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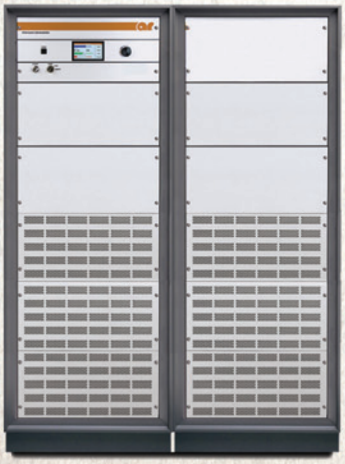

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News in Compliance

FCC News

FCC Proposes Fines for Failure to Respond

The U.S. Federal Communications Commission (FCC) has proposed financial penalties against two companies for failing to respond fully to Commission inquiries regarding activities covered under the FCC regulations.

The cases involve two separate companies that offer outbound calling services to third-party clients (also known as robocalling services). FCC regulations allow robocalls to consumer cellphones only during an emergency or in cases in which a consumer has provided advance consent to receive such calls.

In each case, the Commission sent the subject companies Letters of Inquiry (LOIs) requesting specific information. In the first case, an attorney for Message Communications requested an extension and then submitted information that the Commission deemed "material insufficient." The company has subsequently refused to supply additional information as originally requested by the Commission, despite repeated additional requests.

In the second case involving CallingPost Communications, the company never provided the Commission with any of the information requested by the Commission, despite multiple communications and repeated requests. Instead, according to the Commission's Notice of Apparent Liability, "the company continued to ignore the warnings and provided no answers—merely more excuses."

The Commission has proposed a financial forfeiture of $25,000 against each company for their failure to respond sufficiently to its request for information. In addition, the FCC has notified both companies that their continued failure to provide the information requested in the original LOIs may subject them to further enforcement actions.

The complete text of the Commission's Notice of Apparent Liability in connection with Message Communications is available at incompliancemag.com/news/1409_01. The text of the Notice of Apparent Liability for CallingPost Communications is available at incompliancemag.com/news/1409_02.

Fines for Amateur Radio Operators

Continuing its crackdown on amateur radio operators that illegally monopolize licensed broadcasting frequencies, the U.S. Federal Communications Commission (FCC) has proposed a $22,000 fine for a Detroit area operator, and a

FCC News

separate $11,500 fine for an amateur operator in Pennsylvania.

The monetary fines were proposed in Notices of Apparent Liability for Forfeiture issued in July 2014. In the first case, Michael Guernsey of Parchment, MI was found in violation of FCC regulations, which prohibit intentional interference licensed radio operations and require operators to regularly transmit their assigned call signs. Following local complaints of intentional interference, agents in the FCC's Enforcement Bureau in Detroit monitored signals from Guernsey's amateur station and heard continuous transmission of a prerecorded song along with various animal noises.

In the second instance, agents from the FCC's Enforcement Bureau in Philadelphia monitored transmissions from amateur radio station operator Brian Crow, following several complaints of interference. In one three hour long session, agents monitored Crow's station broadcast pre-recorded voice transmissions from another amateur station, along with emissions from slow-scan television.

The complete text of the Commission's Notice of Apparent Liability for Forfeiture against Guernsey is available at incompliancemag.com/news/1409_03. The Notice of Apparent Liability for Crow is available at incompliancemag.com/news/1409_04.

News in Compliance

European Union News

New List of Standards Issued for EU's Machinery Directive

The Commission of the European Union (EU) has issued an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 2006/42/EC, also known as the Machinery Directive.

The EU's Machinery Directive defines the essential health and safety requirements for a wide range of products, including: machinery and partly completed machinery; lifting accessories; chains, ropes and webbing; interchangeable equipment; removable mechanical transmission devices; and safety components.

The Directive's scope specifically excludes electrical and electronic products covered under Directive 2006/95/EC (the EU's so-called Electrical Safety Directive), including household appliances, audio and video equipment, informational technology equipment and ordinary office machinery.

The extensive list of CEN and Cenelec standards for the Machinery Directive was published in July 2014 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards can be viewed at incompliancemag.com/news/1409_05.

EU Commission Publishes New Radio Equipment Directive

The EU Commission has published the complete text of its new Directive detailing the essential requirements for all types of radio equipment.

The new directive 2014/53/EU, also known as the Radio Equipment Directive (RED), was published in May 2014 in the *Official Journal of the European Union,* and entered into force in June 2014. The RED's essential requirements will eventually replace those in the EU's R&TTE Directive (1999/5/EC). Manufacturers of radio products already on the market will have until June 2017 to comply with the new requirements, while new products placed on the market must comply with the RED as of June 2016.

Perhaps the most significant difference between the RED and the R&TTE Directive is the elimination of wired telecom terminal equipment from the scope of the RED. In addition, the scope of the RED has been broadened to include broadcast receivers, and now explicitly includes radio determination (i.e., RFID) equipment. The RED also stipulates that the manufacturer's/importer's address must be displayed on the device or, if the device is too small, provided in an accompanying user manual.

The complete text of the EU's RED is available at incompliancemag.com/news/1409_06.

Updated List of Standards Released for EU's Directive on General Product Safety

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 2001/95/EC, related to general product safety.

The EU's General Product Safety Directive covers "any product… which is intended for consumers or likely, under reasonably foreseeable conditions, to be used by consumers even if not intended for them, and is supplied or made available, whether for consideration or not, in the course of a commercial activity, and whether new, used or reconditioned." The Directive is intended to ensure the general safety of products beyond those specific safety issues addressed in other product directives, such as the Machinery Directive, the EMC Directive, or the R&TTE Directive.

The list of CEN standards was published in July 2014 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards is available at incompliancemag.com/news/1409_07.


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News in Compliance

Recall News

Medical CO2 Detectors Recalled

GE Healthcare, LLC, of Waukesha, WI has issued a recall of certain models of the company's single-width airway modules and accessories used in hospitals and other healthcare facilities for monitoring CO2 and respiration rates in patients.

According to the company, the recalled CO2 detectors may fail to provide or provide incorrect CO2 values for patients who have been ventilated. As a result, healthcare workers may make critical decisions based on incorrect information, leading to potentially life-threatening changes to patient health, as well as permanent, irreversible impairment.

This recall has been categorized by the U.S. Food and Drug Administration (FDA) as a Class 1 recall, the most serious type of recall in which there is a reasonable probability that the use of a product will cause serious adverse health consequences or death.

For more information regarding this recall, go to incompliancemag.com/news/1409_08.

Companies Recall Charging Kits and Adaptors

Two companies have recently announced recalls of mobile device charging kits due to reports of overheating and burn injuries.

In the first case, Lifeguard Press Inc. of Bowling Green, KY has recalled over 25,000 charging kits manufactured in China. The company says that the wall charging unit can overheat and emit smoke and sparks, posing a fire and burn hazard to consumers. In addition, the prongs on the charger can detach from the charger body and remain in the electrical outlet, posing a risk of electrical shock.

Lifeguard Press says that it has received six reports of wall chargers emitting smoke, and an additional six reports of prongs detaching from the plug. However, no injuries have been reported.

The recalled charging kits were sold under several different fashion brand names, including Lilly Pulitzer, Jonathan Adler and Ban do, at Nordstrom's, Dilliard's, Lilly Pulitzer and additional independent boutique clothing stores nationwide from February through June 2014 for between $25 and $30.

Additional information about this recall is available at incompliancemag.com/news/1409_09.

In the second instance, Gemini Manufacturing Inc. of Gaffney, SC is recalling about 31,000 power

You Can't Make This Stuff Up

Fist Bumps and Germs

Barack Obama, the Dalai Lama and hip hop musicians might have discovered the key to avoiding the spread of germs.

According to a study published in a recent issue of the *American Journal of Infection Control*, greeting another person with a fist bump transfers about 90 percent less bacteria than a conventional handshake. Greeting another person with a "high-five" reduces bacteria transfer by about half of that transmitted by a handshake.

Not surprisingly, the study found that the differences in the transmission rate were largely attributable to the area of contact between hands, as well as the strength and length of the contact.

"People rarely think about the health implications of shaking hands," study co-author, David Whitworth, a biologist at Aberystwyth University in the United Kingdom, told the Reuters News Service. According to Whitworth, reverting to fist bumping instead of handshaking could actually reduce the spread of infectious disease.

The complete text of the study is available at incompliancemag.com/news/1409_13.

Recall News

adaptors/chargers manufactured in China and distributed as free promotional giveaways at U.S. tradeshows from October 2013 through April 2014.

According to the company, the adaptors/chargers can overheat, posing a burn hazard to consumers. Gemini has received one report of a consumer who suffered a hand burn as a result of contact with a recalled adaptor/charger.

Further details about this recall are available at incompliancemag.com/news/1409_10.

Popkiller Recalls USB Car Charging Adaptors

California retailer Popkiller is recalling about 2500 mini USB car charging adaptors manufactured in China.

According to the retailer, improperly mounted plug blades on the unit and inadequate electronic circuitry create a fire and electrical shock hazard to consumers. Popkiller says that it has not received any reports of incidents or injuries related to the recalled adaptors, but has initiated the recall to prevent future such incidents.

The adaptors were sold at Popkiller retail locations in Los Angeles and Costa Mesa, CA from June 2013 through April 2014 for about $4.50 to $6.50.

For more information about this recall, go to incompliancemag.com/news/1409_11.

Halco Recalls LED Bulbs

Halco Lighting Technologies LLC of Norcross, GA has recalled about 9500 of its ProLED-brand LED bulbs manufactured in China.

In a report filed with the U.S. Consumer Product Safety Commission (CPSA), Halco says that, once installed, the LED bulbs can overheat and fall onto consumers positioned below the light fixture, posing both impact and burn hazards to consumers. The company has received reports of five separate incidents in which the LED bulb has separated from the socket, but no reports of injuries.

The recalled LED bulbs were sold at lighting retailers and distributors nationwide from June 2009 through March 2014 for between $20 and $100, depending on the specific model number.

Additional information about this recall is available at incompliancemag.com/news/1409_12.

REALITY Engineering

A Wreck of an Airplane

BY MIKE VIOLETTE

The C-47 Skytrain banked sharply left and the runway came into view, a slash in the thick evergreens. Cresting the top of the ridge, the pilot pulled the power back on the twin engines and set the flaps at twenty degrees. The plane rose slightly with the added lift until the airspeed dropped and the nose of the plane settled flat. The aircraft was on a final approach to a muddy airstrip cut in the center of the pine forest, coming in low and fast at 100 knots, trickier, but less dangerous than a normal approach.

A gusty headwind came straight down the runway, the sky mottled with white clouds hung on bright blue. The sun flickered through the starboard windows into the eyes of a single passenger. The staccato light gave him a headache so Jean-Claude Ouvrier unbuckled from his position on the left side of the aircraft and crossed to the other side. He sat down on one of the right seats and pulled the strap around his chest as tightly as he could, sinking into the webbed seat. These planes were built sparely, to haul people and cargo, and not always too comfortably. Last week's passengers were eighty or so pigs, crated and as nervous as Jean-Claude. The cabin floor had been hurriedly washed down, and not too thoroughly. It stank.

Another strong gust lifted the nose of the craft and then dissipated, swooning the airplane and the middle-aged scientist. It was hot and smelled of burlap and fuel and excrement in the cabin and Jean-Claude was now sweating and felt a little ill.

He craned his neck and tried to look out the front of the plane as the nose fell toward Earth; he glimpsed the tail of a wrecked aircraft just short of the end of the runway. A lump formed in his throat.

The pilot and co-pilot were talking to each other, gesturing and pointing, the pilot's right hand on the dual throttles. Suddenly the twins roared with their combined twenty-four hundred horses, and the pilot twisted the props for maximum pitch, grabbing as much air as they could. The plane rose quickly as it was nearly empty and gently banked again—this time to the right—and down over a valley picking up airspeed as it dove off the ridge. The pilot hugged the ground and set the pitch on the propellers for maximum speed. He was in no hurry to climb out, running at 190 mph, nearly as fast as she could fly. The clouds were too broken to offer any cover and, since he was denied a place to land, he raced the plane down the length of the valley away, which opened out to the sea. There, a front had developed and clouds were collecting.

They rolled out offshore, staying in the clouds until they could gain some altitude and try to survey the landing strip from a safer height. Jean-Claude decided to move a little closer to the front, which afforded a slightly better view out the cockpit and, as he found out, would save his life. He unstrapped himself and quickly switched back to the right side, taking up a seat and cinching the seatbelt and harness tightly around his body. The other jump seat buckles were clamped around emptiness and rattled loosely as the plane made what would be its last run.

The plane plunged into a cloudbank and the windows turned white and the ride turned turbulent and not just bumpy, but with 50-foot drops, like falling into small holes in the sky. Jean-Claude looked at the other three riding in the front of the plane rising weightless in their seats as the plane dropped. This plane was fitted as luxuriously as a cattle car and the aluminum frame and skin rattled nervously as the pilot put the plane into a steep climb.

His stomach lifted as he gripped the leather case he held and suppressed a gag. As the plane climbed, the third in the cockpit, an Army Air Corps officer, neatly folded a map he was reading and tucked it into his shirt pocket. He unsnapped the buckle of his seat belt and clambered out of the cockpit. The plane was rising now at a fairly steep angle, climbing as quickly as she could and the officer had difficulty keeping his feet as he scrambled down the inclined floor of the main cabin to speak with the passenger. He was trim and clean, about thirty-five years old, Jean-Claude judged. A pistol was strapped to his waist. He did not wear a nameplate above his breast and had introduced himself only as *Joe Smith*.

Jean-Claude settled back and waited for the verdict: he really didn't care at this point where the plane would land; he just wanted to put his feet on solid mother Earth.

The officer leaned in close and yelled over the wind and noise of the engines, smiling a little as he noticed how green his charge looked. The officer caught himself and leaned over Jean-Claude. "We're going around to have another look. We can't put down there if the runway is damaged."

Jean-Claude thought to himself that the officer had the keen ability to make observations of the obvious. But he smiled and shook his head, settled back and waited for the turn. The plane kept climbing.

"I've got to get down soon! My appointment." Jean-Claude shouted.

The Air Corps officer shook his head. "Yes, but we want to get you down in one piece, don't we?" He smiled again.

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Jean-Claude did not smile back.

Ever since he had taken up this task, he had been from New England to Los Alamos back to Washington. Now to Eastern Europe. Although he could appreciate how things had progressed from the days of the Wright brothers—not even fifty years had passed and planes were crossing continents and engaging in great air battles—he never got used to flying. Now, here he was in Eastern Europe, flying into an unknown meeting to review papers, stolen from the Nazis. Did they have the bomb? And moreso, unbeknownst to his hosts, could he deliver the book as he must? To someone he never met?

The world had turned inside out. The first great war, *le guerre mondiale,* merely precipitated another, greater war. The acceleration of technology from the turn of the century, the now-unhidden mysteries of the energy locked up in the connectedness of nature was fast-unraveling man's ability to make moral decisions about its power. The smallest of mistakes could catalyze a disaster. Not only was the growth of knowledge moving at a blinding pace, but the unprecedented ability to destroy whole cities was not out of the question. It had already happened in this war: the fire bombing of Dresden and soon enough, Tokyo. A race was on between the Allies and Germany to find the hidden secrets of matter, secrets that would unleash the fury of the energy that held matter together, like looking into the mind of God. Great progress was made as key building blocks of understanding were laid. First, the components of materials, then the mathematics that described the construction of the universe, finally, the methods in chemistry, mechanics and electricity that could make a single bomb to destroy a city.

The brightest minds on both sides of the conflict were racing to develop atomic weapons and the bravest Allied souls were racing to thwart Nazi efforts, to capture knowledge, to disrupt the enemy and destroy their research. Ironically, or in some way thankfully, the biggest mistake that Hitler made was to first demean and campaign against the Jewish scientists and academics, to first deny them advancements, make them *persona non grata*, and then to actively persecute those of that ancient faith. It is the first sign of a declining civilization that places chains on intellectuals and ideological blinders on society. Throughout the nineteen-thirties, Jewish scientists fled Germany in droves, taking their knowledge and, to no small measure, their enmity against the evil that rose and threatened to enslave Europe.

German scientists and engineers were eager to get their hands on isotopes that they could use to build reactors to create fissile material. A necessary component in these reactor designs was heavy water—deuterium oxide—a rare form of water that carried an isotope of that elemental atomic material, hydrogen. Tremendous amounts of electricity were required to produce heavy water by the process of electrolysis. When the Germans seized Norway, early in the war, they captured the Vermok Hydroelectric Plant, which had been producing heavy water for several years before British commandos and local resistance succeeded in heavily damaging the plant, slowing the German effort.

Jean-Claude knew this and he was painfully aware of the lives that had been lost trying to discern and unravel German plans. The effort was mounted by Werner Heisenberg—whom Jean-Claude met five years earlier—just before Germany pushed Europe to calamity. Heisenberg, himself, was ostracized as a "white Jew" after Hitler rose to power. Now rehabilitated, Heisenberg was a member of the *Uranverein* or Uranium Club and headed the effort to light an atomic fire in a German reactor. Now this Nobel Prize winner and acclaimed architect of quantum mechanics was shouldering the effort that threatened even greater destruction. Jean-Claude was now part of the effort to undo the German's advance. He was afraid. Could this cup not pass?

The plane broke free of the clouds and climbed to six thousand feet—not high enough to be out of harm's way, but high enough to avoid being peppered by small arms. Given the mix of the friendlies and unfriendlies below, safety was not guaranteed. The airstrip was a known safe spot—at least it was twenty-four hours ago when this mission was hastily put together. Now, with the landing area possibly compromised, they'd have to decide on another tack.

"Let's go over this again." The Air Corps officer was wearing the uniform as a thin disguise—Jean-Claude wasn't sure for whom he worked, nor did he care to know. "When we reach our destination, we'll put you out with this:" he tapped a case that was strapped to the floor with his foot. "There's enough rations for about a week here…if you don't enjoy them too quickly." He paused and drew from his breast pocket a chain with a dog tag. Jean-Claude could see some numbers stamped on them. "We'll also leave a radio hidden nearby. When you get back to the airstrip," he held up the chain "call on this frequency. Your call

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sign is 'Socrates' and we'll come get you." Jean-Claude mused: He wondered if he was just offered hemlock.

The craft dove rapidly and the runway came into view, laying at a right angle to their path. To the left was the plane that had crashed just shy of the runway, its fuselage intact but its wings broken, like a fallen bird. The strip was open and clear; long yellow tape was unrolled and lay across the west end. It was their signal: all clear for a landing. The C-47 crossed midfield at a thousand feet above the ground to turn left to downwind, parallel to the runway. The wind was stiff, coming straight from the East, and would be right on the nose of the aircraft—ideal for a short-field landing. Two quick turns and they would be on final.

The officer leaned towards the front of the plane as the plane shed another five hundred feet of altitude, the engines thrumming at a quarter-power. To steady himself he was holding onto a conduit that was bolted to the inner wall of the plane. "Any questions?" He asked. Jean-Claude shook his head no but thought to himself 'Yes, many questions.'

Suddenly, a flash illuminated the windows on the port side and there was a concussive BOOM. The plane rolled hard to the left, like it was falling over a cliff. The officer was pitched off his feet and flew across the cabin away from Jean-Claude. The pilot and co-pilot were yelling, yanking back on the yokes and nearly standing on the right rudder pedal. From where Jean-Claude sat he could see out the cockpit window as the plane spiraled down to the left. All he saw was the green tops of trees, coming straight towards the plane. The airframe shuddered as the pilots worked to bring the plane level again. The Air Corps officer raised himself up. His hat had fallen off and a deep gash in the back of his head bled furiously where he had hit the metal rail of the opposite seating. He was holding his head and trying to make it to the front of the plane, the cabin listing sharply to the left.

"Strap yourself in!" Jean-Claude yelled, but the officer struggled forward. Jean-Claude now noticed that one of the engines had shut down. He looked across the cabin and out one of the port windows. The propeller on the left engine was spinning slowly, wind-milling instead of pushing air. Black fluid leaked along the engine nacelle. To the outboard side, he saw the leading edge of the left wing split open, frayed and blackened. The pilot was desperately holding onto the controls, and had pushed the starboard engine throttle to its stops. The remaining engine howled angrily as the plane managed to limp back into the air, gaining altitude slowly now, just brushing the tallest of the pines that reached into the sky. Jean-Claude felt three large whacks from the tops of the trees, pounding the drooping left wing. The pilot jerked the controls hard to the right, but it was too late. With a fourth smack of a pine bough, the left aileron was ripped from its hinges and whipped violently in the airstream, held by shredded linkage from one end to the wing, and danced dumbly in the air.

The officer managed to scramble to the front and got to his seat as the nose of the aircraft dove into the forest. Dark green poured onto the cockpit. Jean-Claude closed his eyes and gripped his briefcase. The plane shook and groaned and shuddered as it passed through the thin tops of the trees, bending the smaller trees and banging hard against the larger ones. The remaining engine screamed and over-ran, free of its propeller that had been smashed off and was flying into the forest in pieces. The airplane skipped momentarily along the tops of the trees before sliding down and into the woods, both wings folding over the top of the fuselage.

The cockpit window broke and pine limbs pierced the cabin. Jean-Claude watched with horror as a long branch impaled the Air Corps officer through his neck, lifting him like a lance; his body shot backwards through the cabin. The pilots had covered their heads but were made bloody, whipped by the glass and tree limbs and dissolving instrument panel. The fuselage rolled as the left wing ripped away from its root. Jean-Claude was suspended in air, hanging from the side of the airplane cabin. Anything that had not been tied or clamped down crashed down the aisle. A large case of ammunition, three hundred pounds heavy, slid down and destroyed the seat he had left moments before. He closed his eyes and waited for the final impact that would take his life.

The forward motion of the airplane slowed and the C-47 settled through the trees to the ground, snapping off branches and boughs and finally hitting the ground, settling on the soft needle-covered floor of the forest. The trees were less dense here and the banging impact of the crash turned into a grinding skid along the ground. The last flight of the Gooney Bird ended not with a bang, but with a curiously soft crunch in a thicket of thinning trees. IN

Excerpted from The Bearers
For George C. in New Hampshire

(the author)

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Characteristics of Air as an Insulator

Product Safety Newsletter - March/April 1989

BY RICHARD NUTE

Dear Readers,
Over the past couple of years many of you have requested that we include more product safety related information in our issues. Of particular interest has been Rich Nute's series of "Technically Speaking" articles. And so… Mr. Nute has graciously agreed to work with us to bring you that series! Look for his column each month. We hope you enjoy the addition of "Technically Speaking" to the pages of In Compliance*.*

A few months ago, we built a clear plastic box containing a four-inch square steel plane, a two-inch diameter steel sphere, and a micrometer drive to precisely adjust the distance between the plane and the sphere.

Recently, we finally had the time to do some testing. We set the distance to a known value and then slowly applied the voltage from a hi-pot tester until the tester tripped. We repeated the process for increasing distances. At each distance, we repeated the test at least once to determine consistency. The repeatability was about 50 volts rms or dc. (Subsequently we learned that the repeatability was related to the resolution of the hipot voltage control itself.)

We performed the test with both dc and 60 Hertz sinusoid waveforms.

Table 1 gives our test data. For ac, we measured the rms value and then calculated the peak value as 1.414 times the rms value. (We confirmed that the ac waveform was sinusoidal by observing the waveform with an oscilloscope.) The table includes ac (50 Hz) and 1.2 x 50 impulse breakdown voltages data from IEC 664.

Plotting these data, we find that the ac peak and dc lines virtually overlay each other. (Figure 1)

AC and DC Dielectric Breakdown of Air (Homogenous Field)

Distance		Breakdown Voltage, kV			
Inch	mm	Peak	DC	Peak*	1.2x50*
0.004	0.10			0.98	1.03
0.010	0.25	1.77	1.80		
0.020	0.51	2.86	2.85	2.70	2.81
0.030	0.76	3.87	3.90		
0.040	1.02	4.81	4.93	4.50	4.64
0.050	1.27	5.80	5.90		
0.060	1.52	6.80		6.00	6.36
0.070	1.78	7.77			
0.079	2.00			7.50	7.82

*IEC = IEC 664, Table AII, AC, Sphere-to-plane.

Straight-line equations from regression analysis:

kV (peak) = 0.877 + 98.6 x D (1.414 x measured data)
kV (dc) = 0.789 + 102.8 x D (measured data)

kV (peak) = 0.852 + 85.8 x D (IEC data)
kV (1.2x50) = 0.879 + 90.0 x D (IEC data)

Where D is the distance between the plane and sphere, in inches.

Table 1

Conclusion: In air, there is no difference in breakdown voltage between ac peak and dc voltages (for mains ac frequencies). This conclusion is incontrovertible. Note that this experiment is a 60 Hertz test, while IEC Publication 664, Table AII, is a 50 Hertz test. The 60 Hertz peak breakdown voltage is in good agreement with the 50 Hertz peak breakdown voltage up to about 5 kilovolts. Further note in IEC 664, Table AII, that the 50 Hertz peak breakdown voltage closely agrees with the 1.2 x 50 impulse breakdown voltage.

When we add these data to the graph, we find that there is still good agreement (although not as good as the ac to dc agreement) between the measured breakdown data and the lEC breakdown data. (We'll examine the degree of disagreement more thoroughly a bit later.)

Conclusion: In air, there is no difference in breakdown voltage between dc, peak ac (either 50 or 60 Hertz), and 1.2 x 50 µsec impulse voltages.

Hypothesis: The breakdown of air is an absolute function of voltage and is not related to the waveform.

Conclusion: The breakdown of air is a linear function of the distance between the two electrodes.

Conclusion: For voltages below some value, air will not break down regardless of distance. (lEC 664 data indicates the lowest voltage for air breakdown is 360 volts peak; our test data indicates the lowest voltage is about 800 volts peak. At this time, I cannot explain this difference.)

A FURTHER LOOK

Let's take another look at what these data imply. Below the breakdown voltage, air is an insulator. Above the breakdown voltage, air is not an insulator. So, air is not always an insulator! What are the conditions, which must be fulfilled for air to be an insulator?

The answer is quite simple: The applied voltage must be less than the breakdown voltage. In mathematical form this can be expressed:

$$V\ (applied) < V\ (breakdown)$$

We can see from the graph that the breakdown of air, V (breakdown), seems to be a straight line. The equation of a straight line is of the form:

$y = ax + b$

where
y is the dependent variable,
a is the slope of the line,
b is the offset (value of y when x is zero), and
x is the independent variable.

The breakdown voltage for air, assuming a straight line, would be:

$V\ (breakdown) = aD + b$

where
a is the slope of the line in kilovolts/inch,
D is the distance, in inches, and
b is the offset, in kilovolts.

Using regression analysis (a function available in many handheld calculators), we can calculate the constants for the slope and the offset. The offset is about 0.8 kilovolt, and the slope is about 100 kilovolts per inch. So, the breakdown equation becomes:

$V\ (breakdown) > 100D + b$ kilovolts

The conditions, which must be fulfilled for air to be an insulator, are:

$V\ (applied) < V\ (breakdown)$

Therefore,

$V\ (applied) < 100D + 0.8$ kilovolts

Let's summarize where we are. Air, as an insulator, has some minimum voltage at which it will not break down,

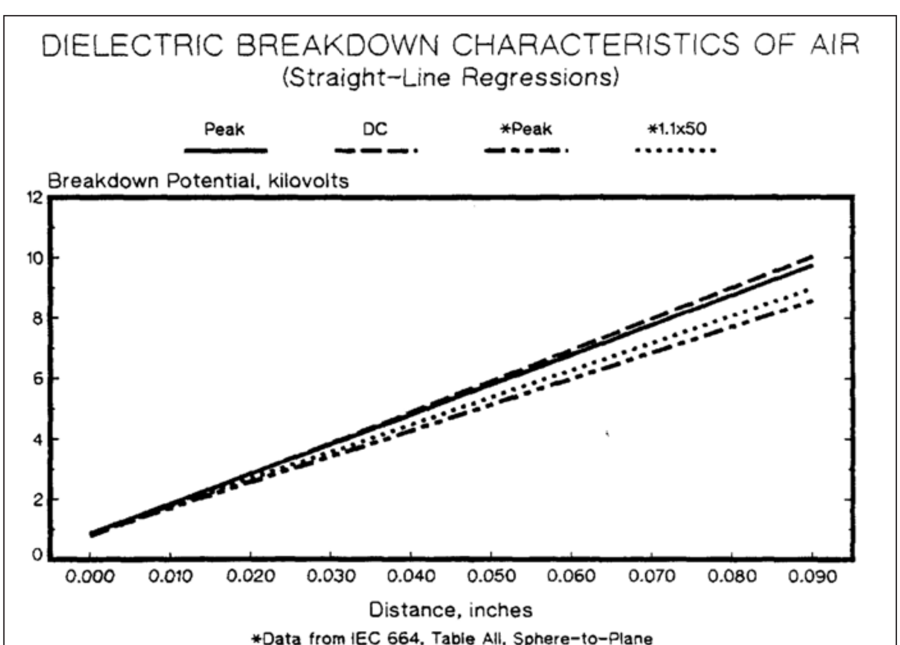

Figure 1

regardless of distance. Above that voltage, the breakdown voltage of air is directly proportional to the through-air distance between the two conductors, At any distance, if the applied voltage is less than the breakdown voltage for that distance, the air is an insulator. (Figure 2)

CONJECTURING ABOUT OTHER INSULATING MEDIA

Intuitively, such characteristics should also apply to liquid and solid insulations. That is, for any insulation there is some minimum voltage at which it will not break down, regardless of distance, and, above that voltage, the breakdown voltage is directly proportional to the distance through the insulating medium. At any distance, if the applied voltage is less than the breakdown voltage for that distance, the material is an insulator.

The statement that there is some minimum voltage at which a material will not break down, no matter how thin, can be supported by the argument that if the solid insulating material is removed and replaced with air, then there is indeed a minimum voltage at which the air will not break down no matter how close the two electrodes. Therefore, a worst-case solid insulation cannot have insulation characteristics less than that of air.

Hypothesis: A material is an insulator if its breakdown voltage exceeds the applied voltage.

(Obviously, this is not a complete definition. but it is an absolutely necessary part of any definition.)

Conversely, a material is not an insulator if its breakdown voltage is less than the applied voltage.

Hypothesis: For any insulating material, whether solid, liquid, or gas, voltage breakdown is a straight line of the form:

$V\ (breakdown) \sim aD + b$

where

a is the slope of the line in kilovolts/inch,
D is the distance, in inches, and
b is the offset, in kilovolts.

Experience tells us that solid insulators are much "better" than air. "Better" is taken to mean that for the same distance, D, the breakdown voltage of solid insulation is very much greater than that of air. To satisfy the equation, "better" would mean that the value of "a," in volts per unit distance, must be very much greater than that of air.

One of the current controversies is whether there is any difference in the breakdown voltage of solid insulation when the applied voltage is dc, ac, or the 1.2 x 50 µsec impulse. I'll reserve discussion of this issue for another time.

EXPERIMENTAL VARIABLES

In performing this experiment, there are a number of variables that must be controlled. The first is the shape of the electric field and the consequent uniformity of the equipotential lines. The second is the detection of the breakdown of air. The third is the measurement of voltage at the instant of breakdown.

When conduction occurs (a breakdown), the conduction will be along a line of force between the two conductors. Indeed, the breakdown will occur on the line where the electric force is greatest among all the lines of force that exist between the two conductors. The greatest electric force is on the shortest line of force.

In this experiment, it is essential that the electric force between the two conductors is uniform and that the equipotential lines between the two conductors are as uniformly spaced as possible. The electric field that produces uniformly spaced equipotential lines is described as a homogeneous field. The electric field is comprised of the lines of force between conductors. These lines of force emanate normal (at right angles) to the surfaces of the respective conductors. For each line of force, the potential between the two conductors divides uniformly along the line.

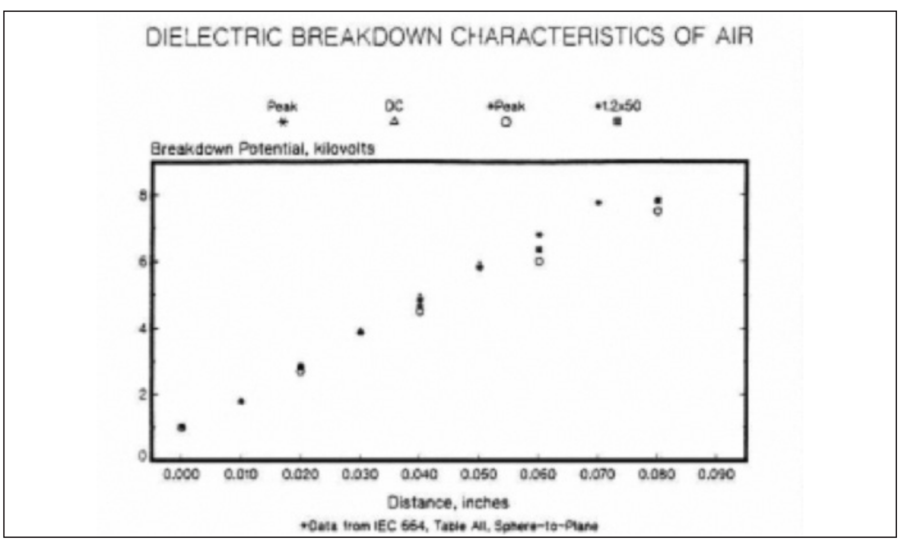

Figure 2

If we divide each line of force in half, and connect those points, we have an equipotential line, which represents one half the potential between the two conductors. Using this process; we can develop the pattern of equipotential lines between the conductors.

We can achieve a perfectly uniform electric field and, consequently, perfectly uniform equipotential lines if the two conductors are planes. But, the field at the edges of the planes would be rather non-uniform, and would therefore need to be accounted for in any experiment. To minimize the field distortion; we could gradually bend one plane away from the other. This would be done along the entire periphery of one plane; the resulting surface would be a plane with a spherical periphery (what you get at the instant a basketball bounces from the floor). The size of the plane is not at all critical, since the size of the electric field is not critical. Thus, the electric field resulting from a sphere in very close proximity to a plane approaches uniformity.

We used a 2-inch diameter steel sphere at distances from 0.01 inch to 0.10 inch from the plane. The distance ranged from 1% to 10% of the radius of the sphere. The scale illustration indicates the worst-case appearance of the two conductors.

The second variable is the detection of the breakdown of air. Fortunately, modern hi-pot testers have electronic trip mechanisms, which are uniform in tripping when an arc occurs. Any trip current is acceptable provided an arc truly occurs just before the trip. This is easy to confirm visually.

The third variable is the measurement of voltage at the time of trip. Here, a digital meter can be very helpful if the voltage is increased very slowly when approaching the breakdown.

DISCREPANCIES WITH IEC 664

After performing the experiment and experiencing the repeatability, it seems appropriate to hypothesize why the differences between our data and the IEC data. When the IEC data is plotted

We chose steel as the material for the electrodes. Massive, thick steel. Whenever an arc occurs, the power dissipated in the arc can melt the metal at either end of the arc.

point-by-point, the data agrees below 5 kV or so, and diverges seriously at 6.5 kv. This could be explained if the IEC had used a sphere where the ratio of distance to sphere radius was more than 10%.

(The hi-pot tester available to me was limited to 6 kV rms and 6 kV dc, so we could not collect data as the ratio increased.) One hypothesis could he that nonlinearity can occur as the ratio increases.

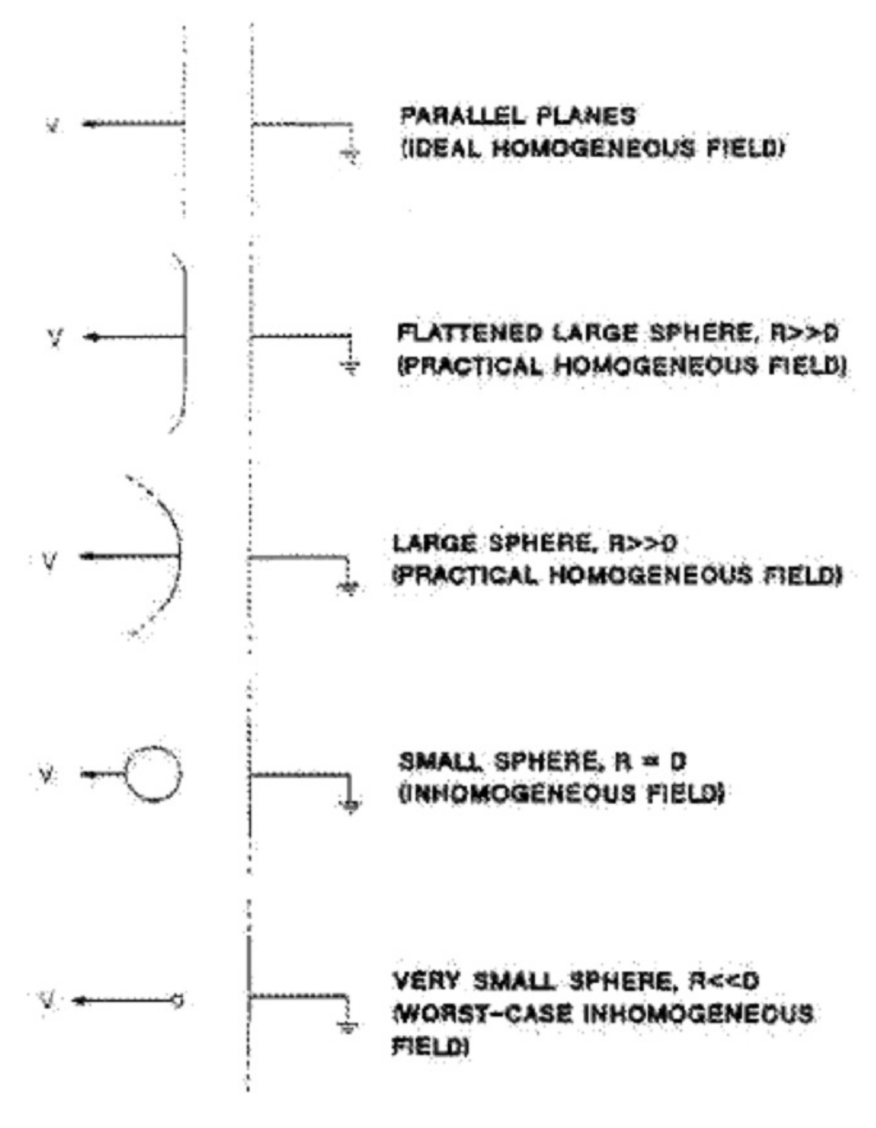

Figure 3

At the lower voltages, the IEC data is not as precisely linear as our measurements. This could be explained by non-uniform observations of the breakdown or by poor control or measurement of the voltage. With the experience of performing the measurement, we found that these are critical to the uniformity and repeatability of the measurement.

There is still one more factor.

We chose steel as the material for the electrodes. Massive, thick steel. Whenever an arc occurs, the power dissipated in the arc can melt the metal at either end of the arc. But, with a good thermal conductor and lots of thermal mass, this is minimized. (In attempting to do the point-to-plane test, we burned up a hardened steel needle when the hi-pot failed to trip and let the arc continue for an undue amount of time.)

THE NON-UNIFORM ELECTRIC FIELD

The other extreme is the perfectly non-uniform field and, consequently, non-uniformly distributed equipotential lines. Such a field is that resulting when the diameter of the sphere approaches zero.

A practical point is an extremely small sphere compared to the distance between the sphere and the plane. Since the lines of force must emanate at right angles to the surface of the small sphere, they are bent in the region of the small sphere and are therefore longer than the single line of force at the end of the sphere. Because the

> But, with a good thermal conductor and lots of thermal mass, this is minimized. (In attempting to do the point-to-plane test, we burned up a hardened steel needle.)

equipotential lines must be normal to the lines of force and equally spaced along the lines of force, the equipotential lines are severely bent near the small sphere. This bending of the equipotential lines increases the total force on any charged particle in the region of the point as compared to a homogeneous field. (Figure 3)

We also repeated the same test with a point-to-plane system. Immediately, we see significant differences. The first is a current indication well below breakdown. The second is lack of repeatability. The third is the slope of the line is about one fourth that of the sphere-to-plane.

WHY THESE DIFFERENCES?

First, the highly bent equipotential lines lead to partial discharge at voltages very much less than the breakdown voltage. What happens is that the air actually breaks down in the region very near the point, but not across the entire gap. This is the same phenomenon as St. Elmo's fire and the streamers that emanate from a Tesla coil, except on a much smaller scale.

Second, because the point has a very small thermal mass, the breakdown arc actually melts the steel at the point, and therefore changes the shape of the point. Thus, the next breakdown is at a slightly higher voltage because the point is less sharp and the equipotential lines in the region of the point are not as severely bent.

The effect of an imperfect electric field is to reduce the breakdown voltage at any given distance. The worst-case reduction seems to be about one fourth of the best-case.

APPLICATION

For a typical 120-volt rated product, the required clearance (UL and CSA) is 3/32 inch (0.094 inch). According to these data, and extrapolating the worst-case point-to-plane, 3/32-inch clearance should break down at no less than 3.47 kilovolts peak or de. The hi-pot potential specified by UL and CSA is either 1000 or 1500 volts RMS (1414 or 2121 volts peak, respectively). So, 3/ 32-inch clearance is more than adequate for the test voltage.

What clearance is necessary to withstand 2121 volts peak? Working backwards, we find that 0.041 inch (less than 1/2 millimeter) will withstand 1500 volts RMS! This is less than one half the distance required by UL and CSA standards!

We can only conclude that the requirements for clearances in various safety standards must be based on some parameter other than that of air as an insulator.

ACKNOWLEDGMENTS

Impetus for this investigation was triggered by my friend and colleague, Jerry Blanz, who also participated in the experiment. Jerry is with Hewlett-Packard in Fort Collins, Colorado, and sits on CSA Subcommittee on No. 220, and Working Group 2 of IEC SC28A.

The required inequality of applied voltage and breakdown voltage was provided by another friend and colleague, Joe Neshiern, Joe is with Hewlett-Packard in Loveland, Colorado. Joe sits on CSA Subcommittee on No. 231, and on the US TAG to IEC 66E.

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MR. Static

How Fast Does a Charge Decay?

BY NIELS JONASSEN, sponsored by the ESD Association

There's a phrase that has been bothering me for years: "How do you remove static electricity?" At one level the question makes sense. Everybody involved in electrostatics understands what the inquirer is trying to ask. But at a physics level, as well as a linguistic one, the phrasing is more dubious. A better expression of the question would be "How do you neutralize the field from static charges?"

INTRODUCTION

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

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

~ The ESD Association

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Why is this phraseology better? Well, first of all, the field from a charge (distribution) is a well-defined concept, which static electricity is not. And secondly, when you do neutralize a field (or "remove static electricity"), you very rarely remove anything from the charged body. (When you ground a negatively charged conductor with a metallic wire and avoid all kinds of discharges, you lead away the excess electrons. But that is the only case where charges can be removed.)

In order for neutralization to happen, the charged area has to be in contact with a medium containing charge carriers of the opposite polarity. A force from the field then acts upon these charge carriers, and, if they have some ability to move, they'll eventually plate out on the charged area. The field from the plated-out carriers will superimpose the original field, resulting in a steadily decreasing "total" field. In other words the static charge is decaying.

So let's change the question from how to remove static electricity to how fast does a charge decay.

BULK AND SURFACE DECAY

It is easier to describe the decay if we consider separately bulk decay, where charges move through the interior of the material, and surface decay, where the movement of charges takes place primarily in a surface layer.

Bulk Resistivity. The rate at which neutralization takes place in a given field depends upon the conductivity γ of the medium. A field E will release a current with the density (current per unit area) j given by

$$j = \gamma E \qquad (1)$$

Equation 1 is often written

$$E = \rho j \qquad (2)$$

where

$$\rho = \frac{1}{\gamma} \qquad (3)$$

is the bulk resistivity of the medium. Equations 1 and 2 are both versions of Ohm's law (in differential form). The field from a given charge will always be proportional to the charge, but the factor of proportionality will depend upon the geometry and dielectric properties of the charged body and its surroundings.

Let's look at a simple example. Figure 1 (situation 1) shows a piece of a material, with the resistivity ρ and the permittivity ε, resting on a grounded plane. A charge q is evenly distributed on the surface of the material. We assume that the distance to other grounded objects is much larger than the dimensions of the charged sample. If the charge density is σ (C • m²), then the field strength in the material is

$$E = \frac{\sigma}{\varepsilon} \qquad (4)$$

According to Equation 2 this field will produce a (negative) current

$$j = \frac{1}{\rho} E = \frac{\sigma}{\varepsilon\rho}$$

But the current density j is also the rate at which the surface density decreases, that is

$$(j=) -\frac{d\sigma}{dt} = \frac{\sigma}{\varepsilon\rho} \qquad (5)$$

The solution to Equation 5 is

$$\sigma = \sigma_o e^{-\frac{t}{\varepsilon\rho}} \qquad (6)$$

where σ_o is the initial value of the charge density. Thus it appears that

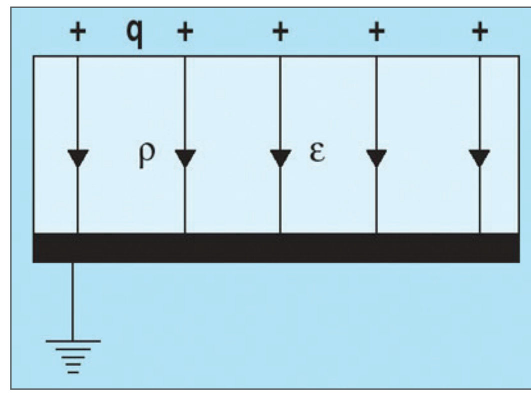

Figure 1: Bulk decay of charge, situation 1.

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The situation is more complicated, however, if the field from the charge, or rather the flux, extends through several dielectrics with different resistivities and permittivities.

the charge is being neutralized exponentially with the time constant

$$\tau_o = \varepsilon\rho \qquad (7)$$

Equation 7 is generally valid when the field from the charge to be neutralized extends exclusively through the medium with the resistivity ρ and the permittivity ε.

Consider a sample of Plexiglas with $\rho \approx 10^{13}\,\Omega \bullet \mathrm{m}$ and $\varepsilon \approx 3 \bullet 10^{11}\,\mathrm{F} \bullet \mathrm{m}^{1}$ ($\varepsilon_r \approx 3.4$). A charge on it will decay with a time constant of about 300 seconds. It should be appreciated that the rate of decay is determined not only by the resistivity, but also by the permittivity. So if we have a sample with the same resistivity as the Plexiglas, but with twice the permittivity, the rate of decay will be half that of the Plexiglas.

The situation is more complicated, however, if the field from the charge, or rather the flux, extends through several dielectrics with different resistivities and permittivities. Thus, a brief digression to discuss electrical flux is useful here.

The electrical flux or E-flux Φ_E through a surface S is defined as

$$\Phi_E = \int_S E \bullet dS$$

If the surface S is a closed surface surrounding a charge q, then, assuming you have the same permittivity all over the surface S, the previous equation becomes

$$\Phi_E = \int_{\text{closed surface}} E \bullet dS = \frac{q}{\varepsilon}$$

This is simply Gauss' theorem, which enables calculation of the field from various charge distributions. Flux being a rather abstract concept, it can be helpful to envisage the situation as a charge "emitting" a certain number of field lines. The number of those field lines through a unit area (perpendicular to the field strength) is equal to the field strength. So the flux through a given area is, roughly speaking, the number of field lines through that area.

Now back to the more-complex situation. Figure 2 (situation 2) shows a sample with the thickness d, permittivity ε, and resistivity ρ, resting on a grounded plane, like that shown in Figure 1. But in this case another grounded plane is placed parallel to the sample at a distance x. Let us assume that the sample is Plexiglas, and that the space above the sample is vacuum (or air) with $\varepsilon = \varepsilon_o$ and $\rho \approx \infty$. The field (flux) from the charge is now shared between the Plexiglas and the air in such a way that the surface potential of a point on the charged surface is the same whether it's calculated as the field strength in air multiplied by x or as the field strength in the dielectric multiplied by d. Thus the charge is expected to decay exponentially again, but now with a time constant τ given by

$$\tau = \tau_o\left(1 + \frac{d}{\varepsilon_r x}\right) \qquad (8)$$

For instance if we choose d = 0.01 m and x = 0.003 m (ε_r = 3.4, the relative permittivity of Plexiglas), we find that τ= 594 seconds. In other words,

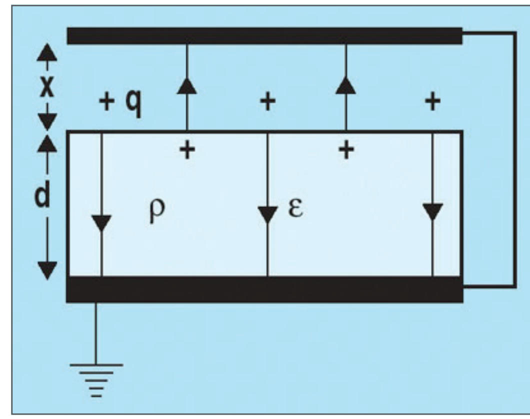

Figure 2: Bulk decay of charge, situation 2.

it takes about twice as long for the charge to decay, even from the same sample of material, simply because of the proximity of another grounded conductor.

The example shown in Figure 2 is a very simplified case, and often it will not be possible to predict the relevant value of the time constant for a given sample in a given geometrical environment.

Surface Resistivity. Special cases are the ones in which neutralization takes place in a shallow layer on the surface of the material. This could be a material treated with an antistatic agent or an insulative substrate onto which a conductive layer is evaporated. If such a layer is highly conductive as compared with the contacting materials, the neutralizing current will run only in this layer. However, part of the flux from the charge will run in the adjoining layers, and the "driving field," that is, the field in the conductive layer, will depend upon the permittive properties of the adjoining insulators. Thus the rate of decay (and the time constant) will depend not only on the properties of the region where the

We have tacitly assumed that there is only one value for the resistivity independent of the field applied. Yet it is often found that the resistivity increases with decreasing field strength.

decay takes place, but also on properties outside the region of decay. This is, in principle, the same problem shown in Figure 2. Usually the processes in thin layers are characterized by defining a surface resistivity ρ_s (in a way similar to the definition of bulk resistivity) by the equation

$$E_s = \rho_s j_s \quad (9)$$

This version of Ohm's law states that a field E_s along a surface with the surface resistivity ρ_s will cause a current with the linear current density j_s (current per unit length, A • m^{1}) in the layer given by equation (9).

Although in the matter of bulk resistivity it is possible in certain simplified cases (Figures 1 and 2) to derive a connection between the resistivity and the rate at which a charge is being neutralized, it is not nearly as simple in the matter of surface resistivity.

Figure 3 (situation 1) shows a piece of material A. At one end of A is a spot of negative charge and, at the other end, a grounded electrode B in direct contact with A. Between B and A is a field. Only that fraction of the flux that runs through the conductive layer will cause a current to neutralize the charge. There is no doubt that if the charge is, say, doubled, then the field strength will be doubled in every point, but the field distribution will be the same. And if the surface resistivity is doubled, the decay rate will be halved. With this geometry, it seems likely that we will have a time constant proportional to the surface resistivity. But, in contrast to simple situation 1 for bulk decay (Figure 1), we cannot theoretically predict--even if we measure the surface resistivity and know the permittivity of the conductive layer--the time constant for surface decay. This is because we don't know how the flux is distributed between the conductive layer and the environment.

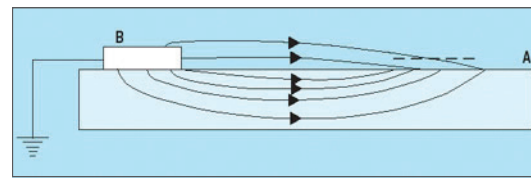

Figure 3: Surface decay of charge, situation 1.

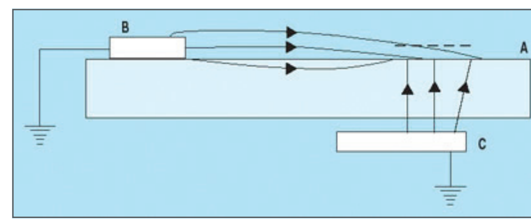

Figure 4: Surface decay of charge, situation 2.

Figure 4 (situation 2) shows a state similar to situation 2 for bulk decay (see Figure 2). Another grounded conductor C is in the neighborhood of the charged sample, but not in direct contact with it, so no neutralizing current will flow to C. And since the flux to B is now lower, so is the neutralizing current, and the time constant will have increased, even if the sample, the charge, and the grounding electrode arrangement is the same.

This discussion has tacitly assumed that there is only one value for the resistivity (be it bulk or surface) independent of the field applied. Yet it is often found that the resistivity increases with decreasing field strength. Nevertheless, resistivities are usually determined at only one field strength (one voltage difference between a set of electrodes on the sample), and we have no way of knowing if this particular field strength is typical for the physical conditions during a decay process.

MEASUREMENT OF DECAY TIME

The previous considerations illustrate that only under very ideal conditions is it possible to calculate reasonably accurately from material parameters (resistivity and permittivity) how fast a charge on an insulator will decay. This is because of two main reasons:

- The resistivity depends on the field strength from the decaying charge (and we rarely know this relationship), and even more importantly,
- The driving field from a given charge depends on the permittive properties of the environment in a usually incalculable way.

So the obvious question is why not measure the decay time directly? If we are dealing with a highly resistive item, it is certainly possible to charge the material and measure how fast the field from the charge decays when the item is placed in a relevant environment. Usually we are interested in semiinsulative materials where the charges are neutralized in seconds or less. And the procedures of measurement have to allow for this.

Over the years several procedures have been developed, and, to be kind, none of them were very successful. A general shortcoming of all these methods is that they do not measure in situ. That is, the measurements are performed not on the material as it normally appears

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when it gets charged, but rather on sheet samples suspended in such a way as to facilitate charging as well as field measurement.

Probably the most commonly used method is Federal Test Method (FTM) Standard 101C, method 4046.1, where a sample is clamped between two electrodes (see Figure 5). A field meter is mounted pointing at the center of the sample midway between the electrodes. The sample is allegedly charged by the electrodes when they are connected to a voltage supply, and the charge decay is taken as the reading of the field meter after the electrodes are grounded. It seems difficult (at least to this author) to be sure that a reading of the field meter is a sign of an excess charge on the material, unless the material is truly conductive. Polarization may certainly show itself, at least with some materials, as an external field, and the rate of relaxation of polarization is not necessarily the same as that of a true excess charge.

Several other questions could be raised concerning this method. The most important one is that a decay time obtained by method 4046.1 for a sheet of a material of a given small size does not reveal much about how fast the field from a charge will be neutralized on a larger sample or item in another location.

In another method, the sample (again a suspended sheet) is charged by a corona discharge. The charger is then removed and replaced by a field meter. (Incidentally, we developed this method, which has the merit of placing a real charge on the surface of the material under investigation, at our laboratory as early as 1977, but ultimately abandoned it since our instrumentation was not fast enough.) Although it has been argued that the

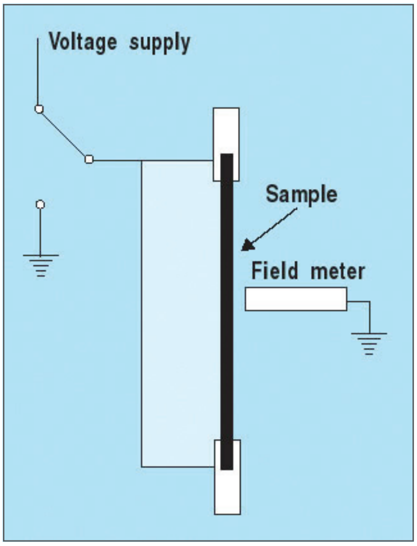

Figure 5: FTM Standard 101C decay of field from charge.

corona charging with air ions may be irregular, one could also argue that the charging experienced in everyday life is irregular too. So this should rather be deemed a virtue of the method. Still the main argument is that one does not measure the charge neutralization (decay) rate under circumstances that resemble normal use of the materials. It should also be mentioned that it is not possible to distinguish between bulk and surface decay using either of these methods, or probably any other method for that matter. It may even be argued that the distinction does not make sense at all. Another objection to any principle, suggested or applied, for determination of charge decay time is that any method capable of detecting the presence and time variation of a charge on an object will occupy a certain fraction of the electrical flux from the charge, a fraction which, without the presence of the measuring equipment, might contribute to the rate of neutralization or decay of the charge. Thus the measured rate of decay will normally be different from (often larger than) the «natural,» undisturbed rate.

CONCLUSION

The considerations presented in this paper may make it seem as if we know nothing about the laws of decay of charges on insulators. This is not the case.

Although we can accurately predict the current I through a resistor with the resistance R from a voltage supply with output voltage V, we have to accept that static electricity (ESD, if you insist) is a little more complicated (and interesting). We also have to accept the fact that there's no way you can predict the decay behavior of a manufactured item placed in an arbitrary environment by doing some laboratory measurements on a sample of the material of said item.

So what do we do when we have to choose between different materials? Well, we know that if we have two materials with different resistivities, bulk or surface, under similar circumstances the one with the lowest resistivity will mean the fastest decay time, although not in an unambiguous way. So the obvious advice is to choose the material with the lowest resistivity. IN

(the author)

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

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COUNTERFEIT
GOODS

The Silent Killer: Suspect/Counterfeit Items and Packaging

BY BOB VERMILLION

Over the past several years, U.S. based organizations have curtailed traditional *internal verification efforts* due to reliance on contract manufacturers, distributors and suppliers to *do the right thing*.

The inspection of ESD sensitive parts is very important, but without special safeguards, the additional handling to remove and repack a product for validation can cause both physical and ESD damage in the process. For parts, including those not sensitive to static electricity, measures must be utilized to detect, inspect and validate the packaging that identifies and protects the product.

Figure 1

In 2010, the author was invited to speak before the NASA QLF (Quality Leadership Forum) and is the first to present on issues of suspect counterfeit ESD packaging & materials in the DoD supply chain. This speaking engagement led to numerous articles and studies on suspect counterfeit or non-compliant materials and packaging used during the manufacturing process. No longer is a supplier's specification sheet adequate proof that an ESD packaging product is compliant to ANSI/ESD S541 or Military Standards.

Many Federal agencies employ the practice to Google Earth suppliers for verification that the business is not a pass-through entity or garage-style operation.

In Fiscal Year 2013, the Department of Homeland Security seized counterfeit goods valued at over $1.7 billion at U.S. borders. The facts are as follows[1]:

1. Counterfeiting costs U.S. businesses $200 billion to $250 billion annually.
2. Counterfeit merchandise is directly responsible for the loss of more than 750,000 American jobs.
3. Since 1982, the global trade in illegitimate goods has increased from $5.5 billion to approximately $600 billion annually.
4. U.S. companies suffer $9 billion in trade losses due to international copyright piracy.
5. Counterfeiting poses a threat to global health and safety.
6. Approximately 5%-7% of the world trade is in counterfeit goods.

In Figure 2[2], the suspect counterfeit fire extinguisher could be filled with compressed air or baking soda. Increasingly, the perpetrators place human lives in the balance just to make more profit. Would the reader have confidence in using the suspect counterfeit fasteners while hoisting a soldier as illustrated in the DUSTOFF helicopter photo, illustrated in Figure 3?

In the examples provided for the fire extinguishers and fasteners, and, especially, today one must really

1. Source: http://www.iacc.org
2. Candice T. Bruce, MSgt, Quality Assurance Technician, 440 SCOS/GWAB, 192 SCMS, 23 Sweeney Blvd., Joint Base Langley-Eustis, VA 23665

Figure 2[2]

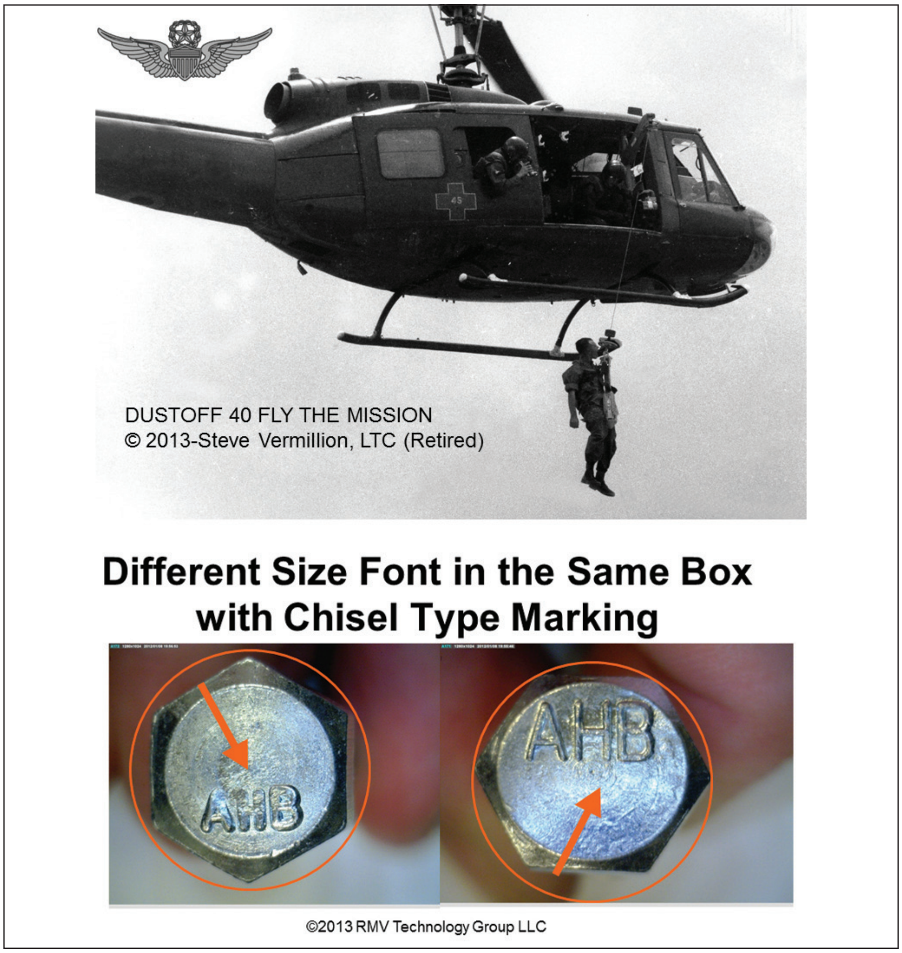

Figure 3

> Supplier non-conformance and suspect counterfeit packaging can represent a hazard to electrostatic discharge (ESD) sensitive devices or components through cross contamination.

understand the global supply chain. Another issue that organizations face is the purchase of products, off the Materials Qualification List, obtained online, in glossy catalogs that land on your desk every month, or reliance upon a vendor specification sheet without verification or validation of the manufactured good's performance. What does the author recommend? Trust but verify!

Supplier non-conformance and suspect counterfeit packaging can represent a hazard to electrostatic discharge (ESD) sensitive devices or components through cross contamination. Figure 4 (page 34) illustrates what happens when ESD sensitive devices from the manufacturer were subjected to long-term storage at 160°F for 14 days (accelerated aging). The test compared new EEE components stored in a *suspect counterfeit* IC Carrier and a compliant Dip Tube for the same duration. The ESD sensitive device packaged in a safe IC Carrier (Dip tube) exhibits no evidence of antistatic transfer. Suspect counterfeit ESD packaging can, however, incorporate the use of antistats containing harmful amines. Supplying amine safe products can prove costly to the counterfeiter. To dip or to spray packaging with a soapy mixture typically found in a grocery store is sometimes utilized as an unauthorized substitute with consequences. Issues with antistats put to rest in the early 1990s have resurfaced. A launch delay due to contaminating antistatic bubble during long-term storage occurred; suspect counterfeit packaging related damage to ESD sensitive devices has

Despite a visual inspection of an outer package label and bar code scanning by an electronic component distributor, suspect counterfeit re-topped electrostatic discharge (ESD) sensitive components could still be purchased in error.

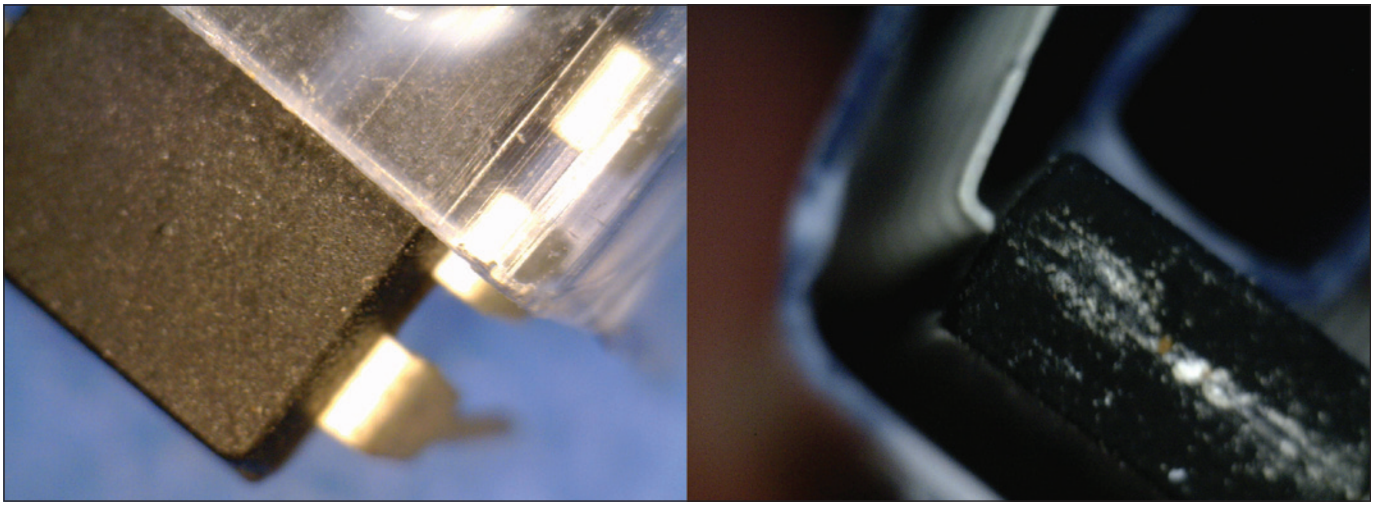

Figure 4 (Items courtesy of Albert Escusa, TI)

taken place during shipping, storage, incoming inspection and manufacturing. Many of these incidents could have been prevented using a formalized qualification sequence reinforced with periodic verification for chemical, physical and ESD control integrity before use in the supply chain.

Several aerospace related occurences have involved long-term storage issues for supplier non-conformance with antistatic foams, antistatic bubble, vacuum formed antistatic polymers and ESD safe moisture barrier bags. The late John Kolyer, Ph.D. (Boeing, Ret.) and Ray Gompf, P.E., Ph.D. (NASA-KSC, Ret.) were advocates in the utilization of a formalized *physical testing* material qualification process. Today, however, some prime contractors and contract manufacturers rely heavily upon a visual inspection process for ESD packaging materials. Over the past 10 years, however, suspect counterfeit ESD packaging materials have continued to infiltrate the global supply chain.

Despite a visual inspection of an outer package label and bar code scanning by an electronic component distributor, suspect counterfeit re-topped electrostatic discharge (ESD) sensitive components could still be purchased in error. To compound the matter, a new and very inexpensive method of removing a component's lettering is now being utilized by the counterfeiter that does not exhibit evidence of tampering as illustrated in Figure 5.

One countermeasure for detection is the use of RFID in packaging for incoming inspection and inventory tracking. Another measure constitutes *hands on* training for incoming shipping and receiving personnel by use of advanced inspection techniques of packaging materials. For example, ESD sensitive components are typically protected by packaging that industry identifies by color: i.e., pink or blue for antistatic bubble, black for carbon loaded polymer JEDEC trays and Tape & Reel.

Figure 5: Left: Original Right: Tampered

> ESD sensitive components are typically protected by packaging that industry identifies by color: i.e., pink or blue for antistatic bubble, black for carbon loaded polymer JEDEC trays and Tape & Reel.

No longer can color be an indicator of static control packaging performance, however, this identification marker is widely accepted by semiconductor, automotive, medical device, aerospace, and defense. A simple and cost effective electrical resistance test can very easily determine if the packaging is compliant beyond misidentification by color. If a package fails this initial test, then it should be flagged for further investigation as components could have been compromised. A simple rule to remember constitutes: *A counterfeiter will not be motivated to package fraudulent ESD sensitive components in compliant static control packaging that could add much more in material costs alone.*

In the packaging area, suspect counterfeit ESD packaging materials that have compromised the supply chain include IC Carriers (The Dip Tube), JEDEC Trays and Tape & Reel. See Table 1 for a more comprehensive list.

IC Carriers, JEDEC Trays and Tape & Reel are utilized in equipment centers (Figure 6). Due to limited space for a single publication, the author will focus on the consequences of using a suspect counterfeit JEDEC tray that is non-compliant to ANSI/ESD S541.

The strapping was charge generating to 2260 and -1295 peak volts as illustrated in Figure 7 (page 36). Earlier, another set of JEDEC trays was evaluated for 2-point resistance that measured a failing value of 6.7 x 10^{11} ohms at 50%RH.

• Blister Packs • Antistatic Bags • Conductive Bags • Static Shielding Bags • Moisture Barrier Bags • ESD Corrugated Boxes • ESD Paperboard • ESD Plastic Corrugated • Plastic Hinged Boxes • Downgraded Corrugated Kraft Box Liner • Antistatic Clamshells • Antistatic Trays • Static Dissipative Trays	• IDPs Polymers • ICPs Polymers • Carbon Loaded • Carbon Coated • ESD Tubing • ESD Foams • Cross-linked • ESD P E Films • Antistatic Films • Antistatic Pallet Wrap • ESD Cleanroom Paper • Antistatic Paper • Antistatic Tape • ESD Work Carriers • Antistatic Work Carriers • ESD Polystyrene Peanuts	• ESD Tape & Reel • ESD Rubber bands • ESD Dip Tubes • Antistatic End Caps • ESD Labels • Antistatic Labels • ESD Wafer Boats • ESD Wafer Packs • ESD Wafer Separators • ESD Tubing, IC Carrier or Dip Tubes • ESD Air Filled Bubble • ESD JEDEC Trays • ESD Microscope Covers • Humidity Indicator Cards • ESD Grid Bags

Table 1

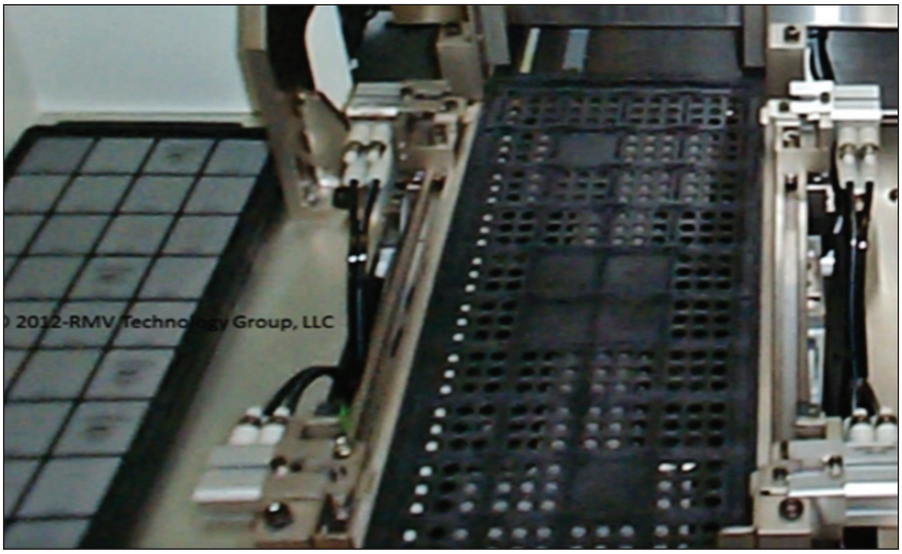

Figure 6

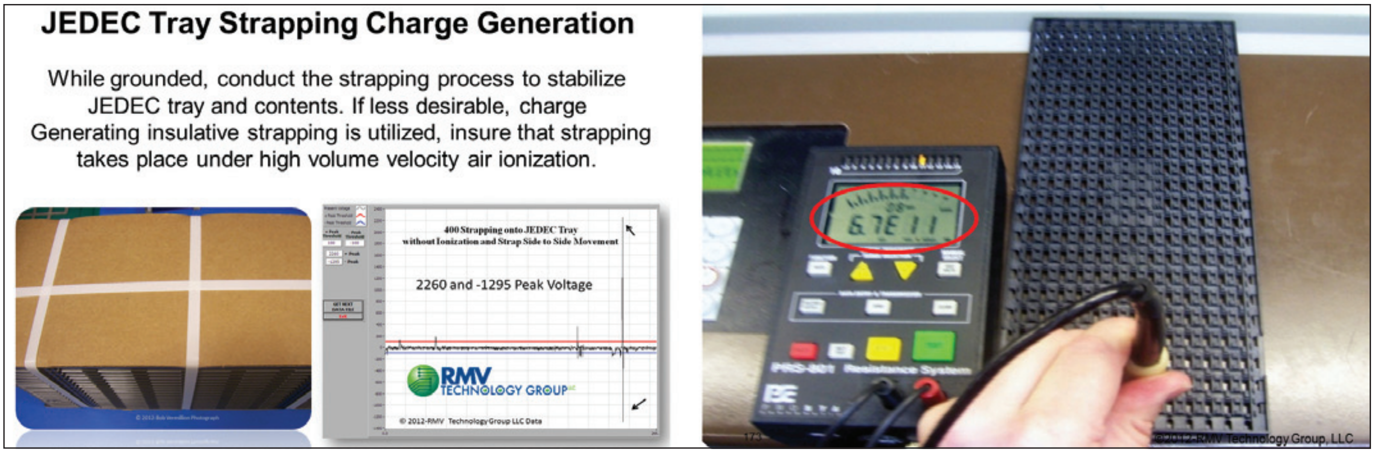

Figure 7

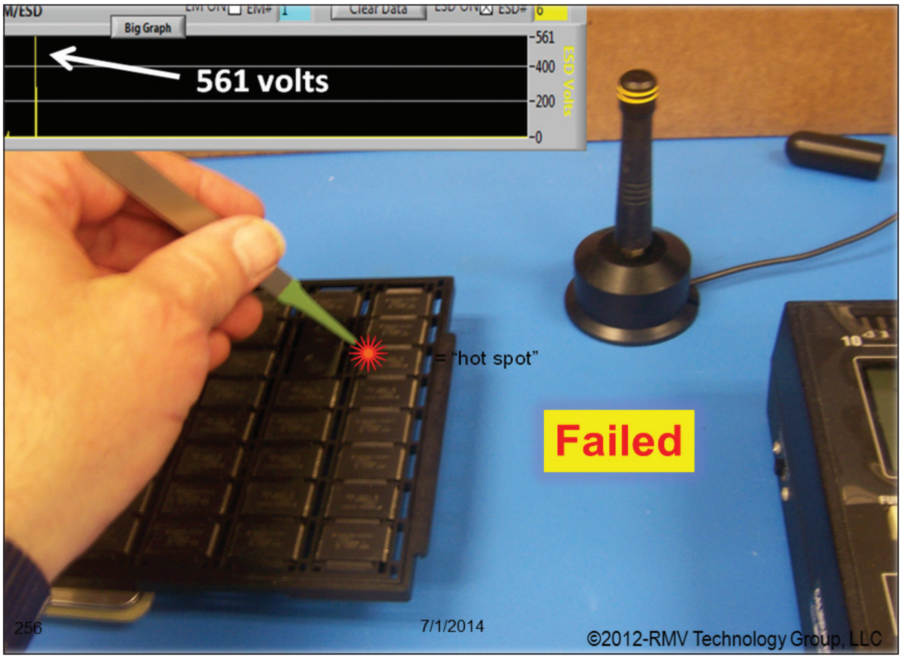

Figure 8

When a suspect counterfeit insulative JEDEC tray is populated with ESD sensitive devices that could be from a legitimate source, then the act of removal of said components for inspection could damage that device Figure 8).

What happens when a JEDEC tray is not properly banded in comparison to a process utilizing ANSI/ESD S541 compliant strapping by a grounded operator using an ANSI/ESD S4.1 work surface during the banding process? A non-compliant strapping process generated ESD events at over 300 volts for a 3 banded JEDEC tray system (Figure 9). Therefore, affixing strapping over a JEDEC tray package (placed in quarantine) without conductive corrugated top and bottom pads should be avoided for ESD compliance.

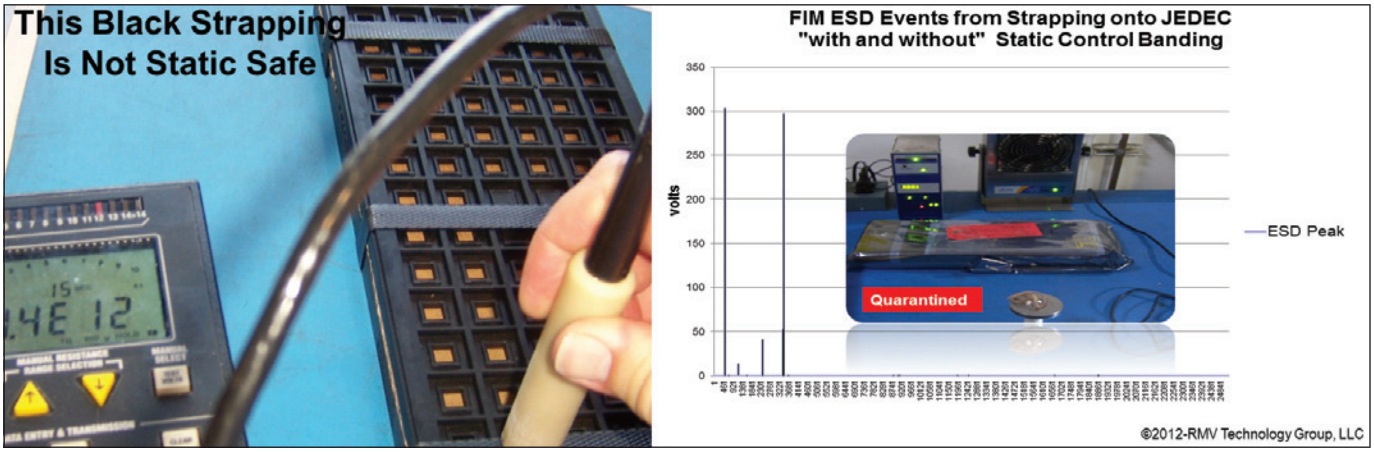

Figure 9

Conversely, using ESD corrugated pads with a protective non-sloughing finish facing inward insures that a charge generating strapping process will not compromise the package. As illustrated in Figure 10, the black strapping is static dissipative with ESD corrugated shielding pads. Thus, sound protocols were utilized by the component maker who utilizes a formalized materials qualification sequence in packaging of EEE ESD sensitive devices. The banding process therefore was unremarkable for ESD events at 9 volts.

In short, testing static control materials and packaging that protects ESD sensitive electronic components needs to be mandatory. It is our view that mission critical parts and components that require ESD packaging must be verified on a regular basis due to supplier non-compliance or suspect counterfeiting. As a consequence, device integrity is less likely be compromised or to become a cause for damage or failure due to the packaging. IN

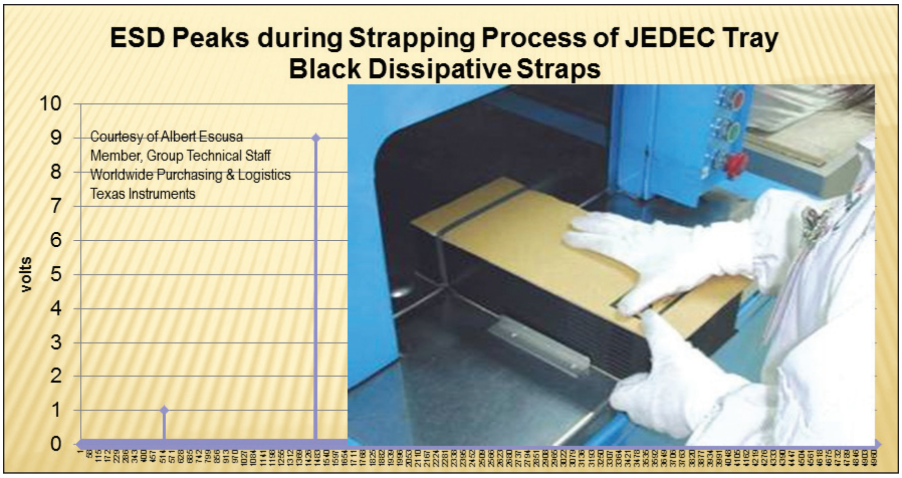

Figure 10

REFERENCES

Special Thanks to Albert Escusa of Texas Instruments for his support.

[1] Vermillion, R. 2010. "Non-compliant or Suspect Counterfeit Materials Can Lead to ESD Hazards and Long-Term Storage Issues." NASA Quality Leadership Forum, Kennedy Space Center.

[2] Bruce, C. T. "Fire Extinguishers." Joint Base Langley-Eustis, VA 23665

[3] Electronic Part Damage by Antistat Vapor, John Kolyer, Ph.D., Arie Passchier, Ph.D. and WG Peterson, The Boeing Company

[4] ESD from A to Z, Dr. John Kolyer and Watson, 2nd Edition

[5] Mil Handbook 1686C

[6] Mil Handbook 263B

[7] Packaging Materials Standards for ESD Sensitive Items, EIA-541, June 24, 1988, Appendix C, "Triboelectric Charge Testing of Intimate Packaging Materials"

[8] ANSI/ESD S20.20

[9] ANSI/ESD STM11.13

[10] ESDA Adv. 11.2

[11] Using An ESD Packaging Materials Qualification Matrix for Contract Manufacturing and Supplier Conformance, Sep 1, 2006, Albert Escusa, Texas Instruments and Bob Vermillion, RMV Technology Group, LLC

[12] Dr. John M. Kolyer, Ph.D., Rockwell International, Telephone interview in 2004

[13] The Charged Device Model & Work Surface Selection, John Kolyer and Donald Watson, October 1991, pp. 110-117

[14] Humidity & Temperature Effects on Surface Resistivity, John Kolyer &Ronald Rushworth, EE, October 1990, pp. 106-110

[15] Vermillion, R. June 1, 2010. "The Dip Tube." *Interference Technology.*

[16] Vermillion, R. November 2010. "JEDEC and Tape & Reel Issues." *Interference Technology UK.*

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I'm Partial to Partial Inductance!

BY BRUCE ARCHAMBEAULT

It is well known (but often forgotten) that the concept of inductance, without defining a complete loop of current, is *completely meaningless*!

Some books give *inductance* of a length or wire, some people talk about the *inductance* of a via, and still others talk about the *inductance* of ground braids, etc. All these discussions about *inductance* ignore the requirement for a complete loop before the *total* or *loop* inductance can be discussed in any meaningful way.

During our first electrical circuits classes as an undergraduate student in electrical engineering, we learn about the Kirchhoff's loop voltage law. This is a fundamental concept in electrical engineering where we sum the voltages around a loop. Partial inductance is a similar concept where we sum contribution around a loop to get the full answer. Recently, a well known EMC consultant told me that he felt the concept of partial inductance is too complex for the typical EMC engineer. I completely disagree! If someone understands Kirchhoff's voltage law, then the concept of partial inductance only adds a few extra terms.

Partial inductance allows a total loop to be broken into multiple branches. We can easily find the partial inductance of these individual branches based on the conductor dimensions. When assembled onto a closed loop, these branches contribute partial inductance, and the distances between branches contribute partial mutual inductances, and the complete loop inductance can easily be found, even if the various conductor sizes within the loop are different!

PARTIAL INDUCTANCE

The definition of inductance requires a current flowing in a loop. *Without a complete loop, there cannot be inductance*. Practical considerations, however, lead us to discuss the inductance of a part of the overall current loop, such as the (partial) inductance of a capacitor. This idea of discussing the inductance of only a portion of the overall loop is called partial inductance [4]. While the concept of inductance without a complete loop is meaningless, we can *assume* the current through a conductor will find a way to return to its source, even if we are not sure how that will happen initially, allowing us to calculate the partial inductance of that conductor.

Partial inductances can be combined to find the overall loop inductance. For the simple case of a rectangular loop of wire where sides 1 and 3 are parallel to each other and sides 2 and 4 are parallel to each other (see Figure 1, page 40), equation (1) can be used to calculate the total inductance from the partial inductances. Note that the partial inductances from each leg of the loop are added, while two times the partial mutual inductances are subtracted to find the total loop inductance.

$$L_{total} = L_{p1} + L_{p2} + L_{p3} + L_{p4} - 2M_{p13} - 2M_{p24} \quad (1)$$

In each portion of the loop we assign a partial inductance value as well as partial mutual inductance between all parts of the loop.[1] If the conductors have different sizes, that is not a problem to calculate the partial inductance values. Naturally, if the current follows a more complex path, additional partial inductances and partial mutual inductances will be needed.

The formulas to calculate the partial inductance and partial mutual inductance look a little messy (see appendix for the full formulas), if we make some simple assumptions that are typical of most cases, then the formulas are much simpler. When the length of the conductor is much longer than the wire radius, the partial inductance for a length of wire is given by (2). When the distance between the conductor is much longer than the conductor length, then the partial mutual inductance between a pair of parallel wires is given in (3).

$$L_p \cong 2 \cdot 10^{-7} \cdot l \left(\ln \frac{2l}{r_w} - 1 \right) \qquad l >> r_w \quad (2)$$

1. In this case, we only show the partial mutual inductance of the parallel sections, since perfectly perpendicular conductors will not have significant mutual inductance.

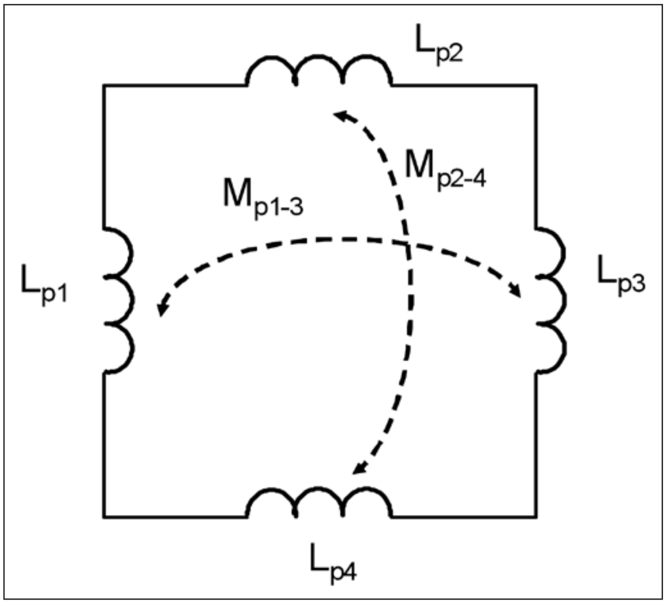

Figure 1: Partial Inductance Components of Simple Rectangular Loop

where

l is the length of the conductor in meters

r_w is the wire radius in meters.

$$M_p \cong 2 \cdot 10^{-7} \cdot l \left(\ln \frac{2l}{d} - 1 \right) \qquad l >> d \quad (3)$$

where

l is the length of the conductor in meters

d is the distance between wires in meters

USING PARTIAL INDUCTANCE

Examining equation (2), we can see that as the length of the conductor increases, so does the partial inductance associated with that conductor. Figure 2 shows how the partial inductance increases with wire length for a 1mm wire radius (calculated from (2)). Examining equation (3), we see the partial mutual inductance *increases* as distance between the wires *decrease*! Figure 3 shows examples of the partial mutual inductance (calculated from (3)) for 30 cm and 50 cm lengths of wire.

We can use these charts and formulas to help understand the usefulness of partial inductance in helping reduce the total loop inductance. For example, if we take a 50 cm long pair of wires that are closely spaced, we can assume the contribution of the short segments at each end is very small compared to the main length, and so we'll ignore them for this example. If we start with both wires with a 1 mm radius, and separated by 5 cm, then we have the following:

$$L_{total} = L_{p1} + L_{p2} - 2 \cdot M_{p12} = 690 + 690 - 2 \cdot 294 = 792nH \quad (4)$$

If we increase the conductor radius for one of the wires to 2mm, we get the following:

$$L_{total} = L_{p1} + L_{p2} - 2 \cdot M_{p12} = 690 + 621 - 2 \cdot 294 = 732nH \quad (5)$$

Not a very impressive drop in total inductance after doubling the wire radius! However, if we go back to the initial wire radius, and decrease the separation between the wires to 2.5 cm, we get the following:

$$L_{total} = L_{p1} + L_{p2} - 2 \cdot M_{p12} = 690 + 690 - 2 \cdot 366 = 648nH \quad (6)$$

It should be no surprise that making the separation between the wires smaller, therefore reducing the loop area, had a more significant impact on the total inductance than dramatically increasing the wire radius. Partial inductance can be used to identify the impact of changing a portion of the overall current loop, thus allowing designers to have the greatest success in lowering total inductance.

SUMMARY

The concept of partial inductance is not difficult to understand and use. It is an extremely powerful concept that helps engineers more clearly think about inductance, and the contributions of conductor size and separation. When the overall loop is more complex than the simple example shown here, partial inductance can be used to find the contributions of all the various portions of the loop. When very complex, a computer program is often needed to calculate the partial inductance components, but the concept of partial inductance remains quite simple and yet very powerful! IN

REFERENCES

[1.] Grover, F.W. 1946. *Inductance Calculations*, New York: Dover Publications.

[2.] Ruehli, A.E. 1972. "Inductance Calculations in a Complex Integrated Circuit Environment," *IBM J. Research and Development.* 16: 470-481.

[3.] Paul, C. 2009. *Inductance: Loop and Partial.* Hoboken: Wiley.

APPENDIX

Full Formulas for Partial Inductance and Partial Mutual Inductance

$$L_{pi} = \frac{\mu_0}{2\pi} l \left[\log\left(\frac{l}{r} + \sqrt{\left(\frac{l}{r}\right)^2 + 1}\right) + \frac{r}{l} - \sqrt{\left(\frac{r}{l}\right)^2 + 1} \right]$$

(A1)

$$M_{p_{ij}} = \frac{\mu_0}{2\pi} l \left[\log\left(\frac{l}{d} + \sqrt{\left(\frac{l}{d}\right)^2 + 1}\right) + \frac{d}{l} - \sqrt{\left(\frac{d}{l}\right)^2 + 1} \right]$$

(A2)

where

l = length of wire (m)
r = radius of wire (m)
d = distance between parallel wires (m)

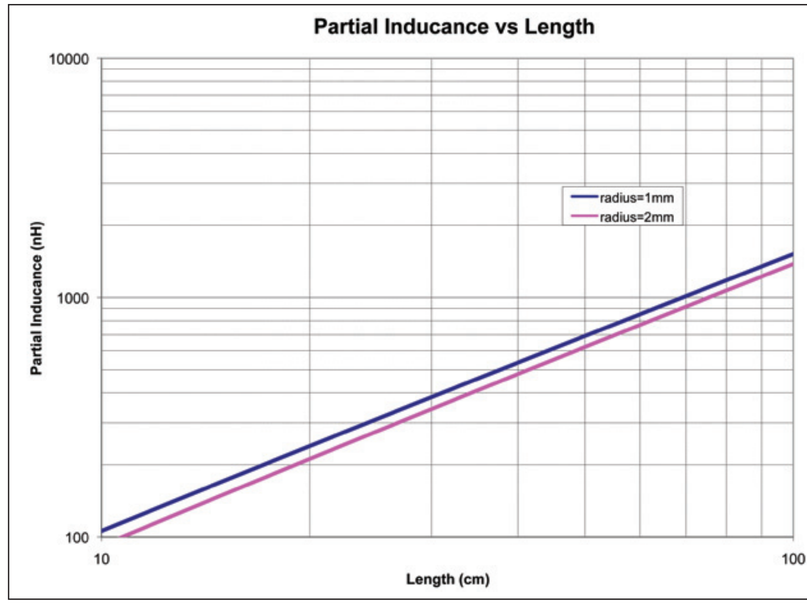

Figure 2: Partial Inductance vs Wire Radius

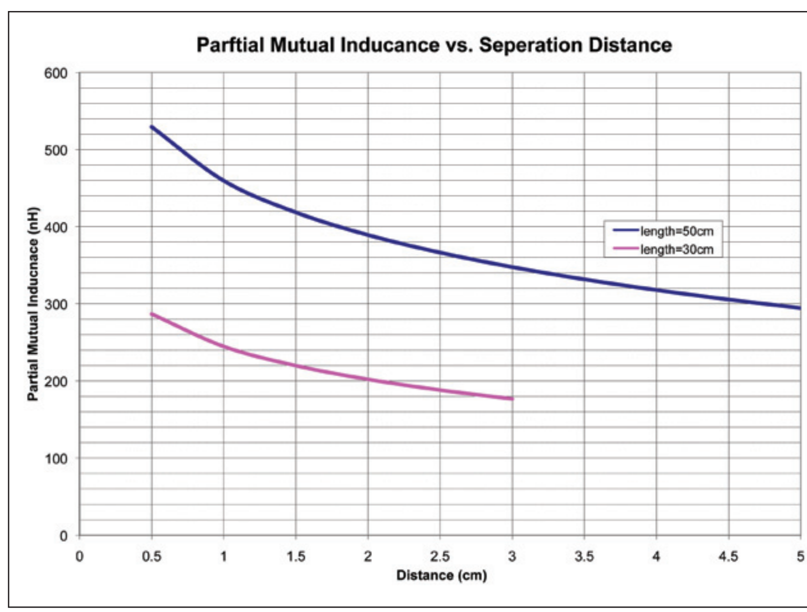

Figure 3: Partial Inductance vs Separation Distance

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ESD Influence on ICs

BY GUNTER LANGER

New developments in electronics manufacturing are increasingly dominated by the requirements of EMC today. Considerable follow-up costs in product development are caused due to the failure of electronic modules in EMC compliance tests.

The integrated circuits that are used in an electronic system are critical for its EMC performance as a whole. ICs are often responsible for interference emissions or immunity weak points and it is difficult to gain control of them in such cases.

The structures of ICs have become smaller and smaller over time which has led to higher switching rates and made a reduction in the supply voltage necessary. Due to these two factors, ICs have become more susceptible to ESD.

In EMC compliance tests according to the standard IEC 64000-4-2, electronic devices are tested with an ESD generator (ESD gun). The ESD generator produces a current pulse (Magnetic flux density near the ESD generator tip (bottom)) as required by the standard, which is injected into the device under test (and an electric disturbance field are induced.). This ESD pulse is coupled into metallic parts of the electronic device and from there moves to the IC via conductive and capacitive/inductive coupling. The amplitude of the disturbance pulse is varied with time on its path to the IC.

The objective of this article is to investigate the coupling paths to the IC. The amplitude of the disturbance pulses that affect the IC is measured as a function of time for the individual coupling paths. This helps identify which coupling is relevant and which parameters (rise time, voltage intensity, waveform, amplitude, current, voltage, electric or magnetic field) have an influence on coupling. These findings allow the development of selected EMC countermeasures to protect the IC.

Apart from the current pulse according to the standard, the ESD generator induces a magnetic and an electric field (and an electric disturbance field are induced., and an electric disturbance field are induced.). Due to the discharge current, a magnetic vortex field is produced at the tip of the ESD generator which swirls through the IC and the module's line networks. A disturbance voltage is induced in conductor loops that are penetrated by the field. This voltage is superimposed on the electrical signals of the electronic system and causes malfunctions in the electronic device.

An inductor is integrated into the tip of the ESD generator. The discharge current from the ESD generator causes a voltage drop across this inductor. This voltage drop generates an electric field (E1) which emerges from the generator's tip and extends into the device under test via the lines and ICs (and an electric disturbance field are induced.). A disturbance current pulse is thus transmitted into the lines and ICs which results in malfunctions in the electronic device.

Apart from the disturbance current sent out via its tip as described in the standard, electric and magnetic fields emerge from the body of the ESD

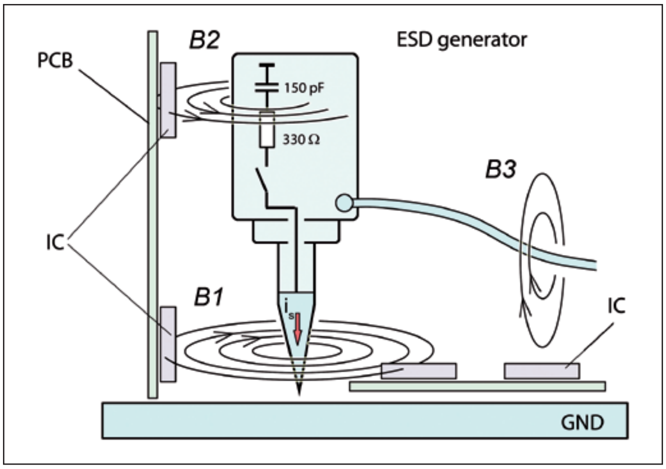

Figure 1: Current pulse injected with an ESD generator into the device under test.

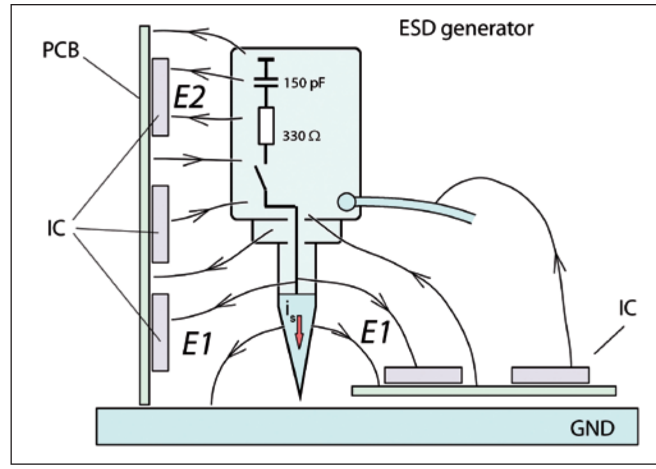

Figure 2: In addition, a magnetic and an electric disturbance field are induced.

generator (and an electric disturbance field are induced., and an electric disturbance field are induced.). If compared as a function of time, these fields and the disturbance event as described by the standard may be totally different. These fields have an additional disturbance effect on the electronic device which may exceed the desired effect caused by the disturbance from the tip. The extent to which these fields interfere with the electronic device depends on how the ESD generator is positioned relative to the device's modules. Weak points may respond in the device purely by chance when the ESD generator is turned and tilted. Functional faults of the electronic device seem to happen in a chaotic way. The developer can no longer understand and analyze the cause and effect relationships.

Magnetic flux density near the ESD generator tip (bottom) shows the first peak current of discharge of the ESD generator in magnified form. Several transients are clearly visible on the leading edge which are designated ESD transients in the following text. The discharge current peak and the ESD transient also produce a magnetic flux B1 (and an electric disturbance field are induced.) with an identical variation over time. The magnetic flux B1 induces a disturbance voltage u_{ind} (Magnetic flux density near the ESD generator tip (bottom)) in a conductor loop of the electronic module. The conductor loop has a size of 8 mm^2. The voltage set for the ESD generator is 2 kV. Furthermore, Magnetic flux density near the ESD generator tip (bottom) shows clearly that the largest voltage induction is generated by the ESD transient. The rise time of the discharge current peak of 0.7 to 1 ns as defined by the standard generates

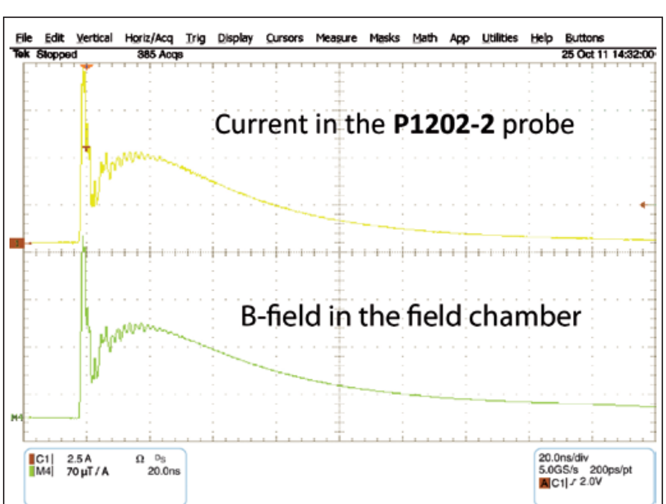

Figure 3: Current as a function of time for the disturbance triggered by the ESD generator (top)
Magnetic flux density near the ESD generator tip (bottom)

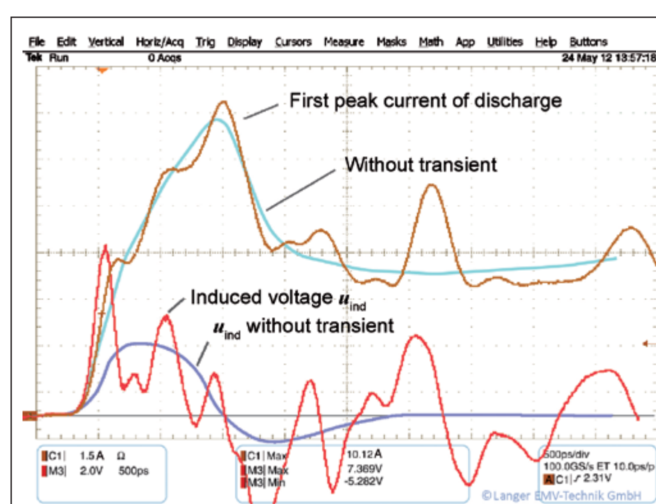

Figure 4: Voltage u_{ind} induced by the first peak current of discharge of the ESD generator in a current loop of the module (ESD generator: NSG435 Voltage: 2 kV)

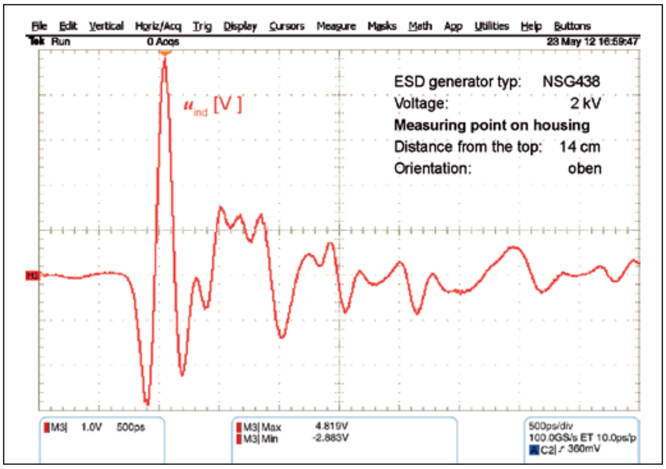

Figure 5: Voltage induced in a conductor loop of 8 mm² by field B2 emerging from the ESD generator housing.

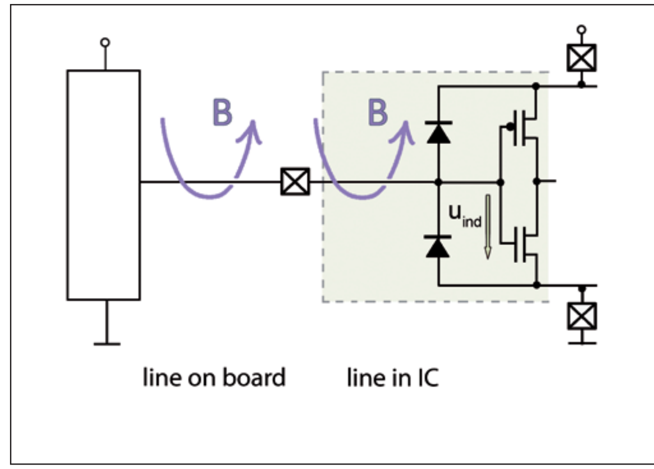

Figure 6: Voltage induced by the magnetic field of the ESD generator on a conductor loop of the electronic module or an IC.

a lower disturbance voltage induction (Magnetic flux density near the ESD generator tip (bottom), curves without transient).

The ESD transient of the ESD generator has a stronger disturbance effect than the discharge current peak. The waveform parameters as defined by the standard are thus not suitable for comprehensively describing the disturbance effect of the ESD generator. Transients strongly depend on the type of ESD generator used in practice.

The fields B2 and B3 boost the disturbance effect of the ESD generator (and an electric disturbance field are induced.). Voltage induced in a conductor loop of 8 mm² by field B2 emerging from the ESD generator housing. shows the disturbance voltage induced by the field B2 in a conductor loop of 8 mm². The voltage variation with time is totally different to the usual curve of the ESD events generally known. The 200 ps-wide spike has the largest disturbance effect on ICs. It has an amplitude of 4.8 V. This pulse was too short for slower ICs of the older generation and hardly caused any trouble at all. Modern, fast ICs can process this narrow pulse and suffer from malfunctions. What is special about this event, i.e. voltage induced by field B2, is it has nothing to do with the standard pulse. It occurs in addition to the actual test, which means that the standard test is no longer unambiguous.

Voltage induced by the magnetic field of the ESD generator on a conductor loop of the electronic module or an IC. shows the operating principle behind voltage induction (equivalent circuit) via the magnetic field B of the ESD generator. The induction loop can be located outside the IC on the printed circuit board or inside the IC package. Outside it is formed by a trace closing to ground via a low-impedance driver in this example. The disturbance voltage enters the IC via the trace by conductive coupling. Within the IC, the induction loop is formed by pins, the lead frame and bonding wire. The voltage u_{ind} induced in the induction loop is present at the IC input. Both voltages, the internal and the external one, cause malfunctions inside the IC. The voltage u_{ind} depends on the rate of change of the discharge current and magnetic field of the ESD generator respectively. This correlation is described by the law of induction: $u_{ind} = -d\,\Phi / d\,t$. The faster the rate of change of the disturbance, the higher the voltage induced. The burst generator

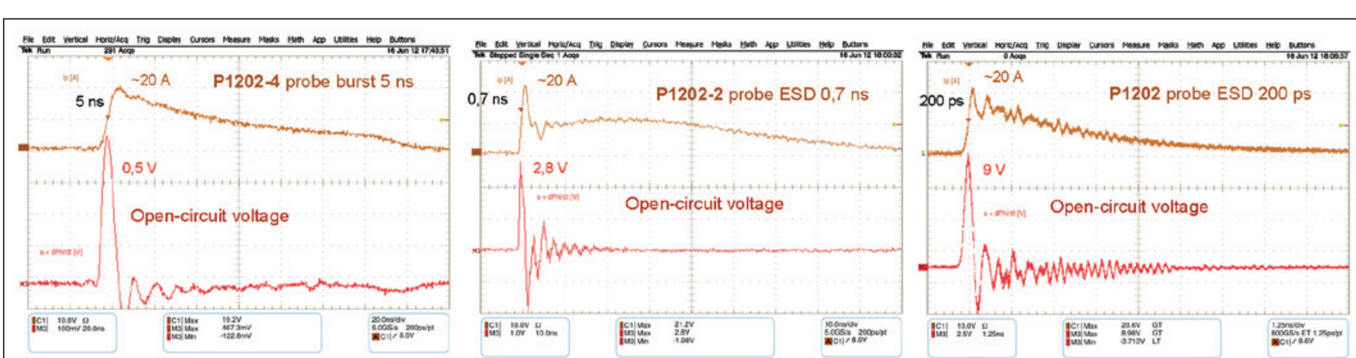

Figure 7: Voltage induced in a conductor loop of 8 mm² during the disturbance events: burst, ESD, ESD transient.

according to IEC 64000-4-4 provides pulses with a rise time of 5 ns. The magnetic fields of the burst generator induce a lower voltage than the disturbance produced by the ESD generator. The ESD generator provides pulses with a rise time of 0.7 to 1 ns and induces a five-fold higher voltage with the same current value. The leading edge transients of the ESD generator have a rise time of approximately 200 ps. These transients will induce an even higher voltage.

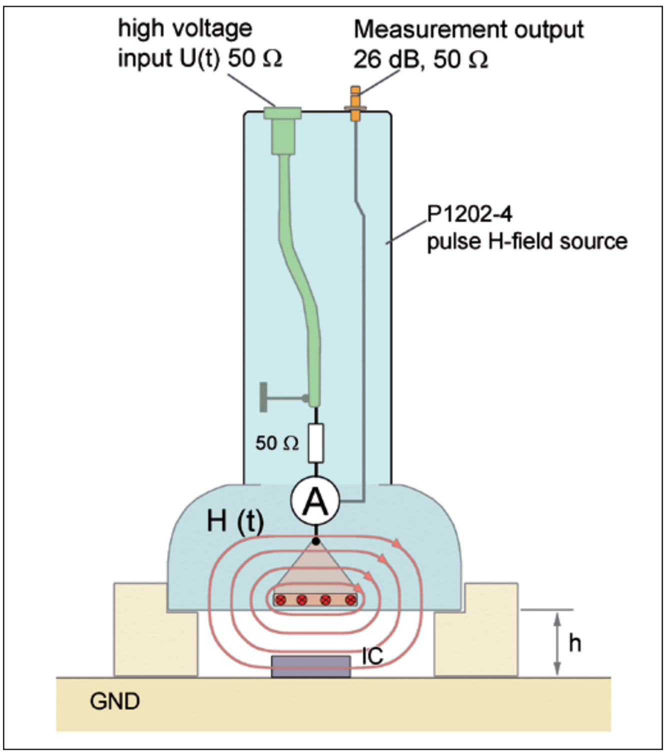

Figure 8: Test set-up to determine an ICs immunity to magnetic field

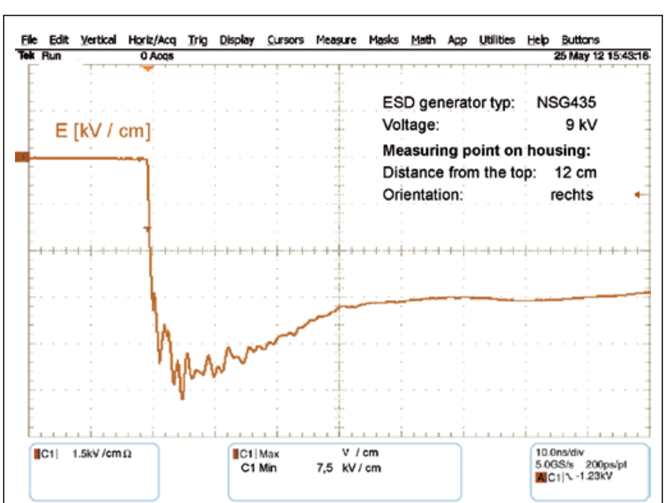

Figure 9: Electric field at the rear part of the NSG435 ESD generator with a voltage of 9 kV.

Voltage induced in a conductor loop of 8 mm² during the disturbance events: burst, ESD, ESD transient. shows this correlation. The current shown here generates a magnetic field B that penetrates the conductor loop. The voltage u_{ind} is induced in the conductor loop. The disturbance events: burst, ESD, ESD transient induce different voltages. The width of the voltage pulse induced corresponds to the rate of change of current. Pulses with a width of 5 ns are produced during a burst event. ESD events generate pulses with a width of 1 ns and ESD transients produce pulses with a width of 200 ps. Modern ICs will also process pulses with a width of 200 ps which will then lead to IC malfunctions or even its total failure.

According to the law of induction, the value of the voltage induced is inversely proportional to the rate of change of the disturbance event. The measurements for Voltage induced in a conductor loop of 8 mm² during the disturbance events: burst, ESD, ESD transient. have been carried out with defined field sources (Test set-up to determine an ICs immunity to magnetic field). These field sources have a fixed field generation geometry for different disturbances. The test current will thus always produce the same field coupling so that the results measured for the three disturbance events described can be compared. An IC can be subjected to the defined fields and its immunity tested in operation.

Switching voltages with a high rate of change occur at the high-voltage switch, current conductors and other components in the ESD generator during the discharge (and an electric disturbance field are induced.). These switching voltages generate electric fields with a high rate of change that couple from the generator housing to the device under test. Electric field at the rear part of the NSG435 ESD generator with a voltage of 9 kV. shows the electric field which emerges from the rear part of an ESD-generator housing. Its rate of change is approx. 1 ns.

Coupling E field into a conductor of an electronic module or IC shows the equivalent circuit diagram and the operational principle behind the coupling in by the electric field of the ESD generator. The electric field couples into a signal line. The capacitive coupling between the affected signal line and the ESD generator is low. The value of this capacitance depends on the surface area of the signal line and is in the fF range for this coupling. The electric field of the ESD generator drives a capacitive current into the signal line. This current flows to ground (GND) via the pull-up resistor or the internal resistor of the connected driver. The current produces a voltage pulse at the resistor. This voltage pulse reaches the input of the IC and interferes with the IC. The peak value of the voltage pulse depends on the rate of change of the electric field, the pull-up resistance and the surface area of the signal line that is subjected to the field. The pulse width depends on the rise time. The faster the rate of change of the disturbance, the higher the voltage coupled in. The burst generator according to IEC 64000-4-4 provides pulses with a rise time of 5 ns. The electric fields of the burst event couple a lower voltage than the disturbance triggered by the ESD generator. The ESD generator provides pulses with a rise time of 0.7 to 1 ns and couples a five-fold higher voltage into the device under test. The highest rate of change of E fields from an ESD generator is approximately 200 ps. Due to these events, an even higher voltage is coupled into the device under test.

This electric coupling was investigated in experiments. A similar test set-up as shown Test set-up to determine an ICs immunity to magnetic field was used for these experiments. An E field source was used to generate the required fields. Electrical coupling into a conductor as a function of the rise time of the disturbance pulse and the value of the pull-up resistor used in the circuit. shows the results. A 5 ns burst pulse and a 200 ps ESD pulse were used for the measurement. In addition, the dependence on the pull-up resistor (driver) used in the set-up was examined.

The voltage coupled into the IC is proportional to the pull-up resistance. The lowest voltage (0.15 V) is coupled into the IC at a rate of change of 5 ns and a pull-up resistance of 50 Ohm. This voltage will not yet interfere with the IC. The highest voltage is generated at a rate of change of 200 ps and a pull-up resistance of 10 kOhm and amounts to 64 V. Electrical coupling into a conductor as a function of the rise time of the disturbance pulse and the value of the pull-up resistor used in the circuit. shows that the 200 ps pulse can already cause malfunctions in the IC with a low-impedance pull-up (driver) resistance of 50 Ohm (with a voltage of 3.5 V). This makes this pulse particularly dangerous for electronic circuits since even the smallest sections of lines that are driven by a low impedance source such as a data bus, address bus, etc. can become a victim of interference this way. The surface area of the size of a test pad on the respective line is sufficient to cause malfunctions in the IC. This problem is limited to modern, highly integrated ICs which are fast enough to process this type of pulse.

It is important for designers to know the immunity of the ICs that are planned to be used for a module with highly integrated circuits. Not all pins of an IC are equally sensitive to EMI. Usually there are just a few highly sensitive pins. These pins have to be identified so that appropriate and effective EMC countermeasures can be taken.

Signal lines should be routed in internal layers and shielded by GND planes on both sides to reduce interference effects from electric fields, for example. It has to be noted that the number of test pads and vias also has to be reduced.

Modern measuring techniques and test devices are available to determine the conducted and radiated immunity of ICs. IN

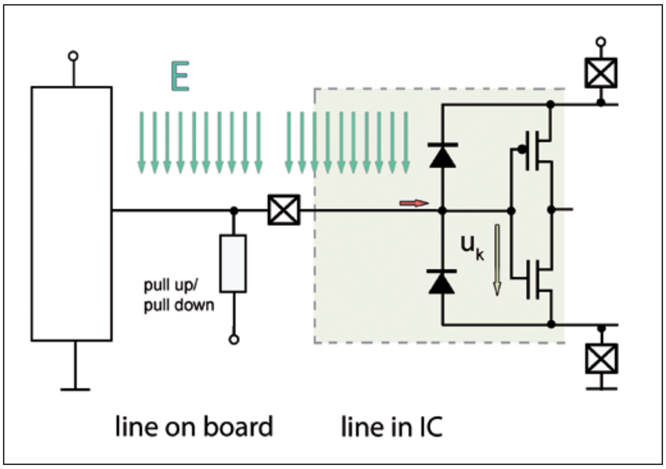

Figure 10: Coupling E field into a conductor of an electronic module or IC

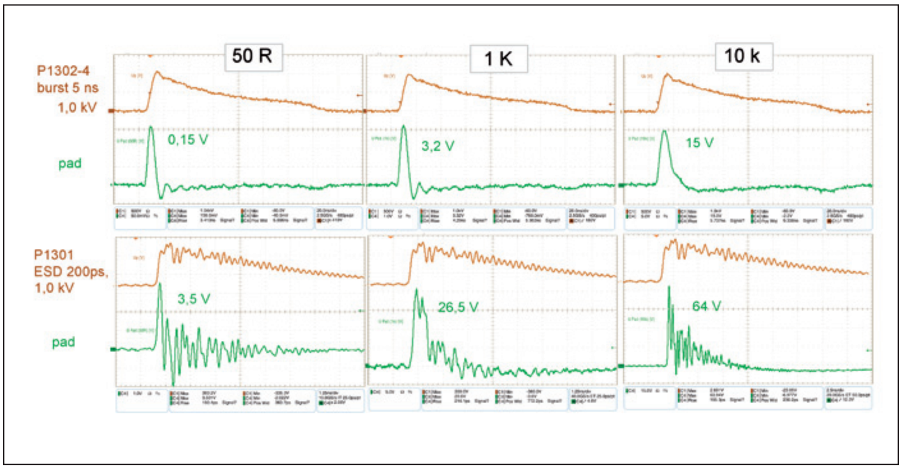

Figure 11: Electrical coupling into a conductor as a function of the rise time of the disturbance pulse and the value of the pull-up resistor used in the circuit

(the author)

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Dipl. Ing. Gunter Langer (*1950) focuses on research, development, and production in the field of electromagnetic compatibility (EMC) since 1980. He founded the Gunter Langer engineering office in 1992 and Langer EMV-Technik GmbH. in 1998. His interference emission and interference immunity EMC measurement technology as well as the IC test system are used mainly in the development stage and are in worldwide demand.


CAUTION
STATIC SENSITIVE
DEVICE

Fundamentals of Electrostatic Discharge

Part Five: Device Sensitivity and Testing

BY THE ESD ASSOCIATION

In *Part Two* of this series ("Principles of ESD Control – ESD Control Program Development"), we indicated that a key element in a successful static control program is the identification of those items (components, assemblies, and finished products) that are susceptible (ESD sensitive devices, ESDS) to ESD and to know the level of their sensitivity. Susceptibility of an ESDS to an ESD event is determined by the device's ability to dissipate or shunt the energy of the discharge or withstand the current and voltage levels involved. Although energy or (peak) current are the most important parameters, the ESD sensitivity or ESD susceptibility is typically classified by its withstand voltage. The withstand voltage is defined by the voltage which causes the discharge, not the voltage which can be measured at the ESDS. Part Two included:

Define the level of control needed in your environment. What is the most sensitive or ESD susceptible ESDS you are using and what is the classification of withstand voltage of the products that you are manufacturing and shipping? In order to have a complete picture of what is required, it is best to know the Human-Body Model (HBM) and Charged-Device Model (CDM) sensitivity levels for all devices that will be handled in the manufacturing environment. ANSI/ESD S20.20 defines control program requirements for items that are sensitive to 100 volts HBM.

Some devices may be more readily damaged by discharges occurring within automated equipment, while others may be more prone to damage from handling by personnel. In this Part Five we will cover the models and test procedures used to characterize, determine, and classify the sensitivity of components to ESD. Today, these test procedures are based on the two primary models of ESD events: Human Body Model (HBM) and Charged Device Model (CDM). The models used to perform component testing cannot replicate the full spectrum of all possible ESD events and there is no direct correlation between discharges in the field and in a test system. Nevertheless, these models have been proven to be successful in reproducing over 99% of all ESD field failure signatures and typically the ESD withstand voltages obtained by models in test systems are worst-case compared to real-world events with the same discharge voltage. With the use of standardized test procedures, the industry can:

- Develop and measure suitable on-chip protection.
- Enable comparisons to be made between devices.

- Provide a system of ESD sensitivity classification to assist in the ESD design and monitoring requirements of the manufacturing and assembly environments.
- Have documented test procedures to ensure reliable and repeatable results.

HUMAN BODY MODEL (HBM) TESTING

One of the most common causes of electrostatic discharge damage is the direct transfer of electrostatic charge from the human body or from a charged material to the electrostatic discharge sensitive item. When one walks across a floor, an electrostatic charge accumulates on the body. Simple contact (or even close proximity) of a finger to the leads of an ESDS or assembly allows the body to discharge, possibly causing device damage. The model used to simulate this event is the Human Body Model (HBM).

The Human Body Model is the oldest and most commonly used model for classifying device sensitivity to ESD. The HBM testing model represents the discharge from the fingertip of a standing individual delivered to the device. It is modeled by a 100 pF capacitor which is charged by a high-voltage supply through a high-ohmic resistor (typically in the megohm regime) and then discharged through a switching component and a 1.5 kW (1,500 ohms) series resistor through the component to ground or to a lower potential. This model, which dates from the nineteenth century, was developed for investigating explosions of gas mixtures in mines. It was adopted by the military in MIL-STD-883 Method 3015, and is referenced in ANSI/ESDA-JEDEC JS-001*: Electrostatic Discharge Sensitivity Testing – Human Body Model*. This document replaces the previous ESDA and JEDEC methods, STM5.1-2007 and JESD22-A114F, respectively. The simplified Human Body Model circuit without any parasitics from the test system is presented in Figure 1.

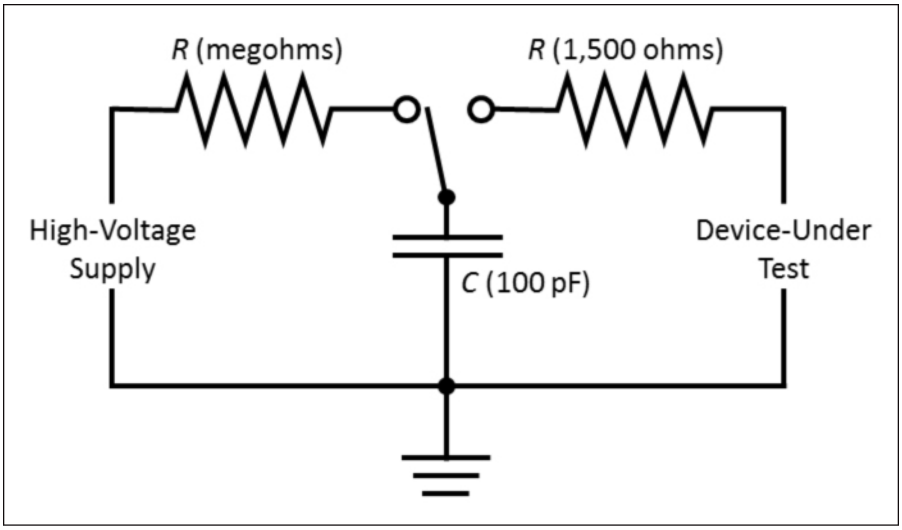


Figure 1: Typical (simplified) Human Body Model Circuit

A typical HBM waveform has a rise time of 2–10 ns, a peak current of 0.67 amps/kilovolts and a double-exponential decay with a width of 200 ns. Typically, the decisive parameter which causes the failure is the energy of the HBM pulse.

Testing for HBM ESD susceptibility is typically performed using automated test systems. The device is placed in the test system and contacted through a relay matrix. One pin is contancted to the HBM network ("zap pin"), and one or several other pins are connected to tester ground ("ground pins"). With today's high-pin count devices, a full test of all possible stress combinations is no longer possible, thus pin combinations have to be selected which guarantee a sufficient coverage to detect weak stress combinations. These pin combinations which have to be stressed are defined in the current HBM standard. Electrostatic discharges (ESD) are applied with a waveform generated by a Human Body Model network. A device is determined to have failed if it does not meet the datasheet parameters using parametric and functional testing.

One has to state clearly that the Human Body Model according to JS-001 addresses *handling issues*. Sometimes, the well-known IEC 61000-4-2 is also called "Human Body Model", but that model addresses ESD events *in a system* under different operating conditions and, therefore, should be applied to *systems only*. The waveform and the severity of the IEC 61000-4-2 and the JS-001 cannot be compared. For handling issues, only JS-001 is meaningful.

CHARGED DEVICE MODEL (CDM) TESTING

The transfer of charge *from* an ESDS to a conductive surface at a lower potential is also an ESD event. A device may become charged, for example, from sliding down the part feeder in automated handling equipment. If it then contacts the insertion head or another conductive surface, which is at a lower potential, a rapid discharge may occur from the device to the conductive surface. This discharge event is known as the Charged Device Model (CDM) event and can be more damaging than the HBM for some devices. Although the duration of the discharge is very short – often less than one nanosecond – the peak current can reach several tens of amperes, causing significant voltage drops in the device and eventually resulting in breakdown of dielectrics (e.g. gate oxides) due to the excessive voltage.

The device testing standards for *CDM (ESD STM5.3.1: Electrostatic Discharge Sensitivity Testing - Charged Device Model and JEDEC Standard JESD22-C101: "Field-Induced Charged-Device Model Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic Components")* were originally published in 1999 and 2000, respectively. The test procedure involves placing the device on a field plate with its leads pointing up, then charging it and discharging the device. All pins are treated equally and are discharged after positive and negative charging. Figure 2 illustrates a typical CDM test circuit with direct charging o the device. The CDM 5.3.1 ESDA document was last published in 2009. A joint JEDEC/ANSI/ESDA CDM standard (JS-002-2014) is about to be released.

OTHER TEST METHODS

Machine Model (MM) Testing

A discharge also can occur from a charged conductive object, such as a metallic tool, or an automatic equipment or fixture. Originating in Japan as the result of trying to create a worst-case HBM event, the model is known as the Machine Model. This ESD model consists of a 200 pF capacitor discharged directly into a component with no series DC resistor in the output circuitry. The discharge waveform can be oscillating, rise time and pulse width are similar to HBM. The Machine Model typically addresses the same physical failure mode as the Human Body Model, although at significantly lower levels.

Testing of devices for MM sensitivity using ESD Association standard *ESD S5.2: Electrostatic Discharge Sensitivity Testing – Machine Model* is similar in procedure to HBM testing. The basic test equipment and the stress combinations are the same, but the test head is very different. The MM version does not have a 1,500 ohm resistor, but otherwise the test board and the socket are often the same as for HBM testing. The series inductance, as shown in Figure 3, is the dominating parasitic element that shapes the oscillating machine model wave form. The series inductance is indirectly defined through the specification of various waveform parameters like peak currents, rise times and the period of the waveform. However, the inductance is not well defined. Hence, for different testers the MM withstand voltage might differ by at

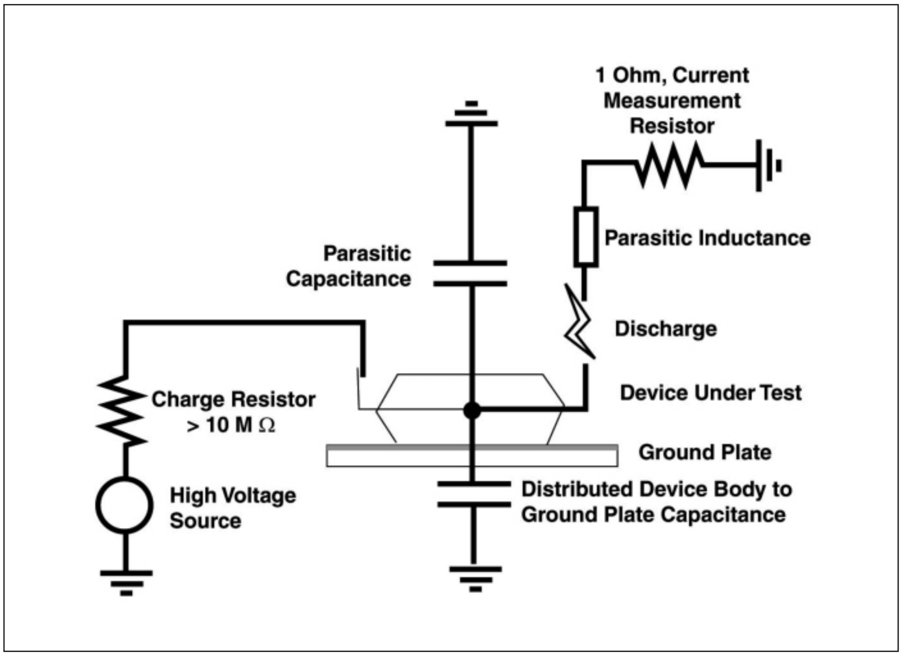


Figure 2: Typical Charged Device Model Test

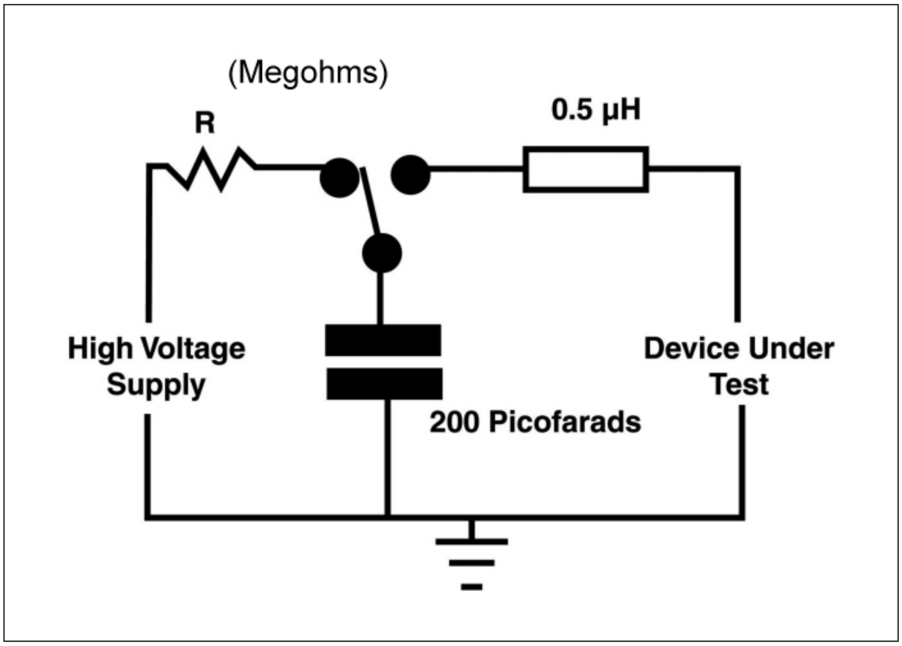


Figure 3: Typical Machine Model Circuit

least a factor of 2–5, although both test systems comply with the current standard. The lack of reproducibility of test results and the fact that the well reproducible HBM addresses the same failure mode as HBM are the main reasons that the industry only rarely is using MM today. JEDEC and ESDA do not recommend to qualify products with Machine Model, but qualifiying with HBM and CDM instead. The ANSI/ESDA MM 5.2 document was last published in 2013, however, with the arguments discussed in Industry Council White Paper 1, "A Case for Lowering Component Level HBM/MM ESD Specifications and Requirements," the test procedure was reclassified from a Standard to a Standard Test Method. Machine Model testing of integrated circuits (ICs) should be limited to failure analysis without correlation of withstand voltages and charging in the field.

Socketed Device Model (SDM) Testing

This model was originally intended to provide an efficient way to do CDM testing. The device is placed in a socket, charged from a high-voltage source and then discharged through the relay to ground. However, a correlation with the CDM standard cannot be guaranteed and there was too great a dependency on the specific design of the SDM tester. Furthermore, today there is no commercial SDM test system available anymore. A Standard Practice (SP) document (SP), SDM-5.3.2, was first published in 2002, and republished in 2013. A technical report, *ESD TR5.3.2 (formerly TR08-00) Socket Device Model (SDM) Tester* which discusses the pros and cons of SDM is also available from the ESD Association.

DEVICE SENSITIVITY CLASSIFICATION

The HBM and CDM methods include a classification system for defining the component sensitivity to the specified model (See Tables 1 and 2). These classification systems have a number of advantages. They allow easy grouping and comparing of components according to their ESD sensitivity and the classification gives you an indication of the level of ESD protection that is required for the component.

The current HBM and standards divide the Class 0 classification into two withstand voltage levels with class 0A being less than 125 volt sensitivity, and class 0B being 125 to less than 250 volts.

If handling class 0A items, or less than 125 volts, program improvements are called for. Basically, to control the environment to decrease the probability of ESD damage in class 0A situations, involves increasing ESD protective redundancies by adding EPA ESD control items and ensuring that they are working properly by increasing the frequency of compliance verifications of those ESD control items perhaps to more stringent required limits.

A component should be classified using both the Human Body Model, and the Charged Device Model. This would alert a potential user of the component to the need for a controlled environment, whether assembly and manufacturing operations are performed by human beings or automatic machinery.

A word of caution; however, these classification systems and component sensitivity test results function as guides, not necessarily as absolutes. The events defined by the test data produce narrowly restrictive data that must be carefully considered and judiciously used. The two ESD models represent discrete points used in an attempt to characterize ESD vulnerability. The data points are informative and useful, but to arbitrarily extrapolate

Classification	Voltage Range (V)
0A	< 125
0B	125 to < 250
1A	250 to < 500
1B	500 to < 1000
1C	1000 to < 2000
2	2000 to < 4000
3A	4000 to < 8000
3B	≥ 8000

Table 1: ANSI/ESDA/JEDEC JS-001 Table 3 - HBM ESD Component Classification Levels

Classification	Voltage Range (V)
C0A	< 125
C0B	125 to < 250
C1	250 to < 500
C2A	500 to <750
C2B	750 to < 1000
C3	≥ 1000

Table 2: ANSI/ESDA/JEDEC JS-002 Table 3 - CDM ESD Component Classification Levels

the data into a real world scenario can be misleading. The true utility of the data is in comparing one device with another and to provide a starting point for developing your ESD control programs.

SUMMARY

Device failure models and device test methods define the ESD susceptibilty of the electronic devices and assemblies to be protected from the effects of ESD. With this key information, you can design more effective ESD control programs. However, do expect devices to become more susceptible. The ESD Association's White Paper "Electrostatic Discharge (ESD) Technology Roadmap – Revised April 2010" includes "With devices becoming more sensitive through 2010-2015 and beyond, it is imperative that companies begin to scrutinize the ESD capabilities of their handling processes. Factory ESD control is expected to play an ever-increasing critical role as the industry is flooded with even more HBM (Human Body Model) and CDM (Charged Device Model) sensitive designs. For people handling ESD sensitive devices, personnel grounding systems must be designed to limit body voltages to less than 100 volts."

FOR FURTHER REFERENCE

- ANSI/ESDA/JEDEC JS-001 *Electrostatic Discharge Sensitivity Testing – Human Body Model,* ESD Association, Rome, NY.
- *ESD STM5.2-2009: Electrostatic Discharge Sensitivity Testing – Machine Model,* ESD Association, Rome, NY.
- *ESD STM5.3.1-2009: Electrostatic Discharge Sensitivity Testing – Charged Device Model,* ESD Association, Rome, NY.
- ANSI/ESDA/JEDEC JS-002 *Electrostatic Discharge Sensitivity Testing – Charged Device Model,* ESD Association, Rome, NY.
- *ESD TR 5.3.2-2013 (formerly TR08-00): Socket Device Model (SDM) Tester,* ESD Association, Rome, NY.
- ESD Industry Council White Paper 1: "A Case for Lowering Component Level HBM/MM ESD Specifications and Requirements," August 2008, and ESD Association's White Paper "Electrostatic Discharge (ESD) Technology Roadmap – Revised April 2010 http://www.esda.org/IndustryCouncil.html.
- ESD Industry Council White Paper 2: "A Case for Lowering Component Level CDM ESD Specifications and Requirements," March 2009, www.esda.org/IndustryCouncil.html.
- Steinman, Arnold, "Process ESD Capability Measurements," EOS/ESD Symposium Proceedings, 2012: 211, ESD Association. Rome, NY.
- Gaertner, Reinhold and Wolfgang Stadler, "Is there a Correlation Between ESD Qualification Values and the Voltages Measured in the Field?" EOS/ESD Symposium Proceedings, 2012: 198, ESD Association, Rome, NY.
- Hyatt, Hugh et al, "A Closer Look at the Human ESD Event," EOS/ESD Symposium Proceedings, 1981, ESD Association, Rome, NY.
- Avery, L.R., "Charged Device Model Testing: Trying to Duplicate Reality," EOS/ESD Symposium Proceedings, 1987, ESD Association, Rome, NY.
- Pierce, Donald C., "Critical Issues Regarding ESD Sensitivity Classification Testing," EOS/ESD Symposium Proceedings, 1987, ESD Association, Rome, NY.
- Avery, L.R., "Beyond MIL HBM Testing - How to Evaluate the Real Capability of Protection Structures," EOS/ESD Symposium Proceedings, 1991, ESD Association, Rome, NY.
- Renninger, Robert G., "Mechanisms of Charged-Device Electrostatic Discharges," EOS/ESD Symposium Proceedings, 1991, ESD Association, Rome, NY.
- Verhaege, Koen, et al, "Analysis of HBM ESD Testers and Specifications Using a 4th Order Lumped Element Model," EOS/ESD Symposium Proceedings, 1993, ESD Association, Rome, NY.
- Kelly, M. et al, "A Comparison of Electrostatic Discharge Models and Failure Signatures for CMOS Integrated Circuit Devices," EOS/ESD Symposium Proceedings, 1995, ESD Association, Rome, NY.
- Wada, Tetsuaki, "Study of ESD Evaluation Methods for Charged Device Model," EOS/ESD Symposium Proceedings, 1995, ESD Association, Rome, NY.
- Russ, Christian et al, "A Compact Model for the Grounded-Gate nMOS Behavior Under CDM ESD Stress," EOS/ESD Symposium Proceedings, 1996, ESD Association, Rome, NY.
- Verhaege, Koen et al, "Recommendations to Further Improvements of HBM ESD Component Level Test Specifications," EOS/ESD Symposium Proceedings, 1996, ESD Association, Rome, NY.
- Gieser, H. and M. Haunschild, "Very Fast Transmission Line Pulsing of Integrated Structures and the Charged Device Model," EOS/ESD Symposium Proceedings, 1996, ESD Association, Rome, NY.
- Chaine, M. et al, "Investigation into Socketed CDM (SDM) Tester Parasitics," EOS/ESD Symposium Proceedings, 1998, ESD Association, Rome, NY.
- Henry, L.G. et al, "Issues Concerning CDM ESD Verification Modules-The Need to Move to Alumina," EOS/ESD Symposium Proceedings, 1999, ESD Association, Rome, NY.
- Henry, L.G. et al, "The Importance of Standardizing CDM ESD Test Head Parameters to Obtain Data Correlation," EOS/ESD Symposium Proceedings, 2000, ESD Association, Rome, NY.
- Vergege, Koen. 1998. "Component Level ESD Testing," *Microelectronics Reliability Journal.*

BUSINESS News

ACS Adds Regulatory Compliance Center in Raleigh

ACS, Inc. announced today its new test lab in Raleigh, NC. The announcement was made during the IEEE 2014 International Symposium on Electromagnetic Compatibility known as EMC 2014. The Raleigh location will continue the company's dedication to exemplary customer service. Initially, the capabilities of the new Raleigh lab will focus on two primary areas of testing: EMC compliance testing and wireless certifications. The Raleigh test lab will employ state-of-the art equipment including a 3 meter semi-anechoic chamber, and a covered 10 meter Open Area Test Site (OATS), both registered and accredited with the FCC, IC, and VCCI. Learn more at www.acstestlab.com.

Advanced Test Equipment Rentals Featured on American Airlines "Executive TV"

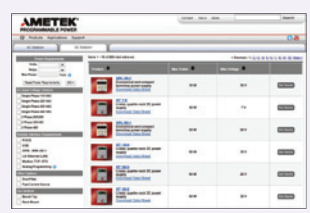
Advanced Test Equipment Rentals has announced they will be featured on American Airlines "Executive TV" during the month of July. The American Airlines "Executive TV" In-Flight Video Entertainment Program broadcasts exclusively on American Airlines domestic and international flights worldwide and features many top companies in their industries. The company will be featured in a two minute segment that focuses on the many highlights and benefits the company provides its customers. Visit www.atecorp.com/fly to watch the segment.

Aeroflex Introduces the 8800 Analog and Digital Radio Test Set

Aeroflex Incorporated announced the introduction of the new 8800 Radio Test Set; a high performance, economical radio test system for Analog AM and FM; and Digital P25, DMR, dPMR, NXDN™, and ARIB T98 technologies. The 8800 also introduces an all new capability known as "Fast Stack", which speeds access to meters and analysis functions by allowing meters and analysis functions to be stacked and then instantly accessed at the press of a button. For more information, contact your local Aeroflex sales office at info-test@aeroflex.com.

AMETEK Creates New AC Source/ DC Supply Selector Guide

AMETEK Programmable Power has released a free online Product Selector Guide designed to help engineers locate the optimal AC source or DC power supply quickly and efficiently. By inputting a few simple parameters, engineers can find the power supply that meets the needs of their application. The new Product Selector Guide features two selector guides in one: the first for DC power supplies and the other for AC power sources. Visit www.programmablepower.com/selector/DC-product-selector.php.



New PV Connector Meets Highest Certification Standards

Amphenol Industrial Products Group now offers a PV connector that meets all three of the highest certification standards on the market, allowing this one connector to be used globally. The new H4 UTX meets IEC50521 TUV 1500V- Class A (All Access), UL6703 1000V (Americas) and JET 1500V (Japan). The H4 UTX is available in all AWGs, from14 AWG to 8 AWG, and are fully matable with all existing H4 PV connectors and the typical PV industry standard connectors. Visit www.amphenol-industrial.com for full technical specifications.

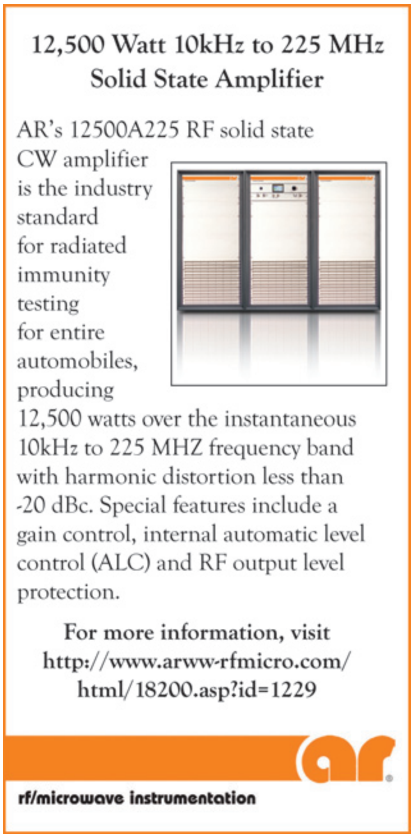
Chroma Introduces Six-in-One Electrical Safety Analyzer

Chroma's 19032 series combines Hipot, Insulation Resistance (IR), Ground Bond (GB), Leakage Current (LC)/AC LC/DC LC, and Dynamic Function Tests. The six-in-one instrument provides savings up to 50% of production line space, by not requiring several safety test instruments. The 19032 series is able to increase the efficiency of electrical safety testing during manufacturing and reducing associated labor costs. For more information on the 19032 Electrical Safety Analyzer series, visit www.chromausa.com.

Diversified Technologies, Inc. and Sigmaphi Sign Collaboration Agreement

Diversified Technologies, Inc. (DTI) has recently signed an agreement with Sigmaphi Accelerator Technologies of Vannes, France. They will be working together on systems for the next generation of particle accelerators. DTI and Sigmaphi will collaborate on the design, development, production, installation, repair, maintenance, and marketing of systems consisting of modulators and power supplies including Klystron Pulse Modulators for a broad range of high power RF applications. For more information, visit www.divtecs.com.

PRODUCT Showcase



Business News

Empower RF Systems Announces Approval of a Patent on "Broadband Linearization Module and Method"

Empower RF Systems is proud to announce the approval of a new patent related to a real time pre-distortion design and technique that is essential for broadband frequency hopping, which is especially critical for military radio communication. The main advantage of the new linearization approach is that pre-correction is being synchronized with the amplifier's distortion components in frequency, time and temperature. For more information on the patent, visit www.google.com/patents/US8736365. Visit Empower RF Systems at www.empowerRF.com.

GCT Launch Improved Tiny Footprint Nano SIM Connector

Following customer feedback GCT is launching the re-engineered SIM8050 Nano SIM connector, which at .425" x .480" has the smallest footprint of any push-pull connector on the market. The product has evolved to include a protective full metal shell and a height reduction to .053". Improved card insertion and extraction allows for a better user experience, while maintaining excellent vibration and shock characteristics. The connector is suitable for 5,000 card insertion cycles, while a card stop function prevents mis-orientation during card insertion. Visit www.gct.co for more information.

GradConn Launches Low Cost Test Probe Cable Assemblies

GradConn has launched a new range of low cost co-axial test probe cable assemblies for the inspection of high frequency circuits. Suitable for testing Hirose MS-156 and Murata MM8030 sub miniature coaxial switch connectors, the new probes offer reliable testing of RF circuits from development thru to final production. For Hirose PCB connectors, the test probe cable assemblies have a mating test cycle durability of 500 operations and 2,000 with Murata. For more information visit www.gradconn.com.

BUSINESS News

Keysight Technologies Begins Operations

Keysight Technologies, Inc. announced the electronic measurement business of Agilent Technologies has begun operating under the Keysight name. It will remain a wholly owned subsidiary of Agilent Technologies until early November when the separation is expected to be completed and Keysight begins trading on the NYSE under the symbol KEYS. For more information, visit www.keysight.com.

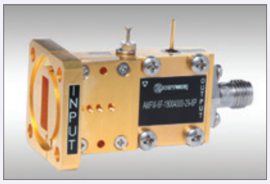
Extruded Elastomer EMI Gaskets from Leader Tech

At Leader Tech's global EMI shielding center in Tampa, the company is able to formulate and extrude high-performance and cost-effective conductive elastomer gaskets. These gaskets are used for numerous applications ranging from consumer products to mission-critical medical and military electronics.

In addition to a stock assortment of seven profiles that are available in multiple sizes, Leader Tech can create custom extruded shapes from 16 different, MIL-SPEC approved material formulations. To learn more about leader Tech's conductive elastomers, visit www.leadertechinc.com/products/enclosure-products/elastomers.

MITEQ Introduces 18-40 GHz Waveguide Low Noise Amplifier

Model AMFW-6F-18004000-29-8P is a recent addition to MITEQ's family of low noise, wideband, and ultra-small Waveguide LNAs in the 18 to 40 GHz band.



This LNA has over 35 dB of gain in a housing that is only 1.32" long and 0.88" wide without the field-replaceable 2.93mm connectors. Gain flatness is a maximum of ±3 dB. Visit www.miteq.com for more information.

Rigol Mixed Signal Oscilloscopes Add Logic Analysis Capability

Rigol Technologies, Inc. announced an expansion in their portfolio of mixed signal oscilloscopes. The new MSO1000Z Series and MSO2000A series add 16-channel logic analysis capability onto these two award winning oscilloscope platforms.

With this introduction, Rigol's MSO portfolio spans from 70MHz to 500MHz instruments, all using the innovative UltraVision architecture. For more information, visit www.rigolna.com.

Saelig Introduces 6GHz Handheld RF Spectrum Analyzers

Saelig Company, Inc. has introduced two new RF analyzers - the new AIM-TTi Series 5 Models - available in 3.6GHz and 6.0GHz versions. They maintain a true handheld format while offering bench-top instrument-quality features. The PSA3605 and PSA6005 weigh just 560 grams and are small enough to fit comfortably into the hand and provide more than 3 hours of operation from each charge of the built-in lithium-ion battery.

Made by one of Europe's leading test equipment manufacturers AIM-TTi, the PSA Series 5 offers exceptional value for the money and is available now from their USA distributor Saelig Company, Inc. Fairport, NY. For detailed spoecifications visit www.saelig.com.

TIA Applauds Bipartisan Medicare Act; Says Expanding Telehealth Coverage will Improve Care

The Telecommunications Industry Association (TIA), the leading association representing the manufacturers and suppliers of high-tech communications networks, applauded Representatives Mike Thompson (D-CA) and Gregg Harper (R-MS) for their bipartisan introduction of the Medicare Telehealth Parity Act of 2014. By expanding Medicare coverage of telehealth services, including the use of store-and-forward technologies and remote patient monitoring for specific chronic conditions, the Medicare Telehealth Parity Act will improve the access to, and quality of, care for Medicare beneficiaries in both rural and urban areas. To read TIA's letter in its entirety, visit: www.tiaonline.org.

Vishay Launches AEC-Q200 Ceramic Disc Safety Capacitors for Hybrid Vehicles

Vishay Intertechnology, Inc. Introduced a new series of AEC-Q200-qualified, AC-line-rated ceramic disc safety capacitors designed to provide high

reliability for Class X1 (440 VAC) and Y2 (300 VAC) automotive applications in accordance with IEC 60384-14.3, 3rd edition. Featuring U2J, Y5S, and Y5U ceramic dielectrics, the AY2 series is optimized for on-board chargers and battery management in electric cars and plug-in hybrid electric vehicles (PHEV), as well as high-reliability industrial applications. The capacitors offer a capacitance range from 10 pF to 4700 pF – with tolerances down to ± 10 % – over a temperature range of -55 °C to +125 °C. For more information, visit www.vishay.com.

EVENTS in Compliance

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European Microwave Week 2014
Fiera di Roma
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www.incompliancemag.com/events/141005

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Understanding Ground Resistance Testing
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ESD Device Design Essentials
Electrostatic Discharge Association
Munich, Germany
www.incompliancemag.com/events/141007_3

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Thermal & Vibration Reliability For Advanced Rugged Electronics 3-day Course
National Technical Systems (NTS)
Santa Clarita, CA
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Advanced ESD Characterization and Test Methods
Electrostatic Discharge Association
Munich, Germany
www.incompliancemag.com/events/141009

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36th Annual Symposium of the Antenna Measurement Techniques Association (AMTA)
JW Marriott Tucson Starr Pass
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Electronic Product Design & Retrofit for EMC Class
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Introduction to Electromagnetic Interference and Compatibility (EMI/EMC) and Best Practices
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Measurement, Control and Laboratory Use Equipment: Designing for Compliance to IEC 61010-1 3rd Ed
UL Knowledge Services
Chicago, IL
www.incompliancemag.com/events/141104_1

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Understanding Ground Resistance Testing Training Seminar
AEMC Instruments
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Thermal & Vibration Reliability For Advanced Rugged Electronics 3-day Course
National Technical Systems
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Military Standard 810G Training
National Technical Systems, Inc.
Plano, TX
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We wish to thank our community of knowledgeable authors, indeed, experts in their field - who come together to bring you each issue of *In Compliance*. Their contributions of informative articles continue to move technology forward.

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VERSATILITY IN THE LIMELIGHT:
NSG 3060 – THE NEW EMC IMMUNITY TEST GENERATION

The Teseq NSG 3060 multifunctional generator system is perfect for every need: A basic start up unit with all expansion options for the most demanding EMC laboratory systems. This new combination of high contrast color touch screen display with thumb wheel guarantees fast and simple operation. The NSG 3060 is designed for the world market, with convenient operation in several languages. In addition to the traditional IEC requirements, the NSG 3060 features ANSI/IEEE coupling modes and continuous monitoring of the EUT supply voltage. In conformance with ANSI/IEEE requirements, the peak surge level is automatically corrected for any phase angle and supply voltage – now that's versatility!

NSG 3060 Highlights:

- **Large touch screen color display**
- **Surge, ring wave and telecom pulse up to 6.6 kV**
- **Burst, Dip/Interrupt and magnetic field options**
- **Coupling as required by ANSI and IEC**
- **Extensive range of accessories**
- **Quickly launch tests from extensive Standards Library or User Test folders**

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