings for the product far in advance of ordering any prototypes. If they do not come to you for help, then it would be wise to take the lead and supply this information even if not requested.

If you are unsure what I'm talking about, this article highlights what is involved in calculating creepage and clearance distances using a spacings calculator and provides recommendations for managing this activity on any future projects.

Determination of Applicable Safety Standard(s)

The first step in determining the correct creepage and clearance distances for your product is identifying which safety standard(s) apply to it. The product specification may include the required standard(s), but if not, you can determine the applicable standard in several ways.

The first way is to consult with the third-party certification agency (Nationally Recognized Test

Laboratory – NRTL) involved in the certification of your product. The NRTL will have a good idea of which standard(s) applies to your product.

Another method is to look at the specifications for existing products your company produces. The new product will likely have similar installation conditions and functions and have very similar safety requirements.

Finally, if these other two options don't pan out, you can always search online for similar products and see what safety standard(s) those products meet.

Determination of Use Environment

Once the appropriate safety standard is identified, the next step is to determine the pollution degree, overvoltage category, altitude rating, measuring category (if applicable), material group for printed circuit board material, and voltage rating for the system (Voltage Line-to-Neutral–AC, RMS, or DC).

You will need to know what type of circuit you will be determining spacings for (i.e., Mains circuits or other). Consult references one and two for the meaning of these terms.

Spacings Calculator

Product safety standards often have multiple creepage and clearance tables to help determine the appropriate spacing values even when provided with a narrow list of information, as mentioned above. The tables are often spread out in several locations which can make finding the correct spacings for a circuit time-consuming and cumbersome. The back-and-forth process of looking at specifications and then the spacings tables and then back again has the potential to lead to confusion which could result in providing an incorrect creepage or clearance number when the pressure is on, and the design team is requesting the numbers. To make the process easier, faster, and more accurate, we highly recommend constructing a spacings calculator. It is based on the standard's creepage and clearance tables but makes it easier to pin down spacing numbers in a much more timely and efficient manner. The NRTL you're working with may also be able to provide a spacings calculator you can use, eliminating the need to create your own.

But, if you're curious like most of my fellow engineers, the rest of this article describes how to create your own spacings calculator.

Using a spreadsheet program like Microsoft Excel, recreate the information for each creepage and clearance table from the standard and use the lookup function to find the correct spacings given the various inputs provided by the design team.

Sometimes the standard(s) allows interpolation for spacing values that fall between two voltages but do not land directly on the voltage identified in the spacings table. In this instance, you will have to include the interpolation calculation as part of the lookup. You can use many resources online if you don't already know how to perform interpolation in Excel.

Once the tables from the standard(s) are entered, and you confirm the lookup function is working correctly, you can use the hide feature in Excel to hide the tables from view.

You will also want to create an esthetically pleasing area in which to enter information and obtain the output (i.e., correct spacings number). For spacings calculators I have created, I have made it so the entering of appropriate inputs is identified by green boxes, and where the results (in mm) are read from are identified by red boxes. Any grey boxes are those where the information is left unchanged.

Figures 1 through 4 are example outputs of a spacings calculator created based on UL/IEC 61010-1 and IEC/UL 61010-2-030.

K.1.2 Clearances and Creepage Distances for MAINS Circuits (PD 2 on PCB)

voltage line to neutral rms or dc	300
Insulation type (BI or RI only)	BI
Altitude (m)	2000
Clearance	3.00
Creepage	3.00

Table K.3 Lookup		
Range	Clearance	Creepage
>150<=300	3.000	3.000

Altitude Correction	1.000

Table K.3 is for Overvoltage Category III

K.1.2 Clearances and Creepage Distances for MAINS Circuits (PD 2 on PCB)

voltage line to neutral rms or dc	600
Insulation type (BI or RI only)	RI
Altitude (m)	2000
Clearance	16.00
Creepage	16.00

Table K.4 Lookup		
Range	Clearance	Creepage
>300<=600	8.000	8.000

Altitude Correction	1.000

Table K.4 is for Overvoltage Category IV

Figure 1

K.3.2 Clearance Calculation (use for everything but MAINS and MC III)

(Use for Mixed Voltages)

max peak working voltage (U_W)	514	Actual Peak not RMS.
max transient overvoltage (U_T)	4000	
Insulation type (BI or RI only)	RI	
Altitude (m)	4000	
maximum voltage (U_M)	4514	
correction factor (F)	0	
clearance for impluse (D1)	3.512	
clearance for working voltage (D2)	7.253	
Clearance	9.06	

Table K.15 Lookup			
	U_M	D1	D2
min	4000	2.930	6.050
max	4530	3.530	7.290

Altitude Correction	1.290

4000 UT is Standard Rated Impulse Voltage for 300V OVC III
Uw based on EUT Test Results @ 300V
Ut = 4000, transient voltage
Uw = 514, peak working voltage
Um = 4514 (Ut + Uw)

Figure 2

Pro Tip 1: For each of the spacings outputs, include lots of notes that will help you remember what the calculation pertains to and how it was derived.

This especially comes in handy if you do not use the spacings calculator tool every day. Notice in the above outputs notes are included where appropriate and that the clause(s) from the standard(s) the calculation pertains to is indicated. Also included are the table numbers the information is pulled from. All of this information will come in handy if you ever need to refer back to the standard for clarification, such as when the spacings numbers calculated are questioned.

Pro Tip 2: A similar process as documented above can be used to help calculate AC Voltage (High-Potential, "Hipot") and Impulse test voltages.

These numbers are often as confusing to figure out as spacings, and they go hand in hand with them. Hipot and Impulse test voltages are applied during product safety testing to prove the insulation has the proper creepage and clearance values.

Summary

Determining correct spacings as part of product development can be a time-consuming and error-prone process. Developing and using a spacings calculator as part of your normal duties as a product safety/compliance engineer/technician makes life much easier. Going through the process to create your own spacings calculator and incorporating its use into your compliance engineering back of tricks is highly recommended. For more information on spacings, please see the following:

References and Further Reading

1. *EN/IEC/UL 61010-1: Standard for Safety—Electrical Equipment for Measurement, Control, and Laboratory Use; Part 1: General Requirements.*
2. *EN/IEC/UL 61010-2-030: Standard for Safety—Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Equipment Having Testing or Measuring Circuits.*

6.7.3.3 Method for Creepage - PD2: PCB

working voltage rms or dc (V)	1144
Insulation type (BI or RI only)	RI
Creepage	11.50

Table 7 (K.13) Lookup	V	PCB 2
min	1000	5.000
max	1250	6.300

Applies to K.2.3 for Measurement Circuits

6.7.3.3 Method for Creepage - PD2: Other Insulating Materials - Group 1

working voltage rms or dc (V)	572
Insulation type (BI or RI only)	BI
Creepage	2.89

Table 7 (K.13) Lookup	V	GRP 1
min	500	2.500
max	630	3.200

Applies to K.2.3 for Measurement Circuits

6.7.3.3 Method for Creepage - PD2: Other Insulating Materials - Group 2

working voltage rms or dc (V)	300
Insulation type (BI or RI only)	BI
Creepage	2.09

Table 7 (K.13) Lookup	V	GRP 2
min	250	1.800
max	320	2.200

Applies to K.2.3 for Measurement Circuits

6.7.3.3 Method for Creepage - PD2: Other Insulating Materials - Group 3

working voltage rms or dc (V)	300
Insulation type (BI or RI only)	BI
Creepage	3.00

Table 7 (K.13) Lookup	V	GRP 3
min	250	2.500
max	320	3.200

Applies to K.2.3 for Measurement Circuits

Figure 3

K.101.2 Clearances for Measurement Category III, PD2

voltage line to neutral rms or dc	600
Insulation type (BI or RI only)	BI
Altitude (m)	2000
Basic	5.50
Reinforced	10.50

Table K.101 Lookup Range	Basic	Reinforced
>300<=600	5.500	10.500

Altitude Correction	1.000

K.101.2 Clearances for Measurement Category IV, PD2

voltage line to neutral rms or dc	300
Insulation type (BI or RI only)	BI
Altitude (m)	4000
Basic	7.10
Reinforced	13.55

Table K.101 Lookup Range	Basic	Reinforced
>150<=300	5.500	10.500

Altitude Correction	1.290

Figure 4

Post-layout Signal Integrity/Power Integrity Simulation Software Expectations

Those who may be looking for a signal integrity (SI)/power integrity (PI) simulation software package should have an idea of what functionality and other characteristics they can expect from such a tool during both pre-layout design and post-layout design.

This article briefly describes the most important post-layout elements when selecting a SI/PI software simulation package. The most important pre-layout design simulation software elements were addressed in a previous article (Reference 1).

Post-layout vs. Pre-layout SI/PI Simulation

For post-layout design, you run simulation to validate performance after the design is complete and you have prototypes in hand. This step occurs after pre-layout activities have been successfully completed. Post-layout is used to find post-layout design problems that may have been missed during the pre-layout design phase or to verify that any revisions made to the design have not introduced any SI or PI problems that didn't exist before the design change.

For pre-layout design, you run simulation and sweeps to help plan key design elements and to define routing constraints prior to building actual prototypes. Pre-layout simulation helps you design nets with good SI and design power distribution networks (PDNs) with good PI.

Post-layout SI/PI Design Simulation

Post-layout SI/PI design simulation is all about finding post-layout SI/PI design problems, i.e., when you have first prototypes in hand and are bringing up boards for the first time or later on in the product development cycle, such as during verification or functional testing where you might discover signal integrity, power integrity, crosstalk or timing related issues.

The post-layout SI/PI simulation software you use should be able to simulate "what if" design variations that help you determine design changes that improve both SI and PI. At a minimum, the SI/PI simulation software used should be able to help you find, fix, measure, evaluate, and re-design as required in the following simulation areas:

- Measure bypass quality for single-ended signal vias.
- Measure interaction between single-ended signal vias and the PDN.
- Measure PDN noise from IC power draw (find PDN locations that require better decoupling).
- Measure PDN impedance (Z) at key locations on the board (find minimum number of capacitors needed to meet target PDN Z).
- Measure DC power loss and current density (find metal areas and stitching vias with excessive current).
- Evaluate the electrical behavior of interconnect and signal vias in the frequency domain (measure return loss and insertion loss for signal nets).
- Measure bit error rate (evaluate bathtub curves and BER for a SERDES channel).
- Evaluate the eye diagram for the channel.
- Measure Z for trace segments and signal vias.
- Measure timing for signal nets (use results to complete a timing budget).
- Measure signal quality characteristics for one or more nets.
- Measure crosstalk between signal nets (caused by coupling from switching aggressor nets).
- Find nets with incorrect timing (screen the entire interface or find nets with wrong flight times).
- Find nets with poor signal quality (excessive overshoot, ringback, non-monotonicity, etc.).
- Find nets with excessive crosstalk.

Other Important Attributes of Post-Layout SI/PI Simulation Software

The SI/PI simulation software should have the flexibility that allows you to screen an entire design for problems, simulate only a group of critical nets, or only verify design revisions have not introduced problems on critical nets.

As noted above, the SI/PI simulation software should also provide detailed and up-to-date documentation that carefully describes how to perform various simulations. It should be relatively easy to learn and use. It won't get used if it's challenging to learn and use, and your designs will suffer.

Finally, post-layout SI/PI simulation software should be reasonably priced. If priced too high, it will be hard getting management's approval to purchase it. If priced too low, it may not be of high quality or provide all the features needed to perform effect post-layout SI/PI simulation.

References and Further Reading

1. "Pre-layout Signal Integrity/Power Integrity Simulation Software Expectations," *In Compliance Product Insights,* July 2021.
2. HyperLynx® SI/PI User Guide, Software Version 9.4.1

PRODUCT MARKETPLACE

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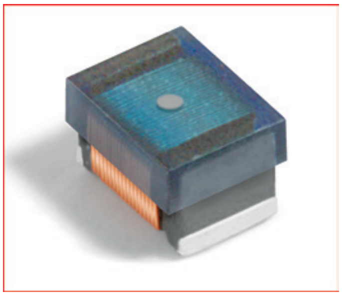

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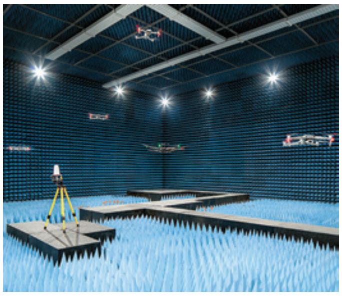

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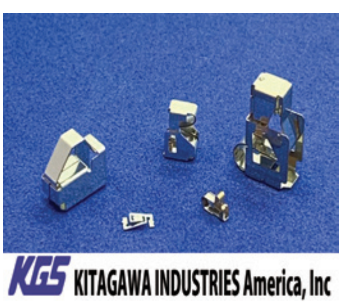

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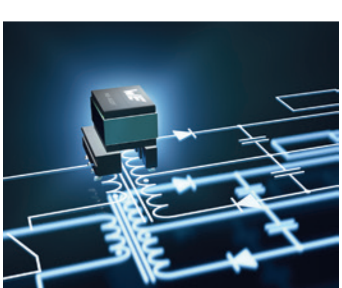

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TRANSMISSION LINE REFLECTIONS AT A SHUNT RESISTIVE AND REACTIVE DISCONTINUITY ALONG THE LINE

By Bogdan Adamczyk

This article discusses the reflections on a transmission line at a shunt resistive and capacitive discontinuity along the line. The analytical results are verified through the HyperLynx simulations and laboratory measurements.

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

1.1 REFLECTIONS AT THE SHUNT RESISTIVE DISCONTINUITY – ANALYSIS

Consider the circuit shown in Figure 1.1, where the transmission line of length l has a shunt resistive discontinuity in the middle of the line, at a location $z = d$.

Note that the transmission line is matched at the source, and the resistive discontinuity and the load resistor values are equal to the characteristic impedance of the line.

When the switch closes at $t = 0$, a wave originates at $z = 0$, [1], and travels towards the discontinuity. At the time, $t = T$ this wave arrives at the discontinuity. The transmission line immediately to the right of the discontinuity looks to the circuit on the left of the discontinuity like a shunt resistance equal to the characteristic impedance of the right line [2].

When this wave arrives at the discontinuity, at the time $t = T$, the reflected wave, v_r and i_r, is created, and we have a situation depicted in Figure 1.2.

The circuit in Figure 1.2 is equivalent to the one shown in Figure 1.3.

The reflection coefficient at the discontinuity is

$$\Gamma = \frac{\frac{Z_C}{2} - Z_C}{\frac{Z_C}{2} + Z_C} = \frac{-\frac{1}{2}}{\frac{3}{2}} = -\frac{1}{3} \qquad (1.1)$$

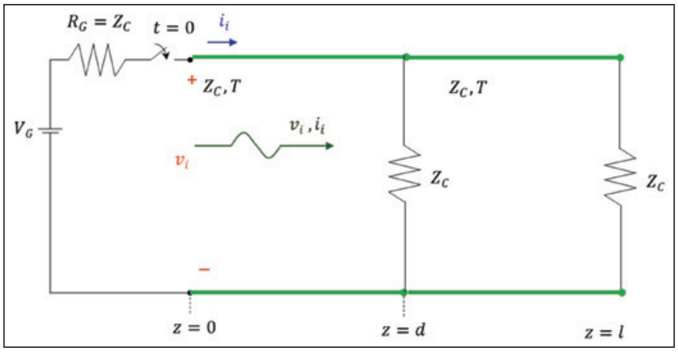

Figure 1.1: Shunt resistive discontinuity along a transmission line

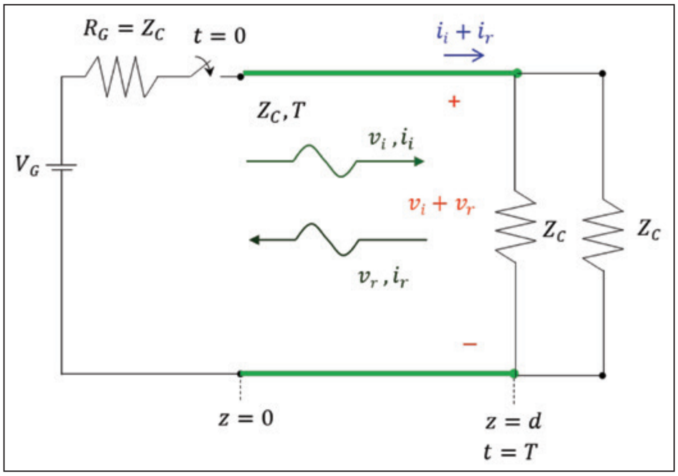

Figure 1.2: Reflection at the resistive discontinuity

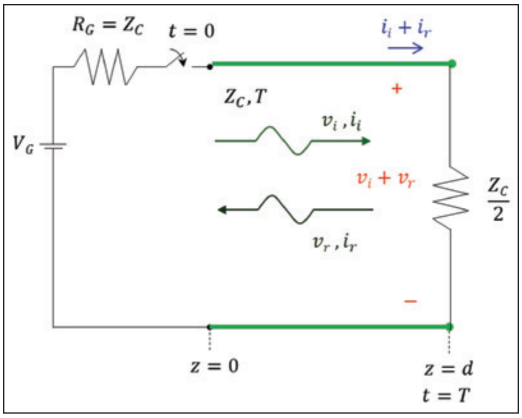

Figure 1.3: Equivalent circuit

The reflected voltage is related to the incident voltage by the reflection coefficient as

$$v_r = \Gamma v_i = -\frac{1}{3} v_i \tag{1.2}$$

The total voltage at the discontinuity is

$$v_d = v_i + v_r = v_i - \frac{1}{3} v_i = \frac{2}{3} v_i \tag{1.3}$$

Since, [1],

$$v_i = \frac{V_G}{2} \tag{1.4}$$

the total voltage at the discontinuity is

$$v = \frac{2}{3}\frac{V_G}{2} = \frac{V_G}{3} \tag{1.5}$$

The reflected voltage travels back to the source, arriving there at $t = 2T$. Since the source is matched to the transmission line, there is no reflection, and the total voltage at the source becomes

$$v_s = v_i + v_r = v_i - \frac{1}{3} v_i = \frac{2}{3} v_i \tag{1.6}$$

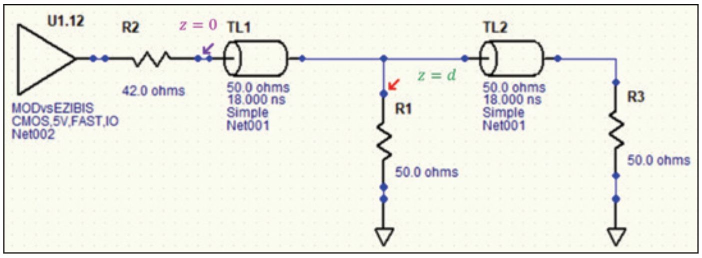

Figure 1.4: Shunt resistive discontinuity - HyperLynx schematic

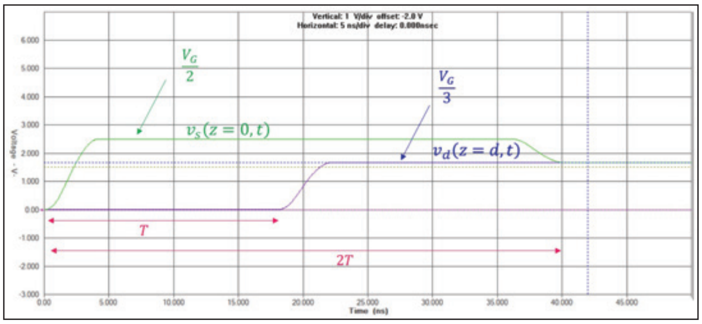

Figure 1.5: Shunt resistive discontinuity - Voltages at the source ($z = 0$) and the load ($z = d$)

1.2 REFLECTIONS AT THE SHUNT RESISTIVE DISCONTINUITY - SIMULATIONS

Figure 1.4 shows the HyperLynx schematic of the transmission line with a shunt resistive discontinuity.

The simulation results are shown in Figure 1.5.

1.3 REFLECTIONS AT THE SHUNT RESISTIVE DISCONTINUITY – MEASUREMENTS

The measurement setup is shown in Figure 1.6.

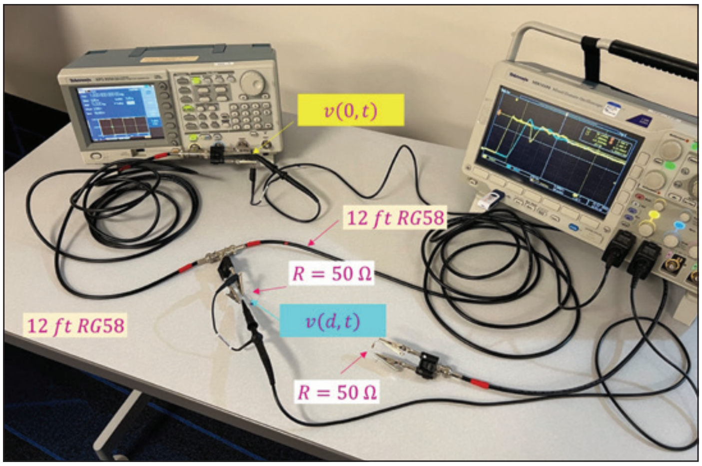

Figure 1.6: Shunt resistive discontinuity – Measurement setup

The measurement results are shown in Figure 1.7.

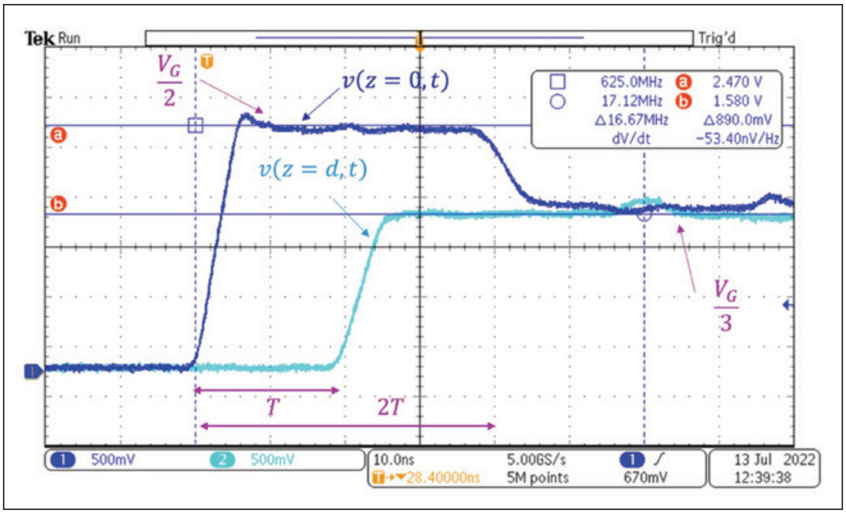

Figure 1.7: Shunt resistive discontinuity – Measurement results

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

2.1 REFLECTIONS AT THE SHUNT CAPACITIVE DISCONTINUITY – ANALYSIS

Consider the circuit shown in Figure 2.1, where the transmission line of length *l* has a shunt capacitive discontinuity in the middle of the line at a location $z = d$.

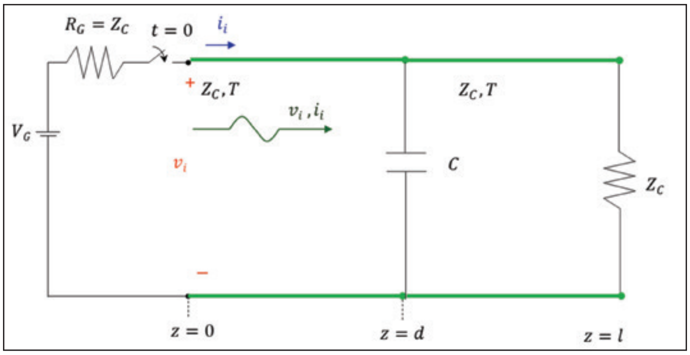

Figure 2.1: Shunt capacitive discontinuity along a transmission line

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

When the switch closes at $t = 0$, a wave originates at $z = 0$, [1], and travels towards the discontinuity.

The transmission line immediately to the right of the discontinuity looks to the circuit on the left of the discontinuity like a shunt resistance equal to the characteristic impedance of the right line [2]. When the incident wave arrives at the discontinuity (at the time $t = T$), the reflected wave, v_r and i_r, is created, and we have a situation depicted in Figure 2.2.

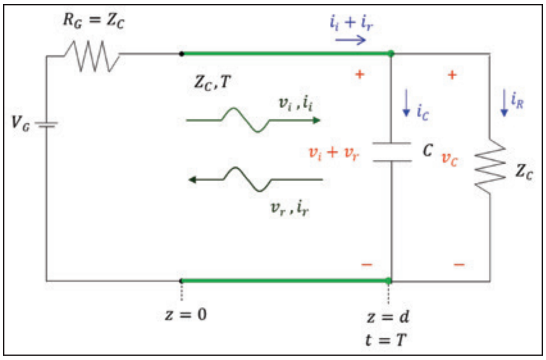

Figure 2.2: Incident and reflected waves at the capacitive discontinuity

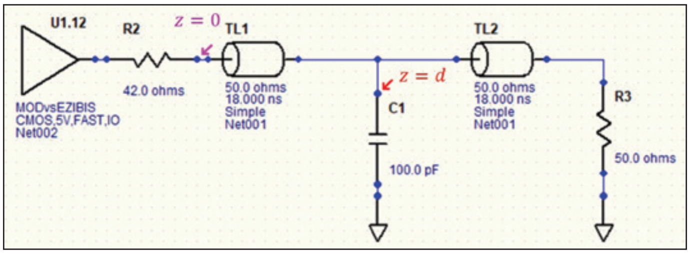

Figure 2.3: Capacitive discontinuity - HyperLynx schematic

This part of the circuit is identical to the one discussed in [3], where the transmission line was *terminated* with an RC load. Thus, the total voltage across the capacitive discontinuity is

$$v_C(d,t) = \frac{V_G}{2} - \frac{V_G}{2} e^{-\frac{2}{CZ_C}(t-T)}, \quad t \geq T \qquad (2.1)$$

Equation (2.1) predicts that at $t = T$, the voltage at the discontinuity is zero and increases exponentially to $V_G/2$. Let's verify these observations through simulations and measurements.

2.2 REFLECTIONS AT THE SHUNT CAPACITIVE DISCONTINUITY – SIMULATION

Figure 2.3 shows the HyperLynx schematic of the transmission line with a capacitive discontinuity.

The simulation results are shown in Figure 2.4.

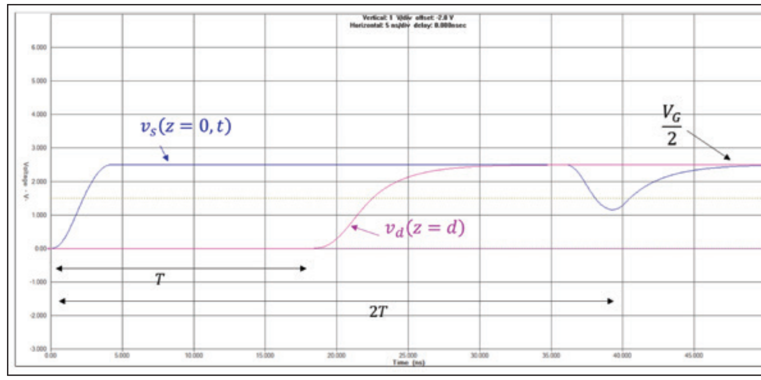

Figure 2.4: Capacitive discontinuity - Voltages at the source ($z = 0$) and the load ($z = d$)

2.3 REFLECTIONS AT THE RC LOAD – MEASUREMENTS

The measurement setup is shown in Figure 2.5.

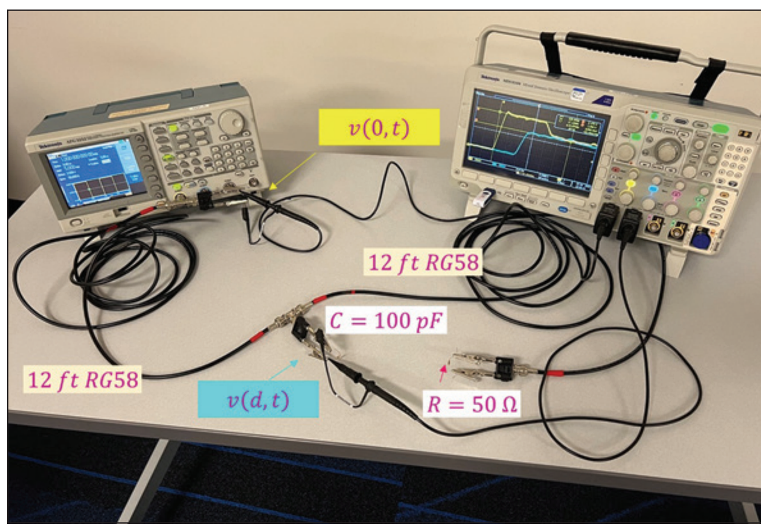

Figure 2.5: Capacitive discontinuity – Measurement setup

The measurement results are shown in Figure 2.6.

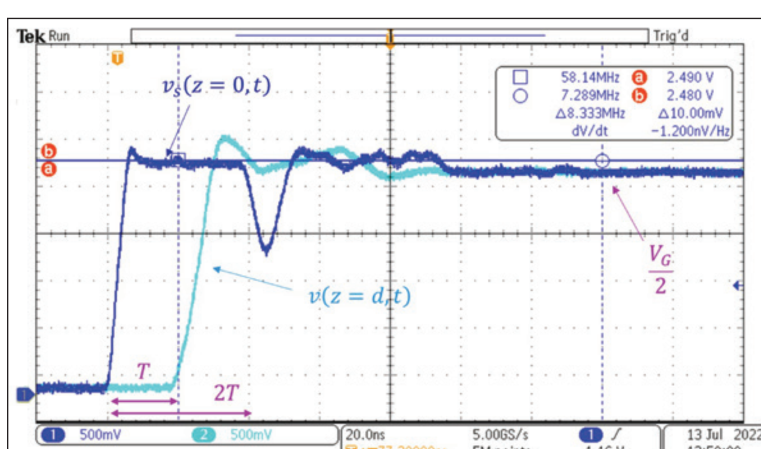

Figure 2.6: Capacitive discontinuity – Measurement results

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

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1. Adamczyk, B., "Transmission Line Reflections at a Resistive Load," *In Compliance Magazine*, January 2017.
2. Adamczyk, B. *Foundations of Electromagnetic Compatibility with Practical Applications*, Wiley, 2017.
3. Adamczyk, B., "Transmission Line Reflections at the RL and RC Loads," *In Compliance Magazine*, January 2021.

COMMERCIAL VERSUS AUTOMOTIVE ESD INTEGRATED CIRCUIT QUALIFICATION PART 1

By Robert Ashton for EOS/ESD Association, Inc.

Robert Ashton is the Chief Scientist at Minotaur Labs, a provider of ESD and latch-up testing located in Mesa, Arizona. Robert is an active member of ESDA working groups for device testing standards and the JEDEC latch-up working group. He has been a regular member of the EOS/ESD Symposium technical program committee. He is currently serving as co-chair of the human metal model (HMM) working group.

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

INTRODUCTION

Integrated circuits intended for automotive applications have higher electrostatic discharge (ESD) qualification requirements than those intended for commercial and consumer electronics. This article is in two parts. Part 1 will discuss why electronic components intended for automotive applications might require more stringent requirements and then review the high-level differences between conventional ESD qualification and automotive qualifications. Part 2, to be in next month's issue of *In Compliance*, will give the specific additional requirements for human body model (HBM) and charged device model (CDM) for automotive qualification.

(This article had its origin in a series of blog posts on ESD testing available at http://www.srftechnologies.com/ESD-RESOURCES.html.)

Automobiles have always had electrical circuits. Even before electric headlights and electric starters, magnetos provided electrical pulses to power spark plugs. The amount of electrical circuitry increased steadily over the years, and today, the radio was replaced long ago as the most sophisticated piece of electronics in a vehicle. The rapid expansion in the high-tech electronic content in automobiles has attracted increased interest across a much wider section of the electronics industry than in the past. Integrated circuit suppliers wishing to become suppliers to the automotive industry must become familiar with the qualification requirements for automotive electronics.

The working environment for automotive electronics is much more severe than is common for most consumer applications. Automotive electronics must work in the dead of winter in Minnesota and crossing Death Valley in the summer. The automotive environment is also an electrically noisy environment, with wiring harnesses carrying sensing circuits as well as high current pulses to operate a wide range of motors and accessories. Automotive electronics are often safety critical. It is, therefore, not surprising that the automotive industry has its own set of qualification requirements for electronic components.
Note: This article will summarize the differences between ESD qualification for commercial and automotive integrated circuits. However, this summary should not be a substitute for a thorough reading of the full standards.

QUALIFICATION DOCUMENTS

The qualification requirements for most commercial integrated circuits are dictated by JEDEC's JESD47 "Stress-Test-Driven Qualification of Integrated Circuits" [1], while automotive integrated circuits are specified by the AEC (Automotive Electronics Council) Q100 standard, "Failure Mechanism Based Stress Test Qualification for Integrated Circuits" [2]. These two documents are very similar in their purpose and methodology. The two documents include the following types of requirements.

This article summarizes the differences between ESD qualification for commercial and automotive integrated circuits, but this summary should not be used as a substitute for a thorough reading of the full standards.

- A list of stress tests required for qualification such as:
  - High Temperature Operation Life
  - Early Life Failure Rate
  - Temperature Humidity Bias
  - Human Body Model (HBM)
  - Charged Device Model (CDM)
- Specification of the test method to be used for each test
  - JEDEC: mostly JEDEC tests, but some Military
  - AEC: a combination of AEC-specific tests, as well as JEDEC and Military tests
- Specification of requirements for each test such as:
  - Temperature for test
  - Humidity during test
  - Sample size
  - Number of failed samples allowed
  - Failure criteria
- When each of the tests is required such as:
  - Design change
  - Change of gate oxide
  - Change of metallization
  - New fabrication site

ESD REQUIREMENTS

We can now compare the requirements for ESD testing in the JEDEC and AEC qualification documents. Both documents require HBM and CDM testing. Table 1 reproduces the HBM and CDM lines from the device qualifications table from JESD47K, while Table 2 reproduces the HBM and CDM lines from the qualification test methods table of AEC-Q100H.

Stress	Ref.	Abbv.	Conditions	Requirements	
				# Lots/SS per lot	Duration/Accept
Human Body Model	JS-001 [3]	HBM	T_A = 25°C	3 units	Classification
Charged Device Model	JS-002 [4]	CDM	T_A = 25°C	3 units	Classification

Table 1: JEDEC requirements for HBM and CDM in JESD47K

Stress	ABV	Sample Size/Lot	# of Lots	Accept Criteria	Test Method	Additional Requirements
Human Body Model	HBM	See Test Method	1	Target: 0 Fails 2KV HBM (Classification 2 or better)	AEC Q100-002 [5]	**TEST before and after ESD at room and hot temperature.** Device shall be classified according to the maximum withstand voltage level. Device levels <2000V HBM require specific user approval. Refer to Section 1.3.1.
Charged Device Model	CDM	See Test Method	1	Target: 0 Fails 750V corner pins, 500V all other pins (Classification C4B or better)	AEC Q100-011 [6]	**TEST before and after ESD at room and hot temperature.** Device shall be classified according to the maximum withstand voltage level. Device levels <750V corner pins and/or <500V all other pins CDM require specific user approval. Refer to Section 1.3.1.

Table 2: AEC requirements for HBM and CDM in Q100H

Two columns from the AEC table which are not relevant to this discussion have been eliminated.

There are three notable differences between the qualification requirements in the two methods:

- The test standards differ between JEDEC and AEC for both HBM and CDM
- The requirements differ
  - JEDEC requires "Classification."
  - AEC gives specific target levels for both HBM and CDM.
- JEDEC requires three samples, while AEC says, "See Test Method."

The difference in the test standards is not as stark as it seems. At the beginning of the AEC Q100-002 for HBM and Q100-011 for CDM are the following statements respectively.

All HBM testing performed on Integrated Circuit Devices to be AEC Q100 qualified shall be compliant to the latest revision of the ANSI/ESDA/JEDEC JS-001 specification, with additional requirements as defined herein.

All CDM ESD testing performed on Integrated Circuit devices to be AEC Q100 qualified shall be per the latest version of the ANSI/ESDA/JEDEC JS-002 specification with the following clarifications and requirements.

These statements show that the basic test methods for HBM and CDM, JS-001 and JS-002, are the same for JEDEC and AEC. JS-001 and JS-002 are joint standards developed by joint JEDEC and the Electrostatic Discharge Association (ESDA) working groups.

> For many years it was "common knowledge" that the specification for HBM was 2000 V and that that requirement was being reduced to 1000 V due to the activity of the Industry Council on ESD Targets.

The number of samples at a voltage level is also the same. While JESD47 specifies three samples, JS-001 also specifies three samples. Q100-002 for HBM does not specify the number of samples, so the AEC requirement is governed by the three samples required by JS-001. For CDM, Q100-011 specifies three samples.

The difference in requirements is more substantial. JEDEC lists the requirements as "Classification." The requirement is, therefore, that all integrated circuit designs must be tested for both HBM and CDM. The actual requirement is set by agreement between the manufacturer of the integrated circuit and the purchaser. For many years it was "common knowledge" that the specification for HBM was 2000 V and that that requirement was being reduced to 1000 V due to the activity of the Industry Council on ESD Targets. This "common knowledge" was, in fact, never true; for commercial product, the ESD levels for both HBM and CDM have always been an agreement between supplier and purchaser.

AEC is much stricter in terms of requirements for HBM and CDM. The basic benchmarks for AEC ESD are an HBM passing level of 2000 V and a CMD passing level of 750 V for corner pins and 500 V for all other pins. As can be seen in Table 2, there are exceptions. Lower levels of ESD robustness can be accepted by the user. The note to see Section 1.3.1 is a requirement for reporting, which reads:

> *For ESD, it is highly recommended that the passing voltage be specified in the supplier datasheet with a footnote on any pin exceptions. This will allow suppliers to state, e.g., "AEC-Q100 qualified to ESD Classification 2."*

Most of the remaining differences between the JEDEC and AEC ESD requirements are in the additional requirement in Q100-002 for HBM and Q100-011 for CDM.

SUMMARY

Part 1 of this article has reviewed why integrated circuits intended for automotive applications might need higher qualification levels and reviewed the documents that specify the qualification requirements for commercial and automotive products. Additionally, it discussed the high-level differences between the ESD requirements for the two market segments. In Part 2, the specific additional requirements for HBM and CDM testing for automotive products will be presented.

REFERENCES

1. JESD47, "Stress-Test-Driven Qualification of Integrated Circuits," JEDEC Solid State Technology Association, https://www.jedec.org.
2. AEC - Q100 - Rev-H, "Failure Mechanism Based Stress Test Qualification for Integrated Circuits," Automotive Electronics Council, http://www.aecouncil.com.
3. ANSI/ESDA/JEDEC JS-001-2017, "For Electrostatic Discharge Sensitivity Testing, Human Body Model (HBM) – Component Level," EOS/ESD Association, https://www.esda.org, and JEDEC Solid State Technology Association, https://www.jedec.org.
4. ANSI/ESDA/JEDEC JS-002-2018, "For Electrostatic Discharge Sensitivity Testing, Charged Device Model (CDM) – Device Level," EOS/ESD Association, https://www.esda.org, and JEDEC Solid State Technology Association, https://www.jedec.org.
5. AEC–Q100-002 REV-E, "Human Body Model Electrostatic Discharge Test," Automotive Electronics Council, http://www.aecouncil.com.
6. AEC-Q100-011 Rev-D, "Charged Device Model (CDM) Electrostatic Discharge (ESD) Test," Automotive Electronics Council, http://www.aecouncil.com.

USING AN AM RADIO AS AN EFFECTIVE TROUBLESHOOTING TOOL

By Dr. Min Zhang

An AM radio can be useful for finding both radiated emissions and ESD events. The biggest advantage of using a radio in EMC engineering is its cost (A second-hand AM radio on eBay costs about 20 USD or less). Understanding how radio works is essential for engineers to use this low-cost technology to troubleshoot complex EMI issues.

Dr. Min Zhang is the founder and principal EMC consultant of Mach One Design Ltd, a UK-based engineering firm that specializes in EMC consulting, troubleshooting, and training. His in-depth knowledge in power electronics, digital electronics, electric machines, and product design has benefitted companies worldwide. Zhang can be reached at info@mach1desgin.co.uk.

USING AN AM RADIO TO LOCATE EMISSION SOURCES

You can find an interesting case study in which police used a simple AM radio to locate marijuana growers in Reference 1. This reminds me of a recent case in which I used an AM radio to successfully locate the noise source at a client's site.

The client's product was a large-size installation located at their factory site. To perform an in-situ EMC test on the EUT, they shut down most of the equipment and lighting during the weekend, but the ambient noise at the site was still large enough to cause issues. Even when the EUT was powered off, the ambient environment exhibited a noise level higher than the limit line defined by the standards (in this case, the EUT was being tested against defense standard DEF STAN 59-411). This can be clearly seen in the results while performing a low-frequency radiated emission scan using a rod antenna (see Figure 1).

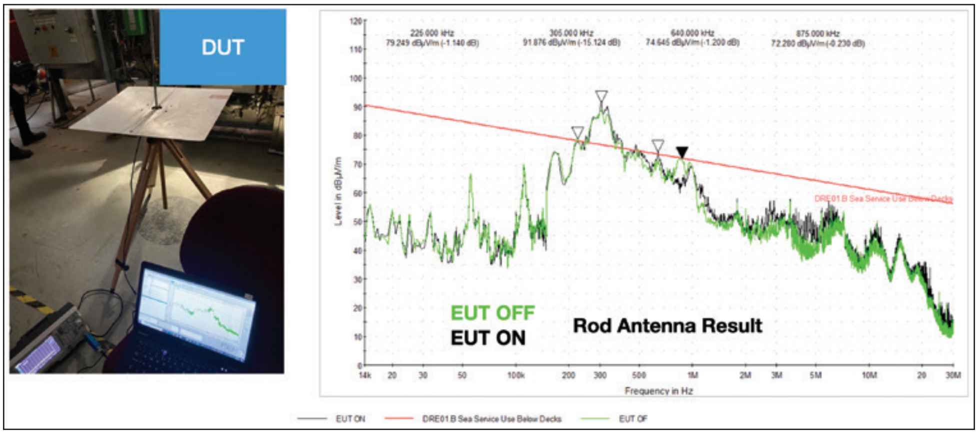


Figure 1: Results of testing using a rod antenna

It was essential to locate the source of the noise and shut it down for the in-situ EMC test. Holding a large-size rod antenna together with the spectrum analyzer and walking in a large factory site proved to be difficult. My handheld spectrum analyzer (a TTI PSA6005) only works from 10 MHz and was, therefore, incapable of tracking down the noise source (although the noise source could radiate to a much higher frequency range). Another tool, a Credence Technologies EM Eye (now part of 3M), also works from 1 or 2 MHz.

In this case, I decided to use a Tecsun PL660 portable radio, tuned it to an AM station, and walked about in the factory. I expected the noise level picked up by the radio would increase when we approached the noise source.

There are three antenna gain settings with my radio, and I selected "DX" for the troubleshooting process. The other two options, "Normal" and "Local," reduce background noise or interference, which was the opposite of what we wanted in this case.

SOME BACKGROUND – WHY DO WE USE AM RADIOS?

AM radios with envelope detectors respond to radiated EMI from current impulses such as lightning, sparks, and magnetic field radiating from a conductor where dI/dt is large. The discriminator in a vintage FM radio is basically an AM envelope detector preceded by a filter with a linear ramp frequency response. The filter converts instantaneous frequent deviations in the program to amplitude deviations, which are then demodulated by the envelope detector. Such detectors are susceptible to impulse noise, especially if preceding stages are not driven into compression via hard limiting or amplifier clipping.

Modern FM receivers, which use phase-locked loops (PLLs) to implement the detection function, are much less susceptible to impulse noise. However, any FM receiver with an automatic gain control (AGC) may also be susceptible, as the constantly changing RF level induced by the EMI will cause the AGC to constantly react, throttling the receiver gain back in response to each impulse.

RESULTS

Using a portable radio, I selected a frequency of 550kHz medium wave (MW) empty channel and walked around at the factory site while listening carefully to the receiver sound. I was able to locate the noise source shown in Figure 2.

When I walked past the area, the radio receiver picked up huge audible noise. It turned out that the culprit was the three-phase power distribution cable located in a cable tray 3 meters above the factory floor.

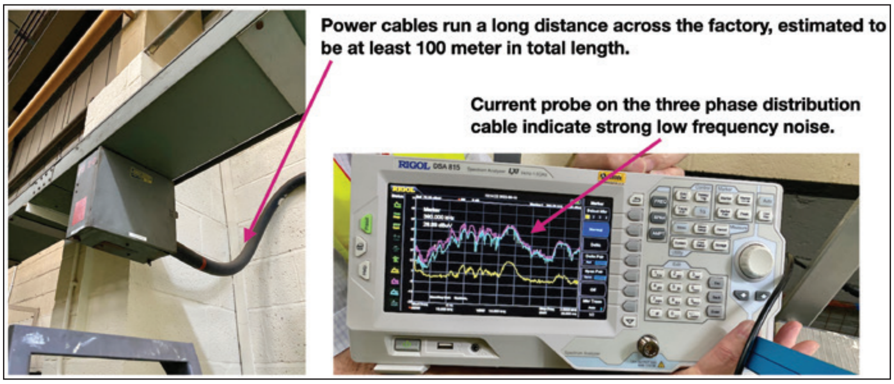


Figure 2: Location of noise source and receiver readings

To confirm this, an RF current monitoring probe was then used to measure the common mode noise on the cable bundle. The noise profile measured using the RF current probe was very similar to what we measured using the rod antenna. The cables were estimated to be about 100 meters in total length, forming a large loop that could radiate strongly at the low-frequency range (500kHz, for instance). The noise disappeared when the power to this part of the distribution line was cut off.

A USEFUL TOOL FOR RADIATED EMISSION TROUBLESHOOTING

The case study discussed previously shows that an AM radio can be used to locate low-frequency radiated noise sources. But the same radio can also be used to help troubleshoot EMI noise at much higher frequencies when selecting the FM band. Modern switched-mode power supplies used in LED lights and compact fluorescent light bulbs are all "nasty" EMI sources. I fixed the radiated emission issues of an LED light with the help of a radio. After the fix, the radio can be played without issues when it is placed near the LED light. (See the YouTube video https://youtu.be/fkNa-FejWsQ that demonstrates the point).

A USEFUL TOOL FOR ESD DETECTION

AM radios are also useful for detecting ESD events, as explained previously. "Pops" in the radio serve as good evidence that nearby ESD events are generating sparks.2 I used an AM radio to locate an ESD problem at a factory site in another situation. In that particular case, when we switched off the lights and kept the room in the dark, we could see the sparks in the dark while listening to the "pops" in the radio receiver.

REFERENCES

1. Wyatt, "How Cops are Finding 'Grow Ops' with AM radios," *EDN*, https://www.edn.com/how-cops-are-finding-grow-ops-with-am-radios.
2. Smith, "Induced Voltage via Electric and Magnetic Fields – ESD Immunity," *Technical Tidbit*, https://emcesd.com/tt2004/tt070104.htm.

Banana Skins

397 Experiences of testing aircraft with high intensity radiated fields (HIRF)

During the testing of one aircraft we suffered a very marked and complete electrical failure of the aircraft (much to the alarm of both the test engineers and the cockpit crew) which turned out to be due to the EUT we were testing being next to the ground power supply controller which didn't like the field we were generating. Since this controller would not be in operation in flight its upset was not critical and it had to be shielded using a sheet of RAM (radio absorber material – Editor) when testing continued.

It's not just the aircraft that can be upset. One trial kept setting off the hangar fire-alarms to the point where the fire brigade eventually disabled the system and left one fireman, with a hand-held extinguisher and radio, to act as the building fire-alarm system fort the duration of our testing.

Expect the unexpected – one can often start testing believing nothing is going to happen to the aircraft and be very surprised when it does. When testing a reasonably large (50 seat) turboprop the whole team was caught slightly unawares when it tried to crawl up and over the chocks as our transmissions upset the propeller pitch controller.

(Taken from: "Whole Aircraft HIRF Test Experiences: A Practical Viewpoint", by Roger Marson, EMC-UK 2006 conference, Newbury, October 17-18 2006.)

398 Checkout terminal display interferes with radio service, FCC close down the store

A new grocery store had been opened in St Louis, MO. This new "high-tech" (now normal) store included the installation of 15 scanning checkout stands with customer enunciator panels. A week before the big grand opening, store management turned on the new checkout stands to verify their functionality. The function tests carried on the rest of that day and into the next. However, the next morning, a group of men walked in carrying radios and red tags. The checkout stands were red-tagged and turned off. The men left.

The late Chris Kendall (CKC Laboratories) was called in as an EMC Consultant to find out what was happening and to fix the problem. Chris went to work and found the problem right away. The enunciator panels had a display driver at the bottom of the display and there were 5MHz data lines running around one side of the panel and then returned on the other side of the panel. The men who arrived were, of course, from the FCC. They were upset because a local repeater was being jammed (at around 110MHz). The fix introduced by Chris was to tie a wire to the ground path and lay the wire on top of the clock traces as an image return. Once this was done, the interference problem went away, the red tags were removed, and the store opened. The lesson? Remember Mary and her little lamb… everywhere the signal goes, its ground is sure to follow.

(Taken from "Who are you guys, and why can't I open my store?" in "Chapter Chatter" by Todd Robinson, IEEE EMC Society Newsletter, Issue 210, Summer 2006. Todd in turn had extracted this item from a compilation of EMC stories presented several years previously by Patrick André of André Consulting, Inc., at a meeting of the IEEE EMC Society's Seattle Chapter.)

399 HVAC system interferes with TV

In April of 2004 I installed a new HVAC system to include a Honeywell EAC F300 Electronic Air Cleaner. Immediately, I noticed on channel 9 off-air TV lines of 'snow'. I subsequently found out that the air cleaner was causing this problem. I checked the air-cleaner's electrical power supply outlet, and it is properly wired and grounded. I have both anew ground to the electrical supply panel and the old one to the cold water pipe. I found a reference to a CORCOM EMI filter Honeywell recommends and installed it. I wired up a metal box, wired it in, tested it with my outlet tester, and it worked for about a day. Now, the snow is back. My wife is broadly hinting if I don't fix it she will want either cable or a dish. Anyone have any ideas?

(From Interference Technology e-news, October 5th 2006.)

400 If electromagnetic waves can penetrate walls, think what they can do to your skin

A groundbreaking patented protection product that helps prevent accelerated skin aging caused by electromagnetic waves and daily environmental pollution. With Clarins exclusive Magnetic Defence and Anti-Pollution Complexes, this gentle, refreshing mist invisibly shields skin, prolonging youth, health and beauty.

Ingredients: Our Magnetic Defense Complex has Thermus Thermophilus and Rhodiola Rosea, two powerful plant extracts which reinforce the skin's natural barrier and provide biological protection against electromagnetic waves.

(We always try to use an amusing or off-beat item for every 100th Banana Skin. Robert Higginson adds (April 6th 2007): Reading what looks like new-age trickery, I put "Thermus Thermophillus" into Google. Some hits include the following.

http://microbewiki.kenyon.edu/index.php/Thermus

https://www.quackometer.net/blog (Quackometer!!!) Post for Tuesday, March 20, 2007

http://forums.randi.org/showthread.php?t=76289 (Very entertaining comments.)

http://waitingforlunchtime.blogspot.com

http://www.strategymag.com/articles/magazine/20070301/edit.html

We don't think that EM shielding manufacturers need worry about losing customers to Clarins, but if people are really that concerned maybe there's a new market opening up for total-body-covering metallised clothing!)

401 Interference problems with lifts (elevators)

I suppose my two worst 'banana skins' were a shopping centre in Leeds and a big manufacturing company in Germany. The shopping centre was a four car VF (variable frequency motor-drive) group of elevators that had been working fine for 3 years and then blew £3,000 worth of central traffic dispatching computer. I was asked to take a look, spent 3 days on site and found 180 earth faults – which was a shock as this installation had been checked for earth loop impedance at my request and passed with flying colours (this was done by a reputable engineering company we all know).

After another £3,000 worth of kit failed again I went back and to my absolute horror I found the 5" mains riser was terminated to a brand new distribution panel being installed while I was on site. The riser went into a gland plate which sat on a cork gasket, nylon insulation washers and powder coated metalwork – no earth conductor at all.

The problem with this is two-fold: firstly, if we suffered a secondary fault such as a door lock short to earth then the elevator could run with the doors open; secondly, the DC bus rises to 600V on each VF drive and could have proved fatal to the users pushing buttons etc. outside the lift. I can recall running into the electrical contractors office and gripping the chief engineer's lapels – and that's about all I can recall.

The second 'interesting' site was one for a big manufacturing company in Germany. A whole factory the size of a car plant with automated trains and conveyors would 'dump' it's Allen Bradley PLC software, roughly every week. The company spent a fortune sending engineers out to re-program these huge machines for six months.

The problem was that the main control system was fed from a supply the other end of the factory and they didn't want the expense of installing an earth conductor, as one was located next to the control panel. Unfortunately this earth conductor turned out to be the roof lightning conductor connecting to hundreds of square metres of roof lead.

I recall this day very well as it was the Saturday of the Hillsborough disaster, and I spent most of it sitting down watching German electrical contractors dig floors up. Thank goodness it worked. I did receive a few funny comments about the disaster, and I thought if this modification doesn't work I'll be in big trouble. Cross bonding? – none…a long and stressful, but successful trip.

(Sent in by Gary Morgan of Liftstore Ltd, February 2007.)

402 Some more interference problems with lifts

I've been doing some EMC training for our customers and one very interesting story came out about a circa 1990's control system with a VF controller. There's a notice on the outside of the controller to say no mobile phones because entering the cubicle with a 3G phone causes both IGBT's to fire at the same time causing a huge bang as two phases join together momentarily before the HRC fuses blow.

All these training days bring out the same stories, you can almost create a tick list for items to check (e.g. a tacho fault will be poor bonding of the trunking runs and pigtails on the screen for the tacho…). From what I can see the two biggest problems are pigtails on the hoist motor terminals combined with poor bonding of the trunking runs.

(Another one from Gary Morgan of Liftstore Ltd, February 2007. Pigtailing cable screens has been deplored by EMC experts and IEC 61000-5-2 for many years – but nevertheless electrical contractors still do it. How long will it take to retrain them all so that fixed installations in Europe stand any chance of complying with 2004/108/EC, as they should from 20th July this year?)

403 Mobile phone masts can interfere with lifts in the same building

Mobile phone masts are something that most people do not want erected close to where they live. As a result of this, phone companies will on occasion approach building owners to see if they would lease space within a building to enable a transmission mast to be erected. If its location is out of sight so much the better as residents will be unlikely to know of its existence and will therefore be unlikely to object.

An obvious out of the way place in a lot of buildings is a lift machine room. One LEIA member has recently come across a NHS hospital where a mast had been erected on the roof and the cables and associated equipment have been located in what was the lift machine room. The hospital trust erected a partition wall in the machine room so the equipment was in a separate area. Although when in the machine room the mast and

Banana Skins *continued*

equipment were out of sight, the cables for the mast ran along ducts through the machine room with the lift supply cables. The problem came to light when the lift was found to be developing serious faults in its drive and safety systems. On investigation, it was found that interference was being introduced into the lift equipment though the earth cable route of the transmission device.

There are guidelines for installers of masts for mobile phones base stations but these had not been followed. The most crucial requirements to avoid interference is the separation distances between cables and the separation of earth cables from other common earth points.

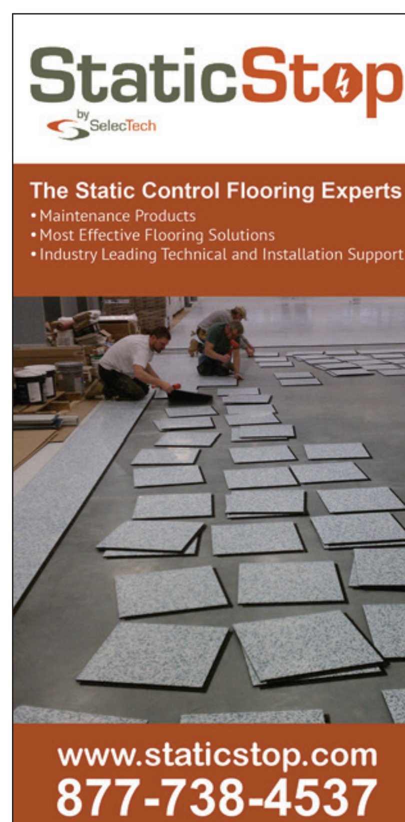
There should not be any equipment related to base stations visible in lift machine rooms. The mobile phone base station aerials should be isolated from earth, but the tower structures they are mounted on had to be at zero potential to earth. This has to be achieved by a large cross-sectional conductor, directly connected to the building earth at the main intake. Any part of the base station that has to be earthed is then connected to this common point. However, the common earth point for the base station must not be connected to the building earth at any other point, such as the machine room lighting conduit. It is then that interference is likely to occur.

Problems with base station installation should be referred back to the building owner who should instruct the base station owner to get the issue resolved. It is also important that access routes to machine rooms do not necessitate walking close to transmission equipment.

(Copied from "Are You Aware (25)", March 2006, a publication of the Lift & Escalator Industry Association (LEIA), https://www.leia.co.uk. We are not sure how the above instructions fit with lightning protection requirements. We understand that these days the lifts and escalator industry now does reasonable EMC testing of control systems, including testing with the controller cubicle doors open – to simulate what a site engineer would do. The problem is that older equipment has never been EMC tested to any standard and can cause some very strange and even dangerous behaviour. In the case that gave rise to the LEIA advice above, we understand that the circa-1985 drive system for the lift decided to travel in any direction and at any speed, and did indeed trap a number of people on many occasions.)

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.

PRODUCT Showcase



Advertiser Index

Upcoming Events

Due to COVID-19 concerns, events may be postponed. Please check the event website for current information.

October 5-7

Grounding & Shielding

October 6-7

Fundamental Principles of Electromagnetic Compatibility and Signal Integrity

October 9-14

44th Annual Meeting and Symposium of the Antenna Measurement Techniques Association (AMTA)

October 11-14

Applying Practical EMI Design & Troubleshooting Techniques

Advanced Printed Circuit Board Design for EMC + SI

Mechanical Design for EMC

October 17-20

Military Standard 810 (MIL-STD 810) Training

October 18

2022 San Diego Test Equipment Showcase

November 1-4

Applying Practical EMI Design & Troubleshooting Techniques

Advanced Printed Circuit Board Design for EMC + SI

Mechanical Design for EMC

November 7-11

EMC Week