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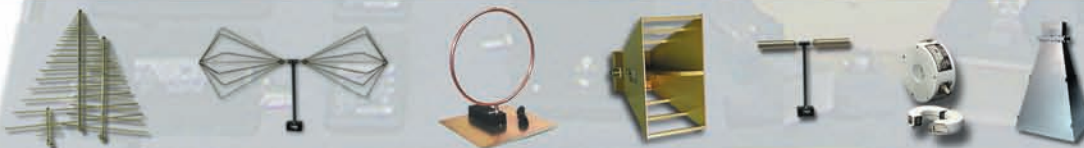
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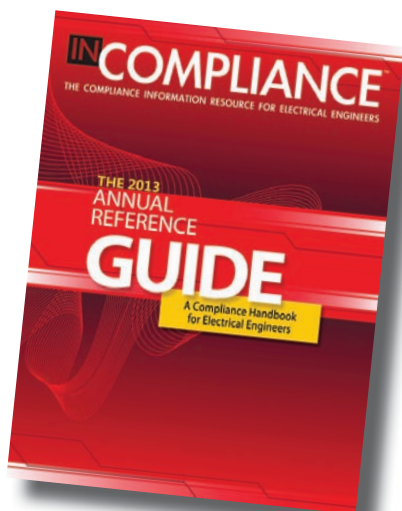
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# September 2013

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Considering EMC techniques during the design phase will minimize EMC problems and avoid disasters uncovered at EMC test time. In the typical case, where the electronic equipment is contained within a single enclosure, enclosure shielding along with cable filtering or shielding are commonly employed to meet EMC requirements. Complex systems, however, may need to be handled differently.

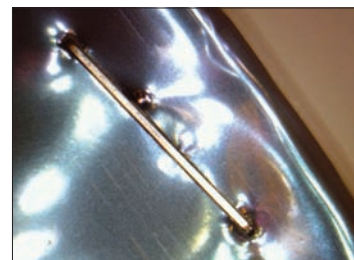
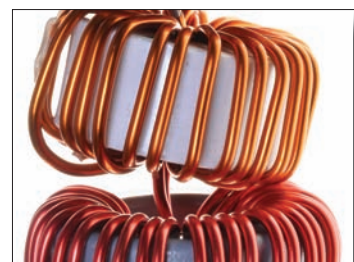
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- 42 Pin Holes & Staples Lead to Diminished Performance in Metallized Static Shielding Bags  
As early as 1985, the author recalls re-occurring discussions of the effects of puncture holes from component leads and stapling of static shielding bags.  
Bob Vermillion



## FCC News

### FCC Proposes \$7 Million Fine for Slamming/Cramming

The U.S. Federal Communications Commission (FCC) has proposed a fine of more than a \$7 million against a Florida-based telecommunications firm that allegedly changed the preferred long-distance telecommunications service of a group of consumers without authorization (a practice

to consumers as employees of their incumbent long-distance carrier. According to the Commission, "Advantage appears to have engaged in this kind of deception repeatedly."

The Federal Communications Act prohibits carriers from changing a subscriber's selection of telephone service providers without their explicit permission, or for billing them without authorization. The proposed forfeiture in this case is nearly five times the

is available at [incompliancemag.com/news/1309\\_01](http://incompliancemag.com/news/1309_01).

### FCC Releases Consumer Complaints Report for Q4 2012

The U.S. Federal Communications Commission (FCC) has released its report on inquiries and complaints made by consumers to the agency's Consumer

The FCC has proposed a fine of more than a \$7 million against a Florida-based telecommunications firm that allegedly changed the preferred long-distance telecommunications service of a group of consumers without authorization and for placing unauthorized charges on consumers' telephone bills.

known as "slamming") and for placing unauthorized charges on consumers' telephone bills (known as "cramming").

In a recent *Notice of Apparent Liability for Forfeiture*, the Commission proposed a fine of \$7,600,000 against Advantage Telecommunications Corporation of Winter Park, FL for 64 instances of slamming or cramming. In this particular instance, Advantage Telecommunications telemarketers allegedly represented themselves

amount proposed by the Commission in December 2012 against a California-based company. In that instance, the Commission proposed a forfeiture of more than \$1.4 million against Preferred Long Distance, Inc. of Encino, CA for allegedly switching long-distance telephone service for 14 consumers without authorization.

The complete text of the Commission's *Notice of Apparent Liability for Forfeiture* against Advantage Telecommunications

& Government Affairs Bureau during the quarter ending December 31, 2012.

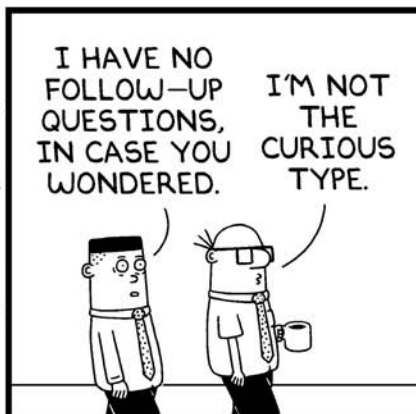
The Bureau regularly tracks inquiries and complaints from consumers on matters within the scope of the Commission's jurisdiction. In the area of wireline telecommunications matters, the Bureau is particularly interested in instances of "cramming" (the placing of unauthorized, misleading or deceptive charges on a telephone bill) and "slamming" (the practice of changing



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## FCC News

a subscriber's telecommunications service provider or calling plan without the subscriber's permission). The Commission also tracks violations of the Federal Telephone Consumer Protection Act (TCPA), which includes regulations covering both the "Do Not Call" registry and unsolicited fax advertisements.

During the period from October through December 2012, the Bureau received a total of 38,428 complaints regarding wireline telecommunication services, with 36,230 complaints (94.3% of the total) in the area of TCPA issues alone and over 2,500 complaints in connection with unsolicited fax advertisements. This represents a significant increase from the 29,638 total complaints received during the October

### FCC Approves Google TV Bands Database

The Office of Engineering and Technology of the Federal Communications Commission (FCC) has approved Google's TV bands database system for operation, in an effort to facilitate the interference-free operation of unlicensed wireless devices operating in TV spectrum bands.

Under the Commission's Part 15 rules, wireless devices that operate on unlicensed TV bands are required to reference an authorized database system to identify those channels that are available for interference-free operation. An authorized database accepts input from a device regarding

bands database system is available at [incompliancemag.com/news/1309\\_03](http://incompliancemag.com/news/1309_03).

### FCC Releases Advisory for HAC Wireless Handset Manufacturers

The U.S. Federal Communications Commission (FCC) has issued an enforcement advisory, warning manufacturers of wireless handsets to accurately report their compliance with the Commission's hearing aid compatibility rules and regulations.

The FCC requires that most wireless service providers offer a minimum number of hearing aid-compatible (HAC) handsets, so that hearing-

The FCC has issued an enforcement advisory, warning manufacturers of wireless handsets to accurately report their compliance with the Commission's hearing aid compatibility (HAC) rules and regulations.

through December 2011 period, with 26,893 (90.7% of the total) involving TCPA issues.

In the area of inquiries, the Bureau also received 7,460 inquiries in connection with wireline telecommunications, including 4,388 inquiries dealing with TCPA issues, during the period from October through December 2012. This compares with 6,072 total inquiries during the comparable period in 2011, of which 3,552 were related to TCPA issues.

The complete text of the Commission's most recent quarterly report is available at [incompliancemag.com/news/1309\\_02](http://incompliancemag.com/news/1309_02).

its specific location and then returns a list of channels available at that location for operation. In this way, the database protects authorized service transmitters from interference while facilitating the operation of unlicensed devices.

The FCC had authorized Google in early 2013 to conduct a public trial of the company's TV bands database to provide an opportunity for the Commission and the public to assess the accuracy of the results being provided by the database.

Google says that its TV band database system will contribute to efforts to free up spectrum for dynamic sharing and improve device connectivity globally.

The Commission's press release announcing its approval of Google's TV

impaired consumers are able to take advantage of wireless communications technology. The Commission monitors compliance with these rules by requiring service providers to file annual HAC status reports and to post this information on their publicly-accessible websites. Wireless handset manufacturers were required to file HAC status reports by July 15, 2013.

Failure to comply with the FCC's reporting and web site posting requirements can result in monetary forfeitures starting at \$6,000 per violation. However, forfeiture amounts can be adjusted upward based on aggravating or mitigating factors, and the Commission can issue forfeitures of up to \$16,000 for each violation, or for each day of a continuing violation, up to



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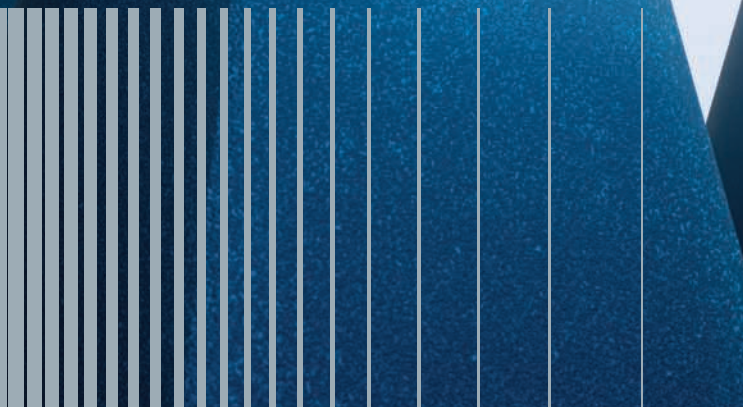
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## FCC News

a maximum forfeiture of \$112,500 for a single act or failure to act.

The complete text of the FCC enforcement advisory on HAC status reporting requirements for wireless handset manufacturers is available at [incompliancemag.com/news/1309\\_04](http://incompliancemag.com/news/1309_04).

### FCC Proposes to Allocate Additional Spectrum for AWS

The U.S. Federal Communications Commission (FCC) has proposed the reallocation of certain spectrum bands in an effort to free up additional spectrum capacity for advanced wireless services (AWSs).

spectrum bands in five megahertz blocks through a competitive bidding process. Comments on the proposed spectrum reallocation are due to the Commission by September 18, 2013.

The complete text of the Commission's *Notice of Proposed Rulemaking* is available at [incompliancemag.com/news/1309\\_05](http://incompliancemag.com/news/1309_05).

### FCC Modifies Travelers Information Station Requirements

The Federal Communications Commission (FCC) has clarified and amended its rules governing the transmission of travel-related information over low-power radio transmitters.

taken unilateral action to expand the scope of their content and operations without FCC permission, while others have attempted to remove restrictions through rule waiver requests.

In a *Report and Order* issued in July 2013, the Commission restated the limits of content to be broadcast by TISs to that which has "a nexus to travel, an emergency, or an imminent threat of danger." However, the Commission also authorized changes which "modestly expand" TIS operating parameters, including the use of multiple simulcast transmitters that can potentially reduce operating costs.

The Commission has also requested comment on a proposal to remove the requirement for filtering TIS

The FCC has proposed the reallocation of certain spectrum bands in an effort to free up additional spectrum capacity for advanced wireless services (AWSs). The FCC has also clarified and amended its rules governing the transmission of travel-related information over low-power radio transmitters.

In a *Notice of Proposed Rulemaking* issued in July 2013, the Commission proposed to license the 2155-2180 MHz band for downlink/base station operations and the 2020-2025 MHz band for uplink/mobile operations. Both spectrum bands are currently unused and available for licensing. In addition, the Commission proposed to license the 1755-1780 MHz band and the 1695-1710 MHz bands for uplink/mobile operations on a shared basis with current Federal spectrum license holders. The Commission's Notice also addresses possible technical solutions for sharing spectrum in these bands to avoid interference.

The Commission has additionally proposed to assign licenses in the above

So-called travelers' information stations (TISs) are licensed by the FCC to transmit noncommercial, travel-related information to motorists on a localized basis. TISs are routinely used to broadcast road conditions and hazards, travel restrictions and weather forecasts to motorists to help reduce traffic congestion. In some cases, TISs are also used to communicate emergency messages that could affect the immediate safety and welfare of travelers.

In addition to compliance with operating power limits, TIS operators are also restricted from transmitting commercial messages that might compete with local commercial broadcasters. However, according to the Commission, some TIS operators have

audio frequencies above 3 kHz. The Commission notes that the filtering requirement does little to improve interference protection of commercial broadcasters but significantly decreases the audibility of TIS broadcasts.

The complete text of the Commission's *Report and Order* on TIS is available at [incompliancemag.com/news/1309\\_06](http://incompliancemag.com/news/1309_06).



## European Union News

### EU Regulation Reduces Permissible Limits for Barium in Toys

The Commission of the European Union (EU) has issued a regulation immediately reducing the permissible limits of barium in children's toys.

Published in July 2013 in the *Official Journal of the European Union*, Regulation No. 681/2013 implements lower migration limits for barium to 18,750 mg/kg for scraped off material, 1,500 mg/kg for dry material, and 375 mg/kg for liquid material. The new lower limits are based on recent science on the tolerable daily intake of

barium, adjusted for the gastrointestinal absorption rate of infants and children.

The new lower migration limits for barium are now in effect.

The text of the EU Commission's Regulation on limits for barium in children's toys is available at [incompliancemag.com/news/1309\\_07](http://incompliancemag.com/news/1309_07).

### EU Commission Updates Standards List for Toy Safety Directive

The Commission of the European Union (EU) has published an updated list of

standards that can be used to demonstrate conformity with the essential requirements of its directive relating to the safety of toys (88/378/EEC).

According to the Directive, a toy is defined as "any product or material designed or clearly intended for use in play by children of less than 14 years of age." The scope of the Directive includes electric toys that are powered by a nominal voltage up to and including 24 V and requires sufficient protections for such devices to prevent the risk of electric shock and/or burns.

The most recently updated list of CEN standards for the Directive was published in June 2013 in the *Official*

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## European Union News

*Journal of the European Union* and replaces all previously published standards lists for the Directive.

The revised list of standards can be viewed at [incompliancemag.com/news/1309\\_08](http://incompliancemag.com/news/1309_08).

### EU Commission Publishes Revised Energy Labeling for Vacuum Cleaners

Continuing efforts originally begun in November 2010, the Commission of the European Union (EU) has issued new regulations regarding the requirements for the energy labeling of vacuum cleaners.

The revised energy labeling requirements were published in July 2013 in the *Official Journal of the European Union* and supplement the labeling requirements previously published in Directive 2010/30/EC regarding vacuum cleaners.

Energy labeling requirements for a variety of home appliances and electronic devices have been promulgated by the

Commission in an effort to increase consumer knowledge about the actual energy consumption of comparable household appliances, thereby creating incentives for manufacturers to improve the energy efficiency of their respective products. In recent years, the Commission has issued revised energy labeling requirements for refrigerators, dishwashers, washing machines, televisions, and air conditioners.

The Commission's revised energy labeling requirements for vacuum cleaners is available at [incompliancemag.com/news/1309\\_09](http://incompliancemag.com/news/1309_09).

### EU Sets Eco-Design Requirements for Vacuum Cleaners

The Commission of the European Union (EU) has issued a Regulation implementing new eco-design and energy efficiency requirements for vacuum cleaners.

The Regulation, which was published in July 2013 in the *Official Journal of the European Union*, is considered an

implementation measure under the EU's Eco-Design Directive, 2009/125/EC. That directive gives the Commission the authority to establish minimum efficiency standards for those "energy-related products representing significant volume of sales and trade, having significant environmental impact and presenting significant potential for improvement in terms of their environmental impact without entailing excessive costs."

The new eco-design and energy efficiency requirements for vacuum cleaners come into effect beginning in September 2014 and are detailed in Annex I of the Regulation. Annex II of the Regulation defines the methods for the measurement and calculation of energy efficiency, while Annex III details the procedures to be used by authorities in EU member states for verifying compliance with the Regulation's requirements.

The complete text of the Commission's Regulation regarding the eco-design and energy efficiency of vacuum cleaners is available at [incompliancemag.com/news/1309\\_10](http://incompliancemag.com/news/1309_10).

## You Can't Make This Stuff Up

### Happiness Barometer Aims to Lift Spirits

Lithuania is reported to be one of the 10 least happy countries in the world, according to 2012 Gallup report. But the mayor and people in Vilnius, that nation's capital, are taking the news in stride.

According to CNN, Vilnius has launched a "Smile to Vilnius" campaign to increase the level of happiness in the city. The campaign uses the recently launched "Happy Barometer"

(available at [www.happybarometer.com](http://www.happybarometer.com)) that allows citizens to record their happiness level on a scale of zero to 10. Vilnius has even erected an outdoor digital display to broadcast happiness levels in real time.

More than 5000 entries were reportedly collected during the first week of the "Smile to Vilnius" campaign, with an average happiness score of 6.1.



## CPSC News

### Sears Recalls Dehumidifiers

Sears, Roebuck and Company and Kmart Corporation of Hoffman Estates, IL have reissued their recall of nearly 800,000 Kenmore brand dehumidifiers manufactured by LG Electronics in China.

According to the companies, the dehumidifiers can overheat, smoke, melt, and catch on fire, posing fire and burn hazards to consumers. Since the initial recall in August 2012, Sears reports that it has received seven additional reports of shorting and fire associated with the dehumidifiers. The reports include one incident involving a severe burn to a consumer and three separate incidents involving fires that resulted in more than \$300,000 in property damage.

The recalled dehumidifiers were sold at Sears and Kmart stores nationwide and online at Sears.com and Kmart.com from 2003 to 2009 for between \$140 and \$220.

Additional details about this recall, including remedies available to consumers who purchased the

recalled dehumidifiers, are available at [incompliancemag.com/news/1309\\_11](http://incompliancemag.com/news/1309_11).

### Home Depot Recalls Portable Fan Heaters

Home Depot U.S.A. Inc. of Atlanta, GA has recalled more than 100,000 of its Soleil-brand portable fan heaters manufactured in China.

According to the company, the heater's plastic housing can melt, deform, and catch fire during use, posing a fire and burn hazard to consumers. Home Depot reports that it has received 464 separate reports of the heaters melting, but no reports of injuries or property damage.

The recalled fan heaters were sold exclusively through Home Depot stores in the U.S. from September 2012 through May 2013 for about \$15.

Additional details about this recall, including remedies available to consumers who purchased the recalled heaters, are available at [incompliancemag.com/news/1309\\_12](http://incompliancemag.com/news/1309_12).

### Outdoor Lanterns Recalled Due to Fire Hazard

Industrial Revolution of Tukwila, WA has recalled about 2,300 multi-purpose LED lanterns manufactured in China.

Industrial Revolution reports that the lantern's wall charger plug can fail during normal use, posing a fire and burn hazard to consumers. The company says that it has not received any reports of incidents or injuries related to the defective lanterns, but has initiated the recall to prevent possible incidents in the future.

The recalled lanterns were sold exclusively through the U.S. stores and website of outdoor retailer REI in April and May 2013 for about \$70.

More information about this recall, including remedies available to consumers who purchased the recalled lanterns, is available at [incompliancemag.com/news/1309\\_13](http://incompliancemag.com/news/1309_13).

## You Can't Make This Stuff Up

### Bug Bomb Collapse

Efforts by a New York woman to rid her apartment of bugs have apparently resulted in the partial collapse of her five-story building.

According to the Reuters News Service, the women deployed nearly two dozen "bug bombs" inside her tiny Chinatown apartment in early July. Unfortunately, fire department officials believe that the highly-flammable cloud of insecticide released

by the bombs was accidentally ignited by the pilot light in her stove or some other kitchen appliance, resulting in an explosion that caused a partial collapse of some of the building's ceilings and walls. Fourteen people were reportedly injured in the blast.

The women reported to fire officials that she had also set off 20 bug bombs in her apartment the previous day without incident. According to the Reuters report, one bug bomb per room is typically sufficient to exterminate most insect infestations.

## Is Static Electricity Static?

Walking on an insulative floor covering produces a predictable charge

BY NIELS JONASSEN, sponsored by the ESD Association

Static electricity is often considered to be the effect of electric charges at rest on insulators or insulated conductors. And this is surely true in part.

### INTRODUCTION

Associate Professor Neils Jonassen authored a bi-monthly static column that appeared in *Compliance Engineering Magazine*. The series explored charging, ionization, explosions, and other ESD related topics. The ESD Association, working with *In Compliance Magazine* is republishing this series as the articles offer timeless insight into the field of electrostatics.

Professor Jonassen was a member of the ESD Association from 1983-2006. He received the ESD Association *Outstanding Contribution Award* in 1989 and authored technical papers, books and technical reports. He is remembered for his contributions to the understanding of Electrostatic control, and in his memory we reprise "Mr. Static".

~ The ESD Association

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Mr. Static Column  
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When a nylon slip clings to the body, or when you have problems leafing through the pages of a magazine, you are witnessing a static effect of electric charges. But the buildup of charge distributions in a thundercloud or on a person walking along a hotel corridor are dynamic processes, and the possible resulting discharges can hardly be called static. Let's look a little closer at some such examples.

### CHARGING BY WALKING

The charging of a person walking on an insulating floor covering is described here in a simplified way.

The contact and friction between a person's shoe soles and the floor separate a charge  $\Delta q$  for each step. If she walks with a rate of  $n$  steps per unit of time, this corresponds to a charging current,  $i_c$ , where  $i_c = n\Delta q$ . In this way she achieves a voltage  $V$

that at first will increase with an average rate of

$$\frac{\Delta V}{\Delta t} = \frac{n\Delta q}{C}$$

where  $C$  is her capacitance. The voltage does not increase smoothly with the constant rate just given, but literally as a step function. This is further complicated by the fact that the capacitance decreases when her foot is lifted and increases again when her foot is put back down on the floor. The voltage,  $V$ , will keep increasing, but not infinitely, because the effect of the charging current will be counteracted by a decay current,  $i_d$ , given by

$$i_d = \frac{V}{R}$$

where  $R$  is the resistance from the person to ground through or across the floor covering. The voltage has reached its maximum value,  $V_m$ , when the two currents balance each other, which is shown as

$$n\Delta q = \frac{V_m}{R} \quad \text{or}$$

$$V_m = Rn\Delta q$$

Let's play a little with this equation. It is easy enough to determine  $R$ , the decay resistance for a given floor and shoe combination. The step rate,  $n$ , is, according to an ISO standard, two steps per second, that is,  $n = 2 \text{ s}^{-1}$ . The charge transferred per step,  $\Delta q$ , looks more difficult to handle, but we can estimate a reasonable upper limit in the following way.

If the breakdown field strength in the space between an elevated sole and the floor is  $E_b$ , then the maximum charge density,  $\sigma_m$ , on the sole is  $\sigma_m = \epsilon_0 E_b$ , where  $\epsilon_0 = 8.85 \cdot 10^{-12} \text{ F} \cdot \text{m}^{-1}$  is the permittivity of vacuum and approximately that of air (see Figure 1).



Hence if the area of the shoe sole is  $A$ , then the maximum charge transferred per step is  $\Delta q_{\max} = A\epsilon_0 E_b$ , and the maximum voltage will be  $V_m = nA\epsilon_0 E_b R$ .

Assuming we can consider the combination of an elevated foot and the floor's surface a pair of planar, parallel electrodes,  $E_b \sim 3 \sim 10^6 \text{ V} \cdot \text{m}^{-1}$ . The sole's area may be about  $150 \text{ cm}^2$ , depending on the shoe size of course. Entering these values into the equation for  $V_m$  (and considering their uncertainties), we find that  $V_m \sim 10^6 \text{ R}$  when  $V_m$  is measured in volts and  $R$  in ohms.

Now suppose we want to be sure that our person does not get charged to

more than 100 V by walking. The equation for  $V_m$  tells us that the decay resistance has to fulfill the condition

$$R < \frac{V_m}{\frac{10^{-6}}{10^{-6}}} = \frac{100}{10^{-6}} = 100 \text{ M}\Omega$$

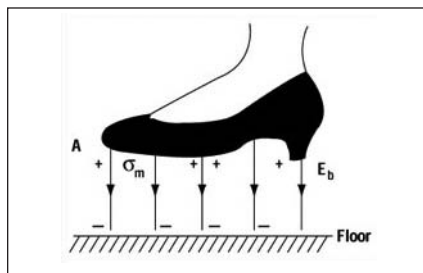


Figure 1: Maximum charge density ( $\sigma_m$ ) on the sole where  $E_b$  is the breakdown field strength between the sole and the floor

The same equation further suggests that the maximum charging current a person may produce by walking on an insulating floor is on the order of  $1 \mu\text{A}$ . Although the capacitance,  $C$ , of the person has no influence on the maximum voltage, it does, in cooperation with the decay resistance, determine the rate with which the voltage increases.

After a time,  $\tau = RC$ , the voltage will have reached (approximately) 63% of the maximum value. It can also be mentioned that the energy,  $W$ , stored electrostatically in the field of the charged person is given by

$$W = \frac{1}{2} CV^2$$

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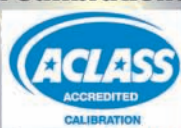
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Possibly the most important device based on static electric principles is the electrostatic filter (or simply, electrofilter) without which, for example, it would be impossible to clean the smoke from traditional power plants.

However, the effect this energy will have if discharged into the environment, on an electronic component, for instance, also depends upon the person's resistance,  $R_p$ , which may be described more or less as the resistance through the person from the location of the charge to the point of discharge.

## CHARGING OF LIQUIDS

A process somewhat similar to the one we've just described above is the flow of an insulating liquid through a tube.

Suppose a liquid is flowing with a volume flow rate of  $u(\text{m}^3 \cdot \text{s}^{-1})$  and has a specific mass  $\rho(\text{kg} \cdot \text{m}^{-3})$  and specific charge density of  $\mu(\text{C} \cdot \text{kg}^{-1})$ . The flow constitutes a current  $i_c$  given by  $i_c = u\rho\mu$ . If the liquid is collected in a conductive, semi insulated container (Figure 2) with a resistance  $R$  to ground and a capacitance  $C$ , the voltage of the container will increase toward a maximum value  $V_m$ , given by  $V_m = i_c R = u\rho\mu R$ , and the energy stored will approach a maximum value  $W_m$ , given by

$$W = \frac{1}{2} C(u\rho\mu R)^2$$

Assuming  $u = 10^{-3} \text{ m}^3 \cdot \text{s}^{-1}$  (1 liter per second or 16 gallons per minute),  $\rho = 10^3 \text{ kg} \cdot \text{m}^{-3}$ ,  $\mu = 10^{-6} \text{ C} \cdot \text{kg}^{-1}$ ,  $R = 10^{10} \Omega$ , and  $C = 200 \text{ pF}$ , we then have

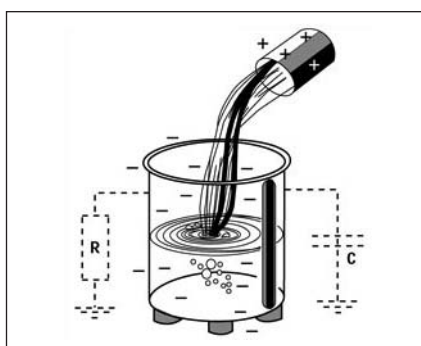
$$i_c = 10^{-6} \text{ A} = 1 \mu\text{A}$$

$$V_m = 10^4 \text{ V}$$

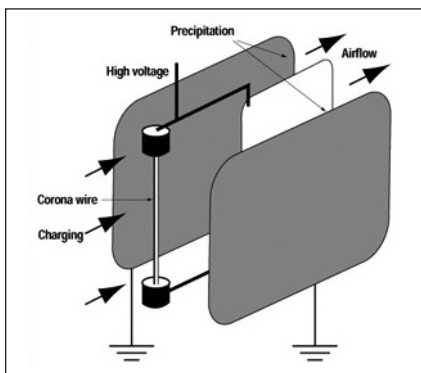
$$W_m = 10^{-2} \text{ J} = 10 \text{ mJ}$$

The maximum values of voltage will, in practice, have been reached within 10 seconds.

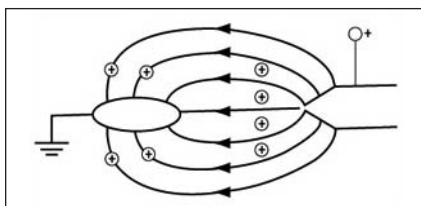
An essential difference between this process and the one of a person being charged by walking is that with the flowing liquid there is a much wider



**Figure 2: Liquid collected in a conductive, semi insulated container with a resistance,  $R$ , to ground and a capacitance,  $C$**



**Figure 3: Air passes through a region of an electrofilter where air ions are being produced by a corona discharge**



**Figure 4: Droplets leave a spray gun with a positive charge proportional to the gun's voltage**

range of charging currents. While we're not going to go into the questions of how or why the liquid gets charged in the first place, or how the charging may be affected by whether the pipe is conductive or insulative, it should be noted that the liquid must have a volume resistivity higher than approximately  $10^7 \Omega \cdot \text{m}$  for any appreciable charging to take place.

This means (among other things) that water cannot charge. Mind you, it cannot charge because of flowing. If spraying is involved, the situation is completely different. In such circumstances, probably all liquids may charge.

## THE ELECTROFILTER AND SPRAY PAINTING

Now let's turn to something completely different.

The two examples we've just discussed are both cases of what you might call "unwanted static electricity," possible causes of production problems or even explosion risks. But we must remember that static electricity has many applications, as we'll see by looking at a couple of examples that also involve a certain degree of nonstatic behavior.

Possibly the most important device based on static electric principles is the electrostatic filter (or simply, electrofilter) without which, for example, it would be impossible to clean the smoke from traditional power plants.

In an electrofilter (Figure 3), the air is passed through a region where air ions are being produced by a corona discharge. Some of the ions will attach to particles in the passing air. This

passing air is then brought into an electric field where the particles may plate out on one of the electrodes.

Whether a particle actually lands on the collector electrode depends upon the magnitude of the airflow, the field strength, and the charge on and the mass of the particle.

Obviously the larger and heavier the particle is, the more difficult it will be to pull it out of the airflow. On the other hand, the larger the particle is, the more ions may attach to it, making the deflecting force larger. An electrofilter should not be mistaken for an electret filter where the electric part of the filtering process depends primarily upon polarization forces.

Another important application of electrostatic principles is spray painting.

If a liquid is vaporized from a grounded spray gun some of the droplets formed are likely to be charged, but not in a predictable way.

If, however, the gun is held at a voltage, for example a positive one as shown in Figure 4, the droplets will leave the gun with a positive charge proportional to the field strength at the nozzle, and hence to the voltage of the gun. The charge will also be proportional (approximately) to the square of the radius of the droplet. If a grounded, conductive object is placed in front of the gun, the droplets will be deflected toward the object because of the field from the gun. By adjusting the airflow rate and the voltage of the gun, it is possible to ensure that practically all the droplets will land on the object.

Although there will be field lines “ending” on any part of the object, obviously the part facing the gun where the field is strongest will get most of the paint. However, by rotating the object to be covered, it is possible to make the

covering very uniform. It should be mentioned that the method described here is only one of a variety of surface treatments using electrostatics.

## CONCLUSION

I hope these simple examples have helped demonstrate that static electric processes often involve dynamic features. So how then can we define a static electric process? I don't believe there is a simple definition. Or rather I think there are two different types of static processes.

Obviously static electricity as traditionally defined encompasses a lot of processes that we call static, although they may have some dynamic features, like decay currents and discharges. But as the examples of the electrofilter and spray painting have shown, we sometimes call processes electrostatic even though there are no charged insulators or insulated conductors involved because the necessary fields are provided by generators with an electromotive force.

And it seems to me that what makes both types of processes static is the fact that the charge carriers are

created by the process itself, like corona ions attaching to the smoke particles in the electrofilter or paint droplets being surface-charged in the electrostatic spray gun.

I'm sure somebody will consider these distinctions too elaborate, but then let's hear a better one. Of course, we could just settle for the old saying from the high school student that static is what your dad gives you a lot of, when you don't come home until three o'clock on Saturday morning. ■

(the author)

NIELS JONASSEN, MSC, DSC, worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. After retiring, he divided his time among the laboratory, his home, and Thailand, writing on static electricity topics and pursuing cooking classes. Mr. Jonassen passed away in 2006.



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# Systems EMC in Medical Electronics

BY WILLIAM D. KIMMEL, PE AND DARYL D. GERKE, PE

Considering EMC techniques during the design phase will minimize EMC problems and avoid disasters uncovered at EMC test time. At this time, the remedial measures are usually very painful.

**I**n the typical case, where the electronic equipment is contained within a single enclosure, enclosure shielding along with cable filtering or shielding are commonly employed to meet EMC requirements.

Complex systems, however, may need to be handled differently. There may be multiple elements within the system. The equipment may require human access during operation, or there may be patient connections requiring isolation measures. There may be internal self compatibility issues. In such cases, a systems EMC approach is appropriate, addressing internal modules on a case-by-case basis: There may be an assortment of digital electronics, analog electronics, power electronics, electric motors, actuators and relays, RF heaters, lasers, and high intensity lamps.

There will always be some digital electronics, with a microprocessor and supporting electronics. Digital electronics are sources of clock emissions and are vulnerable to transients generate internally and external to the system.

There may be analog sensors connected to the patient or to internal sensors. As would be expected, the input amplifier stage is most exposed to and most vulnerable to RF sources, whether internally or from outside sources.

Power electronics may be confined to the power supply, or there may be electric motors, actuators and relays, lasers and high power lamps. Power switching will usually cause conducted emissions, but may also interfere with internal electronics. Voltage regulators are vulnerable to RFI, whether internal or external.







Effective EMC design starts with assessing the external EMC environment, then assessing sensitive and interference sources within the system, then mapping out a design approach.

Effective EMC design starts with assessing the external EMC environment, then assessing sensitive and interference sources within the system, then mapping out a design approach.

## ASSESS THE ENVIRONMENT

The first step in EMC design is to assess the EMC environment, starting with regulatory requirements (IEC 60601), and other applicable requirements (such as vehicle based equipment). There may be nearby high energy threats that pose a problem greater than that covered by regulatory standards, including MRI, diathermy, high intensity lamps, power lasers, and others.

The equipment may have internal EMC issues as well, affecting self compatibility. Power circuits, RF

sources and internally generated ESD need to be considered.

## COMPONENT EMC

In any EMC design, circuit and circuit board design is important, but usually needs to be supplemented by shielding the enclosure and shielding or filtering cables as in Figure 1. The key issues are in keeping the openings small, so as to achieve the necessary shielding effectiveness, and to filter or shield the wire entry points so that adverse energy doesn't enter or leave by wire.

Depending on the nature of the component, shielding may not be needed, but if it is needed, the openings need to be kept to less than  $1/20$  wavelength of the highest frequency threat. Filters are appropriate for power entry and audio frequency analog devices. Filtering for high speed digital may not be feasible, necessitating shielded cables.

These issues are important, and are well covered in detail in various publications. This article will discuss the overall systems aspects.

## BREAK INTO PIECES

With complex systems, we might also shield the entire enclosure and filter or shield the cables. This is certainly worthy of consideration, but it does have some limitations. First, it assumes the entire enclosure can be wrapped up and enclosed during operation, so that the only issues are regulatory in nature. But what happens if the operator must have access to some of the internal components during operation, and that there are no internal compatibility issues? What happens if we have noisy internal components degrading performance of sensitive components in close proximity?

In such a case, it may be appropriate to break the system into multiple simple elements, and handle the system as a number of simple individual elements.

First to note, the designer is free to select the boundaries of EMC control, shielding and filtering each one individually. This can be done at various places, from the entire enclosure to the chip - the key is to place a boundary between the source and the recipient of the interference. Figure 2 illustrates the two approaches. In a), we have the traditional approach, where a number of modules are contained within the enclosure. In this case, the internal modules would not be shielded. In b) we have shielded the individual modules and filtered or shielded the interfaces, as appropriate. The overall enclosure would not necessarily be shielded.

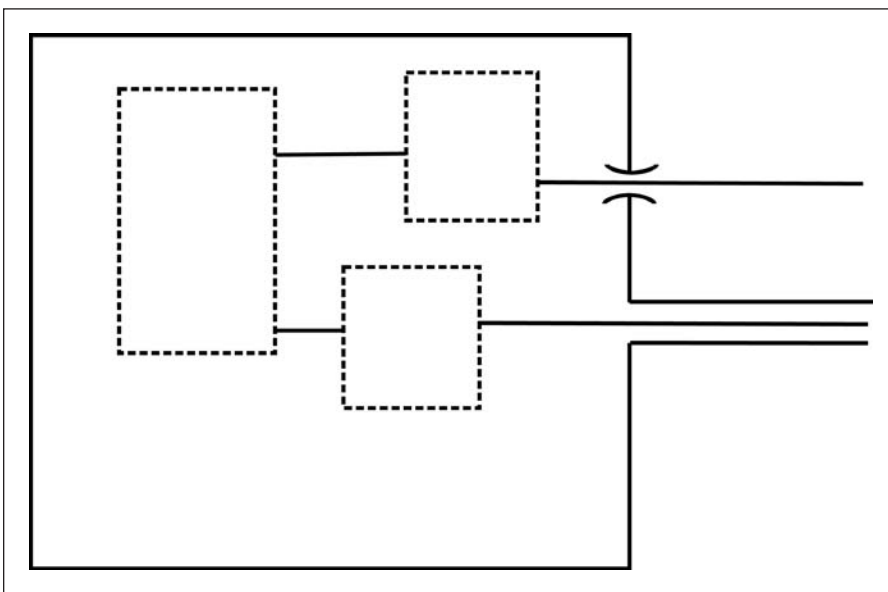


Figure 1: Illustrating the essentials of EMC control - enclosure shielding, filtering or shielding cables.

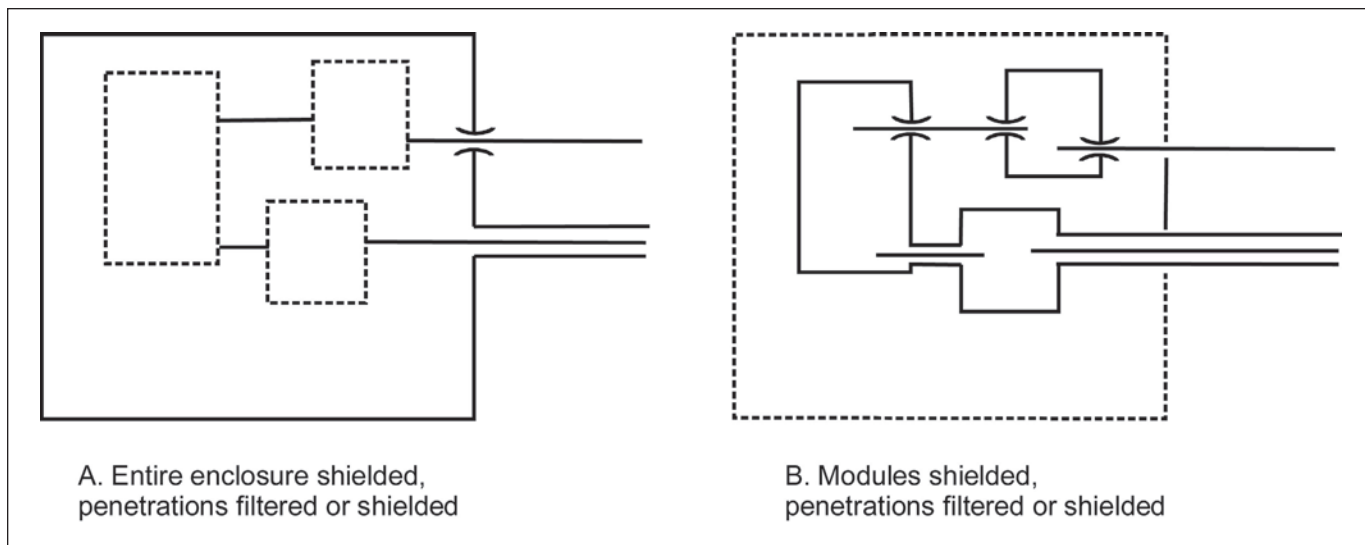


Figure 2: Shielding all or part of the enclosure

## ADDRESS EACH MODULE AS NEEDED

First order of business is to identify the threat for each module. For emissions, the usual case is periodic internal sources. Computer clocks, along with associated harmonic frequencies, constitute the primary regulatory radiated emission limits, but usually don't pose a threat to nearby electronics. Lower frequency switching power sources may be an emission limit issue, but may also pose a threat to sensitive internal electronics. These will include SMPS power supplies, VFD and PWM motor drives, florescent and high intensity lamps, relays and motor starting/stopping transients, high frequency heaters and pulsed lasers.

For immunity, low level analog input devices, notably op amps and voltage regulators, are the most sensitive. Scientific sensing devices can be very sensitive to RF interference, and patient connected devices are especially problematic, as patient isolation concerns dominate. They may be affected by external RFI sources, as cited for regulatory purposes, or by internal interference sources, notably RF heating devices. At higher levels, digital electronics will also start to become affected.

Electromechanical devices are rarely affected by interference, either locally or external, but they may well be

sources of interference. Shielding is usually not needed, as the interference tends to be low frequency conducted.

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Electrostatic discharge can be a problem to any part that is touchable by human operator or patient. Internal ESD may be generated by belts and webs.

Electrostatic discharge can be a problem to any part that is touchable by human operator or patient. Internal ESD may be generated by belts and webs.

## SELECTING THE FIXES

Once the problem areas have been identified, we need to prescribe remedial measures. Let's go through an assortment of electrical and electronics devices typically encountered.

### Electromechanical

By and large, electromechanical devices are not vulnerable to, nor do they generate much, interference in the radiated frequencies. They are substantial sources of conducted interference at conducted frequencies, notably those electronic modules sharing the same power bus.

Different electric motors interfere in various ways. Three phase, split phase and synchronous motors are about as

clean a load as you will find. Starting loads will result on a low frequency transients or voltage sags. Turnoff transients from inductive kick are high frequency transients, as characterized by the electrical fast transient (EFT). These will be primarily conductive in nature, fixable by power line filters, transient suppressers, and possibly power supply design.

Brush type DC motors, including universal motors, share the transients effects mentioned above, as is typical of heavy starting loads and inductive loads. In addition, they generate substantial brush noise - this is primarily a conducted emission issue, best handled by line-to-line capacitors across the brushes or as close to them as feasible.

Modern electronically driven motors all share a common problem - they have the starting and stopping transients as the above motors, but they also generate substantial high power

switching interference - they all provide higher efficiency at the expense of high frequency emissions. The switching frequencies are generated electronically (Figure 3) and drive substantial currents down the lines to the motors.

These include VFD, PWM and brushless DC motors. Although the frequency may vary, and may not even be constant, they all generate lots of switching noise. Motor windings pose an inductive load, tending to even out the low frequency current pulses. The high frequency switching components don't go through the windings, rather, they capacitively couple to the rotor or stator. From there, the current returns to the switching source by one or more paths, often back through the power source, creating an emission problem.

The preferred solution is to block the high frequency currents from leaving the drive electronics. Lacking that, provide a low impedance return path back to the switching source common.

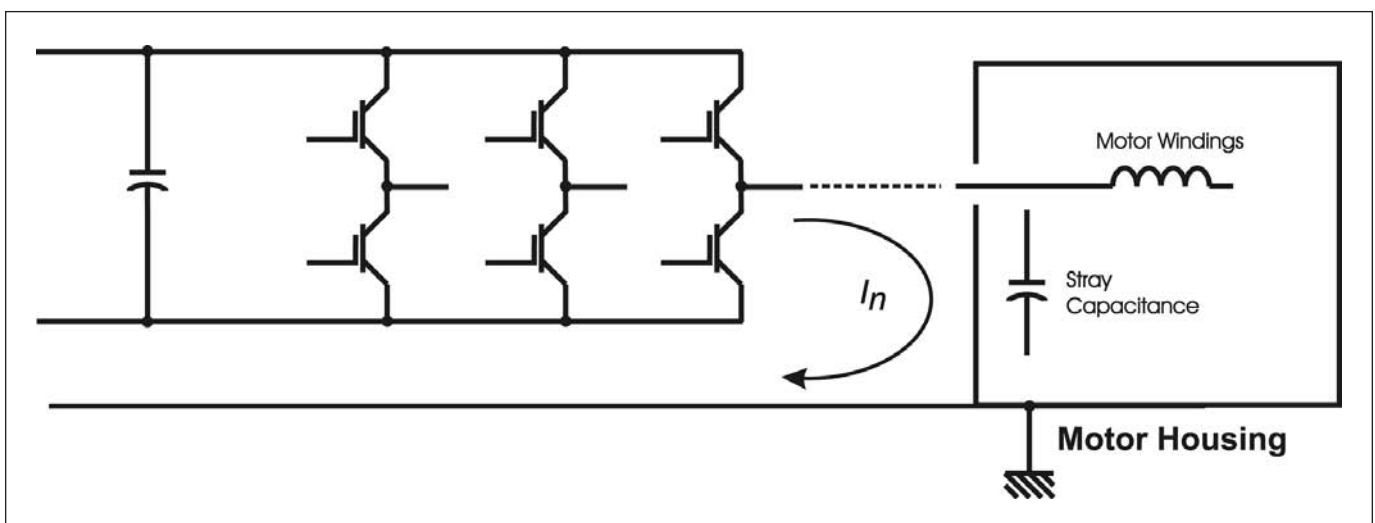


Figure 3: Power switching circuits generate substantial output noise

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Analog sensors are mostly low frequency/low level sources. As such, they are vulnerable to RF sources. Do not assume that the sensor will ignore the radio source - amplifiers looking for 10 microvolts of input signal will go nonlinear with RFI.

## Analog Sensors

Analog sensors are mostly low frequency/low level sources. As such, they are vulnerable to RF sources. Do not assume that the sensor will ignore the radio source - amplifiers looking for 10 microvolts of input signal (as for EKG and EEG) will go nonlinear with RFI which may produce volts of interference to the amplifier input, resulting in a demodulated signal.

The choices are to shield the signal path or filter the signal input to the op-amp. Cable shielding is not always achievable, but is most effective. Signal filtering is feasible for low frequencies, as there is usually ample spacing between signal bandwidth and RF sources.

Such an approach may be reasonable with diagnostic equipment, but is much more difficult to deal with patient connections. Isolation requirements restrict filtering and shielding to be terminated specifically to the isolated input area - the idea is to amplify the

weak input signal before crossing to the un-isolated area of the electronics, and that takes considerable care.

Not all analog sensors are low frequency, a particular case in point is ultrasound, operating at perhaps one MHz, and having receiving signals well below one microvolt, and carrying multiple channels. High frequency filtering is still a viable approach, for frequencies above, say, 10 MHz, but frequencies in the signal band pass cause problems. And, considering the signal strength, any stray noise is a potential threat. Unfortunately, it is not possible to shield from the input amp to the patient leads, but you have to start there - run the shield out as far as possible to block the lower frequencies and filter the higher frequencies.

In any case, it is important to keep local noise from digital and power electronics from getting into the analog section - fortunately, patient isolation pretty much forces you to do so. If you have sensitive inputs, the solution may be EMC design at the circuit board level.

## High Speed Digital

In most cases, high speed digital modules will require shielding of the card or card cage. High speed digital, notably computer clocks, will generate emission noise. These are best handled as close to the source as possible, typically with moderate filtering on the signal lines and good decoupling on the power rails. Filtering high speed signals is limited by signal bandpass - that which can't be filtered will need to be handled by shielding the enclosure, and, if you need to drive high frequencies on the cables, you need to shield the cables, as well.

Where digital signals must leave the module and cannot be filtered, the remaining option is to shield the cables from module to module. Cable shields need to be properly terminated at both ends - pigtailed and single point grounds are not allowed for high frequency threats.

Digital circuits are vulnerable to transients originating by power switching transients within or external to your system. These are mostly carried by conducted paths, either through the power feed, or by ground bounce. ESD, however, is generally propagated to the vulnerable circuit due to injection into the enclosure or to any internal members touchable by humans.

Digital circuits are not as vulnerable to RFI as analog circuits, but they can be affected if the RFI is sufficient. Modern electronics are being powered by ever lower supply voltages, and this is increasingly impacting RF immunity.

## Power Circuits

Power handling varies with the nature of the power source. Equipment

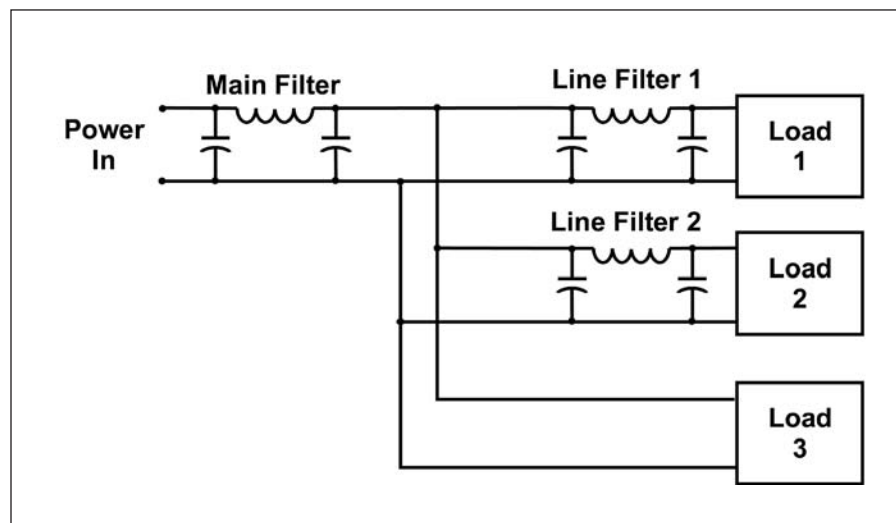


Figure 4: Schematic of cascaded EMC filters



Power handling varies with the nature of the power source. Equipment installed in a fixed location will generally be entirely AC powered. Mobile equipment may be powered by internal batteries or vehicle batteries.

installed in a fixed location will generally be entirely AC powered. Mobile equipment may be powered by internal batteries or vehicle batteries. Equipment using rechargeable batteries may or may not be operable while charging at a wall outlet. Chargers may be pulsed, necessitating testing of the charger, as well.

50/60 Hz line power presents the most common problems - both conducted emissions and immunity, but increasingly, higher frequency radiated emissions and immunity from switching power supplies is occurring.

Distribution of switched power, notably motor drives, needs to be treated, as well via the line power cord, and also to other internal circuits sharing the power bus.

In most cases, power EMC is handled with power line filtering, but where do you put the filter? For a simple system, there is essentially one module to power, with one power supply to filter. But for complex systems, there may be several internal power supplies, perhaps individually filtered, and some number of electromechanical devices that need some kind of protection. Once we have taken care of the internal compatibility problem, we may have installed some local filters and transient protection.

The first inclination is to tack on a big power line filter on the front end, and that may well do the trick. There is a possible drawback, however - stacking up power line filters may lead to unpredictable results. Even under the best circumstances, the behavior of the power line filter is somewhat unpredictable. Most off-the-shelf power filters will have shunt capacitance at both the input and output, and are tested at 50 ohms input

and 50 ohms output. For regulatory testing, the input impedance is also 50 ohms, but is uncontrolled in actual installations, creating an indeterminacy. It's worse at the load, which is also uncontrolled during test as well as in actual installation. For this reason, the manufacturer specified filter attenuation should be de-rated by at least 20 dB.

Adding some internal filtering produces the situation as shown in Figure 4. The capacitors stack up to alter the frequency response of the filter network, generally degrading the overall filter performance, and possibly

starving the power or creating an unstable condition in a power supply. This is not really feasible to predict in advance. Most internal power problems will be show up during prototyping, but may not show up until EMC testing.

Preferably, filter each module individually, then bus the power leads together with minimal filtering before exiting the system enclosure. The exit filter would preferably be a minimal high frequency filter, targeting frequencies above the effectiveness of the internal power line filters. This will minimize possible filter interaction.



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Similar situations occur with battery powered systems with the possible exception of external conducted interference - if the equipment is never operated from line power, then conducted testing is not applicable. And, of course, if the equipment is powered by a vehicle battery, then automotive or avionics conditions will apply, generally with significantly poorer power quality, especially transients.

## ENCLOSURE DESIGN CONSIDERATIONS

Once the individual modules and their interconnect have been addressed, it is necessary to turn to the enclosure and internal cabling. Much can be done to promote internal compatibility by careful design. The key issues in mechanical design is grounding, shielding and power distribution.

### Grounding

For this discussion, ground is defined as the housing for the entire enclosure. Connection to earth ground may or may not exist, but this is mostly irrelevant for EMC issues.

Ground impedance plays a key role in internal module interconnect. Modules are typically bolted down to a structural member. Often, internal EMC problems arise due to ground bounce - a shift in ground between two modules creates a signal error. Reducing ground impedance in the support members in the system can be instrumental in error reduction.

The most important aspect of enclosure ground is to conductively mate all structural members, module shields, etc., together at every possible interval. Use sheet metal planes wherever possible - wire paths are unacceptable as a high frequency ground. Mate planes together at every opportunity - holes and bends are okay (Figure 5).

Mating surfaces must be conductive - hinges, latches, screw threads and bearings are unacceptable connections.

Bolt modules directly to ground. Do not attempt to implement single point ground except where you have a low level analog input. This is difficult to do in a retrofit situation, but readily achievable during initial design.

### Power and Data Cable Routing

A significant amount of EMC problems involve crosstalk in internal power and data cabling. The worst case is tie wrapping sensitive cables with noisy cables.

Start with the basic assumption that similar signals and power are mutually compatible - the problem occurs with bundling noisy power lines with digital signal lines and either of those with sensitive analog lines. Ideally, these would be grouped into separate bundles, but this may be unrealistic for complex systems. If cables cannot be so isolated, then be alert for mixing sensitive and noisy lines - either separate the critical lines, shield selected lines in the bundle, or augment with better filtering.

Minimize daisy chaining of power lines, particularly where noisy sources share power with sensitive electronics. Avoid daisy chaining of signal lines entirely. Avoid tie wrapping power lines with signal lines.

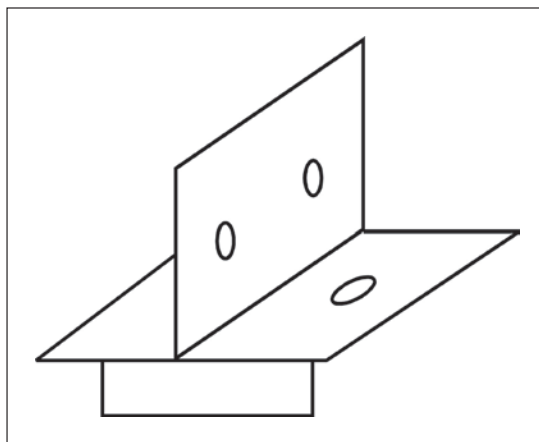


Figure 5: Low impedance grounds need not be planar

Note that crosstalk is minimized by routing cables next to a continuous ground plane, if possible, especially the critical lines. Best to put cable routing under control drawing - EMC performance can vary widely with cable placement.

Since EMC behavior is sensitive to cable position, EMC performance with uncontrolled cable routing may vary considerably from unit to unit.

## SUMMARY

Use a systems approach to handle complex medical equipment. Protect each module, then bolt them together.

Start by identifying key emitters and receptors. Find appropriate fixes for each module, including module shielding, cable shielding and signal/power filtering, as appropriate for each.

Design the enclosure, starting with a well built ground - bolt it together, no wire grounds. Route the cables adjacent to ground. ■

### (the authors)

DARYL GERKE, PE, AND BILL KIMMEL, PE are partners in Kimmel Gerke Associates, Ltd., an engineering consulting and training firm that specialized in EMI/EMC design and troubleshooting issues. Both are degreed engineers (BSEE), iNARTE Certified EMC Engineers, and registered Professional Engineers (PE).



Daryl and Bill have prevented or solved hundreds of EMI problems in a wide range of industries - computers, military, medical, industrial controls, automotive, avionics, railroad, telecom, facilities, and more. They have also trained over 10,000 engineers through their public and in-house training classes. They just celebrated 25 years in full-time practice as EMI/EMC consulting engineers. For more EMI information, visit their web site at [www.emiguru.com](http://www.emiguru.com).



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# Marking and Labeling

It is common for every marketed product to contain some type of marking—label, silkscreen, engraving, stamping, or any combination of these four. Every safety standard has a section or clause that is concerned with marking. Among these markings, a label is the one that is commonly used in most products.

BY HOMI AHMADI

Because important and even critical information—electrical rating, warning, cautionary statements or marking, or even installation instructions—is sometimes printed on a label, the standards require a minimum endurance test to be performed on the label to ensure the printed text and graphics do not smudge or disappear after many handlings. This article reviews the different aspects of labels and some of the applicable tests performed on a label.

Underwriters Laboratories (UL) is among the few National Recognized Test Laboratories (NRTL) that have a comprehensive database of different label suppliers, label materials, and label categories. Also, UL has produced UL 969, *Marking and Labeling Systems*, the Canadian equivalent of which is CAN/CSA C22.2 No. 0.15, *Standard for*

*Adhesive Labels*. Note that the Canadian standard is not harmonized with its U.S. counterpart.

Although these standards are North American based, they are respected globally. UL 969 basically describes some of the tests such as the legibility test, defacement test, adhesion test, temperature test, and exposure-to-different-agents test. UL 969 covers four categories: PGDQ2, PGJI2, PGGU2, and PGJI2.

Most product safety standards, such as UL 60950-1, *UL Standard for Safety for Information Technology Equipment Safety Part 1: General Requirements*, or UL 60065, *UL Standard for Safety for Audio, Video and Similar Electronic Apparatus Safety Requirements*, require the label on the product to be tested for endurance during the type test

*This article addresses specifically labels that pertain to safety-related information issues. Otherwise, the UL trademarks and standards explained here are not relevant.*

or qualification test. UL standards typically refer to UL 969 for matters relating to labels. IEC standards use label endurance tests as outlined below.

The endurance test is typically a simple test that involves rubbing the label surface first with a cloth soaked with water for 15 seconds and then with a piece of cloth soaked with petroleum spirit for 15 seconds. The test is said to be satisfactory if the marking is still legible and the label cannot be removed easily without any sign of curling, wrinkling, shrinkage, or loss of adhesion around the perimeter. Unfortunately this test is not very repeatable, especially if the result is marginal.

UL classifies labels in the following categories:

- PGIS2<sup>1</sup> – Marking and labeling system, limited use
- PGDQ2 – Marking and labeling systems
- PGJI2 – Printing materials
- PGGU2 – Marking and labeling systems materials

## PGIS2

This category covers label and cord tags that have been evaluated for compliance with the requirements in specific UL end-product standards where the performance requirements are different from those in UL 969. Labels in this category are intended for application to very specific products, such as Christmas tree light strings, extension cords, electrical boxes, and cabinets. These labels are typically used to provide warning instructions.

The PGIS2 category covers finished printed labels and unprinted label material used to make printed labels. This category is very limited in scope. Such labels are not recognized for general applications and have limited use.

## PGDQ2

PGDQ2 is the first label category that was developed by UL. This category pertains to a finished preprinted label and is probably one of the most popular and commonly used label categories.

PGDQ2 evaluates a system consisting of ink, label stock, over-lamination, adhesive, and more to determine if they are compatible together when exposed to various temperatures, certain environments, and when applied to various surfaces. As a general rule these labels are sold as finished printed labels. See an example of the UL PGDQ2 label requirements in Figure 1.

In this example, the Type A, B and C labels have been classified for use on different surfaces listed in the table. The label can be used as long as the label is used indoors in an environment between the maximum and minimum temperatures for each surface.

## PGJI2

This category relates to a blank label stock or preprinted stock that has been evaluated together as a system and is similar to PGDQ2 except the end-user does the printing with the compatible ribbon inks that are matched to the label stock. The vendor has the label stock tested with various ribbon inks and for application to certain surfaces while exposed to various temperatures.

Typically, the label printing machines are not specified by UL if using a thermal or mechanical method for applying the ink. PGJI2 vendors usually sell the entire system as a package consisting of the printer, ribbon, and label stock.

When printing in-house, the label must use the PGJI2 system that is compatible with the material, environment, and temperature to which it is applied. The label stock should only be used with the specific ribbon or printer called out in the UL directory. The label stock and ribbon should be identified by the vendor as specified in the UL Certifications Directory. See an example of the UL PGJI2 label requirements in Figure 2.

In this example, the label type SW200, SW300, and SW400 have all been classified for use on different surfaces listed in the table. However the end user must use ribbons/ink type B1000 and S2000 from Company X and Y when printing on label material SW200 and SW300 but can only use ribbon/ink type S2000 when printing on label material type SW400. The labels can be used indoors in an environment between the maximum and minimum temperatures for each surface.

UL ONLINE CERTIFICATIONS DIRECTORY						
PGDQ2.XYZ						
Marking and Labeling Systems - Component						
Marking and Labeling Systems - Component						
<a href="#">See General Information for Marking and Labeling Systems - Component</a>						
Company XYZ Corp. 1000 Washington Ave. USA						
Model No.	Application Surface	Max Temp (°C)	Min Temp (°C)	Indoor Use	Outdoor Use	Additional Conditions
Pressure-sensitive printed labels.						
A, B, C						
	Acrylonitrile butadiene styrene	80	-40	X	-	-
	Aluminum	80	-40	X	-	-
	Galvanized steel	80	-40	X	-	-
	Nylon - Polyamide	80	-40	X	-	-
	Polycarbonate	80	-40	X	-	-
	Polyethylene	80	-40	X	-	-
	Polyphenylene oxide/ether	80	-40	X	-	-
	Polypropylene	80	-40	X	-	-
	Polystyrene	80	-40	X	-	-
	Stainless steel	80	-40	X	-	-

Figure 1: PGDQ2 Classification Example

1 May not necessary comply with UL 969



## PGGU2

This category is limited to the individual parts of a system, such as over-lamination material, adhesive, or blank label stock excluding ink.

This category would be utilized by the label manufacturer in putting together a system. These products are usually sold to the label manufacturer in blank form for the purpose of creating printed label. One of the main benefits of this category is that the label print manufacturer, or the end-

product manufacturer who purchases these recognized materials, can receive the benefit of approvals such as temperature, surfaces, or exposure conditions for which the materials have been tested.

## PGAA

This category refers to the “Authorized Label Suppliers Program” and deals with printing and/or distribution of the UL certification marks. This serves to inform the user that UL has authorized the label manufacturer to

print the UL logo and other UL logo variations, such as control number or product category. Only the suppliers in this category are authorized to print labels with the UL mark.

This category gives the label manufacturer the legal authority to reproduce the UL trademark and does not concern itself with the label material. Labels in this category must only be distributed only to authorized customers.

## LABEL TYPES

Underwriters Laboratories has two categories of label that falls under its Follow-up Services:

- Type L labels
- Type R labels

### Type L Labels

Type L is primarily intended for life safety products and products where manufacturing quality control is more of a safety issue. Another type of product that requires type L is those products where there are many variables in the manufacturing such as cables.

The process for obtaining each types of label is different. For type L, the manufacturer sends a label purchase order to an authorized supplier and sends a copy to UL. UL requires review of the UL Mark layout for UL Marks that have not been previously ordered.

UL's Label Center issues a UL authorization order to the supplier with the UL Mark layout, serial, or issue numbers, quantity to print, and shipping instructions. A copy of the authorization is also sent to the manufacturer. The authorized supplier prints the UL Marks and sends them as specified by UL on the authorization order.

UL ONLINE CERTIFICATIONS DIRECTORY						
PGJ12.ABC Printing Materials - Component						
Printing Materials - Component						
See General Information for Printing Materials - Component						
Company ABC Corp. 123 High Street USA						
Label materials suitable for additional printing using one or more of the following inks.						
Inks						
1 - Company X, Ltd. "B1000" thermal transfer ribbon.						
2 - Company Y, Ltd. "S2000" thermal transfer ribbon.						
Pressure-sensitive systems:						
Model Dsg.	Application Surface	Max Temp (°C)	Min Temp (°C)	Indoor Use	Outdoor Use	Additional Conditions
Unprinted stock dsg: SW 200 Printed label dsg: SW 200 Inks: 1, 2						
	Aluminum (AL)	125	-23	X	-	-
	Epoxy paint (EP PT)	125	-23	X	-	-
	Galvanized steel (GS)	125	-23	X	-	-
	Stainless steel (SS)	125	-23	X	-	-
	Acrylonitrile butadiene styrene (ABS)	80	-23	X	-	-
	Polystyrene (PS)	80	-23	X	-	-
Unprinted stock dsg: SW 300 Printed label dsg: SW 300 Inks: 1, 2						
	Stainless steel (SS)	125	-23	X	-	-
	Acrylonitrile butadiene styrene (ABS)	80	-23	X	-	-
	Polystyrene (PS)	80	-23	X	-	-
Unprinted stock dsg: SW 400 Printed label dsg: SW 400 Inks: 2						
	Aluminum (AL)	125	-23	X	-	-
	Epoxy paint (EP PT)	125	-23	X	-	-
	Galvanized steel (GS)	125	-23	X	-	-
	Stainless steel (SS)	125	-23	X	-	-
	Acrylonitrile butadiene styrene (ABS)	80	-23	X	-	-

Figure 2: PGJ12 Classification Example

There may be cases when a manufacturer selects a label type and material that does not come from any of the label categories. In such scenarios the label may be evaluated as an unlisted component and the end product standard also plays a role.

The UL Label Center normally checks the label network for three main elements:

- Appropriate UL symbol/logo
- Product name (I.T.E, A/V, etc.)
- Four-character control number

It is recommended that the manufacturer supply a copy of the label artwork to the UL engineer responsible for the project who can further advise on other label contents, such as electrical rating, cautions or warnings, model numbers, and so on.

For Type L labels, serial numbers issued by UL are associated with specific locations. If a manufacturer is producing the same product in more than one location, each facility will receive its own labels with dedicated serial numbers.

Follow-Up Services (FUS) base their inspections on the quantity of the labels that are ordered. That is, if the quantity of the labels is high, it will result in more frequent visits by the FUS group.

**NOTE: Due to the changing issue/serial numbers that are controlled by UL, each order for Type “L” Marks must be authorized by a UL Label Center.**

## Type R Labels

Type R labels are the more common of the two. The manufacturer submits the label artwork to the local UL Label Center. UL reviews the UL Mark design and provides an approval stamp if the layout is acceptable. The manufacturer provides a stamped UL Mark layout to the supplier for printing of the UL Mark. The authorized supplier prints

Type “R” UL Marks and sends them directly to the manufacturer. In some case the manufacturer can print in-house if he has the appropriate label stock and ink.

The UL Label Center normally checks the label network for three main elements:

- Appropriate UL symbol/logo
- Product name (I.T.E, A/V, etc.)
- Four-character control number

It is recommended that the manufacturer supply a copy of the label artwork to the UL engineer responsible for the project who can further advise on other label contents, such as electrical rating, cautions or warnings, model numbers, and so on.

**NOTE: Future orders may be placed directly to the supplier as long as the composition of the UL Mark elements does not change from the UL authorized stamped drawing.**

## CONCLUSION

In summary, when selecting a label, the following points need to be considered:

1. Application of the label
2. Follow-up services traceability

In the first case, one would need to consider the surface to which the label is being applied to, the temperature and climatic condition to which it will be exposed, and finally the appropriate UL category. If selecting PGJ12, it is important to ensure that the compatible ribbon is selected.

In the second case, it is important that adequate traceability is in place for UL Follow-up Services. This means that the label packaging/spool should have the original material manufacturer brand name or trademark and material type designation printed on it. For PGJ12, in addition to these two items, the UL recognition mark must appear on the spool or packaging. Basically the UL identification on the product should agree with the individual vendor's recognition in the UL Certification Directory.

There may be cases when a manufacturer selects a label type and material that does not come from any of the label categories. In such scenarios the label may be evaluated as an unlisted component and the end product standard also plays a role. ■

(the author)

### HOMI AHMADI

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Henry W. Ott is President and Principal Consultant of Henry Ott Consultants ([www.hottconsultants.com](http://www.hottconsultants.com)), an EMC training and consulting organization. He has literally "written the book" on the subject of EMC and is considered by many to be the nation's leading EMC educator. He is the author of the popular EMC book Noise Reduction Techniques in Electronic Systems (1976, 1988). The book has sold over 65,000 copies and has been translated into six other languages. In addition to knowing his subject, Mr. Ott has the rare ability to communicate that knowledge to others.

Mr. Ott's newly published (Aug. 2009) 872-page book, Electromagnetic Compatibility Engineering, is the most comprehensive book available on EMC. While still retaining the core information that made Noise Reduction Techniques an international success, this new book contains over 600 pages of new and revised material.

Mr. Ott is a Life Fellow of the IEEE and has served the EMC Society in various capacities including: membership on the Board of Directors, Education Committee Chairman, Symposium Committee Chairman and Vice President of Conferences. He is also a member of the ESD Association and an iNARTE certified ESD engineer. He is a past Distinguished Lecturer of the EMC Society, and lectures extensively on the subject of EMC.

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# Facility Power Filters: Symmetric vs. Asymmetric Performance

Asymmetric filter designs are gaining popularity in industry because of their lower cost and size, however, although this design is successful in eliminating common mode signal issues this paper will show that for certain applications such as TEMPEST these filters offer little to no protection. Symmetric filters, although physically larger and more costly due to the use of more components, provide better filtering in these applications.

BY SERGIO N. LONGORIA

Facility power filters are used in combination with shielded enclosures to offer an environment free of conducted and radiated signals. This combination of shielded enclosure and facility filter is also useful in keeping radiated and conducted emissions from escaping the enclosure as is the case in many defense and military TEMPEST applications. Conducted signals into a shielded enclosure can appear in conductors in symmetrical mode and to a lesser extent in asymmetric mode or, as they are also known, differential mode (DM) and common mode (CM) respectively. All conductors entering or exiting a shielded enclosure must be filtered in order to prevent signals from passing to the other side [1]. But in order to reduce the size and cost of a facility power filter, many filter manufacturers offer asymmetrical filters with little or no symmetrical performance. The CM filter became popular in the electronics

industry as a way of preventing high frequency RF from radiating through the connected power cords. However, there are applications in which the CM filter is not indicated.

Such applications include shielded chamber facility power filters, where low RF frequency rejection for EMC, TEMPEST or HEMP applications is necessary. Since the filtering effort is focused on reducing the amplitude of the unwanted signals, we begin by showing the amplitude of a typical sine wave,

as shown in Figure 1, to represent a signal appearing at the input of a filter. But as mentioned before, signals can appear as symmetric or asymmetric.

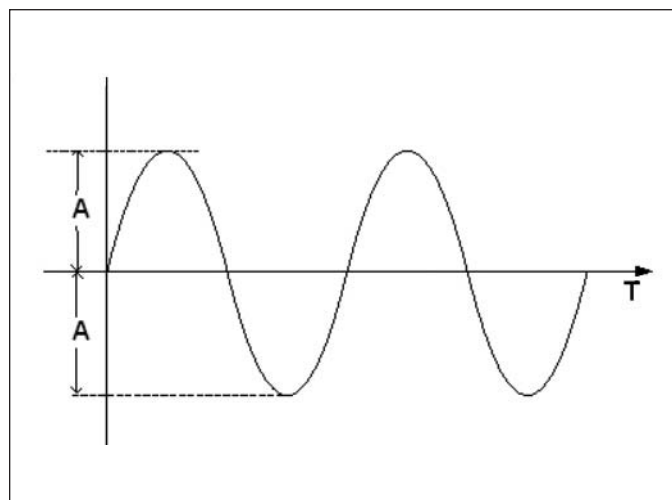


Figure 1: Amplitude of a signal

The symmetrical (differential) signals are those signals that can appear differently in any one of the filtered conductors going into a chamber and are referenced to ground.

## SYMMETRICAL AND ASYMMETRICAL SIGNALS

The symmetrical (differential) signals are those signals that can appear differently in any one of the filtered conductors going into a chamber and are referenced to ground. Consider a filter with two conductors as in Figure 2.



Figure 2: Two conductor filter

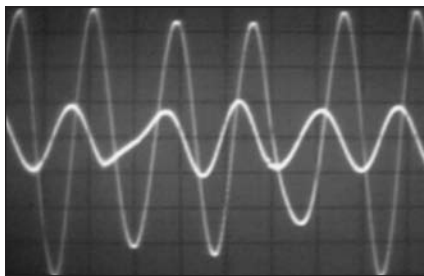


Figure 3: Symmetric (Differential) mode: Different signals appearing at each terminal of a filter and shown together for comparison.

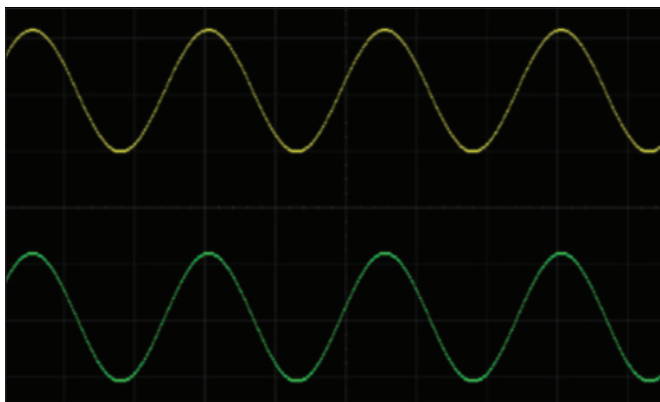


Figure 4: Assymmetric (Common) mode: Same signals appearing at each terminal of a filter and shown separately for comparison.

If the signals appearing at the terminals of the filter are different as the ones shown in Figure 3, then the signals are in symmetrical form.

Asymmetrical (common mode) signals are those that appear equally at the same time and in the same direction on all the conductors going into a filter in a shielded enclosure. These signals use the ground as a return path and all other conductors carry the signal into the enclosure in the exact same proportion. If the signals present at each terminal are exactly the same as in Figure 4, then the signals are said to appear in asymmetrical or common mode [2].

Now that we have defined the two types of signals that may be present in conductors, let us now consider the types of filters used to remove these signals.

## SYMMETRIC FILTERS

Symmetric filter designs (SFDs) consist of discrete inductive and capacitive elements arranged in such a way so as to remove unwanted signals from a particular conductor. Inductors provide

a high series impedance to unwanted signals. Capacitors work in an opposite manner and short unwanted signals to ground; they provide a low impedance path for high frequencies. Together they provide attenuation to unwanted signals appearing on those conductors [1]. These components are not shared with any other elements in another conductor. Consider Figure 5 and notice the distribution of components along the line to load of current flow. This current flow does not interact with the current flow of the second line of a two line filter, in other words, each filtered line is independent of each other. The inductor of a symmetric filter has one line coming in and one line coming out as shown in Figure 6.

Figure 7 shows what an actual symmetric filter looks like with independent component lines for filtering of each power line coming in. A typical procurement specification for facility power filters for use in EMC, defense, and military specify that, "Each filter unit (insert) shall be capable of being mounted individually... and shall include one filter for each phase conductor of the power line and neutral conductor." [1]

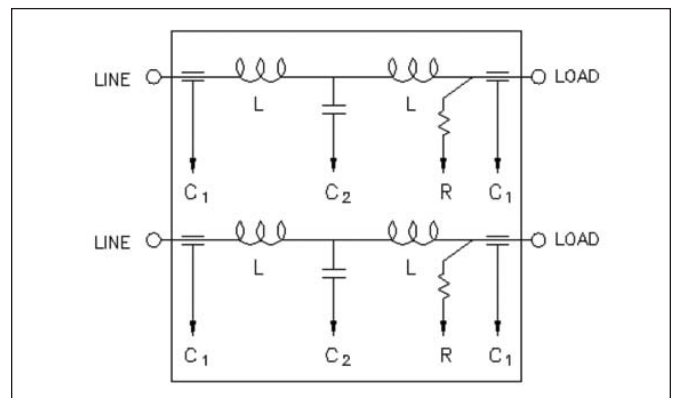


Figure 5: Schematic of a symmetric filter, each line independent of each other



Asymmetrical (common mode) signals are those that appear equally at the same time and in the same direction on all the conductors going into a filter in a shielded enclosure.

One would expect, as the name implies, that a symmetric filter can remove symmetric signals, but as an added benefit a symmetric filter can also remove asymmetric signals. The reason for this may not be too obvious. But let's take one filter line at a time.

Here, there is one signal and one filter line as in Figure 8. The filter line removes any unwanted signal

regardless of amplitude or shape and does not see or care about what is present in another line. A second filtered line may be seeing the exact same signal or a different one, but because each signal is being dealt with independently, all unwanted signals present will be removed as shown in Figure 9. SFDs reject asymmetric mode signals by default. This is because each line of the differential filter will be

equipped with the discrete elements necessary to remove signals present in those conductors whether they are common mode or differential mode.

A filter can be tested for either symmetrical or asymmetrical performance. Meaning that a particular filter can be tested to see how well it removes symmetric or asymmetric signals. This is done by injecting into

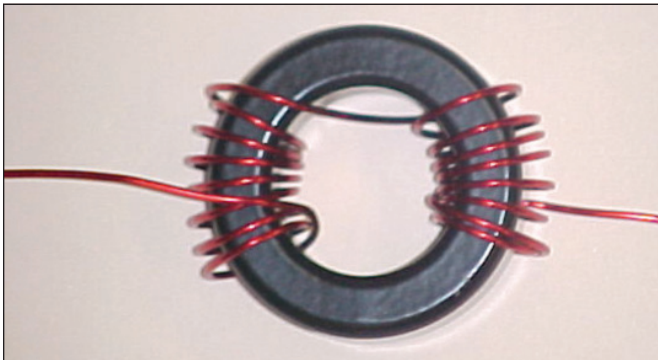


Figure 6: Symmetric inductor

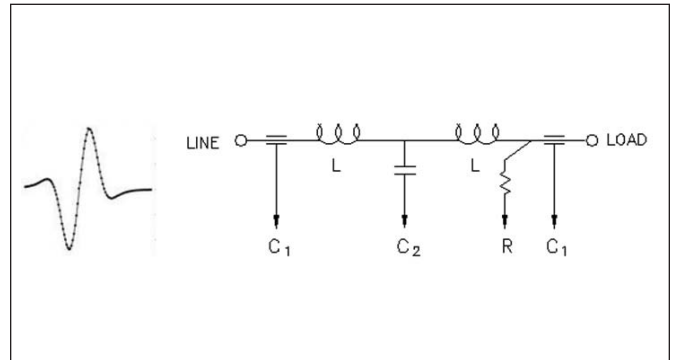


Figure 8: Filter element removing ANY signal from line



Figure 7: Showing two versions of an actual filter with independent filtered lines

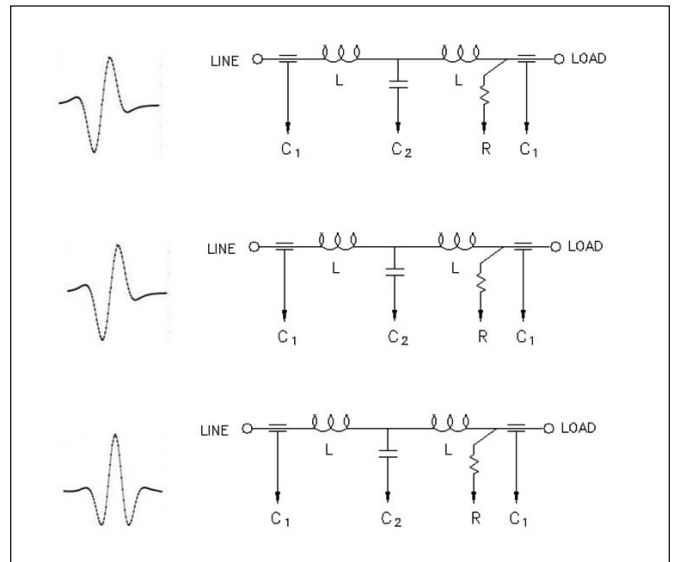


Figure 9: Different (symmetric) signals or same (asymmetric) are removed by independent filtered elements in each line (symmetric filter) regardless of type of signals present.

Symmetric filters are typically bigger than asymmetric filters because each line must have individual inductors, which also makes them more expensive. Symmetric filters also dissipate more power than asymmetric filters of the same capacity.

the filter signals that are different on each conductor or signals that are the same on each conductor, as would be expected. The graph in Figure 10 illustrates that a symmetric filter can remove both types of signals.

SFDs are especially useful in environments where the signals present are chaotic and unpredictable and may arrive in different amplitudes, phases and shapes. Another very useful aspect of this type of filter is that it can be used to remove signals of very low frequencies. EMC testing, such as that found in standards like MIL-STD-461 and -462, requires a quiet RF environment down to 9 kHz. Military and defense applications, in particular, often cite TEMPEST requirements for their shielded facilities and these include low frequency filtering. TEMPEST

requirements typically mandate high levels of attenuation (removal) of low frequencies as far down as 14 kHz or even 9 or 10 kHz [1]. Symmetric filters are not only well-suited for use in these environments, but are the only choice given some of the short comings of asymmetric filters.

Symmetric filters are typically bigger than asymmetric filters because each line must have individual inductors, which also makes them more expensive. Symmetric filters also dissipate more power than asymmetric filters of the same capacity. Asymmetric filters share inductor cores with other lines, reducing needed space and cost. But one must keep in mind that saving on size, cost, and power dissipation is not a bargain if used on the wrong application. Asymmetric filters should not be

used on EMC, TEMPEST or HEMP applications.

## ASYMMETRIC FILTERS

Asymmetric filter designs (AFDs) also consist of inductive and capacitive elements as shown in Figure 11, but arranged such that the lines share the inductor core removing unwanted signals only when they appear in asymmetric or common mode.

Consider the inductor of a two line filter as in Figure 12. It can be seen that the two lines of the filter are made to pass through the inductor core and thus sharing the core between the lines. This has the beneficial effect of being able to leverage the flux cancelling effect of such arrangement and lower the core losses. That is, as current flows in one wire in one direction the other wire has current flowing in the opposite direction. This has the effect of cancelling the magnetic flux generated by the flow of current and the core operates at lower losses.

When the signals appear differently, as is the case when power goes into the inductor and out through the other line in opposite direction (see Figure 13), the inductor does not present a significant opposition to the signals and they pass right through the inductor [2].

While this is beneficial at power frequencies, it is not so with other signals present in the lines. Essentially, the inductor looks like a very small inductor when symmetric signals are present and only appears like a huge inductor to asymmetric signals. A smaller inductor in terms of capacity allows for signals to go through while a big inductor stops low frequencies.

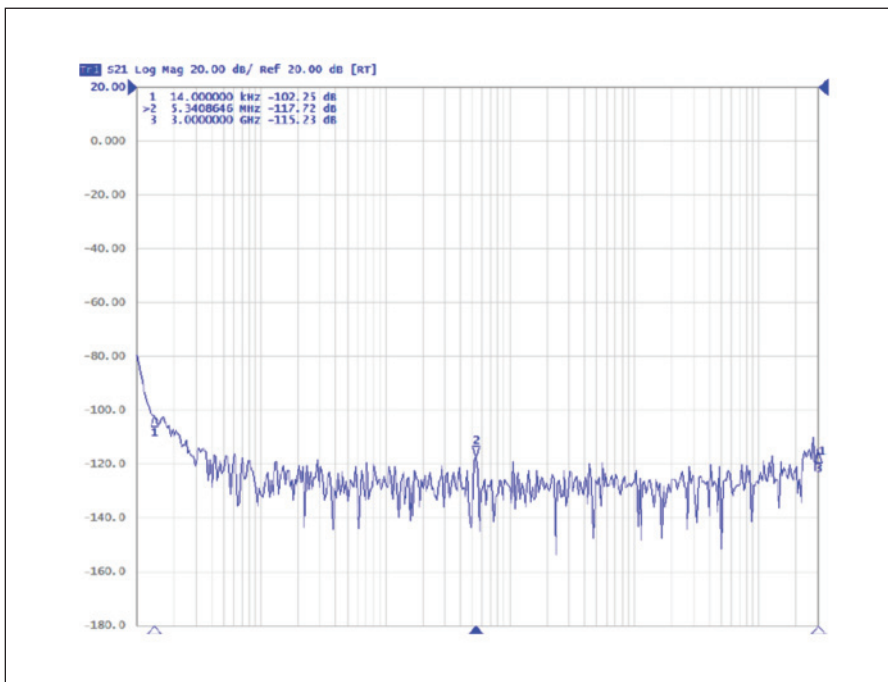


Figure 10: Showing a symmetric filter tested for both symmetric and asymmetric performance producing the same response

Asymmetric filters share inductor cores with other lines, reducing needed space and cost. But one must keep in mind that saving on size, cost, and power dissipation is not a bargain if used on the wrong application.

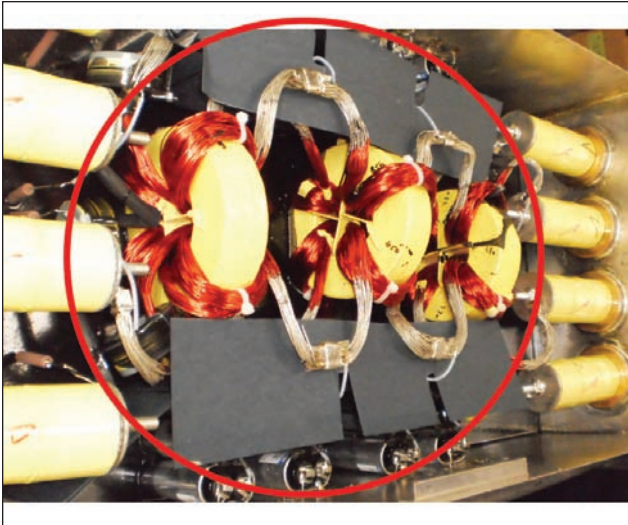


Figure 11: Asymmetric filters share inductors between lines

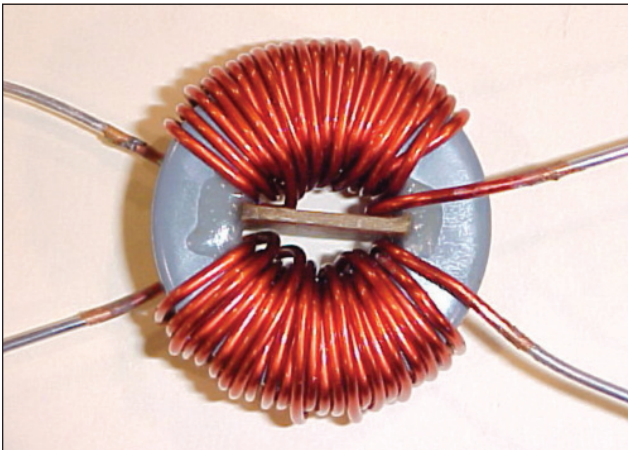


Figure 12: Asymmetric Inductor (two or more lines through it)

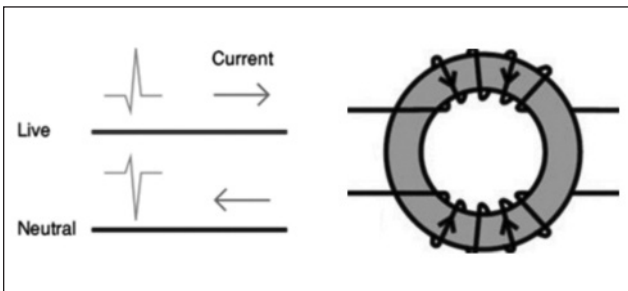


Figure 13: Power signals appearing differentially in a common mode core.

This can be seen clearly when measuring an asymmetric filter for symmetric (DM) and asymmetric (CM) performance as in Figure 14.

The common mode filter is mainly used in low amperage electronic circuitry to eliminate radiated emissions caused by electronic components and their layout. Equipment needs to meet radiated emissions mandated by EMC standards and thus much of what is found in equipment such as computers, televisions and other commercial electronic items are common mode filters. But when it comes to industrial, military or other applications where a high degree of attenuation to unwanted signals is needed, symmetric filters are the right choice.

As previously stated symmetric filters are typically bigger than asymmetric filters, making them more expensive; because as we have seen, symmetric filters do not share inductor cores which would reduce space. We also stated that symmetric filters also dissipate more power than asymmetric filters of the same capacity. But there are other issues with the use of asymmetric filters, such as the need for an electrically balanced system and paralleling considerations.

In AFDs not only must the signals to be rejected appear the same at the filter's input, but the power current in which the filter operates must be balanced. Consider a three phase system, for example. The loads on each phase must be the same in order for the asymmetric filter to operate normally. Any imbalance in

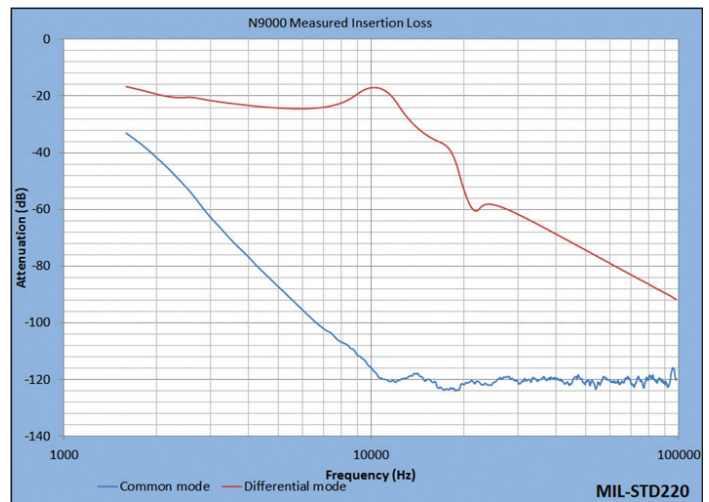


Figure 14: Comparison between CM and DM performance of an asymmetric filter



When using asymmetric filters, the assumption is made that any radiated RF would couple equally and balance into all conductors at once. But in real life no two signals are ever identical or perfectly balanced.

the system will cause added heat to the common core, reducing the life of the filter and significant loss of rejection and HEMP protection capabilities.

Paralleling asymmetric filters to obtain higher amperage lines requires a tandem paralleling schema which increases cable lengths and contributes to the appearance of symmetric signals in the lines and can potentially

imbalance the system. Symmetric signals then would get through the filter. All these factors make paralleling an asymmetric filter an undesirable solution. A symmetric filter can be paralleled more easily and will not suffer from imbalance or rejection performance issues. Each element can be paralleled adjacent to another and matched accordingly with no detrimental effects in the system.

## FILTERS FOR TEMPEST AND HEMP

The term TEMPEST is often used for the field of emission security. The term TEMPEST is a codename to secure government and military electronic communications equipment from potential eavesdroppers that could intercept and interpret those signals. There are some guidelines on how to achieve TEMPEST protection for an installation. These include the shielding effectiveness of a chamber containing sensitive equipment and the insertion loss (attenuation) of the filters in the conductors coming in and out of such chambers. While the levels and degrees of protection may vary according to the threat level the majority of U.S. military and government installations use NSA 65-6/94-106 when specifying the required degree of protection [1]. This states that all conductors into a chamber should be attenuated 100dB from at least 14 kHz as seen in Figure 15.

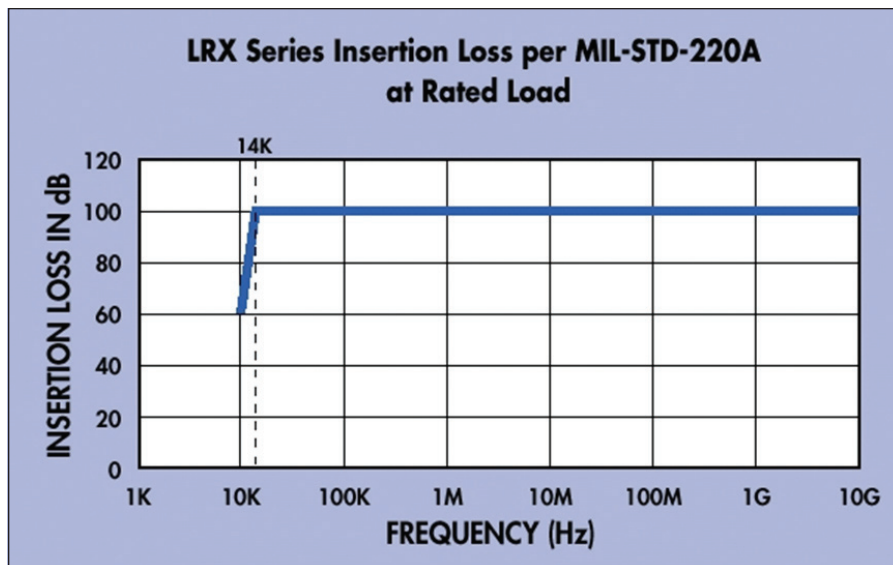


Figure 15: TEMPEST requires that all lines in or out of a facility meet a high degree of attenuation (insertion loss).

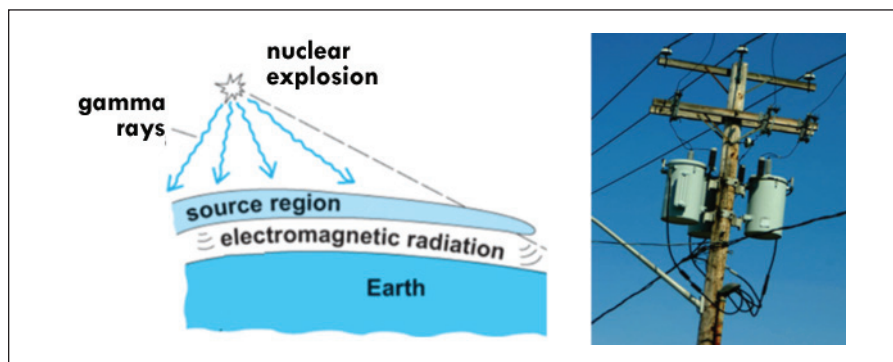


Figure 16: Coupling or electromagnetic energy from an EMP depends on many unpredictable factors.

When using asymmetric filters, the assumption is made that any radiated RF would couple equally and balance into all conductors at once. But in real life no two signals are ever identical or perfectly balanced and any imbalance in a system carrying common mode signals can create a voltage difference between the conductors giving rise to differential signals. And as we have discussed above, a common mode inductor would allow passage of differential signals. If such TEMPEST system relies on asymmetric only filters, or ones with very little symmetric attenuation, the result would be that these signals would pass through into (or out of) the enclosure. As can be seen this is a significant problem in defense and military TEMPEST applications in which the coupling of signals in

Any imbalance in a system carrying common mode signals can create a voltage difference between the conductors giving rise to differential signals. And a common mode inductor would allow passage of differential signals.

the inside of a shielded enclosure is rather chaotic and unpredictable and can be present in both symmetric and asymmetric forms. In such cases, filters should be able to reject both symmetric and asymmetric signals.

Banking on the remote chance that a High-Altitude Electromagnetic Pulse (HEMP) will arrive equally on all power lines (see Figure 16) seems unwise. As we have seen, AFDs depend upon signals arriving equally on its inputs to be able to reject those signals. That signals will arrive just right for an asymmetric filter to stop them is highly unlikely given atmospheric conditions, propagation of the wave, number of electrons released, distance between power lines, etc. In HEMP applications, the EMP will arrive chaotically and unpredictably at the Points of Entry (POE). Filters should be able to reject symmetric signals. If asymmetric only filtering is used, not only will the signals get through, but these unpredictable signals (some of which could be of very high amperage) could cause an imbalance in the common core of the asymmetric filter which would lead to instantaneous saturation of the core(s) and total loss of protection to any form of electromagnetic energy.


## CONCLUSION

It has been shown that symmetric (differential mode) and asymmetric (common mode) signals are different types of signals that may be present in conductors. It is also clear that these may be removed by using symmetric filters. It is been demonstrated that asymmetric filters can only remove asymmetric signals. While asymmetric filters are generally physically smaller and less expensive (due the reduced number of components) than the symmetric filters, the use of asymmetric

filters must be very carefully evaluated or unwanted differential mode signals may inadvertently pass through the filtering network and compromise overall system performance.

A critical point is that filters designed to reject symmetric noise can also reject asymmetric mode signals by default. Unfortunately AFDs can only remove common mode signals due to the sharing of components between lines, which offers very little if any symmetric attenuation. This is why AFDs only come in packages of one box with terminals whereas differential mode filtering may also be offered as discrete individual filter (inserts) elements. That is, the differential filter does not need to share a reactive core with other lines in order to remove unwanted signals, and thus can be packaged in individual lines as in Figure 7 above. The packaging issue brings up the fact that in the

event of a filter system failure, replacing symmetrical filters is much more cost effective than removing an entire three phase filter box after one line has suffered damage. In addition, the down time of replacing one element is much less than that of replacing an entire asymmetric unit.

Table 1 illustrates the recommended uses for symmetric and asymmetric filters. 

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	Symmetric Filter Designs	Asymmetric Filter Designs
Tempest	Yes	No
Tempest/HEMP	Yes	No
HEMP/IEMI	Yes	No
Common mode	Yes	Yes
Differential mode	Yes	No
Accepts Unbalanced loads	Yes	No
Easy parallelization	Yes	No
Easy to replace filter elements	Yes	No
Reduced down time after failure	Yes	No

Table 1

(the author)

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# Pin Holes & Staples Lead to Diminished Performance in Metallized Static Shielding Bags

BY BOB VERMILLION, CPP/FELLOW  
CERTIFIED, ESD & PRODUCT SAFETY ENGINEER-INARTE

As early as 1985, the author recalls re-occurring discussions of the effects of puncture holes from component leads and stapling of static shielding bags.

In July 2013, the ESD Experts page on LinkedIn® started a discussion by a USA computer manufacturing company that generated participation from end users, suppliers and consultants both here and abroad. In years past, some held opinions that pin holes do not greatly affect static

shielding of metallized bags. There is, however, minimal published data to fall back upon regarding this subject matter. One major factor influencing Type III (Mil-PRF-81705E) or a Level 3 (ANSI/ESD S11.4) ESD shielding bag constitutes fracturing of its thin metallized vacuum deposited layer.

Excessive wear and pin holes from leads of circuit cards pose risks. The size and magnitude of the pin holes determine bag attenuation from a high voltage discharge. In Figure 1, left, the reader will observe through hole (“thru-hole”) components and a single microscopic puncture to the right.

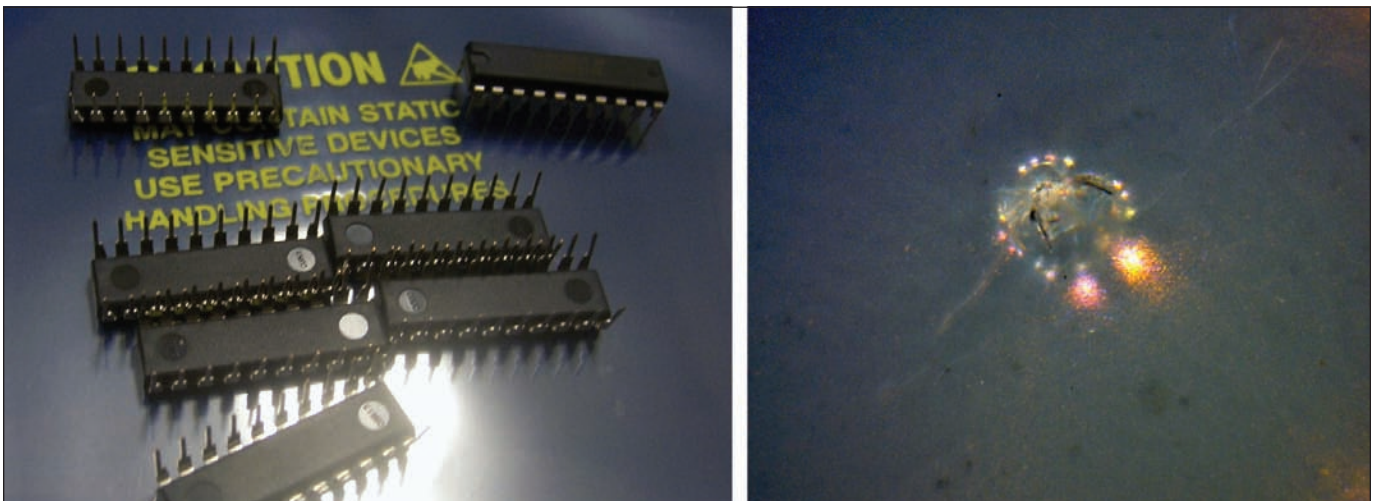


Figure 1



Figure 2

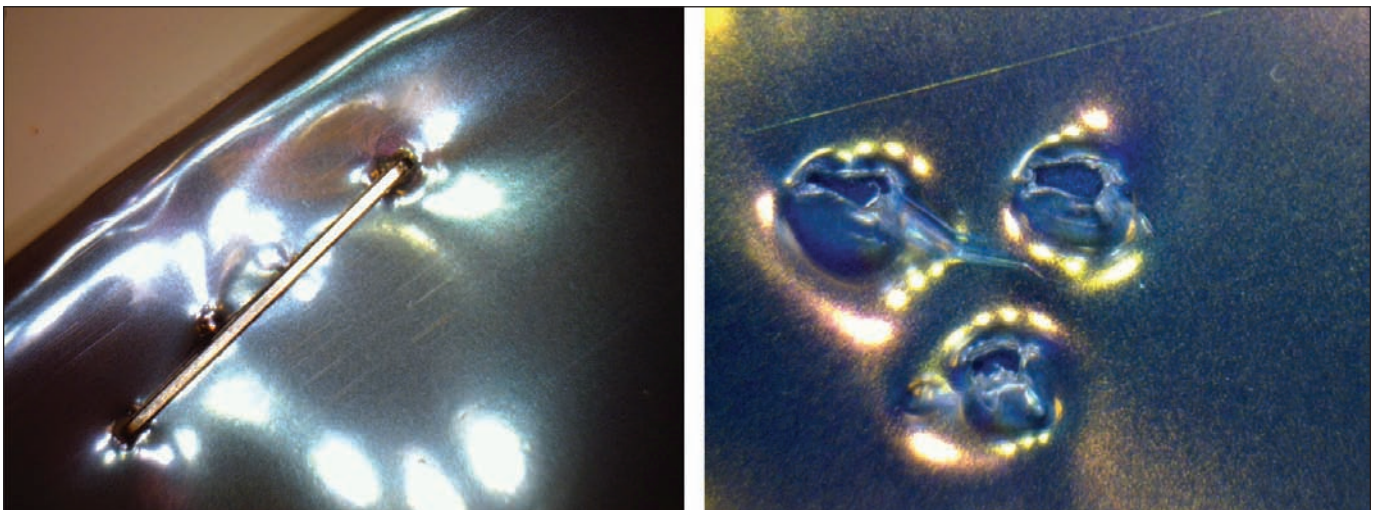


Figure 3

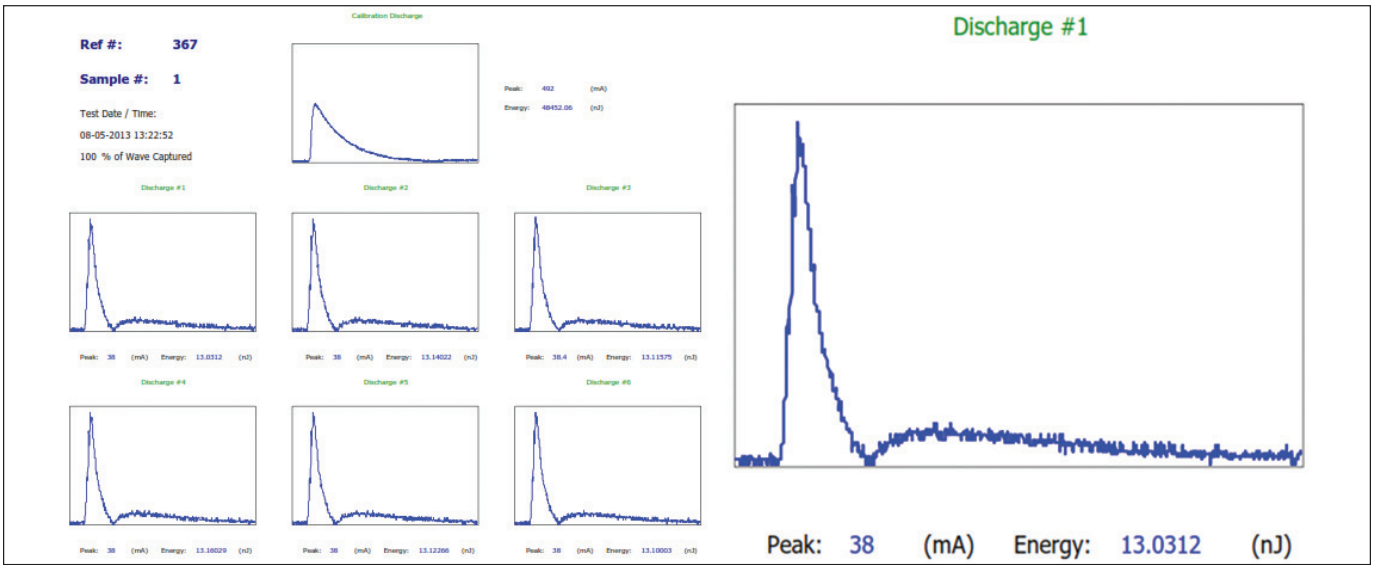


Figure 4

In this article, the author will not address Type I, Level 1 & 2 Aluminum Moisture Barrier Bags (MBB). ANSI/ESD S541-2008 (Packaging Materials for ESD Sensitive Items), ANSI/ESD S11.4-2012 (Static Control Bags Standard) and Mil-PRF-81705E-2010 (performance specification for ESD bag films) reference ANSI/ESD STM11.31 testing for static shielding bags. The current release of ANSI/ESD S541 designates ESD bag shielding at <50nJ. Aerospace & Defense follow Mil-PRF-81705E with a limit of 10nJ max. Consequently, ANSI/ESD S11.31 (Figure 2) was used

by the author to determine the effects of pin hole damage with Type III or Level 3 metallized shielding bags.

This article specifically illustrates the differences in shielding bag performance due to pin holes and stapling. Conditioning took place at 12.3%RH, 73.4°F for 48 hours. Note: ANSI/ESD STM11.31 testing is conducted at 12% & 50%RH after 48 hours of preconditioning for qualification.

In Figure 3, left, one can observe a staple affixed to a shielding bag; the

photograph to the right represents 3 puncture holes in another ESD bag. Each bag was subjected to six (6) discharges at 1KV. A new bag free from pin holes, staples or blemishes produced a series of waveforms as illustrated in Figure 4 and Table 1.

Initial testing of a brand new electrostatic discharge shielding bag (Type III) measured 13nj which is under the limit (<20nJ) set by ANSI/ESD S11.4. However, these shielding results still fall short of the Mil-PRF-81705E requirement of 10nJ max.

PeakCurrent (492mA) 367			12%RH 1			PeakCurrent (504mA) 2			12%RH 2		
Bag 1	mA	HVD	Bag 1	nJ	HVD	Bag 2	mA	HVD	Bag 2	nJ	HVD
1	38.00	1000v	1	13.03	1000v	1	43.20	1000v	1	17.72	1000v
2	38.00	1000v	2	13.14	1000v	2	42.40	1000v	2	17.53	1000v
3	38.40	1000v	3	13.12	1000v	3	42.40	1000v	3	17.30	1000v
4	38.00	1000v	4	13.16	1000v	4	42.40	1000v	4	17.38	1000v
5	38.00	1000v	5	13.12	1000v	5	42.40	1000v	5	17.39	1000v
6	38.00	1000v	6	13.10	1000v	6	42.40	1000v	6	17.26	1000v
Average	38.07	No Holes	Average	13.11	No Holes	Average	42.53	1 Hole	Average	17.43	1 Hole
Median	38.00		Median	13.12		Median	42.40		Median	17.39	
Minimum	38.00		Minimum	13.03		Minimum	42.40		Minimum	17.26	
Maximum	38.40		Maximum	13.16		Maximum	43.20		Maximum	17.72	
St. Dev.	0.16		St. Dev.	0.04		St. Dev.	0.33		St. Dev.	0.17	
PeakCurrent (492mA) 4			12%RH 4			PeakCurrent (504mA)			12%RH 5		
Bag 3	mA	HVD	Bag 3	nJ	HVD	Bag 4	mA	HVD	Bag 4	nJ	HVD
1	48.00	1000v	1	23.00	1000v	1	44.80	1000v	1	21.31	1000v
2	48.00	1000v	2	22.66	1000v	2	46.40	1000v	2	21.42	1000v
3	48.00	1000v	3	21.97	1000v	3	46.40	1000v	3	21.20	1000v
4	48.00	1000v	4	22.51	1000v	4	44.80	1000v	4	21.14	1000v
5	48.00	1000v	5	22.05	1000v	5	46.40	1000v	5	21.07	1000v
6	48.00	1000v	6	21.86	1000v	6	44.80	1000v	6	21.08	1000v
Average	48.00	Stapled	Average	22.34	Stapled	Average	45.60	2 Holes	Average	21.20	2 Holes
Median	48.00		Median	22.28		Median	45.60		Median	21.17	
Minimum	48.00		Minimum	21.86		Minimum	44.80		Minimum	21.07	
Maximum	48.00		Maximum	23.00		Maximum	46.40		Maximum	21.42	
St. Dev.	0.00		St. Dev.	0.45		St. Dev.	0.88		St. Dev.	0.14	

Table 1: 12.3%RH, 73.4°F after 48 hours (continues on next page)



PeakCurrent (504mA)			12%RH 6			PeakCurrent (496mA) 368			12%RH 1		
Bag 1	mA	HVD	Bag 1	nJ	HVD	Bag 1	mA	HVD	Bag 1	nJ	HVD
1	45.20	1000v	1	19.99	1000v	1	50.40	1000v	1	25.10	1000v
2	44.80	1000v	2	19.98	1000v	2	50.80	1000v	2	25.17	1000v
3	45.20	1000v	3	19.92	1000v	3	50.00	1000v	3	25.06	1000v
4	45.20	1000v	4	19.95	1000v	4	50.40	1000v	4	24.97	1000v
5	44.00	1000v	5	19.77	1000v	5	50.40	1000v	5	24.97	1000v
6	44.40	1000v	6	19.90	1000v	6	50.80	1000v	6	25.16	1000v
Average	44.80	3 Holes	Average	19.92	3 Holes	Average	50.47	4 Holes	Average	25.07	4 Holes
Median	45.00		Median	19.94		Median	50.40		Median	25.08	
Minimum	44.00		Minimum	19.77		Minimum	50.00		Minimum	24.97	
Maximum	45.20		Maximum	19.99		Maximum	50.80		Maximum	25.17	
St. Dev.	0.51		St. Dev.	0.08		St. Dev.	0.30		St. Dev.	0.09	
PeakCurrent (496mA) 2			12%RH 2			PeakCurrent (496mA) 3			12%RH 3		
Bag 2	mA	HVD	Bag 2	nJ	HVD	Bag 3	mA	HVD	Bag 3	nJ	HVD
1	48.00	1000v	1	23.99	1000v	1	47.60	1000v	1	22.98	1000v
2	48.00	1000v	2	24.05	1000v	2	47.20	1000v	2	23.06	1000v
3	48.00	1000v	3	23.77	1000v	3	47.20	1000v	3	23.08	1000v
4	47.20	1000v	4	23.79	1000v	4	48.00	1000v	4	23.04	1000v
5	47.60	1000v	5	23.91	1000v	5	47.60	1000v	5	22.99	1000v
6	47.60	1000v	6	23.84	1000v	6	47.60	1000v	6	22.92	1000v
Average	47.73	5 Holes	Average	23.89	5 Holes	Average	47.53	6 Holes	Average	23.01	6 Holes
Median	47.80		Median	23.88		Median	47.60		Median	23.02	
Minimum	47.20		Minimum	23.77		Minimum	47.20		Minimum	22.92	
Maximum	48.00		Maximum	24.05		Maximum	48.00		Maximum	23.08	
St. Dev.	0.33		St. Dev.	0.11		St. Dev.	0.30		St. Dev.	0.06	
PeakCurrent (496mA) 4			12%RH 4								
Bag 3	mA	HVD	Bag 3	nJ	HVD						
1	52.00	1000v	1	28.39	1000v						
2	52.80	1000v	2	28.36	1000v						
3	52.00	1000v	3	28.11	1000v						
4	52.40	1000v	4	28.19	1000v						
5	52.40	1000v	5	28.43	1000v						
6	52.00	1000v	6	28.03	1000v						
Average	52.27	20 Holes	Average	28.25	20 Holes						
Median	52.20		Median	28.27							
Minimum	52.00		Minimum	28.03							
Maximum	52.80		Maximum	28.43							
St. Dev.	0.33		St. Dev.	0.17							

*continued* Table 1: 12.3%RH, 73.4°F after 48 hours

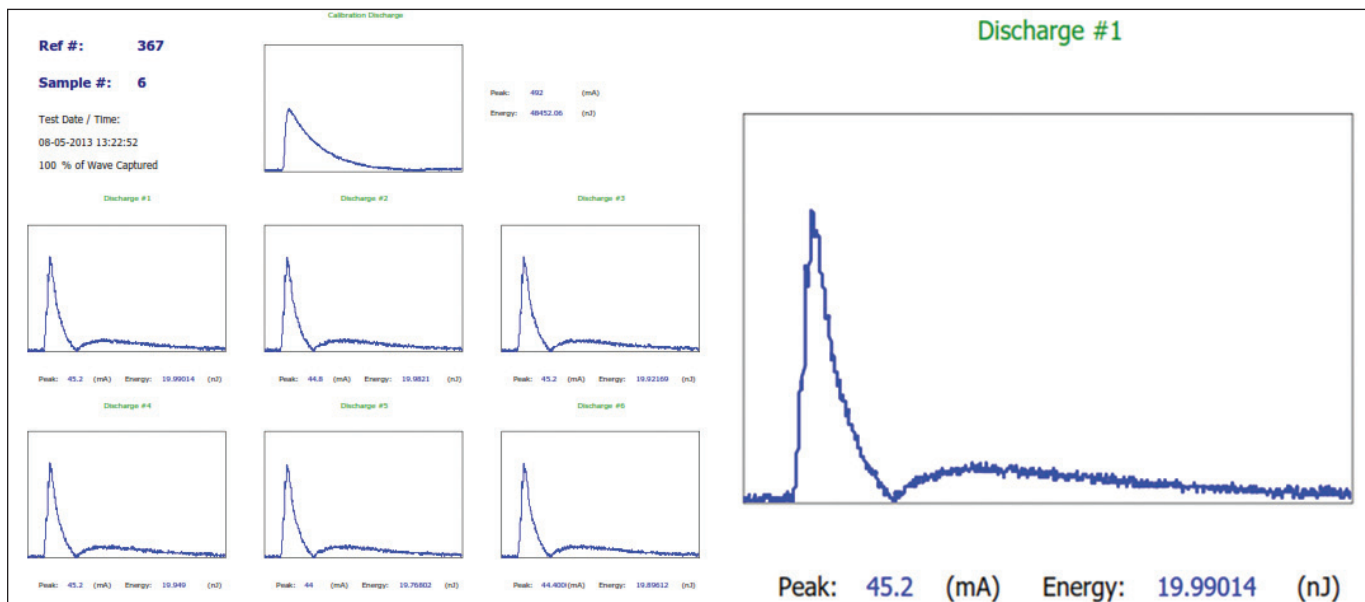


Figure 5

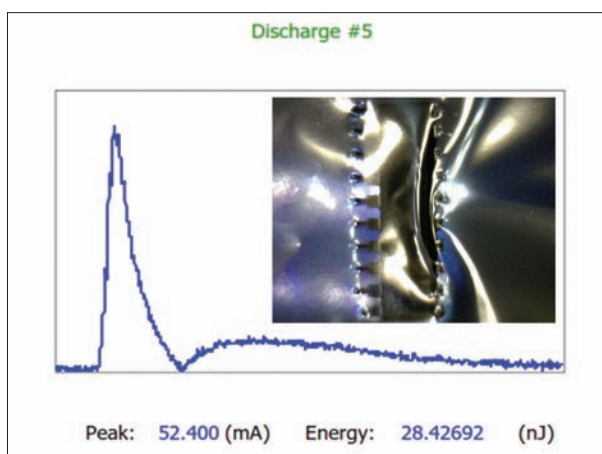


Figure 6

A single staple did impact a new bag's shielding performance from approximately 13nJ to 19nJ (Figure 5). Additional staples would pose a greater problem. In like manner, 20 pin holes were created by pushing an ESD device through a new bag (Figure 6) leading to results in excess of <20nJ. This finding is significant since pin holes caused the bag to fail at 28nJ. The findings for each bag can be viewed in Table 2. The size of the holes did vary from bag to bag.

In summary, it is clearly evident by conducting the ANSI/ESD STM11.31 testing for electrostatic discharge attenuation that ESD bags with pin holes pose risks both inside and outside of an ESD Protected Area (EPA). Reliance upon data avoids speculation and warrants further study by the Author on ESD bag longevity in a manufacturing and distribution environment. Other risks include pin holes that will allow moisture pick up to take place, insects to

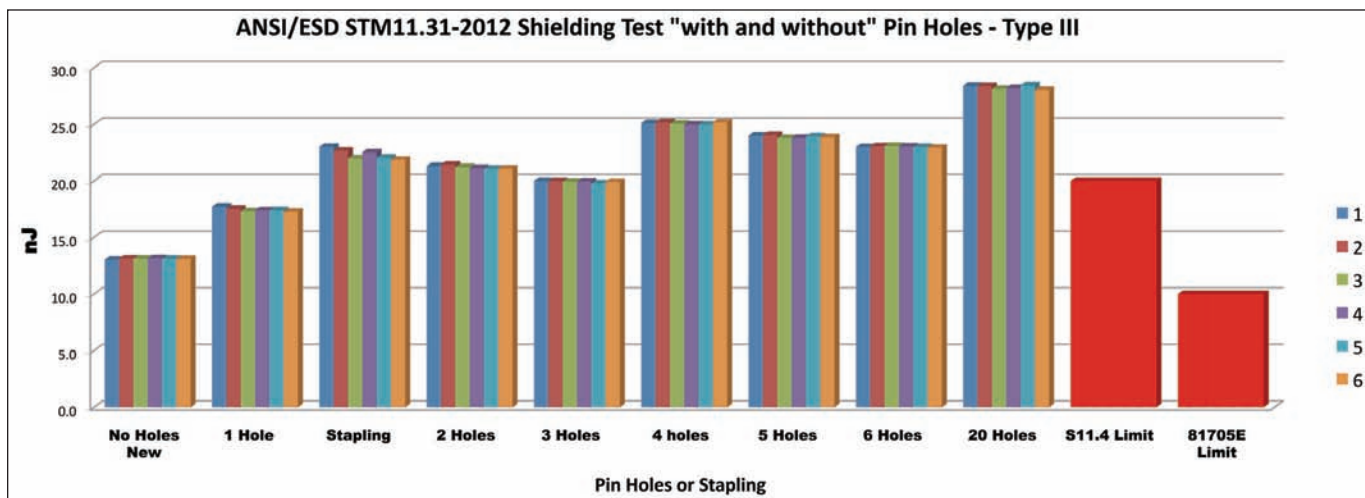


Table 2

It is clearly evident by conducting the ANSI/ESD STM11.31 testing for electrostatic discharge attenuation that ESD bags with pin holes pose risks both inside and outside of an ESD Protected Area (EPA).

enter, dust to infiltrate a package to compromise cleanliness in addition to contamination of the printed circuit board. ■

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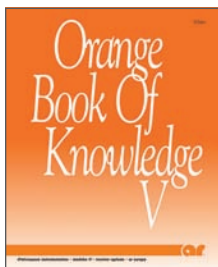
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## Measuring Breakdown Voltage With an ESD Simulator

Special simulator characteristics are needed

BY DOUGLAS C. SMITH

Measuring high voltage breakdown has many uses including tracking down the cause of equipment failure and ascertaining compliance to safety standards.

Some ESD simulators can be used to measure DC breakdown voltage and have the advantage that they can measure breakdown to voltages in excess of 10,000 volts. Not all ESD simulators can do this and the special characteristics required are discussed and an example is given of how this method was used to track down an equipment problem.

Figure 1 shows the details of measuring the breakdown voltage of a small AC plug style transformer of the type often used with small electronic equipment. In this case, a Fischer F-65 current probe was used to measure the waveshape of the breakdown current, but this is not necessary to measure breakdown voltage.

Many ESD simulators work by charging up a storage capacitor, often on the order of 150 pF, to the desired high voltage and then switching the charged capacitor to the tip of the simulator. Unfortunately, ESD simulators that work this way cannot be used to measure breakdown voltage accurately and

many of them have digital controls that also complicate matters. What is needed is a simulator that keeps the storage capacitor connected to the tip at all times and charged through a low current, high voltage power supply.

The KeyTek MiniZap ESD simulator by Thermo Scientific is such a device. The storage capacitor is connected to the tip at all times and is charged by a low current, high voltage supply. The digital display is actually a voltmeter reading the tip voltage in real time. The MiniZap's analog controls (read that as "knobs") facilitate the breakdown voltage measurement.

The method is as follows:

1. Connect the two nodes for the breakdown measurement between the tip of the MiniZap and its ground cable.
2. Using air discharge mode, slowly raise the voltage setting of the MiniZap remembering that the display on the MiniZap is actually reading the DC voltage stress being applied to the circuit or device under test.
3. At some point, the MiniZap fires and turns off the high voltage supply, signaling that a breakdown has occurred.
4. The last reading on the display just before the MiniZap fired is the breakdown voltage of the circuit or device under test.



**Figure 1: Test setup for measuring DC voltage breakdown of a small AC plug style transformer**

Figure 2 shows another example of a breakdown test on another small AC plug style transformer. It is probably best not to have your fingers on the circuit during the actual test, lest you measure **your** breakdown voltage.

Using an ESD simulator, like the KeyTek MiniZap, one can measure breakdown voltage up to 15,000 Volts. If you don't have an outright breakdown but just a leaky path, you will notice the device will load down the reading on the MiniZap, possibly making it impossible to reach the desired voltage.

Here is an example of how measuring breakdown voltage this way proved useful and time saving. I was working on a small embedded controller that used an electromechanical relay to operate a 240 VAC 60 Hz motor that rotated a sizable drum. The problem was that when the equipment was subjected to a 6 kV ringwave lightning surge test, the processor IC was often destroyed (burnt to a crisp).

The processor IC controlled a discrete transistor that operated the electromechanical relay which in turn applied the 240 VAC mains to the motor, so I suspected breakdown of the relay. I connected a MiniZap, on the test bench, from the contacts of a relay to its coil and slowly raised the voltage. The relay was rated at 6 kV, but at 5200 to 5400 Volts breakdown occurred between the coil and contacts! So the relay was not meeting its published specifications and was allowing the lightning surge to be applied directly to the processor circuit with predictable results.

## SUMMARY

Some, but not most, ESD simulators can be used to measure high voltage breakdown in circuits and devices. The KeyTek MiniZap is one such device. The MiniZap will measure breakdown voltages to 15,000 Volts, probably more than most uses require. ■



**Figure 2: Test setup for measuring DC voltage breakdown of a second small AC plug style transformer**

*Equipment used in this Technical Tidbit:*

*Thermo Scientific KeyTek MiniZap Electrostatic Discharge Simulator*

(the author)

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



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

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

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



## **Agilent Technologies Introduces FPGA Development Kit for High-Speed Digitizers Powered by Mentor Graphics**

Agilent Technologies Inc. has introduced the U5340A FPGA development kit, powered by a custom Mentor Graphics design engine, for high-speed digitizers. The U5340A enables customers to deploy advanced real-time signal processing into the FPGAs on board Agilent high-speed digitizers. The development kit leverages the full density and speed of the FPGA while ensuring the digitizer's outstanding multi-gigasample-per-second performance.

More information on the U5340A is available at [www.agilent.com/find/u5340a](http://www.agilent.com/find/u5340a).

## **AMETEK Solidstate Controls Introduces RECon 1000V Modular PV Inverter Line**

AMETEK Solidstate Controls has introduced the RECon 1000V UL Modular PV inverter, manufactured by FRIEM S.p.A. The RECon 1000V is the industry's first modular PV inverter with UL 1741 certification, which covers inverters, converters, charge controllers, and interconnection systems used in standalone (non-grid connected) and grid-connected power systems. UL certification is a widely recognized benchmark that ensures a particular product meets UL standards in terms of quality and performance.

For more information, visit [www.solidstatecontrolsinc.com](http://www.solidstatecontrolsinc.com).

## **The European Space Agency Selects Avera's Record & Playback Solution for Signal Analysis and Monitoring of Galileo Satellites**

Avera has announced that the European Space Agency (ESA)

has selected Avera's Record & Playback solution for signal analysis and monitoring of Galileo satellites. The R&P platform selected by ESA features the RP-5300, a compact 2-channel wideband RF recorder designed to record live RF signals in the field, and the URT-2200 RF Player for GNSS. Avera's R&P solution is powered by RF Studio™, a high-performance RF recorder and playback software specifically designed for RF designers and researchers, to facilitate recording, analysis and storage of RF signals.

For more information, visit [www.avera.com](http://www.avera.com).

## **AVX'S Proprietary X7S Dielectric Enables The First 1206 Size 100V MLCC with 4.7µF Capacitance and 125°C Maximum Temperature**

AVX has introduced the first 1206 size, 100V MLCC capable of exhibiting capacitance of 4.7µF and withstanding operating temperatures of up to 125°C. Employing AVX's newly developed X7S dielectric, the miniature 100V MLCCs exhibit high voltage resistance, high capacitance, low ESR, ripple resistance, and an extended lifetime, and are ideal for use in industrial power supply circuits.

For more information, view the data sheet at [www.avx.com/docs/Catalogs/cx7s.pdf](http://www.avx.com/docs/Catalogs/cx7s.pdf).

## **DMAS Extends Hybrid Absorber Range and Introduces Three New Microwave Absorbers**

Dutch Microwave Absorber Solutions (DMAS) has announced the extension of their hybrid absorber line with two new models. These hybrid absorbers are high performance, ultra wide band, carbon loaded polystyrene absorbers with an operating frequency from 30 MHz to 40 GHz. The HT

hybrid absorbers are tuned for perfect performance over ferrite tiles in (semi) anechoic chamber applications. In addition to the hybrid absorber range, DMAS has also introduced polystyrene microwave absorbers for antenna measurement applications.

For more information, visit [www.dmas.eu](http://www.dmas.eu).

## **IDEAL INDUSTRIES, INC.'s Versatile PrepPRO™ Strips All Coax Types Plus Removes Jackets from Twisted Pair Cables**

IDEAL INDUSTRIES, INC. has expanded its full line of data communications supplies with a new coax/UTP cable preparation tool that eliminates the need to carry multiple tools or to make frequent tool adjustments based on the type of cable being stripped. The IDEAL PrepPRO™ prepares virtually any coaxial cable -- ranging from large RG-6 Quad to RG-59 plenum -- with industry-standard 1/4" x 1/4" strips in as few as two turns of its spinner ring.

For more information, visit [www.idealindustries.com](http://www.idealindustries.com).

## **New Ultra Precision Chip Resistor from KOA Speer Offers Improved Moisture Resistance**

KOA Speer Electronics has introduced the 0603 (1J) size of their RN73H line of ultra-precision thin film chip resistors. Featuring a moisture-resistant protective layer over the resistive film construction, the RN73H1J offers enhanced moisture resistance (85°C+2°C, 85%+4% RH, 1000 hrs).

For more information, visit [www.koaspeer.com](http://www.koaspeer.com).

### High-Performance FSG Gaskets for Electronic Enclosures from Leader Tech

Leader Tech has developed a comprehensive line of FSG fabric shielding gaskets. The company offers 125 different sizes and profiles that are both lightweight and extremely easy to install. Each gasket is manufactured with a resilient polyurethane foam core and a unique, highly conductive nickel/copper ripstop outer fabric that exhibits a shielding effectiveness up to 115 dB when installed.

A complete FSG product catalog is available for download from the company's website, [www.leadertech.com](http://www.leadertech.com).

### New Amplifiers from MILMEGA Used for Wireless Testing

MILMEGA, a TESEQ company, has introduced a new amplifier product range designed to meet test requirements within wireless testing frequency bands. The AS0728 family of amplifiers has a frequency range of 700 MHz to 2.8 GHz. Available in 25 W, 50 W, 100 W and 170 W P1 dB power levels, these new amplifiers are ideal in the wireless communications industry where high reliability, excellent linearity, power density and leading performance are required.

For detailed specifications, visit [www.teseq.com](http://www.teseq.com).

### New Line of Rigol Scope Probes Measure Current or High Voltage Signals

Rigol Technologies, Inc. has introduced the RP1000 Series of oscilloscope probes, the latest addition to their line of passive and active differential probes. The RP1000 series measures current or high voltage signals and includes eight new probes designed to fit any Rigol oscilloscope.

Perfect for high-speed transient current measurements that can't be easily detected with passive current probes or other methods, Rigol's RP1003C, RP1004C, and RP1005C current probes measure higher speed currents up to 100 MHz when used with the RP1000P external power supply.

For more information, visit [www.rigolna.com](http://www.rigolna.com).

### Saelig's New 3GHz High Stability Spectrum Analyzer Available at an Introductory Price

Saelig Company, Inc. has introduced the GSP-930 - a 3GHz Spectrum Analyzer designed on a new generation platform featuring high stability, a large screen display, light weight and compact size. Its advanced Spectrogram and Topography features greatly expand the application range of this versatile RF analysis instrument. Made by GWInstek, Taiwan's largest manufacturer and developer of high quality test and measurement instruments, the GSP-930, normally priced at \$6300, is available now from Saelig Company Inc. at the introductory price of \$4,500 until 10/30/2013.

For detailed specifications, visit [www.saelig.com](http://www.saelig.com).

### Schurter's New Compact SMD Fuse with Extended Currents

Schurter has expanded its successful UMF 250 SMD fuse series with nine additional rated currents. The extension completes the series with a total of fourteen rated currents, ranging from 500mA to 10A. The compact, quick-acting SMD fuse now provides over current and short circuit protection in primary and secondary circuits for an even wider range of applications.

More information on Schurter's UMF 250 series can be found at [umf.schurter.com](http://umf.schurter.com).

### TÜV Rheinland to Launch New Inverter Functionality Testing Program At Intersolar North America

At Intersolar North America, TÜV Rheinland, a Nationally Recognized Testing Laboratory (NRTL), will introduce a smart inverter testing program that enables the grid-connect functions for the emerging architecture of string and micro-grid deployments. The program was discussed publicly with the California Energy Commission and will evaluate smart inverters for critical functionality in five key areas: Connect/Disconnect; Real Power Curtailment; Low/High Voltage Ride-Through; Low/High Frequency Ride-Through; and Volt-VAR Control. These functions are identified in the IEEE 1547a specification and will soon be mandated in the California grid under Rule 21 regulation.

For more information about TÜV Rheinland, visit [www.tuv.com/us](http://www.tuv.com/us).

### VPG Launches Ultra-High-Precision Hermetically Sealed Z-Foil Power Current Sensing Resistors

Vishay Precision Group, Inc. has announced that its Vishay Foil Resistors brand (VFR) has released two new ultra-high-precision hermetically sealed Z-Foil power current sensing resistors with low TCR of  $\pm 0.2$  ppm/ $^{\circ}$ C (from  $-55^{\circ}$ C to  $+125^{\circ}$ C,  $+25^{\circ}$ C ref.), PCR ( $\Delta R$  due to self-heating) of 4 ppm/W typical, and tolerances to  $\pm 0.01\%$ .

Further information about the VHP4Z and VPR247Z and other Vishay Foil Resistors products is available at [www.vishayfoilresistors.com](http://www.vishayfoilresistors.com).

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