NOVEMBER 2024

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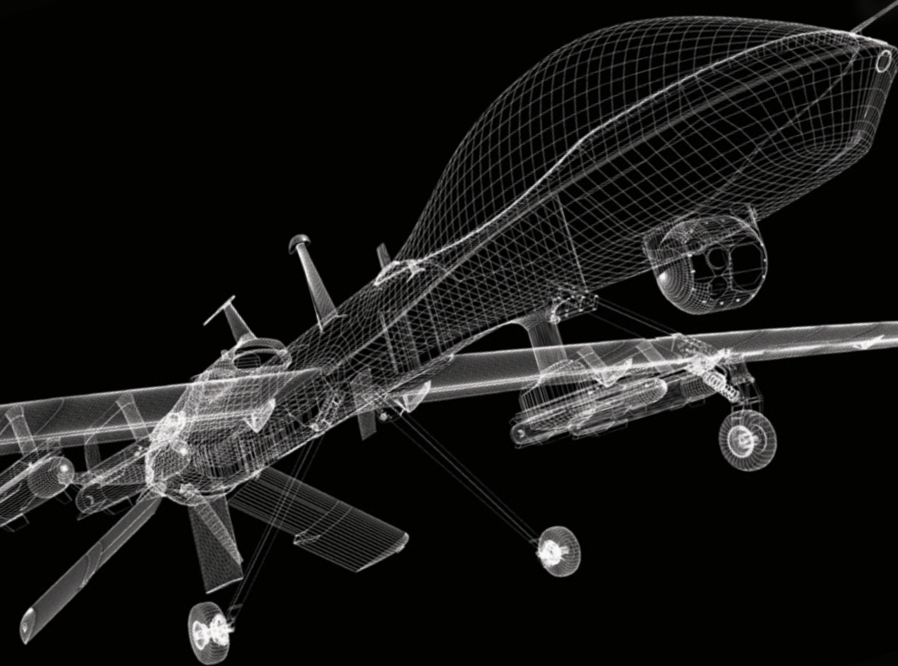
EMI Shielding and Thermal Interface Solutions for Commercial and Defense Drone Technology



PLUS

Navigating Mexico Electrical Safety Certification Requirements

Circuit Spacings: Determining Product Safety Requirements

Preventing Liability from Foreign-Made Products

IN COMPLIANCE

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FEATURE ARTICLES

COLUMNS

DEPARTMENTS

FCC to Require Georouting of 988 Calls to Speed Service Response

The U.S. Federal Communications Commission (FCC) is expected to vote on rules that would require U.S. wireless carriers to implement technology that would speed localized response to 988-related emergencies.

The nationwide 988 Suicide & Crisis Lifeline provides those dealing with severe mental health issues with fast access to trained professionals who can help them quickly access needed support and services. However, until now, emergency calls made from cell phones have been routed to emergency service providers based on the area code of the phone number assigned to the phone.

Under the rules slated to be implemented by the FCC, wireless carriers would be required to adopt georouting technology that would route the calls to 988 call centers based on the caller's location and not their phone's assigned area code.

Once approved by the Commission, the rules would take effect within 30 days of the effective date of the ruling for nationwide wireless carriers. Smaller, non-nationwide carriers would have up to 24 months to adopt georouting technology for 988 calls.

FCC Issues Harmful Radio Interference Notification

A Massachusetts person has received notice from the Enforcement Bureau of the U.S. Federal Communications Commission (FCC) to cease radio transmissions that were found to be interfering with a critical public safety communications system.

According to a Notification of Harmful Interference, a condominium on Worcester Road (known to locals as Route 9) was identified as the location from which radio emissions in the 813-817 MHz band originated. The emissions were linked to recent incidences of interference with the Massachusetts State Police public safety communications system.

Agents visiting the site determined that the source of the interference was a 2002 Newest HDTV Indoor Digital TV Antenna, and that the interfering radio emissions ceased when the antenna was unplugged.

The Notification issued by the Bureau orders the condominium resident to cease all use of the antenna in question, and to identify the further steps they are taking to ensure that future operation does not create further illegal interference.

Mosquitos Found to Have Infrared Sensors

Researchers at the University of California Santa Barbara have reported something about mosquitos that many of us already instinctively knew (!).

The researchers have discovered that nature has provided mosquitos with their own integrated infrared detection system. They say that this capability gives mosquitos the ability to convert heat emanating from human bodies into electromagnetic waves. These waves then heat neurons at the end of a mosquito's antennae, which allows them to zero in on human targets for their blood.

The researchers are hopeful that their work and their findings will lead to the development of more effective ways to repel or eliminate mosquitos, including adding infrared heat to mosquito traps.

Guidance on Chemical Analysis for Medical Device Biocompatibility

The U.S. Food and Drug Administration (FDA) has issued a draft Guidance that provides additional details on the role of chemical analysis in the biocompatibility assessment of medical devices.

Published in the *Federal Register*, the draft Guidance, titled "Chemical Analysis for Biocompatibility Testing of Medical Devices," describes the recommended methodologies for chemical analysis for biocompatibility assessments.

Chemical analysis is one of several approaches that manufacturers can consider when assessing the overall biocompatibility of a medical device. Chemical analysis can reduce the time needed for biocompatibility testing, while also reducing the need for animal testing.

FCC Releases Internet Access Annual Report

97% of U.S. Households Now Meet Broadband Speed Targets, Mobile Connections Continue to Drive Growth

The U.S. Federal Communications Commission (FCC) has released its annual report on access in the United States to Internet connections, including information on the gap between current service levels and the benchmark Internet connection speeds recommended under the Commission's National Broadband Plan.

According to the Commission's report, entitled *Internet Access Services: Status as of December 31, 2023*, approximately 97% of fixed Internet connections to households meet or exceed the speed tier that most closely approximates the target set in the National Broadband Plan of 3 megabits per second (Mbps) downstream and 768 kilobits per second (kbps) upstream. This penetration rate for fixed high-speed service compares with approximately 95% at the end of 2022, 81% at the end of 2013, and just 49% in 2009.

Without accounting for speed, Internet connections overall are growing. By the end of December 2023, there were at least 544 million Internet connections operating at speeds over 200 kbps, a 3.2% year-over-year increase. And, once again, overall growth continues to be driven by dramatic increases in mobile connections. At the end of December 2023, there were approximately 413 million mobile Internet connections, compared with only about 131 million fixed Internet connections.

Upcoming Events

November 5-7
XIV Electromagnetic Compatibility Course

November 15
IoT Applications

November 20-22
Battery Japan

December 3-5
Fundamentals of Random Vibration and Shock Testing Training

EMC BENCH NOTES

How to Use Spectrum Analyzers for EMC

By Kenneth Wyatt

A spectrum analyzer measures power (default) or voltage versus frequency. Most digital harmonic emissions occur in the range 10 kHz to 1 GHz and this defines the minimum frequency range for spectrum analyzers. Some harmonics may even extend up to 3 GHz. Two types of harmonic emissions will be observed: narrowband and broadband. Many times, you'll see a combination of the two.

NARROWBAND VERSUS BROADBAND

Narrowband harmonics are the most common for radiated emissions and most likely to exceed the limits. They appear as a range of narrow spikes and are usually harmonically related (multiples of a clock frequency). For example, Ethernet is usually clocked at 25 MHz, so it's common to see harmonics every 25 MHz, sometimes exceeding 1 GHz. Figure 1 shows a series of 25 MHz clock harmonics (aqua trace). The yellow trace is the measurement noise floor.

Broadband harmonics are normally observed as an increase in the noise floor with periodic broad resonant peaks. The emission is usually highest at the lower frequencies and tapering off gradually. This is normally the result of power conversion circuits, such as on-board DC-DC converters switching in the 100s of kHz to 3 MHz range with transition times of a few ns to sub-ns. Figure 1 shows a typical broadband emission (using Max Hold, violet trace) from a DC-DC converter. Note these harmonics extend out to 1.5 GHz (GPS frequencies).

SETTING UP THE ANALYZER

There will be slightly different settings depending on whether you'll be measuring radiated or conducted emissions. The most common controls include Frequency > Start and Stop (lower and upper) sweep frequencies, Resolution Bandwidth (RBW), Reference Level and Attenuation. Some of these may be sub-choices under the major setup buttons (Figure 2).

There's also Center Frequency and Span (Stop minus Start) that would be useful if you want to troubleshoot a specific harmonic.

Optional settings might include activating a built-in low-noise preamplifier (if included), which helps lower the measurement noise floor and reveal smaller harmonics.

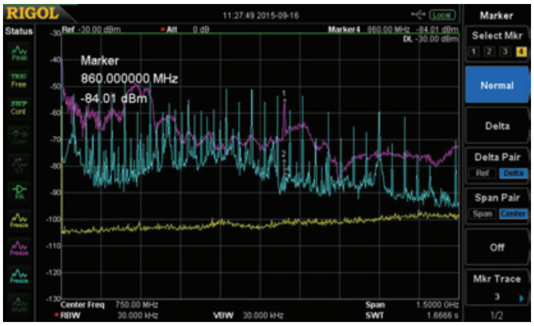

Figure 1: A combination of narrowband (aqua trace) 25 MHz clock harmonics riding on top of broadband digital switching noise voltages. The broadband noise voltage (violet trace) is characteristic of DC-DC converters, which can switch as fast as 3 MHz and with sub-ns edges. Notice these harmonics extend out beyond 1.5 GHz (GPS frequencies).

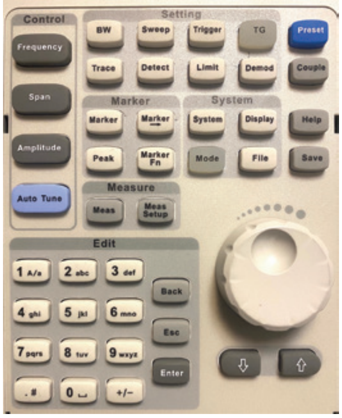

Figure 2: A typical spectrum analyzer setup screen showing the major controls along the left side.

I also like to switch from the default "dBm" (power) vertical units to "dBµV" (voltage), which matches the units used in the compliance limits. You may find this under the Span button. You'll probably want to readjust the Reference Level when changing units to make the 10 dB steps line up with the vertical divisions. You may need to readjust several of these settings to obtain a centered sweep on the display.

Conducted Emissions - Conducted emissions (CE) are the harmonic emissions being conducted out the power cable on products. According to most commercial standards, the analyzer should be set to Start and Stop frequencies of 150 kHz to 30 MHz. The RBW should be set to 9 kHz. However, many stock analyzers may not have the ability to be set to 9 kHz. For troubleshooting purposes, 10 kHz is sufficient.

To measure CE accurately, you'll need a line impedance stabilization network or LISN. If you don't already have one available, I recommend the Tekbox TBCL08, an 8-amp LISN designed for line-operated products, or the TBOH01 10-amp LISN designed for DC-powered products. You'll need a pair of these DC LISNs in order to measure the positive and return power wires separately.

When I perform benchtop troubleshooting, I'll tape down sheets of heavy-duty aluminum foil over the top. The LISN (or DC LISNs) should be bonded to this ground plane so common mode currents can return back to the LISN. The product under test is also placed on this ground plane. See Reference 1 for more detail.

Option: In order to measure differential- and common mode harmonic currents separately, Tekbox sells a product called "LISN MATE" (model TBLM01) that separates the two. Knowing which is the dominant harmonic noise current helps determine what kind of filter topology would be beneficial. See Reference 2 for more information on these measurements and the appropriate filter design to use.

Radiated Emissions - Radiated emissions (RE) are the harmonic emissions being radiated from the product under test. According to most commercial standards, the analyzer should be set to Start and Stop frequencies of 30 MHz to 1 GHz. The RBW should be set to 120 kHz. However, many stock analyzers may not have the ability to be set to 120 kHz. For troubleshooting purposes, 100 kHz is sufficient.

For troubleshooting purposes, I use an uncalibrated antenna placed nearby, as described in Bench Notes 2. Space the antenna about 1m away from the product under test. I usually place the antenna and analyzer about 1m apart (not critical) while manipulating cables, adding ferrites, or mitigating leaky seams. So long as you can observe the emissions in real time, you will be able to assess various mitigations quickly. See Reference 3 for more detail.

I often find most narrowband harmonics tend to be dominant between 50 and 250 MHz, so once I see the "big picture" from 30 to 1 GHz, I'll often reduce the Stop frequency to 300 or 500 MHz so the sweep time is faster. Also, concentrating on mitigating the lower harmonics first will usually do the same for the higher harmonics if related to the same source.

OTHER SETTINGS

There are three other common settings I use while troubleshooting RE: establish a measurement noise floor, display more than one measurement trace, and use markers.

Measurement Noise Floor - I almost always use Trace 1 to display the measurement noise floor. This helps to visually observe the amplitude of harmonic signals being measured. Disconnect the antenna. You'll normally see these trace controls under the Display button. Press Display > select Trace 1, and then press Max Hold. This will build up several sweeps. Pressing Store or Freeze will store that trace on the display.

Ambient Measurement - When measuring outside a shielded room or chamber (typically with an RF current probe or antenna), chances are you'll pick up ambient signals from broadcast radio, two-way radios, DTV, or cellular signals. It's instructive to display the ambient spectrum usage with the product under test Off. This will display the measurement noise floor, plus any active ambient signals. Selecting another trace with the Product On will take the actual measurement of the product emissions, and you should observe frequencies where the product under test is emitting in between the ambients.

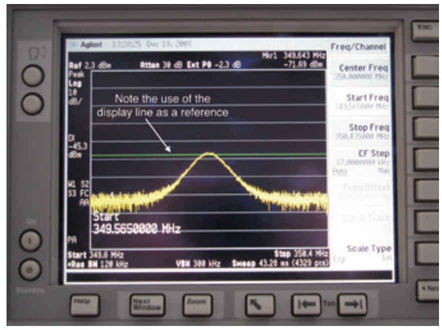

Figure 3: An example showing a single harmonic with Display Line adjusted to the peak. The Display Line serves as a reference for quickly determining whether progress is being made during troubleshooting.

Display Line - Many analyzers have the means to add a horizontal line at an arbitrary amplitude. This is useful when troubleshooting by placing the line at one of the dominant harmonics while you're trying different mitigations. This makes it easy to visually see whether you're making progress or not (Figure 3).

Displaying More Than One Trace - Pressing the Display button will allow you to display several traces at once. Normally, you'd make the first measurement, using Max Hold to build up a collection of scans, then pressing Store, Freeze, or View will store and display that trace. The Display button will allow you to display additional traces, storing each on the display simultaneously. This is useful for "before and after" measurements.

Using Markers - Markers are useful for identifying specific harmonics or resonant peaks. There will likely be up to two Marker buttons: one to select particular markers and one to automatically find the highest peak or "Peak Left/Right." I also use markers on adjacent narrowband harmonics to confirm the fundamental clock as the difference frequency. Some analyzers can display six or more markers, and some can display a Marker Table or otherwise display all the marker amplitudes and frequencies.

SUMMARY

Spectrum analyzers are usually the tool of choice for troubleshooting CE or RE. In recent years, the cost of a basic analyzer has dropped markedly. However, the more expensive lab-quality analyzers will have advanced measurement features that may be worth considering.

Alternatively, some of the more recent digitizing oscilloscopes have built-in advanced spectrum analysis features. Examples include the Rohde & Schwarz RTE, RTO, and MXO series, and the Tektronix Series 4/5/6. They can simultaneously display independent time and frequency domain traces. This ability is quite useful for EMI debugging, where you can relate specific portions of the time domain to a frequency spectrum.

REFERENCES

1. Wyatt, *Workbench Troubleshooting Emissions*, Volume 2, Chapter 3.
2. Wyatt, Review: Tekbox LISN Mate is valuable for evaluating filter circuits, *EDN*.
3. Wyatt, *Workbench Troubleshooting Emissions*, Volume 2, Chapter 4.

PRACTICAL ENGINEERING

Pre-compliance for Product Safety

By Don MacArthur

EMC PRE-COMPLIANCE TESTING

Many articles, entire books, and chapters of books promote the benefits of performing pre-compliance electromagnetic compatibility (EMC) testing and show how easy it is to carry out bench-top EMC measurements using relatively inexpensive and homemade test apparatus.

EMC pre-compliance testing is highly beneficial. I strongly encourage doing it if you are interested in discovering EMC-related weaknesses in your design as early in the product development cycle as possible. Discovering EMC design weakness early means more and less costly solutions are available before the final design is locked down. So, the question is this: *If pre-compliance activities are good for discovering EMC design weaknesses early in product development, why not apply the same thought process to product safety?*

PRODUCT SAFETY PRE-COMPLIANCE TESTING

The tests required for product safety are less complex than those for EMC. Typical product safety tests are dielectric strength (high-potential or hipot), impulse, insulation resistance, ground bond continuity, breakdown of components, etc. You need a tester for each to perform hipot, impulse, insulation resistance, and ground bond continuity. Breakdown of components is a methodology – you need to know which components to short out to cause a fault in the system to see that it responds safely. The only test equipment required is an insulated wire used for shorting out components.

PRODUCT SAFETY TEST EQUIPMENT

Unfortunately, there are no practical ways to build the test equipment required for product safety as there is for EMC pre-compliance testing. However, if your organization is developing safe products, having this equipment on hand is necessary. The positive side is that product safety test equipment is not as expensive as required for EMC testing, and the same product safety test equipment used for pre-compliance testing is often used for full-compliance testing.

If you are involved in developing safe products, have this equipment on hand and start doing pre-compliance product safety testing like you are likely doing for EMC. You will be glad you did.

PRODUCT SAFETY PRE-COMPLIANCE DESIGN REVIEWS

Something else you can do early in the product development cycle regarding product safety compliance, besides just pre-compliance testing, is to have a thorough review of the design conducted by a product safety expert.

Where do you find product safety experts? Experts are found in-house (a staff member from your company's product compliance department or someone on your team skilled in the art) or out-of-house (a product safety consultant or someone from the NRTL you are using for end-product certification).

ESSENTIAL DESIGN REVIEW ACTIVITIES

Once you find a product safety expert, involve them early in the product development cycle and have them start reviewing your design for product safety issues. Specifically, have the expert:

- Review spacings (creepage and clearance distances) to ensure the numbers you are using are adequate and meet the requirements of the product safety standard applicable to the end-product.
- Review printed circuit board layout files to confirm spacings are met.
- Comb through your list of safety-critical components to ensure they have the necessary ratings and approvals.
- Review your instruction/installation manuals to ensure they contain the necessary safety precautions.
- Review the rating label to ensure it contains the required information in the correct format.

It is not 100% guaranteed that if you follow all the above your product will make it through third-party safety certification on the first attempt. Still, you will be closer to achieving success than had you not engaged in these product safety pre-compliance activities.

MILITARY AND AEROSPACE EMC

Portable Electronics Onboard Aircraft

Part 1

By Patrick André

Several times, I have talked with people in the general public about the use of electronics on aircraft, often with the same response: "There is no good reason they have us turn off our electronics." However, those of us in the EMC industry, and especially those in the aerospace aspect of the industry, know how true the issues can be. June 8, 2011, ABC News addressed 75 possible incidents of EMI on aircraft[1]. Keith Armstrong, in his "Banana Skins" series, has nearly 100 documented issues relating to aircraft. On December 12, 2020, a flight computer on Virgin Galactic SpaceShipTwo rebooted due to an EMI issue, causing an abort of the test flight. Thankfully, pilots C.J. Sturckow and Dave Mackay were not hurt and were able to glide to a safe landing.

Concerns about interference in commercial avionics date back to the late 1950s. A special committee of the RTCA, SC-88, with support of the Federal Aviation Administration (FAA), was formed to study the use of electronics by passengers. On April 12, 1963, DO-119 was published but without regulatory limits placed on the radiation emissions of portable electronic devices. However, responsibility for assuring compliance with FAR 91.21 (was FAR 91.19 at the time) remained with the operator of the aircraft.

By the early 1980s, portable computers were making their way onboard, and some airlines subsequently banned their use. One computer trade magazine suggested their readers avoid any airlines that did not permit them to use their computers. A new subcommittee, SC-156, studied the issue. Their first meeting on December 1-2, 1983 was attended by representatives of aviation, the computer industry, and the press. This work resulted in DO-199 - *Potential Interference to Aircraft Electronic Equipment from Devices Carried Aboard*, a two-volume study and recommendations, published on September 16, 1988. In the middle of this period, DO-160C was released, which greatly increased susceptibility test levels and developed new test methodologies.

In 1992, a new special committee, SC-177, was formed to look at how personal electronic devices (hereafter PEDs) would or could interfere with aircraft electronics and systems. International agencies such as the International Civil Aviation Organization (ICAO) were contacted along with the FAA. One hundred thirty-seven incidents were reviewed, with laptop computers being the greatest number of incidents. They determined that the difference between test methods was part of the issue. Commercial electronics are measured at 3-meter or 10-meter distances, while aerospace standards require 1-meter test distances. To validate these issues, testing was performed on commercial electronics that had met FCC and CISPR regulations. The tests used DO-160C test methods with some modifications. Instead of having a conductive ground plane, the table was non-conductive, as used in commercial EMI testing. It was also 80 cm above the ground plane. No conducted emissions testing was needed since all the electronics are battery-operated and not connected to the aircraft.

Also of interest was the coupling path of the interference. The committee analyzed how the interfering signals were being coupled from the PEDs to the electronics. This involved first looking at which systems were most vulnerable, what frequencies they were operating in, and determining if the coupling was into cabling or antenna inputs. The most often affected system was VOR, with other navigation systems, autoflight/instrument landing systems, and VHF communications. One test found VHF susceptibility (break squelch) at 2 μV/m from the first row of seats.

The committee recommended that the use of PEDs should be prohibited "during any critical phase of flight" – which we know as the 10,000 feet rule and that PEDs with transmitters should be prohibited unless determined safe for use. They found that the potential for interference from PEDs was real and that passengers willfully use transmitting devices during landing and takeoff, and although they should not cause interference due to frequency coordination, signals were coupling into aircraft systems.

DO-233 called for further testing to be performed, that the FAA and the FCC should work together and work with industry to determine the emission characteristics from PEDs. It also called for educating the general public about these issues, and to continue work with avionics and the FAA concerning regulation and further the efforts to harden aircraft systems to these signals.

In Part 2 of this blog, we will look at the next RTCA documents that address some of these issues.

1. See https://abcnews.go.com/Blotter/safe-cellphone-plane/story?id=13791569

EMI SHIELDING AND THERMAL INTERFACE CONSIDERATIONS FOR COMMERCIAL AND DEFENSE DRONE TECHNOLOGY

Utilizing Advanced Materials to Ensure High Performance and High Reliability for UAVs

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By Sierra Meloan and Ben Nudelman

Aerial drones are rapidly becoming integral to modern society, dominating headlines in combat tactics and finding widespread use across various industries. From 2020 to 2030, the global drone market is anticipated to grow at a compound annual growth rate (CAGR) of 20%, with much of this expansion taking place in the segments of logistic drones, enterprise drones, and defense drones.

Advancements in drone technology accelerate the need to meet strict demands of lightweighting, electronics thermal management, and electromagnetic interference (EMI) shielding to ensure uncompromised signal integrity.

TYPES OF DRONES AND THEIR GROWING APPLICATIONS

Before we talk about some engineering solutions to thermal management and EMI shielding challenges, let's explore the scope of drones we'll cover in this article. When we say drones, we're referring to unmanned aerial vehicles (UAVs), which are aircraft that are meant to be operated remotely or without a human pilot on board. And while many of the examples we give will refer to drone applications, it's important to note that the products we discuss can and are used in other drone-adjacent remote or aerial applications. This includes commercial aircraft, defense aircraft, electric aircraft, and even ground-based drone defense technology.

Drones come in nearly every shape, size, and price range. They can be as small as a bumblebee or as large as a small passenger jet, and they can cost anywhere from $10 to hundreds of millions of dollars. Their propulsion systems can be electric motors, gas-powered heat engines, and even jet engines, while propeller types include fixed wing and rotary wing.

And, while vertical takeoff and landing (VTOL) and short takeoff and landing (STOL) are not exclusive features of drones, they are common in many types of commercial and defense drones.

Commercial drones are used for non-defense or non-military applications, such as for recreational or industrial purposes. You've likely seen drone footage used for the latest Hollywood blockbuster or in a nature documentary or even experienced drone light displays at sporting events or holiday celebrations. Commercial applications have driven a 25% CAGR in drone usage over the last decade.

From an industrial standpoint, drones are used in a variety of applications. Drones offer improved vision and sensors for agriculture and forestry surveying as well as wildlife tracking. Contractors and civil engineering firms are using drones to inspect difficult-to-reach or dangerous locations such as infrastructure and construction sites. Some drone manufacturing companies are marketing their technology for public safety, touting their benefits for fire inspection, police operation, search and rescue, and even crowd control.

And we can't forget about logistics drones that are used for delivery and fulfillment. Around the world, we're seeing more and more small-scale trials with delivery drones for packages. Drones also play a vital role in getting critical equipment and supplies like medicine to remote locations that may otherwise be difficult to reach. Drones are playing a major part in our lives, even if they aren't always visible or obvious. From Washington to Botswana, from Detroit to Japan, from Hollywood to India, drones are being used for all kinds of purposes and making headlines every day.

DIFFERENCES BETWEEN COMMERCIAL AND DEFENSE DRONES

While some of the technology utilized for EMI shielding and thermal interface materials is common to both defense and commercial applications, there are some notable differences between these classes of drones.

Many defense drones have a high degree of autonomy as well as interoperability, meaning they need to be able to communicate with other military systems. Commercial drones have varying levels of autonomy and interoperability, and it's important to note that those requirements tend to be much more application-specific. For example, a light show is one situation where perfectly synchronized drones that operate autonomously and in communication with the base terminal and the surrounding drones would be required.

Longevity and reliability often vary as well. Defense drones are expected to operate with minimal maintenance for years or decades. They must work continuously for hours or days at a time while potentially carrying hundreds or thousands of pounds of payload equipment and flying at lightning-fast speeds.

On the other hand, commercial drones often have relatively light payloads, if any at all, and use lower-power propulsion systems to operate for shorter periods. Most commercial drones don't have a mission-critical reliability need, except for those utilized for public safety and rescue operations. Recreational drones may need more frequent battery changes and repairs to motors or propellers.

The security and regulatory requirements around each drone type are different as well. Commercial drones are usually only required to meet some U.S. Federal Aviation Administration (FAA) restrictions around flight locations and heights, as well as U.S. Federal Communications Commission (FCC) regulations around wireless communication. The requirements for defense drones are much more strict. Defense drones must meet many military standards, such as MIL-STD-461 for EMI shielding of electronics, in order to provide resistance against interception, jamming, and cyber threats.

When we refer to the advanced technology within drones, we are not only referring to their propulsion and communication modules but also their advanced sensors. Lidar, radar, laser, and ultrasonic sensors are used for collision avoidance and precision positioning when paired with location control GPS sensors and stabilization or orientation modules. Advanced flight analytics, such as time of flight sensors, can give operators details about how the drone is performing relative to environmental conditions and can be used to enhance future flights.

Additional sensors are needed if the drone is meant to do a specific job, such as videography or imaging. Cameras, chemical detection, thermal sensors, and hyperspectral sensors are just a few examples. It's important to note that some of this technology can also collect data internally, process the inputs, and respond automatically or communicate in real-time to the operator. Drones do a tremendous amount of data processing, which is the primary reason they need high levels of EMI shielding and thermal management.


COMTEST
WORRY-FREE
REVERBERATION
CHAMBERS

All devices have different needs for EMI shielding to make sure that nearby electronics are not impacting their performance. The right combination of EMI shielding and thermal interface materials will vary by device and application.

EMI SHIELDING SOLUTIONS FOR DRONE APPLICATIONS

Now that we've provided a brief introduction to drone technologies and requirements, let's dive into how one can shield drones from radiated susceptibility as well as radiated emissions.

An important note is that all devices have different needs for EMI shielding to make sure that nearby electronics are not impacting their performance. The right combination of EMI shielding and thermal interface materials will vary by device and application to provide device-level or component-level protection from unwanted electromagnetic radiation.

Conductive Elastomer Gaskets

One of the most commonly used and versatile solutions for system-level EMI shielding is a conductive elastomer gasket. Conductive elastomers consist of a base polymer such as silicone, fluorosilicone or an ethylene propylene diene monomer (EPDM) that gives the material its flexibility and structure. This base polymer is then embedded with metallic particles such as silver-plated aluminum, nickel-plated aluminum, silver-plated copper, nickel-plated graphite, and others that give the gasket its electrically conductive properties.

The specific particles and binders each lend themselves to different benefits based on the design requirements. For example, fluorosilicones will be used where the gasket may come into contact with harsh chemicals or washdown fluids. A silver-plated aluminum particle will provide very high conductivity, shielding, and galvanic corrosion resistance against aluminum substrates that are exposed to moisture and salt bog.

Conductive elastomers can be extruded into a gasket that sits in a groove or molded into a flat sheet and then die-cut into very intricate shapes, such as those that would be suitable for a connector for grounding. They can provide the advantage of being an EMI shield as well as an environmental seal, cutting down on the number of seals or gaskets required. They can also be developed as co-extruded parts where there is a durable non-conductive gasket permanently bonded to a conductive gasket for an even higher level of galvanic corrosion resistance.

Conductive elastomers can also come in form-in-place formats where a very thin bead of conductive gasketing is robotically applied onto a thin wall for cavity-to-cavity isolation and precise shielding within electronic enclosures.

Conductive Heat-Shrinkable Polyolefin Tubing

One product that has seen particular use in drone applications is an electrically conductive heat-shrinkable polyolefin tubing. The tubing and boots get their conductivity courtesy of a flexible conductive coating filled with either silver or silver-plated copper particles. The tubing has a 2:1 shrink rate, the same as standard shrink tubing, but it offers significant weight reduction compared to braided cable shielding or shielding cable wrap while giving the added benefit of water sealing.

Conductive Coatings and Sealants

Electrically conductive coatings are often applied via airbrushing onto metal or plastic substrates to provide EMI shielding, an intentional ground path, or a corrosion-resistant and conductive surface for mating against conductive elastomer gaskets. Conductive sealant and gap fillers are applied using a caulking gun directly from the packaging tube or unique applicator and are used as gap fillers at the seams of conductive enclosures. Sealants and conductive gap fillers are designed to be painted, sanded, or smoothed so they can provide the optimal surface finish and then integrated with other sealing or esthetic components of an airframe. Some things to consider when working with materials are working life, times, and masking or fixturing for accurate application.

Conductive Plastics

Injection-molded conductive plastic parts are made from engineered polymers that incorporate a conductive powder or fiber into the pellet blend. The pellets are then molded into complex shapes that provide the physical benefits of plastics while adding the advantages of an electrically conductive housing. Conductive plastic parts have a lower density than aluminum for when light weighting is important and provide significant time and cost savings of having to machine metal housings or covers for electronics protection. The final part can incorporate embedded hardware such as captive fasteners and minimize secondary manufacturing practices while holding similar tolerances as machined parts.

Overall, the advantages of using conductive plastics are weight reduction, RF absorption, corrosion resistance, good shielding effectiveness, and suitability for harsh environments. These plastics are ideal for moderate to high volumes, and while they do provide many benefits, some considerations are the initial cost for the injection molding tooling, upfront design time, minimum wall thickness, fluid exposure, and the color options that are available.

Conductive Foam Gaskets

Conductive fabric-over-foam and conductive foam solution applications were developed mainly for high-volume, cost-sensitive, low-compression force applications like consumer electronic devices. The foams used in these gaskets are often urethane or silicone, where higher temperature limits of up to 125°C are required. Conductive fibers or fabrics are used to provide electrical continuity and shielding ability. These materials are often used as a grounding gasket on board-level shields or as a connector gasket that's needed to provide low contact resistance.

There are many advantages to using these gaskets, and one important one is that they are soft with a very low compression force. Additionally, they are lightweight and low density, typically low cost, and work well as a dust seal. Hundreds of standard parts and profiles are available, and tooling for custom parts is a relatively inexpensive option compared to other solutions. One drawback is that foam-based gaskets are typically not recommended for water or moisture sealing.

Board-Level Shielding

While most shielding products are used at the enclosure level, precision-stamped metal shield cans are used to shield components at the board level and give individual component-level attenuation. Board shields come in an infinite number of shapes and sizes with all kinds of board mating styles and precision features. RF broadband absorbers can be added to the shields to give extra RF absorption.

The pros of board shields are that they're low cost and highly customizable with a lot of design options, and they can be integrated into automated assemblies. Additionally, they can be made of several materials and packaged in tape and reel formats, as well as assembled by pick-and-place machines. Aluminum is an increasingly common material for precision board shielding as it has the added benefit of excellent thermal conductivity, serving as a shield and a heat sink. While the upfront tooling cost is a drawback, the low unit cost can certainly make up for that over the course of a high-volume program.

THERMAL INTERFACE MATERIALS FOR DRONE APPLICATIONS

Thermal Gap Filler Pads

Thermal gap filler pads or, simply, gap pads are designed to be soft to reduce component stress when creating an interface between heat-generating components and heat-dissipating surfaces. This conformability helps with vibration dampening and gives the gap pads a large compression range to take up assembly or manufacturing tolerances.

Nearly all gap pads are NASA E595 outgassing certified, meaning they're approved for use in vacuum, space, and high-altitude applications. Gap pads are traditionally manufactured in sheets and can be cut into any shape or size. While common thicknesses range from 0.25 mm up to about 5.0 mm, gap pads can be made in much larger thicknesses as well. One of the advantages of gap pads is their ease of application, as they can simply be peeled off a protective liner and applied onto a heat sink or electronic component.

Thermal Gels

Thermal gels, also known as dispensable gap filler gels, are one-component, fully-cured dispensable thermal interface materials. A single-component material is advantageous because it requires no mixing or additional curing after dispensing onto a substrate. Thermal gels have very different physical properties from those of gap pads, providing some added benefits. These materials can be easily dispensed to meet various tolerance ranges or gap heights without requiring an additional part number in your bill of materials.

While gap pads have a typical minimum thickness of about 0.010" or 0.25 mm, gels can be dispensed in bond lines as thin as about 0.002" or 50 microns and up to well over half an inch on the thicker side. This means significantly increased thermal performance at thinner bond lines as the material can wet out and make effective contact between surfaces. Other benefits include very low compression forces, even lower than those of the already soft gap pads, thus reducing the force on underlying components. They also tend to have a lower density than pads, further reducing weight.

MEETING THE NEEDS OF DRONE APPLICATIONS

As you can see, there are many tools available to ensure heat management and EMI shielding for drones, and many more innovations are on the horizon. Current advancements are focused on higher thermal conductivity, higher flow rate, lower compression force, and higher reliability products to keep up with the needs of higher power connectivity equipment. This includes silicone and non-silicone solutions for gap pads and gels, as well as additions to thermal grease, phase change material, and even two-component material product families.

On the EMI shielding side, current research is directed toward new elastomer solutions, such as unique form-and-place materials and RF-absorbing solutions. The industry is not only developing new products but ensuring that these products are augmented with supporting information, such as high-frequency shielding data up to 115 GHz for EMI shielding products and environmental reliability data. Enhanced reliability testing capabilities aim to better align with customer requirements so that products perform reliably and consistently over the entire lifetime of the device.

Finally, remember that there are easy steps to reduce significant weight and ensure reliability in any environment. Lightweighting products such as conductive heat string tubing and plastics can provide up to 75 percent weight reduction while maintaining an important level of EMI shielding and RF absorption. Conductive foams and some thermal gels allow you to take advantage of light weight solutions while providing grounding or excellent heat transfer, respectively. These are all important considerations to keep drones flying safely and reliably.

NAVIGATING MEXICO ELECTRICAL SAFETY CERTIFICATION REQUIREMENTS

A Guide to the Ever-Changing World of Mexico's Electrical Safety Regulatory Compliance Requirements

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By Claudia Cordon and John Grinager

In our previous article, "Navigating Mexico Certification Requirements for Radio-Telecom Devices" (see *In Compliance Magazine*, July 2024), we outlined Mexican approval procedures for radio and telecom products from a radio-telecom compliance perspective. Separate from radio-telecom requirements, many electronic devices are subject to electrical safety compliance requirements. Fortunately, many of the organizations and processes involved in radio compliance are the same as the ones involved in safety compliance.

In this article, we will review the requirements for three safety standards in Mexico and the processes and actors involved in demonstrating compliance with those requirements. We will also explain how to obtain import documents for devices that fall outside the scope of the three standards. Finally, we will cover an important standard that is applicable to most electronic products regarding labeling, packaging, user guides, and warranties.

KEY PLAYERS IN THE COMPLIANCE PROCESS

Like the radio-telecom compliance process, Mexico has chosen a compliance regime for safety that is enforced at the border and, therefore, includes roles for importers and Mexican customs. The key players involved in the safety certification process include some of the same players as those involved in radio-telecom compliance:

- *Manufacturers*: These provide product documentation and samples (if required);
- *Importers*: They are the official holders of certificates and are responsible for importation;
- *Customs brokers*: Customs brokers assist in identifying the proper Mexican HS code and, when ready, get shipments through customs;
- *Accredited test laboratories*: Test labs must be accredited according to Mexican regulations. They perform tests to prove compliance with official Mexican safety standards (Normas Oficiales Mexicanas, NOMs); and
- *Certification bodies (CBs)*: These are accredited entities that review and determine if a product's test reports and other required documents associated with regulated products comply with the applicable NOM(s). They issue Certificates of Conformity (CoCs) and conduct any subsequent surveillance.

PRODUCT ANALYSIS

Like the radio-telecom compliance process, enforcement of NOMs begins at the border as Customs requires CoCs or equivalent documents prior to allowing entry to the country. To give guidance to its inspectors, the Customs Service has a website that lists possible NOMs to be applied to products based on their HS Codes. Although the Customs Service has matched HS codes to NOMs, the database sometimes lists more than one NOM as applicable when only one applies.

An additional problem occurs when the database lists a NOM, but because the product qualifies for an exemption based on use or other criteria, the NOM is not legally applicable. To begin the analysis of applicable NOMs, Customs brokers normally confirm that the HS code used for a product is appropriate and then review the listed NOMs and provide their opinion regarding which listed NOM(s) apply. This analysis is then reviewed by a CB, which makes the final decision on which NOM(s) are applicable.

THE MOST COMMON SAFETY NOMS

The main objective of safety NOMs is to prevent risks to the health, life, and assets of the user, and compliance with them is mandatory. These technical regulations present the information, requirements, specifications, procedures, rules, attributes, test methods, guidelines, characteristics, or prescriptions applicable to a product and methodology that allow government agencies to establish measurable parameters. These standards are published and updated in the Official Gazette of the Federation (DOF), the official newspaper of the Constitutional Government of Mexico.[1]

The following are the most common NOMs applied to electrical products.

- NOM-001-SCFI-2018, Electronic devices-Safety requirements and test methods[2]
- NOM-019-SCFI-1998, Security of data processing equipment[3]
- NOM-003-SCFI-2014, Electrical products-Safety specifications[4]

NOM-001-SCFI-2018, Electronic Devices-Safety Requirements and Test Methods

This official Mexican Standard specifies the requirements to reduce the risks of fire, electric shock, or injury for the operator and non-professional personnel who may encounter the equipment and, when specifically established, for maintenance personnel.

Scope of the NOM

- Electronic equipment and its accessories that use public service electrical energy (mains) for their supply, with single-phase supply voltages up to 277 V ac at 60 Hz and/or three-phase voltages up to 480 V ac between lines at 60 Hz, as well as other energy sources, such as batteries, accumulators, self-generation and alternative power sources up to 500 V dc.
- Common products, such as TVs, remote controls, electronic toys, speakers, video cameras, charging bases, and other miscellaneous items.
- New, discontinued, rebuilt, reconditioned, used, or second-hand electronic equipment.

NOM-001 Conformity Assessment Procedures

Every approval holder must be registered at a CB before starting the conformity assessment process. The actions of each actor follow:

1. *Importer:* After confirming the HS Code with a Customs broker and obtaining their opinion on applicable NOMs, an importer, or an authorized third party acting on its behalf, submits samples to test lab and application forms and other required documents to a CB.
2. *Certification body:* The CB can analyze the product and confirm which NOMs and certifications apply if the manufacturer needs confirmation. If more than one Model of a product line is included in an approval as a family, the CB will confirm that all models qualify.
3. *Laboratory:* An accredited laboratory tests the product and issues a test report for submission to the CB. (20-40 days, depending on the standard to test)
4. *Certification body:* The CB then issues a CoC for the applicable NOMs.
5. *Extensions*: Extensions of the main CoC to other importers are available without testing or additional samples under the following conditions:
   a. The holder of the CoC must allow the extension to another company; and
   b. The new approval holder accepts responsibility for the Certificate requirements.
6. *Family approvals:* Family formation of products is allowed, and multiple models can appear on the same certificate if they meet the following conditions (listed in Appendix B, B.1 of the Regulation):
   a. Same brand and or manufacturer:
   b. Same type of electronic equipment and/or system;
   c. The same supply voltage, frequency, and the same elements that make up the power supply, when applicable;
   d. The equipment or systems must present the same electrical consumption or have a tolerance of 20% between the models with the highest and lowest consumption;
   e. The insulating, thermal, and electrical materials must be of the same type and operating capacity; and
   f. Mechanical fastening systems must be of the same type and strength.
7. *Final approval:* Unlike the radio-telecom approval process, which results in a certificate of homologation, the CoC is the final document and has a validity period of just one year and must be audited and renewed with additional samples and testing at the ninth month of the validity period.

NOM-019-SCFI-1998, Security of Data Processing Equipment

This official Mexican Standard establishes the security requirements for all peripheral data processing equipment or related equipment that is marketed in Mexico. It is under review as it is partly based on UL 478-1980 4a and other older safety standards. A project to update this NOM was published under PROYECTO de Norma Oficial Mexicana PROY-NOM-019-SE-2020, "Equipos de tecnologías de la información y sus equipos asociados, así como equipo de uso en oficina-Requisitos de seguridad (cancelará a la NOM-019-SCFI-1998 y cancela al PROY-NOM-019-SCFI-2016)" in the DOF. However, as of September 2024, no official NOM update has been published.

Scope of the NOM

- Portable electronic data processing machines, (laptop, notebook), microcomputers, personal systems, personal computers, network terminals (PC-net), servers, etc.
- Printers, plotters, external disk drives, external tape drives, digitizing tablets, image digitizers, optical readers, monitors, and terminals.
- Equipment used for electronic communication between data processing equipment and peripheral equipment, local area networks (LAN), such as concentrators, protocol converters or routers, etc.

NOM-019, Conformity Assessment Procedure, Extensions, and Family Approvals

The conformity assessment procedure of NOM-019 is the same as for NOM-001, except that just one sample is required instead of two, and the testing period of about 5-10 days rather than 20-40 days. Extension procedures and family approvals rules under NOM-019 are identical to those of NOM-001.

NOM-003-SCFI-2014, Electrical Products-Safety Specifications

This official Mexican Standard establishes the characteristics and safety specifications that electrical products, which are imported or marketed, must meet, with the purpose of:

- Protection against dangers from the electrical product itself;
- Protection against dangers caused by the effect of external influences on the electrical product;

- Safe operation; and
- Information on the use and conservation of electrical products, marking and labeling.

Scope of the NOM

This standard applies to electrical products that use public service electricity for their power supply, as well as other energy sources, such as batteries, accumulators, and self-generation, in alternating current and/or direct current, with a nominal voltage of up to 1000 V in alternating current and up to 1500 V in direct current. Common products include tools and lawn care equipment.

NOM-003, Conformity Assessment Procedure, Extensions, and Family Approvals

The conformity assessment procedure of NOM-003 is the same as that applicable to NOM-001, except that the testing period is approximately 20-40 days. Extension procedures and family approvals rules under NOM-003 are identical to those of NOM-001.

NOM vs. NMX

Unlike NOM-019, which is self-contained, NOM-003 refers to various Mexican standards established by CBs (not the Secretary of the Economy), called Mexican Standards or Normas Mexicanas (NMXs). These include NMX-J-521/1- ANCE; NMX-J-524/1-ANCE, NMX-J-038/1-ANCE, and NMX-J-307-ANCE, which in turn have been based on the international standards IEC 60335-1, IEC 60745-1, IEC 60974-1, and IEC 60598-1, respectively.

SUPER-SPECIALIZED EQUIPMENT

As mentioned above, it is possible that the Customs database may associate a NOM with a product that does not necessarily apply. One especially important example of a misapplication of NOM-019 to data equipment occurs with equipment that is only operated by professionals and meets the specialized criteria described on the NOM. Section 1.2 of NOM-019 specifically excludes workstations, servers, fault-tolerant systems, enterprise systems, and other products from its scope.

Although these products are outside the scope, it is possible that Customs agents may mistakenly require a CoC. To avoid this problem, it is possible for an importer to request an expert opinion ("dictamen") from a CB. Presentation of this document at Customs will allow a product to be imported successfully without a CoC.

LABELING-USER GUIDE-WARRANTY REQUIREMENTS

NOM Mark

Upon entering the Mexican marketplace, products certified to any of the three safety NOMs must display the NOM mark. Rules concerning the design, size, and placement of the mark are contained in NOM-106-SCFI-2017[5]. Section 2.4 of this standard states that there are options for the kind of label and its placement on the product as follows:

> *"Any label, inscription, image or other descriptive or graphic material, written, printed, stenciled, marked, engraved in high or low relief, adhered to, superimposed or fixed to the product, its packaging or, where this is not possible due to the characteristics of the product or its packaging, to its packaging, or in digital format within the product software."*

Figure 1 of NOM-106 states that the minimum height of the logo, if printed, must be 2.5 mm (about 0.1 in) high. Further details regarding the physical characteristics of the logo, as well as conditions of use, are found within the standard. An example of a NOM mark is found in Figure 1.

NOM

Figure 1: The Norma Oficial Mexicana (NOM) Mark

ADDITIONAL LABELING, USER GUIDE, AND WARRANTY REQUIREMENTS

Most electrical and electronic devices are also subject to NOM-024-SCFI-2013[6] . This standard covers product information that must appear on the product or its packaging as well as describing the required user guide and warranty requirements. Like other NOMs, the Mexican Customs database may list compliance to this NOM alongside radio, telecom, and safety NOMs as a requirement for importation to the country. To demonstrate compliance, one must use an accredited CB to obtain a document called a "Constancia." The following documents must be provided to the CB as part of the approval process:

- Warranty in Spanish from the Mexican company that will cover it before the customer;
- User Guide in Spanish;
- Label; and
- Package artwork that shows brand and Model (since the rest of the information will be in the NOM-024 label that will be affixed on the package, it is not necessary to repeat this information).

Each of these items needs to show some minimum information to be accepted.

User Guide

A user manual must be in Spanish for it to be accepted by the certifying body in Mexico that will analyze the NOM-024 requirements. The manual can have other languages for global compliance purposes, but it must have a Spanish version at least detailing the following information to be compliant:

- Clear use instructions;
- Warnings (if applicable);
- Importer information (full company name, Registro Federal de Contribuyentes (RFC), equivalent to their Mexican federal tax identification), address and contact information);
- Brand;
- Model;
- Nominal voltage (in Spanish notation); and
- Invitation to read the manual.

Label

For the label, most of the information from the previous point will be repeated, including:

- Model;
- Product description in Spanish;
- Nominal voltage;
- Importer information such as full legal name, RFC number and address;
- Country of origin;
- Warnings (if applicable);
- Invitation to read the manual in case this information is not present in the manual; and
- Brand name.

Warranty

The warranty document needs to clearly show the following information:

- Brand;
- Model;
- Information with regards to where the customer can activate the warranty in Mexico;
- Validity of the warranty;
- Scope of the warranty;
- Procedure of fulfilling the warranty; and
- Importer information such as full legal name, RFC number, contact information and address.

EXEMPTIONS TO NOM-024

It is possible to demonstrate that a given product is exempt from the need for a NOM-024 certificate, specifically if that product is not intended to be commercialized to the public, such as industrial machines that are only intended to be used in factories. To prove that a product qualifies for an exemption, one would need the following items to present to Customs:

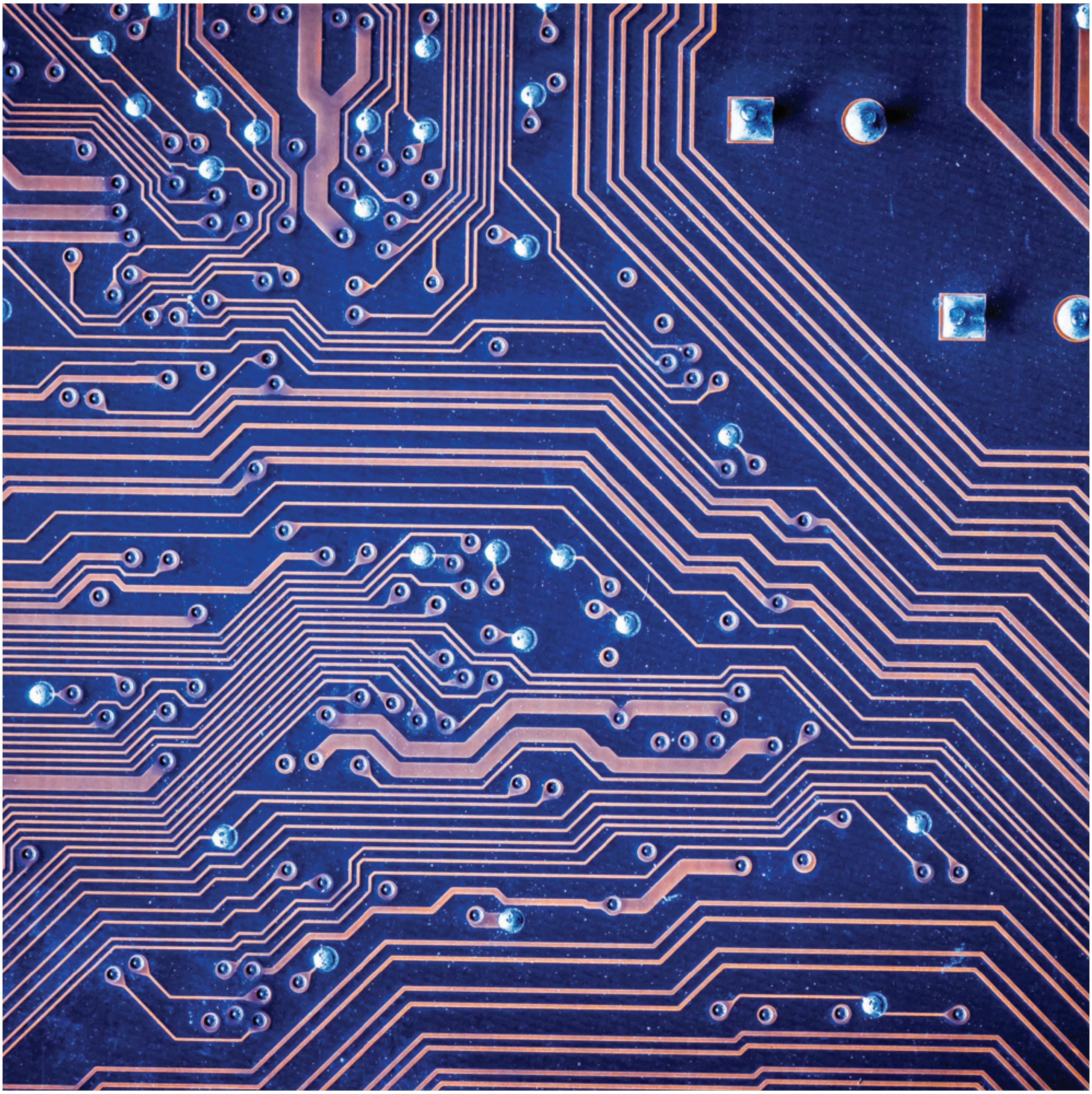
- Copy of the contract that includes commercial, warranty, and installation information (mandatory); or
- Opinion letter issued by a CB stating that under their analysis the product does not fall into the scope of the NOM-024 (voluntary but highly suggested to avoid problems at customs)

ENDNOTES

1. https://www.dof.gob.mx
2. https://dof.gob.mx/nota_detalle.php?codigo=5572453&fecha=17/09/2019#gsc.tab=0
3. https://dof.gob.mx/nota_detalle.php?codigo=4902685&fecha=11/12/1998#gsc.tab=0
4. https://www.dof.gob.mx/nota_detalle.php?codigo=5394047&fecha=28/05/2015#gsc.tab=0
5. https://dof.gob.mx/nota_detalle.php?codigo=5496689&fecha=08/09/2017#gsc.tab=0
6. https://www.dof.gob.mx/nota_detalle.php?codigo=5309980&fecha=12/08/2013#gsc.tab=0

CIRCUIT SPACINGS: DETERMINING PRODUCT SAFETY REQUIREMENTS

A Guide to Identifying and Determining Safety Critical Spacings



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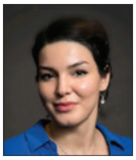

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By Maryam Mahmoodi and Jim Bender

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This article provides a simplified overview of product safety-related circuit spacings and practical methods for effectively determining when critical circuit spacings requirements may apply.

Featured examples help to illustrate applications and provide awareness of alternatives and exemptions to "classic" clearance and creepage approaches, simplifying determination and, in many cases, reducing end-product footprints through smaller printed circuit boards.

IMPACT OF SPACINGS TO SUCCESSFULLY CONTRIBUTE TO A SAFE AND COMPLIANT PRODUCT

Circuit spacings contribute, in part, to safe and compliant products. With almost no exception, end-product and/or component-level product safety standards provide requirements for printed circuit and/or component-level spacings, commonly referred to as "creepage" and "clearance," both critical terms to understand and differentiate.

Creepage and clearance, respectfully, represent the shortest distance measured between two conductors over the surface and through the air. Application of actual creepage and clearance requirements is impacted by many variables including, but not limited to, voltage potential, pollution degree, altitude/environmental conditions, material insulating properties, and available energy.

Note that specific values for such clearance and creepage values are determined by the end-product safety standard, end-product design requirements, and application needs beyond the scope of this article.

The term "opposite polarity" is used to describe a candidate "test" for the application of spacings requirements. It's important to note that not all circuits require spacings separation, and in fact, many do not. Accurately determining where spacings apply vs. do not apply is critical, summarized as follows:

- Determines when critical product safety spacings apply in order to minimize electrical shock hazard and fire risks, excluding functional safety applications such as high-risk medical, life support, etc. Accurately determining opposite polarities simplifies product safety spacing evaluation and
- Evaluates a simplified approach to evaluating the likelihood of two points creating a catastrophic failure caused by an arc, a breakdown in insulation, or a short circuit between the two points.

A simple "rule of thumb" to efficiently determine safety isolation critical "opposite polarity" is as follows:

- Application of a short or open circuit fault resulting in emission of molten metal, smoke, charring, separation of printed circuit board traces, or other similar catastrophic result; and
- Safety isolation provided between primary/secondary, primary/neutral, primary/ground, including protective grounds.

Note: The authors of this article strongly suggest the importance of verifying specific requirements from the applicable end-product application product safety standard.

Please refer to Figure 1, which illustrates examples of measured clearance and creepage.

- Clearance is the shortest distance between two conductors of opposite polarity, measured through air.
- Creepage is the shortest distance measured between two conductors of opposite polarity measured over a surface.

Key factors impacting clearance and creepage values (after determining "opposite Polarity") are listed in the following sections.

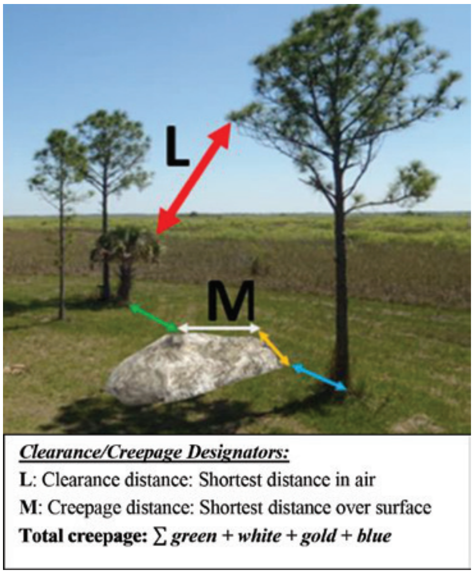

Figure 1: Example of clearance (L) and creepage (M)

- Clean room, hermetically sealed, potted, or suitably masked printed circuit boards

- PD 2: Non-conductive pollution except occasional temporary conductivity from condensation sources.
    - Office environments
- PD 3: Conductive pollution or dry non-conductive pollution occurrences that become conductive from anticipated condensation sources.
    - Non-heated/Non-Air-Conditioned installations, industrial areas, etc.
- PD 4: Persistent conductivity due to conductive dust, rain, or snow.
    - Unprotected outdoor installations

Voltage Measured in Peak or RMS

- Measured difference of electrical potential (voltage) between two points, which is typically the source of electrical shock hazard including rated, working, impulse voltages, etc.

Overvoltage Category (Mains supplied)

Roman numeral designation and examples defining transient overvoltage categories impacting clearance distances only:

I. Transient limited protected installation: Transient protected, isolated products, etc.
II. Supplied from fixed installation: Appliances, portable tools, etc.
III. Fixed/permanent installation: Permanently connected/fixed industrial switches and equipment.
IV. Origination of installation location (utility meters, primary overcurrent protection, etc.)

Pollution Degree (PD)

Four numerical values are assigned to characterize the anticipated pollution of the micro-environment, representing the number of particles in the air as follows:

- PD 1: No pollution or only dry, non-conductive pollution occurs. No influence of contamination.

Comparative Tracking Index (CTI) Ratings, Restricted to Creepage Properties.

Measure of electrical breakdown (tracking) properties of an insulating material on the surface of an insulating material starting with initial exposure to electrical arcing heat carbonization.

- Material Group I 600 ≤ CTI
- Material Group II 400 ≤ CTI <600
- Material Group IIIa 175 ≤ CTI <400
- Material Group IIIb 100 ≤ CTI <175

A CTI value is obtained with testing referenced in IEC 60112 "Method for the Determination of the Proof and the Comparative Tracking Indices of Solid Insulating Materials [1]. Typically, if CTI is not readily known from the printed circuit board safety certification data, many end-product safety standards default and accept Material Group IIIb.

Altitude

- Elevation where end-product is expected or specified for use.
- Standard typically defines 0-2000 meters, with adjustment factors exceeding 2000 meters.

Summarizing

It is important to recognize that voltages can directly influence the applicability of clearance and creepage spacings as well as the actual values for minimum spacing requirements based on:

- *Rated voltage:* Product or component's electrical nameplate maximum operating voltage or range rating.
- *Nominal voltage:* Typical operating voltage within the product or components rated operating range.
- *Working voltage:* Actual insulation voltage measure at the point under consideration when the product is operated within its rated operating range.
- *Input voltage:* Voltage measured at product or component's input.
- *Output voltage:* Voltage measured at product or component's output.
- *Derived voltage:* Voltage measured within a circuit bearing elevated voltages, including but not limited to flyback power supplies, lamp ballasts, display backlit panels, etc.

Opportunities to reduce clearance and creepage spacing values are illustrated in Figure 2.

Increasing value of key factors	Impact on Required Spacing Values
Voltage potential	↑
Pollution Degree (1, 2, 3)	↑
Altitude (w/correction factor)	↑
Conformal Tracking Index (CTI)	↓
Suitable potting compounds or printed circuit board coatings	↓

Figure 2: Factors and their influence on clearance and creepage distances

NAVIGATING THE STANDARD

Once locations/points of "opposite polarity" are confirmed, determining applicable clearance and creepage requirements must be determined and ultimately verified.

Most published product safety standards, regardless of source, including, but not limited to, Underwriters Laboratories, Canadian Standards Association, Factory Mutual Approvals, and International Electrotechnical Commission (IEC), include various clearance and creepage requirements. Of particular interest is IEC's 60664-1 Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests [2].

It's very important to identify the correct clearance and creepage values to maintain an effective product design process and avoid larger than necessary product footprint and/or costly redesigns and time-to-market delay.

INTERPRETATION OF APPROACHES

Effective leveraging of innovative printed circuit board design can dramatically reduce a product's footprint if still complying with the end-product safety standard as follows:

- Limiting available power
- Printed circuit board solder mask additives for surface-mounted device reflow purposes, suitably flame and insulation rated
- Printed circuit board material with suitable conformal tracking index
- Suitably rated insulating potting compounds and conformal coatings
- Reducing the micro-pollution degree with a controlled environment or enclosure providing the same
- Abnormal component/printed circuit board trace failure alternative evaluation/testing.

To demonstrate clearance and creepage reduction opportunities, an enclosed linear power supply, mains-connected printed circuit board example is characterized as follows:

- *Power supply input:* 230Vrms, AC mains connected
- *Transformer output:* 24Vrms (linear transformer)
- *IC78XX:* Generic, Recognized Component, short circuit protected linear regulator, 15Vdc (<15W)
- *Miscellaneous components:* Generic common variety bridge rectifier, resistors, capacitors

- *Environmental assumptions:*
  - Overvoltage Category II (assumes cord-connected appliance)
  - Pollution Degree 2
  - Altitude: 3000m (Typically adds clearance/creepage correction factors if exceeding 2000m)
  - Conformal Tracking Index: Unknown (assumes IIIb)

Let's identify critical locations where clearance and creepage requirements apply. Using unique colors or other symbols to differentiate "open polarity" circuits to help identify candidate clearance and creepage locations, actual clearance and creepage assignments can be determined.

As noted earlier in this article, clearance and creepage application are generally influenced by locations of "opposite polarity." Upon shorting, a catastrophic failure or breakdown of the protective safety isolation system occurs.

Catastrophic failures may be concluded by the application of a short circuit "litmus test" providing evidence of printed circuit board and/or component rupture, arcing, charring, or burning.

Note that the same electrical locations may still be considered "opposite polarity" without a catastrophic result due to the application of a short circuit or breakdown of the protective isolation boundary.

A simple way to determine "opposite polarity" areas (if in doubt from a theoretical "paper analysis" of the electrical circuit) is to electrically short those points in question, observing any subsequent catastrophic results as previously described. This includes consideration (depending on the standard) of a dielectric breakdown test applied across the protective safety isolation system, if applicable.

Clearance and creepage reduction and/or other spacings exception opportunities are defined in many end-product safety standards, which should always be verified:

- Circuits limiting available power to "safe" levels. A well-known reference is IEC 62368-1's "Audio/video, information and communication technology equipment - Part 1: Safety requirements" [3] 15W limit which helps eliminate or minimize fire risks
- Low voltage circuits, typically rated at <60Vrms/42.5Vdc, are typically not capable of providing risk of electrical shock with limited current availability, including effective isolation means
- Protective safety isolation of electrical circuits
- Abnormal failure testing options to verify effectiveness of existing clearance and creepage design
- Some end-product safety standards provide alternate dielectric testing exceptions in lieu of actually measuring clearance and creepages

APPLICATION OF CIRCUIT BOARD APPLICATION OF SPACINGS

Using the generic linear power supply example of Figure 3 and principles provided in this article regarding the application of critical locations of "opposite polarity," one can easily determine when clearance and creepage requirements apply.

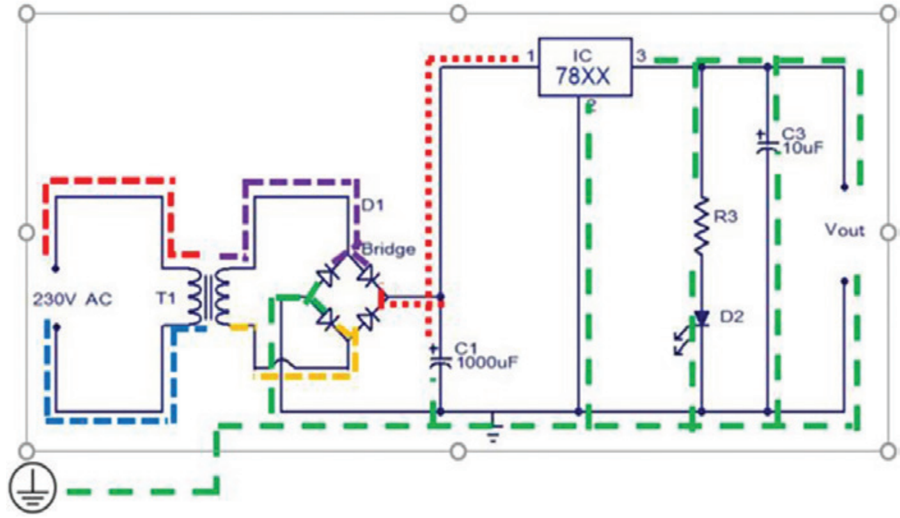

Figure 3: Enclosed, generic linear power supply and opposite polarity designations

Opposite Polarity Candidates (identified by coloring designation of schematic)

T1 Mains connected input (230Vrms)

- If shorted, catastrophic failure of non-current protected input printed circuit board etch may occur.
- Conclusion: Point of interest of "opposite polarity" – Clearance/Creepage spacings apply.

T1: Input/Output (Output = 24Vrms)

- If isolation boundary shorted, isolation means of accessible secondary circuits lost.
- Conclusion: Point of interest of "opposite polarity" – Clearance/Creepage spacings apply

Rectifier D1

- Depending on T1 output voltage, catastrophic failure of printed circuit board etch may occur.
- Conclusion: Point of interest of "opposite polarity" – Clearance/Creepage spacings apply.

C1 (Capacitor)

- Opposite polarity short circuit test will determine if clearance/creepage is safety critical.
- Conclusion: Point of interest of "opposite polarity" – Clearance/Creepage spacings apply.

IC78XX (short circuit limited), R2 (resistor), D2 (light emitting diode), C3 (capacitor)

- Not an "opposite polarity" based on short circuit limited output IC78XX, and SELV.
- Conclusion: Point of interest - Typically not considered "opposite polarity" depending on the safety standard, noting circuits are designated in the same color to conclude not being "Opposite Polarity."

Enclosure/Protective Safety Ground

- Mains-connected components (T1) to enclosure/protective safety ground.
- Conclusion: Depending on the safety standard, noted circuits are designated in the same color to conclude not being "Opposite Polarity."

Other non-mains connected component spacings measured to enclosure/protective safety ground are not considered "opposite polarity."

Note: The above examples of "opposite polarity" are generic in nature. The end-product safety standard should always be consulted for final clearance and creepage definitions and applicability to the end-product being evaluated.

CONCLUSIONS

Determination of clearance and creepage requirements, including interpretations and effective application, can be challenging and often difficult to apply correctly.

Consequences of incorrect spacings can have a significant impact to a product's safe use and application, notwithstanding its product safety certification as applicable.

Product safety and certification issues can be significant, resulting in product introduction delays, costly redesigns, and a larger end-product footprint. In severe situations, personal injury, property damage, or even loss of life may result, including non-compliant safety certifications, costly recalls, and/or degradation to a manufacturer's reputation.

The principles of our featured "opposite polarity" compliance tools provide simplified techniques to determine clearance and creepage applicability. Used with an end-product's safety standard can make the overall product development process more efficient.

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2. IEC 60664-1, *Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests*, 3rd Edition, 2020.
3. IEC 62368-1, *Audio/video, information, and communication technology equipment - Part 1: Safety requirements*, 4th Edition, 2023.

PREVENTING LIABILITY FROM FOREIGN-MADE PRODUCTS

How to Protect Yourself When Selling Foreign Products

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By Kenneth Ross

A quick look through recent 2024 recall notices posted on the website of the U.S. Consumer Product Safety Commission (CPSC) reveals that a majority of recalled products were manufactured in China.[1] And a recent analysis of 1st quarter 2024 recalls by Sedgwick Brand Protection reveals the following products with the highest number of recalls – sports and recreation, children's products, electronics, toys, and home appliances.[2] Most of these products are manufactured in China or other locations in Asia.

The Hong Kong Trade Development Council (HKTDC) analyzed recalls in 2021 and had the following conclusions:

> *According to information collected from the CPSC consumer product recall database, there were 155 recalls involving nearly 36 million units during January-August 2021 that either violated mandatory standards or presented a substantial risk to the public.*
>
> *Imported products accounted for approximately 85.8 percent of the recalls issued (133) and about 89.1 percent of the total number of units recalled (31.8 million) during the first eight months of the year, while U.S. products accounted for 16.1 percent of the recalls issued (25) and approximately 10.9 percent of the total number of units recalled (3.9 million).*
>
> *Mainland China remains the supplier with the largest number of recalls and recalled units, with its products having been involved in eighty-six recalls affecting some 28.4 million units during January-August 2021 (four of these recalls were shared with products from other locations). Mexico ranks third in terms of the total number of recalls behind mainland China and the U.S., with nine recalls involving 87,759 units during January-August 2021, while Vietnam and Taiwan rank fourth each with eight recalls affecting some 1.5 million units and India ranks sixth with seven recalls affecting about 146,400 units.*

And an analysis of 2023 recalls by Don Mays revealed that "four of the top five recalls citing injuries were for small appliances, all of which were manufactured in China." Mays also said:

> *Most of the products named in recalls were manufactured in China. This indicates that robust supply chain controls and adequate risk management procedures may be missing from importing companies' product safety programs. Relying on foreign manufacturers requires an extra level of due diligence to ensure problems won't be encountered once the products get to the US market.*[3]

Given this reality, there are a number of issues that manufacturers and product sellers have to face when trying to prevent future product safety and product liability problems caused by foreign-made products.

WHERE TO BUY PRODUCTS OR COMPONENTS

The first issue is whether it is advisable to buy safety-critical products, component parts, or raw materials from China or any other country with a less sophisticated and less robust safety and quality system. Usually, U.S. manufacturers or product sellers do not buy from foreign sources to buy better-quality products. Rather, they hope to achieve an acceptable level of quality and safety at a lower price.

So, given the increased risks and increased costs of dealing with foreign manufacturers, especially those companies not known for producing high-quality products, can you save enough money by buying from foreign manufacturers to justify the risk? You can spend most or all of your profits on one product liability case or recall if the foreign supplier does not take care of the entire cost, including administrative costs for your employees. And this cost does not include damage to the U.S. manufacturer's or retailer's reputation in the marketplace.

U.S. manufacturers and retailers should have more detailed contracts and specifications when dealing with foreign suppliers. Most contracts and specifications for U.S. and foreign suppliers are inadequate when dealing with some safety issues, such as recalls and defending product liability lawsuits.

Despite this risk, U.S. manufacturers and retailers will continue to buy all kinds of raw materials, component parts, and finished products from China and elsewhere. And these numbers will continue to increase as long as there is no backlash from consumers. In that case, U.S. manufacturers need to be prepared to provide assurances to their immediate customers (i.e., retailers) and the ultimate customer about the safety and quality of these products.

In addition, U.S. manufacturers and retailers need to take extra precautions to minimize the risk to an acceptable level and to be prepared to convince government agencies and consumers that its products are safe. So let us examine some well-known prevention techniques and see what else can and should be done when foreign-made products are imported into the U.S.

CONTRACTS AND INSURANCE

U.S. manufacturers and retailers should have more detailed contracts and specifications when dealing with foreign suppliers. Most contracts and specifications for U.S. and foreign suppliers are inadequate when dealing with some safety issues, such as recalls and defending product liability lawsuits. Since a U.S. based supplier usually can be sued in all states in the U.S., it is a bit easier to deal with issues that are not in the contract and to get the attention of domestic suppliers if something bad happens.

With foreign manufacturers who have no assets or employees in the U.S., and therefore possibly no U.S. jurisdiction in which they can be sued, it is harder to enforce contracts in general and certainly harder to deal with issues not explicitly set forth in the contract.

Some of the issues that could be included in such contracts and specifications involve required certifications or other safety and quality testing, documentation that must be sent to the U.S. in English to support the certifications and testing, confirmation of the foreign manufacturer's understanding of U.S. safety regulatory issues, and clear terms that address when they must tell you about a post-sale safety or quality issue.

You should be sure to include in the contract remedy and damage provisions that are acceptable to you. For example, you may not want the foreign manufacturer to disclaim consequential damages or to argue that repair or replacement is the only remedy. This is especially true for component parts, where the additional costs of repair, replacement, or refund can be enormous. In addition, do you expect the foreign manufacturer to pay for all costs of a recall? If so, be sure it is clearly set forth in the contract.

Of course, the foreign manufacturer should indemnify you and hold you harmless in the event of a product liability claim or lawsuit. However, do you really want them defending the case, or do you want it clear that you control the defense or at least are able to participate in it, even if their insurance applies? Their insurance company should be U.S.-based and financially capable of responding in the future. And you should require a relatively low self-insured retention. Last, it would be good to get the foreign manufacturer's insurance company to pay for your attorneys to help defend the case.

You should think about how you are going to enforce this contract if necessary. Will you have to sue in China? Or will they agree to jurisdiction in the U.S.? And is the foreign company financially capable of paying for any recall or any deductible in an insured matter? If the company goes bankrupt or closes its doors, the insurance premium is not paid and there is no one other than the U.S. manufacturer to pay for the recall. Maybe the foreign manufacturer should be required to post some type of bond with provisions for when the U.S. manufacturer can access the proceeds of the bond.

And the foreign manufacturer needs to agree to cooperate with the U.S. manufacturer in all respects during production, during any product liability case, and during any government inquiry. They need to timely provide documents in English and provide personnel who can explain in a U.S. court of law or in a deposition why their product was reasonably safe.

It is true that many foreign companies will not agree to these contractual and insurance provisions. In that case, the U.S. company must either decide to take the risk, especially if the component is safety-critical, or must increase its review and analysis of the safety and quality of the purchased products so that they meet the requirements of the U.S. company.

See "Manufacturing in China: Minimizing Your Risks by Doing Things Right"[4] by China law expert Dan Harris for a further discussion of contracting issues with the Chinese.

DESIGN PROCEDURES

Safety and quality procedures for foreign manufacturers should not be any different than those applicable to U.S.-based manufacturers. However, it is more important that you know what the foreign manufacturer is doing and how they are documenting the results.

- Some additional questions to consider asking foreign manufacturers include:
- Do they do a hazard analysis, a failure mode and effects analysis, a design review? Do they document these procedures? Do they train their personnel in how to do them? What level of safety is acceptable? Is it up to the foreign manufacturer to decide on levels of safety or do they need your approval for the final design?
- Do they get certifications from respected testing agencies? Do they give these agencies all the necessary information? Are they possibly supplying misleading or incomplete information that potentially jeopardizes the certifications? Is it possible that these certification agencies are inappropriately or incorrectly certifying the product as a result of bribes or incompetence? Should these certifications be done in the U.S. or Canada?

- Should the foreign company just comply with regulations and standards, or should they exceed them? Who decides that and who decides on how much safer the product must be?
- How do you know that the foreign manufacturer continues to comply with the design approved by the certifying agency? Do you confirm compliance on a periodic basis?

MANUFACTURING ISSUES

What type of quality testing do they do – full, partial, random? What do they consider a product that meets specifications? Do they believe that "close enough" is acceptable? Is that acceptable to you?

Should you do full, partial, or random incoming inspection testing of the product or component part? Do you confirm that the foreign manufacturer has not changed the raw material in the part or product they sell you after you or the certifying agency has approved? There are many horror stories of changes made in material or manufacturing processes after approval.

Should you have full-time people at the plant in the foreign country monitoring their manufacturing and quality control processes? Or how often should you visit their facilities, and should the visit be unannounced?

WARNINGS AND INSTRUCTIONS

Do you review and "approve" the warnings and instructions provided by the foreign manufacturer? Do you require them to utilize the services of a competent native English speaker to draft the warnings and instructions? Do you require them to retain a competent U.S.-based attorney to provide advice on the legal adequacy and defensibility of the warnings and instructions?

The U.S.-based manufacturer should not generally undertake the rewriting of the warnings and instructions of a supplier, U.S. or foreign. Doing that makes them more potentially liable. It is better to require the foreign manufacturer to utilize competent people to assist them. They know their products best and should be required to provide you with a component part or finished product that is safe in its design, manufacture, and warnings and instructions.

POST-SALE ISSUES

The foreign manufacturer needs to have competent personnel in-house to receive and evaluate post-sale safety and quality issues. They have to agree to allow you to review this information if it is appropriate. And there should be some agreement on when it is appropriate.

For example, if a Chinese manufacturer sells the same component to ten manufacturers and has a problem with products sold to one or more of those manufacturers, it should be required to tell you about the problems, even if you have not had any with their component. The goal is for you to be able to prevent problems before they happen.

Certainly, you need to be notified immediately if the component part has been inserted into a product made by another manufacturer and has been recalled or repaired anywhere in the world because of a problem with that component. And you should be sure that the supplier's personnel or their advisors are familiar with the U.S. government reporting responsibilities and know what to tell you and when.

The foreign manufacturer's design and manufacturing processes should enable them to narrow the potential universe of problem products so as to allow you to correct or retrieve only those products that need to be dealt with. This includes traceability and marking procedures that are appropriate for the risk level of the particular product.

DEFENDING THE PRODUCT

U.S. manufacturers do not want to be in a position in which their only defense is blaming a foreign supplier. This is especially true if the manufacturer is not in the courtroom with you.

So, while you are evaluating who to do business with and what procedures you want them to adhere to, also consider how they will appear in court if they have to defend the adequacy of their part or product. Are the people who would testify sincere and knowledgeable, and can they speak well (preferably in English)? Do they have documents that have been written carefully and that correctly present what they did to produce a safe and quality product? Will your witnesses be able to understand and use these documents to defend the adequacy of the product or part?

For an informative discussion of these and other risk mitigation techniques when dealing with China-based manufacturers, see the blog "Reducing Your Product Liability Risks from Overseas Products" by Dan Harris.[5] Also, see a webinar presented by this author and Dan Harris on these topics.[6]

CONCLUSION

All of the techniques and concerns mentioned in this article are also important for U.S.-based suppliers. However, given the location of manufacturers who are producing products with problems, it is even more important to go the extra mile with foreign suppliers.

Ultimately, the manufacturer or product seller gets to make a business decision on whom to buy from and what to require them to do. Since it may well be impossible to find a foreign manufacturer that is willing to do all of the things detailed in this article, the company will need to decide what preventive techniques are priorities and when or if the lack of a technique is a deal breaker. In that way, U.S.-based companies will be better prepared to make a rational business decision and assume a future risk that they deem acceptable.

ENDNOTES

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2. https://www.sedgwick.com/brandprotection
3. https://productsafetyinsights.com/publications
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ANALYSIS OF TRANSMISSION LINES IN SINUSOIDAL STEADY STATE

Different Circuit Models and Their Applications: Part 2

By Bogdan Adamczyk

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This is the second of three articles discussing four different circuit models of transmission lines in sinusoidal steady state. In Part 1 [1], Model 1 and Model 2 were presented. In this article, we focus on Model 3. Model 3 is mathematically most expedient for evaluating the *values* of the minima and maxima of standing waves. The *locations* of the minima and maxima of standing waves are determined using Model 4.

TRANSMISSION LINE MODEL 3

To present Model 3, it is helpful to recall Model 1, shown in Figure 1.

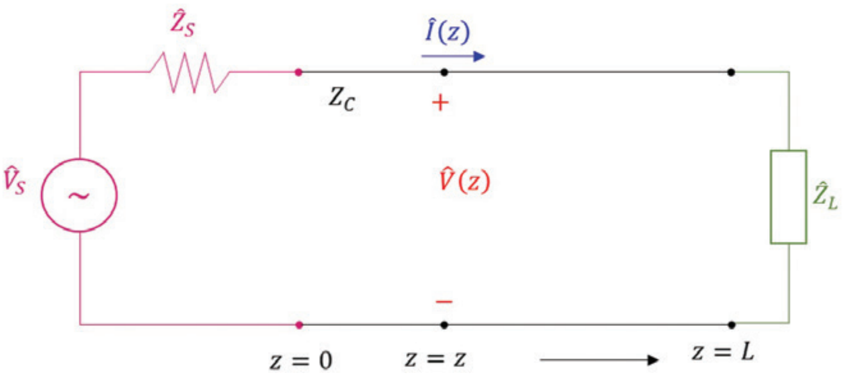

Figure 1: Transmission line circuit – Model 1

In Model 1, we are moving away from the source located at $z = 0$ towards the load located at $z = L$. Model 3, shown in Figure 2, is obtained from Model 1.

In this Model we are moving away from the source to the load, just like we did in Model 1. But in Model 3, the source is located at $z = -L$ while the load is located at $z = 0$.

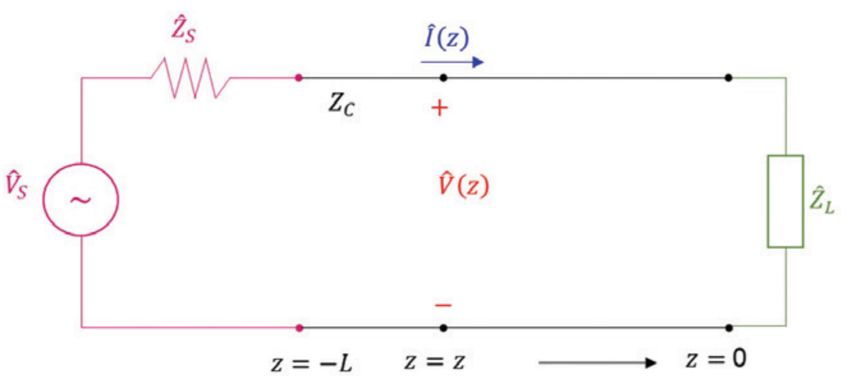

Figure 2: Transmission line circuit – Model 3

In both models, the voltage and current at any location z, away from the source, are given by the same equations:

$$\hat{V}(z) = \hat{V}_z^{+} e^{-j\beta z} + \hat{V}_z^{-} e^{j\beta z} \tag{1.1a}$$

$$\hat{I}(z) = \frac{\hat{V}_z^{+}}{Z_C} e^{-j\beta z} - \frac{\hat{V}_z^{-}}{Z_C} e^{j\beta z} \tag{1.1b}$$

These equations describe the voltage and current along the line, regardless of the value of z, assigned to the location of the source. We can place that location at any convenient point along the line, depending on what phenomenon we want to investigate. In computing the value of the voltage maxima and minima, the source location chosen in Model 3 is the most convenient.

It is important to discern which equations are the same and which are different in both models. In Model 1, the voltage and current at any location z, away from the source, was expressed in terms of the load reflection coefficient as [1],

$$\hat{V}(z) = \hat{V}_z^+ e^{-j\beta z}\left[1 + \hat{\Gamma}_L e^{j2\beta(z-L)}\right] \tag{1.2a}$$

$$\hat{I}(z) = \frac{\hat{V}_z^+}{Z_C} e^{-j\beta z}\left[1 - \hat{\Gamma}_L e^{j2\beta(z-L)}\right] \tag{1.2b}$$

where $\hat{\Gamma}_L$ is the load reflection coefficient. These equations can be written in an alternative way.

$$\hat{V}(z) = \hat{V}_z^+\left[e^{-j\beta z} + \hat{\Gamma}_L e^{j2\beta(z-L)} e^{-j\beta z}\right] \tag{1.3a}$$

$$\hat{I}(z) = \frac{\hat{V}_z^+}{Z_C}\left[e^{-j\beta z} - \hat{\Gamma}_L e^{j2\beta(z-L)} e^{-j\beta z}\right] \tag{1.3b}$$

or

$$\hat{V}(z) = \hat{V}_z^+\left[e^{-j\beta z} + \hat{\Gamma}_L e^{j\beta(z-2L)}\right] \tag{1.4a}$$

$$\hat{I}(z) = \frac{\hat{V}_z^+}{Z_C}\left[e^{-j\beta z} - \hat{\Gamma}_L e^{j2\beta(z-2L)}\right] \tag{1.4b}$$

Equations (1.2), (1.3), and (1.4), valid for Model 1, describe voltage and current at any location z away from the source when the source is located at $z = 0$ and the load is located at $z = L$. As we shall see, the corresponding set of equations for Model 3 is different.

In Model 3, with the choice of the $z = 0$ location at the load, the following equation must be satisfied:

$$\hat{Z}_L = \frac{\hat{V}(0)}{\hat{I}(0)} \tag{1.5}$$

From Eqns. (1.1), valid for both models, we get

$$\hat{V}(0) = \hat{V}_z^+ + \hat{V}_z^- \tag{1.6a}$$

$$\hat{I}(0) = \frac{\hat{V}_z^+}{Z_C} - \frac{\hat{V}_z^-}{Z_C} \tag{1.6b}$$

Utilizing Eqns. (1.6) in Eq. (1.5), we have

$$\hat{Z}_L = Z_C \frac{\hat{V}_z^+ + \hat{V}_z^-}{\hat{V}_z^+ - \hat{V}_z^-} \tag{1.7}$$

leading to

$$\hat{V}_z^- = \frac{\hat{Z}_L - Z_C}{\hat{Z}_L + Z_C}\hat{V}_z^+ \tag{1.8}$$

or

$$\hat{V}_z^- = \hat{\Gamma}_L \hat{V}_z^+ \tag{1.9}$$

Using Eq. (1.9) in Eqns. (1.1), we get

$$\hat{V}(z) = \hat{V}_z^+ e^{-j\beta z} + \hat{\Gamma}_L \hat{V}_z^+ e^{j\beta z} \tag{1.10a}$$

$$\hat{I}(z) = \frac{\hat{V}_z^+}{Z_C} e^{-j\beta z} - \frac{\hat{\Gamma}_L \hat{V}_z^+}{Z_C} e^{j\beta z} \tag{1.10b}$$

or

$$\hat{V}(z) = \hat{V}_z^+\left(e^{-j\beta z} + \hat{\Gamma}_L e^{j\beta z}\right) \tag{1.11a}$$

$$\hat{I}(z) = \frac{\hat{V}_z^+}{Z_C}\left(e^{-j\beta z} - \hat{\Gamma}_L e^{j\beta z}\right) \tag{1.11b}$$

Note that Eqns. (1.11), valid for Model 3, are different from Eqns. (1.4), valid for Model 1. We will use Eqn. (1.11a) to determine the expression for the voltage magnitude and, subsequently, its maximum and minimum. Towards this end, let's express the complex load reflection coefficient in terms of its magnitude and angle as

$$\hat{\Gamma}_L = \Gamma_L e^{j\theta} \tag{1.12}$$

Utilizing Eq. (1.12) in Eq. (1.11a) we get

$$\hat{V}(z) = \hat{V}_z^+\left(e^{-j\beta z} + \Gamma_L e^{j\theta} e^{j\beta z}\right) \tag{1.13}$$

The magnitude of a complex voltage in Eq. (1.13) can be obtained from

$$|\hat{V}(z)| = [\hat{V}(z)\hat{V}^*(z)]^{\frac{1}{2}} \tag{1.14}$$

where the superscript * denotes a complex conjugate. Thus,

$$|\hat{V}(z)| = \begin{matrix}\{[\hat{V}_z^+(e^{-j\beta z} + \Gamma_L e^{j\theta} e^{j\beta z})] \\ \times[\hat{V}_z^+(e^{-j\beta z} + \Gamma_L e^{j\theta} e^{j\beta z})]^*\}^{\frac{1}{2}}\end{matrix} \tag{1.15}$$

or

$$|\hat{V}(z)| = \begin{matrix}\{[\hat{V}_z^+(e^{-j\beta z} + \Gamma_L e^{j\theta} e^{j\beta z})] \\ \times[(\hat{V}_z^+)^*(e^{j\beta z} + \Gamma_L e^{-j\theta} e^{-j\beta z})]\}^{\frac{1}{2}}\end{matrix} \tag{1.16}$$

Multiplying out and simplifying, we have

$$|\hat{V}(z)| = \begin{matrix}\{[1 + \Gamma_L^2 + \Gamma_L e^{-(j\beta z+\theta)} \\ + \Gamma_L e^{j(2\beta z+\theta)}]\}^{\frac{1}{2}}\end{matrix} \tag{1.17}$$

Utilizing Euler's formula for a cosine, we arrive at the expression for the magnitude of the voltage at any location z away from the source as

$$|\hat{V}(z)| = |\hat{V}_z^+|\{[1 + \Gamma_L^2 + 2\Gamma_L \cos(2\beta z + \theta)]\}^{\frac{1}{2}} \tag{1.18}$$

when the source is located at $z = -L$ and the load is located at $z = 0$, (Model 3).

The *maximum magnitude* of the voltage in Eq. (1.18) occurs when the cosine function equals 1. Thus,

$$\begin{aligned}|\hat{V}(z)|_{max} &= |\hat{V}_z^+|[(1 + \Gamma_L^2 + 2\Gamma_L)]^{\frac{1}{2}} \\ &= |\hat{V}_z^+|[(1 + \Gamma_L)^2]^{\frac{1}{2}}\end{aligned} \tag{1.19}$$

or

$$|\hat{V}(z)|_{max} = |\hat{V}_z^+|(1 + \Gamma_L) \tag{1.20}$$

The *minimum magnitude* of the voltage in Eq. (1.18) occurs when the cosine function equals -1. Thus,

$$\begin{aligned}|\hat{V}(z)|_{min} &= |\hat{V}_z^+|[(1 + \Gamma_L^2 - 2\Gamma_L)]^{\frac{1}{2}} \\ &= |\hat{V}_z^+|[(1 - \Gamma_L)^2]^{\frac{1}{2}}\end{aligned} \tag{1.21}$$

or

$$|\hat{V}(z)|_{min} = |\hat{V}_z^+|(1 - \Gamma_L) \tag{1.22}$$

Additionally, Eqns. (1.20) and (1.22) provide an alternative and convenient way of calculating the voltage standing wave ratio (VSWR), as

$$VSWR = \frac{|\hat{V}(d)|_{max}}{|\hat{V}(d)|_{min}} = \frac{1+\Gamma_L}{1-\Gamma_L} \tag{1.23}$$

TRANSMISSION LINE MODEL 4

Model 4 is shown in Figure 3. In Model 4, we are moving away from the load located at $d = 0$ towards the source located at $d = L$.

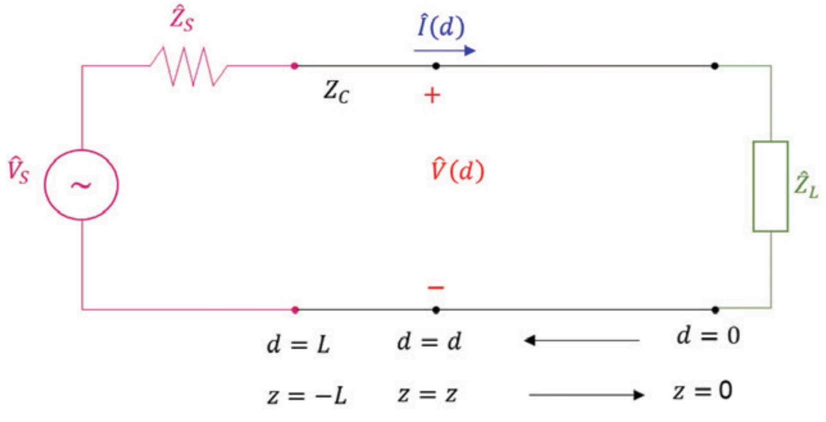

Figure 3: Transmission line circuit – Model 4

Model 4 is obtained from Model 3 by simply relating the distance variables according to

$$d = -z \tag{1.24}$$

Using Eq. (1.24), in Eq. (1.18), the magnitude of the voltage at any location d away from the load becomes

$$\begin{aligned}|\hat{V}(d)| = |\hat{V}_d^+|\{[1 + \Gamma_L^2 \\ + 2\Gamma_L \cos(-2\beta d + \theta)]\}^{\frac{1}{2}}\end{aligned} \tag{1.25}$$

where

$$|\hat{V}_d^+| = |\hat{V}_z^+| \tag{1.26}$$

Equation (1.25) can be rewritten as

$$|\hat{V}(d)| = |\hat{V}_d^+|\{[1 + \Gamma_L^2 + 2\Gamma_L \cos(-(2\beta d - \theta))]\}^{\frac{1}{2}} \tag{1.27}$$

Since cosine is an even function, Eq. (1.27) becomes

$$|\hat{V}(d)| = |\hat{V}_d^+|\{[1 + \Gamma_L^2 + 2\Gamma_L \cos(2\beta d - \theta)]\}^{\frac{1}{2}} \tag{1.28}$$

The next article will utilize Model 4 and Eq. 1.27 to determine the *locations* of the voltage maxima and minima in terms of the distance *d* away from the load.

REFERENCES

Adamczyk, B., "'Analysis of Transmission Lines in Sinusoidal Steady State – Different Circuit Models and Their Applications: Part 1," *In Compliance Magazine*, October 2024.

PRODUCT Showcase

MACHINE LEARNING APPLICATIONS IN THE NOVEL ESD COMPACT MODELING METHODOLOGY

By Wei Liang and Ahmed Ginawi for EOS/ESD Association, Inc.

Wei Liang leads ESD and Latchup strategies for Intel AMS IPs. Previously, he worked on the GlobalFoundries ESD team. Wei holds an MBA from Boston University and a Ph.D. in Electrical Engineering from UCF. He has authored more than 20 peer-reviewed papers and holds more than 10 U.S. patents in ESD.

Ahmed Ginawi joined Intel in 2023 as the Senior Director under the Fundamental IP organization, and before that, Ahmed served as the team lead for foundry IO design and foundry ESD at GlobalFoundries and IBM since 2000. Ahmed has several publications and patents in IP design and ESD applications.

WHY IS ESD COMPACT MODELING IMPORTANT

Electrostatic Discharge (ESD) is well known as one of the major reliability concerns in semiconductor manufacturing. Proper ESD protection solutions are always required to ensure integrated circuits do not fail during an ESD event. During the IC chip designing process, it is always highly desirable to have a complete set of ESD compact models of ESD protection devices that the IC designer could utilize in circuit-level SPICE simulations to achieve optimized circuit performance. It is important to predict and ensure that the ESD protection circuits and the core circuits are operating as desired, and this is key to achieving the right ESD protection solution for the first time. Therefore, the development of the ESD compact model has become one of the most essential elements in ESD device development.

WHAT IS MACHINE LEARNING?

Machine learning is a subfield of artificial intelligence (AI) that uses algorithm models to recognize the patterns in each dataset as well as learn and predict based on the supplied training dataset. It consists of a few steps, including data collection, data preparation, training, evaluation, and model tuning. Figure 1 shows the working flow of the generic machine learning concepts. Utilizing machine learning techniques will promote business success by improving time efficiency and design/prediction accuracy. In the semiconductor industry, for example, foundries are trying to apply machine learning techniques to areas like automatic defect classification, electrical tests, acoustic anomaly detection, and predictive equipment maintenance. It can also be used in EDA development, such as simulation models.

HOW ARE MACHINE LEARNING TECHNIQUES USED IN ESD COMPACT MODELING?

The machine learning technique called Multi-layer Perceptron (MLP) regressor, which is a type of Neural Network model in machine learning, can be used in the new ESD compact model fitting methodology.

In conventional compact model fitting, the modeler fits the model by tuning the parameters of the physical device equations. Figure 2 shows the flow chart of conventional ESD compact modeling fitting. As we mentioned, the fitting step is very time-consuming, and sometimes, the modeler must change the model equations to get the simulated I-V fitted to hardware data and pass the quality check criteria.

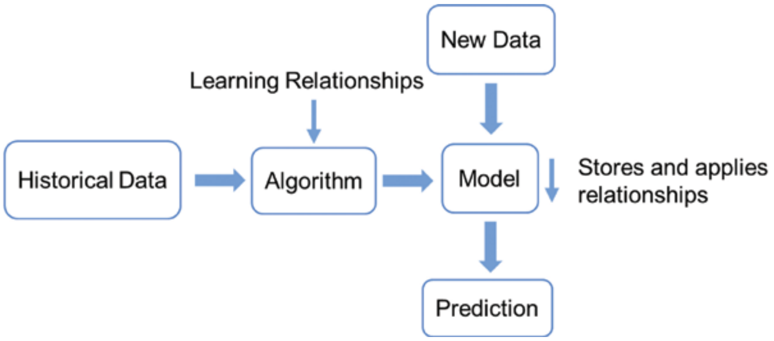

Figure 1: Flow chart of generic machine learning concept.

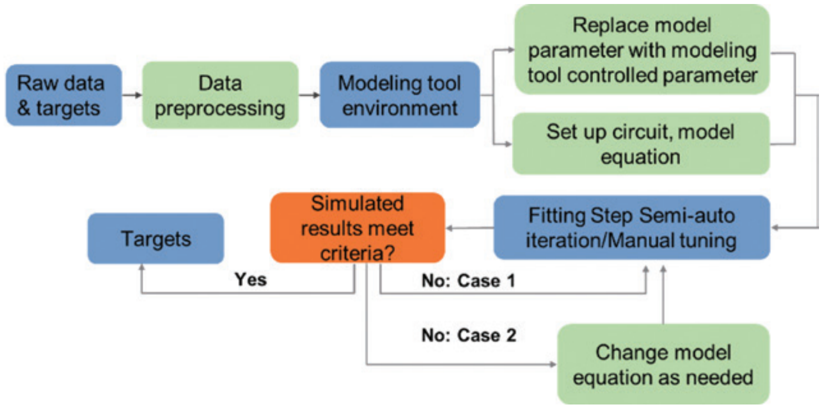

Figure 2: Flow chart of conventional ESD compact modeling fitting.

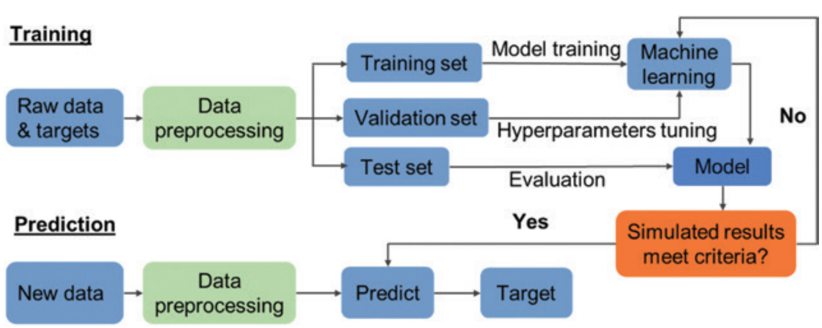

Figure 3: Flow chart of novel ESD compact modeling fitting using machine learning techniques.

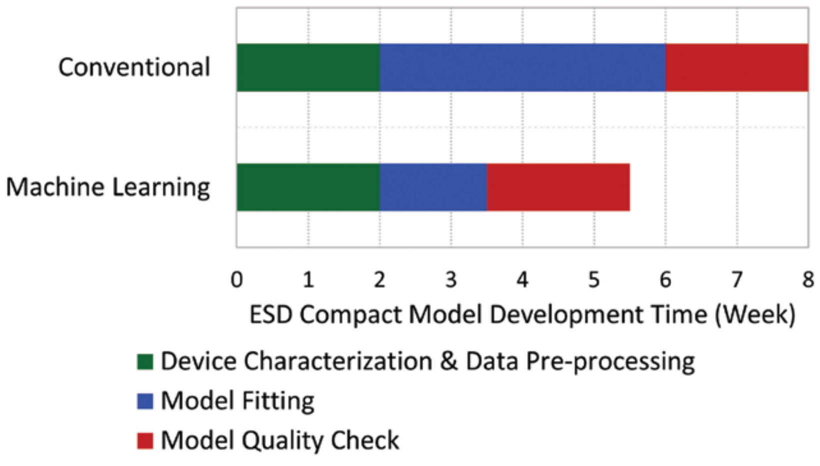

Figure 4: Development time comparison between conventional and novel ESD compact modeling methodology.

In the new methodology, the fitting process is done by a machine learning model with a behavior-based method instead of manually tuning the parameter of the physical equation. Figure 3 shows the flow chart of the ESD compact modeling fitting using machine learning techniques. The pre-processed raw silicon data and design specification of the structure is divided into three sets, including the training dataset and validation dataset (80% of relevant data), the test dataset (20% of the relevant data), and the new dataset (irrelevant data) which is used to check the model prediction accuracy. Irrelevant data refers to a device perimeter that was never used during the training step and is not relevant to the machine learning process but is needed to check prediction accuracy.

WHAT ARE THE ADVANTAGES OF THE NEW METHODOLOGY?

There are two main advantages: efficiency and accuracy.

For efficiency, model development can usually be categorized into three phases: device characterization and data-pre-processing, model fitting, and model quality check. Figure 4 shows the development time comparison between the conventional and novel ESD compact model development. Using the conventional methodology, an 8-week timeline is typically quoted by an experienced ESD device modeler on a new ESD diode model with TLP, vf-TLP, and

DC characteristics. As a comparison, to develop the same model using a novel ESD compact modeling methodology, the model fitting step could save up to 62% of the time, which brings the overall development time saving to 31%. More time could be saved if Machine Learning techniques are applied to data processing and quality checks in the future.

For accuracy, Figure 5 shows an example of the comparison among hardware, machine learning simulated, and conventional SPICE model simulated results for an ESD diode. Figure 6 shows the comparison between hardware data and machine learning model simulated I-V characteristics with ESD perimeter variation.

The machine learning model simulated I-V characteristics with at least 10% better accuracy in matching the hardware. The machine learning model not only has better accuracy and runtime efficiency but also shows a better current saturation effect compared to the traditional SPICE model using physical equations.

Overall, the novel machine learning-based ESD model will significantly simplify the development work and improve the model prediction accuracy over the traditional SPICE model. It could also achieve some challenging work that traditional SPICE models are not good at, like fitting for I-V characteristics with snapback behavior. It would bring evolutionary changes to future ESD compact modeling work.

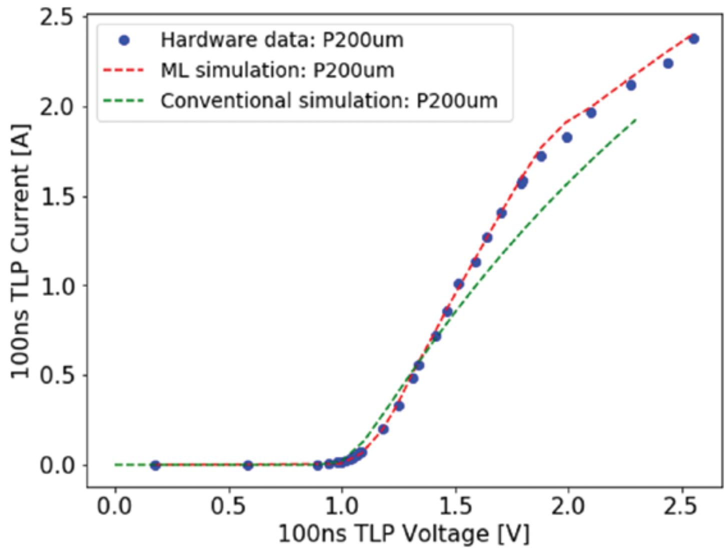

Figure 5: 100ns TLP I-V characteristics comparison among hardware, machine learning model, and SPICE model of the ESD diode.

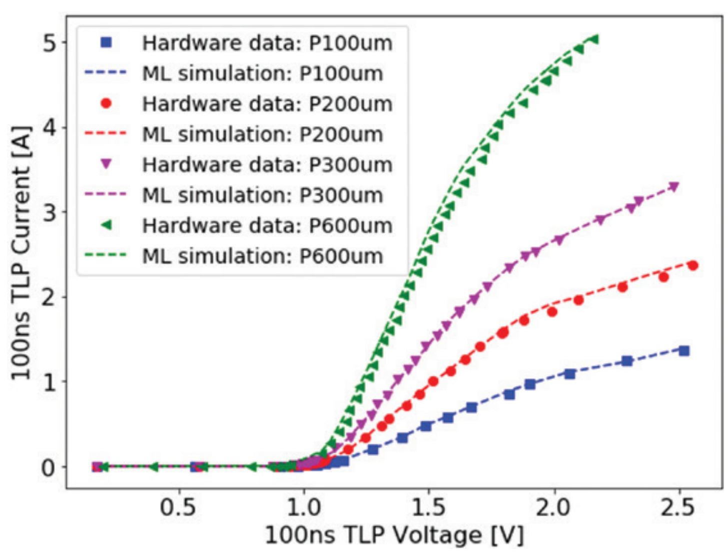

Figure 6: 100ns TLP I-V characteristics comparison between hardware and machine learning model simulation with perimeter variation of the ESD diode.

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1. W. Liang, X. Yang, M. Miao, A. Loiseau, S. Mitra and R. Gauthier, "Novel ESD Compact Modeling Methodology Using Machine Learning Techniques for Snapback and Non-Snapback ESD Devices," in *IEEE Transactions on Device and Materials Reliability*, vol. 21, no. 4, pp. 455-464, December 2021, doi: 10.1109/TDMR.2021.3116599.

USING NEAR-FIELD PROBES TO TROUBLESHOOT RADIATED IMMUNITY FAILURES

By Dr. Min Zhang

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.

Our February 2024 column (refer to Reference [1], "Using a Near-Field Probe to Troubleshoot Transient Failures") introduced a valuable technique for troubleshooting electric fast transient (EFT) failures at the PCB level. The same principle can be applied to troubleshooting radiated immunity failures. In this column, we present a case study to demonstrate these techniques.

In the following example, a company was caught by surprise when they discovered that a new IC daughterboard they designed and mounted on the original IC pinout location suffered from radiated immunity issues. The product, which is an audio device, exhibited tone distortion when exposed to radiated emissions in the 1.2 – 1.4 GHz range. The original IC had been in service for over ten years and was no longer available. The new IC, based on ARM architecture and powered by 3.3V, was intended to replace it.

The daughterboard (covering an area of approximately 374 mm^2 and with a 5 mm distance to the main board) forms a capacitance of approximately 1 pF (calculated using the simple equation $C=\varepsilon_0\varepsilon_R A/h$). The long trace from the daughterboard to the main board likely has an inductance of about 10nH. The self-resonance of this board is then estimated to be 1.5GHz, indicating a higher likelihood of immunity issues in this frequency range.

The immunity test was performed in an anechoic chamber using a far-field immunity test setup, but I only have access to a benchtop immunity setup, a challenge that many engineers face when their product fails the immunity test. They often wonder how they can troubleshoot the issue at their own bench. Additional questions arise, such as whether it is legal to perform a radiated immunity benchtop test and if there are health risks (they often ask, "Will I get cancer?"), associated with it.

IMMUNITY TROUBLESHOOTING USING A NEAR-FIELD PROBE

As shown in Figure 1, the approach we used involved connecting a near-field magnetic probe to a small RF power amplifier (assuming you have a signal generator to drive the amplifier). This setup can generate an intense field near the loop, exposing weak design points on the PCB to a strong magnetic field.

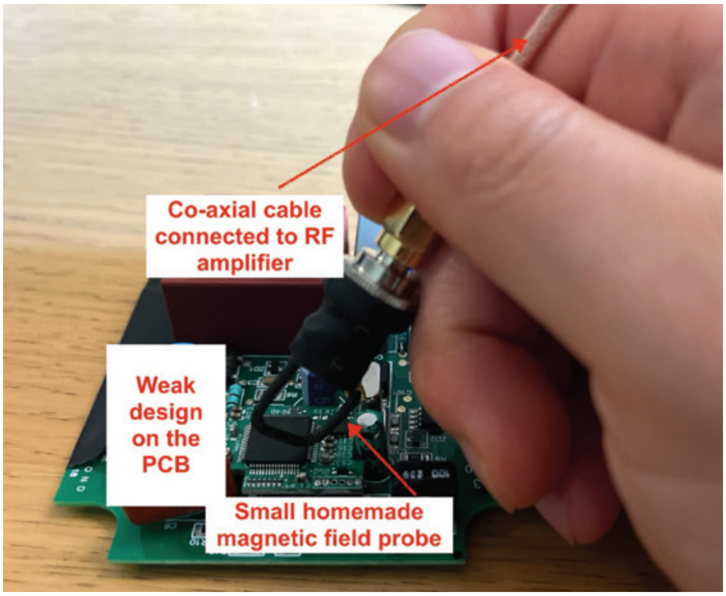

Figure 1: Using a small magnetic loop to inject AM-modulated RF signals into DUT

The detailed setup is shown in Figure 2. The idea was to replicate the same failure mode observed in the chamber, allowing us to troubleshoot and hopefully fix the issue on the bench.

It's important to note that during radiated immunity tests, noise can couple either through cables or directly via the PCB. In this case, we ruled out cable coupling because:

1. At 1.2 GHz, a 2-meter-long cable typically cannot couple noise sufficiently (though exceptions exist, as always in EMC); and
2. Common mode chokes were present on the cable connections.

In this case, when I held the near-field probe (connected to a Tekbox TBDA3B, which, at 1.2 GHz and 1.4 GHz, can still provide sufficient RF power despite being specified for use below 1 GHz) and moved it near the new IC daughterboard, the same failure mode occurred. I was using the AM modulation function on the amplifier, and the board produced a consistent rectified sound, which was very distinct.

Once the noise source was identified, it took some time to find a cost-effective fix, as the client is a small manufacturer with a budget constraint of less than one dollar. Eventually, we discovered that a small ferrite plate from Fair-Rite did the trick. After implementing this solution, the manufacturer tested the product in the chamber, and it passed the immunity test (for details, see Reference [2]). However, this situation highlighted a limitation of the technique.

THE LIMITATIONS OF NEAR-FIELD PROBE TESTING

When addressing the issue, I noticed that placing two or three ferrite plates between the motherboard and daughterboard showed improvement using my near-field probe. However, I couldn't definitively tell the client whether two plates or three would guarantee passing the immunity test. In fact, I believed that even one plate might be sufficient, considering the intense field generated by my small near-field probe compared to the far-field conditions in the chamber.

As a result, I advised the client to test two samples—one with one plate and another with two. Ultimately,

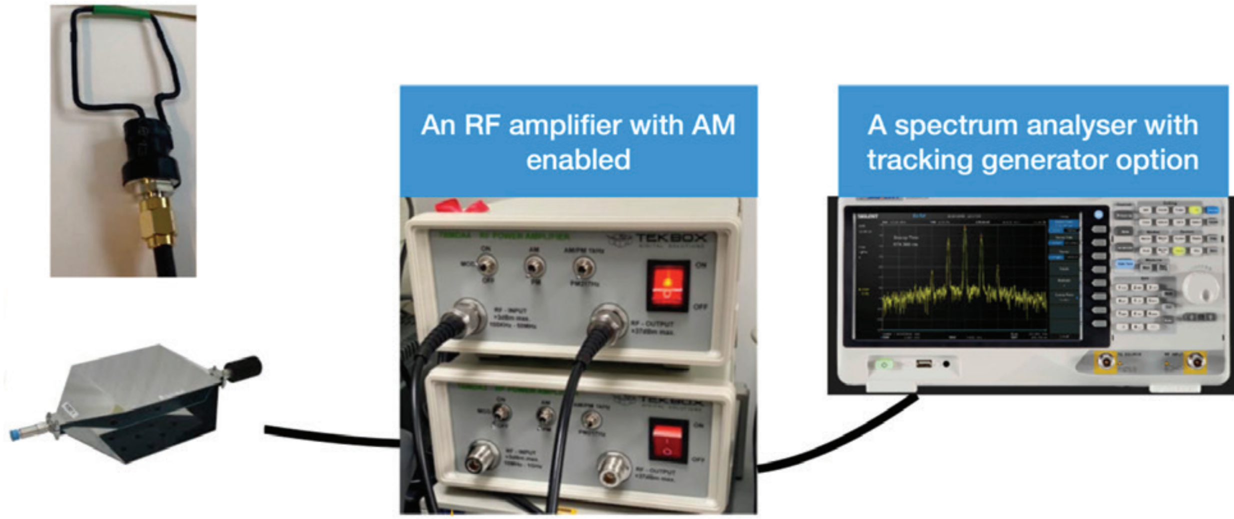

Figure 2: The author's benchtop immunity setup. A TEM cell can also be used for troubleshooting purposes.

the product passed the test with just one plate, as I had suspected, but this couldn't be conclusively determined from the near-field probe test alone.

When I was fixing the issue, I noticed that when I was applying two or three ferrite plates between the motherboard and daughterboard, I could see improvement using my near-field probe. But I was not able to tell my client whether two plates or three plates would be sufficient to pass the immunity test. In fact, in my opinion, even one plate would pass the test, considering the very intense field of my small near-field probe against what they tested in the far field in the chamber. So, I could only advise them to test two samples, one with one plate and one with two.

Eventually, they passed the test with one plate, as I would guess. But I could never tell from my near-field probe test.

Other considerations when using this approach:

1. Magnetic field loops generally perform better than electric field loops.
2. I used a homemade unshielded probe, but a commercially available shielded loop should work equally well. Generally speaking, you should avoid using pickup loops for injection tests (especially as described in [1]) due to the risk of voltage breakdown and heating in the probe. However, this should be fine for small RF signals.
3. Given the small power applied to the loop and its non-directional characteristics, the risk of this test affecting nearby communication devices is generally very low.
4. Most of the RF power will be reflected back to the amplifier rather than being consumed by the loop. So it's advisable to place a 3- or 6-dB attenuator at the amplifier output (though most amplifiers are designed to handle this anyway).
5. Another benefit of using magnetic field loops for this test is that you can use different loop sizes for different types of work. For small PCBs and high-frequency tasks, ensure your loop size is small enough. A rule of thumb I use is that the loop circumference should be smaller than half the wavelength at the frequency you're troubleshooting.
6. Finally, there is no substantial evidence to suggest that exposure to RF sources causes cancer. RF exposure (including thermal and non-thermal effects) is a separate subject, but using a small loop with a few watts output from an amplifier for short periods should be absolutely safe.

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1. Min Zhang, "Using a Near-Field Probe to Troubleshoot Transient Failures," *In Compliance Magazine*, February 2024.
2. Min Zhang, "Structure Resonances: Ways To Identify, Locate, and Fix EMI Issues," *Signal Integrity Journal*, April 2022.

Banana Skins

454 Video projector interferes with audio induction loop

Installers of various equipments may not be aware of audio magnetic induction loops, which are an aid for the disabled. These produce magnetic fields across the whole audio range but primarily from 100Hz to 5kHz with a nominal field strength of 100mA/m in the listening area. Achieving this may mean fields of at least 10A/m a few centimetres from the loop cable.

BS7594, Guidelines for Induction Loops, includes advice to minimise susceptibility to magnetic interference. Basically, these give ways of avoiding a large area earth loop.

A Church where we had installed an induction loop bought, a few years later, a new video projector and computer system. We were called because the installer of the projector was complaining that our loop did not meet specifications, and was causing interference. The picture had "hum bars" moving up and down the screen.

I cured this with nothing more than a 5 metre mains lead. I plugged the projector into the same mains socket as the computer, thus minimising the earth loop. As a further test, I measured loop current and magnetic field, and could show that the installation was close to a text-book example of the theory in BS7594. The video projector supplier had plugged this into a mains supply installed for other equipment.

This was a text-book example of the earth loop which BS7594 warns against. During this dispute, the video supplier had arranged a demonstration of an induction loop which he hoped the Church would purchase. Hearing aid users were not impressed with the loop quality compared with the existing installation. Installing the loop cable on the steel reinforced concrete floor reduced the interference to the video projector. But it also reduced the useful signal to hearing aids, and was not acceptable.

(S*ent in by Robert Higginson of AREAC, 2nd August 2007.)*

455 Switch-mode power supply emissions vary strongly with mains voltage

It's very tempting to believe the CE mark and Declaration of Conformity of a bought-in power supply, but… A power supply with active mitigation (PFC) was tested at 220V and behaved perfectly reasonably. But at the UK version of the harmonized European 230 V, actually 244 V, it drew current from only one half-cycle of the mains supply, and emitted very significant amounts of even harmonic currents and DC. This behaviour persisted down to 227 V, then the current in the 'other' half cycle gradually increased, so that at 222V the waveform was reasonably symmetrical and the second harmonic emission was very low.

This has been reported anecdotally before, but the effect is not widely known. It can be even more marked if the output current is well below the rated value. Half-wave operation is, of course, a big 'No-No' according to the standard, except under very special circumstances.

Ideally, all users of OEM power supplies should check the emissions with a power analyser, which can be much less costly than the full-specification IEC/EN 61000-4-7 instrument and gives reasonable results on fluctuating loads. But at least an observation of the input current waveform, using a current probe or low-value resistor and an isolating transformer, will detect half-waving and other misdemeanours, such as cycle-skipping, that may affect the equipment being powered, or even other associated equipment.

(Copied entire from: "John Woodgate's Column", by John Woodgate, The EMC Journal, *January 2007, pp 13-14.)*

456 EM emissions from hybrid vehicles

The results from the emission testing carried out on the seven alternative powertrain vehicles have, with one exception, been found to exceed the emissions limits as specified by 95/54/EC, CIPSR 12 and 97/24/EC. The majority of the excessive emissions correspond to vertical polarisation for broadband, and the maximum frequencies for these excessive emissions were 127MHz for broadband and 144MHz for narrowband.

Since the vehicles were tested under dynamic conditions where practicable, the vehicles may well have met the requirements of 95/54/EC when tested in the normal 'static' mode, whilst producing emissions in excess of the legislative limits when the power electronics and electrical machines are activated.

Nonetheless, the results from one of the hybrid electric vehicles demonstrate that a well-engineered hybrid electric vehicle need not present any more of a threat than conventional IC (Internal combustion) engined vehicles.

(*Extracted from* "Investigation of electromagnetic emissions from alternative powertrain road vehicles," *Alastair Ruddle, Executive Summary, MIRA report No: 01-845060, 28 May 2002.)*

457 Computer interferes with amateur radio

One investigation revealed a computer that was putting out a strong fifteenth harmonic on the two-meter amateur bands (144-148MHz). It was energetic enough that a mobile operator found that the resistivity of the coolant did not follow Ohm's law. The liquid resistivity showed an increase when the electric field was increased. This phenomenon was also observed for hydrocarbons by Kinkenberg and Van der Minne.

A more recent event occurred in January 1996 with the integration and testing of the Spacelab Multi-Purpose Experiment Support Structure (SL MPESS) carrier for the United States Microgravity Payload-3 (USMP-3) on the ST-75 shuttle mission. During the Freon flow balancing of the USMP-3 Freon system, a leak was discovered in one of the Freon flex lines. ESD was suspected and later confirmed by the Kennedy Space Center (KSC) material science division and this author.

During investigation of the Spacelab fluid line failure, another ESD failure was found on a space shuttle ground support equipment fluid line. The fluid line carried N2O4 at the fuel storage facility. The KSC materials laboratory recommended conducting fluid lines in this application.

It is hoped that this article will encourage greater awareness and that special care will be taken in the design and routing of fluid line systems in the future.

(Extracted from: "ESD in Fluid Lines: Theory and Application in the Petroleum and Aerospace Industries," Robert A Green and Robert S Axley, ITEM 1997, *pp 108-139.)*

458 ESD in fluid lines

From 1953 to 1971 over 35 accidents involving fire and explosions in aircraft during or after fuelling were attributed to electrostatic discharge (ESD). Most of these accidents involved JP-4 hydrocarbon fuel flowing through nonconductive fuel lines with TEFLON® as the hose liner. These fluid lines consisted of an extruded Teflon tube reinforced with a braided stainless steel outer jacket. Many of the ESD failures produced leaks in the hose. Fluid line leaks were also observed during the testing of the Pratt & Whitney J57P55, the Westinghouse J34WE46 and the General Electric CJ805 engines.

One failure that occurred in the aerospace industry during the late 1960's on a spacecraft launch vehicle had an interesting effect on the spacecraft. The guidance computer commanded the propulsion to shut down early, preventing the vehicle from reaching its design altitude. After extensive review of the telemetry and the systems design, it was concluded that ESD had caused the guidance computer to malfunction. The source of the ESD was researched extensively and found to be the nonconducting Freon lines which ran internal to the computer. The ESD arced through the Teflon and into the computer causing the malfunction to occur.

Laboratory experiments on this configuration were performed to verify that ESD could occur. It was discovered that it took around 20,000 volts to arc through this Teflon thickness. Also, it was found that the resistivity of the coolant did not follow Ohm's law. The liquid resistivity showed an increase when the electric field was increased. This phenomenon was also observed for hydrocarbons by Kinkenberg and Van der Minne.

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(Extracted from: "ESD in Fluid Lines: Theory and Application in the Petroleum and Aerospace Industries," Robert A Green and Robert S Axley, ITEM 1997, *pp 108-139.)*

459 Hi-tech ambulance gear goes to waste

Millions of dollars worth of communications equipment installed in ambulances nationwide has been sitting idle for six months because it interferes with radio reception.

New Zealand's 550 ambulances were fitted with mobile data terminals and automatic vehicle locators worth $3 million in November and December as part of a $16 million call-centre upgrade, which saw eight communications centres merged into three.

"Six months on, we just have these useless things sitting on the dashboards and it feels like we're operating blind half the time," said an ambulance officer who did not wish to be named. Staff were told that the units - which were meant to relay patient information - would be in place before the merger early this year, but that had not happened, the officer said.

Since the closure of communication centres in New Plymouth, Hamilton, Palmerston North and Masterton in February, all ambulance calls have been routed through Wellington, Auckland and Christchurch.

At the time of the closures, St John communication centre coordinator Tony Blaber said local knowledge on the ground would not be lost thanks to the cutting-edge technology, which would allow dispatchers to pinpoint the location of calls and direct the nearest ambulance or rescue helicopter to incidents.

Mr Blaber told The Dominion Post that during trials the screens, which accounted for $500,000 worth of the project, had been found to interfere with the quality of radio reception at the "extremities" of the signal. "For most places in the country where the radio signal is strong, there would be no problem, but for isolated pockets where it's marginal, it had a slightly degrading effect."

Trials were under way around New Zealand and upgraded screens should be in place by the end of July. Though it was disappointing that the system was not completely operational as yet, the new centres had been doing an excellent job, he said.

(Copied entirely from "Hi-tech ambulance gear goes to waste" by Ruth Hill, The Dominion Post, *Monday, 11 June 2007.)*

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

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