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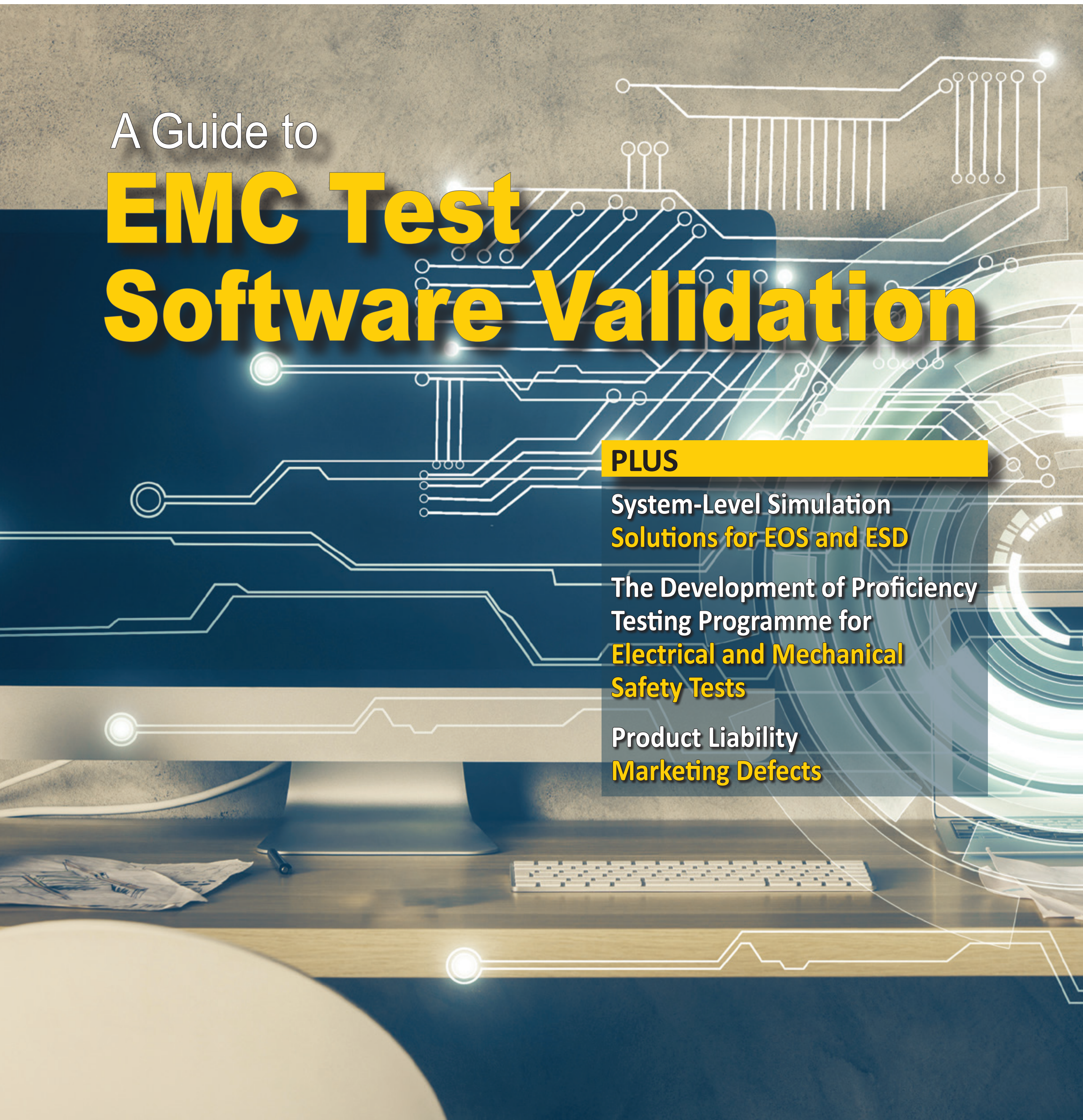

A Guide to EMC Test Software Validation

PLUS

System-Level Simulation Solutions for EOS and ESD

The Development of Proficiency Testing Programme for Electrical and Mechanical Safety Tests

Product Liability Marketing Defects

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DONALD HEIRMAN 1940-2020

Don Heirman, age 80, died on October 30, 2020 from complications due to Covid-19. He was born in Mishawaka, Indiana and after graduation from Purdue University and with his active military duty in the Pentagon, he started his professional career with Bell Laboratories in 1963 in New Jersey. He later became the manager of its Global Product Compliance Lab as a distinguished member the technical staff. Upon retirement from Bell Labs, he started his own consulting business—Don HEIRMAN Consultants—specializing in standards education and training in his discipline of Electromagnetic Compatibility (EMC), in which he remained active until his death. He was a communicant of St. Leo the Great Catholic Church in Lincroft, NJ for over 50 years, serving as an usher on Saturday night masses, singing in the choir on Sundays, and on the 50th anniversary committee in 2008 contributing a review of old photos taken of the parish and parishioners over those years and designing a lapel pin for the occasion.

In his early years, he attended St. Joseph Catholic Church and grade school in his home town of Mishawaka, Indiana, where he was born and where his parents who predeceased him, Agnes and Chester Heirman, lived for close to 60 years as his father worked for Uniroyal (Ball Band) for over 40 years. He then graduated from Mishawaka High School in 1958. His father also graduated from MHS in 1935. His mother graduated from Washington High School in South Bend, Indiana in 1938. At MHS Don was the editor-in-chief of the 1958 yearbook—The *Miskodeed* and photographer of the Newsletter—*Alltold*. He was a member of the National Honor Society, Junior Kiwanian, Science Club, Engineering Club, Quill and Scroll, Ushers Club, A Cappella Choir, and co-salutatorian of his senior class. He attended the class 50th reunion in July 2008 and enjoyed visiting with those he had not seen for those 50 years. It was there that his wife took ill with cancer that eventually she succumbed to in January 2009.

He received his BSEE and MSEE degrees at Purdue University in 1962 and 1963, respectively. While on campus, he was inducted into many honorary

photo courtesy Jerry Ramie

organizations including Iron Key, Omicron Delta Kappa, Tau Beta Pi, Eta Kappa Nu, Phi Eta Sigma, Quarterdeck, Pershing Rifles, Scabbard and Blade, and Pendragon. He also was on a military ROTC scholarship with the Navy where he became the Battalion Executive Officer. He was the executive President of residence hall H-3 which is now Wiley Hall (Excalibur Club), member of the student legislature, member of the Newman Club and in the University Choir. He also served as a resident hall counselor at H1 (now Owen Hall) during his graduate work. It was while in Wiley Hall he met Lois who was the administrative assistant to the Hall manager. They married on campus in 1963 while Don was completing his Master's Degree.

Upon receiving his BSEE in 1962, he was commissioned as an Ensign in the US Navy Reserves. He immediately attended grad school to earn his

MSEE specializing in electromagnetic waves and propagation. He then started his active duty at the Pentagon in Arlington, VA where he was responsible for predicting HF radio propagation for ship to ship and ship to shore use each day. During his two year activity duty (1963-1965) he was on military leave from Bell Laboratories as he started there in the fall of 1963. During his tour of active duty he and his wife experienced the Washington events to honor President Kennedy when he was assassinated in November 1963. He recalled well those times of national tragedy and being at the entrance of Arlington National Cemetery as the caisson procession passed by within 15 feet of he and his wife on the way to the burial plot of the "eternal flame". Don continued his Navy service after his active duty tour in the research reserves drilling on Wednesday evenings, one weekend a month, and two weeks active duty for training (each year) and retired in 1985 after over 20 years of service with the rank of Commander.

In 1963, he married Lois Smith on Purdue campus while in graduate school. He then reported for active duty in the Pentagon in the fall of 1963. Lois predeceased him in 2009 after 45 years of marriage. She is buried in Arlington National Cemetery where Don will be buried. This honor was a result of his serving his country in the Navy for over 20 years before he retired in 1985. His parents—Agnes (Horvath) and Chester—who lived for close to 60 years in Don's home town of Mishawaka, Indiana, predeceased him in 2005 and 2004, respectively.

At the time of his death, he was President of Don HEIRMAN Consultants which was a training, standards, and educational electromagnetic compatibility (EMC) Consultation Corporation which he founded in 1997 after his early retirement from Bell Laboratories. Previously he was with Bell Laboratories for over 30 years in many EMC roles. He started working on predicting and then suppressing power line interference on telephone lines. A noteworthy activity was the work he did on the US Navy's project Sanguine which was installed in northern Wisconsin and communicated with segments of the fleet worldwide. This extremely low frequency (ELF) system also coupled undesired ELF energy onto the local telephone plant which had to be mitigated. Don created the process on how the mitigation would work and then saw it implemented. Later his efforts turned to high frequency RF interference on telephone lines which led to his work on meeting regulatory RF interference requirements and being named Distinguished Member of Staff. During the last 13 years of his employment, he focused on product EMC regulatory compliance and was named senior EMC consultant eventually being promoted to Manager of Lucent Technologies (Bell Labs) Global Product Compliance Laboratory, which he founded, and where he was in charge of the Corporation's major EMC and regulatory test facility and its participation in ANSI (American National Standards Institute) accredited standards and international EMC standardization committees. During the last year before he retired early from Bell Labs (Lucent Technologies), he was named adjunct professor and senior research scientist at the University of Oklahoma and Associate Director for the University's Center for the Study of Wireless EMC. At the university he trained graduate students on EMC principles and testing as the Center studied the immunity of hearing aids to mobile phones used in close proximity. He continued his association with the Center for many years.

Don's activity in the EMC profession was extensive and started with his joining the Institute of Electrical and Electronics Engineers (IEEE) back in the early 1970s. He then moved quickly to join the IEEE EMC Society and the local IEEE New Jersey Coast Section activities.

His activity in the EMC profession was extensive and started with his joining the Institute of Electrical and Electronics Engineers (IEEE) back in the early 1970s. He then moved quickly to join the IEEE EMC Society and the local IEEE New Jersey Coast Section activities. In the Section, he served as the Section Newsletter editor, Vice Chairman and finally Chairman. For the EMC Society he was the EMC Chapter (NJ Coast Section) Newsletter editor, Vice Chairman and then Chairman—all this by the early 1980s. In 1980-1981, he increased his EMC Society contribution by being elected as the President of the Society. From then on he has held multiple jobs in the Society including member of its Board of Directors, Vice President for Standards (a position he held for many years until 2009), Chairman of the Society's technical committee on EMC measurements (for over 25 years), and Chairman of the standards committee (for over 17 years) receiving a special recognition award for 25 years of service to the EMC Society standards community (given at the Society's 50th anniversary symposium in Hawaii in 2007 where he was co-technical program Chairman). His work on establishing accurate electromagnetic emission measurements qualified him for IEEE Fellow in 1987. He has also received numerous awards from the IEEE and the American National Standards Institute including its prestigious Charles Proteous Steinmetz Award, Laurence Cumming Award, Richard Stoddart Award, ANSI Finnegan, the IEEE Centennial, and Millennium medals. In 2007, he became a Life Fellow of the IEEE. In 1991, he was general Chairman of the IEEE Cherry Hill (NJ) EMC symposium where for the first time workshops were held outside of the previous three day only symposium where attendees could get special instruction from experts in the field.

He also became heavily involved in standards beyond the EMC Society at the IEEE level starting in 1983. He held many positions including member, Vice Chairman and Chairman of the Standards Board, Chairman of the New Standards Committee, and Chairman of the Procedures Committee starting in the mid-1990s. When the standards department became the IEEE Standards Association (SA) in 1996, he rose from member of its Board of Governors to President of the SA in 2005-2006. With the latter position, he became a member of the IEEE Board of Directors and Executive Committee, a post he held in 2005 and 2006. Along the way he was a member of the IEEE Ethics and Member Conduct, the Publication Services and Products Board, and the Marketing and Sales committees.

Nationally, he has been a member of the American National Standards Institute (ANSI) Accredited Standards Committee C63® (EMC) since 1981 rising to subcommittee Chairman to then Chairman in 2006. His work there included standards on construction of regulatory compliance test facilities (which he authored a key standard on construction

> In quiet time which was seldom, Don had a passion for model railroading especially operating and collecting vintage Lionel equipment from as early as 1941 when his father gave him his first train set.

of special test sites which is still used today after being first published in 1988), accurate RF emission measurements, and immunity of TV receivers to RF interference.

Internationally, he was heavily involved with EMC related standardization of the International Electrotechnical Commission (IEC) and its Special International Committee on Radio Interference (CISPR). He started that commitment back in 1984 with his first CISPR meeting in Australia and worked his way from secretary and Chairman of a major working group responsible for EMC measurement instrumentation to Chair of the overall subcommittee which included basic standards for measurement methods, measurement instrumentation, and statistical methods (the subcommittee was CISPR Subcommittee A which is responsible for the CISPR 16 series of standards). Along the way, he not only was a contributing expert on these committees, but also a technical expert in the sister Subcommittee I which is responsible for CISPR 22 and 24 (and their destined replacements, i.e. CISPR 32 and 35, respectively). Finally, he reached the highest office in CISPR becoming its Chairman in October 2007. In parallel by virtue of his leadership in CISPR, he was named to the IEC Advisory Committee on EMC (ACEC) starting in 2001 and later Chairman in 2013. These standards organizations held their meetings all over the world which allowed Don and his wife to travel extensively which they both really enjoyed.

Back in the United States, he joined several US Technical Advisory Groups (TAGs) of the US National Committee (USNC) of the IEC including those associated with CISPR Subcommittees A and I as well as one associated with RF safety. This led to his being elected to the USNC Technical Management

Committee in 2000 which he served at his death. His role there increased from voting member to group manager for electromagnetics responsible for supporting such TAGs as those for CISPR and TC77 (EMC with immunity focus) and others. He became Chair of the USNC TMC Coordinating Committee on EMC also in 2000 where he worked with US TAGs that had EMC activity in their standards.

He had leadership positions in other organizations such as his being President of the US National Cooperation for Laboratory Accreditation (NACLA). He also was a member of the Association for the Advancement of Medical Instrumentation where in recent years he was the Chairman of its EMC committee responsible for a major guidance document on the use of wireless technology in health care facilities. He also was a member of the Board of Directors of the US EMC Standards Corporation representing them on the USNC Technical Management Committee as well as a member of the executive committee of the Conformity Assessment Section of the American Council of Independent Laboratories. In the latter organization, he represented ACIL on the Smart Grid Interoperability Panel and its Testing and Certification Committee.

He has presented numerous workshops, tutorials, and technical papers internationally. Since 1973, the number of technical presentations and papers on a variety of EMC measurement related subjects and associated standards exceeded well over 60. He also gave close to 100 training courses in the US as well as in Europe. Finally, he is listed in several "Who's Who" publications including Who's Who in Technology, Who's Who in Science and Engineering and Men of Achievement.

His contributions were vast to his EMC discipline where he has been called "Mr. EMC Standards". He had chaired hundreds of meetings during his professional career that led him to jokingly state that his tombstone will say "no more meetings"! A complete review of his career is on his website at http://www.donheirman.com.

In quiet time which was seldom, he had a passion for model railroading especially operating and collecting vintage Lionel equipment from as early as 1941 when his father gave him his first train set. He had built a multilevel layout in his basement and attended many model railroading events as a member of the Lionel Collectors Club of America (LCCA) and Lionel Operating Train Society (LOTS). In 2008, he was on the LOTS committee that planned its annual convention in South Bend, Indiana. This brought him back to the area where he was born and raised in next door Mishawaka, Indiana. During the convention, he provided local commentary on the various day bus tours through the South Bend, Mishawaka, and Elkhart areas as well as the tour of Notre Dame University campus and the national College Hall of Fame in downtown South Bend. Participants thanked him and his wife Lois for this addition to the tours.

photo courtesy Mike Violette

His final resting place will be at Arlington National Cemetery at the same plot as that of his wife Lois. It will be a military funeral ceremony.

In lieu of flowers, it is requested that donations be made to the American Diabetes Research Foundation, 1701 N. Beauregard Street, Alexandria, VA, 22311 or American Cancer Society, Eastern Division, Monmouth Unit, P. O. Box 5066, Cherry Hill, NJ 08034-5066.

FCC Authorizes All-Digital AM Radio

The U.S. Federal Communications Commission (FCC) has adopted regulations that will allow AM radio stations to operate using all-digital broadcast signals.

Under the terms of a Report and Order, AM broadcasters will now have the option of converting their current analog or hybrid analog/digital transmissions to all-digital operations. The decision will support improved AM audio quality while also allowing broadcasters to provide listeners with additional information such as the name of the artist or the title of a song.

The Report and Order also establishes rules intended to protect existing AM broadcast stations from interference. Further, stations converting to all-digital operations must notify the Commission and the public at least 30 days in advance of their transition, and continue to participate in the Emergency Alert System.

As we've previously reported, analog signals are increasingly subject to interference from electronic devices, and fewer than 250 AM stations have adopted hybrid operations. According to FCC Chair Ajit Pai, all-digital broadcasts will offer listeners a higher quality audio experience over a greater geographic area and enable AM operators to remain competitive in the broadcast market.

EU Commission Amends List of Harmonized Standards for Certain Radio Equipment

The Commission of the European Union (EU) has moved to update its list of harmonized standards applicable to certain types of radio equipment.

Published in the Official Journal of the European Union, Implementing Decision (EU) 2020/1562 modifies Annexes I, II, and III of Implementing Decision (EU) 2020/167. Those Annexes list 13 additional harmonized standards applicable to: 1) advanced surface movement guidance and control systems; 2) primary surveillance radars; 3) broadcast sound receivers; 4) international mobile telecommunications equipment; and 5) fixed radio systems.

The Implementing Decision also serves notice of the Commission's intention to withdraw references to several harmonized standards that have either been revised or that are considered obsolete. However, the Commission says that it will defer the withdrawal of such standards until a later date to give manufacturers time to take appropriate actions.

Thailand Enacts Ban Against Importation of Electronic Waste

The nation of Thailand has reportedly passed legislation that will prohibit the importation of hazardous electronic waste into that country.

According to an article posted to the website of the *Bangkok Post*, the ban covers 428 types of electronic waste (e-waste), which is defined by Thailand's Commerce Ministry as "electric and electronic components and scraps."

Violations of the newly implemented e-waste ban are punishable by a jail sentence of up to 10 years, a financial penalty equivalent to five times the value of the illegally imported e-waste, or both.

According to a separate article in *Recycling Magazine*, Thailand and other Southeast Asian countries became target spots for the disposal of e-waste following the implementation of China's National Sword policy in 2018, which banned the importation of electronic and plastic waste into that country.

Company Reaches Settlement with FCC Over Marketing of Unauthorized Devices

In one of the largest settlements in recent memory, a New York-based company has agreed to pay a $250,000 civil penalty for selling radio equipment and devices that exceeded legal radiated emissions limits.

According to an Order and Consent Decree issued by the U.S. Federal Communications Commission in late October, Ubiquiti, Inc. marketed certain models of WiFi access points that operated at power levels higher than those stipulated in their grants of certification. Based on testing conducted by the Commission's Office of Engineering and Technology (OET), it was determined that the affected models contained an error in the software driver calibration data. That error caused the devices to be capable of exceeding permitted radiated emissions limits and allowing the emissions to emanate into restricted frequencies.

In response to a Letter of Inquiry from the Bureau's Spectrum Enforcement Division, Ubiquiti acknowledged that the devices in question were capable of operating outside of its authorized parameters and that it had delivered a firmware update to all affected devices operating in the U.S. that resolved the excessive power and radiation issues identified in the OET's testing. The company subsequently filed a Class II permissive change request with a telecommunications certification body (TCB) to reflect compliance with the minimum requirements, which was granted.

> The company agreed to designate a senior corporate manager with responsibility of overseeing future compliance.

In addition to the civil penalty, Ubiquiti also agreed to designate a senior corporate manager with responsibility of overseeing future compliance. The company will also implement a compliance plan, including a compliance manual and a compliance training program, to ensure future compliance with the Commission's Rules.

PCB RETURN-CURRENT DISTRIBUTION IN THE STRIPLINE CONFIGURATIONS

By Bogdan Adamczyk

Last month's article, [1], discussed the distribution of a PCB return current in a microstrip configuration. This article discusses the current distribution for the stripline configurations.

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

RETURN CURRENT DISTRIBUTION IN A SYMMETRIC STRIPLINE CONFIGURATION

Consider a symmetric stripline configuration, shown in Figure 1, where a PCB trace of width w is placed in-between two planes, at the same distance h from each plane; x is the distance from the center of the trace.

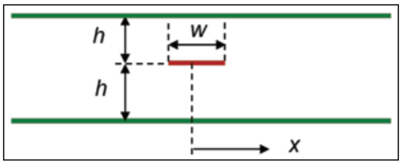

Figure 1: Symmetric stripline configuration

The possible plane combinations are shown in Figure 2.

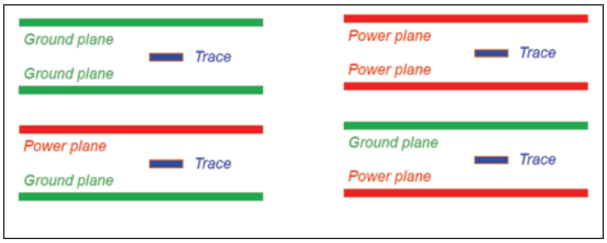

Figure 2: Plane combinations for a symmetric stripline

Figure 3 and Figure 4 (on page 14) show the CST Studio simulations of the ***E*** and ***H*** fields, respectively [2].

The current distribution on each reference plane is described by its current density [3] *J(x)*:

$$J(x) = \frac{I}{w\pi}\left\{\tan^{-1}\left[e^{\left(\frac{\pi(x-w/2)}{2h}\right)}\right] - \tan^{-1}\left[e^{\left(\frac{\pi(x+w/2)}{2h}\right)}\right]\right\} \quad (1)$$

Eq. (1) represents the current density in just one of the two reference planes. The total reference plane current density is twice of that in Eq. (1).

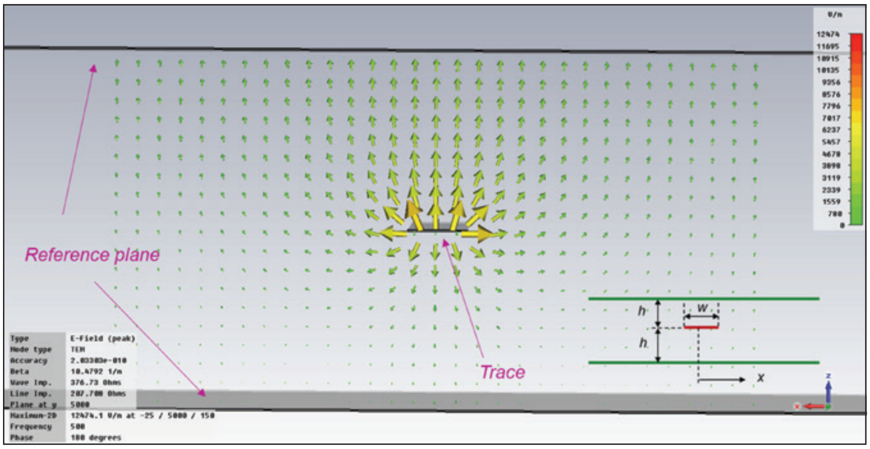

Figure 3: Symmetric stripline - simulated ***E*** field

Figure 5 shows the Matlab plot of (normalized) current density as a function of *x/h* for both the symmetric stripline and a microstrip configuration.

Note that the stripline current does not spread out as far as in the case of a microstrip line. At a distance ±4*x/h* from the center, the current density in a stripline rapidly decays toward zero, while in a microstrip, there's still a noticeable non-zero current density.

Figure 6 shows the % of the total return current for both configurations, contained in the portion of the plane between ±*x/h* of the centerline of the trace.

Table 1 shows more detailed results for the stripline configuration [3].

In the stripline configuration, 99% of the current is contained within ±3 *x/h*. Virtually all current is contained within ±10 *x/h*.

RETURN CURRENT DISTRIBUTION IN AN ASYMMETRIC STRIPLINE CONFIGURATION

Consider an asymmetric stripline configuration, shown in Figure 7, where h_1 is the distance between the trace and the closest plane, where h_2 is the distance between the trace and the furthest plane.

Figure 8 shows an 8-layer PCB where the signal V_1 is placed between two ground planes, while the signal H_2 is routed between a power plane and a ground plane.

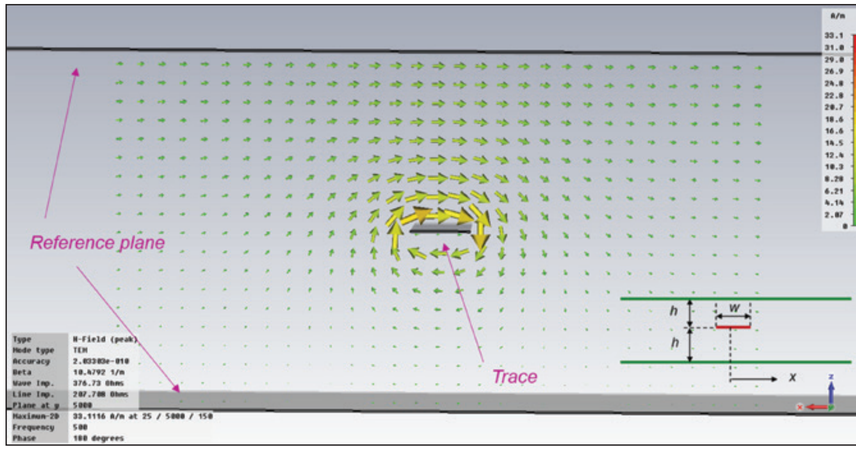

Figure 4: Symmetric stripline -simulated ***H*** field

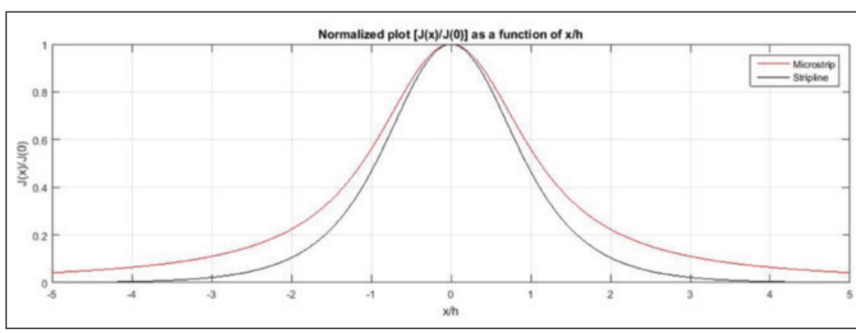

Figure 5: Current density in a symmetric stripline (Matlab)

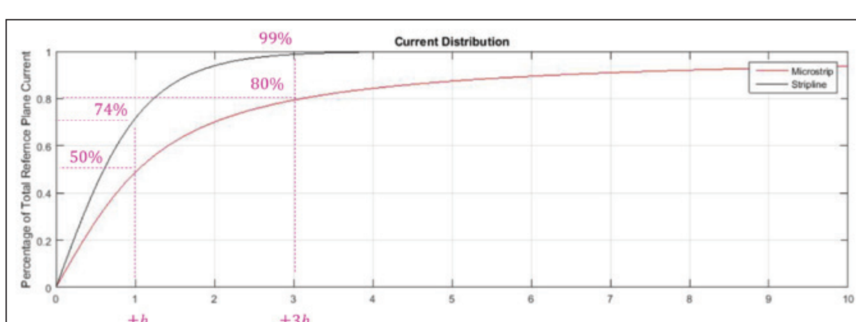

Figure 6: Cumulative distribution of the return current

Figure 9 shows an asymmetric stripline configuration where two orthogonally routed signal layers are placed between the reference planes.

Figure 10 shows a PCB topology where two high-frequency traces are placed between the reference planes.

Figures 11 and 12 on page 16 show the CST Studio simulations of the ***E*** and ***H*** fields, respectively.

x/h	% of Current
1	74
2	94
3	99
5	99.95
10	99.9999756

Table 1: Cumulative current in % for a stripline configuration

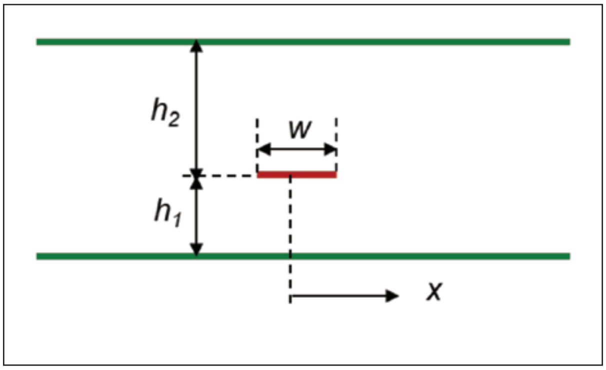

Figure 7: Asymmetric stripline configuration

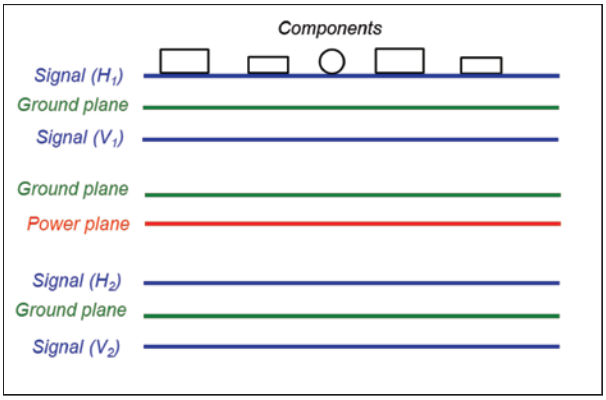

Figure 8: 8-layer board PCB with a single trace between two planes

The current distribution for the close and far reference plane is described by its current density [3] $J(x)$ as

$$J_{close}(x) = \frac{I}{w\pi}\left\{\tan^{-1}\left[\frac{e^{\left(\frac{\pi(x-w/2)}{h_1+h_2}\right)}-\cos\left(\frac{\pi h_1}{h_1+h_2}\right)}{\sin\left(\frac{\pi h_1}{h_1+h_2}\right)}\right] - \tan^{-1}\left[\frac{e^{\left(\frac{\pi(x+w/2)}{h_1+h_2}\right)}-\cos\left(\frac{\pi h_1}{h_1+h_2}\right)}{\sin\left(\frac{\pi h_1}{h_1+h_2}\right)}\right]\right\} \quad (2)$$

$$J_{far}(x) = \frac{I}{w\pi}\left\{\tan^{-1}\left[\frac{e^{\left(\frac{\pi(x-w/2)}{h_1+h_2}\right)}-\cos\left(\frac{\pi h_2}{h_1+h_2}\right)}{\sin\left(\frac{\pi h_2}{h_1+h_2}\right)}\right] - \tan^{-1}\left[\frac{e^{\left(\frac{\pi(x+w/2)}{h_1+h_2}\right)}-\cos\left(\frac{\pi h_2}{h_1+h_2}\right)}{\sin\left(\frac{\pi h_2}{h_1+h_2}\right)}\right]\right\} \quad (3)$$

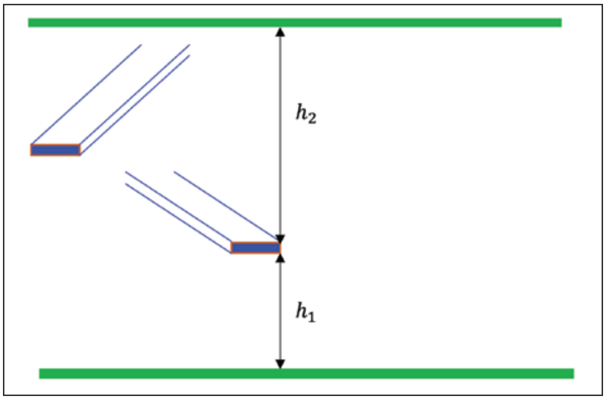

Figure 9: Asymmetric stripline configuration

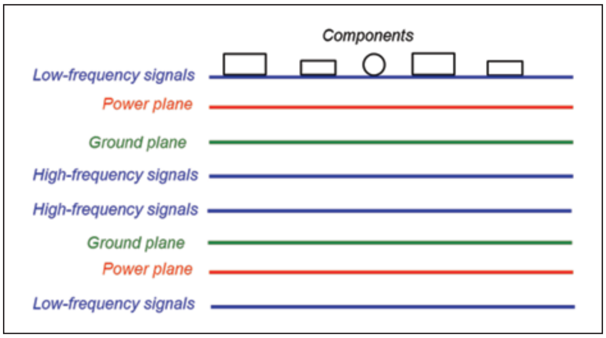

Figure 10: 8-layer board PCB with two traces between the reference planes

Figure 13 shows the Matlab plot of (normalized) current density as a function of *x/h* for both planes.

Note that, directly under the trace, 75% of the current flows on the closest plane and 25% on the far plane. At distance, greater than ±3 *x/h*, the currents in both planes are of the same magnitudes.

Finally, Table 2 shows the percentages of the return current in each plane for different h_2/h_1 ratios [3].

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2. Scott Piper, *CST Microwave Studio Simulations*, Gentex Corporation, 2012
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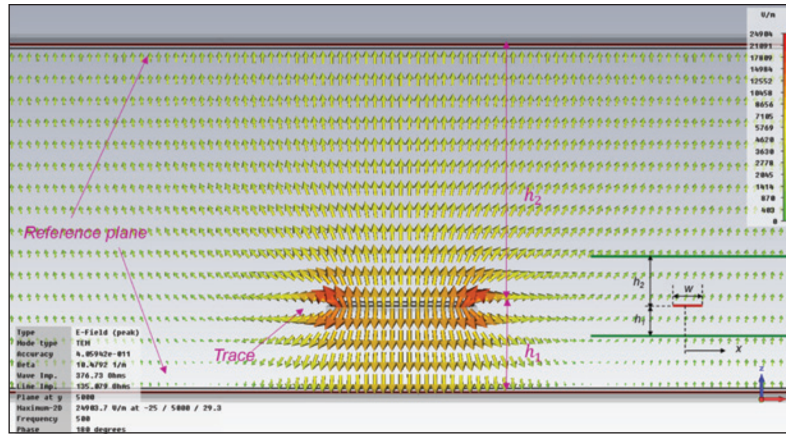

Figure 11: Asymmetric stripline - simulated ***E*** field

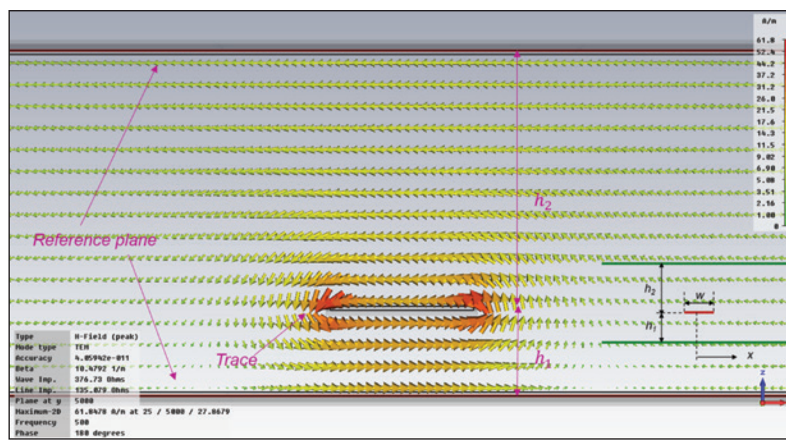

Figure 12: Asymmetric stripline -simulated ***H*** field

h_2/h_1	Close Plane	Far Plane
1	50%	50%
2	67%	33%
3	75%	25%
4	80%	20%
5	83%	17%

Table 2: Percentages of the return currents for different h_2/h_1 ratios

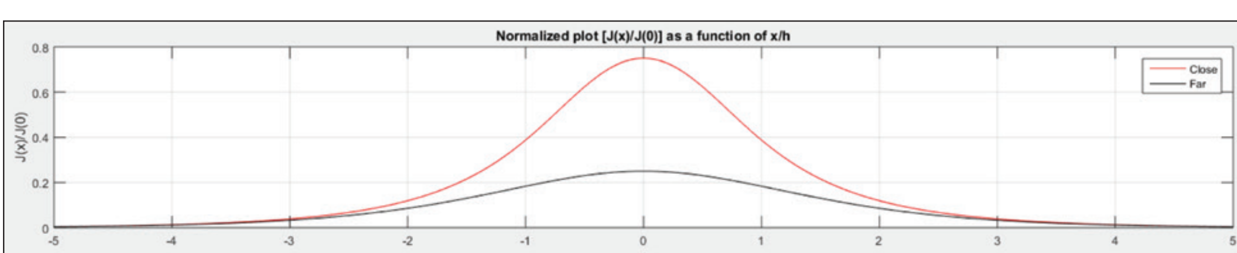

Figure 13: Current density in an symmetric stripline ($h_2 = 3h_1$)

FACTORS INVOLVING ESD PROTECTION CELL DESIGN SELECTIONS

By Hans Kunz for EOS/ESD Association, Inc.

How is the proper ESD Protection Cell chosen for a particular design application? Perhaps there is a more fundamental question—why is there more than one ESD Protection Cell in the first place? The answer to this second question will help answer the first.

An ESD Protection Cell must meet three basic criteria: it must be robust—able to carry required ESD current without being damaged; it must be effective—able to protect the rest of the Integrated Circuit (IC) during the ESD event, and it must be transparent—it must not interfere with normal IC operation. If the only two constraints were robustness and effectiveness, the ESD Protection Cell design would look like a perfect short— capable of carrying large amounts of current with no voltage build-up. Alternatively, if transparency were the only constraint, the ESD Protection Cell would look like a perfect open—drawing no current away from the rest of the IC circuitry. But both sets of constraints do exist, and the ESD Protection Cell Designer is faced with a requirement for perfectly contradicting attributes. The solution is to divide the operational space into multiple regions: a region where the ESD Protection Cell is robust and effective and a region where the ESD Protection Cell is transparent. How the operational space gets divided can have enormous consequences to the overall IC and ESD performance, and no one ESD Protection Cell can divide the space in a way that is applicable to every unique design application. The best ESD Protection Cell for a particular design application is the one that best divides the operational space between the transparency requirements and the robustness and effectiveness requirements.

DIVIDING THE OPERATIONAL SPACE

The simplest, and perhaps most common, example of a divided operational space is the splitting of the space into multiple voltage regions. As shown in Figure 1 (on page 18), the ESD Protection Cell draws significantly different amounts of current, depending on the applied voltage. Below a certain voltage level, the ESD Protection Cell draws almost no current and offers transparency to the rest of the IC circuit. This region is denoted in Figure 1 by the blue box on the left. Above a certain voltage, the ESD Protection Cell impedance lowers drastically, allowing current flow beyond the current delivered by the ESD event, without a voltage build-up that exceeds what is allowed by the rest of the IC circuitry—this is the region where the ESD Protection Cell is robust and effective and is denoted in Figure 1 by the orange box. If the voltage extends beyond the orange box, the ESD Protection Cell is not effective because it can no longer protect the IC. The region in the orange box is commonly referred to as the **ESD Design Window**. Space was purposefully left between the regions in Figure 1 — this space represents design margin.

If the operational space is not well-understood and not divided correctly, unexpected problems may arise. Take, for example, a fault condition which takes the pad voltage beyond the normal operating voltage. If this condition is not anticipated in the division of the voltage regions, the voltage could exceed the transparent region and initiate the ESD Protection Cell's low impedance state. This could interrupt the IC

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

operation or even cause damage to the IC or the ESD Protection Cell. This effect also leads to what is known as Electrical Overstress (EOS) damage [See Ref. 3].

As technologies shrink, the voltage level at which circuit damage occurs is reducing faster than the transparency requirements reduce, leading to a tightening of the window in which the ESD Protection Cell can operate in its low impedance state [1]; this narrow window is also very common in high voltage (e.g., >20V) design applications [2], where lower margin may be present between allowed operating conditions and on-set of circuit damage. Due to the narrowing of this window, it becomes more and more difficult to keep the ESD Protection Cell's low impedance state fully in the ESD Design Window, and other techniques are applied.

One potential solution to the tightening ESD Design Window is to allow the ESD Design Window to start encroaching onto the Transparent Region, as shown in Figure 2.

In this scenario, as the region where the IC circuit is damaged pushes to the left, the ESD Design Window is also pushed to the left and starts to overlap the region where the ESD Protection Cell must be transparent. To continue simultaneously meeting all the requirements, it must be ensured that the ESD Protection Cell's trigger voltage (the voltage at which the ESD Protection Cell switches from its high-impedance state to its low-impedance state) remains outside the Transparent Region. It must also be ensured that, even if the ESD Protection Cell does enter the low-impedance state, it cannot remain in this state. In Figure 1, this was ensured because the entire low-impedance portion of the ESD Protection Cell's i-v curve was outside the Transparent Region. Now that a portion of the i-v curve extends into the Transparent Region, the conditions under which the ESD Protection Cell remains in the low-impedance state must be well understood and compared to the normal operating conditions, so that it is certain that the ESD Protection Cell will not remain in this state if it is triggered.

There is an important distinction that must be made—it is the actual application that matters, not the intended or assumed application. Take, for example, an IC input pin versus an IC power supply pin. The first instinct may be to deem the power supply pin as riskier than the input pin, due to the fact that the power supply pin will likely see an applied voltage capable of supplying significant current—current which could allow the ESD Protection Cell to remain in its low-impedance state. Similarly, the input pin may be viewed as safer because it will likely be driven by a signal with limited current: current that cannot maintain the low-

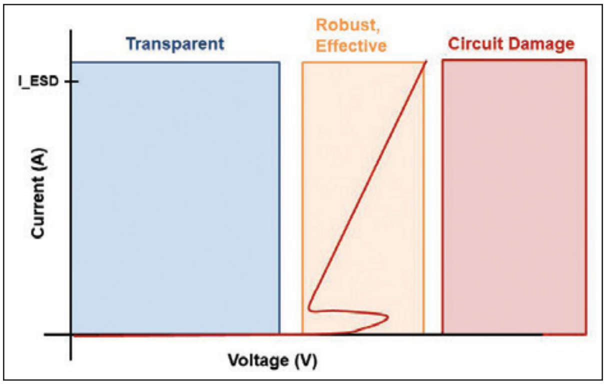

Figure 1: Operational space divided into two voltage regions

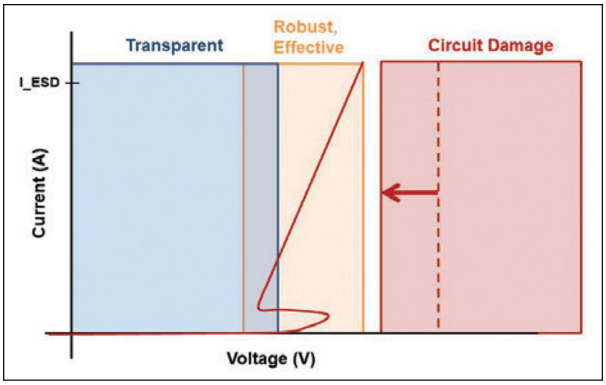

Figure 2: Overlap of transparent and robust, effective regions

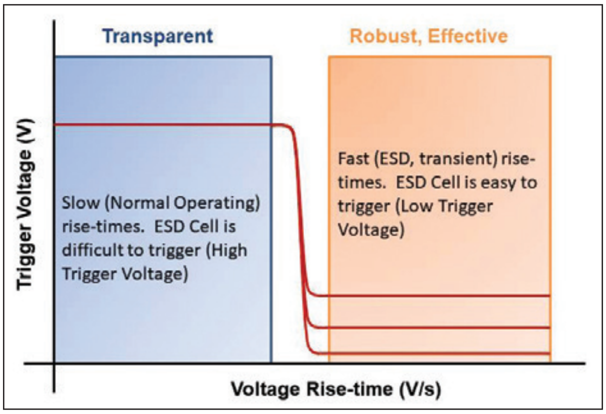

Figure 3: Differentiating operating regions on voltage rise-time

impedance state. But how is this input pin going to be applied in the actual system? What if the input pin is used to set a permanent state, and will be tied directly to a power supply in the system? In this scenario, the input pin is no less risky than the power-supply pin. It is crucial that the system designer knows the limitations of the IC and that the IC designer knows how the IC will be used in the system.

Thus far, the examples of dividing the operating space into regions have centered on voltage. But what about other characteristics that differentiate the normal operating signal characteristics from the ESD event characteristics? One such characteristic is rise-time—how quickly the signal moves from low to high voltage. Under ESD events, very fast rise-times are present, and, if the normal operating signals are slower, then ESD Protection Cells can be equipped with triggering circuits that respond differently to ESD events than to normal operation signals.

Figure 3 shows an example of such a characteristic. In this example, the regions are separated, not by voltage, but rather by the voltage rise-time. For the purpose of illustration, consider the two regions of Figure 3: 1) Slow rise times on the left and 2) Fast rise times on the right. With this dual strategy, the trigger circuit is designed to more easily trigger for faster rise-times than slower ones— thus, the ESD cell can be tuned to be difficult to trigger during normal operation, but easy to trigger under ESD events. Figure 3 shows three different ESD Protection Cell curves-- this is to emphasize that not only can the ESD Cell be designed to have different trigger voltages for slow and fast rise-times, but that the difference in the trigger voltage can also be controlled, depending on the specific characteristics of the ESD Protection Cell. If the separation of the rise-time regions is not made correctly, or transient events are present that were not anticipated by the ESD Protection Cell designer, then triggering can occur at unintended times. One such example occurs in 'hot-plugging' applications: scenarios where the system has to be connected to power systems that are already energized. These types of events produce voltage rise-times that are difficult to quantify and make it difficult to properly determine the needed selectivity of the trigger circuit.

Another difference between normal signals and ESD events that can be leveraged by the ESD Protection

Cell designer is the environment in which the IC is present. Many ESD Protection requirements are intended for safe-handling before the IC is placed in the actual system. If the ESD Protection Cell can detect if it is in a system, it can be designed to respond accordingly. For example, the presence of power to the IC can be used as a criterion for confirming the IC is in an active system. In this scenario, an ESD Protection Cell could be equipped with a triggering circuit that is disabled when power was supplied to the IC. While this strategy can be used to successfully protect the IC during handling, it limits the effectiveness of the ESD Protection Cell during normal operation. If system-level ESD performance is depending on the IC's internal ESD Protection Cells for part or all of the ESD performance, then this needs to be known to the IC designer so that proper ESD Protection Cell selection can be made.

ADDITIONAL FACTORS

While most of this article has focused on ensuring that the ESD Protection Cell's operation properly selects between ESD events and normal operating signals, there are other factors that must be considered in the ESD Protection Cell selection process. One such factor is area—the IC must be able to accommodate the area consumed by the ESD Protection Cell. Similarly, there may be processing options required for the ESD Protection Cell that are not required for the rest of the IC design. Adding these options may increase the cost of the IC fabrication process, and a different ESD Protection Cell may be a less expensive alternative, even it consumes more area. Another factor is the total capacitive loading—some applications limit the amount of capacitance, further limiting the overall size and type of devices used in the ESD Protection Cell.

Additional constraints can come from the required behaviors of the system outside normal operation. As an example, a common requirement is 'fail-safe' ESD design; in this scenario, the ESD Protection Cell has to be designed to ensure that the signal pin does not offer a low-impedance path to a power supply when power to the IC is lost or purposefully removed. In many ESD Protection strategies, a forward-biased diode is used to a positive supply rail. In these scenarios, loss of power would violate the fail-safe requirement, leading to a conflict between the ESD Protection Cell and the Transparency requirements.

RF Design Space

While the above design spaces apply to digital and analog applications, the applications for RF designs often allow less separation of the "ESD Design Space" from the "RF Design Space." This is due to overlap in the spectral content of the two spaces and to the sensitivity of the RF circuit to parasitics. For this reason, a co-design strategy is more desirable—that is, the ESD Design Space is shared with the RF Design Space in such that the ESD Cell becomes part of the RF functionality.

CONCLUSION

The ESD Protection Cell Designer is faced with the challenge of simultaneously meeting numerous constraints—many of which require conflicting attributes. An ESD Protection Cell must present a high-impedance to normal operating signals and yet a low-impedance to ESD events. Meeting both requirements simultaneously is achieved by dividing the operation space between normal operation signals and ESD events and designing an ESD Protection Cell that behaves very differently in the different regions. Due to the myriad of normal operating signals, there is no 'one-size-fits-all' ESD Protection Cell and selecting the proper ESD Protection Cell requires careful consideration of the ESD Protection Cell's behavior across the entire operational space.

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Banana Skins

302 Early colour TV interference from early police radio handset, warns criminals

About the time of the introduction of 'Panda' cars in the UK came a new Police hi-tech system known as the Personal Radio. In many Police forces this consisted of a pair of UHF radios, a transmitter and a separate receiver. The receiver was the more interesting of the two from an EMC point of view. Crystal controlled, single frequency and not much bigger than a packet of king size cigarettes, it had a vicious local oscillator that radiated very strongly.

The introduction of Police PR radios came about at the same time as the UK was just getting switched on to colour television. Regrettably, immunity from RF interference was not one of the finer qualities of this new entertainment system. I recall being told a story by Alan who was a licensed Amateur Radio colleague who happened to be a local Policeman. Apparently, invited (?) into someone's home one day, the proud owner of his new colour television was watching a programme in glorious and over-saturated colour. Much to the annoyance of it's owner, the television suddenly reverted to a black and white picture when Alan and radio walked into the room. Alan quickly turned off his PR receiver and the colour returned. Further tests revealed that even if he stood outside the front door of the terraced house with his PR receiver switched on, the TV was determined to stay in black and white until he walked away.

Allegedly this phenomenon was quickly communicated in criminal circles. Alan told me that it was no coincidence that more than one or two criminals were seen to run out of the back door before the bobby actually knocked on the front door. It seems that the early warning system was not just confined to Fylingdales in those days!

(Sent in by Graham Eckersall, G4HFG/W4HFG, Approvals Manager, Barcrest Group, July 13 2004.)

303 Power quality problems will get worse

The widely publicized breakdowns and subsequent blackouts in the public power networks of the Northern United States and several European countries are extreme examples of phenomena that occur on a smaller scale many times every day. Studies have shown that Dips, or "brown-outs," and Interrupts, or "dropouts," in the public power supply are tending to increase in frequency in our overstretched power networks, causing further degradation in the quality of the electric power supply. The results of power interruption can cause equipment reset and data loss, resulting in such consequences as breakdown of production or even danger to life.

The situation is not going to improve in the short term. As more functions are packed into increasingly smaller volumes, power consumption inevitably increases. Further, the increased use of microprocessors means that equipment incorporating them is potentially more susceptible to power line fluctuations.

(Taken from "Dips/Interrupts Testing Gets an Update," by Martin Lutz and Nicholas Wright, Conformity, *November 2004, page 12.)*

304 Interference problems within a vehicle

When I sampled the Audi A3 Sportback recently with this same choice of transmissions, I could not decide which I preferred. For the GTI I emphatically opt for the conventional manual: even with the ESP (Electronic Stability Program) disabled, in versions fitted with DSG there was excessive interference from background electronic systems. Requests via my right foot for full-throttle acceleration would often be refused for several frustrating seconds.

(Note from the Editor: DSG stands for Direct Shift Gearbox, a semi-automatic gearbox with a steering wheel-mounted 'paddle change' and no clutch.) (Taken from: "Regeneration" *by Peter Dron, a motoring review of the latest VW Golf GTI, in the Daily Telegraph's Motoring section, Saturday November 6th 2004, pages 1-2, http://www.telegraph.co.uk.)*

305 Interference can trigger airbags

Millions of cars have been recalled by the National Highway Traffic Safety Administration (NHTSA) and similar government safety agencies around the world, because of what is known as 'inadvertent air bag deployment'. This includes cars sold by virtually every leading auto manufacturers including BMW, Chrysler, Ford, General Motors, Hyundai, Land Rover, Mazda, Mercedes-Benz, Saab, Toyota, Volvo and Volkswagen.

In addition to rough roads, light jolts, stones bouncing off the road surface and light bender-fender impacts at speeds air bag deployment is unexpected, the reasons for inadvertent air bag deployment include electrical shorts, dirty electrical connections, normal Supplementary Restraint System (SRS) wear and tear, static electricity and an incoming or outgoing cell phone call.

The following incident was reported by a driver in the USA, where cellphones use the PCS system and operate at 1.9GHz: "I was holding the phone at arm's length so I could see the display to dial, in my left hand, so that it was almost touching the centre of the steering wheel when the air bag went off like a bomb. My hand was violently bent over so far that my fingers nearly touched the inside of my forearm. My head was wrenched backwards and to the left like somebody was trying to twist it off my neck. The pain of the air bag hitting my hand was excruciating; it felt like my hand was on fire and went on for what seemed like forever."

The above driver did some investigation, and concludes that: "The thinking is that, in certain circumstances, the electric current coupled into the vehicle wiring from the cell phone antenna when it is close to an air bag igniter can be enough to cause deployment of the air bag. The antenna of my cell phone was, at most, an inch-and-a-half from the centre of the steering wheel when the air bag went off. A US organization involved in EMC testing said that the field at such a small distance from a mobile phone is likely to be in the region of 70V/m."

It is impossible to say with absolute certainty that the cell phone set off the air bag. There are too many unknowns: the exact strength of the 1.9GHz current required to trigger the air bag; the exact distance of the cell phone antenna from the igniter; and the exact strength of RF field emitted from the cell phone's antenna and its coupling factors into the vehicle's wiring. *(Editor's note: But it seems very unlikely that the airbag should operate spuriously at the exact time that the cellphone was close to its igniter.)*

The Automotive EMC Directive requires whole cars sold in Europe to be tested for immunity at a minimum of 30V/m up to 1GHz, in Europe. Since the above cellphone operated at 1.9GHz it is outside the range of this testing and the susceptibility of the car's systems at this frequency is unknown. Also the testing is done with continuous wave (CW) and amplitude modulation (AM), not with the pulsed modulated (PM) signals typical of a mobile phone.

There are no legal immunity requirements for the USA – but all the reputable motorcar manufacturers apply immunity tests anyway to help reduce their risks of liability lawsuits. The EMC immunity specification employed by the manufacturer of the vehicle involved in the above requires electronic 'components' (subassemblies) to pass tests at 200V/m from 1-400MHz in a stripline or TEM cell, and 80V/m from 0-1000MHz in an anechoic chamber. Plus the whole vehicle is tested with radiated external fields at 200V/m from 6-30MHz, 140V/m from 30MHz-1.3GHz, and 70V/m from 1.3-3GHz – but these are the *external* field strengths: the fields inside the vehicle during these tests are not controlled so are unknown (the same comment applies to Automotive EMC Directive immunity testing).

The cell phone concerned operated at 1.9GHz, hence it was outside of the frequency range for the 'component' testing range – and the whole vehicle testing might not have created 1.9GHz fields at the steering wheel with field strengths comparable with those created by the close proximity of a cell phone. So neither this particular manufacturer's tests, nor tests under the Automotive EMC Directive, could be sure to reveal the susceptibility of the airbag igniter to very close proximity of a cell phone transmitting at 1.9GHz. Note that about half of the cell phones in Europe operate at 1.8GHz, using the GSM system, so this brief analysis also applies to them.

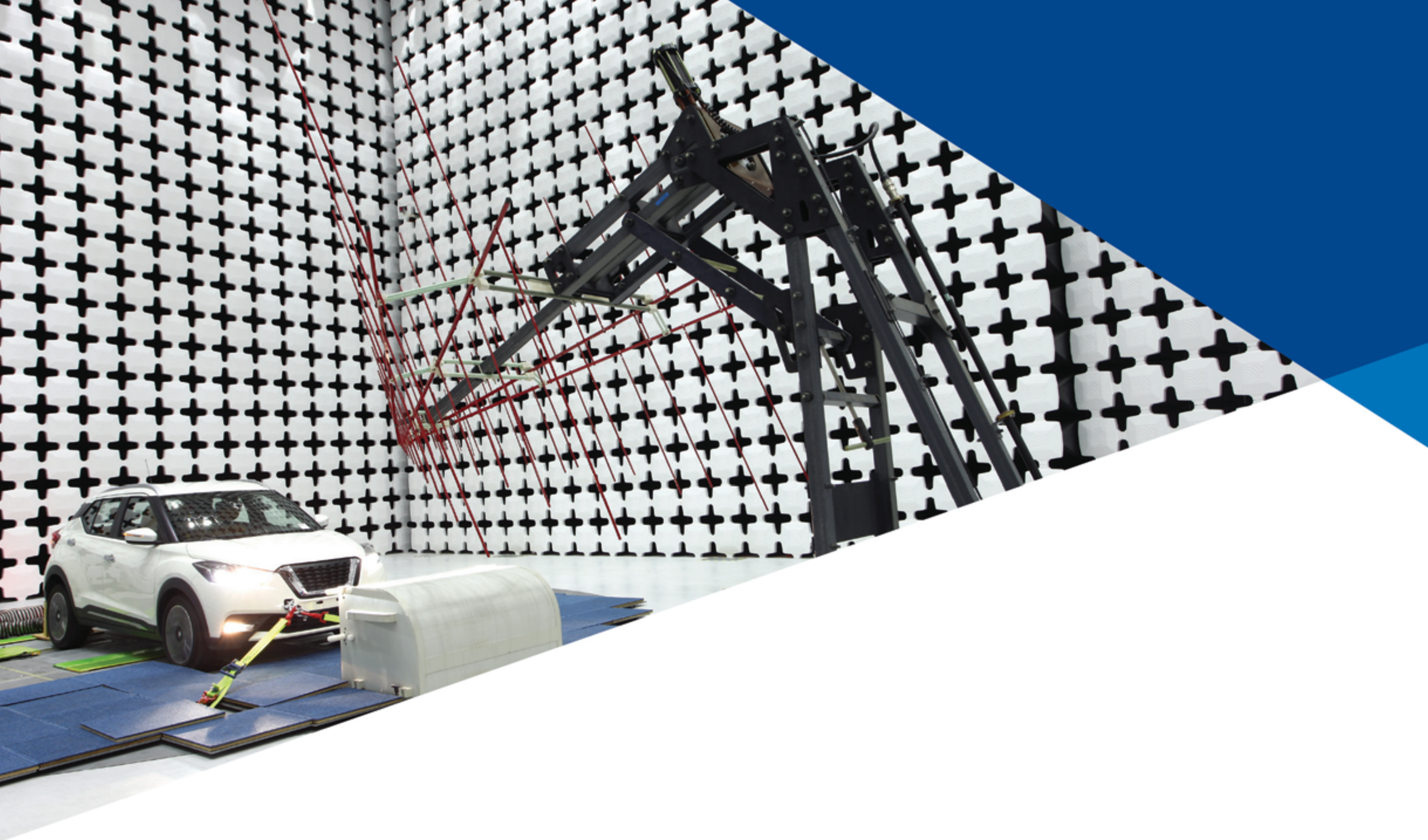
(Adapted from information sent in by Martin O'Hara of the Automotive EMC Network by email in April 2004.)

306 Cell phones interfere with Lexus sensors

After incidents where cell phone calls apparently interfered with a sensor in some 1998 Lexus GS300 and GS400 sedans, the NHTSA recalled them (No. 98V080): "Due to a manufacturing defect of the yaw rate sensor for the vehicle stability control (VSC), the VSC can operate improperly if the sensor is affected by certain electromagnetic waves, such as from a cellular phone. Should this occur, the brake can operate unexpectedly, affecting steering and speed control, increasing the risk of a vehicle crash."

(Sent in by Martin O'Hara of the Automotive EMC Network by email in April 2004.)

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



A GUIDE TO EMC TEST SOFTWARE VALIDATION

Complying with ISO 17025 Edition 2017, Section 7

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By Jack McFadden

Software has assimilated itself into almost every aspect of our lives. It resides within our homes, vehicles, phones, workspaces, and so on. We find it in our televisions, speakers, light switches, and on and on and on. It is everywhere. Resistance to software's assimilation is futile. It makes our lives easier.

Perhaps not coincidentally, the negative consequences of software-related incidents have drastically increased in the past few years. One of the most recently publicized incidents of software "gone bad" is software's contribution to the Boeing 737 Max malfunctions, which led to two fatal crashes in 2018 and 2019. The Boeing 737 Max malfunction is a case where the software's reported performance appears to have contributed directly to aircraft falling out of the sky. These and other incidents have not just gained the public's attention. They have also served as a catalyst for changes within the industry, such as the use of quality management systems (QMS) to demonstrate that software does what it is designed to do.

But concerns about software performance pre-date the recent incidents. The National Institute of Standards and Technology (NIST) published a document nearly twenty years ago titled "The Economic Impacts of Inadequate Infrastructure for Software Testing" (available at https://www.nist.gov/system/files/documents/director/planning/report02-3.pdf). According to Table ES-4 in the document, the economic impact in the U.S. economy at that time of an inadequate software testing infrastructure carried with it a cost of nearly $60 billion annually.

In fact, I found a number of companies that track the cost of software incidents and their economic impact. One such company is Tricentis, a software testing company (https://www.tricentis.com). In their most recently available "Software Fail Watch" report from 2018, the company estimates lost revenue related to software failures in 2017 at about $1.7 trillion, certainly not a trivial amount!

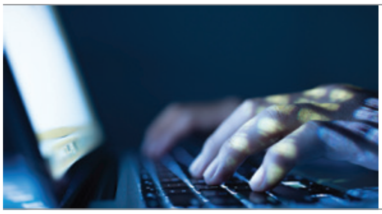
RELEVANCE

Our increased awareness of unintended software issues and the consequences of bad software design has prompted efforts to clarify software validation requirements, such as those found in Section 7.11 of the 2017 edition of ISO 17025, Testing and Calibration Laboratories. However, in point of fact, the addition of Section 7. 11 to the standard does not represent a new requirement per se. There have always been requirements in ISO 17025 to validate test methods and procedures, as well as requirements to ensure that computer software meets testing requirements for accuracy, range, repeatability, etc. (Indeed, one would be unable to validate anything without including the test software within the process validation!) The 2017 edition of ISO 17025 2017 simply increased the visibility of software validation requirements in the standard due to the growing problem related to poor software performance.

But all of this leads to a single question, that is, how do you know whether your test software is actually behaving the way you think it should. So the objective of this article is to aid the reader in better understanding how to develop evidence that test software is performing within its intended design.

SOFTWARE VALIDATION/VERIFICATION: SOME DEFINITIONS

You prove your test software is performing within design parameters through the use of a validation/verification (V/V) process. A software V/V process is simply the gathering of data to build a reasonable body of evidence (confidence) that your test software is performing within expected parameters and documenting your results. This would typically include



> Software-based V/V processes can be as simple as a logbook recording a test case and its results, providing a source that you can reference during audits.

a manual calculation of the test software equations, recorded evidence that test parameters were set correctly, proven test cases, system checks, etc.

There is one caveat here. I'm making the assumption that your V/V process checks produced satisfactory results. If not, you're responsible for documenting your process deficiencies, initiating corrective actions and following your established QMS procedures regarding noncompliance findings. The more robust your V/V process, the greater the degree of confidence you'll have that your test software is behaving the way it should.

Software-based V/V processes can be as simple as a logbook recording a test case and its results, providing a source that you can reference during audits. The rigor of your V/V process could also be at the other end of the spectrum, in which you attempt to create every possible scenario and document the results. But, no matter how much you test your software, reaching 100% confidence is impractical and may well be impossible to achieve.

My wife, Bobbi, is convinced there are people out there that will always find a way to break something. (Of course, she's not referring to me!) It may be some folks just have a knack for finding errors, but where is the dividing line between too little and too much? That question is beyond the scope of this article but is merely intended to show you where you can find the tools (sources) to create your own software V/V process. You get to decide where to draw the line.

SOME V/V PROCESS RESOURCES

There is a host of material on the internet, commercial books, and organizations that are readily available to help guide your V/V software validation process from concept through to final design. Much of the relevant material is outside the electromagnetic compatibility (EMC) field, but the sources really don't matter that much since the V/V process is essentially the same.

If you're thinking Deming Circle or Cycle Wheel, which championed the "Plan-Do-Check-Act" approach, you're on the right path. However, I would add one more element to the "Plan-Do-Check-Act" approach. It would be "observe," as in "Observe-Plan-Do-Check-Act" or OPDCA. You can find more information about the OPDCA model at Foresight University (http://www.foresightguide.com/shewhart-and-deming).

If you're comfortable checking out this and other resources and proceeding on your own, you can stop reading this article. But let me provide my own brief guide to the V/V process.

A BRIEF GUIDE TO APPLYING V/V PROCESSES

The first V/V process consideration is the type of software you use. Is it a commercially available off the shelf (COTS) product with limited or no ability to customize the test process, or is it a modified off the shelf (MOTS) program in which the test process is more open for modification? (Two examples of MOTS products are National Instrument's Labview and ETS-Lindgren's TILE!.) Or is it custom-made software in which every aspect has been created to meet your exacting specifications? Your answer can directly affect the V/V process you want.

Evaluating COTS Software Using the Black Box V/V Method

We will start with the easiest approach. If you have COTS software, then I recommend using the "black box" V/V method. If performed correctly, this method allows you to use your test system's standard checks that you are required to perform, and which will serve to validate both your hardware and setup system as well as your software processes. You generate known good inputs, measure with calibrated instruments, record your results, and then compare the recorded results with the expected standard requirements. And you apply the standard specified tolerances for frequency, amplitude, etc.

To illustrate, let's use as an example MIL-STD-461G, radiated emissions RE102 greater than 30 MHz. First, you replace the receive antenna in the system setup with a calibrated signal source. The inputs are test conditions, test limits, transducer correction factors, receiver measured data over frequency, and a known good signal from a calibrated source. RE102 requires the system check target amplitude to be the test limit minus six decibels (test limit – 6 dB). The actual calibrate signal source settings are a little different. The system check signal generator output target amplitude base equation is:

System Check Target Signal Generator Amplitude
= (Test Limit-6 dB)-Antenna Correction Factor

Your system variability (tolerance) is required to be within +/- 3 dB of the system check target. The test conditions are dependent on the frequency range you're at, which is dependent on the antenna you are using. The base equation for the final or corrected level is:

Final (Corrected) Level
= Receiver Recorded Value + Antenna Correction Factor
+ Signal Path Insertion Loss - External Preamplifier gain (if required)

The amplitude results of the system check should be within +/- 3 dB from the system check target which, as I discussed earlier, is the test limit – 6dB. The antenna correction factor will effectively cancel since you will add the antenna correction back through your corrected (final) level equation, ideally using the same calculation that you used during the system check. It also applies to the ambient and equipment under test (EUT) frequency sweeps. This verifies not only the process but the test calculations and software control.

Ideally, the person that created or modified the software should not be the individual tasked with validating it. You are best served by having someone with a different perspective test the MOTS software.

Unfortunately, we are not finished. We completed the system check's target, frequency and amplitude V/V, but these did not cover test conditions. However, the test condition validation is much easier, and is simply a matter of recording the frequency sweep measurement test conditions versus the test standard. A simple photograph of the receiver during the sweep can be used to record start frequency, stop frequency, resolution bandwidth, frequency step size, frequency dwell, sweep time, and the detector used. The photograph can be reviewed with the standard's test conditions, and you have now completed a black box V/V process for MIL-STD-461G, RE102.

Evaluating MOTS Software Using the White Box V/V Method

The white box V/V method is best suited for MOTS and custom-created software. Although you could use the black box V/V method with custom software, I don't recommend it. Using the black box V/V method for MOTS and custom-created software could save time if everything goes according to plan (green light schedule). And using the black box method for MOTS and custom software has the same disadvantages as the waterfall software design method. The feedback (test results) are delivered well downstream, and any necessary design modifications end up costing you more time and more money.

I highly recommend using a "check early and check often" philosophy for MOTS and custom software. The difference between the black box and white box methods is accessibility. With the black box method, you do not have control (access) of the inner workings of the software but simply monitor the results of the operation and report your findings. With the white box methodology, you have access to virtually all aspects of the software and can test the test software's inner operation and verify its performance.

MOTS V/V requirements pertain to functions or routines you've created or modified. There will be a point at which you won't be able to modify the software since the software manufacturer is responsible for ensuring proper software operation and likely limits access to the software's basic functions. Typically, this would include instrument drivers, basic EMC/EMI functions, and maintenance actions.

You could use the black box V/V method for any of MOTS functions you cannot change. Changes you make to the software should be verified and validated prior to release, always remembering that validation and verification are simply creating evidence that the software is adhering to your process and the applicable standard. The basic differences between the black box and white box methods include the level at which you are testing and the functions/routines you modified or created. You control the lower-level software functions and verify their performance. The software V/V is a process.

Let me offer an example in which you create a limited selection routine within a MOTS software. You would open the routine, operate the function, and verify the results. It takes no more effort. It sounds simple until you have a few hundred or more modifications to observe and validate. The complexity is within the sheer volume of the items you may need to verify.

You could take it one step further by creating different test cases where the user intentionally enters incorrect information to see how the software responds. Good software should provide error handling routines. And don't forget that you have some of the same tools available to you that you do when applying the black box method. The standard required system checks are useful tools to prove that the software is doing what it is supposed to do.

Software verification/validation importance has increased with the software infiltration into almost every aspect of our lives. QMS standards and processes are responding to the software intrusion with heightened scrutiny.

Ideally, the person that created or modified the software should not be the individual tasked with validating it. You are best served by having someone with a different perspective test the MOTS software, since the person that created or modified the software knows the software's intricacies and their approach will likely result in a lower level of rigor in detecting errors. The goal is to "bulletproof" the product before it is released.

Evaluating Custom Software Using the White Box V/V Method

You can apply the same white box method to evaluate a V/V process described previously to custom created software. I recommend that development testing be part of your design process and that you test and record routines as you build them. There are differences between software design development testing and software V/V. The biggest question is when within the custom software design process to apply the V/V method. The V/V process typically takes place after the custom software design freeze and before product release. Although the software should be tested as the design process moves forward, remember the "test early and test often" philosophy.

I must reiterate that testing within the design development is not part of the V/V process. It is part of maturing the product, which is part of the design process. The development test results should also be documented for future prosperity. It could be stored and used within the "lessons learned" database, which may help you meet other QMS standard requirements.

I recommend performing a risk analysis and creating a test case table for custom software based from the results of the risk analysis then V/V testing each test case. Seed the test cases with intentional errors as well as known good variables. Remember that the goal is to ensure the product is performing within expectations and that some people are geniuses when it comes to breaking things. Conduct the test cases and record the results while keeping in mind any noncompliance results require a failure analysis and corrective actions.

CONCLUSION

Software verification/validation importance has increased with the software infiltration into almost every aspect of our lives. QMS standards and processes are responding to the software intrusion with heightened scrutiny, and ISO-17025 2017 has devoted an entire section regarding software verification/validation. Further expanding the need to provide evidence the software is performing within its expected behavior. Meeting the software V/V process requirements is not extremely painful with the proper awareness. It is simply a matter of recording evidence the software is functioning within its design.

SYSTEM-LEVEL SIMULATION SOLUTIONS FOR EOS AND ESD

By Karthik Srinivasan and Norman Chang for EOS/ESD Association, Inc.

As electronic systems become more pervasive in today's world, particularly in mission critical systems, it becomes more imperative that they do not fail within the warranty period. Electrical overstress (EOS) and electrostatic discharge (ESD) damage are two of the major reasons for field failures. Designers of these electronic systems must be aware of the various methods by which EOS and ESD damage can occur and thus apply multiscale, multidomain, and multiphysics simulation solutions to address these issues.

The performance, reliability, and longevity of an electronic system that has direct exposure to system ESD events depend on the system's immunity from an ESD discharge event. Yet, the components of the system are designed independently with predefined specs and margins in mind. Because the components come from various sources, and often from different companies, they are usually designed by separate teams working in silos and in accordance with predefined margins. As a result, the ESD consequences at the system level can be difficult to identify and mitigate.

What's more, ESD is not a single physics problem; it's a combined electrical, thermal, and mechanical problem. Electromagnetic (EM) fields can become second- and third-order effects for other devices within the system, and the mitigation challenge stretches from design into test and measurement. The ability to deliver high performance, integrated systems that meet customer demand while reducing design costs requires a highly accurate and efficient process for simulating across a cohesive chip, package, and system environment.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Therefore, system-level ESD failure is a growing concern in electronics design and is a cumulative sum of errors of ESD failure and interaction between integrated circuit(IC), components, package, printed circuit board (PCB), and system. (See, for example, Reference [1] where the principles of system-level co-design have been described for both mobile and automotive applications.)

The modeling and simulation methodology for system-level ESD testing in compliance with IEC61000-4-2 [2] is outlined in Figure 1. As stated in Reference [3], realistic models of an ESD gun generator, connector, ESD protection element, PCB plane, trace /vias, and IC ESD are needed in the simulation. This article also briefly addresses modeling technology and a list of solver technology as well.

In particular, the article notes that a realistic chip ESD model is important for the determination of voltage/current on the chip pins. Other recent works [4,5,6] focused on the correctness of the ESD gun pulse, protection elements and models for PCB traces, and correlation versus measurements. However, the difficulty in creating a full-wave compliant model for various forms of connectors present a challenge in system-level ESD simulation. In this article, we outline a comprehensive chip-package-system ESD simulation methodology that addresses the interface modeling between the ESD gun and system and the interface modeling between the system and IC chip(s).

AT THE CHIP LEVEL: CHIP ESD COMPACT MODEL (CECM)

The first aspect that we will focus on is accurate device and component modeling at the chip level. A chip ESD compact model (CECM) (Figure 2) is an accurate and compact representation of a die. It contains a compact passive model capturing on-die

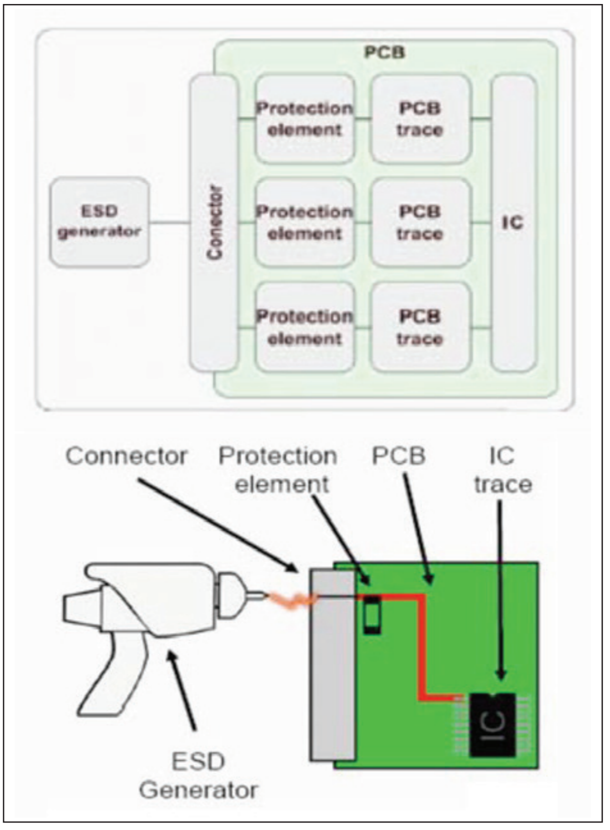


Figure 1: Modeling components needed in PCB ESD simulation, courtesy of IEW 2010 [1]

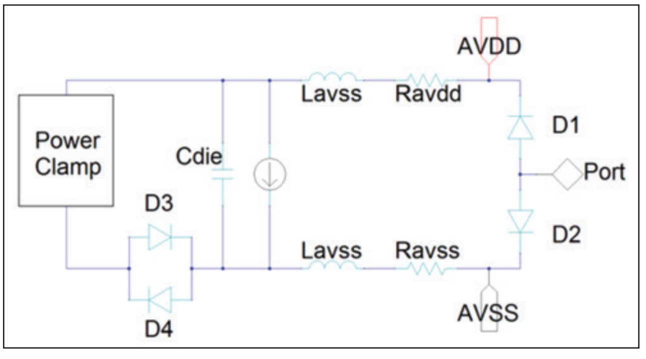


Figure 2: Chip ESD compact model (CECM)

parasitics, the current signature model of ports for a specific scenario [7], and optional ESD protection elements (e.g., diodes and RC-based clamps). In the passive model, the total capacitance (i.e., Cdie) of a power/ground domain pair includes power/ground coupled capacitance, on-chip decoupling capacitance, and capacitors from non-switching cells and their C-loads. Because the ESD spectrum is broadband, the die model must be accurate in the GHz range. Therefore, a reduced RC or RLC network model of the die is included.

CECM is a SPICE model that enables users to perform various "what if" analysis, such as leaving the on-chip ESD protection in or out to see how the PCB ESD protection performs in PCB ESD simulation. Without on-chip ESD protection elements in CECM, the V(t) and I(t) on the chip pin (or pad) becomes the energy that is propagated through the connector/PCB/on-board ESD protection elements. In general, the larger the on-chip capacitance (Cdie), the smaller the amplitude of voltage/current at the chip pins. Since this is a power-on PCB ESD simulation, the voltage and/or current amplitude should not have excessive value at the chip pins. When running a PCB ESD simulation with chip ESD protection elements in CECM, the V(t) and I(t) of the chip pins will be reduced accordingly, thereby minimizing over design while helping to ensure that overall ESD protection is adequate.

A key part of this holistic approach starts at the chip level with an ESD simulation tool that enables design teams to plan, verify, and signoff intellectual property (IP) and full-chip system-on-chip (SoC) designs for integrity and robustness to combat ESD[8,9]. ESD analysis is performed using such a tool at the layout and circuit levels to help users identify and isolate design issues that can cause chip or IP failure from charged-device model (CDM), human body model (HBM), or other ESD events once the design is verified.

The starting point is the chip ESD compact model(CECM), which is a synthesized model in a SPICE netlist format that can be used in any SPICE simulation or system-level tools. This behavioral model mimics the behavior of the chip power-delivery network along with the ESD protection devices embedded in it. A chip power model (CPM) can be used by system vendors who require a highly accurate abstracted model of the chip power delivery network to perform system-level power-integrity analysis and optimization. Think of it as reducing a massive billion-node+ on-chip power grid to a compact spice model that can be used for package or system simulations.

In the process, the integrity of the model is maintained in both the time and frequency domains. The model does not preserve any actual design information and hence protects designers' IP from being shared with a third-party vendor performing system assembly. Systems engineers can use any number of CECMs as part of their system-level ESD analysis. This enables virtual prototyping at the system level. The system vendor can request the integrated circuit (IC) vendor's respective models and can create a virtual prototype for the complete system to do a trade-off analysis.

DISCRETE COMPONENTS: TVS DIODES, CMF/EMI/ESD FILTERS

Commercial transient voltage suppressor (TVS) diode vendors provide model parameters in their data sheets. Commercial simulation software can

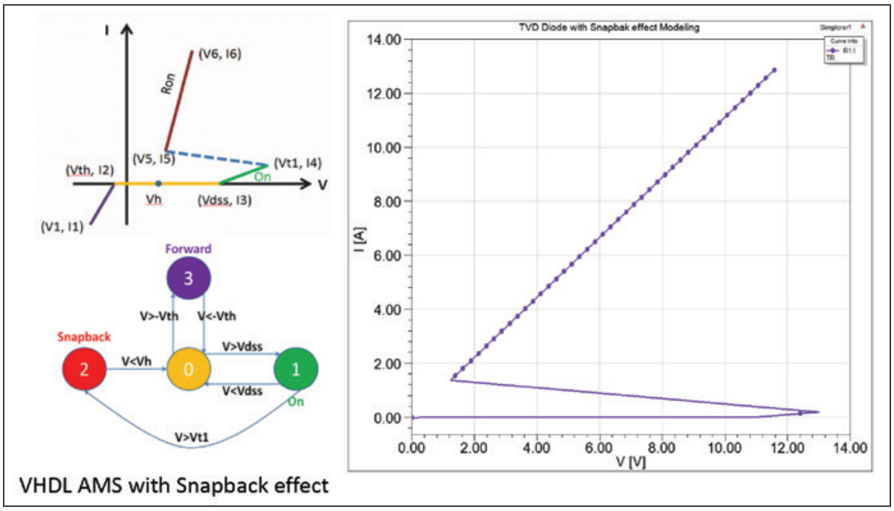


Figure 3: TVS diode modeling examples

provide an approximate model for the TVS diodes that is dependent on input parameters from the datasheet. Figure 3 shows how software can support TVS snapback effect modeling with very high-speed integrated circuit hardware description language – analog mixed signal (VHDL-AMS). VHDL-AMS is a standardized language used for describing digital, analog, and mixed-signal systems.

An ESD filter can be modeled in a full-wave 3D finite element method (FEM) solver using a circuit tool. This full-wave 3D FEM model is parameterized with manufacturing tolerance. This model can be directly plugged into the circuit simulation tool as an EM-based parametric model component and verified with measured result. A high-frequency structure simulator (HFSS) provides fully encrypted component designs for electronics device/modules and systems that protect customer IP.

ESD GUN ZAP MODELING

ESD generators are used for testing the robustness of electronics subjected to ESD events. There are two different discharge methods for an ESD simulator, and this article replicates a contact type ESD gun model [8,10], as shown in Figure 4 on page 34 and with good correlation of measurement result. HFSS can handle a full transient solution to make a complete ESD gun model with transient behavior. This FEM based transient simulation models ESD gun radiation effects as well as the cable interconnect network according to standard, IEC 61000-4-2.

SYSTEM LEVEL ESD SIMULATION

Finally, a workflow is needed to incorporate all the different elements of the system previously discussed. Models of chip, discrete components, ESD zapping, and package and board can be plugged into the workflow to enable a system level chip-package-board and chassis solution for ESD simulation, as shown in Figure 5.

APPLICATION EXAMPLES

Efficient ESD design for the system must recognize energy entering the interface IC pin in terms of a residual pulse [10]. Typical implementation of a USB2 interface is shown in Figure 6 as a first application example [10]. System-level ESD protection is primarily ensured with an external TVS, CMF/EMI filter, and/or ESD filter.

As secondary protection, IC pins have their own respective on-chip ESD protection that meets both human body model (HBM) and charged device model (CDM) requirements. The IC1 in the PCB schematic in Figure 6 shows differential pins for the USB that need protection using a TVS device. As will be discussed here, the common mode filter (CMF) plays an important role in overall protection efficiency. CMF is primarily intended to filter common mode noise that results from two phase lags between the differential signals (either unequal PCB trace lengths or unequal loadings) or from EMI pick-up through a USB cable. All of these protection devices have parasitic capacitance that will affect high-speed signal distortion. The optimum placement of components in Figure 6 determines the effectiveness of

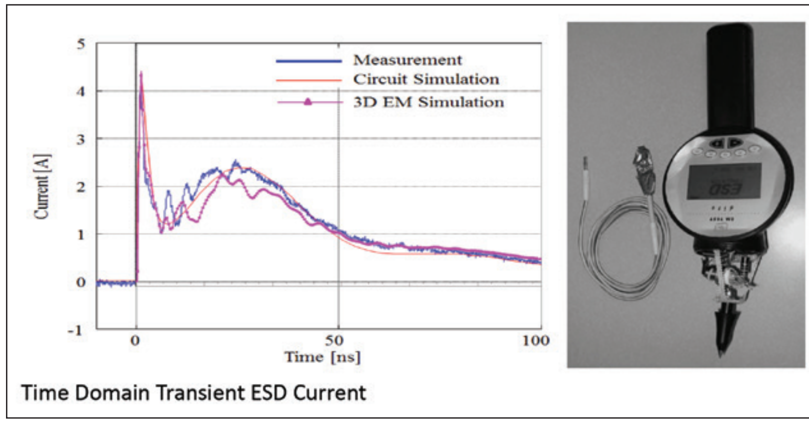


Figure 4: HFSS transient solver simulation results

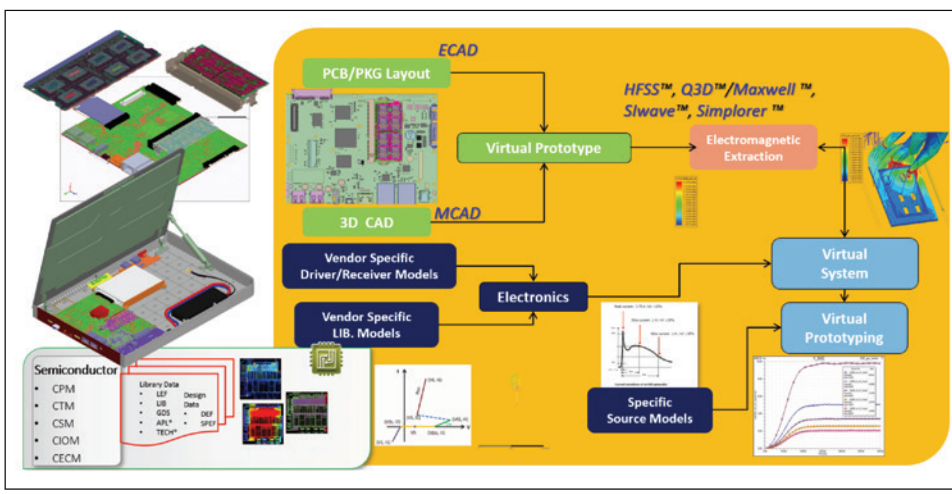


Figure 5: System-level ESD modeling workflow

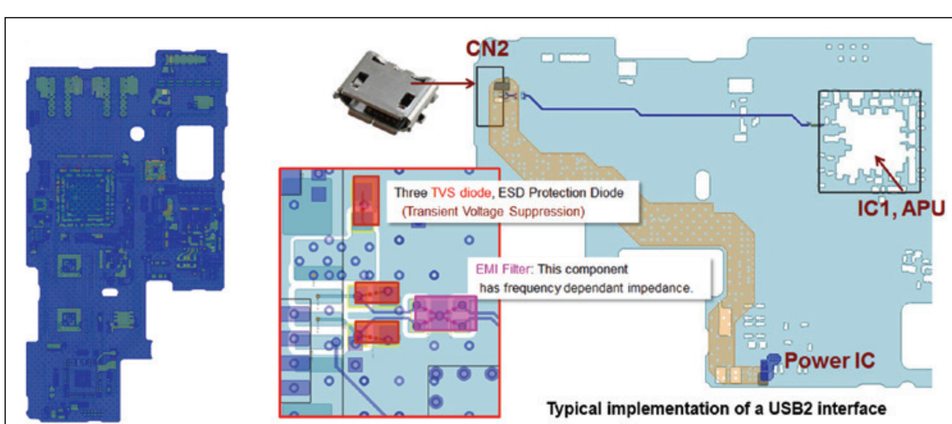


Figure 6: Mobile phone PCB and typical implementation of a USB2 interface

ESD protection while having minimum impact on signal integrity.

Figure 6 also shows the actual board implementations for ESD protection with the processor IC, the TVS diode, and EMC filter or CMF, board traces, and the micro USB receptacle on the left. Most of the USB signals are routed within inner layers in a strip-line configuration to minimize crosstalk between the traces and coupling from radiation sources such as RF chips and/or the ESD gun. The EMI filter is placed after the TVS, precisely between the TVS and processor IC. The TVS is placed just behind the receptacle. The PCB interconnect from the TVS to the processor IC is about 5.5 cm long.

Chip-package-system (CPS) transient simulations are performed as shown in Figure 7 on pages 36 and 37 to determine the residual pulse current waveform at the IC pin while high speed USB communication is happening between AP and USB device. The simulation considers the TVS, the PCB interconnects, the passive devices, and the CECM.

We injected the 5kV ESD discharge current waveform (red curve) on the USB connector shield location (120Vp @ USB connector ground) and detected a residual voltage pulse on the processor IC input signal trace, 2.78Vp (blue curve). Figure 7 (b) shows specific failure mechanisms activate during an ESD event, depending upon the nature and magnitude of the event and the circuit elements (device level) encountered by the over stressed pulse. Semiconductor junction leakage may occur, or dielectric breakdown or latch-up could be triggered. Each of these conditions can lead to thermal issues, melting or cracking, and shorting or open circuits, which in turn may cause additional failures.

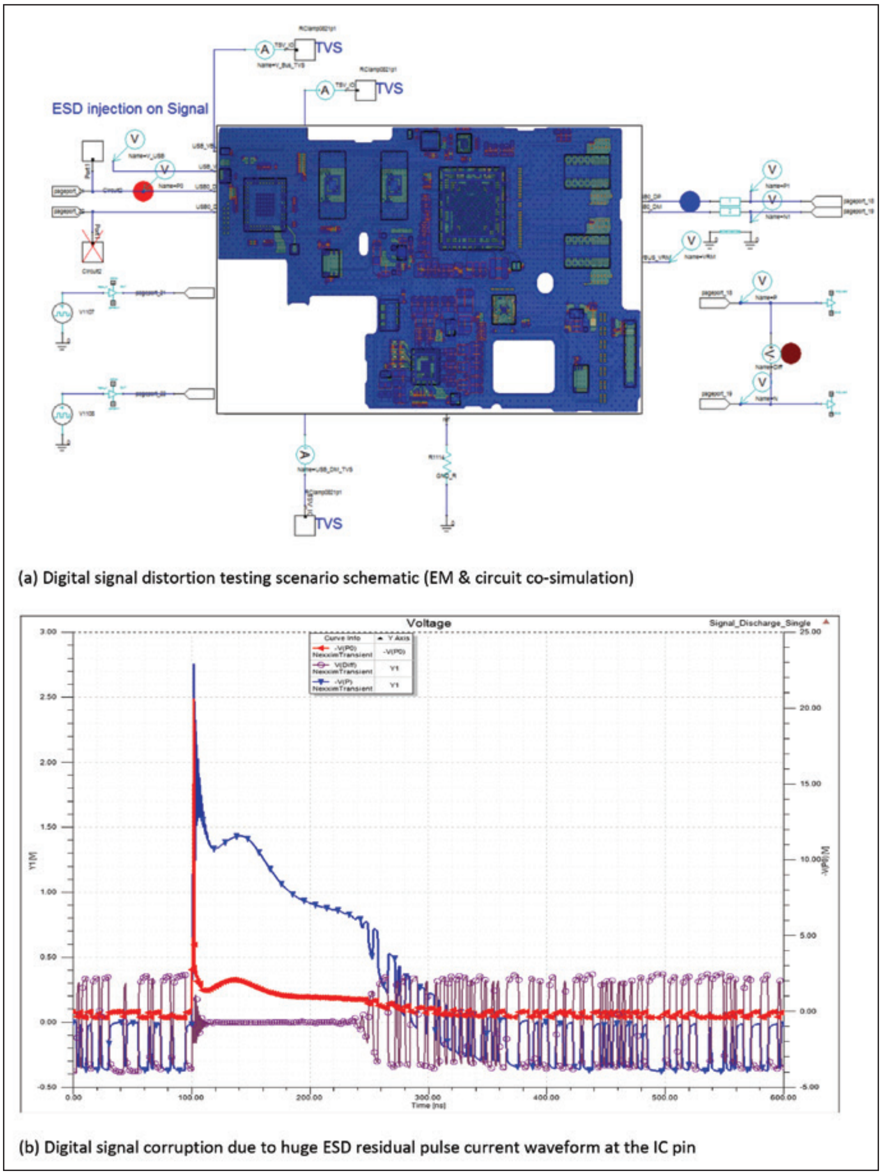
Another example demonstrates ESD propagation modeling [10] with a return ground path effect as shown in Figure 8 on page 37. This return path impacts ESD propagation on PWR, GND and signals. In this model, we intentionally selected the SLC line on the mobile PCB to see how the return ground path effect would depend on the impedance variation in the range of zero to hundreds of ohms.

With zero-ohm reference return current path, we get 42.5uV on SLC node1. With one ohm return ground path impedance, we get 2.7V on SLC node1, which is large enough to create ESD damage on the SMD. Figure 9 on page 38 shows the waveform on the highlighted objects.

A what-if analysis was done on the design to simulate the system with different chip models capturing different Cdie. Figure 10 on page 38 shows chip pin voltage V(t) changes with different chip Cdie in CECM(s).

In another simulation example, we analyzed a USB2 interface's impact on an ESD event and provided a system design guide in terms of ESD propagation. System-level ESD protection can be ensured by different module levels, and, at the IC level, IC pins have their own on-chip ESD protection. This, however, does not necessarily mitigate transient effects within the system. The USB2 connector shield was stressed with the ESD discharge current from the 5kV ESD gun model, and the engineers were then able to simulate the transient effects. This type of methodology easily allows teams to make additional design trade-offs in terms of device spacing and additional filtering and protection mechanisms.

In the third example, we analyzed the ESD current propagation with a return ground path effect, which can impact power, ground, and signals. There are challenges in measuring voltage or currents on IC pin or package bump location, and it is impossible to probe them without breaking the IC package. When designers use software to do virtual prototyping for system-level ESD, there are no such measurement limitations. Without this barrier, designers can get insights on whether to put more ESD protection on PCBs or on-chip.



(a) Digital signal distortion testing scenario schematic (EM & circuit co-simulation)

(b) Digital signal corruption due to huge ESD residual pulse current waveform at the IC pin

Figure 7: Demonstrates the simulation method and the resulting residual voltage waveform (blue curve in (b)) at the IC pin when the connector shield is stressed with the ESD discharge current (red curve in (c)) from the 5kV ESD gun model.

EXPERIMENTAL VERIFICATION

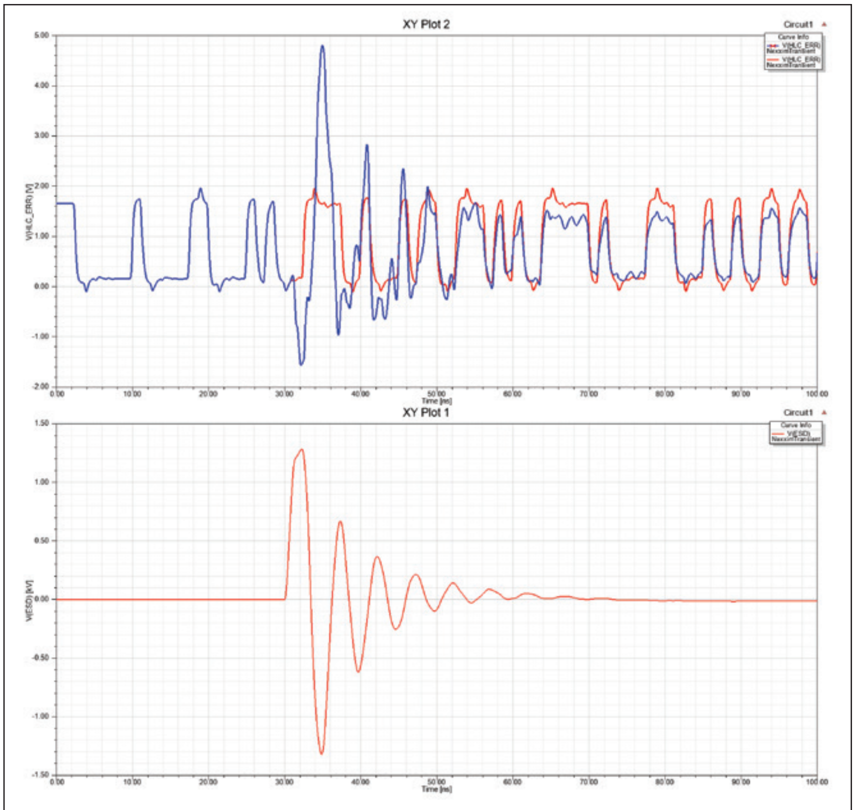
Finally, we must validate this simulation approach with test and measurement as part of the validation process. The ESD discharge current waveform injected by the ESD generator and the voltage waveform on the processor IC input signal trace are measured to validate the simulation results, as shown in Figure 11(a) on page 39. The injected current waveform is measured using a test board and a current probe shown in Figure 11(b).

The voltage waveforms across the TVS and CMF are measured using a custom designed test board with three TVS diodes and a mounted CMF, as shown in Figure 11(c). To measure the voltage waveform, two 50-ohm coaxial cables were used to connect the test board (via SMA connection) to the oscilloscope with an attenuator and ferrite beads.

Figure 11(d) shows the measured (sky blue) and simulated (orange) voltage waveform on the USB connector pin and processor IC input signal trace. This allows us to verify the accuracy of simulation results as shown at probe point at SOC input pin.

SUMMARY

IC and systems design can no longer be viewed as separate disciplines when it comes to analyzing



(c) Digital signal disruption due to relatively small ESD coupling impact

Figure 7 *continued*: Demonstrates the simulation method and the resulting residual voltage waveform (blue curve in (b)) at the IC pin when the connector shield is stressed with the ESD discharge current (red curve in (c)) from the 5kV ESD gun model.

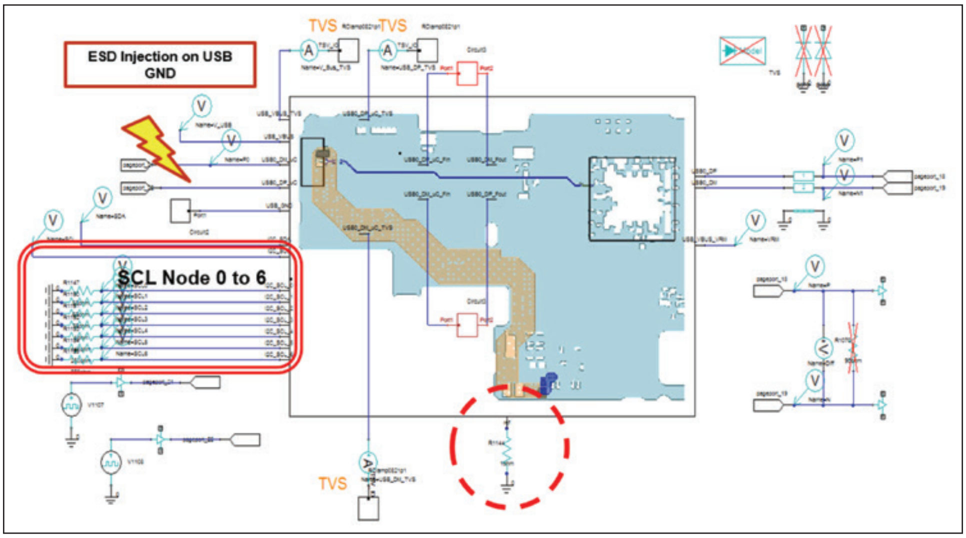


Figure 8: System return ground path effect on SLC node

and preventing ESD. The complexity of SoCs, the boards they sit on, and the packages within which they are located are all connected and can be potentially affected by ESD in isolated areas[10].

Now, there is a comprehensive chip-package-system (CPS) ESD simulation methodology that addresses IEC61000-4-2 testing conditions. It starts with an innovative full-chip ESD compact model, which is then combined with full-wave transient models of the ESD gun, ESD protection devices, PCBs with vias, advanced packaging (including 3D ICs), and connectors — for unrivaled system-level ESD analysis.

It can be challenging to protect against ESD in complex, high-speed technologies, as these require careful signal path design and must survive system-level ESD requirements. Simulation, therefore, has become an essential part of designing ESD robust electronic systems. A holistic methodology effectively and efficiently locates and mitigates ESD risks well before hardware prototypes are available, saving teams time, effort, and money. This approach can lead to more reliable and efficient systems in crucial applications, such as automotive, avionics, 5G and, yes, in-flight entertainment systems.

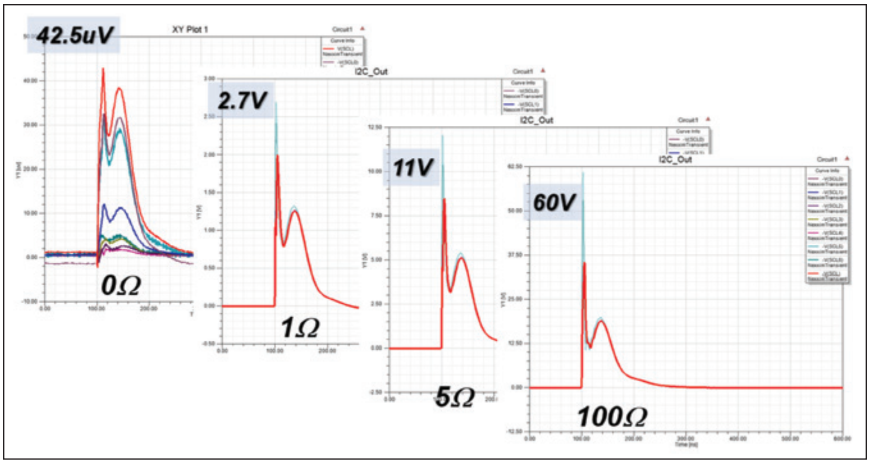


Figure 9: ESD propagation modeling result at SLC node1

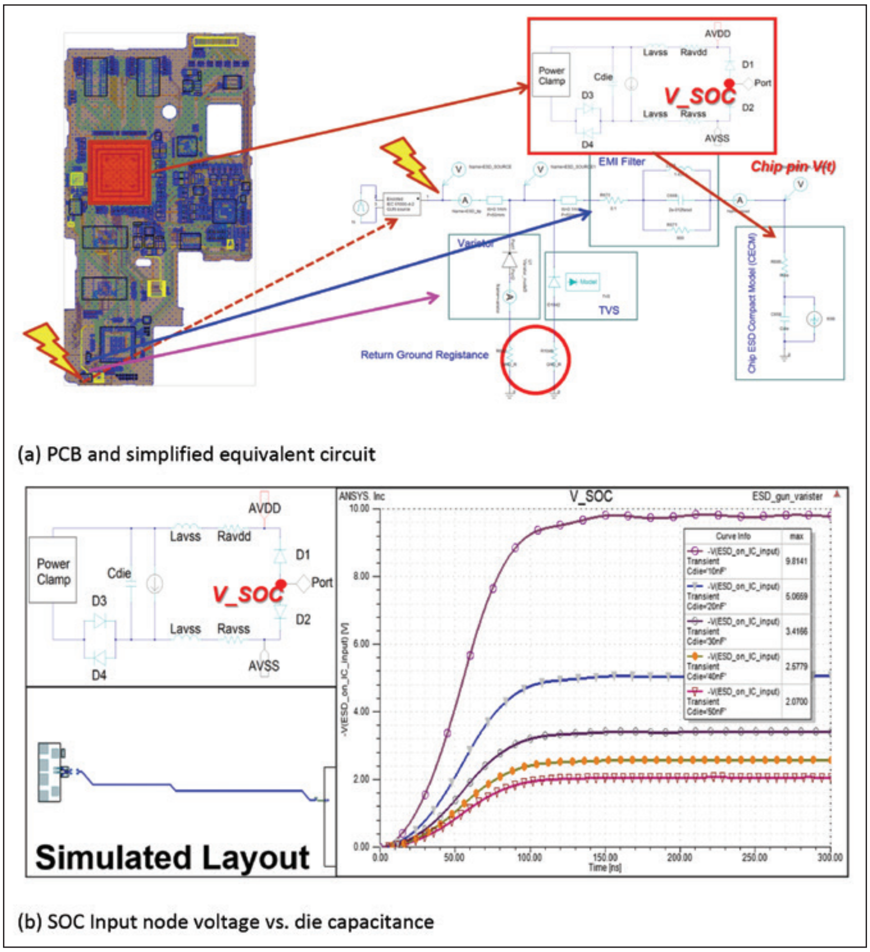


Figure 10: Chip pin V(t) in CPS ESD with different CECMs

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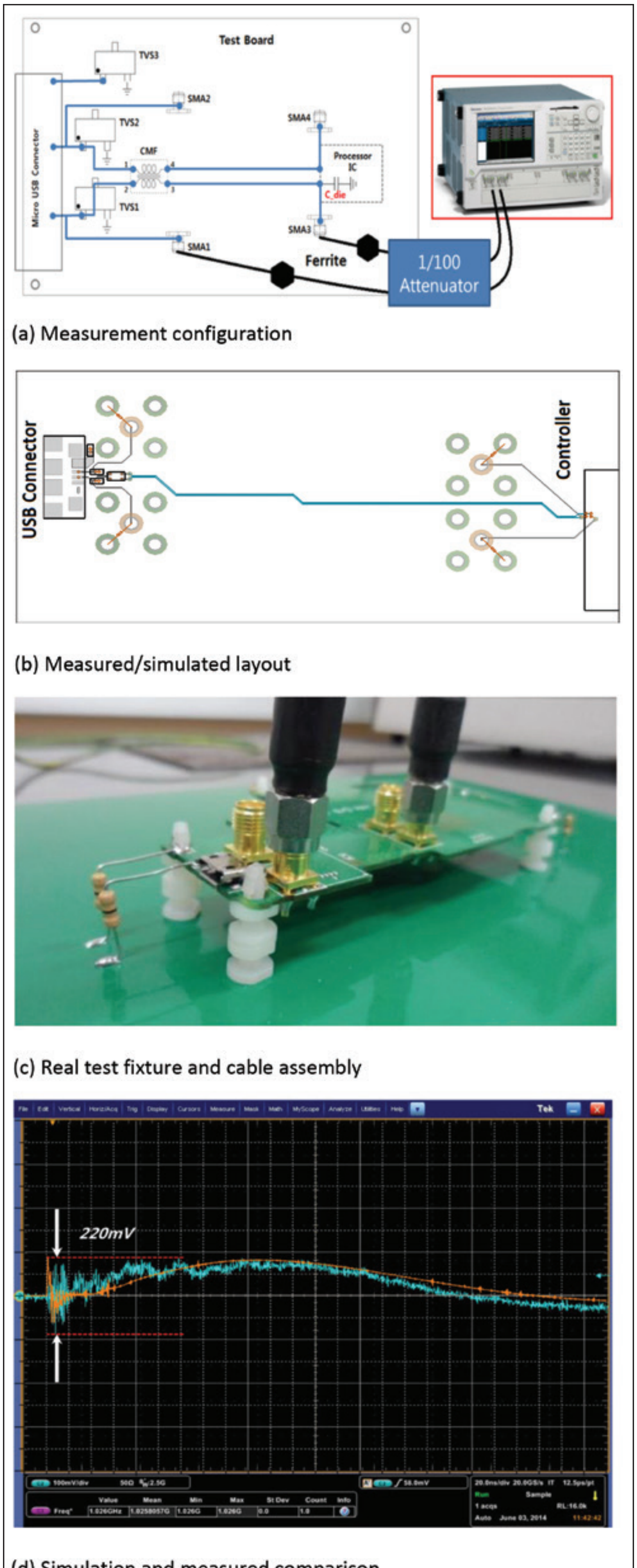

(a) Measurement configuration

(b) Measured/simulated layout

(c) Real test fixture and cable assembly

(d) Simulation and measured comparison

Figure 11: Experimental verification with custom PCB design

THE DEVELOPMENT OF PROFICIENCY TESTING PROGRAMME FOR ELECTRICAL AND MECHANICAL SAFETY TESTS

By S.L. Mak and H.K. Lau

***Editor's Note:** The paper on which this article is based was originally presented at the 2018 IEEE International Symposium on Product Safety Engineering in San Jose, CA. It is reprinted here with the gracious permission of the IEEE. Copyright 2020 IEEE.*

The ISO/IEC 17025 accreditation is essential to consumer product testing laboratories. According to the requirements of the Consumer Product Safety Improvement Act (CPSIA), consumer products shall be sent to third-party testing laboratories for testing before they can be put into the market. The certified third-party testing laboratories must already obtain the ISO/IEC 17025 accreditation in the specified test category [1]. The accreditation bodies require the ISO/IEC 17025 accredited laboratories to regularly join the proficiency testing (PT) scheme in appropriate testing areas.

The Hong Kong Accreditation Service (HKAS) provides ISO/IEC 17043 accreditation services to proficiency testing providers in Hong Kong [2]. Current proficiency testing providers are providing three different proficiency test areas: (1) calibration; (2) medical testing; and (3) chemical testing [3]. As the majority of testing and certification companies in Hong Kong are providing consumer product testing services, they can only join the proficiency testing organized by overseas services providers, such as LGC in UK, IQTC in China, ASTM in USA or IEC. In addition, the HKAS also irregularly organizes proficiency testing programmes to the accredited laboratories (e.g., acoustics testing carried out in 2015) [4]. However; they only invited the laboratories that are already accredited by HKAS to join the programme. Therefore, it is impossible to determine the competitive between HKAS accredited laboratories and other overseas laboratories.

In order to fulfill the need of the industry, the Open University of Hong Kong (OUHK) is planning to develop a proficiency testing programme that is suitable for electrical and mechanical safety tests in Hong Kong. This article describes the development process of the proficiency testing programme, frequency of testing, selection of test specimen and method of data analysis.

PURPOSE OF PROFICIENCY TESTING

The ISO/IEC 17025 standard was developed to specify the general quality and technical requirements for the competence of testing and calibration laboratories. It specifies both the management and technical requirements. The management requirements require the laboratories to apply the proficiency testing and use the results to develop appropriate preventive actions. Meanwhile, top management shall review the result of interlaboratory comparisons or proficiency tests in the management review meeting.

In the technical requirements, on the other hand, the quality assurance system shall include: 1)the use of certified reference materials to validate the test; 2) participate in the proficiency testing; 3) replicate tests or calibrations using the same or different methods; 4) retesting of retained samples; and 5) correlation results for difference characteristics of a specimen [5].

Some researchers described that proficiency testing is a good platform to supplement a laboratory's internal quality control procedure and enables the comparability of measurement between laboratories. In other words, it can be considered as an external partial audit of laboratory quality management system [6].

INTERNATIONAL STANDARDS FOR PROFICIENCY TESTING PROGRAMME

Several international standardization bodies have published guidelines and criteria for the development of proficiency testing programmes. ISO/IEC 17043 describes the general requirements for proficiency testing and is adopted by most of the accreditation bodies to offer accreditation services, such as UKAS, NATA, A2LA, CNAS and HKAS. Table 1 shows other guidelines published by standardization bodies in describing essential criteria of a proficiency testing programme. Most of them are applicable to a specific product, such as fabric or water.

The ASTM D6674 and ASTM E2027 are designed for chemical or fabric materials testing. The OUHK, on the other hand, addresses proficiency testing programmes for mechanical and electrical safety testing in accordance with ASTM E1301.

There are other PT programmes, such as medical testing, chemical or fabric testing available in the market. They summarized the challenges of PT development, including:
1) selection of specimen; 2) homogeneity and stability validation of specimen, and;
3) selection of statistical analysis method to test the differences between laboratories [8].

Standard Code	Standard Description
BS EN ISO/IEC 17043: 2010	Conformity assessment – General Requirements for proficiency testing
ASTM E1301-95	Standard Guide for Proficiency Testing by Interlaboratory Comparison
ASTM D6674-01	Standard Guide for Proficiency Test Program for Fabrics
ASTM E2027-17	Standard Practice for Conducting Proficiency Tests in Chemical Analysis of Metals, Ores, and Related Materials
BS ISO 13528: 2015	Statistical Methods for use in Proficiency Testing by Interlaboratory Comparison
PD 6644-1: 1999	Proficiency testing by Interlaboratory comparisons – Part 1: Development and Operation of Proficiency Testing Schemes
PD 6644-2: 1999	Proficiency testing by Interlaboratory comparisons – Part 2: Selection and use of Proficiency Testing Schemes by Laboratory Accreditation Bodies

Table 1: List of standards for developing the proficiency testing programme

Requirements	Standard Description
General requirements	• Appoint well-experienced staffs to develop and maintain the PT scheme; • Gain ISO/IEC 17025 accreditation to demonstrate the competence in the measurement of the properties being determined.
Personnel	• Appoint qualified and well-experienced staffs to develop and maintain the PT scheme; • Appoint expertise to form advisory group to provide the comments in order to continual improvement
Equipment, accommodation and environment	• Make sure that all the facilities and equipment for the PT scheme are to be traceable and calibrated.
Design of PT schemes	• The measurands shall be properly selected by consulting the advisory group and laboratories. • The specimen shall be homogeneous or checked for stability. • The assigned value shall be measured by the reference laboratories (either our own laboratory or subcontractors) • Clear instruction shall be made to PT participants to pre-treat and operate the test specimen • A laboratory ID will be randomly assigned to each PT participant. This ID will be used to represent the participant throughout the study to ensure the confidentiality of the participant's identity.
Data analysis and evaluation of PT scheme results	• A proper statistical analysis method shall be adopted to analyze the result provided by each PT participants.
Management requirement	• The PT scheme provider shall design an appropriate quality management system (QMS) to meet the ISO QMS requirements.

Table 2: List of essential requirements of ISO/IEC 17043: 2010 [9]

DEVELOPMENT PROCESS OF PROFICIENCY TESTING PROGRAMME

The development of a proficiency testing programme includes several major steps: 1) develop a Quality Management System (QMS) and obtain the ISO/IEC 17025 laboratory accreditation; 2) develop the proficiency test scheme; 3) invite laboratories to join the trial run of proficiency testing scheme to valid the scheme; 4) modify the scheme, and; 5) apply for the ISO/IEC 17043 proficiency testing provider accreditation.

Step 1: We will appoint a reference laboratory to conduct the preliminary measurement and find the assigned value for determining for interlaboratory differences. We will assign our own laboratory to be the reference laboratory and gain the ISO/IEC 17025 accreditation.

Step 2: All essential requirements of ISO/IEC 17043 must be met by the PT scheme. Table 2 shows the major essential requirements and explains how we proceed to meet the requirements.

The criteria of PT specimen homogeneity and stability shall be established and analyzed. ISO Guide 34, ISO Guide 35, and ISO 13528 can be referenced to develop the criteria. According to ISO/IEC 17043, it is acceptable to consider the effect of uncertainty if the specimens are not sufficiently homogeneous or stable. The ISO 13528:2015 Annex B suggested a four-step method to test for homogeneity. Table 3 shows the steps to test for homogeneity.

In one of our trial PT programmes, two measurands are selected to be measured, i.e., kinetic energy of projectile toys (Figure 1) and sound pressure level of sound-emitted products (Figure 2). We establish the procedure to test stability.

All samples were brought from the same batch from the supplier, such that they are considered to be homogeneous. Therefore any one of the samples is being representative to the batch and is sufficient for this analysis. In order to simulate the actual operations of PT items through the PT program, the reference laboratory will carry

Step	Descriptions
1	Preparation and packaging of the samples
2	Random select at least ten samples per batch
3	Prepare two subsamples from each sample
4	Samples will be measured randomly under repeatability conditions. The samples will be considered to be sufficiently homogeneous if $s_s \leq 0.3\hat{\sigma}$

Table 3: Method for testing homogeneity [10]

Figure 1: Projectile toy for proficiency testing

Figure 2: Sound emitting toy (rattles) for proficiency testing

out the following: 1) determine assigned value (KE) of the sample; 2) repeat operation of the sample as required for 20 times; 3) repeat operation of the sample as required for determining the travelling speed for 5 times; 4) determining the kinetic energy (KE) of the sample, and; 5) apply the statistical method to determine the homogeneous.

The second trial of PT programme is on electrical safety testing. The measurement of creepage clearance is selected and sent the specimens to the interested laboratories. The creepage distance means the shortest distance along the surface of a solid insulating material between two conductive parts (Figure 3).

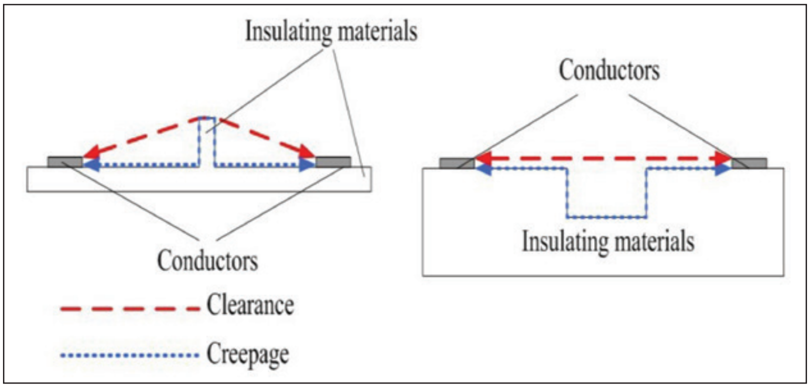

Figure 3: Measurement of creepage and clearance distance

IEC 60601, IEC 62115 or IEC 60335 specify the required values and the minimum creepage distance can avoid failure due to tracking. Failure in creepage distance may cause short circuit and fire hazard. It should be noted that larger clearances are required if the product is subjected to mechanical vibration. The degrees of pollution are other factors to affect the required creepage distance [11].

Although the measurement of creepage distance is critical to the safety of electrical products, the standards do not specify the resolution and accuracy of measurement instruments. Some laboratories are using the Vernier caliper, and others may use measuring microscopes (Figure 4). ISO Guide to Uncertainty of Measurement (GUM) divides the uncertainty to Type A and B. Type A uncertainty can be evaluated by the statistical analysis of series of observations. Type B uncertainty can only be evaluated by means other than the statistical analysis of series of observations.

Some examples of sources of uncertainty that lead to Type B evaluations are: 1) reference instruments calibrated by laboratory; 2) physical constants used in the calculation of the reported value; 3) environmental effects that cannot be sampled; 4) possible configuration/geometry misalignment in the instrument, and; 5) resolution of the instrument [12]. Due to different measurement instruments having different resolutions, the uncertainty of measurements may be different. The Programme aims to evaluate the competence of laboratories and the uncertainty of measurement due to the resolution effect of measurement instruments.

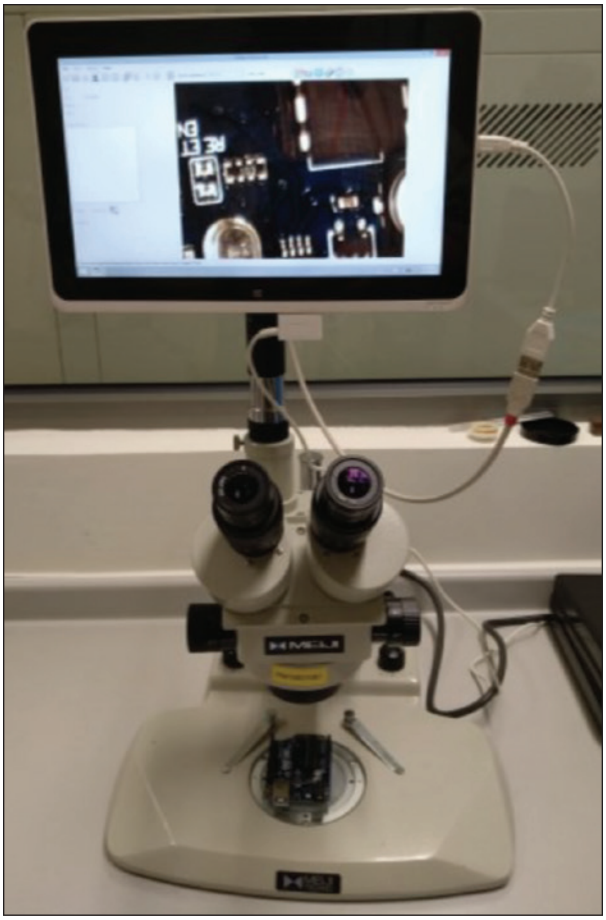
Figure 4: Measuring microscope

EVALUATION OF PROFICIENCY TESTING RESULTS

The participated laboratories will submit the measurement results to the PT provider. Then the PT provider shall apply the pre-determined appropriate statistical method to analyze the difference between PT participants. The most common methods are z scores and En scores. The assumption of z scores are made with a hypothesized distribution of competent laboratories and not on any assumption about the distribution of the observed result. We can interpret the z scores by:

- A result that gives $|z| \leq 2.0$ is considered to be acceptable;
- A result that gives $2.0 < |z| < 3.0$ is considered to be questionable;
- A result that gives $|z| \geq 3.0$ is considered to be unacceptable.

En scores will be used if the PT participant's ability having the result close to the assigned value within their claimed expanded uncertainty. The method is commonly used for PT in calibration.

For the PT programme used in this research, the z score method is found to be more suitable to evaluate the difference in the conducting the quantitative measurement, such as kinetic energy and creepage distance.

CONCLUSION

This article described the development process of a proficiency testing programme that is suitable for electrical and mechanical safety tests. The current HKAS accredited proficiency testing programme only covers chemical and medical tests and calibration. The new proficiency testing programme can fulfill the need of industry in order to meet the ISO/IEC 17025 requirements and help to industry to evaluate the differences between different laboratories or locations.

ACKNOWLEDGEMENT

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PRODUCT LIABILITY MARKETING DEFECTS

Liability for Words and Pictures You Use for Marketing

Manufacturers of products and providers of services can be held liable for injury, damage, or economic loss suffered by a customer or a third party based on all aspects of its products and services. This includes the product or service itself, all written materials that accompany the product including warnings and instructions, and all oral and written statements made before and after sale. As a result, manufacturers and service providers must provide a reasonably safe product, competent services, and written and oral statements that do not diminish the quality or safety of the product or service, or confuse the customer into doing something that results in injury, damage, or loss.

These types of lawsuits have become more common as products have become safer and fewer accidents occur, and plaintiffs' lawyers have looked for other claims surrounding the sale of a product. In some cases, these claims can even be brought by an entire class of people who purchased the product.

The so-called "no-injury class action" is usually based on some representation by the manufacturer before sale and the dashed expectations of customers as to things such as performance, safety, quality, or durability. Even without provable damage, settlements have exceeded hundreds of millions of dollars, with at least one involving an alleged design defect in computer chips in Toshiba laptops exceeding $2 billion.

SOME EXAMPLES

Examples of past litigation will be helpful in illustrating how expansive the theories can be and how easy it is, in some situations, to bring such a suit. Here are some notable cases:

- One of the early cases that established product liability involved marketing brochures. The case of *Greenman v. Yuba Power Products, Inc.* (1962), dealt with a Shopsmith power tool. While the California Supreme Court mainly used this case to adopt the

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By Kenneth Ross

theory of strict liability for the first time, it also discussed marketing issues. It said that the jury could have reasonably concluded that statements in the manufacturer's brochure were untrue, that these statements constituted express warranties, and that plaintiff's injuries were caused by their breach. The marketing literature used phrases such as "insures perfect alignment of components" and "every component has positive locks" and "provides rigid support."

- One of the original drug product liability cases (*Toole v. Richardson-Merrell*, 1967) resulted in liability because the drug was advertised as "virtually non-toxic," "safe," and free of "significant side effects." In addition, the marketing of prescription drugs directly to consumers, which is a fairly recent phenomenon, has been the subject of a great deal of litigation. The typical allegation is the failure to adequately warn the user while the defense is the "learned intermediary doctrine," which is under attack because of this direct marketing. The way in which the product is advertised and marketed and the disclaimers and safety precautions that are provided to consumers are issues in these cases.
- In a case from 1990 involving Johnson & Johnson baby oil, an injury occurred when a baby swallowed the baby oil and it got into its lungs. The mother was not alarmed because she knew that baby oil was safe. Unfortunately, it was not safe in lungs and a severe injury resulted. The plaintiff's human factors expert said that the product label, which used the term "pure and gentle," perpetuated a belief that the product was very safe and benign in all foreseeable situations.
- Another case from the early 1990s involved the Jeep CJ-7, which was advertised driving up Pikes Peak at a high rate of speed around tight turns on the mountain. These turns were called "J turns" because the marks in the mountain road looked like a "J." The plaintiffs saw the ads and thought the roll bar would protect them if the vehicle turned over. It didn't and they were severely injured. The case proceeded on the theory of misrepresentation using the Jeep ads as evidence that such driving was foreseeable and intended. This despite the fact that the plaintiffs drove the Jeep off the top of a road flying almost 50 feet through the air and landing upside down. The court called the advertising an example of "intentional incitement of unlawful conduct."
- A manufacturer of recreational products was held liable because its promotional video showed users without safety equipment, which the warnings and instructions required be used. Even though the plaintiff did not see the video, the jury believed that the manufacturer was sending a mixed message about following the safety precautions it provided with the product.
- Other examples from litigation include use of the terms "bulletproof," "absolutely safe," "stops assailants instantly," "tamperproof," "shatterproof," "harmless," and "indestructible." These terms used in advertising or on product packaging were presumably relied on by the user to their detriment and, in some cases, resulted in liability for the manufacturer.

Allegations of defects in the way the product was marketed, while not usually the primary focus of most product liability cases, have been used by plaintiffs when necessary. Even if not specifically alleged, marketing statements have been an integral part of many claims, especially those involving failure to warn or instruct. And with the advent of the Internet and extensive websites set up by manufacturers and product sellers, there are many more opportunities for a manufacturer to slip up and say or show something that will create a problem in the event of an incident.

THEORIES OF LIABILITY

Unlike a typical product liability case, there are many more theories that can be alleged. I want to quickly describe a few of the possible theories in the sections that follow.

Strict Liability and Negligence

Many of these marketing cases are brought primarily under the theories of strict liability or negligence. The allegations are that the product is defective in its design or warnings and instructions and, in addition, that the product did not meet the consumer's expectations as to safety, quality, or durability. The marketing literature might be a piece of evidence that, for example, shows the product being used inconsistently with the way it is described in the instructions, and the user relies on the picture and is injured.

Or, there is nothing wrong with the marketing literature and there is just some inadequacy in the warnings or instructions, either in something they say or don't say. Or the advertising refers to the product as "rugged" and "solid" and that forms a basis for expectations about how strong it is and what type of misuse it can withstand. In this situation, the marketing defect claims would be part of a typical defect claim and the plaintiff would rely on strict liability or negligence and not try to use breach of warranty, fraud, or misrepresentation, all of which can be harder theories to prove.

Manufacturers are required to provide adequate warnings and instructions to the purchaser to allow them to use the product safely and correctly. Injury, damage, or loss resulting from inadequate or incorrect information can be the basis for a product liability lawsuit against the manufacturer. Warnings and instructions usually accompany the product and possibly are included in some of the literature that the manufacturer uses to sell the product. Under these theories, any oral or written statements made by anyone in the supply chain can also be used to argue that the warnings and instructions were inadequate, confusing, or inconsistent, or that the marketing literature undermined the severity of the warnings provided with the product.

Breach of Contract

In some situations, an injured party can sue for breach of contract and base the claim on oral or written statements made during the sales process or in the warranties in the contractual documents. The damages could be based on injury or damage, but usually would include a claim of economic loss. The contractual terms and conditions should govern the potential liability and recoverable damages except for implied warranties that have not been disclaimed.

Express Warranty

In both contracts and marketing/sales, warranties can be created by operation of law under the Uniform Commercial Code (UCC). Express warranties are created by the following:

- Any affirmation of fact or promise made by the seller to the buyer that relates to the goods and becomes part of the basis of the bargain;
- Any description of the goods that is made part of the basis of the bargain; or
- Any sample or model that is made part of the basis of the bargain.

The above create an express warranty that the goods shall conform to the fact or promise, description, or sample or model. It is not necessary that the seller use formal words such as "warrant" or "guarantee" or that he or she have a specific intention to make a warranty. However, it is necessary that these involve "the benefit of the bargain," which means that they occur at the time of or before the purchase is consummated. In other words, the purchaser will say that they relied on these statements, sample or model to purchase the product and to use it.

An express warranty can be created by any written or oral statement or even by the appearance of the product. These statements are included in the sales and marketing literature, catalogs, website, and all statements by salespeople.

While terms and conditions usually attempt to limit any express warranty to "defects in workmanship and material" or only warrant that the product "conforms to the specifications in the catalog," the purchaser will seize on any inconsistent or expansive language to argue that additional express warranties were provided and that he or she relied on them to buy and use the product. If express warranties are deemed to have been created, this could be a problem as courts have said that a seller can't generally disclaim them.

So sellers need to be aware of everything that is expressly said about the product. This includes marketing and sales literature by the manufacturer and everyone else in the supply chain, and every oral statement by anyone that ultimately gets to the purchaser either before sale or even after sale as long as they occurred before the accident or product problem.

Even advertising issued after an accident can adversely impact your defense. The problem arises if your defense is that the plaintiff was using the product unsafely. That is hard to argue if your advertising shows a user using the product in the same way.

Implied Warranty

The UCC also creates an implied warranty of merchantability and fitness for a particular purpose. These warranties are implied in every sale of a product that is subject to the UCC unless they have been disclaimed. Most terms and conditions disclaim these warranties, however it is possible that the terms and conditions may not govern the sale and these warranties will therefore not be disclaimed.

Since these are implied warranties, the scope of their applicability is governed by the UCC. The definition of "fitness for a particular purpose" has some relevance. This UCC section says:

> *"Where the seller at the time of contracting has reason to know any particular purpose for which the goods are required and that the buyer is relying on the seller's skill or judgment to select or furnish suitable goods, there is …an implied warranty that the goods shall be fit for such purpose."*

Many written statements assist the purchaser in determining the type of product to buy. Therefore, even if this implied warranty is disclaimed, it is possible that there will be an express warranty that the goods are fit for the purpose expressed in a company's written material. And, in many situations, this implied warranty will not have been effectively disclaimed. In addition, if the purchaser expressly tells the sales personnel what the product will be used for and confirms with these personnel that the product to be purchased is the correct one to buy, a warranty could arise, be it express or implied.

Misrepresentation and Fraud (Common Law and Statutory)

Theories alleging liability for injury, damage, or loss caused by intentional or negligent misrepresentation have also been used. Intentional misrepresentation involves statements that are intended to induce action by another, such as to use a product in a certain way. These statements are alleged to create an unreasonable risk of injury in that they are false or that the person making them does not have the knowledge he or she claims to have.

Negligent misrepresentation involves giving false information to another that causes injury or damage from actions taken by another person in reliance on that information. The negligence can occur by the person failing to exercise reasonable care in determining the accuracy of the information or by failing to exercise reasonable care in the way in which the information is communicated.

Misrepresentation and fraud cases carry a heavy burden of proof, and that is probably why most plaintiffs, in a typical product liability injury case, generally rely more on strict liability, negligence, and breach of warranty than on misrepresentation or fraud.

However, every state has some form of consumer fraud statute that can be separately used to allege fraud and deceptive trade practices. These laws are based on the Uniform Deceptive Trade Practices Act or Uniform Consumer Sales Practices Act. The elements necessary to prove are much less than common law fraud and a successful plaintiff is usually also entitled to treble damages and attorney's fees.

Many of the state statutes don't require actual injury or damage in order to recover. And some courts have allowed a nationwide class action to proceed based on an alleged violation of these state statutes.

INTERACTION OF THESE THEORIES

In product liability claims and litigation, plaintiffs can allege claims of breach of contract, breach of warranty, misrepresentation/fraud, negligence and strict liability (defects in design, manufacture, and warnings and instructions). They will use the product and any statements printed or uttered by the manufacturer to support their claims.

A major element of proof for many of these theories is that the purchaser or injured party relied on the statement, misstatement, or lack of a statement. Despite that requirement, even if the plaintiff didn't rely on the statement, statements can be put into evidence for other purposes to support another claim or to portray the manufacturer as careless or intentionally misleading. In addition, some statements make it more difficult for the manufacturer to defend itself, such as when the injured party did something unsafe that seemed to be authorized by the manufacturer or at least not prohibited.

PREVENTIVE TECHNIQUES

It has been said that much of product liability reflects the inability of American engineering to match the claims made for products by its marketing professionals. Given the wide range of products that companies manufacture and services they provide, it is difficult to articulate clear guidelines on what to say and not to say when advertising and selling products. However, let me try to provide some of my thoughts based on my many years of experience.

The first rule is the old saw, "say what you mean" and "mean what you say." Many problems in this area are caused by unclear, unsupported, and incorrect statements caused by unclear or incorrect thinking. If you want to promise that the product will perform in a certain way, then be sure it can do it. There really is no defense if a product is used as you advertised and it doesn't work the way it should work. This may result in a disgruntled purchaser and no claim. But it could just as easily result in a warranty claim, a personal injury case, or a class action based on some misrepresentation.

Therefore, the first rule is that if you clearly say or promise something that is material to either the purchaser's decision to buy the product or helps with the safe use of the product, it should be clear and correct. Lawyers who review these representations might have a difficult time commenting on these factual assertions in your advertising and marketing unless they are very knowledgeable about the product and your company. Despite that, while lawyers should not make you justify each and every fact, they can point out statements that seem too good to be true or suggest where you should have documented substantiation for the claim.

An example is use of the phrase "maintenance free." While I will discuss puffing below, this is a clear statement with no limitations and can be a problem if not true. If it isn't qualified by "almost" or "virtually" or "in most situations" and someone buys the product and this turns out to be false, they could claim that they didn't get the product they thought they were getting. And if the claim is based on a state's consumer protection laws, they don't even need to prove damages. In addition, if the user does not perform maintenance and the product fails, injuring a user, the manufacturer might have a problem defending the case. However, this shouldn't be a big risk as appropriate maintenance procedures, if any are necessary, should be discussed in the instructions.

Puffing is different and is legally acceptable. Puffing is not viewed as an expression of a fact but instead as an opinion about a product's performance or attributes. As a result, "puffery" does not constitute an express warranty. So phrases like "never lets you down" or "strong" or "finest product of its kind available today" or "premium quality" have all been deemed acceptable puffing or opinion and not a factual assertion that can be the subject of a lawsuit. This, of course, does not mean that a customer may not sue over some puffing that resulted in injury or damage.

Courts have identified different factors to consider when distinguishing puffing from facts. They are buyer sophistication, trade usage, whether the goods are prototype, the presence of hedging, and the level of specificity, with specificity being the most important.

Of course, it is up to the judge or jury as to whether they believe it is fact or opinion. And a purchaser who believes the puffery and suffers a problem might sue you. So, you should try to anticipate how customers will react to everything you say, be it fact or opinion, and determine if they will use the product in an unsafe or incorrect way or think it is stronger or lasts longer than it does, or buy it for an inappropriate use. If they will rely on puffing or facts and it could result in injury, damage, or loss, think how you will defend the statement and if in doubt, soften or limit the language.

In your literature and advertising, statements that should always raise a question are absolutes or clear statistical statements that can be challenged even if they are not facts. Puffery may allow you to claim that your product has the best quality, but saying it is the "strongest" or "safest" on the market can be objectively tested and challenged by a customer or a competitor. Or a user could think the product can be subjected to forces that ultimately result in product failure and injury. In addition, while using terms like "virtually" and "almost" are very good at indicating that the product is something other than the absolute best of whatever you are selling, use them sparingly as they can unnecessarily detract from the message and make it unclear.

Let's consider some statements that have appeared in marketing or technical literature with comments about whether or not they may be problematic.

- "Safe" – this is acceptable because it is not an absolute. It would be hard to challenge. Despite that, some lawyers will not let their clients use "safe" in connection with a product. My counter-argument is that since we are required to sell a "reasonably safe" product, why can't we say that it is "safe?" I wouldn't say "completely safe" or "absolutely safe." On the other hand, one problem with saying "safe" is that it might imply that your other products aren't safe.
- "Helps bring safety to the next level" or "safer" – this is acceptable as it doesn't guarantee absolute safety. However, you should be careful when saying that some of your products are safer than your remaining products. While the law allows manufacturers to sell products with different levels of safety, an issue can arise if the plaintiff argues that the less safe product you sell is not safe enough. The fact that you sell a safer product can constitute the "reasonable alternative design" that plaintiffs are required to prove in many jurisdictions to succeed in a design defect claim.
- "State of the art design" – this means that the design is as good as the best design on the market. This is more easily challenged but still acceptable as long as you have a basis for making the statement. "Optimized design" is vaguer and is also acceptable.
- "Ensures," "assures," and "insures" – most lawyers believe that these words constitute an express warranty. But it depends on the phrase to which it is connected. If the remainder of the phrase is somewhat general, then I don't mind use of these words. For example, if you say that the product's design "ensures that the product will provide the user best in class service, that should be acceptable since "best in class" is a pretty vague term. And, if it doesn't, then that is a problem whether or not you use the word "ensure." One way to soften it is to say something like "helps to ensure."

Of course, in most situations, the plaintiffs have to prove some injury or damage based on these statements. If they don't buy the product, I can't think of any claim they can make. And if they buy the product, most courts have been tough on plaintiffs by requiring them to prove some damage or loss. Many of the "no injury class actions" have been dismissed because the alleged damage or loss has been illusory or more in the mind of the customer.

Another area of importance for product literature is the potential for inconsistencies between safety and operational information in the marketing literature and in the instructions and warnings. While it is not necessary to place all of the safety information in the marketing and advertising literature, there should not be confusing and misleading information that some customer may rely on in place of the product's actual warnings and instructions.

In addition, inconsistencies between representations in the marketing literature and in the field by salespeople can also create problems. Salespeople can create express warranties or can inappropriately alter the well thought out advice in carefully crafted instructions with simple statements made during the sales process. Customers have very good memories when it comes to what the salesperson thinks is "puffing" and the customer believes is a "promise of performance."

With advertising, below are some rules I have used in counseling manufacturers and product sellers:

- Unsafe practices or conditions should not be shown unless it is clearly noted that they are intended for demonstration purposes only. For example, removing guards or shields from equipment for illustration.
- Bystanders should be shown in a safe location or at a safe distance from the product.
- Show the product with all safety equipment, including labels and guards.

- All ads should accurately represent the product. Performance claims should be reasonable and in accordance with design specifications.
- When illustrated, the product should always be shown in an appropriate and safe use. That's why driving a car or other vehicle in a potentially unsafe manner in an ad should be done very carefully. Most manufacturers, when they feel compelled to cross the line or get close to the line on safe use, put a disclaimer under the ad that reads something like "Professional driver on closed course. Do not attempt."

  With the Jeep CJ-7 case in mind, I've always wondered whether these would be deemed adequate. Despite that, I suspect that no one is suing for such advertising as most of these product demonstrations could be considered obvious hazards where no warning is needed.
- Personnel using the product should be wearing appropriate personal protective equipment. This can be a problem even if the injured party did not see the ad and rely on it when using the product. It is hard to argue that they were using the product unsafely when it is shown being used that way in the company's advertising.

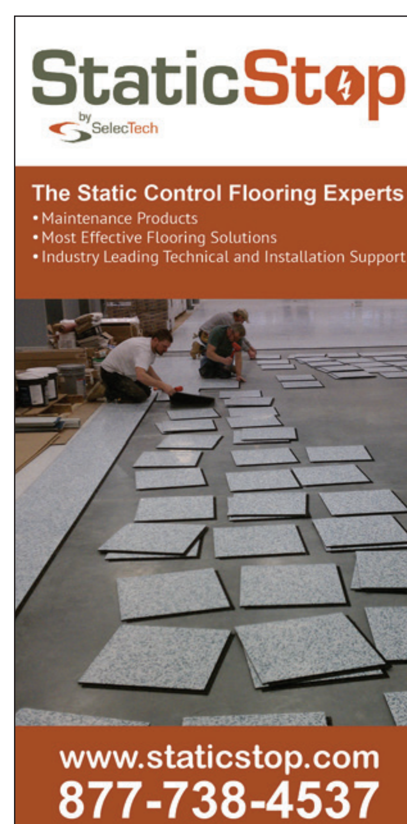
You should consider all of the representations that will be made about the product and set up a corporate policy to be used by in-house and outside personnel when developing such statements. This will help avoid such problems before they get to the lawyer for review. In addition, doing seminars to such personnel to explain why certain statements can be problematic can be very helpful in heading them off before they sneak into marketing literature.

CONCLUSION

Marketing and advertising personnel need to talk to the sales force and to the engineers so that the story, as told by all of them, is accurate and appropriate. Lawyers should educate their clients about how to decide what to write and how to write it, and what and when to send to the lawyers for their review.

Analyzing a company's potential risk in this area is useful in establishing appropriate procedures for creating and reviewing written literature, and for creating guidelines on how a product is to be sold. Doing this will help satisfy customers whose products work as promised and help them use the product safely and correctly. This will all result in lower risk to the manufacturer and product seller.

PRODUCT Showcase



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