Control of low audio frequency magnetic fields from cables, as required by some spacecraft EMI control standards, is best implemented as a conducted emission measurement, but these may require exceptionally efficient transducers and techniques, which are discussed herein.

Common-mode conducted emission (CMCE) limits and measurements are often specified within spacecraft EMI standards, such as the Space & Missile Command’s SMC-S-008, EMC Requirements for Space Equipment and Systems [1], and the NASA Goddard Space Flight Center’s General Environmental Verification Standard (GEVS) [2].

Above audio frequencies, the rationale for such control is generally either the control of cable-to-cable crosstalk, and/or indirect control of radiated emissions. Such control and measurement is much more accurate and repeatable than radiated measurements when the cable is electrically short.

At audio frequencies, effective cable design usually precludes interference from crosstalk. There is no need to control CMCE at audio frequencies unless an unusually low-level signal is carried by a cable, and/or there are restrictions on the quality of shielding available, or the ability to twist a signal with its return.

But there is a special case where the control of CMCE at frequencies down to the very low end of the audio spectrum is desirable, and that is when a platform has a magnetic cleanliness requirement. Such platforms carry sensitive magnetometers. A sample derivation of such a limit is presented.

**BACKGROUND**

Consider the variable-mu magnetometer pictured in Figure 1. While this is earthbound test equipment, it will be shown that its sensitivity corresponds well with existing CMCE requirements in references [1] and [2].

**Figure 1:** Electro-Mechanics Company EMCO 6640 variable-mu magnetometer (circa 1964).
WELCOME TO THE UNITED STATES OF EMC

THE STATE OF IEC
UCS 500N7 Immunity Test Simulator as per IEC, ANSI/IEEE, Belcore
- Surge & Telecom pulse 7 kV;
- Burst, Ringwave, Dips/Interruptions up to 300 V
- Extensive range of 3-phase coupling filters and accessories

THE STATE OF ISO
Automotive Test Simulators for any international and worldwide car manufacturer standards
- ISO, SAE, Chrysler, Ford, GM, Toyota ...

THE STATE OF AIRCRAFT & MILITARY
Netwave, programmable AC/DC source up to 60 kVA
- DO-160, MIL-STD 704, Boeing, Airbus
- Recovery function

Your partner for all your needs throughout NORTH AMERICA:
EM TEST USA > 9250 Brown Deer Road > San Diego, CA 92121 > USA
Phone +1 (202) 256-1576 > E-mail tom.revesz@ametek.com

www.emtest.com
The EMCO 6640 has 50 kHz bandwidth and 60 dep’t wideband sensitivity. An EMI receiver connected to its analog output can tune in narrowband signals down to 13 dBpT (13 dBpT + 10 * log (50 kHz) = 60 dBpT).

An EMCO 6640 or similar device can measure the field from a test sample and its interconnecting cables by specifying a distance and configuration of the test set-up and sensor. In fact, this has been done in the 1967 vintage RE04 MIL-STD-461 requirement and MIL-STD-462 test method.

Such a control may be valuable for an equipment housing, but since such fields fall off with the cube of distance (at distances where the equipment dimensions are small relative to the separation distance), it is most likely cables will be the culprits. Also, an optimally designed platform will separate magnetic sensors from localized magnetic hotspots, but it may be more difficult to separate sensors from any and all cables. Finally, magnetic emissions from cables fall off directly with distance (or in the case of cables above a conductive ground plane, as the square of distance) so that cable CMCE, although nowhere near as “hot” as a motor or transformer, may appear so at a distance.

In order to derive a CMCE limit from a magnetic flux density limit such as 13 dBpT, it is helpful to convert from units of flux density to magnetic field, assuming free space permeability.

The basic relation \( B = \frac{\mu H}{2\pi} \) converts to dBpT = dBuA/m + 2 dB uH/m in log-space. Hence, 13 dBpT is 11 dBuA/m.

If a cable far from ground carries a current “I” causing a circulating magnetic field “H”, that relationship is the familiar \( H = \frac{I}{2\pi r} \).

Assuming a separation of one meter between cable and sensor and converting to log-space, an H-field of 11 dBuA/m implies a common mode current on the cable of 27 dBuA. However, the more common situation is that the cable is near a conductive ground plane, and if the height above ground “s” is small relative to the observation distance “r”, then the relationship between the common mode current and resultant circulating magnetic field is \( H = \frac{I (2s)}{2\pi r^2} \).

For a typical case where “s” is 5 cm and “r” is 1 meter, the above equation introduces a 20 dB relaxation in the allowable cm current, which is then 47 dBuA rather than 27 dBuA.

The ground plane is our friend! Compare this computed value of 47 dBuA with the Figure 2 CMCE low frequency plateau limit in the two standards cited in the Introduction.

The previous derivation does not prove that the low frequency CMCE limits shown in Figure 2 are derived from

---

**Figure 2:** Existing spacecraft CMCE limits.

**Figure 3:** Transfer impedances of typical EMI current probes employed in the CE01/101 frequency range.

**Figure 4:** Degraded noise floor of HP 8566B spectrum analyzer below 100 Hz: about 33 dBuV at 30 Hz.
Low-level, Audio Frequency Conducted Emission Measurements

magnetic cleanliness requirements; the actual origin of the GEVS limit is shrouded in the mists of time. The derivation only goes to show that such a CMCE limit can be very useful in controlling magnetic cleanliness. The SMC limit is a GEVS derivative: it has no separate lineage. It differs from the GEVS limit in that it applies to the total CMCE from a unit, as opposed to just the power interface or individual cables. The SMC limit is measured by lifting the unit off ground, reattaching it via a wire, and measuring the CMCE through that wire, or alternatively by clamping a current probe around all the cables emanating from the unit.

As this is written (late 2011), the existing GEVS CMCE requirement applies only to power lines. However, a revision currently in process will extend applicability to all cables. The new revision will also relegate the requirement below 150 kHz to those platforms with a specific need for magnetic cleanliness, with the generally applicable limit above 150 kHz being based on crosstalk control. The 30 Hz to 50 MHz SMC limit applies to all platforms and all cables, with possible extensions to both lower and higher frequencies on a platform-dependent basis.

Finally, before moving on to CMCE test methods, it should be noted that another common form of such control is through design requirements mandating balanced above-ground circuits, or single-ended circuits, with dc isolation between signal returns and ground. This is practical at audio frequencies where uncontrolled parasitics will not perturb basic circuit functions.

TEST EQUIPMENT – CURRENT PROBES

A preferred technique for making audio frequency CMCE measurements is the legacy current probe-based CE02 measurement of MIL-STD-462 (1967). However, current probes available in most EMI test facilities (Figure 3) are not efficient enough to measure accurately at a level 6 dB below 50 dBuA (the Honeywell 3892 being a possible candidate, but are long obsolescent and only available if the test facility already owns one). To assess how efficient a transducer must be, the noise floor of the EMI receiver or spectrum analyzer must be known. Published specifications for the Rohde & Schwarz EMI receivers and spectrum analyzers show a noise floor at 30 Hz above 20 dBuV. Obsolescent machines such as the HP 8566, designed to be used above 100 Hz but often “pushed” down to 30 Hz with resultant degraded noise floor, show even higher noise levels at 30 Hz (Figure 4). If the goal is to accurately measure a 30 Hz signal at 50 dBuA with a noise floor at 20 dBuV, the current probe transfer impedance cannot be less than -24 dB Ohm. None of the current probe transfer impedances in Figure 3 are adequate for that task.

Traditional EMI test current probes are based on ferrite cores. Cores constructed of other available materials, similar to laminated transformer cores, have better low frequency response. Transfer impedances of three such commercially available low frequency probes are shown in Figure 5.

Comparison of Figures 3 and 5 reveals that the least efficient Pearson probe is about 20 dB more efficient than any of the Figure 4 probes except the obsolescent and very scarce Honeywell probe. Additionally, all the Pearson probes are more efficient than the Honeywell model below 60 Hz.

A current probe inserts impedance into the line around which it is clamped. Generally, the inserted impedance is the transfer impedance divided by the turns ratio. For the special case when a resistor shunts the probe output, the inserted impedance is the shunt resistance divided by the square of the turns ratio. For the three Pearson probes discussed herein, the inserted impedances are negligible:

<table>
<thead>
<tr>
<th>Model</th>
<th>$Z_0$, Ω</th>
<th>Inserted Impedance*, mΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>3525</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>4688</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>5101</td>
<td>0.5</td>
<td>5</td>
</tr>
</tbody>
</table>

* Source: Pearson Electronics

Tri-Mag, Inc. can build standard and custom design EMI filters for any industry

- Medical, Military & Industrial
- EMI Filters
  - Single Phase Filters
  - Three Phase Filters
  - Power Entry Modules
  - IEC Inlet Filters

Military Medical Industrial

In addition to our wide range of standard products and our capabilities of building custom products to fit any application, all of Tri-Mag, Inc. Filters are built in the USA.

ROHS Compliance

1601 N. Clancy Ct., Visalia, CA 93291
Phone: (559) 651-2222 Fax (559) 651-0188
www.tri-mag.com sales@tri-mag.com
EMC

TEST EQUIPMENT – CURRENT PROBE ALTERNATIVE

For measurements on power lines or between a unit case and ground, the transformer method pioneered by the Solar Electronics Company can be adapted to provide even more efficient low-level, low frequency measurements. If measurements on individual cable bundles are necessary, an efficient current probe such as those discussed previously, is necessary. Regardless, the transformer method may still be helpful under certain conditions.

The transformer method is based on Solar Application Note AN62201, which has been around long enough that it was adopted by the United States Army and included in the 1971 Notice 3 to MIL-STD-462 (the “pink notice”). The application note, found in any edition of the Solar Electronics Catalog relies on the fact that a current probe is a type of transformer; therefore, a different kind of transformer may be substituted. The connection into the circuit, shown in Figure 6, is the same as for MIL-STD-461 CS01 or CS101. But instead of driving the Model 6220-1 coupling transformer with a power amplifier, the transformer’s primary side is connected to an EMI receiver or spectrum analyzer. A loading resistor shunts the primary side to reflect a resistance into the secondary. The resulting transfer impedance has a flat asymptotic plateau at frequencies where the transformer’s reactance is higher than the shunt resistance.

The principle of operation is that the secondary, unloaded on the primary side,
has about 1.2 mH inductance. The reactance of that inductance, shunted by different resistors, yields a family of curves as shown in Figure 7. Because of the Model 6220-1 turns ratio of 2:1 primary to secondary, the transfer impedance plateaus in Figure 7 are equal to one-half the shunt resistor value in the circuit of Figure 6. [3] Given the 1.2 milliohm secondary inductance, the highest transfer impedance available at 30 Hz is about -13 dB Ohm. That value is obtained with no load, which is inadvisable since that would insert the entire 1.2 mH inductance into the power-line impedance. That is known to cause switched mode power supply instability. [4] The problem can be avoided using a 1 Ohm shunt, reflecting 0.25 Ohm into the power-line. Transfer impedance degrades 1 dB to -14 dB Ohm, which is the maximum practical transfer impedance available with this technique. This is 8 - 12 dB better than the various Pearson probes achieve.

If even better low frequency sensitivity is needed, say if the custodians of SMC-S-008 extend their CMCE limit below 30 Hz, an ordinary 50 or 60 Hz power transformer can be of assistance. A 60 Hz 120 V transformer primary stepping down to 25.2 volts and 2 amp load current yielded the transfer impedance shown in Figure 8, when the primary was loaded by 10 Ohms and the secondary was used to carry the current. A large increase in sensitivity is attained, acquired at the cost of inserting almost 0.5 Ohms in series with the circuit-under-test. Of course, the possibilities here are only limited by access to the power transformer of choice. It should be noted that somewhere between 1 to 10 kHz the power transformer performance deteriorated, and at 1 Hz the measured current waveform was distorted. A 50 Hz transformer could be expected to work to a slightly lower frequency, and the upper limit issue is not a problem because the 6220-1 or a current probe with adequate sensitivity is available at and above 1 kHz.
COMMON MODE MEASUREMENTS

In addition to efficient transducer factors, a key property of a current probe to be used for making pure differential or pure common mode measurements (measurements that involve multiple conductors passing through its window) is adequate rejection of the undesired mode. The Pearson probes all provide at least 80 dB of differential mode rejection when used to measure common mode current up to 10 kHz. Brand new models 4688 and 5101 measured upwards of 90 dB rejection, but EMC Compliance’s well-used Model 3525 measured just over 80 dB. The cases are identical in construction, so hard use accounts for the difference. Figure 9 is a plot of traditional CE01 limits superimposed on the CMCE limit of Figure 2. The dm rejection of the cm test method must exceed the difference between the CE01 limits and the CECM limits. The 80+ dB rejection of the Pearson probes more than suffices, except for the most relaxed GEVS CE01 limit. In the new GEVS, that limit is replaced by MIL-STD-461F CE101, with a low frequency plateau of 100 dBuA. For such a standard, the cited probes are a solution to making these sensitive cm measurements.

To achieve maximum rejection of the undesired mode with multiple wires penetrating the window, it is necessary that the wires be tightly coupled to each other and centered in the window, so that capacitive coupling between either wire and the grounded current probe case is nearly equal. This is normally achieved with a split nonconductive dowel drilled down the center to take the two wires. It must be long enough so that wires clearing it drape away from the current probe body, and its diameter is just less than the probe window.

Using a pair of Solar 6220-1s to implement the transformer method in lieu of current probes, Figure 10 transforms into Figures 11 through 13 (pages 89 and 90). An important difference between hinged current probes and transformers is that a current probe may be opened and closed and wires rearranged within it without disturbing the flow of current to the test sample. The same is not true for a transformer. However, because the primary side is isolated from the current carrying secondary, the sense in which the primaries are connected to each other can be changed without disturbing the flow of current to the test sample, which is a blessing for any device which has to “boot” and requires significant time to reach proper operation subsequent to power cycling. The only difference between Figures 12 (cm measurement) and 13 (dm measurement) is how the bnc-to-banana adapters interconnect. Connections to the secondaries, shown in Figure 10, don’t change.

For optimal rejection of the undesired mode, it is critical that the two transformers have exactly identical
transfer impedances. Of course, this criterion is unachievable in practice, and although this technique produces more efficiency than the use of a current probe, the use of a single current probe to reject the undesired mode will always be superior. Undesired mode rejection is enhanced by using shunt resistors of lower resistance than the reactance of the transformers at the desired frequency. In this investigation, each transformer was shunted by 0.47 Ohms, for a net shunt resistance of about 0.235 Ohms. That compares favorably with the reactance of 1.2 mH at 30 Hz being 0.22 Ohms. Nevertheless, the maximum undesired mode rejection was about 40 dB.

Inspection of Figure 9 reveals that 40 dB differential mode rejection is insufficient to yield accurate cm measurements, because the dm limit is much more than 40 dB above the cm limit. However, the vast majority of electronic loads do not
generate noise below the dc-dc converter frequency, and in that case the 40 dB value will be perfectly adequate. Low audio frequency conducted emissions are usually generated by rotating machinery of one kind or another, so if the test sample performs that sort of function, a current probe is a must.

There is a way around a low dm rejection ratio. This involves a modification to the cm measurement as per SMC-S-008, which requires measurement of total cm current, measured between test sample case and ground by raising the test sample case above ground and connecting it to ground with a wire, as shown in Figure 14.

The modification is to replace the current probe with the 6220-1 as per Figure 6, but instead of inserting a power wire, its secondary is inserted in series with the ground wire, effectively making the coupling transformer secondary as shunted by the primary, a series element in the ground connection (in Figure 15).

This technique measures only the common mode current driven into ground, and thus there is no need to reject the undesired mode. It is ideal for working to SMC-S-008, but it is overkill if working to GEVS or any similar requirement that controls CMCE on a per-cable basis. Nevertheless, in the case of the unit that doesn’t generate frequencies below that of its electronic switching power supply, there won’t be any significant CMCE. A total summation of nothing is still nothing.

**CONCLUSION**

For the test facility that finds itself rarely working to one of these spacecraft EMI requirements, if the requirement is to only test the power interface, or if an SMC-like total CMCE measurement is made and the test sample generates no noise at audio frequencies, the CS01 coupling transformer technique is a handy way to measure with existing assets and adequate
sensitivity. If a test facility is going to be making such measurements routinely, or if the test sample has cable connections beyond power that require individual sampling and generates significant audio frequencies, then the Pearson probes or probes with similar performance are preferable.

ACKNOWLEDGMENT

Mark Nave’s detailed review of the work contributed greatly to the overall effort and is deeply appreciated. The author would like to thank Pearson Electronics for the loan of Models 4688 and 5101 current probes in developing this article.

REFERENCES/NOTES

1. SMC-S-008, EMC Requirements For Space Equipment And Systems, 13 June 2008.


3. This can be understood by recognizing that the resistance shunting the primary reflects across the windings by the square of the turns ratio. That reflected value, multiplied by the current flowing through it is converted on the primary side by the turns ratio, so the end result is that the effective shunted value is the primary resistance divided by the turns ratio.


Ken Javor has worked in the EMC industry for thirty years. He is a consultant to government and industry, runs a pre-compliance EMI test facility, and curates the Museum of EMC Antiquities, a collection of radios and instruments that were important in the development of the discipline, as well as a library of important documentation. Mr. Javor is an industry representative to the Tri-Service Working Groups that write MIL-STD-464 and MIL-STD-461. He has published numerous papers and is the author of a handbook on EMI requirements and test methods. Mr. Javor can be contacted at ken.javor@emccompliance.com.
FIGHTING CLIMATE CHANGE MEANS MORE ELECTRONICS

Electrification clearly facilitates our progress toward a resource-efficient and climate-friendly energy system. The share of electricity in total energy demand is projected to increase drastically in all the decarbonisation scenarios of the recent European Union (EU) Energy Road Map 2050\(^1\) (Figure 1).

Wind and solar power are examples of expanding technologies for renewable power. Germany now has 25 gigawatts of installed solar power\(^2\). Electric vehicles, light emitting diode lamps and heat pumps are energy efficient electrical technologies of importance when fighting climate change. In virtually all such technologies, electrical energy is passing power electronics.

In addition to power electronics, there is also an increased use of electronics for supervision and control.

Smart Grid is More than Networks

The smart grid is a very topical issue. The term is widely used by many, especially politicians. Now the International Electrotechnical Commission (IEC) has defined the concept of smart grid\(^3\). The definition states that the smart grid is an electrical energy system that uses information technology. The smart grid is thus not only related to electrical networks, but to the entire power system. With smart grid technologies as well as power technologies for renewables and improved energy efficiency, there is an increased use of electronics.

We see growth in the use of power electronics, as well as electronics for information technologies.

One example of smart grid application is the possibility of charging electric car batteries during hours with a surplus of low cost renewable energy. When electricity price is high, electric cars may feed energy back to the electrical network. This can be achieved using a continuous transfer of electricity price information with automatic control of the power flow to and from the electric cars. The term smart grid is thus enabling a "smart" electrical system where the entire power system, with networks as well as connected equipment, is converting between electrical energy and other forms of useful energy.

Smart Grid and the Concept of EMC

The physical characteristic of smart grid technologies, with an increased incorporation of potentially sensitive electronics, naturally has implications with respect to electromagnetic compatibility (EMC). The satisfactory function of electrical and electronic equipment with respect to electromagnetic disturbances is the aim of EMC. The IEC defines\(^4\) electromagnetic compatibility as "the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment". In the European Union EMC Directive the "equipment or system" of IEC corresponds to the EU term "equipment", where equipment in turn is subdivided into apparatus and fixed installation.
Electromagnetic disturbances may be radiated or conducted and electrical/electronic equipment is potentially sensitive to any or to both of these types of disturbances. Disturbances are in turn subdivided into a number of low and high frequency phenomena, where IEC defines low frequency up to and including 9 kilohertz.

**Field Experiences with Smart Grid Technology**

Examples of lack of EMC in relation to evolving smart grid technologies have been reported in Sweden. Kilowatt-hour meters in households sending data signals through power lines have caused interference with, for example, dimmer controlled lamps and electrical appliances. There are also cases reported where electrical apparatuses in households have interfered with electronic kilowatt-hour meters with adverse errors in registration of energy. Power electronics in wind power plants have emitted disturbances interfering with transfer of kilowatt-hour meter readings as signals on power lines.

Power electronic-based photovoltaic solar and wind energy equipment may emit disturbances causing variations such as voltage fluctuations and unbalance. However, with a proper design such equipment may well improve voltage quality, for instance by reducing depth of voltage dips.

**VOLTAGE QUALITY AND EMC**

Both IEC and EU define EMC to cover electromagnetic phenomena from zero hertz. Furthermore, the IEC defines the following principal electromagnetic conducted phenomena:

Conducted low-frequency phenomena:
- harmonics, interharmonics
- signals superimposed on power lines
- voltage fluctuations
- voltage dips and interruptions

---

**Figure 1: Share of electricity in final energy demand, according to the EU Energy Road Map 2050**

Since 1952 we have provided ferrites for your signal solutions. We are committed to developing with you as technology advances and needs change for EMI Suppression, Power, and RFID Antenna Applications.

Fair-Rite places the highest value on quality, engineering, and service. Our experienced team of engineers can assist with new designs and technical support.

**Fair-Rite Products Corp.**
www.fair-rite.com

P.O. Box 288, 1 Commercial Row, Wallkill, NY 12589-0288 USA
Phone: 1-888-FAIRRITE (324-7748)/845-895-2055 • Fax: 1-888-FERRITE (337-7483)/845-895-2629
E-mail: ferrites@fair-rite.com
• voltage unbalance
• power frequency variations
• induced low-frequency voltages
• DC component in AC networks

Conducted high-frequency phenomena:
• induced voltages or currents
• unidirectional transients
• oscillatory transients

Voltage quality can be seen as an umbrella name for deviations from ideal voltage conditions at a site in a network. This is equivalent to electromagnetic disturbances of the voltage at the site. With no disturbances the voltage quality is perfect, otherwise it is not. Electromagnetic disturbances are defined as electromagnetic phenomena that may degrade the performance of equipment.

Adequate voltage quality contributes to the satisfactory function of electrical and electronic equipment in terms of electromagnetic compatibility. Electromagnetic disturbances as imperfect voltage quality at a site in a network can be regarded as electromagnetic emission from the network. According to the EMC Directive, a network is equipment.

The technical function of an electrical network is electromagnetic energy transfer with adequate voltage quality at its sites (connection points). Similarly, immunity of an electrical network can be seen as the ability to absorb disturbing emissions (such as distorted current) with adequate voltage quality while transferring energy or, in other words, with satisfactory function. For example, for low order harmonics and voltage fluctuations, network strength is relevant for network immunity.

Geomagnetically-induced current caused by space weather is another example of the relevance of electromagnetic immunity for keeping an electric grid functioning satisfactorily.

The importance of voltage quality to achieve EMC is clearly stated in a report from the Council of European Energy Regulators (CEER): “Due to the nature of electricity, voltage quality is affected by all the parties connected to the power system. When voltage quality is too poor, a...
key question is whether the disturbance (e.g. a harmonic disturbance) from a customer’s installation into the power system is too big or whether the power system (the short circuit power) at the point of connection is too weak. The aim should be to have an electromagnetic environment where electrical equipment and systems function satisfactorily without introducing intolerable electromagnetic disturbances to other equipment. This situation is referred to as electromagnetic compatibility (EMC).”

EQUIPMENT-BASED POWER SYSTEM MODEL

Power systems consist of electrical equipment. Beyond safety, the usefulness of electricity in power systems relies on the function of such equipment. Electromagnetic compatibility is about the satisfactory function of equipment with respect to electromagnetic disturbances.

According to the EMC Directive, equipment are either apparatus or a fixed installation. Apparatuses are part of the EU system for CE marking, while fixed installations are not. However, protection requirements on emission and immunity are enforced on all equipment.

Examples of fixed installations are power plants, power supply networks, wind turbine stations, industrial plants and railway infrastructures. According to the EMC Guide, the classification of fixed installations is wide and the "definition covers all installations from the smallest residential electrical installation through to national electrical and telephone networks, including all commercial and industrial installations”.

Applying the concept of fixed installations to power systems may suggest a schematic illustration like Figure 2. As indicated in the picture, various types of equipment are connected to other types of equipment. Equipment for energy conversion is normally connected to only one other type of equipment, creating a network. Equipment for conveying energy, such as networks, are normally connected to several other types of equipment including networks.

COMPATIBILITY MARGINS AND PROTECTION REQUIREMENTS

The objective of protection requirements for equipment, including fixed installations such as electrical networks and connected equipment, is the achievement of EMC.

When aiming for EMC in electrical power systems, it is reasonable to apply the same reference for voltage quality (emission) in electrical networks as for limits on immunity of connected equipment. This is schematically indicated in Figure 3, where a common compatibility level is applied.
for voltage quality as well as for immunity of connected equipment. Electromagnetic compatibility levels are defined in the IEC 61000-2 series (IEC 61000-2/4/12 for use as references for emission and immunity of equipment). For very slow voltage variations, limits are given in the standard IEC 60038. Network emission levels, which are essentially voltage quality planning levels, are defined with a margin in relation to compatibility levels, as indicated in Figure 3.

PROTECTION REQUIREMENTS FOR EQUIPMENT IN POWER SYSTEMS

In the following example, application of protection requirements on emission and immunity are illustrated for selected principal electromagnetic phenomena.

HARMONICS AND INTERHARMONICS

Origins of low order harmonics are, for example, classical line commutated diode and/or thyristors based rectifiers. Examples of equipment emitting high order harmonics are voltage source converters, such as transistors which are switched at high frequency.

Emission of low order harmonics can often be modeled as current sources, while high order harmonics normally appear as voltage sources. In between these two simplified models there is naturally a more complex reality. Resonances may increase the complexity further.

When harmonic current of low order is injected into a network, the voltage is distorted which reduces voltage quality. The level of voltage distortion is dependent on the network strength. Similarly, high frequency current harmonics may cause voltage harmonics in the network. Network strength in terms of short-circuit power or fundamental frequency short-circuit impedance is less essential for voltage quality at higher frequencies. The geographical spread of higher frequency distortion is normally relatively small.

Current harmonics may cause overheating of e.g. neutral conductors and capacitors in three-phase systems. Voltage harmonics may upset electronics, e.g. due to multiple zero crossings. Loading capability of induction machines may be reduced.

Some sources of interharmonics are frequency converters and transformers saturated during energizing.

Suggested responsibilities for equipment’s accountable parties are given in Table 1. Compatibility margins are found in IEC 61000-2/4/12. A basis for apportionment of harmonic disturbances in networks is available in IEC 61000-3-6.

Voltage Fluctuations

Voltage fluctuations may range from very slow voltage variations to rapid voltage fluctuations. Very slow voltage variations are equivalent to variations within voltage ranges, i.e. voltage deviations from nominal values. If the nominal voltage is 230 volt and the actual voltage is 240 volt, there is a voltage variation of 10 volts, which is an electromagnetic disturbance. However, a very slow variation causing an offset

<table>
<thead>
<tr>
<th>Responsible</th>
<th>Emission</th>
<th>Immunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network operator</td>
<td>Voltage quality planning levels</td>
<td>Apportioning of distortion limits (except at public low voltage), network strength at lower frequencies</td>
</tr>
<tr>
<td>Equipment connected to network (may be another network)</td>
<td>Fulfillment of emission standards (e.g. within CE marking system), as well as as well as fulfillment of network operator apportioning levels</td>
<td>Fulfilling of immunity standards (e.g. within CE marking system), as well as consideration for EMC in own equipment</td>
</tr>
</tbody>
</table>

Table 1: Responsibility for protection requirements – harmonics and interharmonics

The first thing to do when faced with an out-of-tolerance unit is to read through the calibration certificate and data to get a firm understanding of what specifically failed calibration.
of only 10 volts is, in practice, not expected to cause any interference. Limits for very slow voltage variations are given in IEC 60038 at supply terminals, i.e. the connection point between the network and connected equipment.

Suggested responsibilities for controlling voltage fluctuations within the network system are given in Table 2. Slow voltage variations in a network are depending on a number of technical issues ranging from design, maintenance and operation.

Rapid voltage fluctuations may cause flickering of lights. Source of disturbance may be electric arc furnaces that cause rapid current fluctuations.

Suggested responsibilities for equipment’s accountable parties are given in Table 2. A framework for apportioning of distortion limits is given in IEC 61000-3-7.

CONVERGENCE OF STANDARDS

A smart grid enables more renewables and more efficient use of electricity. The smart grid also is expected to boost use of electronically based equipment in the electrical power system.

To realize the smart grid, the following issues are important to consider:

1. EMC is essential for a robust smart grid, both with respect to radiated and to conducted disturbances.

2. Power quality is a means to achieve EMC between the smart grid and connected equipment.

3. Electrical networks, including smart grids, are equipment.

4. Protection requirements, such as those for emission and immunity, also are valid for electrical networks.

5. Protection requirements for networks and connected equipment should be economically and fairly balanced.

6. A complete set of standards for EMC in power systems, including power quality, is needed from the standardization community.

7. Seeing EMC as a technical issue, where cost optimization is to a large extent governed by the standardisation community, regulatory frameworks should be designed without links to market mechanisms, i.e. similar to the handling of electrical safety.

CHANGING FOCUS IN LOW FREQUENCY EMC OVER TIME

Over the years, focus has shifted between various electromagnetic phenomena. During 1980s, low-order harmonics were high on the agenda due to the introduction of thyristor and diode based current stiff line commutated power electronics. Similarly, voltage fluctuations causing flickering lights were of great concern where arc furnaces were the main source of disturbances. In the 1990s, the use of variable speed drives for induction motors was introduced.
on a large scale. Voltage dips were causing interruptions in industrial processes due to inadequate immunity for those drive systems.

Presently, there is an increased awareness of electromagnetic disturbances in the frequency range 2 to 150 kilohertz. This is due to switched converter technologies used over time in an increasing number of apparatuses, from energy efficient luminaries to charging units for electrical vehicles. Due to connection of wind and solar power at the end of weak feeders, the occurrence of temporary overvoltages is a disturbance of increased concern. Regardless of the phenomena, it is clear that a appropriate division of responsibilities for networks and connected equipment is paramount.

NOTES


17. Electromagnetic Compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of disturbing installations to MV, HV and EHV power systems, IEC/TR 61000-3-6, Ed. 2.0, February 2008.

Dr. Magnus Olofsson is an IEEE Senior Member and chairman of the Technical Committee TC 7 (Low Frequency EMC) of the IEEE EMC Society. He is president of Elforsk, which is the Swedish Electrical Utilities’ R & D Company.
Dedicated to Delivering
News, Articles, and Ideas on EMC, Product Safety, Designing for Compliance and Regulatory Updates.

Print editions every month!
Digital editions monthly and archives online!

InCompliancemag.com for compliance information 24/7!
The World In Compliance and e-Product Showcase e-Newsletters!

We help you stay informed.
Sign up for free subscriptions at www.incompliancemag.com.
PC BOARD EMI

If properly done, PC board (PCB) design control techniques can be the most cost effective means of resolving EMI issues. The techniques involve:

• partitioning
• board stack-up
• use of isolating lines
• routing
• board level shields

Other techniques involving additional component costs include high frequency grounding of the board and filtering techniques. It is important to mention that if these techniques are designed in at the initial stage, there will be minimal impact to schedule and cost. Correct techniques begin with component placement. Critical circuits (i.e. clock circuits, clock driver, etc.) and functions should be grouped together, providing the shortest trace lengths between components. Engineers should consider the use of multi-layer boards, having many ground planes, designing high-speed traces (such as transmission lines), and employing proper and adequate filtering and decoupling components. In addition, designers should add placements for filtering components, but place jumpers or “zero-ohm resistors” to hold them in place and only add the real components if required to by the test. Early board prototype testing can produce useful insight into potential problem areas. Board areas with high radiation and the measuring of interconnect cable noise currents are indicators of potential system radiation sources.

Both radiated noise and conducted noise can be a problem in these systems. For conducted noise issues, the use of ferrite chokes and proper signal line layout can prevent a host of issues when considered in the design phase rather than later on.

It is a well-known fact in the EMC community that the closer you are to the source of an EMI problem, the more efficient and less expensive it is to fix. One cannot get any closer than by using a board level shield (BLS). Having stated that, it is important to mention that there is no substitute for proper circuit design and layout.

Looking at a basic formula for RF emissions:

\[ E = 1.316 \frac{AIF^2}{DS} \]

where:

- \( E \) = microvolts / meter
- \( A \) = radiating loop area in cm²
- \( I \) = current in amps
- \( F \) = frequency in MHz
- \( D \) = measurement distance in meters
- \( S \) = shielding effectiveness ratio
Technology Advancements in Board Level Shields for EMI Mitigation

Figure 1: Section through one of the perimeter via holes (Courtesy of Eur Ing Keith Armstrong C.Eng MIEE MIEEE, Cherry Clough Consultants)

Figure 2: Courtesy of Eur Ing Keith Armstrong C.Eng MIEE MIEEE, Cherry Clough Consultants
Let’s examine the formula and break it down to better understand it. First we will eliminate 1.316 as it is a constant. D is the measurement distance specified by the standard to which you are testing. D can also represent the distance from the device to an object with which it may interfere. In any case, these are factors beyond the control of the device designer. If we further examine this formula, we see that emissions (E) increase linearly with current and loop area but increases exponentially with frequency. We see that it is extremely important to keep loop area as small as possible, especially for high current and/or high frequency circuits. We have seen over many decades that the most common cause of failure is caused by excessive loop area. Whether the excessive loop areas are caused by poor layout or by the offensive signal coupling into other circuits with large loop areas, the result is the same; failure to meet your mandatory emissions requirements. Whether the excessive loop areas are caused by poor layout or by the offensive signal coupling into other circuits with large loop areas, the result is the same; failure to meet your mandatory emissions requirements. PCB layout software that does not include EMC software will generally not consider loop area. Therefore, the designer must take control and lay out high current and high frequency circuits manually to be sure to minimize loop area. Of course, if you cover the entire loop area with a shield, there is no loop area exposed and that value goes to zero. Again, keeping the loop area as small as possible allows for the smallest possible shield.

Going back to the formula we see that one term has not been addressed, S. S is for shielding. Once the designer has chosen the circuit components, which will determine the frequency and current, and has reduced the loop area to the smallest possible geometry, if the device does not meet its requirements, there is only one thing left to do. Shielding! Looking at the opening statement of the article, the closer this shielding design is to the problem, the better. Allowing for proper BLS mounting must be done at the PCB design stage. It is essentially impossible to properly mount a BLS after the board has been laid out.

Consider this; the BLS supplier only provides 5 sides of the required 6-sided Faraday cage you are attempting to build. It is up to the PCB designer to build into the PCB the sixth side, usually an imbedded ground plane. The designer must also provide properly spaced mounting pads, as well as determine if through-hole or surface mounted methods will be used. Although BLS parts are needed to manage EMI requirements for both immunity (for product performance) and regulatory needs (FCC, EU etc.), the board shield design is usually not the only factor in EMI performance. As mentioned, the sixth side of the Faraday cage is the PCB ground plane, and the PCB design itself has much influence on overall EMI performance.

Remember that these same basic design principles hold true for susceptibility. Therefore, BLS works equally well for emissions and/or susceptibility.

Board level shields are generally categorized into four basic types:
1. one-piece
2. two-piece
3. drawn
4. one-piece with removable sections

A one-piece BLS is typically a stamped and formed sheet metal can, often produced on high-speed presses. These are usually the least expensive for high-volume production. A two-piece BLS is also stamped, with individual fences and covers. The two-piece BLS can be provided assembled, or as individual components. These are often used where access to PCB components is necessary for inspection, testing or rework. One-piece with removable sections is a one-piece BLS with removable areas that are scored for easy removal and access to components for adjustment or repair. A separate replacement cover is required. A drawn BLS is a one-piece BLS that uses drawn stamping technology to produce a BLS with no slits or apertures at the corners.

**BLS FLATNESS**

As more fine pitch components are utilized on a PCB, thinner solder paste thicknesses are required to prevent shorts or bridges. This has translated into better flatness requirements for SMT board level shields. Current flatness requirements are typically 0.10mm to 0.05mm. Drawn shields and rigid corner technology (US Patent 7,488,902 B2 Figure 3) can improve flatness capabilities by acting as a stiffener for the whole shield. Additionally, where acceptable, through hole features can be utilized to ensure a good mate exists between the BLS and PCB during assembly and reflow. Existing products and solutions are eye-of-needle pins and other compliant pins (Figure 4).

A newly available product is the through-hole lock pin (Figure 5), which allows for precise and repeatable fixturing of the BLS (frame or single piece) to the PCB for the subsequent reflow operation (conformal to the PCB).

**POST REFLOW INSPECTION/TESTING**

In the PCB manufacturing process, there are often post reflow inspection or testing requirements that need as much open access to the PCB components as possible. For SMT BLS frames, the pickup bridge can be in the way of this inspection or testing requirement and must be removed. Post installation/reflow access to PCB components under the BLS pickup bridge is a common requirement. Manual removal of the pickup bridge by cutting or bending has been a necessary, labor-intensive step. A new product feature is the ReMovl pickup bridge (Figure 6). It is a pre-cut bridge for easy toolless removal or automated removal (Figure 7).

**PRODUCT REWORK**

For some applications, it is important to have the capability to rework areas on the PCB covered by the BLS. This may be part of the initial manufacturing process or later work in the field. Single piece BLS with simple rework capability is required. One solution is the EZ Peel BLS with scored lid (Figure 8, page 104). However, separate replacement covers are required, and this can lead to inconsistent performance on removal and replacement of the scored section.
An alternative to this solution is the ReCovr BLS, a good alternative to the EZ Peel solution since it can reuse the original cover (Figures 9 and 10). It has the advantages of a two-piece BLS at a cost comparable to a one-piece BLS. Recent enhancements to the latching features of this design improve the cover retention force both as delivered, and after removal and replacement. This feature allows for applications where shock and vibration may be encountered.

**LONG-TERM PERFORMANCE AND RELIABILITY**

While many BLS applications have short product lifecycles, there are also many longer-term applications in automotive, industrial automation and military programs which require sustained performance over many years. In these cases, both corrosion concerns and tin whiskering must be considered in the base material and plating choices.

**MULTI-FUNCTIONAL BLS**

As relative PCB space continues to shrink and power/heat generation per unit area grows, more multi-functional BLS and thermal products will be needed. One potential solution exists with BLS and integrated thermal pads. If the frame assembly to PCB includes a pickup bridge for automated placement, this bridge needs to be removed to allow for contact of thermal interface material to the PCB component. The Removl pickup bridge is an ideal option for this application. The Removl pickup bridge facilitates the manufacturing process by simplifying the removal of the pickup bridge.

**CUSTOMER REQUIREMENTS/INDUSTRY DRIVERS**

Today, based on current customer application needs for BLS products, there are even more choices and product features available. These technology innovations were driven by the application needs across multiple...
Technology Advancements in Board Level Shields for EMI Mitigation

industries. These additional design choices are summarized in Figure 11.

**CONCLUSION**

As you now see, board level shields are not just five-sided metal boxes anymore. Today’s advanced BLS designs provide solutions for many manufacturing, performance and rework requirements. Understanding all the options and utilizing the BLS design selection guide can help lead you to the most efficient and cost effective solution. In addition to the guide, remember that a trained field application engineer may still be the best choice for proper BLS design and feature selection.

Gary Fenical, EMC Technical Support Engineer and NARTE Certified EMC Engineer, has been with Laird Technologies for 29 years. He is a specialist in RF shielded enclosures and has been responsible for the design and/or measurement and quality control of hundreds of large-scale shielded enclosures, as well as a number of shielded equipment cabinets and housings. He was instrumental in the design and construction of Laird Technologies’ state-of-the-art World Compliance Centers and has authored many articles on EMC requirements for medical devices, mutual recognition agreements and guidelines to meet the essential requirements if the EU EMC Directive. He has also authored several seminars, presented worldwide, on the EU EMC Directive, international compliance, and designing for EMC and EMC requirements for medical devices. He holds the patent for the invention of heat-treated beryllium-copper knitted wire mesh gasket. Other patents are pending.

Paul Crotty, Director of Engineering and Product Development for EMI Metals, has been with Laird Technologies for 15 years. He holds a B.S. in Mechanical Engineering from Rensselaer Polytechnic Institute and has previously served as an officer in the U.S Navy. Within Laird Technologies, he has held various roles in tooling, engineering, and product design and has been instrumental in establishing the global resources for Laird Technologies EMI Metals capabilities. He holds several patents related to board level shield products with additional patents pending.
The Evolution of EMC Testing for Electrified Powertrains in Automotive Vehicles

A Brief History of Automotive EMC Testing and Standards Development

BY ROB KADO, JIM MUCCIOLI, DALE SANDERS AND TERRY NORTH

From the time when automotive vehicles were essentially mechanical with spark ignition the only electrical system, through the many decades that brought the development of electrical, electronic and computer controlled automotive systems, the need for and methods of automotive testing have evolved along with the vehicles. At one time, electrical testing was sufficient. But with the dawn of the digital computer era, compatibility became a major issue. Those pesky clocked systems are inherently noise producers and are also subject to immunity issues. During the 70’s, industry experience included the development of advanced fuel management systems, then in progress to meet new exhaust emission standards, but the technology at the time was limited to analog controls. By the 80’s, however, the digital revolution was well underway, bringing digitally controlled fuel injection systems and many other applications that pushed the envelope of EMC concerns. The automotive official equipment manufactures (OEM) recognized this challenge and began to develop EMC testing and evaluation capability. Initially, there were no applicable standards tailored for vehicle EMC, so the OEMs developed internal procedures that eventually became published as EMC requirements for both vehicle and component validation. Vehicles present a particularly challenging EMC immunity profile as they are numerous and versatile, being able to reach radio frequency (RF) exposure locations not accessible to most other products. Where most consumer electronics may be exposed to RF fields of a few volts per meter, vehicles face much greater threats and must be validated accordingly. Over the years, automotive OEMs have made extensive use of road trips to RF transmitter and other high RF field sites to map the vehicle EMC environment, and have adapted their requirements and test methods to effectively protect vehicle electronics from these environmental threats.

One key example to illustrate this point is the introduction of vehicle passive restraint systems in the 80’s. At that time, not all automotive OEMs had full vehicle EMC test facilities, however, they were aware of the potential immunity risks that electro-explosive systems presented and were fully committed to an exhaustive evaluation for EMC at both the component and vehicle levels. In past experience, in order to adequately validate this new technology, the standard component test methodologies were implemented and several new ones were developed in order to provide a greater diagnostic capability to predict system performance before the system was fully integrated. To evaluate the vehicle immunity profile, use was made of the military facilities at White Sands Missile Range, NM, which had the capability of generating high-level RF fields over the electromagnetic spectrum from long wave to microwave. On the test vehicles, the electro-explosive devices that trigger the passive restraint system deployment were instrumented with state-of-the-art monitoring capability so the amount of coupled RF current at each test frequency could be monitored. Due to this exhaustive evaluation and the experience gained, it was possible to establish good correlation between vehicle test validation methods and corresponding component validation.
The Evolution of EMC Testing for Electrified Powertrains in Automotive Vehicles

procedures. This thorough analysis and evaluation led to a successful launch of this new technology without the adverse reactions that might have otherwise occurred. The EMC test methodologies that were put in place by vehicle OEMs became the basis for future EMC standards. Over the years, the automotive OEMs have worked with SAE, ISO, CISPR and IEC to develop workable EMC standards that reflect the real world EMC environment and the need to provide vehicles that can operate reliably in this environment. These cooperative efforts are ongoing.

VEHICLE EMC TESTING

An important element in the design and development of today’s complex vehicles is assuring the compatibility of the electrical system and its numerous subsystems with itself and the environment in which it is used. To assure electrical system compatibility, we must understand and control the (RF) emission and immunity characteristics of all components and systems in the vehicle. This also includes fully characterizing these systems with regard to their immunity to electrostatic discharge (ESD) and other transient voltages. Furthermore, inductive components, such as motors and solenoids, must be evaluated to determine their potential to generate transient voltages within the vehicle’s electrical system.

Vehicle EMC testing can be broken down to three major categories: immunity, emissions, and ESD/transients. In the following sections, we will describe in more detail how each is tested and the types of facilities required.

RF Immunity

In the presence of high electromagnetic fields created by radio transmitters (whether portable, mounted on the vehicle or roadside installations), the electronic subsystems on the vehicle could malfunction, cease to function temporarily, or experience a catastrophic failure. Furthermore, as electronics in general increase in complexity and the threat of interference increases, today we have much more spectral content generated with respect to cell phone use, radio/television broadcast, aftermarket electronics and the standard electrical content of vehicles. Testing for RF immunity not only covers external sources or devices, but also the actual in-vehicle electronics interfering with each other.

The general frequency range covered for immunity is 10 kHz – 4 GHz, with the capability of testing to 18 GHz when known threats exist. Along with this, the capability exists to generate the various types of modulation to simulate modulation used by standard real-world devices.

For the lower frequency range of 10 kHz – 30 MHz, a transverse electromagnetic mode (TEM) cell (Figure 1) or transmission line system (TLS) is typically used. In both cases, the field is created from an overhead structure and kept uniform/homogenous around the vehicle while various functions are monitored using shielded video cameras, wheel speed sensors and fiber optics for vehicle bus traffic and diagnostics. Both test methodologies are similar in that power is created using an RF amplifier (usually 10kW power) through a transmission line acting as an antenna radiating an RF field up to 200 V/m, depending on the specification. For the vehicle in the TEM cell shown in Figure 1, the metal plate above the vehicle is the septum or radiating antenna. A RF absorber is placed in specific locations in the TEM cell to help mitigate high voltage standing wave ratio (VSWR) situations.

For the mid to upper frequency range of 30 MHz – 800 MHz, an anechoic chamber is used. The vehicle and, in some cases, the antennae are on turntables as multiple sides of the vehicle must be tested based on harness routing and module location.

Figure 1: A vehicle positioned in a vehicle TEM cell
As with all immunity testing, monitoring such as cameras and fiber optics are used that are not affected by the RF being applied. Figure 2 shows a typical anechoic chamber with a vehicle on the turntable; note also that various antennae can be used to apply the fields. For these frequency ranges, depending on the equipment used, 1kW to 10kW is required to generate fields up to 200 V/m.

For the high frequency range of 800 MHz – 18 GHz, an anechoic or reverberation chamber is used. The advantage of a reverb chamber is that a single sweep is performed and testing is done; often with an anechoic chamber the testing takes much longer as the high frequency causes a very narrow beam width. The narrow beam width requires multiple positions of testing to cover the entire vehicle and ensure all areas are exposed to the RF field. In a reverb chamber, the field is generated and stirred with paddles to provide full exposure to the field surrounding the entire vehicle in a single sweep. Figures 3 and 4 show a typical reverb chamber with a vehicle and a closer shot of the paddles used for stirring the field. Another advantage of a reverb chamber is that much less power is required to create high field strengths of 200 V/m.

Another type of vehicle RF immunity testing is the testing of on-board transmitters. This test simulates the effect of radios being installed and used in a vehicle such as CBs, ham radios and more common devices such as cell phones or walkie-talkies. The testing consists of outfitting a vehicle with the various antennae both internal and external to the vehicle (e.g. roof top or bumper installation) and broadcasting at the various frequency and power levels while monitoring for disruption of normal vehicle operation. Figure 5 shows an example of antennae placement for on-board transmitter testing in a vehicle.

**RF Emissions**

The second major part of EMC testing is emissions; measuring the amount of noise a component and its wiring/apparatus puts out while in normal operation. This testing reveals potential interference, not only with other on-board electronics, but also with adjacent vehicles and other electronics/installations in the real world.

To protect for on-board receivers and other electronics, testing is performed per CISPR 25. The vehicle is tested in an anechoic chamber and the on-board antennae of the vehicle are used to measure their applicable fields; for other frequency bands, magnetic mount antennae are placed in the standard installation locations and used for measurement. Figure 6 shows an example of a vehicle in such an anechoic chamber.

To protect for off-board receivers and installations, testing is performed per CISPR 12; the main difference is the antennae used are set at a 3 or 10m distance from the vehicle. This testing is also performed either in an anechoic chamber or open area test site (OATS).

To further validate these results; especially for AM/FM radio bands, radio noise evaluation testing is performed. During this testing, levels of injected power at the various frequencies are broadcast while the different subsystems are operated to evaluate reception.

In addition to RF emissions and as a result of new electrified powertrain vehicles, magnetic field emissions testing is also required. This testing is performed using special magnetic field probes and tested per International Commission on Non-ionizing Radiation Protection (ICNIRP) to limit human exposure to...
The Evolution of EMC Testing for Electrified Powertrains in Automotive Vehicles

such fields. The testing is performed in various locations, mainly throughout the interior of the vehicle where a human being would be. Figure 7 shows an example of a probe measuring magnetic fields in the engine compartment of a vehicle.

**Other Types of Vehicle EMC Testing**

There are other various types of EMC testing that occur on a vehicle such as (ESD), conducted transient emissions (CTE) and electrical tests. ESD is the simulation of discharge that occurs normally between a human and some part of the vehicle; this can be from entry, exit, or simply attempting to push a button or reach for the door handle. CTE is a measurement of the voltage transient that occurs when an inductive load such as a motor, solenoid or actuator is switched. Finally, various electrical tests are performed, such as load dump and reverse battery, to simulate these potential events.

As can be seen, vehicle EMC testing is very in-depth and costly. The photos provided here are from the Chrysler EMC Facility which is valued at over 30 Million USD. With electrified powertrain emerging as a new technology in vehicles, the challenges for EMC increase. With such vehicles, new considerations such as testing while the vehicle is plugged into its charger, regenerative braking and, finally, operation cycles on a charged battery versus test time (some test runs can take in excess of five hours) are part of the validation process. The specifications are evolving as well;
Figure 8 shows a set-up diagram for an electric vehicle to be tested while charging. As the specifications continue to be established and evolve to meet changing product requirements, the industry will adapt and evolve as well, as it always has in the past.

AUTOMOTIVE COMPONENT/MODULE TESTING

Similar to vehicle EMC testing, automotive component testing is categorically broken down into three types: emissions, immunity and ESD/transients. EMC requirements and test set-ups for automotive components are established by International Standards and OEM specifications that have been derived directly from vehicle testing and real-world experiences/measurements. Components that undergo EMC testing to established OEM component requirements provide a high confidence level of EMC (emissions, immunity and ESD/transients) performance when integrated into a vehicle or into a vehicle system. This is a significant distinction from other industries for several reasons:

1. All electronic products sold in the United States are required by law to be compliant to FCC Part 15. However, FCC Part 15 only addresses RF emission levels of an electronic product. Automotive OEMs at both the vehicle and component level require immunity and ESD/transient testing, as well as emissions. It should also be noted that automotive OEM emissions levels are much more severe than FCC requirements.

2. Vehicle operating environments, thus their requirements, are generally much harsher for automotive components than other electronic products sold in other industries. For example, vehicles are expected to operate safely in a wide range of operating temperatures and different weather conditions, as well as under exposure to varying sources of electromagnetic fields (natural and manmade), all of which impact electric components and design.

3. Automotive component EMC tests, conditions, set-ups and facilities have been developed specifically for correlation to vehicle environments. Compliance to automotive OEM component EMC requirements is considered as a pre-qualification. Components must also comply with vehicle EMC requirements when installed in a vehicle. As such, automotive components are given a functional and operational impact assignment as part of the pass/fail test criteria. This assessment is similar to what other safety critical industries are starting to adopt using International Standards such as ISO 26262. See Reference 1.

THE AUTOMOTIVE EMC DESIGN, REQUIREMENTS, VERIFICATION, AND VALIDATION PROCESS

The history and emphasis the automotive industry places on EMC (emissions, immunity, ESD/transients), from vehicle to individual components, requires a comprehensive process which comprises a collaboration of OEM and tier suppliers, as well as multiple engineering disciplines. To manage the EMC design, requirements, verification and validation process, a system engineering approach is typically used.
THE SYSTEMS ENGINEERING PROCESS AS APPLIED TO AUTOMOTIVE EMC

See References 2, 3, 4, 5 and 6.

The EMC systems engineering methodology integrates all requirements and objectives; additionally it facilitates the identification and specification of unknown or hidden requirements leaving behind a traceable, repeatable, documented path of engineering effort and decisions. Below is a high-level description of this approach that is used in the automotive industry.

The EMC system engineering process starts with OEMs and tier suppliers defining the following concepts for components, system architecture and vehicle integration:

- **System** – a set of components acting together to achieve a set of common objectives via the accomplishment of a set of tasks.

- **System behavior** – a sequence of functions or tasks, with inputs and outputs, which must be performed to achieve a specific objective.

- **Requirements** – mandates that something must be accomplished, transformed, produced or provided. The attributes of a good requirement are that it is unambiguous, understandable, traceable, correct, concise, unique and verifiable.

- **Traceability** – in reference to requirements; a requirement is said to be traceable if one can identify its source. The source may be a higher-level requirement or a source document defining its existence. An example would be if a component-level requirement (weight, reliability) is traceable back to a vehicle-level requirement.

- **Operational concept** – an operational concept is a shared vision from the perspective of the users and development participants of how the system will be developed, produced, deployed, trained, operated, maintained, refined and retired to meet the operational needs and objectives.

It is recommended that a background study based on the following questions should be considered in preparation for the systems engineering process:

**System requirements**

- Has the need for the system or product been established and justified?
- Has the overall system technical design approach been justified through a feasibility analysis?
- Has the mission for the system been defined through scenarios or profiles?
- Have all basis system performance parameters been defined (technical performance measures)?
- Has the system or product lifecycle been defined (design, development, test and evaluation, production and/or construction, distribution, operational use, sustaining support, retirement and disposal)?
- Has the planned operational deployment and distribution been defined (customer requirements, quantity, distribution schedule)?
- Has the operational environment been defined in terms of temperature extremes, humidity, vibration and shock, storage, transportation, and handling? A dynamic scenario is desired.

**System trade-off studies**

- Have trade-off evaluations and analyses been accomplished to support major design decisions?
- Have all feasible alternatives been considered in trade-off studies?
- Have such analyses been accomplished with lifecycle considerations in mind (decisions based on lifecycle impacts)?
- Have system trade-off studies been adequately documented?

Once the above concepts have been defined and the background study performed, the six-step design process is applied as illustrated in Figures 9, 10, 11 and 12.

**Step 1 - Bound the system for EMC**

- Identify all external items.
- Establish interactions.
- Create system context diagram.

**Step 2 - Identify the source of requirements**

- Collect requirements.
- Sort requirements by classification.

**Step 3 - Discover and understand requirements**

- Discover system-, subsystem- and component-level requirements.
- Brainstorm scenarios.
- Benchmark competition.
- Use behavior models to:
  - discover “hidden” interface requirements.
  - resolve conflicts between models and scenarios.

**Step 4 - Create alternatives**

- List performance and operational objectives.
- Prioritize requirements with weighting factors.
• Synthesize physical architecture to support each alternative.
• Perform trade-off between candidate architectural solutions that satisfy the requirements.
• Collect the results in a derived set of requirements based on the chosen solution.

Step 5 - Select the best solution

• Compare the various alternatives, rank them and select the best approach.
• Evaluate candidate architectures using measures of effectiveness.

Step 6 - Validate best solution

• Compare proposed systems implementation.
• Select the best solution.

• Define validation plan

• Link to design requirements at each level (vehicle, system, component)

• Verify all requirements. (mandatory)

• Plan for verification starting early and continuously at the system level.

• Requirements Trace requirements forward to verification and link verification back to the requirements at all levels.

• Verification methods are:
  - inspection
System engineering process summary

- The EMC systems engineering process methodology integrates all requirements and objectives, and facilitates the identification and specification of unknown or hidden requirements.
- The systems engineering process leaves behind a traceable, repeatable, documented path of engineering effort and decisions.

THE IMPORTANCE OF EMC TEST PLANS AS GOVERNING DOCUMENTATION

See References 2, 3, 4, 5 and 6.

As automotive engineers work through the six-step design process, many documents are generated. For EMC, the most important document is the EMC test plan. Most OEM in North America provide a template to follow when generating this document. When properly completed, the EMC test plan provides a traceable link of not just the EMC tests performed and test parameters, but also documentation of the operating modes/states, justification of performance criteria, component uses in vehicles and systems, a component’s mechanical and electrical interfaces, as well as any deviations and assumptions required for individual test circumstances.

Elements of a good EMC test plan to consider for any device-under-test (DUT) (component or vehicle) should describe or answer the following information:

1. DUT part number and revision
2. DUT subassemblies such as PCB, hardware and software revision

![Figure 11](image1.png)

**Figure 11: The “Big V” - validation and verification**
3. DUT manufacturing/assembly location and suppliers
4. DUT customer and production release date
5. DUT releasing/program engineer
6. DUT EMC test plan revision history
7. Applicable EMC test standards (OEM or international)
8. EMC test facility, location, contact and accreditations
9. Type of EMC test report requested: engineering development, sign-off design validation or sign-off production verification
10. OEM/customer sign-off (if applicable)
11. DUT description and intended use
   a. DUT and DUT family introduction and functional description
   b. DUT description and sample selection
   c. DUT electrical and mechanical schematics, layout and diagrams
   d. DUT software functional description of operation
   e. DUT bill-of-materials (BOM)
   f. DUT operating modes
   g. DUT electrical and mechanical inputs, outputs, power requirements, loads and monitoring requirements
   h. DUT calibration procedures
12. Required loads, harness and support equipment needed to operate DUT
13. For each individual EMC test, the following should be noted or referenced:
   a. test modes
   b. environmental conditions
   c. grounding schemes and requirements
   d. harness requirements
   e. applicable loads and monitoring equipment
   f. power supply and signals

Figure 13: ESS bench setup for CISPR25 Radiated Emissions/ISO 11452-2 radiated immunity

Figure 14: ESS (close-up) on a copper ground plane for CISPR25 radiated emissions/ISO 11452-2 radiated immunity testing
g. functional and operational requirements  
h. test deviations  
i. pass/fail criteria  
j. instructions if an anomaly is observed  
k. any DUT safety precautions or procedures

THE EMC TEST PLAN AND ELECTRIFIED POWER-TRAIN TECHNOLOGY

See References 2, 3, 4, 5 and 6.

As test standards evolve and adapt to new technologies in the automotive industry, the overall vehicle requirement remains essentially the same. For example, the emerging electrified powertrain technology has not had a substantial impact for vehicle EMC emissions, immunity and transient requirements; however, it has increased the importance of the EMC test plan for systems such as the energy storage system (ESS) which is a large part of the electrified powertrain architecture. ESSs have come to encompass several competing electric vehicle (EV) and hybrid electric vehicle (HEV) architectures. In turn, the ESS contains multiple sub-systems in addition to just battery cells.

The ESS and its sub-systems include design variables such as high-voltage DC-to-DC power converters, battery cell charging/discharging schemes, varying numbers of battery cells, shapes and technology, cooling schemes (liquid and/or air), diagnostic sensors (thermal, voltage, current, etc.), overall ESS physical shapes, sizes and weight, as well as on-board vehicle orientations.

When writing an EMC test plan for ESS, collaboration with the EMC test facility is a good idea. The size and weight of the ESS alone can cause an issue when testing. For example, an ESS can range from 8 cubic feet to more than 64 cubic feet in size and weigh 700 to 2500 or more pounds. EMC test facility chambers and ground planes need to be able to handle the weight as well as be able to safely move the ESS in and out of the chamber. Also, thought should be given to the orientations of the ESS needed for emissions and immunity testing, with consideration given to maintaining minimum clearances per the international or OEM standards used for testing. Some examples are shown in Figures 13, 14 and 15.

Another aspect the EMC test plan should clearly specify is the monitoring requirements of the ESS. It is not uncommon that input/output requirements to monitor an ESS are double or triple that of a normal automotive component and may require special software that interfaces to software running the EMC test, so when/if an observed anomaly occurs during a test cycle, the test parameters are known.

Finally, with regards to the ESS, the EMC test plan should note the high-voltage (HV) power requirements, charging procedure and safety operation procedure for working with the HV. The goal of the EMC test plan is to provide for safe operation, reduced test down-time and a traceable document for future testing and product development.

SUMMARY

The authors have presented a brief history of the development of methodologies by automotive OEM to effectively validate new technologies and the cooperative role OEM have played in the generation of new EMC standards, including an overview of vehicle and component EMC testing. The advantage of the system engineering process in providing an organized and traceable method to meet the challenges
of validating new technologies was presented, along with a practical approach to apply this method to a particular product. The importance of EMC test plans, particularly for complicated systems and new technologies, was stressed along with some useful guidelines for developing an effective test plan. Finally, the need for an EMC test plan to meet the particular challenges of validating electrified powertrain technology was described.

REFERENCES


Rob Kado is the EMC Manager and Senior Technical Specialist for Chrysler Group LLC; his responsibilities include Component/Vehicle Validation, Research and Development, Specifications, and Operations. Rob is a member of several SAE/ISO EE/EMC Groups and, more specifically, a United States Delegate to CISPR/ISO.

James P. Muccioli is an EMC consultant and owner of Jastech EMC Consulting LLC (over 25 years). Additionally, he has worked for X2Y Attenuators, Chrysler and United Technologies. Mr. Muccioli has taught EMC undergraduate courses and professional education seminars at Lawrence Technological University, the University of Michigan-Dearborn and the University of Michigan. He is an iNARTE certified EMC, ESD and Master EMC Design Engineer, and a member of SAE J-1113, SAE J-551 and the SAE IC EMC Task Force (chairperson). Mr. Muccioli received an IEEE Fellow in 1998 for contributions to integrated circuit design practices to minimize electromagnetic interference and has also served on the IEEE EMC Society Board of Directors (1993-1998 & 2001-2003).

James P. Muccioli

Dale Sanders is an Independent EMC Consultant for Jastech EMC Consulting LLC and owner of eM Design Concepts LLC. His experience includes EMC design, analysis, and testing. Mr. Sanders serviced in the U. S. Marine Corps and holds a BSEE from the University of Michigan-Dearborn. Mr. Sanders has guest lectured on EMC topics at the University of Michigan-Dearborn and University of Detroit-Mercy, as well as developed EMC course criteria, topics, projects and lab experiments. Mr. Sanders is a senior member of the IEEE and active member in the IEEE EMC Society, NDIA, and SAE. He has authored numerous EMC technical papers and application notes on EMC test methodologies, EMC design solutions and filter products.

Dale Sanders

Terry M. North is an independent EMC consultant for Jastech EMC Consulting, LLC. His early experience includes service with the U. S. Army in RF communications and with Ford Motor Company in advanced fuel systems design. Over the more than 20 years that he was with Chrysler, he contributed to the development of a world-class, in-house automotive EMC capability and assisted in the overall advancement of the automotive industry in EMC. Mr. North was also involved in the EMC development and qualification of passive restraints systems. He was a major contributor in the development of Chrysler corporate EMC standards and served as a consultant on EMC and E/E systems issues. Mr. North is a senior member of the IEEE.

Terry M. North

Rob Kado
When calibrated test equipment is found in an out-of-tolerance condition, there is additional risk to all products on which it was used. It is important to understand the magnitude of the potential risk because it can lead to dangerous consumer situations and additional business costs.

Typically quality systems have a procedure for handling non-conforming material, however, this is non-conforming instrumentation used in a process, not material produced by a process. There is little guidance available describing how to evaluate out-of-tolerance conditions leaving engineering and quality personnel to develop their own process. When faced with an As-Found: Out-Of-Tolerance (OOT) condition, a systematic approach to identify what the out-of-tolerance values were, when, where and how the OOT unit was used, will help concentrate your efforts to identify those areas that will need further analysis.

NON-COMPLIANCE

What does out-of-tolerance mean? Calibration is a comparison of a metrology laboratory’s standard, with a known value and uncertainty, to the unknown behavior of a unit submitted for calibration. When the unit under test (UUT) does not meet the expected test limits, it is considered to be Out-of-Tolerance. The type of measurement data and calibration information provided can vary widely, depending on the type of metrology laboratory performing the calibration. For instance, at the National Metrology Institutes (NMI), such as NIST, the metrology laboratory may provide the comparison data only and not utilize any test limits and not make any statement of compliance. It is up to the instruments’ owner to perform any analysis and determine the compliance status of each individual piece of calibrated equipment. For the typical NMI customer, this process is relatively easy to handle because they are staffed with highly knowledgeable metrology professionals who are responsible for a limited quantity of lab standards. However, if this is the only information received by a manufacturing environment customer, who has significant quantities of test and measurement equipment, monitoring the behavior of each individual piece of equipment is impractical at best! Fortunately, the manufacturers of test equipment have done most of the analysis work. This is accomplished through the manufacturers’ published specifications which describe what type of behavior can be expected for the majority of the units manufactured, following a typical calibration interval. It is from the Original Equipment Manufacturers’ (OEM) published specifications that purchasing decisions are made. It is also from these published specifications that a commercial calibration provider will most likely determine the allowable tolerances, or test limits for the calibration process. Many commercial calibration providers offer a default service that uses the OEM’s published specifications; however, it is the responsibility of both the customer and the calibration lab (internal or external), to agree upon the specifications which will be used in the calibration process. A customer can request their equipment to be calibrated against any specification they provide. Once the calibration specifications have been agreed upon, the laboratory can calculate the test limits against which the laboratory results can be compared and a statement of compliance can be determined.

As-Found: Out-of-Tolerance

What to do next?

BY PHIL MISTRETTA
As-Found: Out-of-Tolerance - What to do next?

The first thing to do when faced with an out-of-tolerance unit is to read through the calibration certificate and data to get a firm understanding of what specifically failed calibration.

STATEMENT OF COMPLIANCE

Most commercial calibration customers are looking for the calibration laboratory to make a statement of compliance for the As-Found condition of the Unit Under Test (UUT). On the surface, making this determination appears rather straightforward and simple, however, upon closer examination, it becomes more complex; there are no perfect instruments and no perfect measurements. All measurements have some degree of uncertainty and how to deal with these uncertainties with respect to making a statement of compliance differs greatly. There are several different approaches which could be used when making compliance statements. Some labs will not make a statement at all; some labs will mark the data that does not meet the limits with an asterisk or some other means, but not make a compliance statement; still other labs will make a compliance statement, quantify the results with an uncertainty value and provide additional consumer risk information. In any case, it is critical for the customer to understand the decision rules used by the laboratory in making any compliance statements.

The statement As-Found: In-tolerance is generally assumed to mean that the entire instrument, all functions, parameters, ranges and test points - are within the calibration specifications at the time of calibration, for the stated conditions at the location where the calibration took place. An As-found: in-tolerance condition is a good indication the UUT was performing within expectations since the last calibration was completed. For the commercial calibration customer who has hundreds or thousands of calibrated items, the statement of compliance may be the single most important piece of information on a calibration certificate. In essence the metrology laboratory, staffed with measurement experts, has completed an initial data evaluation and concluded the unit to be performing within the agreed upon specifications so the customer does not have to spend very much additional time reviewing the calibration. Likewise an As-Found: Out-Of-Tolerance (OOT) condition indicates that at least one data point in the data report drifted or shifted beyond the allowable tolerance limits and the measurements it was providing may not have been accurate at some point since the previous calibration. Again, the laboratory measurement experts have indicated that this unit had a problem and needs further analysis by the customer. The As-Found: Out-Of-Tolerance statement of compliance is the flag or trigger for many quality or manufacturing engineering departments to start an investigation, evaluation or analysis.

THE PROCESS

The object of the OOT evaluation process is to identify the at risk products the Out-of-Tolerance units touched. The following approach is not very difficult and follows a logical thought process; however there are a few pitfalls to be aware of and to avoid. This is an investigation; I caution against having the end result already in mind. It is tempting to want the conclusion to show that there were no at risk products because of the work involved. The answers to the questions in the process will lead you to the appropriate conclusion. The approach here is to eliminate products without risk and to narrow down the pool of at risk products.

WHAT IS OUT-OF-TOLERANCE?

The first thing to do when faced with an out-of-tolerance unit is to read through the calibration certificate and data to get a firm understanding of what specifically failed calibration. A complete set of As-Found and As-Left calibration measurement data is essential for a proper out-of-tolerance evaluation. A Calibration Certificate without data is never a good idea, but when faced with an out-of-tolerance unit, the lack of measurement data will significantly impact the ability to conduct an analysis and quantify any potential risk. If the metrology laboratory provides an out-of-tolerance report that only shows the out-of-tolerance data you have something on which to conduct an evaluation, but even this limited information does not provide a complete picture. A review of all the calibration data should be done to identify what functions, parameters, ranges and test points were found out-of-tolerance. For example, let’s say a voltmeter has a full scale range of 1000 V, a resolution of 1 V, and an accuracy of ± 5 V, and the unit was found to read 1006 V at full scale (out-of-tolerance) and in-tolerance at all the other readings which were taken every 200 V. This means that during the use of the voltmeter, over its most recent calibration cycle, any measurements between 800 V and the full scale 1000 V were likely giving erroneous values to the user of the meter for the measurements taken. Again, a full set of data will be very helpful at this point in answering questions like: how many points within a range were out-of-tolerance; was the entire range out of tolerance; were all the ranges even checked; was there a linearity issue; was only the zero out-of-tolerance;
The quality of the calibration and quantity of data available can have a tremendous impact on narrowing the scope of the evaluation at this point.

or only the full scale reading out of tolerance; were other relevant test points close to or at their limits? The quality of the calibration and quantity of data available can have a tremendous impact on narrowing the scope of the evaluation at this point.

**WHEN DID IT HAPPEN?**

The next step should be to identify the *time frame* during which questionable measurements may have been taken. This objective is to identify a specific time when the instrument was last known to be taking correct measurements. Often, this is going to be the previous calibration date; the historical calibration certificate will have this date. Basically, the unit was known to be measuring correctly when it left the metrology lab through its As-Left measurement data on the most recent calibration certificate. This will provide a starting point to work from, and most likely the longest period to examine. If you are fortunate to have a well-developed measurement assurance program, you might have collected additional data during the period in question which can reduce the evaluation time frame. Most metrology laboratories follow good metrology practices (GMetP) and conduct mid-cycle checks, tests, and inter-comparisons, also called cross-checks, to determine the “health” of their measurement processes and provide confidence in the quality of the measurement process. If these checks are documented and have measurement data, you may be able to reduce the period of questionable measurements. For example, let’s say the voltmeter in a production cell was found out-of-tolerance during its annual calibration, but you have a process where a precision voltage source is used to verify the performance of the voltmeter every quarter. A review of this data may allow you to conclude the voltmeter was performing accurately 3 months ago, so the questionable period is only going to be the last 3 months instead of 12 months which significantly reduces the pool of potential at risk products. A schedule of cross-checks and inter-comparisons is often developed for critical measurements or high volume processes in order to reduce risk, liability, and evaluation time.

**WHERE IS IT USED?**

The objective at this point is to identify *where* this instrument has been used during the questionable period. This is where the really big challenges can start. Typically, this is where the last link in the chain of traceability is often broken, linking the actual calibrated instrument to the processes, products and services provided. The ease of identifying potential impacted product depends upon the design of the end users processes and systems. In a large facility test equipment can move around without tracking its location. This is especially true of handheld instruments and bench level instruments. A robustly designed system with strict instrument control procedures will be able to identify exactly where any given instrument was located for any given time frame. Nearly all companies have a system that assigns an identification number to each instrument, and some even track its assigned department or location, but few systems track the movement of equipment within the facility and even fewer log the date and use of instrumentation. The maintenance of such an instrument movement log must be strictly followed, any hole or missing location data will bring any evaluation to a halt. Imagine a facility with 50 identical instruments that move around different production cells without any control. It would be impossible to identify what measurements or products it touched and what errors went undetected. With a robust tracking system that indicates if and when this instrument moved, you should be able to identify where this instrument was at any given time.

**HOW IS IT USED?**

The last step in the out-of-tolerance information gathering process is to identify how the out-of-tolerance instrument was being used. Determine exactly what measurements were being made at a given location, during the time frame in question. This information will likely be found in the end users procedures, or the operator’s work instructions, or an engineering specification. The objective at this step is to determine whether the out-of-tolerance instrument *could* have affected any of the products manufactured or services provided by this instrument, in this time frame, in this location, for these measurements. This can be accomplished by reviewing the process documentation, and all revisions that were in effect during the time frame in question, for the out-of-tolerance measurements that were identified in the first step. Were any of the out-of-tolerance functions, parameters, ranges and test points used to make the measurements listed in the process documentation? If the answer is no, congratulations, your evaluation has ruled out the potential risk to product. Now you just have to completely document the steps you have taken, your conclusion and justification, as
any auditor will tell you, if it isn’t written, it didn’t happen, you must produce objective evidence.

ANALYZING THE IMPACT

If the process documentation indicates that measurements were taken using any of the out-of-tolerance functions or ranges, then you have to go further and quantify the severity of the impacted products or services. Now comes the most difficult part of the process, quantifying the impact on products and services. In order to effectively complete this analysis, a thorough understanding of the affected process is necessary and a working understanding of tolerances and the application of uncertainties is extremely helpful. Due to the wide variety of applications and situations possible, a few sample cases will be used to illustrate the analysis process for common situations likely to occur.

Case 1: No Impact

Let’s say the process documentation states that the voltmeter is used to measure a 600 V on a product with a process tolerance of ± 10 V. Since our process measurement was not in the out-of-tolerance portion of the meter (800 V to 1000 V), we can conclude with reasonable confidence that no product was affected.

Case 2: Impact Evaluation Using Ratios

In Case 2 we will use accuracy ratios in our analysis. An analysis by ratios can help quantify the potential impact by a rough order of magnitude, but may not be sufficient. For instance, a ratio change from 100:1 to 80:1 may be fairly insignificant, but a ratio change from 4:1 to 2:1 could have quite the impact on the end products. A ratio analysis may be a quick way to rule out potential recalls if the ratios involved are sufficiently high. However, if the ratios are low, then additional evaluation becomes necessary. This method may also be the only option available if there isn’t any historical process measurement data to review. For example in this case, the process documentation states that the voltmeter is used to measure a 1000 V on a product with a process tolerance of ± 50 V. Since our process measurement was in the out-of-tolerance portion of the meter (800 V to 1000 V), we can conclude with reasonable confidence that no product was affected.

Case 3: Impact Evaluation Using As-Found Calibration Data

In this case, the process documentation states that the voltmeter is used to measure a 1000 V on a product with a process tolerance of ± 50 V. Since our process measurement was in the out-of-tolerance portion of the meter (800 V to 1000 V), product might have been negatively impacted. We need to go a step further and compare our process tolerance to the magnitude of the out-of-tolerance data. The process tolerance in this case was ± 50 V, so our process limits are 9950 V to 1050 V. The accuracy of the meter was ± 5 V which means the meter is 10 times more accurate than our process tolerance giving us a Process Accuracy Ratio (50 V / 5 V) of 10:1. Now the calibration report stated the meter was reading 1008 V when the calibration lab injected a precision 1000 V into the meter, which basically means the meter behaved as if it had an accuracy of ± 8 V which drops our Process Accuracy Ratio (50 V / 8 V) to 6.25:1. Is the risk due to a reduced process ratio acceptable? That comes down to a business decision.

Due to the wide variety of applications and situations possible, a few sample cases will be used to illustrate the analysis process for common situations likely to occur.

As-Found: Out-of-Tolerance - What to do next?

Due to the wide variety of applications and situations possible, a few sample cases will be used to illustrate the analysis process for common situations likely to occur.
As-Found: Out-of-Tolerance - What to do next?

Case 4: Impact Evaluation Using As-Found Calibration Data and the Lab’s Uncertainty

Continuing with Case 3 information, let’s say the metrology lab reported their uncertainty for the measurement: 1008 V ± 7.1 mV. That means the value they report lies somewhere between 1007.9929 V and 1008.0071 V. This additional uncertainty will carry on down to the process tolerance calculation. So in the worst case the meter was actually delivering process limits of 9957.9929 V to 1058.0071 V, which in our case is insignificant because the resolution of the meter is not sensitive enough to see this small difference in voltage. It is interesting to note that in this situation the metrology lab had an uncertainty of ±7.1 mV for the calibration against the unit’s tolerance of ±5 V which provides a calibration Test Uncertainty Ratio of 704:1 (5 V / 7.1 mV) meaning the calibration lab standards were over 704 times more accurate than the meter being calibrated. Here is where the value of that pesky Test Uncertainty Ratio those metrology guys are always talking about comes into play. Had the metrology laboratory’s uncertainty been ±1.25 V, their reported measurement would have been 1008 V ± 1.25 V, and the TUR would have been 4:1 (5 V / 1.25 V) meaning the meter would have actually been delivering process limits of 9957.675 V to 1059.25 V, which when rounded by the resolutions of the meter become 9958 V to 1059 V. Now this additional count might not seem like a big deal, but it does increase the size of the potential recall and increase the potential risk and cost.

Again, here is where a complete calibration report with As-Found and As-Left data becomes very helpful. This is also the point where the Test Uncertainty Ratio (TUR) and the Uncertainty of the Calibration Laboratory come into play and why all calibrations should include uncertainties for every measurement. The laboratory’s uncertainty information on the measurements they provide will give you the information to further refine your evaluation and subsequent analysis. Every bit of measurement information at your disposal allows you to make additional distinctions, observations, calculations and improves the quality and confidence in your conclusions and recommendations for further actions. The cost of a single product recall will far exceed the additional cost associated with a complete calibration which includes As-Found and As-Left data with uncertainties.

As cases 2, 3, and 4 illustrate, an out-of-tolerance instrument that could affect the end product or service can lead to a tremendous amount of work because the analysis will need to be completed for each product or service identified. This could lead to hundreds or thousands of calculations! As you can imagine, any effort spent in the four steps (what, when, where, and how) in the evaluation process which eliminates additional products to be analyzed is well worth the time. When faced with an As-Found: Out-Of-Tolerance (OOT) condition, a systematic approach to identify what the out-of-tolerance values were, when, where and how the OOT unit was used, will help concentrate your efforts to identify those areas that will need further analysis. The objective is to filter out as many possible items that do not need closer analysis so you can get to the ones where detailed analysis is required in order to quantify the impact to the products or services provided.

All this evaluation and analysis is a tremendous amount of work. However, it does not have to be difficult. A well thought out electronic system linking instrumentation to processes and product traceability as part of a measurement assurance program can ease the burden of out-of-tolerance evaluations and analysis. A measurement assurance program is more than a calibration program; it is a thought process to link and relate measurements through the entire produce life cycle, from concept to end product. Hopefully this approach and general guidelines will ease the burden to solving one of the most dreaded situations in the measurement world: the evaluation of an out-of-tolerance instrument and its potential impact.

Phil Mistretta is a Metrology Manager for Transcat Inc. in Rochester, NY. He has a background in EMC/EMI compliance testing, lean manufacturing engineering and over 25 year of experience in the field of Metrology. He is member of IEEE and ASQ and is an ASQ-Certified Calibration Technician. He is a graduate of Central Texas College and pursuing a BS in Engineering Physics at the University of Buffalo New York on a part time basis.
Military EMC design can be particularly vexing. Multiple environments combined with multiple threats lead to multiple requirements. The threat levels, and the resulting requirements, are usually more stringent than found in the commercial world.

As a result, commercial design techniques are often woefully inadequate for military applications. This can lead to frustration for those moving into military EMC from other areas. It can also lead to frustration to those wishing to use COTS (commercial off the shelf) equipment in military environments.

In this article, we’ll explore some of the unique EMC challenges presented by military electronics, and how they differ from those of the commercial world.

**MULTIPLE ENVIRONMENTS WITH MULTIPLE THREATS**

Unlike commercial equipment, military systems may need to work in a wide range of environments. These can range from the arctic to the desert, and from the bottom of the ocean to outer space. Fortunately, most systems only need to operate in selected environments, rather than in every potential situation. This leads to subsets of requirements, and even tailoring in select cases.

Furthermore, military systems are often subjected to multiple threats. These threats are typically more severe than in commercial environments. Here are some examples of five general environments and their associated threats, and how they contrast with nonmilitary environments.

**Fixed Land Based** - This environment includes residential and office buildings. For commercial electronics, these are considered relatively benign in terms of EMC. As an aside, this is the primary EMC environment for most commercial electronics.

The emissions concerns are moderate, and are aimed at protecting nearby television receivers. The susceptibility concerns are a bit more challenging, and include threats such as RF (radio frequency) energy from nearby handheld radio transmitters, human ESD (electrostatic discharge), and power disturbances such as lightning or EFT (electrical fast transients.)

These same buildings on a military base, however, may pose much more severe conditions, particularly for radiated emissions and susceptibility. Both field levels and frequency ranges can be much higher than commercial environments. Due to radar systems, those frequencies can extend to 40 GHz or more,
well above the typical 1 - 5 GHz upper limits for commercial equipment. Also, many military systems are designed to include protection against EMP (electromagnetic pulse) effects from nuclear weapons, which adds another level of complexity.

As such, commercial emissions requirements may not be adequate to protect nearby military communications receivers, which can be much more sensitive than a television receiver. Commercial susceptibility requirements may also be inadequate, due to radio and radar transmitters with higher radiated field levels, and EMP. The little bit of good news is that commercial levels for ESD and power disturbances are often still adequate.

**Mobile Land Based** - These environments include cars, trucks, buses, etc. Even for commercial vehicular electronics, these can be quite harsh. The emissions concerns are severe, and usually aimed at protecting entertainment radios (AM/FM), with secondary concerns for protecting land mobile VHF/UHF radios. The susceptibility concerns are also severe, and include RF, ESD, and a range of power transients and other power disturbances unique to vehicles.

Military vehicles share these same concerns, but as with fixed systems, the frequencies and amplitudes may be well above commercial levels. Nevertheless, commercial vehicular electronics can be expected to do fairly well in military environments, but may need some additional protection for radar and EMP.

Due to their experience working with harsh environments, we’ve found that commercial vehicular EMC engineers often have a relatively easy time making the transition to military electronics.

**Marine Based** - These environments include large surface ships, submarines, and even smaller water craft. Ships with metal hulls have vastly different EMC concerns depending on whether the equipment is located above deck (outside) or below deck (inside).

For both the military and commercial environment, emissions concerns are severe and are aimed at protecting communications and navigation receivers, including radar. Susceptibility concerns are also severe, and include RF and power disturbances. Since most military ships have multiple communications and radar transmitters, the levels and frequencies can be much higher than for commercial ships.

A classic tale of military EMC at sea was the sinking of the HMS Sheffield in the Falkland Islands War in 1982. It turns out there was a compatibility problem between the satellite communications and a defensive radar system. The “solution” was to disable the radar when communicating via satellite. Unfortunately, the launch of an enemy missile went undetected during one of these radar blackouts, and the ship was lost due to an EMC problem.

One bit of good news is that ESD is usually not a big concern for marine applications, due to high humidity conditions. A notable exception is helicopter ESD, which has resulted in special requirements for both helicopters and electronics equipment (and ordnance) that might be located near a helicopter landing pad. Lightning and EMP, of course, are major concerns for all military naval vessels.

**Air based** - These environments include all aircraft, and include small aircraft, helicopters, fighters, bombers, and more. Like ships, EMC concerns vary depending on whether the electronics are located inside or outside the aircraft. An emerging concern is the use of composite material rather than aluminum, which can affect overall shielding performance.

The commercial and military EMC environments are actually quite similar. In fact, the predominant commercial avionics requirements (RTCA DO-160) are derived from the military requirements (MIL-STD-461). The commercial requirements are even a bit more comprehensive, and include very specific lightning and power quality requirements.

Additional military concerns include HIRF (high intensity RF) and EMP. The former can come from radar exposure which may be quite high in a tactical situation, or as a weapons effect. ESD is also a big concern, particularly for helicopters transporting materials or munitions.

Magnetic field emissions are a unique concern for antisubmarine warfare (ASW) aircraft. One way of locating submarines is to look for low level magnetic field perturbations. The sub hunters need to maintain clean electronic environments so they can detect the perturbations.

**Space** - This is probably the most unique and varied of military environments. There has been very little commercial space electronics, although this may be starting to change. Nevertheless, we expect to see the commercial space designers closely follow military design practices.

Due to the expense of launching hardware into space, the EMC requirements are often highly tailored. Extensive engineering efforts are made to optimize (and not over design) for EMC. Extensive testing is performed to assure EMC is achieved. After all, if something doesn’t work, it is almost impossible to fix (the Hubble telescope being one very expensive exception.)

Space electronics are subjected to several environments that must be considered. For example, during pre-launch, precau-
tions must be taken to prevent damage due to human ESD. During launch, precautions must be taken to prevent damage due to triboelectric charging and also due to high RF levels from tracking radar, etc. In a tactical situation, the RF may also include antimissile efforts. Once on-orbit, space electronics are subjected to “space charging,” and also cumulative degradation from ionizing radiation present in space.

Another unique space requirement is “magnetic cleanliness.” This is often a requirement for satellites that employ magnetometers for navigation. Even small magnetic fields, from either permanent magnetization or from power electronics, can interfere with the on orbit navigation.

MILITARY EMC REQUIREMENTS

These various environments and threats have resulted in specific EMC requirements. Although these have evolved over the years, we now have two major military EMC requirements, MIL-STD-461 and MIL-STD-464.

### TABLE IV. Emission and susceptibility requirements.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE101</td>
<td>Conducted Emissions, Power Leads, 30 Hz to 10 kHz</td>
</tr>
<tr>
<td>CE102</td>
<td>Conducted Emissions, Power Leads, 10 kHz to 10 MHz</td>
</tr>
<tr>
<td>CE106</td>
<td>Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz</td>
</tr>
<tr>
<td>CS101</td>
<td>Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz</td>
</tr>
<tr>
<td>CS103</td>
<td>Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10 GHz</td>
</tr>
<tr>
<td>CS104</td>
<td>Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz</td>
</tr>
<tr>
<td>CS105</td>
<td>Conducted Susceptibility, Antenna Port, Cross-Modulation, 30 Hz to 20 GHz</td>
</tr>
<tr>
<td>CS106</td>
<td>Conducted Susceptibility, Transients, Power Leads</td>
</tr>
<tr>
<td>CS109</td>
<td>Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz</td>
</tr>
<tr>
<td>CS114</td>
<td>Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 200 MHz</td>
</tr>
<tr>
<td>CS115</td>
<td>Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation</td>
</tr>
<tr>
<td>CS116</td>
<td>Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz</td>
</tr>
<tr>
<td>RE101</td>
<td>Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz</td>
</tr>
<tr>
<td>RE102</td>
<td>Radiated Emissions, Electric Field, 10 kHz to 18 GHz</td>
</tr>
<tr>
<td>RE103</td>
<td>Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz</td>
</tr>
<tr>
<td>RS101</td>
<td>Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz</td>
</tr>
<tr>
<td>RS103</td>
<td>Radiated Susceptibility, Electric Field, 2 MHz to 40 GHz</td>
</tr>
<tr>
<td>RS105</td>
<td>Radiated Susceptibility, Transient Electromagnetic Field</td>
</tr>
</tbody>
</table>

Source: MIL-STD-461F
MIL-STD-461 is applied at the module (box) level. The current revision level is MIL-STD-461F, and should be applied to new procurements. Existing equipment may use earlier versions, so it is important to be sure you are using the correct version when dealing with updates or legacy systems. MIL-STD-461F provides both recommended test levels and the test procedures for a number of different tests. These are divided into four broad categories:

CE - Conducted Emissions  
CS - Conducted Susceptibility  
RE - Radiated Emissions  
RS - Radiated Susceptibility

These are further subdivided into specific tests, with a three number designator, such as RE101. As an aside, older versions of MIL-STD-461 (A,B, and C) used the same nomenclature but with two number designators, such as CS06. This distinction is important, as legacy systems may still be using the older versions of MIL-STD-461 for qualification purposes. For more details, see MIL-STD-461F, Table IV.

Note that not all tests are required for all equipment. Rather, different tests and different levels are recommended for various situations. These recommendations are based on anticipated environments and threats. For more details, see MIL-STD-461F, Table V (page 126).

Note that requirements may vary among the different services for similar equipment. For example, the electric field radiated emissions (RE102) differ for Army, Air Force, and some Navy aircraft. Since Air Force and most Navy aircraft rarely use radios below the 2 MHz, they have no recommended requirements at the lower frequencies, while the Army goes down to 10 kHz.

Special cases may deserve special attention. For example, Navy aircraft used for antisubmarine warfare extend their electric field emissions (RE102) down to 10 kHz. They also include magnetic field emission requirements (RE101) that are not recommended for other Navy aircraft. The reason is that hunting for submarines often means detecting low level magnetic fields at low frequencies. In order to detect these fields, the local environment must be clean at those low frequencies.

There are two important philosophical differences between MIL-STD-461 and commercial requirements. First, MIL-STD-461 can be tailored as needed. Second, test failures can be waived. Of course, both require the customer to agree. We feel both of these options should be considered as needed, as they often yield good EMC systems engineering solutions. One caveat on MIL-STD-461. It is not a guarantee of ultimate EMC, but rather it increases the overall probability of success. You still need to plug everything together and see if it works.

MIL-STD-464, the second common EMC requirement, is applied at the systems or platform level. This document supersedes a number of older documents, and addresses grounding, bonding, lightning, EMP, HIRF, and more. Since this requirement applies to the platform level, it is often of secondary concern to the box/module designer.

Unlike MIL-STD-461, the actual test methods are not well defined in MIL-STD-464. This makes sense, as these are platform requirements, and platforms can vary widely. But as a result, these requirements can be difficult if not impossible to validate at the box level.

In spite of the system emphasis, we have seen increasing attempts by the platform designers to “flow down” their system requirements to the box designer. Since systems level testing is not appropriate at the box level, the result is often a request for engineering analysis. This is certainly prudent early in the design, but should not be a substitute for testing later at the full system/platform level.

DESIGN SOLUTIONS – SYSTEMS ENGINEERING OVER CIRCUIT BOARDS

This is an area where commercial and military systems differ in their EMC approaches. Most commercial designs focus on circuit board design, and then apply shielding as needed. Military systems, however, take the opposite approach, emphasizing shielding (and other systems design issues) over the circuit boards.
We’ve seen this subtle difference cause frustration for designers moving from commercial to military electronics. We recall one young EMC engineer who was questioning why his new company even hired him. As he said, “All they worry about here is grounding, shielding, and cables. They aren’t even using my circuit board experience.” He felt much better after we assured him that his EMC experience was indeed very valuable – only the focus was different.

Most military systems are already in metal enclosures. Thus, shielding becomes a key EMC design approach. Furthermore, many military systems use embedded controllers, and don’t need the latest and greatest speeds and raw performance. As a result, there is more emphasis on systems design, and less on circuit board design. (We still recommend good EMC circuit board design practices for military electronics.)

The systems design solutions often revolve around interfaces. These include the following:

**Power** - This is an *energy interface*. Design protection of this interface typically combines passive circuits (filters and transient protection) with active power supply circuits. The goal is to provide clean regulated output power under varying input conditions. Since the bandwidth for power is low, the input power wiring is often unshielded.

**Signal** - This is an *information interface*. Design protection of this interface typically includes a combination of passive circuits (filters and transient protection) with active I/O circuit design. Due to bandwidth requirements, filtering is often traded off with external cable shielding or even fiber optics. Thus, cables and connectors also become an important part of this interface, along with the specific I/O circuits.

**Grounding** - This is primarily a *safety interface*, but it also affects the power and signal interfaces. The primary strategy here is topology control. Single point grounds are preferred for low frequency circuits, such as analog sensors and input power. Multi-point grounds are preferred for high frequency circuits, such as digital and RF circuits. Hybrid grounding approaches (using capacitors and inductors to make grounding paths and connections frequency dependent) are often used when both types of circuits or threats are present.

---

**TABLE V. Requirement matrix.**

<table>
<thead>
<tr>
<th>Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations</th>
<th>Requirement Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CE01</td>
</tr>
<tr>
<td>Surface Ships</td>
<td>A</td>
</tr>
<tr>
<td>Submarines</td>
<td>A</td>
</tr>
<tr>
<td>Aircraft, Army, Including Flight Line</td>
<td>A</td>
</tr>
<tr>
<td>Aircraft, Navy</td>
<td>L</td>
</tr>
<tr>
<td>Aircraft, Air Force</td>
<td>A</td>
</tr>
<tr>
<td>Space Systems, Including Launch Vehicles</td>
<td>A</td>
</tr>
<tr>
<td>Ground, Army</td>
<td>A</td>
</tr>
<tr>
<td>Ground, Navy</td>
<td>A</td>
</tr>
<tr>
<td>Ground, Air Force</td>
<td>A</td>
</tr>
</tbody>
</table>

**Legend:**

- **A**: Applicable
- **L**: Limited as specified in the individual sections of this standard
- **S**: Procuring activity must specify in procurement documentation

Source: MIL-STD-461F
Shielding - This is an electromagnetic field interface. This is usually bi-directional, and designed to contain internal electromagnetic fields (emissions) while providing protection against external electromagnetic fields (susceptibility.) Design strategies include metallic enclosures, and then sealing any penetrations or discontinuities with gasket, screening, and filters.

In addition to interfaces, risk management is an important aspect for EMC systems design. This is accomplished several ways:

- **Design reviews** - Most military programs follow a detailed design procedure that includes formal design reviews at critical junctures. Additional design checkpoints may also be employed. We often recommend dedicated EMC reviews. These can be brief, yet can be helpful in uncovering potential EMC problems early in the design process.

- **Engineering tests and analysis** - Many military programs depend on test and analysis throughout the design process to validate design approaches. We certainly encourage this.

- **Documentation** - Most military programs have mandatory documentation requirements. These typically include an EMC Control Plan, and EMC Test Plan, and an EMC Test Report. All three are used to document the process, and as communications tools between the contractor and customers. Yes, we know that most engineers don’t like documentation, but this is a very important part of the EMC systems design process.

### MISSION SUCCESS TRUMPS COST

All this design effort, analysis, test, and documentation costs money, which can lead to complaints about $100 hammers or $400 toilet seats. In spite of carping by politicians, the extra costs are usually justified. Furthermore, since most military systems have relatively low volumes, there are fewer units over which to amortize the extra engineering and test costs.

Military equipment must operate as designed and when needed. Reliability is crucial. For example, you can’t power down or push the reset button on a missile or torpedo after it has been launched. Furthermore, you don’t want them turning around and coming back home.

The true bottom line is not cost, but mission success. Remember, lives are often at stake. Our servicemen and women who go in harm’s way deserve the absolute best engineering we can deliver – EMC and otherwise!

### CONCLUSIONS

1. Military EMC is different from commercial EMC. There are multiple environments to consider, with multiple threats. Those are usually much more severe than commercial threats.

2. Complex military systems require systems engineering approach. The focus is often on interfaces, rather than on circuit boards. Design reviews and documentation are critical to keep everyone in the loop and on schedule.

3. Mission success trumps costs, and reliability is key.

### BIBLIOGRAPHY


_Daryl Gerke, PE and Bill Kimmel, PE_ are the founding partners of Kimmel Gerke Associates, Ltd. The firm specializes in EMC consulting and training, and has offices in Minnesota and Arizona. The firm was founded in 1978 and has been in full time EMC practice since 1987.

Daryl and Bill have solved or prevented hundreds of EMC problems in a wide range of industries - computers, medical, military, avionics, industrial controls, vehicular electronics and more. They have also trained over 10,000 designers through their public and in-house EMC seminars.

_Daryl and Bill are both degreed Electrical Engineers, registered Professional Engineers, and NARTE Certified EMC Engineers. Between them, they share over 80 years of industry experience. For more information and resources, visit their web site at www.emiguru.com._
You spend months, or even years, designing a product. After it’s all ready to be shipped to your customer, you find out that you need a safety certification mark. So in a panic, you send the product off to a test lab for evaluation. The shipment is sitting in your loading bay waiting for the final certification to arrive and then the bad news arrives. Your test lab tells you that it fails! This is not only heartbreaking, but time, effort, and money are wasted in redesign. Not to mention the delay in shipping your product to the customer! Everyone is looking at you and wondering why it wasn’t initially designed correctly. If only you had a manual entitled “Things I need to know to design my product to ensure that it will pass safety testing”! Oh wait…you do! It’s called a safety standard. It may have been published by the IEC, UL or CSA, but it contains everything you need to know, right there, in black and white.

If designers have access to safety standards, why is it that most products submitted for certification have a flaw of some sort that causes the product to fail the safety evaluation? Sometimes these flaws are minor in nature (e.g. missing label, wrong wire color used) which don’t take much time to fix. But sometimes the flaws require a complete redesign (e.g. replace the power supply, redesign circuit boards, redesign the enclosure). Why don’t designers pay more attention to the requirements? A variety of reasons come to mind: lack of time to research the requirements, lack of knowledge that the safety standard exists, miscommunication within the design team, etc. Even if the designer does look at the standards, it is often difficult to understand the requirements (if you can find them). Anyone who has read a safety standard will agree that they are not easy to understand, and tend to bring on lengthy discussions when it comes to interpretation of the requirements.

What is a designer to do? There are a variety of steps that the designer can take to help insure against costly redesigns.

**DETERMINE THE MARKET WHERE THE PRODUCT WILL BE SOLD**

The first thing to find out is exactly where your company will want to sell this product. Your marketing department may have already determined this (but may not have shared this with the design team). North American manufacturers will often focus on sales in North America, only later to be surprised when they find out the extent of the redesign required to comply with European requirements. Knowing the target market may affect many aspects of the design: voltage ratings, component selection, wiring methods, etc. For example, selecting an auto-ranging power supply (100-240V) will allow your product to be used in Europe (220-240V), Japan (100V) and North America (120V). If you’ve designed for the North American market only, you may have neglected the other voltage options, resulting in a costly redesign.
Now that you know what countries you will be targeting, determine what safety related marks are required. The United States and Canada have a variety of options available; many certifiers (e.g. CSA, UL, TUV Rheinland, etc.) are accredited by both the Standards Council of Canada (SCC) and the Occupational Safety and Health Administration (OSHA) as a Nationally Recognized Test Lab (NRTL). Knowing that you can talk to a single certifier to gain simultaneous marks for both countries will make things much easier.

Europe uses a self-evaluation method called the CE Mark. The CE Mark declares compliance to all the directives applicable to the product (e.g. Low Voltage Directive, EMC Directive, and Machinery Directive). Because it is a self-evaluation mark, manufacturers can evaluate the product themselves (with a high level of risk to the manufacturer), or use an agency to evaluate the product on their behalf (low level of risk). Europe has some extra requirements to consider, namely the RoHS and WEEE directives, which have specific restrictions on toxins (mercury, lead commonly used in solder, etc.) and requirements for disposal methods. Many component manufacturers have lead-free alternates to be selected for European markets.

Some countries, such as Japan, have a list of products that need to be certified. Any product not on this list does not need to be evaluated for safety. It’s important to look into this beforehand so you can learn the requirements (if any) before designing your product.

**DETERMINE THE CORRECT SAFETY STANDARD FOR THE PRODUCT**

Now that you know where your product will be sold and the certification marks required for each market, you can determine the safety standard(s) that apply to your product. If you are designing Information Technology Equipment (ITE), you are fortunate because many countries have adopted the same safety standard (IEC 60950-1) [1] and only tweaked it slightly to meet with their National Electrical Codes. Often meeting the requirements for one country will meet the requirement of other countries sharing the same standard.

Some products are not so lucky and have different standards in each country. For example, Industrial Control Equipment has a standard in the United States (UL 508) [2], a very...
different standard in Canada (CSA C22.2 No. 14) [3], and a completely different standard in Europe (EN 61010-1) [4]. In circumstances such as this, you may need to design with three different standards in mind!

Knowing what the applicable standards are will allow you to purchase them, review their requirements, and use your new knowledge in the design of your product.

**SELECT COMPONENTS THAT ARE SUITABLE FOR THE STANDARD**

Most safety standards contain a list of component standards that are acceptable for compliance. Use these when selecting components! The safety standards generally allow for two choices: (1) evaluate the component to the applicable component standard (as listed in the standard), or (2) evaluate the component to the product’s safety standard. If the component is already certified to the applicable component standard, you can be assured that the component is suitable and will not require additional testing. An uncertified component (including CE marking because it is self-declared) will require additional testing. In general, this testing is at an additional cost and will extend the amount of time allotted for certification.

Keep in mind that each standard may have different requirements for components. For example, the ITE standard for the United States will list many UL standards that need to be met. Since UL standards are used in the United States only, these certifications alone will not be suitable for the European market.

**OBTAIN COMPONENT LICENSES**

Many component datasheets and catalogues state the safety certification marks and safety standards that the components have been evaluated to. Don’t believe them. The marketing teams that produce these datasheets and catalogues make mistakes, incorrect assumptions, or use outdated information. You need to collect proof that each component is certified according to their claims.

Some agencies, such as UL, CSA and TUV Rheinland, have powerful databases on their webpage that allow you to search for licenses. Use these online tools for all your components!

Now that you are sure that the certifications are valid, you need to ensure that you are using the component according to its ratings. Often these ratings are listed on the agency websites and are easy to check. However, for some components, finding the listing on the agency website is not enough. Sometimes the certification record is vague, doesn’t list the exact standard, doesn’t include things like current and voltage ratings, etc. The only practical way to be sure that the component will be acceptable is to get the licenses from the manufacturer. Component licenses will sometimes include an important section entitled “Conditions of Acceptability”, because the component evaluation is not a complete product evaluation. The Conditions of Acceptability include conditions that will need to be met in the end-use product (e.g. enclosure requirements, wiring details) and assumptions that were made during certification (e.g. required airflow, fusing). UL provides this for every component certification in their UL Recognition Program. Other certifiers may provide the conditions, but not always. It is crucial to obtain the Conditions of Acceptability for key components such as power supplies, dc-dc converters and transformers.

Read the Conditions of Acceptability and license and ask yourself “Am I using this component according to its rating?” If you will be using a power supply in a 60°C environment, but the license states a rating of 40°C, then you are using that supply outside its ratings. Never mind that the manufacturer may have provided a derating curve in their datasheet. If it hasn’t been evaluated by a certifying agency, consider it to be unproven and therefore unreliable. Using a component outside of its ratings will void the certification of the component and result in retesting of the component in your specific equipment. This is an extra cost and hassle that should be avoided if possible. One simple way of correct this is to source a more suitable component with the correct ratings or adjust your equipment ratings.

Also ask yourself if you are meeting all the conditions stated in the Conditions of Acceptability. If the Conditions of Acceptability state that there must be airflow over the power supply, make sure you are providing that same airflow. If the Conditions of Acceptability state that a terminal block is not for field wiring, you cannot use that terminal for field wiring! You must evaluate these Conditions of Acceptability as they apply to your product with a critical eye!

One more thing to consider is to make sure the licenses you receive from the manufacturer are current! Manufacturers are eager to send you agency licenses that show compliance to old standards or cancelled certificates. Always double check that the component is still certified (confirm on the agency website), and ensure that the standard (and the edition of the standard) used for compliance is listed in your product’s safety standard.

Remember, even if the component is certified, if it’s not certified to the correct component standard, used outside of its ratings, or certified to an older version of the standard, consider it to be uncertified. If you include that component into your design, you will have increased certification costs to cover the extra evaluation and testing.
Call for Papers, Workshops, and Tutorials

The IEEE Product Safety Engineering Society seeks original, unpublished papers and tutorials on all aspects of product safety and compliance engineering within the following scheduled tracks:

Forensics Track
Leadership Track
ITE Product Compliance Track
Medical Devices Track
Risk Assessment Track

General Track - Papers and presentations in the General Track will include:
- Product Specific
- Hazard Specific
- EMC / RF
- Components
- Certification
- Standards Activities
- Research
- Environmental
- Demonstration Papers

Author’s Schedule:

All dates require that the associated documents be loaded into EDAS by the due date:

Abstract/Draft Formal Paper Presentation Submission
May 21, 2013

Notification of Abstract Acceptance
June 7, 2013

Final Paper/Presentation submission
July 19, 2013

Acceptance of Papers
August 16, 2013

Please go to the Author page of the ISPCE web for comprehensive submission instructions including paper templates on the Authors tab at: www.psessymposium.org

**Keynote Speaker**

Joe Bhatia
President and CEO of ANSI
(American National Standards Institute)

ISPCE 2013 will be held at the Westin Austin at the Domain
Single/Double Rate: $149
DESIGN A SUITABLE ENCLOSURE

There are many things to look for when designing an enclosure for your product. Not only does it have to match the “look” that your marketing department desires, but it has to be functional and pass the tests of the appropriate safety standard. There are a variety of things to look at, including material selection, material thickness, openings (including ventilation) and sturdiness necessary to pass the tests of the standard.

Material Selection

Are you considering a plastic enclosure or metal enclosure? Plastic enclosures have some additional requirements to consider, such as flammability ratings of the plastic. These details are described in the safety standard. Consider the plastic to be a component and look it up on the agency website (UL has an excellent online database for plastics). Make sure the specific plastic you are using is listed there, with the appropriate flammability rating and in the correct color. If your plastic is not listed on this website, not only will you be required to have flammability testing conducted, but annual confirmation tests will also be required (at additional cost to you).

Material Thickness

Plastics that are certified will have been tested at a specific thickness. Often the flammability rating will differ depending on the thickness of the plastic. Making sure that the minimum thickness in your enclosure is greater than that listed on the agency certification is critical.

Openings

Openings in the enclosure, generally for ventilation purposes, create a few challenges: (1) if they are too big the user may be able to touch the circuit inside, creating a shock hazard, (2) if the enclosure is providing a fire enclosure the openings may allow flaming particles to exit or enter the enclosure, thereby defeating the purpose of the fire enclosure, and (3) large openings that house a fan or moving part could introduce pinch hazards without suitable shielding. Ensure that all your openings comply with the requirements of the standard.

Tests

Enclosure tests are commonly conducted in safety evaluations. The enclosure must be sturdy enough that it won’t allow a hazard to occur after falling, being leaned on, stood on, impacted, heated, cooled, exposed to UV radiation, or any other foreseeable situation that may affect the safety of the product. You need to consider all the possible tests that will be conducted, as described in the safety standard, and design accordingly.

DETERMINE THE REQUIRED SPACINGS

Knowing what spacings are required between different types of circuits, or between a circuit and an accessible part (i.e. the enclosure) is critical. Planning and designing your wiring boards when you know what is required will save you much time and effort, and will avoid that costly redesign.

Identification of Circuits

The first step is to identify different circuits and accessible parts (i.e. mains circuit, unearthed secondary circuit, earthed enclosure, floating enclosure, etc.).

Create a Block Diagram

Each of these circuits and parts can be considered (and drawn as) a block. Include components that bridge these different blocks (i.e. a transformer, capacitor, relay, etc.). Litter your block diagram with arrows between blocks to indicate where insulation is required. See Figure 1 for a sample block diagram.

Determine the Level of Insulation Required

Referencing the safety standard, determine the type of insulation required between each of the blocks identified with an arrow. Examples of insulation include: basic insulation, reinforced insulation, and supplementary insulation.
Using Tables in the Standard

Determine the creepage distances and clearances required for each of the locations indicated with an arrow. These requirements are found in the safety standard, generally in tables. The required distances will differ depending on the working voltage and the type of circuit.

After determining the required spacings, ensure you are applying these when laying out printed wiring boards. Also consider clearances between boards and enclosures or between adjacent boards.

SINGLE FAULT EXAMINATION

Knowing what single fault tests will be conducted on your product will help immensely during your design. You need to design your product so it can withstand the fault applied and remain safe. A fire or a shock hazard is unacceptable. Single fault tests include shorting and overloading transformer windings, short circuiting or open circuiting components (i.e. capacitors, legs of optocouplers, transistors, resistors, etc.), blocking air ventilation openings and stalling fans. Anticipating these faults and designing protection devices (such as fuses) into your design will be extremely beneficial.

OTHER STANDARD REQUIREMENTS

Every safety standard is different. You, as the designer, need to thoroughly go through the standard to make sure all requirements are met. There will be clauses about earthing methods and bonding tests, requirements for the sizes of wire used, disconnect devices, fusing requirements, touch current requirements, electric strength testing requirements, etc. Knowledge of these requirements will improve your design.

USING CONSULTANTS WHO UNDERSTAND THE REQUIREMENTS OF YOUR SAFETY STANDARDS

Consultants familiar with your safety standard can be a genuine asset for your design team. They have experience with the safety standard and agencies. They know what requirements you need to consider and can identify common pitfalls. They can advise you on the suitability of the components selected and assist with the design of your product (i.e. enclosure design, circuit board layout, etc.). Relying on a consultant will allow you to focus on other aspects of the design, feeling confident that the design will not result in failures during safety certification and evaluation.

SUMMARY

It’s critical to know the market your product will be shipped to before the product design is started. Once you know this, you can use the appropriate safety standards when designing your product. Using consultants to assist with understanding the safety standard is another option to be considered.

If you are unfamiliar with the appropriate safety standards that will be used to evaluate your product during safety certification testing, your design will most likely fail. Your components may not be suitable, your enclosure may be inadequate, your circuits may need to be redesigned, etc. When your product fails during safety certification, you will be charged more for extra evaluation. Furthermore, certification failure significantly delays your time to market while you spend time and effort to fix the problems.

Designing to meet the safety standard is the smartest thing you can do!

REFERENCES


Cherie Forbes is an electrical engineer focused on helping manufacturers gain safety certifications such as UL and CSA. She has worked in the product safety industry for fifteen years and is currently an independent consultant at CertAssist Consulting Inc. She was formerly Manager of Engineering for Lamothe Approvals and has published numerous articles and conducted seminars to aid manufacturers with product design. She is currently a member of IEEE Product Safety Engineering Society (PSES), Society of Manufacturing Engineers (SME), Professional Engineers of Ontario (PEO) and Silicon Halton. She can be reached at cherieforges@certassist.ca or www.linkedin.com/in/forbescherie.
The job of the product safety engineer is to reduce the risks associated with a product to an acceptably low level. The product safety engineer is interested in protecting the life and health of the customer who will use the product. However, the testing involved in safety engineering can entail some risks of its own. The environment for safety testing itself needs to be designed to provide an adequate level of safety for the person performing the test. This requires appropriate test equipment, properly designed environment, well documented procedures, personal protective equipment, training and monitoring of personnel who have access to the test lab.

There are numerous potential risks in the safety test lab, and these typically are similar to the potential risks we test for in our products. There are electrical hazards including shock and arc blast. There are thermal hazards including burns and the risk of flame. Mechanical hazards include risks from hazardous moving parts or from heavy objects crushing body parts. High energy lasers can be exposed in testing, and electrical arcs will generate significant amounts of UV light creating a risk of cataract formation in the eye. Medical products may generate ionizing radiation. There are even chemical exposure hazards for some testing. All of these potential risks need to be properly addressed and mitigated.

INJURY STATISTICS

It is difficult to find statistics for injuries in the product safety testing profession. As a profession, the number of practitioners is small and it doesn’t warrant its own category by the U.S. Bureau of Labor Statistics (BLS). However, the BLS does record injuries as a rate per 100 workers, and it is reasonable to put product safety engineering in the same category as electrical manufacturing. For the most part, the types of hazards are similar. While the time spent at a desk will lessen the product safety engineer’s total exposure time to hazards, it also reduces their experience and practice. An analogous situation would be comparing a professional carpenter versus a weekend woodworker. The professional may be exposed to the risk of injury for 40 hours a week, but this gives them the practice and experience to do the work right. The weekend woodworker may spend only 4 hours a week with a table saw, but their lack of experience significantly raises the risk of injury.

The BLS keeps records of reportable injuries, which are injuries severe enough to require medical treatment. The most recent BLS statistics are for 2009 where there were 3.5 reportable injuries per 100 workers in the electrical equipment, appliance and component manufacturing industry [1]. This is the most appropriate recorded category to extrapolate for product safety engineering and it shows a real risk of injury. Product safety testing is too small of an industry to be broken out separately by BLS, and it is likely that many injuries sustained during safety testing are not reported as worker compensation claims.
The rate of fatalities is a harder to extrapolate as the total number is lower and doesn’t allow the BLS to categorize fatalities by narrow industry sectors. The total for 2009 in the United States was 4,551 out of approximately 130 million workers [2]. The fatality rate for the manufacturing sector was only about two thirds the overall rate for private industry, and this represents about one fatality per 1500 injuries in the electrical manufacturing sector. I do not have sufficiently specific data and I will not extrapolate to the product safety testing industry.

**APPLICABLE REGULATIONS**

Product safety testing laboratories must comply with the applicable occupational health and safety regulations of the jurisdiction in which they are located. The general principles of regulations are generally similar between North America and Europe. The application of these principles and the level of enforcement may be more variable in other jurisdictions, but I will address The United States and Canada specifically and Europe in general.

The governing authority in the United States is the Occupational Safety and Health Administration (OSHA) under the Department of Labor [3]. The OSHA rules apply to almost all employees in the private sector. Although there is a common belief that small employers are exempt from OSHA rules, this is a misunderstanding. The enforcement procedures may differ depending on the employer’s size, and although OSHA will rarely audit a company with ten or fewer workers, these companies are still subject to the regulations. The OSHA regulations cover general work practices and some specific work situations. However, the requirements are NFPA and ANSI standards which are incorporated into OSHA regulations by reference [4]. The OSHA directly covers requirements for training, monitoring and reporting of injuries along with safety practices common among different work environments.

While OSHA is reviewing and adoption NFPA 70E for electrical safety, it is currently a reference document not carrying mandatory requirements. Following NFPA 70E will demonstrate due diligence should an OSHA inspector arrive at a facility. NFPA 70E is not to be confused with NFPA 70. Whereas NFPA 70 covers the rules for the installation of electrical equipment, NFPA 70E covers the rules for safe work practices around exposed hazardous voltages. Additional applicable standards referenced by OSHA are numerous and include, but are not limited to, ANSI standards such as ANSI Z87.1-89 for eye protection, ANSI Z87.2 for respiratory protection and ANSI A14.2-56 for metal ladder use. Additional regulations will apply for specific risks such as laser and X-ray testing.

The regulations for Canada are similar in their technical requirements. The regulations are governed by Health Canada under the Canada Occupational Health and Safety Regulations [5][6]. Many specific requirements are covered by referenced standards including the Food and Drugs Act, Hazardous Products Act, Nuclear Safety and Control Act, Radiation Emitting Devices Act and Controlled Products Regulations [7-11]. The Controlled Products Regulation for example specifically covers the marking and warning requirements for chemicals and hazardous materials. The specific requirements are very similar to those called out by OSHA in the United States.

European requirements will vary from country to country. The European Union does set some standards since the EU is intended to allow the movement of workers across borders without problems. The body setting policy at the European Union level is the European Agency for Safety at Work [12]. As with product safety regulations, there are EU Directives regarding occupational safety that member bodies are required to incorporate into national law. The framework is established in Directive 89/391 with additional Directives written to cover physical hazards, noise, radiation exposure, personal protective equipment, hazardous material handling and marking and many more potential hazards [13][14]. These Directives in turn may have specific applicable standards. For example, EN 50191 covers the installation and use of electrical test equipment and EN 60825-4 covers guarding and protection when there is exposure to Class 3 or Class 4 lasers. Each country must adopt these regulations as a minimum standard, but individual countries may choose to enact stricter regulations. The policy regarding the enforcement of regulations is handled at the national level and is not determined by the European Commission.

**BASIC PRINCIPLES**

Many product safety engineers will groan when they think about OSHA looking at their lab, but the general approach espoused by Environmental Health and Safety (EH&S) professionals can be implemented with minimal hassle and significant benefits. A six step approach can be used; eliminate the risk, provide adequate guarding and protection, use proper personal protective equipment (PPE), provide proper hazard marking and warning, train the affected employees and use continuous improvement. Although the final item isn’t always included in some safety programs, it is important. Proper analysis is required whenever there is an injury or even a “near miss”. Continuous improvement allows you to better focus a general safety program to the narrow
ELIMINATING RISK

Product safety testing involves abusing products to make sure that they fail in a safe manner. This may mean that the product safety engineer will be exposed to hazards, but the exposure can be controlled through the use of safe work practices. For example, measurements of hazardous voltages can be made without exposing personnel to those voltages by applying test probes using clip-on leads while the equipment under test (EUT) is disconnected from power. The test engineer should use enough test leads and meters to simultaneously record necessary voltages at once. Power can then be applied after all test leads are secured. This eliminates the risk of electrical shock by placing the hands close to hazardous voltages, and it reduces the risk of an arc flash from a test probe accidentally shorting out terminals as it is inserted into live equipment. Another example of risk reduction is the addition of outriggers during the stability testing of large, heavy equipment. The outriggers will stop the fall of equipment if it should start to tip over when subjected to the test force. Alternately, a large test jig can be used that will arrest the fall of equipment when it reaches a tilt of 12°, allowing a 10° tip test without the risk of equipment falling over onto personnel. Consider requiring more than one person be present in the laboratory when any potentially hazardous testing is performed. The second person should be clear of the area where the test is being performed so that they will not be put at risk should something go wrong with the test.

GUARDING AND PROTECTION

The next step is to provide adequate guarding and protection. Flammability testing should be done in a fume hood that will safely extract the combustion gasses from the room. The same fume hood can be used for other tests where volatile chemicals may be used or testing where there may be toxic gasses released into the air. The room itself should have a sprinkler system to protect in the event that a fire does start and get out of control. Hand-held fire suppression equipment should be available should materials ignite during fault testing. Sand or fire blankets can be used for small fires allowing for an easier cleanup. Special fire suppression equipment may be needed depending on the materials being tested, particularly with alkali metals such as lithium.

Flammable chemicals should be stored in an approved flammable storage cabinet. Chemicals should be stored in their original containers. If smaller volumes of chemicals are moved to another container, that container must be properly marked with the appropriate chemical properties.

If the EUT generates radiation, shields against that radiation need to be provided for the test engineer. This applies for both ionizing radiation and nonionizing radiation such as a laser. Wearable monitors may be required depending on the type of radiation.

Additional equipment may depend on the type of testing being performed. If your laboratory staff must work with tall equipment, consider providing personnel with a rolling platform ladder (Figure 1). This will provide a large and stable work surface for working above ground level and is preferable to a step ladder. Provide lifting equipment...
ELECTRICAL DESIGN

The safety laboratory needs to be designed with the proper electrical connections for the type of equipment to be tested. This may mean providing a variety of outlets of different ratings. One technique is to provide a higher current multi-phase outlet, and then to use adapter boxes that provide specific outlets, each with the proper overcurrent protection. Consider installing an Emergency Power Off (EPO) button that shuts off selected power in the room. The EUT gets connected to a protected outlet, and if there is a problem of such severity that the test engineer cannot easily disconnect power, the EPO can be used to shut off power to the EUT. The EPO can also be used to disable the door lock via an electronic strike plate, allowing entry by emergency responders should there be a situation in the lab requiring fire or medical personnel. In such cases, an indicator light should be placed outside the door to the laboratory to indicate that the EPO has been activated. Please note that the EPO should not turn off lights in the laboratory.

Ground Fault Circuit Interrupters (GFCIs) are required for outlets in close proximity to sources of water. However, GFCI should not be used in other locations for supplementary protection. GFCIs are susceptible to nuisance tripping due to the leakage current of ITE, and they can be impractical in the laboratory environment. Safe work practices are required to reduce the risk of exposing personnel to fault current. AFCIs are susceptible to tripping during abnormal condition testing and could terminate testing prematurely. Arc Fault Circuit Interrupters (AFCIs) also should not be used in a safety laboratory to provide supplementary protection. AFCI’s intended purpose is to shut off power when arcing can go undetected in a residential environment where there are lots of flammable materials. AFCIs are not used in commercial environments in general and would provide few benefits in the safety laboratory.

If you perform fault testing that will result in tripping a branch circuit breaker, you need to take additional precautions. Circuit breakers are not designed for repeated tripping. Their detents and internal components will weaken slightly with each trip. Ground faults are especially hard on circuit breakers and significantly shorten their operating lives. Instead of depending on the branch circuit breaker to terminate a test, insert overcurrent protection between the EUT and the branch circuit breaker. This supplementary overcurrent protection must be of a type and rating such that it will open before the branch breaker, and it should be installed in such a way that it can be easily and safely replaced. The supplementary protector can be replaced as it degrades preventing the need to replace circuit breakers in an electrical panel. This protection can be installed in the previously mentioned adapter boxes. The box can then be unplugged and safely disassembled to replace the supplementary protector.

PERSONAL PROTECTIVE EQUIPMENT

All personnel who use the lab need to be issued the proper personal protective equipment (PPE) for the type of work that they do. The type of PPE should be based on the testing performed and the risks to which the personnel will be exposed. It is also important to note that “personal” is part of PPE. Each employee who works in the laboratory should be issued their own PPE. It is not to be shared among employees. PPE needs to be chosen in the correct size and type for the employee and they need to be trained in its proper use. Employees need to understand that if they don’t have the proper PPE, they should forego the test until it can be done safely.

Safety glasses should be worn in almost any safety test laboratory as they will be recommended for many types of tests. Physical tests, ranging from drop tests to impact tests, may result in flying debris. Abnormal condition tests can have unpredictable results that can also result in flying debris. In the United States, NFPA 70E requires safety glasses be worn whenever working around exposed hazardous voltages. Electrical arcs generate intense ultraviolet light which can contribute to cataract growth in the eyes, so the glasses should provide UV protection in additional to impact protection.

PPE will be needed as physical protection for a number of risks possible in the test laboratory. Hearing protection may be required if testing will involve loud equipment. Safety shoes should be worn when working with heavy equipment to protect feet from crush injuries. These shoes should also have electrically insulating soles to reduce the shock hazard. Protective gloves may be required for some types of tests (Figure 2). Different gloves may be needed for protection against thermal burns, sharp edges or chemical hazards. Chemical exposure may also dictate the use of respirators. If so, the respirators need to be fitted properly, the filters need to be selected based on the hazard and the employee needs to be medically evaluated and well trained in the use of the respirator.

NFPA 70E imposes fairly strict requirements for PPE for working
with exposed hazardous voltages, so it is best to eliminate
the need for the test engineer to place their hands in the
equipment while it is live. If this must be done, NFPA 70E
will require differing levels of protection depending on the
voltages present. This protection includes electrical gloves
with leather protectors, safety glasses, face shields and flame
resistant clothing. The PPE required for testing a 120 V hand
mixer may be simple, but much more would be required for
testing a 250 kW, 480 V uninterruptible power supply. Do not
rely on the practice of keeping one hand in your pocket. This
may reduce the risk of hazardous current running through
your heart, but you still run the risk of creating an accidental
short circuit. This could still allow hazardous current to run
through your hand resulting in significant burns. In higher
power equipment, it can result in an arc flash or arc blast that
can do even more damage.

Make it easy for employees to keep their PPE in or adjacent
to the laboratory. Even if the employee’s office isn’t far
away, there can be the temptation to just run a quick test
even if they forgot to bring their PPE. Lockers or cubbies
allow easy storage of safety glasses, lab coats, safety shoes,
ear protection and other PPE. Provide additional PPE if you
have regular visitors to the laboratory. Safety glasses and ear
plug dispensers can easily be placed immediately outside the
laboratory area allowing the quick outfitting of visitors when
needed.

MARKING AND WARNING

Marking and warning should be used where hazards cannot
be eliminated, guarded or controlled below safe levels.
Chemicals should be properly marked where they must be used
and the Material Safety Data Sheets (MSDS) must be available
to personnel to provide them with the proper warnings, PPE
requirements and information (Figure 3). Mark areas where
there will be exposed hazardous voltages. The test engineer may be
aware of the exposed voltages, but there may also be a possibility of
others entering the lab without such knowledge. These people need to
be able to see the proper warning signs to know the hazard is present.
Similar marking should be used for hot surfaces or exposed hazardous
moving parts. The National Electrical Code prohibits placing
any object in front of an electrical panel, so mark the proper exclusion
area around the panel. Use floor

marking for areas used for storage of large items to clearly
delineate storage areas from aisles.

Certain hazards will require additional marking. There will
need to be marking on the door into the laboratory if there are
radiation hazards, whether they are ionizing or nonionizing.
Specific information about lasers in the laboratory will need
to be marked including the laser class and the wavelength.
Signs on the door should indicate the required PPE if there is ongoing
testing dictating specific PPE be used at all times.

TRAINING

All affected employees need the proper training to reduce
their risk of injuries. Affected employees include not only
those performing the testing, but those with access to the
laboratory area while testing is being performed. Personnel
unfamiliar with specific testing may enter the lab and these
people need the training to be able to assess and handle the
risks present. It is important to document which employees
have been trained and what hazards they have been trained
to handle. An employee not trained to handle a specific
hazard should not be permitted to perform testing where
that hazard may be present. Training needs to be repeated
periodically both as a refresher and to ensure new standards
and requirements are well communicated.

The various regulating agencies, such as OSHA, mandate
the training. Employees must be trained in the use of PPE
before they can perform the tasks that require the PPE. If
special equipment is required to perform a task, the affected
employees must be trained to use the equipment. Employees
must be trained in proper
ergonomics, lifting techniques and
use of hoists if their job requires
them to lift heavy loads.

Training on its own has a limited
benefit if there isn’t enforcement
of the rules. Enforcement need not
be draconian, but it does need to
provide an incentive to follow safe
work practices. Laboratory safety
needs to be part of the corporate
culture, and the laboratory manager
is responsible for the safety of the
employees in the lab. It is important
that the managers cultivate a culture
of safety so that they can act as
guides, not policemen.

CONTINUOUS
IMPROVEMENT

Any laboratories safety program
should include continuous
improvement. Work practices may need to be tailored to the specific testing performed. If there is an incident, update the workplace practices for the laboratory to address appropriate corrective actions for the issue. Look for near misses and use them as an opportunity for improving work practices. Work with your employer’s Environmental Health and Safety group to help minimize risks in the laboratory.

Continuous improvement should not be just a top-down program. All of the laboratory personnel should be involved. Suggestions that come from the workers in the lab are more likely to be easy to implement than programs dictated from management alone. Track incidents to determine if changes are having the intended effect.

CONCLUSION
The risk of injury in the safety test laboratory may seem low, but there are real hazards that do result in injuries and even a risk of death. The proper design of the laboratory along with good training and the proper use of protective equipment can significantly reduce the risk of injuries. The implementation of proper safety can be done cost effectively if designed into a laboratory program. These costs can pay for themselves by eliminating possible higher expenses ranging from noncompliance fines from the Occupational Safety and Health authority, withdrawal of an occupancy permit for unsafe condition, lost time from injured workers and increased workers compensation costs.

ACKNOWLEDGMENT
I would like to thank Lauri Johns-Andersch, Microsoft’s Employee Safety and Health Program Manager, for help reviewing this paper and teaching me the details of the legal requirements of OSHA compliance.

REFERENCES

Ted Eckert is currently a compliance engineer for Microsoft Corporation where he is responsible for products including video game systems and tablet computers and where he serves as Microsoft’s representative to the U.S. National Committee for TC108. Previously, he was a Staff Compliance Engineer at APC-MGE, a division of Schneider Electric. Over his career as a product safety engineer, Ted has tested industrial electronics, power distribution products, air conditioners, information technology equipment and toys.
One of the biggest frontiers in electrical engineering in this early part of the 21st century is the development and implementation of smart grid technology.

Development of greener technologies and alternative fuels has become a global economic priority, so smart grid technology has the potential to be one of the next great technological waves. It can jump-start stagnated economies, and can fundamentally change the way power is delivered to consumers of electricity worldwide. The environmental benefits that smart grid technology can deliver are collectively demanded by most of Earth’s inhabitants at this time, and the decrease in dependence on fossil fuels and other nonrenewable power sources is also sought through this new technology.

Smart grid technology can be viewed as a merging of power systems, information technology, telecommunications, switchgear, and local power generation, along with other fields that were once electrical technologies of separated industries. As these separate technologies become merged, much of the safety considerations will have to be merged and reconciled as well, particularly at interfaces. In some cases, new insight may have to be given to safety that was not necessary in the past.

This article provides a brief overview of smart-grid technology, and then explores the safety considerations that should be addressed in the design of smart grid technology equipment, particularly in low-voltage AC power applications operating below 1000 V AC. It recognizes smart-grid technology as the merger of power generation, distribution, metering and switching equipment with communication, information technology, and with new user applications. Then, it suggests a modular approach of evaluating the safety of smart-grid technology based on the safety requirements of the individual merged technologies. In addition, examples of some likely smart-grid applications and the safety considerations that would need to be addressed are discussed. It also points out known safety issues with localized electric power generation systems that will be more enabled by smart grid technology.

WHAT IS A SMART GRID?

A smart grid combines the existing electrical infrastructure with digital technologies and advanced applications to provide a much more efficient, reliable and cost-effective way to distribute energy. The main function of a smart grid is to manage power consumption in optimal ways, providing the network with more flexibility in case of emergencies. Within the context of smart grids, there are different kinds of supporting technologies, such as smart meters that can help monitor energy consumption and promote more effective distribution. [1]

SMART GRID: WHAT TO EXPECT

Power industry experts look to the smart grid in much the same manner as computer and telecommunications technology as the merger of power generation, distribution, metering and switching equipment with communication, information technology, and with new user applications.

© 2010 IEEE. Reprinted, with permission, from 2010 IEEE Product Safety Engineering Society Symposium Proceedings
experts looked at the advent of the internet, or “information superhighway” less than a generation ago. It is viewed as the necessary next step in order to modernize the power distribution grids, but there is no single view on what shape or format the smart grid will take.

Without a doubt, the expectation from the power generation and transmission industry is realization of efficiencies. Better sampling of usage and understanding demand patterns should allow the electric utilities to lower the use of power-generation plants, possibly saving millions of dollars by not having to build new plants to meet increases in power demand. Many of these plants burn coal and other fossil fuels that are non-renewable and greenhouse-gas producing sources of energy, and they are increasingly becoming more scarce and expensive.

ALEXANDER GRAHAM BELL VS. THOMAS EDISON

A popular comparison that points out the magnitude of change in the telecommunication industry as opposed to that of the power industry is to hypothetically transport Alexander Graham Bell and Thomas Edison to the 21st century, and allow them to observe the modern forms of the telecommunications and power industries that they helped create. It is said that Alexander Graham Bell would not recognize the components of modern telephony – fiber optics, cell phones, texting, cell towers, PDA's, the internet, etc. – while Thomas Edison would be totally familiar with the modern electrical grid [2]. Thus, with smart grid, there is the potential to modernize and advance the architecture of the power systems technology in the 21st century, as the newer technology has already advanced the telecommunications technology.

Still, Mr. Edison would be just as astonished as Mr. Graham Bell with the present power grid technology as it is today. The century-old power grid is the largest interconnected machine on earth. In the USA, it consists of more than 9,200 electric generating units with more than 1 million megawatts of generating capacity connected to more than 300,000 miles of transmission lines.[2] Mr. Edison would not be familiar with nuclear power plants or photovoltaic cells, as these technologies were developed after his death in 1931.

To celebrate the beginning of the 21st century, the National Academy of Engineering set out to identify the single most important engineering achievement of the 20th century. The Academy compiled a list of twenty accomplishments that have affected virtually everyone in the world. The internet took thirteenth place on this list, “highways” were ranked eleventh, but sitting at the top of the list as the most important engineering achievement of the 20th century was the development of the present electric power grid.

A MODULAR APPROACH TO SMART-GRID SAFETY

Since smart grids will involve the merger of new and familiar technologies, it would make sense to take a modular approach to safety. The best way to approach this new, merged technology is to break it down into its component technologies, then use existing or new standards to evaluate safety issues involving the component technologies. That is, rather than develop a single standard for, say, a new electrical service equipment with intelligence, for a smart meter, it would make sense to continue to use the base product safety standard for meters, but plug-in the additional telecommunications and information technology safety modules. Likewise, other product applicable safety modules, such as requirements for outdoor equipment, can serve as supplements or overlays to the base meter standard in this case.

Hazard-Base Safety Engineering Standard IEC 62368-1

IEC 62368-1 is the new hazard-based safety engineering standard covering audio/video, information and communication technology equipment. This state-of-the-art safety standard classifies energy sources, prescribes safeguards against those energy sources, and provides guidance on the application of, and requirements for those safeguards. It uses the “three-block” model for pain and injury from the energy source to the person, with the middle block covering the safeguarding necessary to prevent or limit the harmful energy to a person. [3]

If we agree to take a modular approach to evaluating the safety of the smart-grid technology equipment, then IEC 62368-1 will be well-suited for providing the plug-in modules for evaluating the safety of the information technology and communication circuitry portion of the smart grid equipment.

For example, if we have a smart meter with integral information technology and telecommunication interfaces, you could use the international or locally-adopted safety standard for power meters, then use IEC 62368-1 to evaluate the type of personnel that would require access to the smart meter (“skilled,” “instructed,” or “ordinary”), [3] and then determine the level of safeguarding necessary in such areas as isolation from the power equipment, isolation from the telecommunication equipment, construction of the enclosure as a safeguard against accessibility to shock and containment of fire, and so forth.

IEC 60950-1 Continued Use

For the near term, we would expect to use IEC 60950-1 to evaluate smart grid equipment with communication and information technology circuitry for safety, as well as the
required protection and separation from other circuits that they require. [4] This would be until IEC 62368-1 becomes adopted by national standards committees.

IEC 60950-22 for Outdoor Information Technology and Communication Circuits
As both IEC 60950-1 and IEC 62368-1 standards reference IEC 60950-22 as a supplemental standard for equipment installed outdoors. We should expect this standard to be used extensively for smart-grid equipment. This standard provides requirements and considerations for enclosure construction, overvoltage category consideration, and pollution degrees (environmental exposure) associated with information technology and communications equipment installed outdoors.[5]

SAFETY OF UTILITY-OWNED SMART-GRID EQUIPMENT
As is the case today, we would expect safety of utility-owned smart-grid equipment located within the power generation or transmission circuits, up to and including the service conductors to the customers’ buildings to continue to be evaluated for safety in accordance with basic utility-safety standards or Codes. These standards include IEEE C2, “National Electrical Safety Code,” and CSA C22.3, “Canadian Electrical Code, Part III.”

EXAMPLES OF SMART-GRID TECHNOLOGY

Automatic Metering Infrastructure (AMI)
Automatic Metering Infrastructure (AMI) is an approach to integrating electrical consumers based upon the development of open standards. It provides utilities with the ability to detect problems on their systems and operate them more efficiently.

AMI enables consumer-friendly efficiency concepts like “Prices to Devices.” With this, assuming that energy is priced on what it costs in near real-time, price signals are relayed to “smart” home controllers or end-consumer devices like thermostats, washer/dryers, or refrigerators, typically the major consumers of electricity in the home. The devices, in turn, process the information based on consumers’ learned wishes and power accordingly. [2]

Safety Concerns of AMI-Enabled Equipment
We could reasonably expect to see some form of communication interfaces and information technology in some appliances that traditionally would never have had such interfaces (washer/dryers, refrigerators, etc.). With this, we should expect a modular approach in evaluating the safety of these appliances, whereby we evaluate the communication subsystems as we would for communication equipment and information technology equipment (ITE), while the bulk of the appliance is evaluated in accordance with the basic safety standard that normally applies to such appliances. This would mean that either IEC 60950-1 or IEC 62368-1 are used to evaluate the communications and information technology subsystems, and communication links would be classified TNV, limited-power circuits, or the like if metallic, and other non-metallic communication technologies such as optical or wireless would be evaluated accordingly.

EXAMPLE: ELECTRIC VEHICLE POWERING
Email was arguably the “killer app” that most enabled the propagation of high-speed internet. It is not yet known what the smart-grid “killer app” is going to be, but like pre-season predictions of who is going to win the Super Bowl or the World Cup, some think that it is going to be plug-in hybrid electric vehicles (PHEVs) and possibly full electric vehicles (EVs).

As plug-in electric vehicles replace gasoline-only burning vehicles on the market, parking lots will need to be equipped with outdoor charging stations. We would not expect any commercial or government establishments to give away free electricity, so we should expect to see the rise of pay-for-use charging stations, integrating technologies such as electrical metering, switching, information technology, telecommunications, and currency-handling technology.

A pay-for-use charging station might involve the following technologies:
A. An AC-power outlet receptacle to plug in the vehicle for charging;
B. Electric power metering to measure electricity use;
C. Switchgear to switch charging circuits on or off, once enabled by information technology, and provide overcurrent protection or active shutdown in the event of a short-circuit fault in the vehicle’s or the charging circuit’s circuitry;
D. Information technology equipment to process the sale, timing, and user interface to purchase electrical charge, and to enable/disable the charging switchgear;

E. Telecommunications to communicate the sale and power use back to the electrical power retailer. We might expect to have campus-type communications from the charging station to a central control station, and then have a trunk telecommunication connection to the network;

F. Currency handling technology, which might involve direct input of paper or coin currency, credit-card transactions, smartcard or wireless interface, or, quite possibly, cell-phone enabled transactions; and

G. The equipment would be located outdoors and be installed in a weatherproof housing.

Higher Overvoltage Category for Information Technology in Charging Station

The meter safety standard and switchgear standards may assume that these components are installed in Overvoltage Category IV or III environments, but the information technology equipment standard expect equipment to be installed nominally in Overvoltage Category II environments.

According to IEC 62368-1, Annex I (also IEC 60950-1, Annex Z), electricity meters and communications ITE for remote electricity metering are considered to be examples of Overvoltage Category IV equipment, or equipment that will be connected to the point where the mains supply enters the building. “Power-monitoring equipment” is listed as examples of Category III equipment, or equipment that will be an integral part of the building wiring. In these higher overvoltage categories (IV and III), the value of the mains transient voltages is higher than it would be expected for general indoor-use Category II AC mains connected appliances. This translates into a need for much greater creepage and clearance isolation distances, as well as much higher electric-strength withstand voltages.

Information technology equipment, on the other hand, is generally utilized in Overvoltage Category II environments, or connected to outlets on branch circuits a safe distance away from the service equipment. Also, as the amount of off-the-shelf, commercially-available ITE sub-components increases in the charging station, it becomes more infeasible to simply increase the spacings or the quality of insulation. It may be necessary to use surge protection devices, either integral to the equipment, or externally connected to limit transient voltages from Overvoltage Category III and IV to Overvoltage Category II.

Protection of Communications Circuits

Metallic connections to a telecommunication network would need to be evaluated in accordance with IEC 62368-1 or IEC 60950-1.

Additionally, intra-campus communication conductors, such as those used for intra-system communications or status alarms, will also need to be protected like telecommunication conductors in accordance with the local electrical code or practices. This may mean putting telecommunication protectors—primary (voltage) or secondary (power-cross)—at each end of a campus-run communication conductor where there exist an exposure to lightning or to accidental contact with electric power conductors.

User Accessibility

Additionally, the charging station terminal where the user pays for and plugs in his electric vehicle needs to be made safe so that unskilled persons may use the station. This would require the highest levels of guarding against intentional access to hazardous voltages.

ENERGY STORAGE SAFETY

Locally-generated electrical energy, such as that from photovoltaic systems, needs to be stored during accumulation cycles for use during peak demand cycles. In most cases, this will be achieved by use of DC storage batteries that invert the electrical energy to AC for local use or for sale back to the electric company. Battery technologies such as lithium ion or valve-regulated lead acid batteries are the most likely present technologies to be used, though advanced batteries such as sodium batteries may be considered.

The size and capacity of these battery storage systems would historically have been found in commercial or industrial installations where only service personnel would have access. Now as part of smart grid and green-power initiatives, you can expect to see such systems in residential locations where anyone might have access.
Safety issues to be considered include:

1. Prevention of access to live parts at high electrical energy levels;
2. Prevention of access to live parts at shock potentials;
3. Ventilation of batteries that outgas explosive gases, such as hydrogen from lead-acid batteries.
4. Containment of batteries capable of producing excessive heat during breakdown or thermal runaway.
5. For outdoor applications, suitably housing the batteries in an outdoor enclosure that, if equipped with lead-acid batteries, is well ventilated in accordance with IEC 60950-22 to prevent the accumulation of explosive gases.

**OTHER SAFETY CONCERNS – LOCAL POWER GENERATION**

Local power generation systems, such as photovoltaic systems, generators, fuel-cell systems, and the like, for which the smart grid will permit the sale of power back to the utility, involve the following safety concerns:

**Synchronization**

The frequency of the locally-generated power has to be synchronized with that of the main grid.

**Islanding**

Islanding is a condition in which a portion of an electric power grid, containing both load and generation, is isolated from the remainder of the electric power grid. When an island is created purposely by the controlling utility—to isolate large sections of the utility grid, for example—it is called an intentional island. Conversely, an unintentional island can be created when a segment of the utility grid containing only customer-owned generation and load is isolated from the utility control.

Normally, the customer-owned generation is required to sense the absence of utility-controlled generation and cease energizing the grid. However, if islanding prevention fails, energized lines within the island present a shock hazard to unsuspecting utility line workers who think the lines are dead.[6]

**CONCLUSION**

The smart grid promises to bring on a new age of distributing electricity in more efficient and greener ways, while enabling the developing of new ways to efficiently utilize and control power.

In many ways, it will take the form of a merger of power generation, distribution, switching, and metering technology with communications and information technology, along with other applications of electrical energy. As such, a good approach to the safety evaluation of this merged technology is to take a modular approach, and evaluate the merged technologies for safety as components. Furthermore, IEC 62368-1, the new international hazard-based safety engineering standard for audio/video, information and communication technology is well-suited for use in this modular-safety approach.

**REFERENCES**


**Don Gies** has been a product compliance engineer for over 25 years. Since 1989, Mr. Gies has worked at AT&T-Bell Laboratories/Lucent Technologies/Alcatel-Lucent as a product safety engineer, responsible for obtaining product safety certifications for his company’s telephone and information processing equipment from domestic and international product safety organizations.

Mr. Gies has become a leading subject matter expert for his company in the field of global product safety compliance, working primarily with Alcatel-Lucent's wireless base station equipment. He is a member of the Alcatel-Lucent Technical Academy. Prior to working at AT&T, Mr. Gies was a Tempest engineer for Honeywell-Signal Analysis Center, where he worked on various secure communications projects for the US Army Communications -Electronics Command.

Mr. Gies graduated from Rutgers University - College of Engineering as an electrical engineer. He is an iNARTE Certified Product Safety Engineer.
Thermal testing, also known as heat testing, is one of the most critical tests required by the majority of regulatory safety standards in determining the safety of a product. Excessive heat is the number one enemy in any electrical or electronic circuit. Designers are perpetually trying to improve the way to reduce heat or partially cool their products because they are being asked to design products with higher power density into smaller sizes, while operating temperatures of components or devices have not changed greatly over the past few decades. This means that component temperatures must be well controlled to avoid any failure and to increase the reliability of the product.

This article will cover basic fundamentals for thermal measurement and provide some of the methodology used to arrive at accurate measurements.

**CHOOSING A THERMOCOUPLE**

Accurate temperature measurement of components can be challenging. An important tool used in thermal measurement is the thermocouple, one of the most accurate and repeatable.

Although there are many devices or methods used for measuring temperature, thermocouples are one of the simplest and most commonly used sensors. Having said that, using an infrared camera can quickly help identify any hot spot.

Thermocouples consist of two wires of dissimilar metals, joined near the measurement point or junction (Figure 1). The output is a small DC voltage measured between the two wires. This differential voltage is then converted to a temperature using specially designed equipment such as a chart recorder or data logger.

There are over a dozen different types of thermocouples commonly used in various industries. Most of these have been given internationally recognized letter designator types, such as B, C, D, E, G, J, K, L, M, N, P, R, S, T, and U.

Types J, K, and T are among the most commonly used thermocouple types in the electronic industry due to their ease of use, low cost, and availability. Each thermocouple has its own temperature range and accuracy. For example, the range for type J thermocouples is $-210^\circ C$ to $+750^\circ C$, while for type T the range is $-100^\circ C$ to $+350^\circ C$; for this reason, they are used for different applications. These temperature ranges are approximate because manufacturers state slightly different temperatures.

---

**Figure 1: Thermocouple composition**

---
Product Safety

Thermal Testing: A Primer

In Compliance 2013 Annual Guide
www.incompliancemag.com

numbers. They also have different color codes. For example, in North America a type J is white and red, but in the rest of the world a type J is typically black and white.

The following is a list of recommendation that must be considered before taking any thermal measurements:

- Choose the thermocouple based on your application — expected temperature, environment, abrasion, oil, etc. For example, if you are measuring temperature of a component in a furnace, it is best to use a type C thermocouple.
- Ensure that the chart recorder or data logger is compatible with the thermocouple wiring. If you are using type K, ensure that the data logger is also set to type K. An incorrect setting will result in measurement errors.
- Visually and physically check the outer jacket for any obvious damage by running the thermocouple wires through your hand and feeling for any possible damage.
- Visually check the tip. The smaller the weld tip, the more accurate the results will be. Figure 2 illustrates two different weld tips.
- A good weld has a small tip with a very small amount of wire stripped, whereas a poor weld shows the opposite.
- Check each thermocouple for its functionality. Valuable time can be wasted if the thermocouple is damaged or is not functioning correctly after it is affixed to a component. One of the easiest methods is to hold each thermocouple between your thumb and index finger for a few seconds. The thermocouple should read your body temperature (37ºC).
- Take care when using thermocouples in a noisy environment or when attaching them to windings of a transformer. Thermocouples typically have no shielding and can be susceptible to EMI noise. Measuring magnetic temperature can be tricky, in particular when measuring switching transformers. The closer the thermocouple tip is to the windings, the more accurate the results are. However, it is best if the thermocouple tip is not touching the magnet wires directly since some of the windings carry high voltages and this may damage the data logger if it comes in contact with the thermocouple. The safest approach is placing the thermocouple tip on insulation tape, which covers the winding. One of the best ways to overcome an electrical noise problem is to use a thermocouple with shielded leads and connectors or to rout it away from noisy circuits.
- Ensure that a thermocouple is calibrated.
- When repairing and welding a thermocouple, it is critical that the weld tip is carefully checked to ensure the weld is secure and that the thermocouple is recalibrated prior to use.
- Avoid using a thermocouple with long lead length. High resistance in the wire may lead to errors. Use an appropriate extension wire and adapter, if longer length is needed.
- Avoid performing thermal testing in an uncontrolled environment, high traffic area, or areas exposed to any air-conditioning. Excessive air movement will impact the final results.

MEASURING TECHNIQUES

The following factors may affect the final results:

- Position of the thermocouple: Critical when measuring temperature on the winding of a choke or transformer. The results are more accurate the closer the thermocouple is placed to the windings.
- Use of excessive glue or cement: Extra volume and mass can assist heat transfer, in particular when temperatures are close to their limits. Use an exact dose of adhesive. When using adhesive, ensure that the adhesive possesses a high thermal conductivity.
- Obstruction of the airstream around the thermocouple wires.
- Equipment voltage: Temperature results usually vary as the input voltage to the equipment changes. For example, some units run hotter at 90 Vac, while others may run hotter at 264 Vac. It is recommended that the input voltage source is as stable as practical. Any small variations in input voltage will result in variations in temperature. Ensure voltage tolerances are taken into consideration, as each safety standard uses different tolerance percentages.
- Equipment load: Equipment load plays a crucial role in the final thermal results. In the majority of the cases, the higher the load, the higher the temperature on individual

Figure 2: Good weld vs. poor weld
components. Most product safety standards require the equipment under test (EUT) to be loaded to its maximum normal operating load during the heating test.

- Local ambient conditions: As mentioned before, it is important that the thermal test is performed in a controlled environment. If there is excessive air movement, then the final results cannot be considered as accurate. One of the simplest solutions is to conduct tests in a corner of the lab where there is less traffic and there is no air-conditioning blowing cold air directly on the EUT.

- Stabilization or thermal equilibrium: In certain instances, engineers record the final data after a certain time, such as after one or two hours of operation. Since different products behave differently and reach their maximum temperature at different times, it is important to record the final data ONLY after the EUT has reached thermal equilibrium.

It would be helpful to explain what thermal stability is. A temperature is determined to be constant or stabilized when the graph on a chart recorder or data logger is shown to be flat without any temperature rise and shows three successive readings are within 1°C of each other when taken at 30-minute intervals. Unfortunately, there is no harmonized standard that defines thermal stability and each standard has its own definition. The most important point to bear in mind is that temperature rise is always an exponential curve. Therefore the easiest method is to use a chart recorder or data logger simply because the curve as temperature becomes stable is readily visible.

Figures 3 and 4 illustrate respectively measurements where thermal equilibrium has been achieved and where complete thermal stability has not been achieved.

**DOCUMENTING THE RESULTS**

Before publishing the final results, take the following steps:

- Review the raw data to ensure that nothing unusual stands out. Use engineering judgment. For example if the body temperature of an metallic oxide varistor (MOV) is lower than that of the printed circuit board (PCB) on which it is mounted, the data should be checked again.
• Compare the test data to previous test data that has been done on the same product to find out if they all follow similar patterns.

• For almost each measurement of data, there is a limit to which the data is compared. These limits can be derived from verifiable sources such as product safety standards, component manufacturer data sheets, internal procedures, etc.

Tables 1 and 2, from IEC 60950-1, show the limits for some components.

• Prepare the final report by tabulating the data, correcting it to the corresponding $T_{\text{mra}}$ (manufacturer recommended ambient), and include the limits for each component where possible.

COMPUTING TEMPERATURES

Typically manufacturers market their products much higher than 25°C. Based on the manufacturer’s recommended ambient temperature, also known as $T_{\text{mra}}$, either the limits or the measured temperatures must be corrected accordingly.

The formula below shows how to make the adjustment:

$$T < T_{\text{max}} + T_{\text{amb}} - T_{\text{ma}}$$

### Table 1: Temperature, limits, materials, and components

<table>
<thead>
<tr>
<th>Part</th>
<th>Maximum temperature ($T_{\text{ma}}$) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation, including winding insulation:</td>
<td></td>
</tr>
<tr>
<td>– of Class 105 material (A)</td>
<td>100 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 120 material (E)</td>
<td>115 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 130 material (B)</td>
<td>120 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 155 material (F)</td>
<td>140 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 180 material (H)</td>
<td>165 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 200 material</td>
<td>180 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 220 material</td>
<td>200 $^{abc}$</td>
</tr>
<tr>
<td>– of Class 250 material</td>
<td>225 $^{abc}$</td>
</tr>
<tr>
<td>Rubber or PVC insulation of internal and external wiring, including power supply cords:</td>
<td>75 $^d$</td>
</tr>
<tr>
<td>– without temperature marking</td>
<td>Temperature marking</td>
</tr>
<tr>
<td>– with temperature marking</td>
<td></td>
</tr>
<tr>
<td>Other thermoplastic insulation</td>
<td>See e</td>
</tr>
<tr>
<td>Terminals, including earthing terminals for external earthing conductors of STATIONARY EQUIPMENT, unless provided with a NON-DETACHABLE POWER SUPPLY CORD</td>
<td>85</td>
</tr>
<tr>
<td>Parts in contact with a flammable liquid</td>
<td>See 4.3.12</td>
</tr>
<tr>
<td>Components</td>
<td>See 1.5.1</td>
</tr>
</tbody>
</table>

a If the temperature of a winding is determined by thermocouples, these values are reduced by 10 °C, except in the case of
   – a motor, or
   – a winding with embedded thermocouples.
b For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature.
c The designations A to H, formerly assigned in IEC 60085 to thermal classes 105 to 180, are given in parentheses.
d If there is no marking on the wire, the marking on the wire spool or the temperature rating assigned by the wire manufacturer is considered acceptable.
e It is not possible to specify maximum permitted temperatures for thermoplastic materials, due to their wide variety. These shall pass the tests specified in 4.5.5.
Thermal Testing: A Primer

Where:

\[ T = \text{measured temperature} \]

\[ T_{\text{max}} = \text{maximum limit allowed} \]

\[ T_{\text{amb}} = \text{local ambient} \]

\[ T_{\text{ma}} = \text{maximum ambient temp permitted by the manufacturer.} \]

Example

An electrolytic capacitor is measured to be 63°C at a room ambient of 23°C. The capacitor is rated for 105°C and the manufacturer needs to qualify this product to 50°C operation. Does this component meet the required limits?

Using the above formula:

\[ 63 < 105 + 23 - 50 \]
\[ 63 < 78 \]

The component meets its permitted limit.

If the \( T_{\text{ma}} \) is higher than 25°C, then the manufacturer has the choice of:

- Testing it on the bench in the lab and then mathematically correcting the temperatures as shown using the formula above
- Testing the product in an elevated environment, such as a heating oven

An oven is used when there is a specific request or the lab environment is unstable. When testing in an oven, accurately document the oven air temperature, level of oven air circulation, oven humidity, and sample placement. Additionally, an oven is used when the product is temperature controlled as stated in Clause 1.4.12.2 of IEC 60950-1, 2nd Ed. Most test agencies and standards allow both methods.

If the \( T_{\text{ma}} \) is 50°C or less, it is recommended that the testing is done on the bench. If the \( T_{\text{ma}} \) is higher than 50°C, then it is recommended that the testing is done in an oven.

<table>
<thead>
<tr>
<th>Parts in OPERATOR ACCESS ARE AS</th>
<th>Maximum temperature (( T_{\text{max}} )) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metal</td>
</tr>
<tr>
<td>Handles, knobs, grips, etc., held or touched for short periods only</td>
<td>60</td>
</tr>
<tr>
<td>Handles, knobs, grips, etc., continuously held in normal use</td>
<td>55</td>
</tr>
<tr>
<td>External surfaces of equipment that may be touched a</td>
<td>70</td>
</tr>
<tr>
<td>Parts inside the equipment that may be touched c</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 2: Touch temperature limits

---

a Temperatures up to 100 °C are permitted on the following parts:
- areas on the external surface of equipment that have no dimension exceeding 50mm, and that are not likely to be touched in normal use; and
- a part of equipment requiring heat for the intended function (for example, a document laminator), provided that this condition is obvious to the USER. A warning shall be marked on the equipment in a prominent position adjacent to the hot part.

The warning shall be either
- the symbol (IEC 60417-5041 (DB:2002-10)):
- or the following or similar wording

WARNING

HOT SURFACE DO NOT TOUCH

b For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature.

c Temperatures exceeding the limits are permitted provided that the following conditions are met:
- unintentional contact with such a part is unlikely; and
- the part has a marking indicating that this part is hot. It is permitted to use the following symbol (IEC 60417-5041 (DB:2002-10)) to provide this information.
Testing in an oven is typically exponential, where testing on the bench is typically linear when mathematically corrected.

Table 3 shows the temperature results of an information technology equipment (ITE) product that was tested both on a bench as well as in an oven.

Looking at Table 3, it is clear that testing on the bench and then mathematically correcting the values to the manufacturer’s stated $T_{ma}$ is much harsher than when it is tested in a heating oven that was set to $T_{ma}$.

**DETERMINING LINEAR FEET PER MINUTE**

Another issue that designers sometimes face relating to thermal testing is the terminology used in some of power supply specifications. Some power supply manufacturers use the term cubic feet per minute (CFM), while others may use linear feet per minute (LFM) when a supply requires forced air cooling. CFM is a measurement of volume while LFM is a measurement of velocity. Most fan manufacturers use CFM, while board designers prefer to use LFM as this makes calculating thermal derating curve or power dissipation much easier.

LFM is equivalent to CFM divided by the cross-sectional area of interest.

The larger the cross-sectional area, the smaller the LFM for a given CFM, as shown in the formula below:

$$\text{LFM} = \frac{\text{CFM}}{\text{area (ft}^2\text{)}}$$

Where:

- area is the cross-sectional area of the opening which typically happens to be the fan box size in square feet.
- if the fan is square, then the cross-sectional area is $L \times W$.
- if the fan is circular, then the cross-sectional area is $\pi r^2$.

**Example:**

A fan measures 40 x 40 mm and has a CFM of 5.2, then the LFM is calculated as:

1 mm = 0.00328 ft.
40 mm = 0.1312 ft.
$40 \text{ mm}^2 = 0.0172 \text{ ft}^2$
$\text{LFM} = \frac{5.2}{0.0172}$
$\text{LFM} = 302$

**REFERENCES**


---

**Table 3: Bench vs. Oven testing**

<table>
<thead>
<tr>
<th>TC Locations</th>
<th>Bench °C</th>
<th>Bench Adjusted to 50°C</th>
<th>Oven at 50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 windings</td>
<td>78.48</td>
<td>105.61</td>
<td>92.57</td>
</tr>
<tr>
<td>L24 winding</td>
<td>99.16</td>
<td>126.29</td>
<td>112.1</td>
</tr>
<tr>
<td>PCB next to Q9</td>
<td>91.36</td>
<td>118.73</td>
<td>104.56</td>
</tr>
<tr>
<td>CR32</td>
<td>63.84</td>
<td>90.97</td>
<td>77.73</td>
</tr>
<tr>
<td>PCB next to U19</td>
<td>50.02</td>
<td>77.15</td>
<td>65.59</td>
</tr>
<tr>
<td>Q40 body</td>
<td>77.40</td>
<td>104.53</td>
<td>91.19</td>
</tr>
<tr>
<td>Ambient</td>
<td>22.87</td>
<td>48.98</td>
<td></td>
</tr>
</tbody>
</table>

**Homi Ahmadi** is the Compliance Engineering Manager at Extron Electronics in Anaheim, CA and has responsibility for Extron global regulatory compliance affairs. He has extensive background in compliance which includes product safety, EMC and environmental. He is a Sr member of IEEE and iNARTE product safety engineer. He has published numerous articles and conducted seminars both in the US as well as UK to aid manufacturers with product design and compliance activities. He is currently a member of IEEE Product Safety Engineering Society (PSES). He received his Bachelor’s Degree in Engineering from the University of Mid-Glamorgan in Wales-UK. He held the position of program chair at IEEE PSES in Orange County from 2008-2010.
Hazard Based Safety Engineering (HBSE) principles have been used to better understand product safety and to help guide the design and evaluation of appropriate safeguards through analysis of sources, causes and mechanisms of harm. UL Applied Safety Science and Engineering Techniques (ASSET™) takes HBSE to the next level. ASSET leverages the strength of HBSE principles by expanding and integrating them with other established safety science and engineering techniques, including elements of risk management, systems and reliability engineering, functional safety and human factors. This paper outlines the expansion and integration of these principles and techniques, and demonstrates the potential of taking HBSE to the next level.

ASSET addresses diverse forms of harm, hazardous sources and objects of harm (persons, property, environment, critical operations), across a broad range of products, systems, services and applications, based on safety science. An asset in any organization is an item of value, a resource that provides advantage, such as a product realization design process that achieves safety by design. The design and evaluation of safety requires a systematic, methodical process. The effective use of a complete set of suitable, consistent design and evaluation techniques can help demonstrate that reasonable care and due diligence was exercised in the safety of a design.

The HBSE concepts initially conceived by engineers at HP/Agilent targeted typical types of hazards and forms of injury involving electronics products, such as information technology and office equipment. The HBSE concepts and tools have been further developed and applied with the support of research engineers at Underwriters Laboratories. UL University has been serving as the principal instructional organization for HBSE workshops. UL uses HBSE and applied safety science and engineering techniques in many facets of its work, such as research, development and interpretation of standards, and risk assessment with hazard and failure analysis of new and emerging products, applications and technologies. Applied safety science and engineering techniques will be briefly introduced in the context of safety and risk, and outlined in the context of other technical and managerial processes.

SAFETY
Safety and protection address the risk of harm. Safety has many meanings, applications, levels and contexts. Generally speaking, we can consider safety as freedom from unacceptable risk of harm. (IEC/ISO Guide 51). But let’s consider the qualifiers in this statement.

© 2010 IEEE. Reprinted, with permission, from the proceedings of the 2010 IEEE International Symposium on Product Compliance Engineering.
© 2012 UL LLC. All rights reserved.
This document may not be reproduced or distributed without authorization.
Harm can include unwanted effects or consequences, including injury or damage to health of persons (or animals including livestock and pets), damage to property or the environment, or interruption in essential commercial operations. This harm may be the result of a variety of factors, independently or in combination or sequence, involving hazardous situations and circumstances. Risk of harm is based on probability and severity, that is, the likelihood of harm occurring and the severity of its consequences if it occurs.

Unacceptable risk of harm is a level that is not tolerated. The degree of tolerance varies in accordance with many factors, including specific applications, situations and circumstances of product use, misuse and exposure. Risk attitudes and appetites vary among individuals, companies, industries, cultures, etc. Levels of unacceptable risk may be defined, for example, by regulatory bodies, authorities having jurisdiction, standards development bodies, etc., with input from others involved or affected.

Freedom from unacceptable risk of harm is a beneficial condition. But like many other freedoms that we enjoy, this freedom also comes at a cost. To achieve safety is no small task. It requires comprehensive, systematic review of all potential harm from hazards, and the prioritization of mitigating safeguards throughout the entire product lifecycle, considering all manners of exposure. Safety is relative, posing a challenge in product realization to balance with other design requirements, factors and constraints. This balance may be addressed, for example, by risk-benefit analysis, cost-benefit analysis or other techniques.

Safety is not without any risk, but with risk reduced to an acceptable level – by design, analysis and validation, including evaluation and testing for certification. It is said that safety is no accident. It is the practical manifestation of suitable design concepts, applied consciously and conscientiously.

Risk Management

There are a variety of means to assess, reduce and manage risk of harm. Risk analysis involves hazard identification and risk estimation in terms of likelihood of the occurrence of harm and the severity of its consequences should it occur.

Risk evaluation involves judgment of acceptability of risk. This leads to analysis of options to accept or reduce this risk, and then maintain or control it at an acceptable level. In some cases, this risk level may be considered to be As Low As Reasonably Practicable (ALARP), typically used in risk-benefit analysis for medical devices having health benefits to balance the risk of harm.

But risk is not necessarily a simple or straightforward combination of probability and severity rankings. Weighting factors may be applied to rankings, and scales may be nonlinear or contain discontinuities. Other factors may also need consideration, such as frequency, exposure, vulnerability, etc. In estimating and evaluating risk, it is important to consider that when the severity of consequences is very high (serious harm, death), then the likelihood must be demonstrated or known to be reliably low. This approach would be more conservative (safe) than an initial assumption of very low probabilities, resulting in trivializing (even unintentionally) the importance of potentially severe consequences.

Risk Management Publications

Many publications address various aspects and applications of risk management, including international guides, standards and series published by organizations such as the IEC (International Electrotechnical Commission) and ISO (International Standardization Organization), ranging from general-use to industry-, product-, hazard-, harm- and safeguard-specific categories. Basic references, some with very recent publications, include ISO IEC Guide 51 (Safety aspects), ISO 31000 (Risk management — Principles and guidelines), IEC/ISO 31010 (Risk management – Risk assessment techniques), IEC Guide 116, Guidelines for safety related risk assessment and risk reduction for low voltage equipment, IEC 60300-3-9 (Dependability management), and Risk Assessment Guidelines for Consumer Products (in Official Journal of the European Union, referencing GPSD, General Product Safety Directive and RAPEX, Community Rapid Information System).

Additional IEC and/or ISO Guides cover more specialized aspects such as terminology (73), vulnerability (50, 71), applications (37, 63, 78, 110, 112), environment (64, 106, 114), and procedural matters (2, 75, 104, 108).
Many publications address various aspects and applications of risk management, including international guides, standards and series published by organizations such as the IEC (International Electrotechnical Commission) and ISO (International Standardization Organization).

Certain industries, such as medical devices and machinery have developed a tiered structure of risk publications. Publications covering medical devices range from guides on safety aspects (ISO Guide 51) and drafting of safety standards (ISO/IEC Guide 63) to risk management for medical devices (EN ISO 14971), quality management systems for regulatory purposes (ISO 13485), to more specific standards on basic safety and essential performance (IEC 60601-1), followed by a series of collateral standards (IEC 60601-1 to IEC 60601-112), particular standards (IEC 60601-2-1 to IEC 60601-2-54) and essential performance requirements (IEC 60601-3 (-1)). Likewise, publications covering machinery range from guides on safety aspects (ISO Guide 51) and drafting of safety standards (ISO Guide 78) to general standards on risk assessment principles (EN/ISO 14121-1), practical guidance and examples (-2), to more specific standards on design concepts with terminology, methodology (EN/ISO 12100-1) and technical principles (-2), and electrical equipment of machines (EN 60204-1).

ASSET and Risk Management

ASSET integrates the current IEC/ISO body of knowledge on risk management, and addresses specific aspects including appropriate risk and hazard identification, risk reduction and risk control. For example, guidelines are provided for a suitable assessment of the scope of the analysis, including general characteristics, intended use and users, environment, installation, operation, maintenance, repair, shipping, storage, and reasonably foreseeable unintended use and misuse conditions. Then for hazard identification, additional steps help identify sources and possible conditions for harm. Risk estimation is supplemented with guidance to estimate and express risk. Risk evaluation is aided by steps to define and apply tolerable risk criteria for decisions. Risk reduction is guided by steps to analyze protective measures that reduce and/or control risk via safeguard attributes. Reassessment of residual risk is supplemented by steps to monitor and apply field data.

Safety Engineering Management Processes

Technical processes include the expansion and adaptation of HBSE, hazard analysis and risk assessment concepts, as well as application of techniques such as FTA and FMEA. Managerial processes include risk management, but the more overarching common element is “management” itself. Safety engineering management not only involves risk management, but also asset-, enterprise-, quality systems- (incl. quality assurance and continuous improvement), process- (design, mfg), document-, decision-, systems engineering- and system safety-, product safety-, project- and project risk-, design-, concurrent engineering-, design review-, configuration-, change control-, supply chain-, dependability-, life cycle model-, data (records), information security-, knowledge-, learning-, incident/recall- and disaster/emergency- management. As for risk management, these additional safety engineering management aspects are also addressed in many IEC, ISO and other publications. Document references are available upon request.

Safety Strategy

The strategy to meet safety objectives begins with applied safety science and engineering techniques. This helps to identify and prioritize research, and apply these findings to develop safety requirements and test methodologies that are appropriate, proactive, focused and consistent. This can then lead to safety attributes that are properly identified, validated and controlled for all scenarios, conditions, and lifecycle stages, both up and down the supply chain. The result is a demonstrated degree of safety and improvement.

Hazard Based Requirements

Hazard-based safety standards can offer clear safety objectives and various means to meet them. A hazard-based approach serves to reduce risk of harm by addressing each hazard. This approach would determine which undesirable effects are to be avoided, the susceptibility to them, their
conditions and causes, and appropriate protection against them. A hazard-based standard would identify the objectives of protecting against each specific undesirable effect, and directly relate them to appropriate protection requirements and limits. HBSE principles have also formed the foundation of hazard-based requirements in product standards such as IEC 62368-1, Audio/video, information and communication technology equipment – Part 1: Safety requirements.

**ASSET EXPANSION OF HBSE CONCEPTS AND TOOLS**

ASSET expands the basic HBSE concepts and analysis tools in ways that include the following, as shown in Figure 1.

**HBSE Premise**

The HBSE Premise for Injury is a 3-block model based on energy transfer, which outlines the 1) hazardous source and 2) transfer mechanism to 3) a body/part that is subject to injury. Injury can occur when the magnitude and duration of energy transfer exceeds the body/part susceptibility, or its inability to withstand it.

Examples include mechanical forms of energy that may cause various types of physical injury; thermal energy (heat) that may cause skin burn injury; electrical energy that may cause “electric shock” or unwanted physiological (including lethal) effects; and electrically caused fire that may cause injury and property damage. This model can forewarn of injury if its elements can be quantified, in terms of the characteristics of the energy source and rate and degree of transfer (delivered and received), and the inability of a body/part to withstand it (susceptibility).

However, this simple model can be expanded in a variety of ways, adapted to address other types of hazards, transfers and harm. For example, the hazardous source (1) can involve other forms of energy, including acoustic noise, pressure (sonic/ultrasonic/fluid/gas), explosion/implosion, arc flash/blast, radiation (visible, UV, IR, ionizing (gamma)/non-ionizing (laser)), vibration, fields (electric/magnetic/electromagnetic), unintended motion or activation, as well as potential energy (suspended masses, support failures) or stored energy (springs, capacitors) that may be converted to other forms.

In addition, the hazardous source (1) can also be in the form of matter. This could include an object (person contributes to transfer), involving a sharp edge (laceration) or small part (choking) or long part (strangulation), where other factors of the harm mechanism need also be considered. This could also include a harmful substance, such as chemical (toxic/carcinogenic) or biological (bacteria) material. Recall the RoHS (Restriction of Hazardous Substances) directive that curtails the use of materials such as lead, mercury, cadmium, hexavalent chromium, PBB and PBDE to infinitesimal levels (parts per million).

The transfer mechanism (2) can cause harm in a direction to the body (e.g., applied force), as well as away from it (e.g., extracted heat), or even involve a reduction or restriction of transfer (energy or substance) that is needed to maintain health (e.g., air restriction due to small-part choking hazard).

And in addition to injury to persons (3), other forms and objects of harm can be addressed. Such harm may also involve damage to health or welfare of persons, injury to animals (livestock, pets), and damage to property, the environment or essential commercial operations.

![Figure 1: HBSE Premise, 3-block energy transfer model for injury, expanded](image-url)
Other factors must also be considered. For example regarding environmental harm, lifecycle issues of electrical and electronic products raise additional safety concerns. With concern for PBTs (Persistent Bioaccumulative Toxins), is the hazard persistent, taking a relatively long time to break down in the environment? Is it bioaccumulative, whereby substances collect in living organisms and ultimately end up in the food chain and persons? Is it toxic, with known potential for harm, whether acute (immediate) or chronic (longer-term)? By what means is it transferred, and in what amounts and durations, and to what degree?

Other functional aspects such as incorrect outputs can also lead to harm, involving energy or substance, due to hardware, software or human interface factors, resulting from incorrect control, timing, duration, sequence, etc. These aspects are more closely associated with functional safety, addressed separately.

**HBSE Process**

The HBSE Process is a flow diagram that considers all sources (hazardous energy) associated with a product, how they may cause harm by transfer, and how this transfer can be reduced to protect against injury. It helps us to analyze specific protective mechanisms (safeguards) having features and properties that are needed to protect against specific harm mechanisms.

This simple model can also be expanded in a variety of ways. For the first HBSE Process step (1), “Identify Energy Source”, consideration is needed for all sources (energy/substance) that are supplied to, contained within, converted by, used by or associated with the product.

For the next step (2), “Is Source Hazardous”, consideration is needed for whether the source is capable of causing harm. These steps need to conducted for each type of source, transfer means/mechanism, potential for harm and entity subject to harm. Is the source hazardous with respect to the product function, application, environment, uses, users and others involved, exposed, having access, or otherwise affected?

Is this an unacceptable risk of harm? How is an acceptable level of risk determined? What factors may this depend on (use, users, environment, values, etc.)? What conditions make the source hazardous or its transfer harmful? Can this occur in normal operation and intended, normal use? Or does it require an abnormal or unintended condition? Must other unwanted or fault conditions have occurred in the past or exist in the present?

Are these conditions of omission (inaction) or commission (action/reaction)? Do they involve hardware, software and external influences (environment, human interaction and error, etc.)? Are these conditions reasonably foreseeable? It’s been said that all conditions are foreseeable (which may not necessarily require action), but following an incident a jury may decide what is reasonable (what actions should have been taken).

The product may have been evaluated to perform all design functions as intended (do what intended). But have all reasonably foreseeable conditions been anticipated? Has the product been evaluated to suitably and safely respond to all these conditions, combinations and sequences and at least fail-safe (NOT do what NOT intended)? Has this performance been validated by test? Have the safeguards, and their specific properties, relied on for this performance been evaluated and controlled?

For the next step (3), “Identify Means by which Energy can be Transferred to a Body Part”, consideration is also needed for direction and/or restriction of transfer, whether to, from, or blocked (if needed) from the person (body part) or other object of harm (property, environment, etc.).

![Figure 2: HBSE Process with expansion notes](image-url)
For the next step (4), “Design Safeguard Which Will Prevent Energy Transfer to a Body Part”, consideration is also needed for preventive safeguards that reduce, control or eliminate the source (total amount), as well as mitigating safeguards that reduce, control or eliminate the transfer (transferred rate, duration and amount). The hierarchy of protection should be to first eliminate the hazard (design it out), then guard against the hazard (reduce the source and then the transfer), then warn about the hazard (relying on personal responsibility and other factors for avoidance). In some cases it may also be possible to reduce susceptibility to a hazard by increasing the resistance to the source, such as through material properties including resistance to ignition.

For the next steps (5), “Measure Safeguard Effectiveness” and (6) “Is Safeguard Effective”, much additional consideration is needed to properly understand and apply this “effectiveness” measure, which involves safeguard attributes. Which specific properties of safeguards are relied upon for each protective function? Under what conditions must they function effectively? What conditions may tend to degrade this performance or render it ineffective? How well do these attributes hold up under each of these conditions, including combinations and sequences? Just as in evaluating risk, when the severity of consequences is high (i.e., safeguard failure), the likelihood must be demonstrated or known to be reliably low.

Safeguards attributes are properties of protective features and mechanisms, which need to be specifically identified, evaluated and validation tested under all reasonably anticipated conditions, and controlled in design and manufacturing. These attributes can be summarized in the descriptive term DURESS (Durability, Usability, Reliability, Efficacy, Suitability, Scalability), which helps describe the needed characteristics:

Durability – protective characteristics should be able to withstand, and not be adversely affected by conditions, circumstances and scenarios of use (reasonably foreseeable use, unintended use, misuse or abuse)

Usability – protection should function as needed, without interfering with normal, intended product functions (so as not to invite defeating of safeguards)

Reliability – protection should maintain its essential performance throughout its entire design life, in all conditions and stages of the product lifecycle (cradle-to-grave)

Efficacy – protection should be able to effectively perform the needed safety function, without introducing or increasing other hazards (fix one problem but create another)

Suitability – protection should be provided to a degree appropriate for the application, based on the level of risk with a suitable safety factor that demonstrates the degree to which tested performance limits exceed minimum thresholds of harm

Scalability – protection should perform as needed in the intended scale of use, properly interacting with other materials, components, systems and environments (small-scale properties appropriate for large-scale applications and conditions)

**HBSE Fault Tree for Injury**

Fault Tree Analysis (FTA), a deductive, graphical, top-down analytical method in which the top event is a fault, such as harm or other undesirable event. It outlines the necessary and sufficient conditions and logical relationships for this harm to occur, in order to determine the most likely contributors (root causes on critical paths) and the most effective safeguard strategies.

The HBSE fault tree for injury outlines conditions leading to the injury top event, with initial necessary and sufficient conditions of hazardous energy and exposure of (for transfer to) a susceptible body part. This fault tree model can be expanded to include other types of hazards and harm. It can also depict the order of priority for safeguards, to eliminate, guard or warn about the hazard. Such FTA models have been successfully used in analysis of fire scenarios, including those caused by lithium ion batteries.

**FTA AND FMEA/FMECA**

To complement the deductive, top-down FTA, one can use an inductive, bottom-up analysis method such as Failure Modes and Effects Analysis (FMEA) or Failure Modes and Effects Criticality Analysis (FMECA), which more directly considers the effect of severity and risk rankings. This method begins at the “bottom”, with individual items (components, materials) and their functions (in each operating mode). Failure modes, effects, severities, likelihoods and other factors are determined, and then potential causes, recommended actions, and resulting effects are analyzed methodically. Integrated FTA/FMECA techniques have also been successfully applied to fire risk involving lithium ion batteries, as we presented at the latest NASA Aerospace Battery Workshop (2009).

**SYSTEMS ENGINEERING**

Elements of the systems engineering approach address scope and context, from concept through all product lifecycle stages (cradle-to-grave), from design through prototyping, manufacturing, assembly, packaging, transport, storage, installation, commissioning, operation, maintenance, repair, decommissioning, reuse to disposal.
Specific properties of materials and components, including hardware, software and human elements, need to be compatible with the needs, influences and interfaces of subsystems and the overall system, including external systems and the environment (micro and macro). Functions, characteristics and properties need to be considered for materials, components, devices, circuits, subsystems, systems and processes, as contributing to harm or to protection.

**RELIABILITY ENGINEERING**

Reliability engineering elements address the criticality of safety-critical functions and features, and the conditions under which they must continue to perform effectively. Reliability approaches such as probability of failure, circuit redundancy and fail-safe modes are also used in techniques such as FTA and FMEA, and addressed by a number of related disciplines, including system safety and dependability management.

**FUNCTIONAL SAFETY**

Functional safety is a special field that specifically addresses electrical, electronic and programmable systems. Similar to other types of safeguards, reliance is placed on specific functions or characteristics of a product, requiring certain attributes. But a safeguard in functional safety is considered to be the essential performance of hardware and software controls that manage safety-critical functions. Some functional safety aspects may be directly protective by design (life safety). Functional safety aspects in other applications address functions for which failure may lead to increased risk of harm (immediate or imminent), loss of a required level of protection, or other reduced ability to protect against harm. In “single-fault” analysis, the conditions that rely upon protective mechanisms to operate should be considered as given conditions, and any failure or inadequacy of this protection would be considered as the fault condition.

**HUMAN FACTORS**

Elements of human factors address many aspects, including anthropometry, physiological responses and susceptibility to energy and substance transfer, behavior (product use, misuse, abuse or hazard avoidance), human error, interaction, and other human characteristics including performance, limitations, etc. related to aspects of a product or system, such as design, manufacturing, operation, maintenance, etc.

**SUMMARY**

ASSET integrates these elements to leverage the strengths of HBSE, risk management, and other techniques, to optimize the value of our resources and assets: our individual and

---

**Figure 3: HBSE Fault Tree for Injury, expanded**
collective safety knowledge, experience and expertise. The application of safety science and engineering techniques to any hazard is based on examining the types and mechanisms of harm in order to consider appropriate mechanisms for protection. This analysis includes the conditions and circumstances that must be present, first for harm to occur, and then for protection against it. It’s a basic but robust approach, in which simple tools can be applied, with appropriate subject matter expertise, to simple or complex scenarios in a consistent, repeatable manner, an asset to any organization.

“The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hard substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judge like the lawyers. He cannot, like the architects, cover his failures with trees and vines. He cannot, like the politicians, screen his shortcomings by blaming his opponents and hope the people will forget. The engineer simply cannot deny he did it. If his works do not work, he is damned.” - Herbert Hoover (1874 - 1964).

ACKNOWLEDGMENT

The author wishes to acknowledge the HP/Agilent authors of the initial HBSE concepts, including R. Nute, R. Corson, J. Barrick and D. Adams, as well as UL Research, Engineering and University staff including R. Davidson and D. Bejnarowicz for their valuable technical contributions toward this material.

REFERENCES


Thomas Lanzisero is a Sr. Research Engineer and Distinguished Member of Technical Staff at UL LLC (Underwriters Laboratories, Melville, NY) with nearly 30 years of applied practice in safety engineering. He is a registered Professional Engineer (P.E.) and principal instructor and practitioner of Hazard Based Safety Engineering (HBSE). He has led development of Applied Safety Science and Engineering Techniques (ASSET™), including the ASSET Safety Management Process for informed decisions to achieve, maintain and continuously improve safety as a design objective. This work has recently been recognized with a 2011 IEEE Region 1 Award for Technological Innovation.

This and related hazard analysis and risk assessment work has been extensively published and presented, including keynote presentation on the safety of consumer electronics into the future at the 2012 International Conference on Consumer Electronics (ICCE) by the IEEE CES, 2012 Advanced Product Safety Management course at St. Louis University, 2010 and 2011 International Symposium on Product Compliance Engineering by the IEEE Product Safety Engineering Society, 2011 IEEE Chicago Argonne National Laboratories Technical Conference, International Consumer Product Health and Safety Organization (ICPHSO 2011), Association of Southeast Asian Nations (ASEAN), Asia Pacific Economic Cooperation - Joint Regulatory Advisory Council (APEC JRAC Risk Assessment Workshop), American Society of Safety Engineers (ASSE) and NASA (2009 NASA Aerospace Battery Workshop).

An IEEE Senior Member, Tom is Founding Chair of the Long Island, NY Chapter of the IEEE Product Safety Engineering Society (PSES) and Vice Chair of the IEEE Risk Assessment Technical Committee (RATC). He serves as technical expert in committees for electric shock protection and risk management, including US National Committee Technical Advisory Groups (USNC TAGs), the International Electrotechnical Commission (IEC TC64 MT4) and the International Organization for Standardization (ISO 31000 / ANSI Z690). He can be contacted at +1.631.546.2464 or thomas.p.lanzisero@us.ul.com.
Applied Safety Science and Engineering Techniques (ASSET™)

The Evolution of Hazard Based Safety Engineering into the Framework of a Safety Management Process

BY THOMAS LANZISERO

Applied Safety Science and Engineering Techniques (ASSET) merge hazard based safety engineering and safety science principles in an overall framework of a safety management process to achieve, maintain and continuously improve safety. The ASSET process has been synthesized from current, industry-standard risk assessment and risk management guidelines, including recent ISO, IEC and ANSI publications.

Basic relationships are explored among hazards, exposure and harm to persons, property and the environment. Various potential approaches to protect against harm are then explored in the framework of safety management, systems engineering, quality management systems, concurrent engineering, human factors and other relevant principles.

This ASSET Safety Management process has potential application in virtually any industry and product segment to support informed decisions on solutions to difficult safety issues, using sound safety science and engineering experience and judgment. This article for the 2011 IEEE PSES symposium covers the ASSET safety management process, its guiding principles and objectives.

ASSET OBJECTIVE

The objective of the ASSET Process of Safety Management is to utilize Applied Safety Science and Engineering Techniques (ASSET™), together with existing standards, codes and regulations, to achieve, maintain and continuously improve the safety of products, processes and services for safer living and working environments. ASSET™ (Applied Safety Science and Engineering Techniques) is a trademark of Underwriters Laboratories Inc.

BACKGROUND

This article follows the introductory article Applied Safety Science and Engineering Techniques (ASSET™): Taking HBSE to the Next Level (In Compliance, November 2012) which was presented at the 2010 ISPCE of the IEEE Product Safety Engineering Society, and had established the case and set the stage for ASSET.

A similar article was published by the American Society of Safety Engineers in their SH&E (Safety Health and Environment) Standards Digest, a publication of their Engineering Practice Specialty. ASSET also reflects concepts of the ANSI/ASSE Z690 series, the US national adoption of ISO 31000, ISO/IEC 31010 and ISO Guide 73, initiating membership on the ISO TAG on Risk Management.

Certain ASSET principles have been applied and presented in recent conferences including the 2009 NASA Aerospace Battery Workshop ("FTA (Fault Tree Analysis)/FMEA (Failure Modes and Effects Analysis) Safety Analysis"

© 2011 IEEE. Reprinted, with permission, from the proceedings of the 2011 IEEE International Symposium on Product Compliance Engineering.

© 2012 UL LLC. All rights reserved. This document may not be reproduced or distributed without authorization.

With essential technical input and development of Bob Davidson and strategic leadership of Dan Bejinowicz, ASSET was developed in the safety management process framework. Notification has just been made that this ASSET work has earned a 2011 IEEE Region 1 Award (Northeastern US) in the category of “Technological Innovation (Industry or Government): For significant Patents, for discovery of new devices, development of applications or exemplary contributions to industry or government.”

ASSET is now the subject of a 2-day workshop to put your skills to the test by applying ASSET analysis to example products and prepare to address difficult safety issues using a multi-disciplined, team-oriented approach, supported by science as well as your own experience and judgment.

**ASSET APPLICATION**

The ASSET process has application in areas including the development of safety standards, codes, and regulations, and the design, evaluation, compliance, certification and safety management of products, processes and services. As such, ASSET applies to functions and responsibilities including safety designers, regulatory compliance, product safety certifiers, standards/codes developers and product and program safety managers. ASSET can also help to integrate and address the needs of various stakeholders including regulators, AHJs, standards developers, trade and professional organizations, consumer groups, government agencies and the public.

For example, relevant safety requirements are generally determined by first establishing the scope of the product, process, or service in question. This scope is then compared to the scope of identified standards, codes and/or regulations that may potentially apply. The scope and context of the assessment itself is also established, including boundaries, and scope alignment on all three counts is sought. In this early stage and throughout the process, potential gaps need to be identified and bridged. A gap may exist for example, if a product, process or service – in the context of its application – does not fall completely within the scope of existing safety standards. Another gap may exist whereby a product, process or service falls within the scope of a safety standard, but involves features, functions, technologies or applications that may (a) introduce a safety hazard, and (b) not be anticipated or addressed by the requirements in the standard.

**ASSET AND STANDARDS**

ASSET provides a process and methodology for (a) complementing existing standards in evaluating the safety of products, processes or services, (b) assisting in the evaluation of products, processes or services not within the scope of existing standards, (c) evaluating product features (materials, constructions), functions, technologies or applications not anticipated or covered by existing standards. In these situations, ASSET can be applied to (1) help identify hazards not anticipated or covered by existing standards and the need for additional requirements to meet the safety objective (intent) of the standards, and (2) help identify alternative protective measures not anticipated by the standard but which can achieve an equivalent level of safety to the protective measures specified in the standard, thereby meeting the safety objective (intent) of the standard.

In fact, the ASSET process stages include repeated “spec-checks”, whereby the initially identified requirements are assessed at each stage.

**ASSET SAFETY MANAGEMENT PROCESS**

The ASSET process of safety management was developed as the evolution of hazard-based safety engineering principles and safety science into an overall framework of a safety management process. Hazard Based Safety Engineering (HBSE) was originally conceived by HP/Agilent, and targeted typical types of hazards and forms of injury involving electronics products, such as information technology and office equipment.

The ASSET process is based on a number of acknowledged risk management/risk assessment principles and processes, for example those found in publications including but not limited to ISO/IEC Guide 51, IEC Guide 116, ISO 31000, ISO/IEC 31010, ISO 14121, ISO 14971, IEC 60300-3-9 and ANSI/ASSE Z690.

This process involves stages to (a) formulate the right types of questions to identify the scope of the product, system or service to be evaluated for potential harm, (b) identify and analyze hazards (potential sources of harm), (c) identify, analyze and evaluate protective measures to reduce the risk of harm (e.g., risk of injury from products), (d) assist in the determination of whether or not an acceptable level of safety is achieved, (e) understand and apply methods to maintain and continuously improve safety. This can help explain, apply and enhance existing requirements, and help address emerging technologies, products and applications.
This ASSET process was developed to address a broad spectrum of applications, and each stage has different needs and significance for the assessment of different products, processes, services in different applications. The following provides a brief look at each ASSET process stage and its objectives.

**Determine Scope/Context**

The goals of this stage are to determine and attempt to align the scope and context of the following: the product, process or service to be assessed, the assessment itself and the initially identified requirements. Relevant topics include (a) the subject of the assessment, including systems aspects of materials, components, subsystems, environment and boundaries with interfaces and interactions, (b) intended implementation, operation, use, users and others affected (c) conditions and requirements for installation, (d) recommended procedures for maintenance and repair, (e) potential effects of packing, shipping and storage, (f) reasonably foreseeable misuse (using a sub-process developed to determine degrees of reasonable foreseeable misuse and associated guidance), (g) other conditions or factors of potential impact, and (h) applicable standards, codes and/or regulations.

**Identify/Analyze Hazards**

The goals of the stage are to (a) identify potential types and sources of harm (hazards), (b) determine how harm can occur (hazardous situations, hazardous and harmful events) and the severity of the harm, (c) sort consequences by the level of severity (initial consequence evaluation akin to worst case scenario, with guidance on severity factors, and consideration of extent and exposure of harm), and (d) determine if the applicable standards, codes and/or regulations address the identified hazards, or if there are gaps that need to be addressed.

**Specify/Identify/Design Protective Measures**

In this stage, protective measures are specified, identified or designed, depending on the given function and responsibility being fulfilled. For example, a protective measure may be specified by developers of standards, codes and regulations, designed by a manufacturer or identified by an evaluator. This stage has goals to (a) establish the safety objective(s), (b) determine the need for protective measures, (c) identify the potential protective measure strategies, categories and mechanisms, (d) analyze and prioritize protective measures, and (e) specify, design and implement the protective measures.

**Evaluate Protective Measures**

The goal of this stage is to determine whether protective measures are adequate and effective by (a) evaluating whether and how protective measures meet specific safety objectives, (b) identifying safety attributes that are being relied upon and need to be controlled, and (c) evaluating those safety attributes. In order to determine if the goal of this stage is achieved, key questions are asked which include the following:

- Have all the hazards been identified?
- Have the safety (risk reduction) objectives been determined?
- Have the protective measures intended to address the hazards and achieve the safety objectives been identified and designed?
- Have tests and evaluations been conducted to demonstrate that the protective measures are capable of achieving the safety objectives with acceptable results?
- Have the constructions, components and materials that are relied upon for the protective measure to meet the safety objectives been identified?

![Figure 1: ASSET Process of Safety Management](image-url)
• Have their safety-related characteristics (safety attributes), factors which may degrade those characteristics, and the tests and evaluations needed to determine their adequacy been identified?

• Have the necessary evaluations/tests been performed with acceptable results?

Through this point in the ASSET process, these stages generally involve activities such as hazard based safety engineering, safety research, safety design, conformity assessment and new standards development. It is also noted that the evaluation of certain protective measures, including life safety devices, may effectively begin at this stage.

Decision Gate: Acceptable Level of Safety Achieved?

There are two basic outcomes of this safety decision. If it is determined that an acceptable level of safety has been achieved, then there is a need to control, monitor and review to maintain safety. However, if an acceptable level of safety has not been achieved, there is a different need to assess and decide on action. This may involve revisiting earlier process stages or discontinuing.

This point of the ASSET process generally involves conformance and compliance activities.

Control/Monitor/Review to Maintain Safety

At this stage, if determined that an acceptable level of safety has been achieved, the goal is to ensure that safety is then maintained by (a) establishing controls throughout the life cycle, up the supply chain, to ensure that safety is maintained, (b) monitoring field performance down the supply chain and factors that may impact safety by means of surveillance and follow up, and (c) periodically reviewing and assessing results and deciding on appropriate actions.

Decision Gate: Present Level of Safety Maintained?

Similar to the prior decision gate, there are also two basic outcomes of this safety decision. If determined that the present level of safety is being maintained, then there is a need to control, monitor, and review. However, if the present level of safety is not being maintained, there is a different need to assess and decide on action. Again, this may involve revisiting earlier process stages or discontinuing.

This point of the ASSET process generally involves activities including certification, market and conformity surveillance, follow-up for certification mark integrity, updates in regulations, standards and codes, and assessment of new/emerging technologies that may either benefit or threaten safety.

Identify Opportunities for Improvement

The goal of this stage is to monitor and identify the opportunity, or the need, for improvement in (a) safety and safety standards and (b) the processes, methods and tools used to determine whether and how safety is achieved and maintained. These opportunities are then assessed to decide on action, which may involve revisiting earlier process stages.

Activities involved in this stage of the ASSET process include improvements in regulations, standards and codes, as well as improvements in safety assessment processes, methods and tools.

MEETING THE OBJECTIVE

The stated objective of the ASSET Process of Safety Management is to utilize Applied Safety Science and Engineering Techniques (ASSET™), together with existing standards, codes and regulations, to achieve, maintain and continuously improve the safety of products, processes and services for safer living and working environments.

By this we mean to a) achieve an acceptable level of safety (once determined, based on specific safety objectives), b) maintain that present level of safety (throughout the entire lifecycle of the product, process or service, under all anticipated conditions, considering upstream (suppliers) and downstream (users and all affected) the supply chain), and c) continually seek and assess opportunities for improvement (based on the availability, need or demand for improvements).

ASSET stresses the importance of assessing the sources, causes and conditions of harm (as did HBSE before it), as well as the risk of harm (severity, likelihood, extent, exposure). ASSET also addresses different forms of potential harm to various entities, including persons (injury or health risk), property, the environment and even continuity of critical operations and functions. Sources are categorized in terms of energy or matter/substance that may be harmful, from different sources in various forms, conversions or conditions. The standard HBSE tools (3-block energy transfer model for injury, HBSE process to evaluate a safeguard and standard injury fault tree) are adapted and expanded.

Then the most effective protective measure strategies can be determined, with appropriate identification, evaluation and control of safety attributes -the very properties and characteristics of protective measures relied upon to achieve, maintain and improve this level of safety.

The ASSET process supports informed decisions using the best available information, data and other resources, based on the best available knowledge and experience, at progressive stages of development. This can help identify the degree of
confidence in the decision and the relative need and value of additional inputs or analysis. ASSET can also serve as a tool for effective communication and interaction to share information, as needed by various stakeholders.

**ACKNOWLEDGMENT**

The author wishes to acknowledge the indispensable technical and strategic contributions of Robert J. Davidson, Jr. and Daniel E. Bejnarowicz of UL University.

**REFERENCES**


8. Hazard Based Safety Engineering (HBSE) UL Supplement, Underwriters Laboratories Inc., 2003


15. Potential Failure Mode and Effects Analysis in Design (Design FMEA), SAE J1739, 2009

**Thomas Lanzisero** is a Sr. Research Engineer and Distinguished Member of Technical Staff at UL LLC (Underwriters Laboratories, Melville, NY) with nearly 30 years of applied practice in safety engineering. He is a registered Professional Engineer (P.E.) and principal instructor and practitioner of Hazard Based Safety Engineering (HBSE). He has led development of Applied Safety Science and Engineering Techniques (ASSET™), including the ASSET Safety Management Process for informed decisions to achieve, maintain and continuously improve safety as a design objective. This work has recently been recognized with a 2011 IEEE Region 1 Award for Technological Innovation.

This and related hazard analysis and risk assessment work has been extensively published and presented, including keynote presentation on the safety of consumer electronics into the future at the 2012 International Conference on Consumer Electronics (ICCE) by the IEEE CES, 2012 Advanced Product Safety Management course at St. Louis University, 2010 and 2011 International Symposium on Product Compliance Engineering by the IEEE Product Safety Engineering Society, 2011 IEEE Chicago Argonne National Laboratories Technical Conference, International Consumer Product Health and Safety Organization (ICPHSO 2011), Association of Southeast Asian Nations (ASEAN), Asia Pacific Economic Cooperation - Joint Regulatory Advisory Council (APEC JRAC Risk Assessment Workshop), American Society of Safety Engineers (ASSE) and NASA (2009 NASA Aerospace Battery Workshop).

An IEEE Senior Member, Tom is Founding Chair of the Long Island, NY Chapter of the IEEE Product Safety Engineering Society (PSES) and Vice Chair of the IEEE Risk Assessment Technical Committee (RATC). He serves as technical expert in committees for electric shock protection and risk management, including US National Committee Technical Advisory Groups (USNC TAGs), the International Electrotechnical Commission (IEC TC64 MT4) and the International Organization for Standardization (ISO 31000/ ANSI Z690). He can be contacted at +1.631.546.2464 or thomas.p.lanzisero@us.ul.com.

ASSET is trademark of UL LLC

ASSET and HBSE workshops are available through UL.
The verification of electrostatic discharge (ESD) protection in a complex integrated circuit (IC) design is extremely challenging. Leading-edge designs have many supply domains and voltage levels for different functional parts like radio frequency (RF), digital and high voltage blocks, making ESD checking a complex and error prone task. Relying on manual verification alone poses a significant risk of missing design flaws, which can be very costly during manufacturing and in the field. Consequently, automated ESD checking is highly desired in today’s design flow. This article outlines the essential requirements of the ESD verification flow as defined by the ESD Association (ESDA) Electronic Design Automation (EDA) Tool Working Group [1].

![Figure 1: A simple ESD verification flow mapped to sample IC design flow.](image)

Figure 1 illustrates the timeline and main stages for an example design flow. The IC product design flow (top row) needs to be synchronized with an ESD development and implementation flow (middle row). The latter needs to be supported by an ESD check flow (bottom row).

The following sections describe the main IC development phases and give examples of different ESD checks relevant for these phases.

**PRODUCT DEFINITION PHASE**

The ESD performance specifications usually follow commonly accepted standards. However, depending on the field of application, they can be modified by marketing teams and IC customers. Product design specifications and required ESD performance dictate specifications of ESD components and ESD cells. Based on these functional requirements, suitable ESD cells are defined per each pin application node (signal, power, and ground). Typically the ESD cells are made accessible to the designer in a dedicated ESD library.
In a situation when a mature semiconductor technology is used with already developed ESD libraries, only placement and product specific modifications of the existing ESD components and ESD cells need to be verified. For a new IC product that uses a new semiconductor process, an ESD library may not be available and no specific cell level ESD checks can be executed. However, performance specifications of the needed ESD library could still be defined, together with the IC customer, based on the available ESD technology development data and ESD EDA data from other products/technologies.

Based on the available design data in this design phase, the following ESD checks can be performed:

- Protected device checks to verify that the available ESD library cells can provide the required safe operating conditions for the protected components at each pin, for the given design functional requirements.
- Cell-level checks on the existing ESD cells.
- Package-level checks to determine, for example, expected peak charged device model (CDM) currents, as well as package and die specifications to meet CDM performance specifications.

Due to the nature of these data, a simple check of the ESD compliance can be done based on the ESD characteristics of the ESD cells in a design database. The following is an ESD EDA check example performed during product definition.

An early analysis of the integrity of I/O cell, bus placement and the overall ESD robustness is one of the essential factors of a successful chip design. An ESD floorplanning checker for the chip could enforce the ESD design rules to be verified while planning I/O cell and power bus placement. In particular, the checker could verify the existence of an ESD cell/device between pads, estimate parasitic resistance between pad and ESD cell/device, and give a rough estimate of the chip ESD robustness by predicting pad voltage (Figure 2).

**CHIP ARCHITECTURE PHASE**

At this design stage, the functional/behavioral level of chip architecture is defined and the required ESD components and library cells are identified. No circuit or layout level IC description is available in this phase. Similar to the previous section, cell level checks and protected device checks can be performed. The available design data are similar to those described in the previous section.

**MODULE AND FULL IC DESIGN PHASE CHECKS**

This is the main design activity phase, involving complex interaction between all product teams. It can be divided into three sub-stages.

The first stage is the floorplanning of the chip architecture modules and the standard digital I/O and power banks. The ESD checks that could be done at this design stage are limited to top-level verification of the ESD network within the digital I/O banks and ESD connectivity between the different modules, the related I/O banks in the different power domains and the package level ESD connections. These checks include:

- Protected device checks for the digital modules.
- Cell-level checks for the new ESD library cells.
- Intra-power domain checks for the digital intellectual property (IP).
- Floor plan/top-level ESD checks for the power and ground domain bus crossing.
- Basic package level checks.

The second stage is the design of IP modules and analog I/O pad rings. At this design stage, the analog (and RF) modules and the related I/O banks are physically designed. In many cases, the analog IP module team is different from the I/O and power/ground cell design team, which is often responsible for integrating the ESD library cells. The module team may not have detailed information about the ESD components used at cell level and special attention is needed when checking the overall ESD implementation. A certain level of co-design between the analog modules and the dedicated ESD protection cells may be needed as well. Based on the available design data, the following ESD checks could be performed:

**Figure 2: A sample I/O assembly checked with an ESD floor plan checker. Tool output flags missing ESD protection devices and large resistances in the ESD current path.**
• Cell-level checks for the analog pin ESD library cells (can be newly developed, e.g. for custom analog form factors or in-module/off- pad ring placement).

• Intra-power domain checks for analog pad rings.

• Intra-power domain checks for each analog module.

• Inter-power domain checks (if there are several power domains in one analog module).

• Protected device checks for the individual modules.

• Special ESD rule checks on specific analog/RF blocks/IP’s – e.g., differing ESD target levels.

Specific tool functionality is needed for the cases where the ESD protection cells are placed in the analog pad ring, which is not available to the team performing the ESD checks at module level. Such tool functionality can be extended to allow verification of module ESD robustness against cross-power domain or cross-IP stress events. This is especially useful when the counter pins are not available physically but some information about the involved ESD network (ESD cells, connectivity) is present in the design database. This can be considered a “virtual chip integration” where only a particular module design is physically available to the team running the check. This situation also applies to the verification of a given module involving evaluation of ESD performance of third party IP (“black box”).

The third stage is full-chip IP and I/O integration, including package. This is the final level of ESD checks applied to the whole IC. The main purpose is to verify the integration of the individual IP ESD circuits at top IC level, to check for the new cross-IP integration ESD violations and parasitic devices, and to verify that the protected components at each individual IP module are still operating in their ESD safe operating area (SOA) for stress combinations including other IP.

Based on the available design data, the following ESD checks could be executed:

- Inter-power domain checks.
- Package-level checks.
- Protected device checks for the full IC.

For certain classes of designs (e.g., some digital designs), it might be possible to implement certain hierarchy of checks so that at the full chip level the individual design blocks are considered as “black boxes” and only the integration of the blocks is verified.

The following is an example of ESD checks of the module and full IC design phase aimed at identifying potential ESD weaknesses of I/O assemblies (rings or arrays). An I/O assembly could be checked at this stage with an ESD verification tool covering both the layout checks and the electrical checks. The layout checks could ensure that the predefined ESD rules are strictly followed. In particular, the checker could flag input buffer gates and output buffer drains without adequate ESD protection, parasitic bipolarons, violations of minimum ESD metal width, etc. The electrical checks of I/O assembly at this stage can vary in complexity: they can use simplified I/O netlists only or include detailed models of ESD protection elements and parasitics. The verification of primary ESD current path existence and checking of alternative current paths for each pin-to-pin combination is the main objective of the check at this stage [2]. The checker could flag the situation where no ESD current path exists or where an unintended parallel path with weak devices becomes preferred during an ESD event. Basic checks can be done using an extracted netlist from the schematic for all pin-to-pin combinations. This can then be followed by a more detailed analysis for selected pins using the netlist extracted from the layout. Figure 3 shows part of an I/O ring with primary and alternate current paths for a given pin stress combination. An appropriate check of these two current paths would involve high speed static and dynamic simulations on the large netlist of interconnect and ESD relevant components.

**DESIGN QUALIFICATION PHASE**

In this phase, final design audits and ESD performance assessments are executed using the verification results from the previous phases. This is often done based on a custom, company-defined standard practice methodology, summarized in an “ESD check list” or other document. The goal is to confirm that all required ESD verification activities have been performed.

EDA tool functionality at this design stage is mostly related to reporting and documenting the results of the checks executed earlier and storing the results in a suitable database for further analysis. Such analysis is usually needed for product ESD troubleshooting during IC qualification.
In practical design cases involving complex IC products and ESD solutions, there could be situations in which some ESD violations may still be reported when an IC is sent for manufacturing due to limitations of the ESD verification tools or due to non-ESD-related product development priorities. However, under all circumstances, the result of the formal ESD EDA check runs could allow for easy product ESD troubleshooting. The ESD EDA checker output could help with relating possible ESD test failures with identified ESD design marginalities.

The ESD checks of the final IC verification phase are most extensive. They are similar to the checks which have been performed during earlier design phases. However, ESD EDA tools could be capable of operating on much larger netlists, including full chip resistance, capacitance, and package information. The following are a few ESD EDA check examples performed during this phase.

A final ESD IC check could include verification of all designated ESD current paths using an EDA tool. To achieve better accuracy for a given pad stress combination, more than one ESD path could be found and analyzed since ESD current flow may not be limited to the shortest path identified earlier. A report from such a tool will include calculated node voltages and currents and can be used for the ESD signoff before the tape-out. Figure 4 shows an example of the final chip-level checker output, where three distinctive ESD paths for a chosen pair of pads (IO_D2 and IO_ANA) were found. Voltages and currents along ESD paths have been found by running DC simulations where an HBM 1.33A current has been forced between the two pads. Simulated voltage potentials and currents at each path node are shown in Figure 4. Bus parasitics have been included in simulations. For example, the voltage difference between nodes V2 (7.76V) and V3 (5.35V) is coming from both the diode D1 voltage drop (2.39V) and VSSIO bus resistance voltage drop (0.01V). Voltage stresses across most sensitive devices are being monitored to ensure that while the total voltage drop between stressed pads may be high (16.48V), devices are not being stressed in excess of their failure limits. In particular, voltage between VDD and VSS in this example does not exceed the 0.68V, and the IC core can be considered ESD robust.

After completion of the initial IC integration, critical cross-domain boundaries between different supply voltage networks on a chip could be identified. The high voltage drop across these boundaries during an ESD stress makes them more prone to ESD damage than the devices placed within the same power domain. The increasing number of different supply voltage domains in today’s generation of chips necessitates an automated check to find devices that would be impacted during an ESD event. Depending on the acceptable voltage stress level for the specific devices at the domain interface, ESD design weaknesses could be identified by an EDA tool after checking thousands of possible interface connections. In addition, protection measures already implemented at power domain boundaries (diodes connected to an interface gate oxide, etc.) have to be taken into account as well when analyzing ESD robustness of devices at power domain boundaries. Figure 5 (page 168) gives an example of a cross-domain level shifter, where a gate connected to node 1 could be overstressed during an ESD event.

**CONCLUSIONS**

In this article the, essential requirements of an effective ESD EDA verification flow were described. These requirements are aligned within the IC design community ESD verification needs. The proposed verification flow offers a systematic approach to check ESD robustness across all IC blocks at
different phases of design flow. This approach allows for the avoidance of many ESD design flaws, reducing the overall design cycle time. The ESD EDA tools would improve the ESD predictive capabilities by generating extended netlists (including ESD device, resistance, capacitance and package) and retiring an approach of crude “back of the envelope” extractions, manual/visual checks and resource-intensive SPICE simulations. Another important benefit of these tools is the possibility to use them for systematic ESD design optimization. The ESD EDA check requirements outlined in this article could be the basis for additional effort by the EDA vendors to adapt their tools and to make a comprehensive ESD verification flow feasible.

REFERENCES


More details on the proposed ESD EDA verification flow can be found in the ESDA Technical Report ESD TR18.0-01-11 [1], which is available for as a free download at http://www.esda.org/standards.html. At the time of the writing, the ESDA EDA Working Group consisted of the following members: Michael Khazhinsky (Silicon Labs), Fabrice Blanc (ARM), Gianluca Boselli (Texas Instruments), Shuqing (Victor) Cao (Global Foundries), Norman Chang (Ansys), Dan Clement (On Semiconductor), Rosario Consiglio (Impulse Semiconductor), Maxim Ershov (Silicon Frontline), Melanie Etherton (Freescale Semiconductor), Eleonora Gevinti (ST), Harald Gassner (Intel), Matthew Hogan (Mentor Graphics), Larry Horwitz (Synopsys), Kelvin Hsueh (ESD Consultant), Mujahid Muhammad (IBM), Louis Thiam (Cadence), Nitesh Trivedi (Infineon), and Vesselin Vassilev (Novorell).

Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the Association has broadened its horizons to include areas such as textiles, plastics, web processing, cleanrooms and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness through standards development, educational programs, local chapters, publications, tutorials, certification and symposia.

Michael G. Khazhinsky is currently an ESD staff engineer/designer at Silicon Labs’ Broadcast Products Division in Austin, Texas. Prior to joining Silicon Labs, he worked at Motorola and Freescale Semiconductors where he was in charge of the TCAD development for the new and emerging CMOS and NVM process technologies, as well as the development of ESD, latch-up and I/O physical architecture design solutions with a focus on SOI and ESD EDA. Michael earned the M.S. degrees in Electrical Engineering and Physics from Moscow State Institute of Electronic Engineering and the Ph.D. degree in Physics from Western Michigan University. Michael is a Senior Member of IEEE and the ESD Association. Michael served as a member of the IRPS, IPFA and EOS/ESD Symposium Technical Program Committees, as well as a Workshop Chair and Technical Program Chair of EOS/ESD Symposium. He currently serves on the Management Committee and as the Vice General Chair of the 2011 EOS/ESD Symposium. Michael co-authored over 30 external papers and gave a number of invited talks on ESD, process/device TCAD, and photonic crystals. He was a co-recipient of six EOS/ESD Symposium and SOI Symposium “Best Paper” and “Best Presentation” awards. Michael currently holds fifteen patents on ESD design, with additional patents pending.

Figure 5: Power domain boundary-crossing check. Due to increased Rbus, the primary ESD current path (thick line) becomes less attractive, resulting in stressed gates at node 1.
Electrostatic discharge (ESD) design rules verification has grown in volume and complexity as integrated circuit (IC) designs have become more complex and added significantly more power domains. With each additional power domain, verification of the signals that cross these domains becomes more difficult (particularly in the identification of inadvertent paths), as well as the check of interactions between circuit blocks that may result in many potential ESD discharge current paths [1]. While not strictly related to ESD, designs that incorporate multiple power domain checks are particularly susceptible to subtle design errors that are difficult to identify in the simulation space or with traditional PV techniques. Often, these subtle reliability errors don’t result in immediate part failure, but in performance degradation over time. Effects such as negative bias temperature instability (NBTI) can lead to the threshold voltage of the PMOS transistors increasing over time, resulting in reduced switching speeds for logic gates [2-4]. At the same time, hot carrier injection (HCI), which alters the threshold voltage of NMOS devices over time [5], and soft breakdown (SBD) [5] also contribute as time-dependent failure mechanisms, adding to the degradation effects of gate oxide breakdown.

ESD rules for ICs with multiple power domains, IP reuse, and system integration require greater complexity to avoid device damage. Design hierarchy also comes into play where some rules are applied on a top cell and/or top pads, but others are applied between internal blocks that cross multiple power domains. Tracking the rules and the nets to which they apply is by no means a trivial task when performed manually. Automation is necessary to effectively and efficiently cope with these requirements.

As a result, multiple methods have been developed using modeling or simulation to perform chip-level ESD verification [6-8]. However, while simulation-based ESD verification methods, to verify compliance to human body model (HBM) and charged device model (CDM) requirements, are effective, they do not necessarily check all elements in the design for ESD violations. In particular, internal interfaces between different supply domains are not explicitly checked. Additionally, getting device models for simulation at these extreme conditions is often problematic.

Part 1 of this series, “Outlining the Essential requirements of the ESD Verification Flow”, provided an overview of the essential requirements of an effective ESD EDA verification flow [14]. This article (Part 2) discusses a well-established topological methodology for checking ESD design rules. The ESDA Technical Report 18, “ESD Electronic Design Automation Checks” (TR18) [13], provides an overview of recommended ESD checks that should be performed to validate appropriate ESD protection structures within a design. We will focus our effort on TR18 rule 5.1.3, which applies to internal interfaces between power or ground domains, a requirement that has been recently highlighted [9-11]. Rather than modeling or simulating, the methodology uses the device netlist topology to check all domain crossing interfaces and associated ESD devices in the entire design,
and is realized using the Calibre® PERCTM tool from Mentor Graphics. Although internal interfaces may span many levels in the design hierarchy, checking is done hierarchically by utilizing a novel technique for topology-aware verification. In addition to performing topology checking, at times there is the need to include both topology and physical information to create a more comprehensive checking environment. Such an environment is required to perform ESD layout verification checks [12].

The following sections cover the targeted ESD rules, the new hierarchical algorithm, ESD rule variations, and verification results.

**THE ESD RULE**

Transistors’ gates can be exposed to direct ESD events. This is particularly common in input receivers, although many other topologies can expose a gate oxide to an ESD discharge path. Since gate oxides (by virtue of their small capacitance) cannot shunt any significant amount of current, they have to be considered voltage pulse driven as far as their failure mechanism is concerned. It is irrelevant whether the gate oxide is connected to signal, ground, or supply. The failure criteria will depend on the actual combination exercised and whether a soft vs. hard oxide breakdown sets the failure limit (application-dependent) [13].

ESDA TR18, check 5.1.3 [13] is intended to verify presence of protections on signals that cross a power domain boundary. As shown in Figure 1, when the pad VDD1 is struck with respect to VSS2, a high voltage could be developed across the gate-source oxide of the NMOS in the VDD2 power domain.

To define our rule, we begin by identifying the ESD protection strategy; to protect this component we need to ensure that the voltage across it does not exceed the set failure level. A simplified overview of the check that needs to be performed to ensure the gate oxide is adequately protected is as follows:

**For each net in design,**

IF net connects *driver* and *receiver* THEN check power domains of driver and receiver

IF different power domains THEN check for anti-parallel diodes

IF anti-parallel diodes do not exist THEN ESD error

Drivers and receivers are determined by net connectivity, as are the different power domains. Because this is an interface, the pieces of the circuit that must be checked are usually distributed between different levels of the design hierarchy, so it is not obvious how to check the rule independently on a cell-by-cell basis. However, using a flat approach does not provide sufficient capacity to run larger chips. For scalability reasons, it becomes necessary to develop a hierarchical topological approach to efficiently solve this issue. We present here such a method that performs hierarchical verification.

**HIERARCHICAL VERIFICATION**

**Overview**

The first requirement is a SPICE netlist, which can be either a schematic netlist or a netlist extracted from the layout. In the latter case, the LVS-like runset used for extraction must ensure that all ESD protection devices are extracted (Note: parasitics are not extracted, just intentional devices). While the netlist must contain the proper text names for device pins (so that power and ground domains can be established), in general, texting in the netlist is not used extensively for verification (see Figure 2).

The second input is an ESD rule deck. It specifies the ESD design rules to be checked, and the list of power and ground domain names. Power and ground names are not generated automatically; they must be specified in the rule deck per the design specification. This rule deck is essential for making the verification method generic. For ease of discussion, however, we will describe the method in the context of the ESD design rule formulated above.

Conceptually, the hierarchical algorithm runs in two steps:

1) initialization, and 2) rule-checking.

![Figure 1: Typical signal cross-domain ESD issue (source: EDA Tool Working Group (2011), from ESD Electronic Design Automation Checks (ESD TR18.0-01-11) [13]](image)
In the initialization step, the algorithm gathers ESD-related topology information from each cell and propagates it throughout the design. In the second step, the algorithm checks ESD design rules independently, cell by cell, as each cell now has access to the entire ESD protection scheme propagated from all other cells.

**ESD Rule-Checking**

Once net connectivity is defined, we can check the ESD design rule cell by cell. Since a net’s path through devices is, in general, instance-dependent, we cannot just check each cell once. Instead, we find a list of representative instances with unique net connectivity for each cell. Depending on the amount of regularity in the design, the list of instance representatives can be orders of magnitude smaller than the list of all instances for a cell. This greatly improves the speed of the tool compared to checking a flat netlist and is done while preserving any instance specific configurations.

**Rule Deck Coding Considerations**

Given the diversity in ESD rules, it is important to develop a robust rule deck that will not miss real violations. Within the framework of our method, there are two basic approaches: one is to code a new rule for each variation, and the other is to code a single general purpose rule that covers all variations. The tradeoff is speed vs. rule complexity. The first approach is simpler but slower, as each net will be checked multiple times (once for each rule). The second approach is faster but obviously more complex.

The rules should include checking of properties of the ESD protection devices, such as ESD components widths. Also, the rules should handle different protection types. For example, the ESD protection circuit in Figure 1 could be a dynamic or static clamp or diodes.

Similarly, the drivers and receivers in real circuits are not necessarily simple inverters. They can be NANDs, NORs, etc. However, this does not need special attention from the rule-writing point of view. The tool automatically handles different types of logic gates.

Moreover, the tool can recognize multiple drivers/receivers on an interface net—for instance, a driver with a fan-out to three inverters (in the same domain or in different domains). The rules should take advantage of this ability and report all drivers/receivers associated with a violation.

At the global level, a robust rule deck should also include other ESD checks. For example, the parameters used in the domain crossing interface check can be dependent on properties of the supply protections. As an example, in the case shown in Figure 1 where the driver and receiver have separate VDDs and VSSs, we are able to make a determination of the checks to be performed and determine the need for the specific protection circuit specified (in this case, anti-parallel diodes).

**RESULTS**

ESD rule decks have been written using this technique and have been verified in production design flows for both large blocks and complete chips. We will review the results in terms of functionality (How well did it identify real problems?) and reporting (How easy is it for users to manage and correct errors?).

**Functionality**

In practice, designs with multiple power and ground domains often involve hundreds or thousands of crossings that need to be verified. In addition to determining what signals require ESD clamps for protection, the crossing audit is also needed to determine which ground domains need interface protections.

In one example, for noise isolation purposes, a PLL was designed with separate ground domains for the core and 1.8V circuits. Traditionally, crossings between domains were checked manually to see if ESD clamps were present. However, crossings can be very difficult to find, since the connections may need to be traced through multiple schematics and there can be hundreds, if not thousands, of crossings. Using the PLL example, the hierarchical ESD audit identified all 133 crossings in just a few seconds. The crossing audit also successfully caught missed instances of clamps in the preliminary design.
The output from the rule deck lists all the crossing nets and is organized by hierarchy (Figure 3). For each net, the MOSFETs on both sides of the interface, together with the associated grounds, are shown. This output can be customized as desired, and Calibre PERC provides a results viewing environment (Calibre RVE) to highlight devices in the schematic and/or layout when they are selected in the report. All 133 results are displayed in the graphical tree view shown in Figure 3. Analysis of these results will identify the specific details for each failure.

The schematic representation in the results viewer can provide a different perspective of an error (Figure 4) This often provides a holistic view of the connectivity, enabling much easier debugging than the original schematic. Of course, as these results are displayed in Calibre RVE, highlighting back to the original schematic is also supported.

Because you can specify nets, devices, pins, etc., and create “groupings” for testing conditions, the tool can use these conditions to determine how to evaluate a design.

**CONCLUSION**

In this paper, we presented a well-established, topologically-driven hierarchical verification methodology that has been developed to automate ESD rule-checking. It can handle large ICs and check ESD protection rules on the original design without netlist reduction. The hierarchical algorithm uses a novel topology-aware concept, allowing for verification of chip-level ESD design rules. The presented method has been extensively verified and is being used in production to significantly improve ESD quality.

Until now, there has been a clear gap in EDA solutions to address the demands of circuit and electrical verification. The ability to use both netlist and layout (GDS) information simultaneously to perform electrical checks enables designers to address both reliability concerns arising from crossing multiple power domains and catastrophic failures from ESD that can have large effects on yield and reliability. In addition, this method can employ topological constraints to verify that the correct structures are in place wherever circuit design rules require them.
An automated solution that verifies circuits at both the schematic and layout phase can reduce cost and time to market, while improving yield and device reliability.

REFERENCES


At the time of writing, the ESQA EDA Working Group consisted of the following members: Michael Khazhinsky (Silicon Labs), Fabrice Blanc (ARM), Gianluca Boselli (Texas Instruments), Shaqing (Victor) Cao (Global Foundries), Norman Chang (Ansys), Dan Clement (On Semiconductor), Rosario Consiglio (Impulse Semiconductor), Maxim Ershov (Silicon Frontline), Melanie Etherton (Freescale Semiconductor), Eleonora Gevinti (ST), Harald Gossner (Intel), Matthew Hogan (Mentor Graphics), Larry Horwitz (Synopsys), Kelvin Hsueh (ESD Consultant), Mujahid Muhammad (IBM), Louis Thiam (Cadence), Nitesh Trivedi (Infineon), Vesselin Vassilev (Novorell).

Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the Association has broadened its horizons to include areas such as textiles, plastics, web processing, cleanrooms and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness through standards development, educational programs, local chapters, publications, tutorials, certification and symposia.

Matthew Hogan is a Calibre Marketing Engineer for Mentor Graphics, with over 15 years of design and field experience. He is an active member of the ESD Association involved with the EDA working group and Symposium technical program committee. Matthew is a Senior member of IEEE and member of ACM. He holds a Bachelor of Engineering from the Royal Melbourne Institute of Technology and an MBA from Marylhurst University. He is actively working with customers who have an interest in Calibre PERC and 3D-IC. Matthew Hogan can be reached at matthew_hogan@mentor.com.
Discontinuing Use of the Machine Model for Device ESD Qualification

BY CHARVAKA DUVVURY, ROBERT ASHTON, ALAN RIGHTER, DAVID EPPES, HARALD GOSSNER, TERRY WELSHER, AND MASAKI TANAKA

The machine model (MM) test, as a requirement for component electrostatic discharge (ESD) qualification, is being rapidly discontinued across the industry. This article is intended to illustrate why MM evaluation is not necessary for qualification. The following major conclusions can be made about MM in general:

- MM is redundant to the human body model (HBM) at the device level since it produces the same failure mechanisms, and the two models generally track each other in robustness and in failure modes produced.
- MM testing has more variability than HBM due to MM’s greater sensitivity to parasitic effects in the tester circuitry.
- There have not been any significant engineering studies (with verified data) which could be used to establish required passing level.
- The test method was incorrectly given the name “machine model”, though no firm unique connection between the model and actual machine-induced device failures was ever established. In fact, the model was developed as a “low-voltage HBM”.
- The charged device model (CDM) does a better job of screening for fast metal-to-metal contact events than MM.
- The vast majority (>99%) of electrical failures in manufacturing correlate to CDM and electrical overstress (EOS), and not to MM.
- MM testing has not shown any additional failures not explained by CDM, HBM or EOS.
- MM testing consumes resources and creates time-to-market delays while only providing failure modes or protection strategies that HBM and CDM already cover.

It is important to understand the scope of this article. It summarizes what has been learned about the test method only. The information summarized here in no way diminishes the importance of adequately grounding any metal which may come in contact with ESD-sensitive devices nor the importance of avoiding hard metal-metal discharges.

BACKGROUND TO THE ISSUE

As will be explained below, the machine model is a widely misunderstood component ESD qualification test method. It continues to generate confusion for both original equipment manufacturing (OEM) customers and their integrated circuit (IC) suppliers during ESD qualification. Many companies and design organizations continue to use MM, mostly as a legacy “required” practice, despite the fact that it has been downgraded by three standards bodies and is no longer recommended for qualification testing in accordance with JEDEC JESD47. The automotive industry, a longtime user of this method, no longer requires it in their AEC-Q100 list of qualification tests. The scopes of the JEDEC (JESD22-A115) and ESDA (ANSI/ESD STM5.2) test method documents have also been changed to reflect this status. There are a number of reasons for these changes, as outlined below. The continued use of MM for qualification based solely on legacy requirements has no technical merit given the information...
that has been gathered over the last few years. Those companies who continue to use MM take on an unnecessary and burdensome business approach. The reasons against use of the MM are given below.

1. Historically speaking, the 200pF, “0 ohm” model, which later became known as the machine model, originated with several Japanese semiconductor corporations as a worst-case representation of the human body model. The model was later presumed by some, because of the lower discharge impedance, to simulate abrupt discharge events caused by contact with equipment and empty sockets (functional testing, burn-ins, reliability testing, pick and place operations, etc.). This happened at a time when the very fast rise time of metal-metal discharges was not well-understood. Since that time, the charged device model has been proven to quite adequately cover these events.

2. Recently, M. Tanaka-san (Renesas Electronics) at the September 2011 JEITA meetings [3] presented rationale and data supporting the elimination of the MM test. According to his historical account, the so-called “machine model” originated at Hitachi (now Renesas Electronics) about 45 years ago and was introduced to Japanese semiconductor customers as a test case to represent the HBM test in their IC product test report. This test method spread widely to the Japanese customer base and was later established as an ESD test standard by the EIAJ in 1981. Around 1985, some people began mistakenly to refer to the test as the machine model. Then, starting in 1991, ESDA, JEDEC and IEC adopted the model and its name as a new test standard. As use of the model increased, it was realized that the machine model name caused a lot of misunderstanding that needed to be clarified.

3. In the early days of ESD device testing, there was also a desire to avoid the high pre-charging voltages of the HBM test (2kV and higher). The 200pF and low impedance of MM was thought to be an equivalent but safe lower voltage test to address the same failure mechanisms as HBM. However, establishment of a single translation from MM voltage to HBM voltage has been difficult to achieve. Protection design has traditionally been focused on meeting the HBM requirement, but MM testers are susceptible to parasitic circuit elements; these parasitics from relay switching networks in the simulators cause more variation in the MM waveform than waveforms from HBM testers. In spite of this and without any supporting data, 200V MM became established as a de facto requirement. It was thought to be the safe level for handling, and that this level had to be simultaneously met along with the de facto 2kV HBM standard. In reality a device with a 2kV HBM withstand voltage might have an MM withstand voltage anywhere from 100 to 300V, depending on the device characteristics and the MM tester parasitics. This led to much of the confusion associated with specifying both HBM and MM specification levels.

4. The next important reason for discontinuing MM is that fast discharges to or from a metal surface are not correctly represented by the MM. The characteristics of the MM rising pulse were not established based on comparison to measurements on machine pulses, but rather were determined by characteristics of the already developed HBM simulators. The fast rising leading edge of metal-to-metal discharges are actually more effectively simulated using the current standard CDM test methods. This is known today because of the development of high speed oscilloscopes. However, during the 1980s there was a misunderstanding that MM was a good representation for CDM. This misunderstanding actually delayed the eventual development and acceptance of the CDM standards used today. Later in the 1990s, with much improved and accurate test for CDM and wider recognition that the fast discharges are covered by CDM alone, the test for MM frequently became replaced with CDM.

**MM VS. HBM AND CDM**

The waveforms for HBM, MM and CDM are compared in Figure 1 (page 176). The HBM and MM have similar ranges of rise time (2-10ns). Therefore any thermal heating in silicon taking place in this time period leads to the same failure mechanisms for both models. This holds true for all technologies, including advanced technology nodes. This early part of the waveform determines where protection circuits must be deployed in design. With similar rise time characteristics, HBM and MM encourage the same protection designs. For CDM, on the other hand, the rise time is much faster (0.1 – 0.5 ns) and often leads to a unique failure mechanism like oxide breakdown. Even more important, the observed ESD field failures are dominated by oxide breakdown when the CDM level is not adequate. Thus, a different set of protection strategies are generally needed for CDM. This makes it even more critical to focus on CDM qualification, instead of duplicating the HBM test information by using the MM. In Figure 1, we also show the observed failure modes for the same I/O pin after stressing with HBM, MM and CDM. It is clear that with HBM and MM the damage sites were the same in the protection diode, but with CDM stress the damage site corresponds to oxide breakdown in the output transistor. This also illustrates the fact that meeting high levels of MM does not improve CDM performance until the right effective design techniques are employed.

Commercial MM testers have inductors built into the MM stimulus circuit. These inductors must be present to produce the oscillatory waveform required in the MM test method. The inductors, however, actually slow down the MM waveform (Figure 1), and therefore MM cannot represent...
very fast metal-to-metal contact discharge as CDM does. On the other hand, the CDM test is directly represented by elevating the package potential and directly grounding the pin to produce the fast discharge. MM cannot be relied on to accurately model fast metal to metal contact discharges, which are known to occur in the field.

**METAL DISCHARGE VERSUS CDM DISCHARGE**

The analysis of M. Tanaka [2] is shown here to demonstrate that a metal discharge from a small metallic object to a device is similar to the commonly used CDM test. Tanaka considers small objects because large machines (typically >10 pF) are almost always grounded for reasons beyond ESD and thus pose little practical threat for these events. On the other hand, tools and small machines are difficult to ground and may lead to charging effects where the capacitance of the metal object is related to surface area and distance. These values can range from <1pF to nearly 10 pF. For example, this value could be as much as 1pF for a small metal object of 10 cm² at a distance of 0.5 cm. Both the small metal discharge and the CDM discharge can be represented by the same set of equations for I(t), and thus both can be expected to generate the same discharge event if the values of the parameters are similar. Figure 2 illustrates the case for a small object of 10 pF for both metal discharge and CDM discharge.

The above analysis is confirmed by measurements as shown in Figure 3, [2] where the discharge in (A) from a charged tweezer to IC pin is the same as the direct discharge from metal as shown in (B), and both are similar to the generated CDM discharge in (C). The time scale for both metal discharge and CDM discharge are indeed the same, clearly indicating that CDM is a good representation of the metal discharge in the Electrostatic Protected Area (EPA).

- **Metal discharge events are well represented by the CDM test.**
- **Most of the field failure returns for ESD have been replicated by the CDM test, but none with MM testing that are not also produced by HBM.**

The Industry Council on ESD Target Levels has studied HBM and MM results on a wide variety of designs in many technologies and concluded that MM is intrinsically related to HBM, with a correlation factor range that is dependent on the HBM design level [3]. This data is represented in Figure 4 (page 178). However, the most important conclusion of the
Discontinuing Use of the Machine Model for Device ESD Qualification

Figure 2: Discharge current equation for metal discharge or CDM discharge [1]

This formula can be applied to both case of the metal discharge and CDM discharge.

\[ i(t) = \frac{V}{\omega L} e^{-\frac{R_d t}{2L}} \sin \omega t \]

\[ \omega = 2\pi f = \sqrt{\frac{1}{LC} - \frac{R_d^2}{4L^2}} \]

Figure 3: Comparison of measured waveforms for metal discharge and CDM discharge events [2]: (A) discharge from a charged tweezer on pin, (B) direct discharge from metal and (C) CDM test discharge
study was that MM is a redundant test and a sufficient level of MM robustness is automatically included in an adequate HBM design. This also includes the bipolar nature of the MM stress. Any oscillatory waveform which might be measured during discharges in the field is sufficiently covered if the part is proven to have an adequate HBM design.

This minimum design value, as measured by a MM tester, is well above any voltage remaining on all properly grounded machines in an ESD protected manufacturing environment. In essence, meeting a safe value for HBM (and CDM) is sufficient for production of ICs without needing to evaluate MM as an additional qualification.

• The machine model test method specification to qualify ICs does not model or advance the real world ESD protection of IC products.

• IC evaluation with MM does not give any additional information as to how to address machine ESD control.

• While MM is an unnecessary qualification test, it is important to emphasize that control of voltage on machine parts that might contact device pins in accordance with ESD programs specifications such as S20.20 programs is still important.

FIELD DATA ANALYSIS
The work from the Industry Council has shown that most of the overstress field returns exhibit failure signatures of higher energy EOS, and that the level of HBM ESD from 500V to 2000V (shown as the HBM Failure Analysis Return (FAR) window in Figure 2) on 21 billion shipped units did not show a correlation to the customer field return rates. Similarly, these very same shipped units (500V to 2kV HBM) also had MM levels in a range between 50-300V, as also seen from Figure 2. Therefore it can be concluded that the EOS field returns are indeed not related to this range of intrinsic MM levels. That is, it does not matter if a shipped device has a measured MM value of 50V or 300V.

• Devices with various measured MM levels have shown no correlation to real world EOS failure returns.

STANDARDS BODIES AND POSITIONS ON MM
During the last two decades, the electronics industry’s standards bodies have changed their viewpoint with regard to MM and its requirement for IC qualification. At present, JEITA in Japan does not recommend MM. The Automotive Electronics Council’s AEC Q100 standard gives a choice between HBM and MM, but does require CDM. In recent years, JEDEC has strongly recommended discontinuing use of the MM for ESD qualification because of its test variability and non-correlation to real-world failure modes. In general, standards bodies have come to recognize that:

• IC Qualification to HBM and CDM provides all the necessary ESD test requirements.

• MM testing of ICs is redundant to HBM and does not reflect unique real-world component ESD failure modes.

• Billions of IC components have been shipped worldwide and qualified using HBM and CDM testing only. No field failures have been found that would have been prevented by additional MM qualification.

The following statements are from the JEDEC web site:

• “JESD22-A115B is a reference document; it is not a requirement per JESD47G (Stress Test Driven Qualification of Integrated Circuits).”

• “Machine Model as described in JESD22-A115B should not be used as a requirement for IC ESD Qualification.”

• “Only human body model (HBM) and charged device model (CDM) are the necessary ESD Qualification test methods as specified in JESD47G.”

The ESD Association has downgraded the MM document from a Standard (S5.2) to a Standard Test Method (STM5.2) [4] and has adopted the following position:

• The ESD Association does not recommend using MM ESD as described in STM5.2 for IC qualification. IC Qualification should be done using the current standard HBM and CDM methods.
CONCLUSIONS

The information in this document supports the discontinuation of MM as part of IC qualification. The most important point to note is that a wide range of products, having only HBM and CDM testing performed, are being shipped today at volume levels in the billions with no field returns due to ESD. These products, passing at or above the recommended minimum HBM and CDM levels, are being routinely shipped by major suppliers and are accepted by major OEMs. No increase in field return rates has been observed with MM removed from qualification for these products.

The confusion generated by MM has persisted in the industry for over two decades. The presumed need for this test is causing additional qualification delay due to an extraordinary consumption of design/test resources, added delays in time-to-market and, in some cases, an impact on IC speed and performance. Maintaining safe HBM and CDM levels is sufficient to meet all IC manufacturing, handling and assembly needs.

EPILOGUE

Different customer sectors may feel that they need enhanced ESD requirements for specific reasons. For example, some automotive customers have more consistently required MM model testing; the impression being that an independent and redundant test provides enhanced safety, improved quality and reduced defectivity. However, industry experience has shown that passing a redundant (to HBM) MM qualification test does not help automotive manufacturers achieve these goals. Meeting current industry standard HBM/CDM will insure that a product can be safely handled with sufficient margin to prevent ESD damage and maintain the quality/reliability of the product as shipped from the component manufacturer. Since many suspected ESD failures turn out to be higher energy EOS in nature, methods to prevent electrical overstress during manufacturing will also help maintain product reliability.

COMMON GOALS

We have presented evidence and arguments that the MM test of ICs is redundant and there is no proof that devices have failed in the field because MM evaluation was not done. We strongly recommend that this test be discontinued for ESD qualification. This will save the semiconductor industry a tremendous and an unnecessary burden by greatly reducing the routine characterization that is done to support the qualification process. The ESD robustness designed into integrated circuits to survive HBM and CDM testing will provide protection against any MM-like stress. Eliminating MM testing of ICs has no deleterious effects and will free up resources for more important engineering challenges.

REFERENCES


Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the Association has broadened its horizons to include areas such as textiles, plastics, web processing, cleanrooms and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness through standards development, educational programs, local chapters, publications, tutorials, certification and symposia.

Charvaka Duvvury is a Texas Instruments Fellow working in the Silicon Technology Development Group. His current work is on development and company wide support on ESD for the nanometer submicron CMOS technologies. Charvaka has made numerous international presentations on ESD phenomena and protection design. He received his Ph.D. in Engineering Science from the University of Toledo. After working as a Post-Doctoral Fellow in Physics at the University of Alberta in Canada, he joined Texas Instruments in 1977. He has published over 140 papers in technical journals and conferences and holds 65 patents. He has co-authored books on hot carriers, modeling of electrical overstress, and ESD reliability phenomena and protection design. (John Wiley & Sons, 1995, and 2nd Edition in 2002).

He is a recipient of the Outstanding Contributions Award from the EOS/ESD Symposium (1990), Outstanding Mentor Award from the SRC (1994), numerous Best Paper and Best Presentation awards from the EOS/ESD Symposium. He has served as the General Chairman both in 1994 and in 2005. He is a contributing Editor for the IEEE Transactions on Device and Materials Reliability (TDMR). Charvaka has been a member of the ESD Association Board of Directors since 1997, promoting university education and research in ESD. He is a co-chair of the Industry Council on ESD Target Levels. Charvaka is also a Fellow of the IEEE.
Effectiveness of Multilayer Ceramic Capacitors for Electrostatic Discharge Protection

BY CYROUS ROSTAMZADEH, FLAVIO CANAVERO, FERAYDUNE KASHEFI AND MEHDI DARZANDI

A simple technique to deal with ESD can be achieved by mounting multilayer ceramic capacitors (MLCC) at the PCB I/O connector pins that is the ESD entry point. EMC engineers recommend using 0603 MLCC’s placed at close proximity to each connector pin, mandating low-inductance mounting strategy associated with the PCB traces and vias. When selecting surface-mount technology (SMT) MLCC for ESD protection of I/O pins, engineers specify the ESD capacitor value, its DC voltage rating, and a choice of technology (X7R or C0G). MLCC, as an ESD bypass or shunt device, is used to divert the ESD current to ground. ESD protection devices should perform ESD mitigation and should not exhibit degradation, while maintaining ESD robustness throughout the life span of a product. Nevertheless, post-ESD examination of small foot-print 0603 MLCC’s reveals serious structural damage, manifesting itself electrically in a dramatic change in the impedance characteristics. This is a major departure from a pre-ESD capacitor, thus resulting in excessive low frequency leakage and functional misbehavior.

BACKGROUND

Electrostatic discharge (ESD) is one of the most important reliability problems in the electronic circuit industry. Typically in the integrated circuit (IC) industry, one-third to one-half of all field failures (customer returns) are due to ESD. As ESD damage has become more prevalent in newer technologies due to the higher susceptibility of smaller circuit components, there has been a corresponding increase in efforts to understand ESD failures through modeling and analysis. Manufacturers of integrated circuits provide ESD test information. However, the ESD data on IC level standards (human body model (HBM), charged device model (CDM), machine model (MM) and latch-up-to-the-system testing) is often confusing.

Design of robust ESD circuits remains challenging because ESD failure mechanisms become more acute as critical circuit dimensions continue to shrink. Circuit board designers are further constrained by the ability to design highly congested PCB’s and meet ESD requirements. HBM provides much insight into device behavior during an ESD event [1,2].

An ESD event is the transfer of energy between two bodies at different electrostatic potentials, either through contact or via an ionized ambient discharge (a spark). This transfer has been modeled in various standard circuit models for testing the compliance of device targets. The models typically use a capacitor charged to a given voltage and then some form of current-limiting resistor (or ambient air condition) to transfer the energy pulse to the target.

In order to meet the module level ESD tests, various methods and techniques on printed circuit boards have been implemented and investigated. One effective technique is to add discrete noise-decoupling components or filters into
Effectiveness of Multilayer Ceramic Capacitors for ESD Protection

Multilayer ceramic capacitors (MLCC) are employed as an ESD bypass mechanism at the connector pins of electronic control modules. An automotive control module may require the use of a single high-density connector with pin density in excess of 200. In a typical application, a connector may present the designer with a matrix of 4 x 50 (4 rows of 50 pins at each row) in a tightly congested PCB real estate. To accommodate the ESD protection for each and every I/O pin at the connector of highly congested PCB real estate, design engineers recommend the use of 0603 style MLC capacitors. In most applications, MLC capacitors used for ESD protection are rated for 100 V stress level. However, post-ESD characteristics of MLCC’s are often ignored or misunderstood. In reality, MLCC’s exposed to ESD stress exhibit a dramatic shift in characteristic impedance behavior. Careful examination of MLCC’s reveals permanent structural damage resulting in excessive low frequency leakage. Post-ESD behavior of MLCC’s results in a functional deviation for the control module, and it is fundamentally unsafe to use the product for its intended application. It is suggested that low profile 0603 capacitors should not be used for ESD protection, as reported in this paper. Alternative solutions can be met by the use of low profile transient voltage suppressors (TVS) or fast metal oxide varistors (MOV). However, 0805 style MLCCs with high value capacitance (> 47 nF) provide a good solution and are safe to be used as an ESD bypass element.

MLCCs used as a protective device or mechanism should consider the voltage, peak power and energy as the key components of an ESD threat. It is thus necessary to fully characterize the amplitude and timing of ESD components. Therefore, protection structure should reduce the voltage, peak power and energy threats by shunting the stress currents away from fragile portions of the microcontrollers and other ICs [4].

To solve ESD problems, MLC capacitors employed as ESD bypass or filter component on printed circuit boards (PCB), must shunt the ESD transient current safely to ground. It is important that MLC capacitors, employed as bypass components, absorb the ESD voltage and current safely and protect the device under test with no degradation. In addition, the MLC capacitor must remain within its parametric tolerance for it to be considered a reliable protection mechanism.

MLC CAPACITOR AS AN ESD PROTECTION DEVICE

Multilayer ceramic capacitors are designed for use where a small physical size with comparatively large electrical capacitance and high insulation resistance is required. The general purpose 0603 (1.6 mm x 0.5 mm) class II, type X7R (-55°C to +125°C) is a popular choice for automotive electronic control module design. Therefore, it is a common practice to apply X7R MLCC’s as an ESD protection component at all I/O pins.

Figure 1 illustrates a horizontal grind of the 0603 MLCC (magnification X 100) with plates spaced at 21 μm apart for a 10 nF, X7R type II capacitor. A higher value capacitor is designed with an increased number of plates. This will result in a narrow dielectric thickness, a possible drawback for high voltage transients. At the present time (May 2012), capacitor values for a type II X7R 0603 (100 V) range from 180 pF to a maximum value of 39 nF. However, the capacitor value range for the same technology but with larger physical size (0805) varies from 220 pF to a maximum value of 120 nF. This can be an important factor if ESD protection capacitor value is determined to exceed the maximum value of 39 nF available in 0603 package.

Figure 1: Standard 0603 MLCC (magnification x100)
Figure 2 illustrates two different styles of MLCC technology with respect to the design of conductive plates. Capacitor manufacturers recognize the over-voltage stress concern and have provided an ESD-enhanced MLCC product. Close examination of Figure 2 demonstrates the style B MLCC is an ESD-enhanced design.

Figure 3 illustrates a horizontal grind of an ESD-enhanced MLCC at x100 magnification. Comparison with Figure 1 demonstrates the differences in plate geometry design.

Printed circuit board designers with fundamental EMC training are required to ascertain the optimum mounting strategy for ESD capacitors. EMC engineers verify a “Y-connection” topology for all of ESD capacitors at every I/O pin of the connector. MLCC must be placed in close proximity to the I/O pin (< 1cm) with a short trace (< 1cm) to the PCB return plane. In this manner, added PCB parasitic trace inductance and its degradation effect on the effectiveness of the ESD bypass capacitor is minimized. The general concern is to limit the added inductance due to PCB mounting inductance, and thus provide a low-impedance path for ESD current flow to return plane.

Another limitation would be to use the lowest value capacitor available, where it is most effective at higher frequencies. ESD would result in an RF current with a bandwidth in excess of 330 MHz. The choice between a 1 nF and 680 pF would easily be reduced to the latter one. However, ESD HBM consists of a 150 pF capacitance, thus a higher value MLC capacitor is preferred. A voltage divider network is established by the combination of HBM capacitor and MLCC. The voltage developed across a larger value MLCC, would lower the voltage developed across an integrated circuit, as indicated in Equation 1.

\[ V_{MLCC} = \frac{C_{HBM}}{C_{HBM} + C_{MLCC}} V_{ESD} \]  

Eq. 1

Figure 4: Improved electrical model of MLC capacitors
Therefore, where $V_{MLCC} \ll V_{ESD}$ it is required that $C_{MLCC} \gg C_{HBM}$.

### MLC CAPACITOR ELECTRICAL MODEL

Several electrical models of capacitors are available in textbooks and RF publications used by the EMC/RF community to describe the electrical behavior of MLC capacitors. A simple series RLC network is commonly used to provide accurate behavior for most applications. However, simple RLC model fails to provide the additional technical insight required for analysis of MLCC’s exposed to ESD pulse. The modified model presented in Figure 1 has additional elements to describe the behavior of MLC capacitors exposed to ESD stress. In fact, the model described here is an accurate electrical description, necessary to account for the various physical attributes found within a capacitor.

1. $L_1$ is the series parasitic inductance associated with plate connections.
2. $L_2$ is the equivalent series inductance. It is also known as $L_{ESL}$.
3. $R_1$ is the equivalent series resistance (also known as $R_{ESR}$) and represents the actual ohmic resistance of the plates. This value is typically very low. It causes a power loss of $\Delta P_{R_1}$. Its contribution to the total dissipation factor is $D_1 = 1/\left(\omega R_1 C_1\right)$.
4. $C_1$ is the nominal capacitance.
5. $R_2$, the dielectric loss, is a parallel resistance arising from two phenomena; molecular polarization and interfacial polarization (dielectric absorption). Dielectric loss is a complex phenomenon that can change with frequency in most any manner that is not abrupt. Its contribution to the total dissipation factor can be approximated by $D_2 = 1/\left(\omega R_2 C_2\right)$.
6. $C_2$ is the parallel dielectric absorption capacitor.
7. $R_3$, the leakage resistance or insulation resistance, is a parallel resistance due to leakage current in the capacitor. This value is typically very high. It causes a power loss of $\Delta P_{R_3}$. Its contribution to the total dissipation factor is $D_3 = 1/\left(\omega R_3 C_1\right)$.

The impedance characteristics of type II (0603, X7R MLC) capacitors for a 680 pF and 10 nF is illustrated in Figure 5.

ESD is a high frequency pulse with a rise time of less than one nano second, resulting in spectral content in excess of 330 MHz. Hence, the choice of ESD capacitor is reduced to a smaller value MLCC, as seen in Figure 2. Closer examination of Figure 2 reveals a lower impedance for a 680 pF (1.71 Ω at $f = 330$ MHz) compared with a 10 nF (3.97 Ω at $f = 330$ MHz). Another consideration may be the result of capacitive loading of certain I/O signals, i.e., CAN bus, where a limited capacitance can be added to the communication bus.

The requirements of a lower value ESD capacitor, as in the previous paragraph, may suggest the use of the lowest value MLCC available to the industry. In addition, there is a third factor that is outlined in Table 1; $R_3$ (insulation resistance) that may add additional incentive for the use of the lowest value MLCC.

<table>
<thead>
<tr>
<th>Nominal Value @ 1 kHz</th>
<th>680 pF</th>
<th>10 nF</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>49 pF</td>
<td>91 pF</td>
</tr>
<tr>
<td>L2</td>
<td>931 pF</td>
<td>1.73 nH</td>
</tr>
<tr>
<td>C1</td>
<td>680 pF</td>
<td>10 nF</td>
</tr>
<tr>
<td>C2</td>
<td>4.10 pF</td>
<td>4.10 pF</td>
</tr>
<tr>
<td>R1</td>
<td>5.15 kΩ</td>
<td>4.10 pF</td>
</tr>
<tr>
<td>R2</td>
<td>753.73 Ω</td>
<td>34.57 Ω</td>
</tr>
<tr>
<td>R3</td>
<td>$1.471 \times 10^{12}$ Ω</td>
<td>$.01 \times 10^{12}$ Ω</td>
</tr>
</tbody>
</table>

Table 1: MLCC 0603 capacitor model components
value MLCC. However, further insight is required to distinguish the apparent easy choice.

In Table 1, all nominal and parasitic elements for both capacitors are listed as per MLCC supplier A.

It is important to note that the insulation resistor $R_3$ is an order of magnitude higher in value for smaller value capacitor (Table 1). As more plates are stacked up to accommodate higher value capacitance in the same physical volume of the 0603-style package, the dielectric thickness is reduced by a factor of 14.7. Therefore, as a consequence of thinner dielectric material between the capacitor plates, the insulation resistor for higher value capacitor is reduced by the same ratio (capacitor ratio: 10 nF/680 pF = 14.7, insulation resistor ratio: $0.1 \times 10^{12} \Omega / 14.7 \times 10^{12} \Omega = 1/147$). It is clear that a higher value capacitor will sustain a dielectric breakdown in lower ESD voltages. It was suggested by this argument, for ESD applications, only necessary to consider lower-value capacitors with higher insulation resistance in order to protect for dielectric breakdown, i.e., 680 pF vs. 10 nF. Further investigation was required to address the accuracy of aforementioned statement.

If a smaller capacitor presents a higher insulation resistance as shown above, it is important to examine the behavior of the insulation resistance after ESD tests. For further insight, it is important to evaluate the impact of ESD stress on 680 pF and 10 nF capacitors by characteristic impedance of post-ESD capacitors.

**HUMAN BODY ESD TEST**

ESD tests for automotive applications are derived and based on a human body model specified by original equipment manufacturers (OEM) [5,6,7,8,9].

A typical HBM discharge network consists of a 150 pF capacitor with a 2 kΩ resistor. The HBM capacitor can be charged up to 25 kV for an air-discharge test. The static charge accumulated on the 150 pF discharge network capacitor (charged to 25 kV) would amount to 3.75 μC. ESD is
a high-frequency, high-voltage and high current event that can deposit 46.875 mJ of energy in the protection device in a relatively short time duration.

HBM provides much insight into device behavior during an ESD event. Although the HBM stress is characterized by a certain charging voltage, $V_{\text{HBM}}$, the 2 kΩ series resistor of the circuit is usually much larger than the impedance of the device under test, so we think of the HBM tester as current sources, with the peak HBM current equal to 12.5 A. ($V_{\text{HBM}} = 25 \text{ kV}$, air-discharge).

**PRE-ESD AND POST-ESD MEASUREMENTS**

In order to evaluate the impact of ESD stress on 0603 MLCCs, two different types of tests were performed. Since a populated electronic control module is the intention of a realistic test, it is important to evaluate the impact of ESD stress per OEM ESD test techniques. In another method, a 0603 MLCC network was prepared, as shown in Figure 6, with two short wires (< 1 cm) at each end. Terminal 1 was connected to a ground plane where an ESD gun return wire would normally be connected. The ESD discharge tip was slowly approached to the floating terminal until an air discharge was achieved.

Pre-ESD and post-ESD characteristics of the 0603 capacitor were recorded using an Agilent 4294A impedance analyzer (40 Hz – 110 MHz) with the help of an Agilent 16034G test fixture.

Capacitors were removed from test PCB or ESD network wires, and mounted inside the 16034G test fixture for impedance characterization.

It was decided to apply an ESD pulse to a fully populated automotive electronic control module as designed with rigorous EMC guidelines. As OEM ESD requirements provides guidelines [7,8,9] for remote I/O access ESD stress tests. An HBM model with discharge network as outlined in section IV was calibrated and ESD voltage levels from +/- 4 kV up to +/- 25 kV were applied in successive order. After each discharge, the MLCC was removed and analyzed on an impedance analyzer as per the previous method.

Figure 7 illustrates the impact of the ESD pulse at +/-15kV level for the 680 pF capacitor. Figure 8 illustrates the impact of the ESD pulse at +/-15kV level for a 10 nF capacitor.

Post-ESD capacitor dielectric damage is illustrated in Figures 9 through 11 (horizontal grind) on a magnification scale of 100. The physical damage to X7R and C0G technologies are shown.
In Figure 12, a modified electrical model represented as per Figure 4, was used to illustrate post-ESD effects on both capacitors. In the electrical model per Table 1, R3 was replaced with a 500 Ω resistor to represent the nominal pre-ESD value provided by MLCC manufactures in Table 1 (14.7 x 10^12 Ω).

It is important to note that the 10 nF capacitor developed severe leakage from 40 Hz up to 20 kHz, and for 680 pF the upper frequency is approximately 200 kHz. The impedance of both capacitors registers a 500 Ω resistive value in the aforementioned frequency range. It is thus concluded that ESD has caused non-recoverable, permanent damage to the MLCCs. Post-ESD behavior suggests physical damage to dielectric material due to metallization of capacitor plates. In reference to Figure 4, it is clear that R3 has shifted from its pre-ESD nominal value as per Table 1 (for 680 pF, R3 = 1.471 x 10^12 Ω, or for a 10 nF, R3 = 0.1 x 10^12 Ω to an extremely low value of 500 Ω).

The issue of why the 680 pF MLCC has a 500 Ω leakage up to 200 kHz, whereas 10 nF shows the ill-effect only up to 20 kHz, can be explained as follows: the circuit of Figure 4 simplifies to the parallel of C1 and R3 at low frequencies, and the knee of the impedance curve appears for f ~ 1/2πR3C1. For post-ESD, the 680 pF MLCC is dominated by R3 from DC to ~ 300 kHz, whereas R3 contributes only up to 20 kHz for the 10 nF capacitor. Figure 13 illustrates the post-ESD leakage resistance degradation.

It is clear that smaller size MLCC will suffer extreme leakage to a much higher frequency range. Use of higher value MLCCs is recommended, in contradiction to previous recommendations.

As an extension to exposure of 0603 MLC capacitors to ESD stress, additional ESD tests were performed on modules populated with larger 0805 MLC capacitors. Figure 14 illustrates the impact of +/- 25 kV HBM ESD stress on a 4.7 nF capacitor. It is clear that a 4.7 nF 0805 capacitor would fail the ESD requirements. However, extending the capacitor size (value) in an 0805 package to 10 nF results in ESD compliance.

CONCLUSION

This study is an examination of the physical damage to the 0603 MLC capacitors exposed to ESD transients. It shows that permanent damage to dielectric material...
resulted for ESD voltages in excess of 15 kV. The use of 0603 MLC capacitors for I/O connector pins, as an ESD bypass mechanism, is not recommended and should be avoided. However, in larger footprints, 0805 MLCCs will meet the ESD stress for 25 kV requirements, provided the capacitor size exceeds 10 nF, and is rated for 100 V applications. A preferred ESD bypass solution would use a low capacitance transient voltage suppressor (TVS, $C_{TVS} < 100$ pF) or a fast metal oxide varistor (MOV).

However, I/O pin ESD capacitors in the range of 1 nF to 100 nF are often utilized as an input RF filter at the connector pins. The ESD capacitors provide a bypass element for the induced RF currents on the module harness due to impinging electromagnetic fields. Low value TVS capacitance is insufficient to provide the required filter across the 1 MHz – 200 MHz frequency bandwidth. Use of a TVS in parallel with a 0603 capacitor (10 nF – 100 nF) is recommended, where permissible.

Figure 14: Measured post-ESD for a 4.7 nF 0805 capacitor

REFERENCES


Cyrous Rostamzadeh  
Senior IEEE Member  
Senior EMC Technical Specialist,  
Robert Bosch LLC, Plymouth, MI, USA  
Cyrous.Rostamzadeh@us.bosch.com

Professor Flavio Canavero  
IEEE Fellow  
Politecnico di Torino, Italy  
Flavio.canavero@polito.it

Professor Feraydune Kashefi  
IEEE Member  
Department of Electrical Engineering at Azad University, Shabestar, Iran  
fred.kashefi@gmail.com

Mehdi Darbandi  
School of Electrical & Computer Engineering, Tehran University, irandarbandimahdi@gmail.com
As medical devices go wireless, medical manufacturers face a new set of regulatory requirements and restraints. In addition to medical registration, wireless medical devices must receive radio spectrum approval. While the devices vary greatly, the wireless aspects are relatively uniform. That is to say, there are seemingly unlimited healthcare applications but only finite methods of sending data and, of course, limited RF spectrum. Thus, the wireless aspects of even a cutting edge medical device generally fall into familiar categories for international communications and radio spectrum authorities.

In my experience, international wireless compliance is often new territory for medical device manufacturers. Most countries, however, have had regulatory regimes in place for years and have well-established wireless regulations. Certain rules or restrictions may change, but the international process as a whole maintains fundamental characteristics and common pitfalls. Here are a few things to keep in mind before going global with a wireless medical (or any wireless) device.

**CHECK OPERATING FREQUENCY AND APPLICATION EARLY AND OFTEN**

A manufacturer should never assume commonalities between radio spectrum allocations across countries. Yes, commonalities exist, such as for certain ISM bands. However, one should always verify this and should also note the allowable output power. Many regulatory agencies publish frequency allocations on their website. Further, in some countries, certain RF technologies, such as ultra-wide band, may not be allowed at all.

**MINIMIZE WORK AND COSTS**

Medical manufacturers often purchase wireless components, from WLAN modules to GPRS modems, from an external vendor. So a radio module may already be approved in a given country. This ‘modular’ approval might be sufficient for the entire medical device, or it could reduce the cost, in-country testing, or paperwork needed for the regulating communications agency. Many countries require a local representative or license holder for a wireless certification. Manufacturers who have gone through medical registration and distribution with local partners should try to use their existing in-country network to fulfill any local representative requirements.

**DON’T FORGET THE EXTRAS**

In addition to the RF modules used in the device, medical products or systems may have supplemental components. Items such as power supplies, access points, or notebooks will likely need in-country certification. Medical manufacturers should speak with their vendors early and present them with a list of documents they will need. If, for example, a medical device works with a wireless access point, the AP vendor may need to provide block diagrams,
From wireless routers to innovative applications in medical equipment, mobile technology's impact on the world is limitless. At CW we're not just researching what's new in wireless test standards, we're prepared for what's next in wireless technology.

Our extensive wireless capabilities include: DECT- DFS- Cellular PCS - LTE/AWS- 4G Amplifiers - 802.11 b/g/a/n Access Points - 802.15.4 Zigbee – 802.15 Bluetooth – VoIP.

We want you to experience the difference between customer service and total customer satisfaction!
Telecom/Wireless will find that the communications authority ultimately dictates the 23600-2400 MHz range. Medical manufacturers, however, authorized the use of medical body area networks (MBANs) in 190. As this suggests some overlap between the organizations on this issue.

In Compliance Magazine has reported, the FCC has recently published recommendations relating to compliance. This and FCC have issued a joint press release and the FDA has manufacturers. In the United States, for example, the FDA and FCC have issued a joint press release and the FDA has published recommendations relating to compliance. This suggests some overlap between the organizations on this issue. As In Compliance Magazine reported, the FCC has recently authorized the use of medical body area networks (MBANs) in the 23600-2400 MHz range. Medical manufacturers, however, will find that the communications authority ultimately dictates the parameters for use of a country’s RF spectrum. Indeed, the FDA has officially ‘suggested’ that medical devices using RF adhere to all FCC regulations. In a 2007 publication, the FDA recommended RF medical devices undergo safety, EMC, and wireless testing. This is for the purpose of better anticipating how the device will function in a medical environment and ensuring crucial data transmissions do not fail. While these are valid points, the FDA recommendations are requirements for the FCC. Internationally, one generally sees communications agencies function autonomously. Exemptions to a RF-related regulation on the grounds that a device is medical are rare. Thus the manufacturer enters another jurisdiction.

Employees of medical manufacturers who have dealt with the FDA and its international counterparts may not end up handling the international wireless approval projects for the same devices. This task could go to an EMC, safety, or RF engineer. As mentioned, existing in-country networks, formed from distributors or medical compliance partners, can benefit the wireless process. Yet, since the regulatory agencies function separately, the employee managing international wireless submittals may not need an understanding of the medical registration process as it exists in each country (assuming someone has that covered). As the use of wireless medical technology accelerates, we may see the regulatory landscape evolve throughout the world. For now, medical manufacturers will join the IT, telecommunications, and many other industries in facing the world of international wireless compliance.

Michael Cassidy is the founder of MC Global Access. His company provides product certifications throughout the world and advises clients on regulatory requirements. Michael was a project manager at Intertek’s Global Market Access Program before TUV Rheinland recruited him. At TUV Rheinland, Michael worked in the International Approvals group as an international specialist and was promoted to operations manager. He has obtained hundreds of product certifications in countries across the globe for a variety of manufacturers. Michael lives in the San Diego area with his wife Sara. When he is not working on international product certifications, he enjoys surfing and traveling. Michael can be reached at mcassidy@mcglobalaccess.com.
Recent Changes to GR-63-CORE

BY CLAYTON FORBES

Telcordia recently released GR-63-CORE Issue 4 “Physical Protection Requirements for Network Telecommunications Equipment”, with a total of 27 new requirements (Rs) and objectives (Os). It has been six years since the document was updated and, as in previous releases, the specification has numerous technical changes.

The first change you will notice is the reactivation of Section 3. Going back to the Issue 2 version of the specification in 2002, Section 3 was a look forward to generic framework requirements. In the Issue 3 release of 2006, this section was deleted from the document and was left dormant. For the Issue 4 release, the section is activated and renamed as “Equipment Spatial Design Requirements for Frames and Chassis”. Activating this section allows for segregation between the office space planning requirements (Rs) and objectives (Os) and equipment spatial Rs and Os. In Section 4, some of the technical changes that will be reviewed include a new operational high temperature requirement based on the airflow of the equipment under test (EUT), new energy efficiency requirements, and an optional operational random vibration test, to name a few. Some tests remain unchanged and will be skipped in this recap. These include surface temperature, mixing flowing gas, hygroscopic dust, and acoustics.

SECTION 2 - FACILITY AND SPACE PLANNING REQUIREMENTS

In previous issues of the document, space planning requirements and objectives were intertwined with test requirements throughout Section 4. In the latest version, the Section 4 Rs and Os dealing with building layouts, such as Central Office Lighting Requirement R4-98 and Objective O4-99, are moved to Section 2 and relabeled as R2-31 and O2-32. Other requirements and objectives that are moved around in the document can be tracked between the versions by using their absolute number, which is the bracketed number in the Rs or Os. By doing this, Sections 3 and 4 have become much cleaner and easier to follow for both manufacturers and laboratories.

SECTION 3 - EQUIPMENT SPATIAL DESIGN REQUIREMENTS FOR FRAMES AND CHASSIS

Section 3 now defines the spatial requirements for frames and chassis. The section includes most of the original Rs and Os from Section 2 and thirteen new Rs and Os. The thirteen new Rs and Os include R3-4 and R3-5 that say access to anchoring bolts is needed when shelves are installed in a frame. R3-7 is that a frame must have the ability to join to an adjacent frame at the top. R3-8 states that a dimensional drawing of the equipment must be supplied and enclosed in the test report. R3-29 demands that the mounting holes for a chassis be a closed slot.

TEMPERATURE TESTING

For the three storage temperature tests (low-temperature exposure and thermal shock, high relative humidity exposure, and high-temperature exposure and thermal shock) there is no change to the testing. The specification does clarify that testing the units in an unpackaged state is an acceptable test.
method. It also allows for slower ramp rates during the high humidity exposure test. The slower ramp rates allow the test to remain non-condensing for larger systems.

The operating temperature test has undergone significant changes. An ongoing issue with equipment being supplied to end-users is the airflow cooling pattern they use. Equipment with airflow patterns that deviate from the required preferential pattern of R4-34 or O4-35 will now be tested to a higher operational temperature. The high operational temperature test is performed at either 50ºC or 55ºC depending on whether the equipment under test (EUT) is frame level equipment or shelf (chassis) level. Now if the equipment has a non-preferential air intake, i.e. not in the front of the EUT, the maximum operating temperature rises to 60ºC or 65ºC depending whether it is a rack or a shelf. These new high temperature requirements are from Table 5-1 and 5-2 of the specification (Figure 1). Equipment with the non-preferential air intake can still be tested to the lower temperature levels if it is supplied and tested with an air deflector or air baffle that changes its air intake to the front of the equipment as stated in O4-36. Another change to the operating temperature profile was done to align the test with the requirements of ETSI EN 300 019-2-3 Class 3.2. During the 96 hour humidity dwell, the temperature and humidity are raised from 28ºC, 90% RH to 30ºC, 93% RH.

**ALTITUDE, TEMPERATURE MARGIN, FAN COOLED EQUIPMENT**

Altitude testing remains essentially the same with two exceptions. The temperatures for the test are raised to align with the changes in the operational temperature and humidity test. These temperature changes are also shown in Table 5-1 and 5-2 (Figure 1). The second change is to the alternate altitude test method using temperature compensation. In Issue 3, if the equipment met the configuration criteria to apply the temperature compensation method, it could be used. This entailed adding 1ºC/1000 feet to the operational temperature. For a shelf level product, the test temperature was 61ºC, 55ºC for the operational requirement, and 6ºC to simulate the 6000 feet from Objective 04-11. Objective 04-12 from Issue 3 is met by default since its required temperature for a shelf product is 58ºC. In Issue 4, the altitude of the test site can be considered and subtracted from the temperature compensation. If the test site is 3000 feet above sea level, the test will be performed at 58ºC, 55ºC from Objective 04-10 and 3ºC for the altitude compensation ((6,000 feet - 3000 feet

<table>
<thead>
<tr>
<th>Table 5.1 Variable Test Temperatures for Frame-level Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Air Inlet Location</td>
</tr>
<tr>
<td>Front aisle or none</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>All others</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5.2 Variable Test Temperatures for Shelf-level Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Air Inlet Location</td>
</tr>
<tr>
<td>Front aisle or none</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>All others</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Figure 1: Tables 5.1 and 5.2 from the GR-63-CORE*
fire resistance testing for the line burner to consistently self-extinguish due to the high velocity airflow. Once the protocol of ATIS-0600319.2008 has been completed and the EUT has complied due to the line burner self-extinguishing, one additional burn for that location will need to be performed. That burn will be done with the fans in a non-operating mode in accordance with two new objectives 04-44 for frames or O4-50 for shelves. The second change deals with printed circuit boards (PCBs) having a distance to each other equal to or greater than 25 mm. Under Issue 3, varying distances between the adjacent cards caused no change in the burn profile. The new Issue 4 protocol for adjacent PCBs greater than 25 mm away, is to leave the PCB in place and insert the line burner through the faceplate on the component side of the card. The line burner peak flow rate is then calculated in the same way as other burns, using the vertical height of the card and adjusted to 50% of the calculated flow rate.

MECHANICAL TESTING

The Category “A” packaged drop test is updated to change the required (1) edge and (2) corners the packaged product is dropped on. The change was performed to align with shipping industry standards. The number of drops remained at a total of 13.

The unpackaged drop is the key change in this section for equipment weighing less than 25 kg. The traditional free fall flat drops onto a non-yielding surface (concrete) from 3.9 inches or 3 inches, depending on its weight, remains, but the number of flat drops was increased to all possible rest surfaces. The two corner drops and two edge drops were changed to pivot drops. These pivot drops, known in the industry as a bench handling, were adopted from MIL-STD-810G Procedure VI of Method 516. The new test procedure is to place the unpackaged, unpowered equipment onto a wooden bench surface or non-yielding surface on its normal rest face. While using one edge as a pivot point, the opposite edge is lifted 4 inches or 45°, whichever is less. The elevated edge is then allowed to free fall onto the bench top. This procedure is then repeated for the pivot edge and the two adjacent edges along the bottom. The drop sequence is then repeated for any other surface the unit could be rested on normally. If your item is able to be rested on a bench top on any of the surfaces, the number of drops would increase from the five required in Issue 3 to 30 in Issue 4. The 30 drops would include six free fall drops, one of each face, and 24 pivot drops, four on each face’s edge.

Seismic testing has a clarification on which bolt the load cell should be placed on during the test if concrete anchors are omitted from the testing. The load cell is placed on the bolt at the innermost position, if the framework allows for a variety of anchor locations. In the test cases that were analyzed, this position was found to have the highest loads relative to the other mounting bolts locations. The second clarification is for
testing of multiple shelves in a single frame. In accordance with the specification, units weighing less than 23 kg have to be placed at the top of the rack. In order to allow multiple units to undergo seismic testing in a single frame, direction is given that the smallest unit is to be placed at the top of the rack at the highest location. However, the lowest unit still has to be within the top 20% of the frame.

Office vibration has an additional test option to use a random vibration profile in lieu of the traditional 0.1 g sine sweep. The random vibration curve was adopted from the Class 4M5 requirements of EN ETSI 019-2-4 to align testing with European requirements. The issue with this alignment, done to reduce testing, will be the fixture requirements from each of the documents. GR-63-CORE has the requirement that shelf level products are placed at a specified height in a telecom frame depending on their weight. ETSI EN 300 019-2-4 requires that the test article be placed in a rigid fixture per IEC 60068-2-47, which telecom two-post frames do not comply to. However since European requirements for weather-protected equipment is performed to Class 3.2 of EN ETSI 019-2-3, the Issue 4 test curve is +3 dB higher as shown below (Figure 2). Based on this difference, a response accelerometer can be placed at the mounting location of the EUT in the telecom frame to verify it envelopes the Class 3.2 requirements. If it does not, separate tests will need to be performed for each of the documents.

The final change in the document in the acoustic section is the removal of the acceptance criteria for unattended locations.

REFERENCES

ETSI EN 300 019-2-3 v2.2.2 (2003-04) – Environmental Conditions and environmental tests for telecommunications equipment; Part 2-3: Specification of environmental tests; Stationary use at weatherprotected locations.

ETSI EN 300 019-2-4 v2.2.2 (2003-04) – Environmental Conditions and environmental tests for telecommunications equipment; Part 2-4: Specification of environmental tests; Stationary use at non-weatherprotected locations.


Clayton Forbes has been working in the testing industry for 30 years, 24 of those years with NTS. Currently he is the Operations manager for NTS’ Northeast Division and was a member of the GR-63-CORE re-write committee. Clayton has served as a technical advisor on various committees in both the commercial and military industries. He is presently serving his second term as Vice Chair for the ATIS STEP-NPP committee and also participate on the SC-135 committee who’s responsibilities include RTCA/160 specification.
IEEE Milwaukee Section presents the
2013 EMC Seminar
with Kenneth Wyatt

Tuesday, March 19, 2013
Crowne Plaza Milwaukee Airport Hotel
Milwaukee, Wisconsin

This year’s program is focused on Developing a Personal EMC Trouble Shooting Kit that will meet today’s challenges of tight engineering budgets. The assembly of your own EMC Troubleshooting Kit will keep the “Focus of EMC” at the forefront of your designs. Mr. Kenneth Wyatt has developed an outstanding approach that can be implemented for less than $5,000.00 (including spectrum analyzer)! Those attending will greatly benefit from Ken’s tutorials and classroom experimentation of these recommended tools.

For more information contact Jim Blaha at jblaha@ieee.org.

Go Global Compliance, Inc. provides global engineering and certification services for electrical/electronic products to more than 150 countries and covering 6 continents.

- One-stop-shop covering global safety, emc, hygienic, energy efficiency, environmental, machinery, radio and telecom.
- 3D+ years of global regulatory experience with international renowned test laboratories.
- First hand knowledge on country regulations, labeling, documentation and packaging.
- Process Link® services ensure your procedures integrally tied to global regulations and certifications.
- Local representative services, competitive prices and lead times to accommodate your products get Worldwide, On Time.
- Go Global Compliance Academy® seminars and webinars to update you on ever changing regulations.

Go Global Compliance, Inc.
Tel: 408-416-3772
peter@goglobalcompliance.com
www.goglobalcompliance.com

ANNUAL VENDORS’ NIGHT
FREE ADMISSION
for all activities

Wednesday, April 17th, 2013
Holiday Inn, Boxborough, MA

5:00 PM . . . Registration Opens
5:30 PM . . . Exhibition Hall Opens
7:00 PM . . . Dinner (free for attendees, must RSVP by April 1)
9:00 PM . . . Door Prize Drawings
9:30 PM . . . Exhibition Hall Closes

Visit as many as 50 Booths featuring the latest in EMC and Safety Compliance.

For information & reservations, please visit
www.nepss.net

SAVE THE DATE

Tuesday, September 17, 2013
Minnesota EMC Event

This Annual Event will be held at the Ramada Mall of America in Bloomington, MN – a major suburb of Minneapolis. The Hotel is located five minutes from the Minneapolis-St. Paul International Airport.

The Annual Event will have three technical tracks; EMC and Medical Devices, EMC Standards (commercial and military), and Test Labs for EMC. Interested speakers may contact Dan Hoolihan for more details at danhoolhanemc@aol.com.

A Vendors table-top show will be held in conjunction with the three technical tracks. For further details on exhibiting at the MN EMC Event, contact Dan Hoolihan at danhoolhanemc@aol.com.
<table>
<thead>
<tr>
<th>Consultants Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Andre Consulting, Inc.</strong></td>
</tr>
<tr>
<td><strong>Don HEIRMAN Consultants</strong></td>
</tr>
<tr>
<td><strong>Henry Ott Consultants</strong></td>
</tr>
<tr>
<td><strong>Hoolihan EMC Consulting</strong></td>
</tr>
<tr>
<td><strong>Kimmel Gerke Associates, Ltd.</strong></td>
</tr>
<tr>
<td><strong>Montrose Compliance Services</strong></td>
</tr>
<tr>
<td><strong>RTF Compliance</strong></td>
</tr>
<tr>
<td><strong>Wyatt Technical Services, LLC</strong></td>
</tr>
</tbody>
</table>
AK-40G Antenna Kit

A.H. Systems AK-40G Antenna kit with a frequency range of 20 Hz – 40 GHz provides all the reliable antennas, current probes, and cables needed to satisfy a wide array of customer requirements. Each kit contains a tripod, azimuth and elevation head and a tripod carrying case. All with next-day, on-time delivery. Visit our web site at www.AHSystems.com

A.H. Systems, Inc.
tel: 818-998-0223
sales@ahsystems.com
www.ahsystems.com

Meet Compliance with A2LA

A2LA is a private, non-profit membership association, whose primary mission is to provide comprehensive internationally recognized accreditation for laboratories, inspection bodies, proficiency testing providers, reference materials producers and product certification bodies. Assessments are conducted using international standards and specific requirements developed in cooperation with specifiers.

A2LA – American Association for Laboratory Accreditation
tel: 301-644-3248
www.A2LA.org
Rent EMC Compliance Test Equipment

Advanced Test Equipment Rentals offers a wide range of EMC test systems up to 40 GHz. Applications for product testing, power quality, automotive, communications and aerospace are supported. Test standards include MIL-STD 461, DO160, IEC 61000, and ISO7637. Next day delivery and technical support are available for most equipment.

Advanced Test Equipment Rentals
tel: 888-544-2832
rentals@atecorp.com
www.atecorp.com

AR’s new MultiStar Multi-Tone Tester

AR’s new MultiStar Multi-Tone Tester is a state-of-the-art system designed to test RF Radiated Immunity faster than ever before. The MT06000 system allows users to test multiple frequencies (tones) simultaneously, and contains all the instruments needed to perform radiated immunity testing from 80MHz-6GHz for IEC 61000-4-3.

For more information visit
www.arww-rfmicro.com/html/18200.asp?id=1109

MIL-STD-188-125 HEMP Filters

Captor HEMP filters enhance our proven and reliable lines of EMI filters, TEMPEST filters and Feedthru capacitors. Captor HEMP filters have been tested and meet the requirements of MIL-STD-188-125-1 and -2.

Call Captor to discuss the solution to your EMI/EMP problems.

Captor Corporation
tel: 937-667-8484
sales@captorcorp.com
www.captorcorp.com

Chomerics Releases New Web Resources

Parker Chomerics is a manufacturer of EMI shielding, thermal management, optical display enhancement and protection, and engineered thermostatics. EMI shielding products include gaskets, coatings, compounds, vents, windows, conductive plastic, tapes, and microwave absorbers. Thermal products include insulator pads, gap fillers, adhesive tapes, grease, flexible heat spreaders and phase change materials.

Chomerics
a Division of Parker Hannifin
tel: 781-939-4791
www.chomerics.com

Regulatory Compliance Testing


Test Locally Sell Globally!
FCC - Wireless - Telecom - CE Marking Pre-compliance Testing Product Safety

Compliance Worldwide, Inc.
tel: 603-887-3903
sales@cw-inc.com
www.ComplianceWorldwide.com

EMC Simulation Software from CST

CST is a world leader in computer simulation of radiated emissions and susceptibility. CST STUDIO SUITE® provides powerful solutions for complex EMC analysis including coupled simulations which enable large system analysis and installed performance studies. Many years of in-house expertise support the tools and give customers confidence in simulation results.

CST of America
tel: 508-665-400
info@cst.com
www.cst.com
### ED&D – Certified Product Safety Equipment
ED&D, incorporated in 1990, is a world-leading manufacturer of industrial test equipment for product safety applications. Products are made in accordance with many national or international standards, such as IEC, CE, CSA, UL, VDE, MIL, EN, ASTM. In addition, our ISO 17025 calibration services fully certify our products and recalibrations.

**Educated Design & Development, Inc. (ED&D)**  
Domestic: 800-806-6236  
International: 1-919-469-9434  
info@productsafet.com  
www.productsafet.com

### Reliable Testing Services
Located in Kanata, Ontario and operating since 1988 as a product certification test lab, we offer a broad range of electronics testing and certification services. We provide high quality and reliable testing services to the electronics, telecommunications, medical, military, aeronautical and automotive industries.

**Electronics Test Centre**  
tel: 613-599-6800  
fax: 613-599-7614  
sales@etc-mpb.com  
www.etc-mpb.com

### Load Dump 200N200
Stand alone LD Simulator for DUT supply up to 200 A

**EM TEST USA**  
tel: 858-699-1685  
products.emtest@ametek.com  
www.emtest.com

### Calibration Plus™ Saves Time and Money
Manage calibration and repair of your antennas, probes, LISNs and more, with ETS-Lindgren’s Calibration Plus™! You get a customized program with priority scheduling, special pricing, signed Certificates of Conformance, and archived records. All work is performed in our A2LA accredited lab. Details:
www.ets-lindgren.com/maintenance

**ETS-Lindgren**  
tel: 512-531-6400  
info@ets-lindgren.com  
www.ets-lindgren.com

### Axos – Compact Immunity Test System
The new AXOS5 compact immunity test system integrates all of the best features of our stand alone test systems into one single economic solution. It combines 5 kV Burst/EFT, Surge combination wave, AC/DC Dips & Interrupts, along with an integrated single-phase coupling/decoupling network into one compact test system.

**Hipotronics Inc**  
tel: 845-230-9240  
EMCsales@hipotronics.com

### New 5kV EFT Capability
HV TECHNOLOGIES has announced the TRA3000 Immunity Tester now offers the ability to test to 5kV EFT pulses as new product standards have added this requirement. The enhanced EFT module with the same physical footprint fits directly into the existing TRA3000 mainframes allowing users to extend test capabilities with on-site upgrades to 5kV EFT pulses.

**HV TECHNOLOGIES, Inc.**  
tel: 703-365-2330  
www.hvtechnologies.com
Keep Informed
Keep informed as we monitor compliance activities, product news and events throughout the world. The World In Compliance e-newsletter reports on industry developments and trends, standards developments, emerging technologies, and other pertinent developments in the world of compliance. The e-Product Showcase offers the latest industry products and events. Sign up today!

www.incompliancemag.com/subscribe

Commercial & Military Shielded Room Filters
LCR provides shielded room filters for commercial and military applications. The 057 series High Performance Filters serve commercial customers for shielded enclosures, EMC test laboratories and anechoic chambers. Our Military filters include F1960 Facility/Shielded Room Power Line Filter Cabinets which meet MIL-STD-220. The F15000 Filters and Enclosures comply with MIL-F-15733 and our Tubular Filters comply with MIL-F-15733.

LCR Electronics, Inc.
tel: 610 278-0840
www.lcr-inc.com

MuMetal® Alloy for Electromagnetic Shielding
MuMetal® is the most recognized brand of magnetic shielding alloy, worldwide. Unknown by many, MuMetal® is not a generic name - it is a registered brand and exclusively available from Magnetic Shield Corp., Bensenville, IL USA. Specify MuMetal® in your design and have us prototype, qualify and manufacture to your specifications.

Magnetic Shield Corporation
Mr. Brad Friestedt
tel: 630-766-7800
shields@magnetic-shield.com
www.magnetic-shield.com

MuShield Custom Magnetic Shielding Enclosures
For over 50 years, The MuShield Company, Inc. has been a leading manufacturer of custom magnetic shielding enclosures. An ISO-9001:2008 certified company, MuShield guarantees a high quality manufactured product which will meet or exceed your requirements for EMI Shielding and design.

The MuShield Company, Inc.
tel: 603-666-4433 x 21
fax: 603-666-4013
info@mushield.com
www.mushield.com

OKAYA New Products LV & SV
Electrical characteristics:
• Max. Discharge Current 5000A (8/20μs)
• Voltage protection level 1500V max (at AC250VProduct)
• Surge Current Life 1000A (8/20μs) Approx 500 times
• UL1449-3 Type 2 (permanent connect)
• cUL: C22.2 No8 IEC61643-1 EN61643-11

Applications:
• Motion control
• Inverter or servomotor control
• Industrial machine
• Robot
• And more

Okaya Electric America, Inc.
tel: 219-477-4488
www.okaya.com

HYB-NF High Performance Fireproof Absorber
HYB-NF is a hybrid absorber manufactured from a fire proof, fibrous composite, impedance matched to ferrite tiles. Designed for use in EMC, FREE SPACE and MIL Test Chambers, the hybrid allows broadband testing from 26 MHz up to 60 GHz, and withstands field strengths greater than 300V/m. Exclusively from Panashield.

Panashield, Inc.
tel: 203-866-5888
fax: 203-866-6162
help@panashield.com
www.panashield.com
PRODUCT/SERVICE SPOTLIGHTS

Bringing Products To Market
Professional Testing (EMI), Inc. is a NVLAP accredited full service test laboratory providing EMC, Product Safety, Reliability and Hazardous Location testing and consulting services. Our team of experts can assist you at almost any stage of your product development cycle: from design assistance to beyond the final product test report.

Professional Testing (EMI), Inc.
tel: 800-695-1077
info@ptitest.com
www.ptitest.com

EESeal - Instant Retrofit EMI Filter
Quell’s EESeal adds an EMI filter to YOUR connector in seconds; the thin elastomeric insert easily slips onto the pins, no soldering. It connects capacitors/components between selected pins and the connector shell. It’s a proven, reliable, permanent solution. FREE custom samples typically ship within 2-3 days. ISO9001 & AS9100 Certified.

Quell Corporation
contact: Paul Miller
tel: 505-243-1423
EESeal@Quell.us
www.eeseal.com

Reliant EMC
Your Compliance Source!
Reliant EMC, your EMC compliance source, offers World Class Emissions and Immunity test instrumentation from York EMC, Laplace Instruments, Spitzenberger & Spies and OnFILTER, which enables you to reduce cost and time by Pre-Compliance or Self-Certifying your products for EMC. Reliant EMC supports the Americas for your Electromagnetic Compliance needs.

Reliant EMC LLC
tel: 408-600-1472
www.reliantemc.com

NEW EMI/Environmental Connector-Seal
Spira’s NEW Connector-Seal gaskets now come in a Front-Mount configuration, providing excellent EMI/Environmental protection! Our unique patent-pending design includes a rigid layer between either silicone or fluorosilicone sealing, and includes our patented spiral gasket for excellent EMI shielding. Provides extremely durable and reliable one atmosphere environmental sealing for flange-mounted connectors. Contact us for information and a free sample!

Spira Manufacturing Corporation
tel: 818-764-8222
fax: 818-764-9880
info@spira-emi.com
www.spira-emi.com/whatsnew

FM Approved Retractable Telescoping Fire Sprinkler
Sprinkler Innovations manufactures the only FM Approved Retractable Telescoping Fire Sprinkler for Anechoic Chambers. For more information, check out our website at www.sprinklerinnovations.com, or contact our office for a free DVD of our sprinkler head. Call Jim Beers at 800-850-6692.

Sprinkler Innovations
tel: 800-850-6692
jbeers@sprinklerinnovations.com
www.sprinklerinnovations.com

TDK Model VC-06 Video Camera
The new VC-06 hi-definition, all digital, color video camera was developed for remote monitoring of equipment during EMC testing in a shielded room or anechoic chamber. Designed to operate in harsh electromagnetic environments, it is ideal for anechoic chamber monitoring, shielded access control, and test action archiving. Contact TDK for more information.

TDK RF Solutions
tel: 512-258-9478
info@tdkrf.com
http://tdkrfolutions.com
Teseq’s Calibration Laboratory Renews A2LA Accreditation

Teseq’s calibration laboratory gained renewed accreditation to the international standard ISO/IEC 17025 in an assessment by the American Association for Laboratory Accreditation (A2LA). In addition to its renewal, Teseq has added several RF parameters to its scope of accreditation and is now accredited to calibrate CDNs, ISNs and compact immunity generators.

Teseq
tel: 732-417-0501
usasales@teseq.com
www.teseq.com

Battery Testing Whitepapers and Webinar from TÜV SÜD


TÜV SÜD America Inc.
toll-free: 800-TUV-0123
info@tuvam.com
www.TUVamerica.com

Custom, Time-to-Market Solutions

Safety is evolving. So is UL. Today, UL’s technical engineering experts ask manufacturers what their time-to-market needs are. Understanding that one size doesn’t fit all, UL works collaboratively throughout the certification process, providing customized solutions to meet manufacturer’s unique needs—without jeopardizing safety, quality or integrity for speed.

UL
tel: 877-UL-HELPS (877-854-3577)
fax: 360-817-6278
cec.us@us.ul.com
www.ul.com/appliances

No Job Too Large or Too Small!

Shielding the World Since 1972
Celebrating Our 40th Year Anniversary

• Offering Complete Turn-Key Solutions for the EMC Industry
• Pre-fabricated design allows rapid installation
• Solutions are fully customizable to meet the needs of clients

Universal Shielding Corp.
20 West Jefryn Blvd.
Deer Park, NY 11729
tel: 800-645-5578
info@universalshielding.com
www.universalshielding.com
Associations, Education & Training .... 207
Associations ................. 207
Books .......................... 207
EMI/EMC ......................... 207
ESD .......................... 207
Product Safety ............... 207
Codes, Standards and Regulations .......... 207
Education ....................... 207
Publications .................... 207
Training Courses .............. 207
Videos .......................... 207

Chambers, Antennas & Accessories 207
Absorbers ...................... 207
EMC .......................... 207
Honeycomb RF .......................... 207
Low Frequency ..................... 207
Microwave ..................... 208
Anechoic Materials .............. 208
Antenna Couplers .............. 208
Antenna Masts .................... 208
Antennas ............... 208
Biconical ..................... 208
Broadband ..................... 208
EMI Test ..................... 208
Horn ..................... 208
Log Periodic ..................... 208
Loop ..................... 208
Nonionizing Radiation Hazard .... 208
Rod .......................... 208
Tunable Dipole .................... 208
Whip .......................... 208
Cells ........................ 208
GTEM .......................... 208
TEM & Strip Line .................. 209
Chambers ..................... 209
Anechoic ..................... 209
Reverberation/Mode-Stirred ........ 209
Fire Protection .................. 209
Helmholtz Coils .................. 209
Injection Clamps .................. 209
Sensors/Transducers, RF Field .................. 209
Shielded Buildings .................. 209
Shielded Rooms/Chambers .................. 209
Turntables ..................... 209

Consulting & Services 209
Calibration & Repair Services .................. 209
Conductive Painting Services ................. 210
Consultants ..................... 210
Cleanroom/Static Control .................. 210
EMC .......................... 210
EU .......................... 210
GOST ..................... 210
Lightning Protection .................. 210
Medical Device .................. 210
Product Safety .................. 211
Quality ............................. 211
Telecom ..................... 211
Tempest ..................... 211
Transients ..................... 211
VCCI ..................... 211
Design Services .................. 212
Equipment Rental & Leasing .................. 212
Manufacturers’ Representatives .................. 212
Shielded Enclosure Design, Relocation Services .................. 212
Site Attenuation Testing Services .................. 212
Site Survey Services .................. 212

Electrical & Electronic Components 212
Adapters ..................... 212
Air Filters ..................... 212
EMI Air Filters ..................... 212
Shielded Air Filters ..................... 212
 Arrestors ..................... 212
Attenuators ..................... 212
Backplanes ..................... 212
Backshells ..................... 212
Bluetooth Modules ..................... 213
Breakers ..................... 213
Cabinets/Enclosures .................. 213
Cable Assemblies .................. 213
Circuit Breakers .................. 213
Connectors ..................... 213
Couplers ..................... 213
Diodes ..................... 213
Electronic Cooling Fans .................. 213
Fuses ..................... 213
Grounding Rods .................. 213
Impedance Matching Networks .................. 213
Inductors ..................... 213
EMI/RFI ..................... 213
Surface Mount ..................... 213
Switchmode ..................... 213
Integrated Circuits .................. 213
LEDs and Displays .................. 213
Liquid Crystal Display Modules .................. 213
Military (MIL-SPEC) Connectors .................. 213
Oscillators ..................... 213
Potentiometers ..................... 213
Resonators ..................... 213
RF Frequency Converters .................. 213
Solid State Relays .................. 213
Surge Suppressors .................. 213
Switches ..................... 214
Terminal Blocks .................. 214
Thyristors ..................... 214
Transformers ..................... 214
Power Line Isolation .................. 214
Signal Line Isolation .................. 214
Telecommunications .................. 214
Third-Party Approved, EU .................. 214
Third-Party Approved, US/Canada .................. 214
Toroidal ..................... 214
Varistors ..................... 214

EMC/EMI Control 214
Air Cooling Systems .................. 214
Architectural Shielding Products .................. 214
 Arrestors, Lightning and Surge .................. 214
Braid, Bonding, and Grounding Accessories .................. 214
<table>
<thead>
<tr>
<th>Capacitors</th>
<th>214</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic</td>
<td>214</td>
</tr>
<tr>
<td>Decoupling</td>
<td>214</td>
</tr>
<tr>
<td>Electrolytic</td>
<td>214</td>
</tr>
<tr>
<td>Filter</td>
<td>214</td>
</tr>
<tr>
<td>Mains (X and Y)</td>
<td>214</td>
</tr>
<tr>
<td>Planar Array</td>
<td>214</td>
</tr>
<tr>
<td>Tantulm</td>
<td>214</td>
</tr>
<tr>
<td>Chokes</td>
<td>214</td>
</tr>
<tr>
<td>Conductive Materials</td>
<td>214</td>
</tr>
<tr>
<td>Additives</td>
<td>214</td>
</tr>
<tr>
<td>Adhesive</td>
<td>214</td>
</tr>
<tr>
<td>Epoxy</td>
<td>214</td>
</tr>
<tr>
<td>Foam</td>
<td>214</td>
</tr>
<tr>
<td>Laminates</td>
<td>215</td>
</tr>
<tr>
<td>Lubricants</td>
<td>215</td>
</tr>
<tr>
<td>Plastics</td>
<td>215</td>
</tr>
<tr>
<td>Connector Fingers</td>
<td>215</td>
</tr>
<tr>
<td>Cord Sets, EMI</td>
<td>215</td>
</tr>
<tr>
<td>Ferrite Beads, Rods and Forms</td>
<td>215</td>
</tr>
<tr>
<td>Filter Coils</td>
<td>215</td>
</tr>
<tr>
<td>Filter Pins</td>
<td>215</td>
</tr>
<tr>
<td>Filtered Connectors</td>
<td>215</td>
</tr>
<tr>
<td>Filters</td>
<td>215</td>
</tr>
<tr>
<td>Absorptive</td>
<td>215</td>
</tr>
<tr>
<td>Antenna</td>
<td>215</td>
</tr>
<tr>
<td>EMC and RFI</td>
<td>215</td>
</tr>
<tr>
<td>EMC Test Chamber</td>
<td>215</td>
</tr>
<tr>
<td>Power Line</td>
<td>215</td>
</tr>
<tr>
<td>RF and Microwave</td>
<td>215</td>
</tr>
<tr>
<td>Shielded Air</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Room</td>
<td>216</td>
</tr>
<tr>
<td>Signal Line</td>
<td>216</td>
</tr>
<tr>
<td>Third-Party Approved, EU</td>
<td>216</td>
</tr>
<tr>
<td>Third-Party Approved, US/Canada</td>
<td>216</td>
</tr>
<tr>
<td>Finger Stock</td>
<td>216</td>
</tr>
<tr>
<td>Foils, Shield Tape</td>
<td>216</td>
</tr>
<tr>
<td>Gaskets</td>
<td>216</td>
</tr>
<tr>
<td>Resistors</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Cable Assemblies and Harnesses</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Conduit</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Connectors</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Enclosures</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Modules</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Tubing</td>
<td>216</td>
</tr>
<tr>
<td>Shielded Wire and Cable</td>
<td>217</td>
</tr>
<tr>
<td>Shielding Coatings</td>
<td>217</td>
</tr>
<tr>
<td>Shielding Compounds</td>
<td>217</td>
</tr>
<tr>
<td>Shielding Material</td>
<td>217</td>
</tr>
<tr>
<td>EMI/RFI</td>
<td>217</td>
</tr>
<tr>
<td>Magnetic Field</td>
<td>217</td>
</tr>
<tr>
<td>Shielding, Board-Level</td>
<td>217</td>
</tr>
<tr>
<td>Suppressors</td>
<td>217</td>
</tr>
<tr>
<td>Suppressors, Transient</td>
<td>217</td>
</tr>
<tr>
<td>ESD Equipment &amp; Products</td>
<td>217</td>
</tr>
<tr>
<td>Air Ionizers</td>
<td>217</td>
</tr>
<tr>
<td>ESD Tape</td>
<td>217</td>
</tr>
<tr>
<td>Meters</td>
<td>217</td>
</tr>
<tr>
<td>Static Charge</td>
<td>217</td>
</tr>
<tr>
<td>Simulators</td>
<td>217</td>
</tr>
<tr>
<td>EMP</td>
<td>217</td>
</tr>
<tr>
<td>ESD</td>
<td>217</td>
</tr>
<tr>
<td>Lightning</td>
<td>218</td>
</tr>
<tr>
<td>Static Control</td>
<td>218</td>
</tr>
<tr>
<td>Containers</td>
<td>218</td>
</tr>
<tr>
<td>Flooring</td>
<td>218</td>
</tr>
<tr>
<td>Footwear</td>
<td>218</td>
</tr>
<tr>
<td>Garments</td>
<td>218</td>
</tr>
<tr>
<td>Mats</td>
<td>218</td>
</tr>
<tr>
<td>Monitoring Equipment</td>
<td>218</td>
</tr>
<tr>
<td>Packaging</td>
<td>218</td>
</tr>
<tr>
<td>Workstations</td>
<td>218</td>
</tr>
<tr>
<td>Wrist Straps</td>
<td>218</td>
</tr>
<tr>
<td>Transient Detectors and Suppressors</td>
<td>218</td>
</tr>
<tr>
<td>Materials, Adhesives &amp; Coatings</td>
<td>218</td>
</tr>
<tr>
<td>Absorbing Materials</td>
<td>218</td>
</tr>
<tr>
<td>Adhesives</td>
<td>218</td>
</tr>
<tr>
<td>Alloys</td>
<td>218</td>
</tr>
<tr>
<td>Coatings</td>
<td>218</td>
</tr>
<tr>
<td>Foams and Foam Materials</td>
<td>218</td>
</tr>
<tr>
<td>Insulation</td>
<td>218</td>
</tr>
<tr>
<td>Powders</td>
<td>218</td>
</tr>
<tr>
<td>Resins and Compounds</td>
<td>218</td>
</tr>
<tr>
<td>Sealants</td>
<td>218</td>
</tr>
<tr>
<td>Silicone Conductive Sponge</td>
<td>218</td>
</tr>
<tr>
<td>Thermally Conductive Silicone Materials</td>
<td>218</td>
</tr>
<tr>
<td>Thermoplastic Components</td>
<td>218</td>
</tr>
<tr>
<td>Thermoplastic Components</td>
<td>218</td>
</tr>
<tr>
<td>Power &amp; Power Management</td>
<td>219</td>
</tr>
<tr>
<td>Constant Voltage Regulators</td>
<td>219</td>
</tr>
<tr>
<td>Converters</td>
<td>219</td>
</tr>
<tr>
<td>Cord Sets</td>
<td>219</td>
</tr>
<tr>
<td>Electronic Loads</td>
<td>219</td>
</tr>
<tr>
<td>Interrupters, AC Power</td>
<td>219</td>
</tr>
<tr>
<td>Isolators, Power/Signal Line</td>
<td>219</td>
</tr>
<tr>
<td>Line Cords</td>
<td>219</td>
</tr>
<tr>
<td>Motors</td>
<td>219</td>
</tr>
<tr>
<td>Multiple Outlet Strips</td>
<td>219</td>
</tr>
<tr>
<td>Overcurrent Protection</td>
<td>219</td>
</tr>
<tr>
<td>Overvoltage Protection</td>
<td>219</td>
</tr>
<tr>
<td>Power Amplifier</td>
<td>219</td>
</tr>
<tr>
<td>Power Converters</td>
<td>219</td>
</tr>
<tr>
<td>Power Cords</td>
<td>219</td>
</tr>
<tr>
<td>Power Distribution Systems</td>
<td>219</td>
</tr>
<tr>
<td>Power Entry Modules</td>
<td>219</td>
</tr>
<tr>
<td>Power Generators</td>
<td>219</td>
</tr>
<tr>
<td>Power Line Conditioning Equipment</td>
<td>219</td>
</tr>
<tr>
<td>Power Rectifier</td>
<td>219</td>
</tr>
<tr>
<td>Power Supplies</td>
<td>219</td>
</tr>
<tr>
<td>Switch Mode Power Supply</td>
<td>220</td>
</tr>
<tr>
<td>Switching Power Supplies</td>
<td>220</td>
</tr>
<tr>
<td>Safety and Protective Equipment</td>
<td>220</td>
</tr>
<tr>
<td>Safety and Warning Labels</td>
<td>220</td>
</tr>
<tr>
<td>Product/Service Directory</td>
<td>Index</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Software Suppliers</strong></td>
<td>.220</td>
</tr>
<tr>
<td>3D Simulation Software</td>
<td>.220</td>
</tr>
<tr>
<td>Anechoic Chamber Software</td>
<td>.220</td>
</tr>
<tr>
<td>EMC Simulation Software</td>
<td>.220</td>
</tr>
<tr>
<td>EMC/EMI Software</td>
<td>.220</td>
</tr>
<tr>
<td>ESD, Static Control Software</td>
<td>.220</td>
</tr>
<tr>
<td>Product Safety Software</td>
<td>.220</td>
</tr>
<tr>
<td>Signal Integrity and EMC Analysis Software</td>
<td>.220</td>
</tr>
<tr>
<td>Wireless Propagation Software</td>
<td>.220</td>
</tr>
</tbody>
</table>

| Standards Suppliers | .220 |

<table>
<thead>
<tr>
<th>Test &amp; Measurement Equipment</th>
<th>.220</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>.220</td>
</tr>
<tr>
<td>Low Noise.</td>
<td>.220</td>
</tr>
<tr>
<td>Power</td>
<td>.211</td>
</tr>
<tr>
<td>RF</td>
<td>.221</td>
</tr>
<tr>
<td>Analyzers</td>
<td>.221</td>
</tr>
<tr>
<td>EMI/EMC Spectrum</td>
<td>.221</td>
</tr>
<tr>
<td>Flicker.</td>
<td>.221</td>
</tr>
<tr>
<td>Harmonics</td>
<td>.221</td>
</tr>
<tr>
<td>Network</td>
<td>.221</td>
</tr>
<tr>
<td>Power Quality</td>
<td>.221</td>
</tr>
<tr>
<td>Telecom</td>
<td>.221</td>
</tr>
<tr>
<td>Automatic Test Sets</td>
<td>.221</td>
</tr>
<tr>
<td>Avionics Test Equipment</td>
<td>.222</td>
</tr>
<tr>
<td>Buildings, EMC Testing</td>
<td>.222</td>
</tr>
<tr>
<td>Burn-in Test Equipment</td>
<td>.222</td>
</tr>
<tr>
<td>Calibration &amp; Repair Services</td>
<td>.222</td>
</tr>
<tr>
<td>Current Leakage Testers</td>
<td>.222</td>
</tr>
<tr>
<td>Data Acquisition Monitoring Systems</td>
<td>.222</td>
</tr>
<tr>
<td>Dielectric Strength Testers</td>
<td>.222</td>
</tr>
<tr>
<td>Electrical Safety Testers</td>
<td>.222</td>
</tr>
<tr>
<td>EMC Testers</td>
<td>.222</td>
</tr>
<tr>
<td>EMP Simulators</td>
<td>.222</td>
</tr>
<tr>
<td>Environmental Chambers</td>
<td>.222</td>
</tr>
<tr>
<td>ESD Test Equipment</td>
<td>.223</td>
</tr>
<tr>
<td>Fiber-Optic Systems</td>
<td>.223</td>
</tr>
<tr>
<td>Flow Meters</td>
<td>.223</td>
</tr>
<tr>
<td>Gaussmeters</td>
<td>.223</td>
</tr>
<tr>
<td>Generators</td>
<td>.223</td>
</tr>
<tr>
<td>Arbitrary Wave Form</td>
<td>.223</td>
</tr>
<tr>
<td>ESD</td>
<td>.223</td>
</tr>
<tr>
<td>Fast/Transient Burst</td>
<td>.223</td>
</tr>
<tr>
<td>Impulse</td>
<td>.223</td>
</tr>
<tr>
<td>Interference</td>
<td>.223</td>
</tr>
<tr>
<td>Lightning</td>
<td>.223</td>
</tr>
<tr>
<td>Signal</td>
<td>.223</td>
</tr>
<tr>
<td>Surge Transient</td>
<td>.223</td>
</tr>
<tr>
<td>Ground Bond Testers</td>
<td>.223</td>
</tr>
<tr>
<td>Ground Resistance Testers</td>
<td>.223</td>
</tr>
<tr>
<td>Hipot Testers</td>
<td>.223</td>
</tr>
<tr>
<td>Meters</td>
<td>.224</td>
</tr>
<tr>
<td>Megohmmeters</td>
<td>.224</td>
</tr>
<tr>
<td>Field Strength</td>
<td>.224</td>
</tr>
<tr>
<td>Magnetic Field</td>
<td>.224</td>
</tr>
<tr>
<td>Radiation Hazard</td>
<td>.224</td>
</tr>
<tr>
<td>RF Power</td>
<td>.224</td>
</tr>
<tr>
<td>Static Charge</td>
<td>.224</td>
</tr>
<tr>
<td>Static Decay</td>
<td>.224</td>
</tr>
<tr>
<td>Monitors</td>
<td>.224</td>
</tr>
<tr>
<td>Current</td>
<td>.224</td>
</tr>
<tr>
<td>EMI Test</td>
<td>.224</td>
</tr>
<tr>
<td>ESD</td>
<td>.224</td>
</tr>
<tr>
<td>Ionizer Balance</td>
<td>.224</td>
</tr>
<tr>
<td>Static Voltage</td>
<td>.224</td>
</tr>
<tr>
<td>Oscilloscopes and Transient Recorders</td>
<td>.224</td>
</tr>
<tr>
<td>Probes</td>
<td>.224</td>
</tr>
<tr>
<td>Current/Magnetic Field</td>
<td>.224</td>
</tr>
<tr>
<td>Electric Field</td>
<td>.224</td>
</tr>
<tr>
<td>Voltage</td>
<td>.224</td>
</tr>
<tr>
<td>Receivers</td>
<td>.224</td>
</tr>
<tr>
<td>EMI/EMC</td>
<td>.224</td>
</tr>
<tr>
<td>RF</td>
<td>.225</td>
</tr>
<tr>
<td>Tempest</td>
<td>.225</td>
</tr>
<tr>
<td>RF Leak Detectors</td>
<td>.225</td>
</tr>
<tr>
<td>Safety Test Equipment</td>
<td>.225</td>
</tr>
<tr>
<td>Shock &amp; Vibration</td>
<td>.225</td>
</tr>
<tr>
<td>Testing Shakers</td>
<td>.225</td>
</tr>
<tr>
<td>Susceptibility Test Instruments</td>
<td>.225</td>
</tr>
<tr>
<td>Telecom Test Equipment</td>
<td>.225</td>
</tr>
<tr>
<td>Temperature Cycling Systems</td>
<td>.225</td>
</tr>
<tr>
<td>Used &amp; Refurbished Test Equipment</td>
<td>.225</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Testing Services</th>
<th>.225</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accredited Registrar</td>
<td>.225</td>
</tr>
<tr>
<td>CE Competent Body</td>
<td>.225</td>
</tr>
<tr>
<td>CE Notified Body</td>
<td>.225</td>
</tr>
<tr>
<td>Environmental Testing and Analysis Services</td>
<td>.226</td>
</tr>
<tr>
<td>Homologation Services</td>
<td>.226</td>
</tr>
<tr>
<td>Pre-Assessments</td>
<td>.226</td>
</tr>
<tr>
<td>Product and Component Testing Services</td>
<td>.226</td>
</tr>
<tr>
<td>Testing Laboratories</td>
<td>.227</td>
</tr>
<tr>
<td>Accelerated Stress Testing</td>
<td>.227</td>
</tr>
<tr>
<td>Acoustical Testing</td>
<td>.227</td>
</tr>
<tr>
<td>BSMI Compliant Certification Testing</td>
<td>.227</td>
</tr>
<tr>
<td>CB Test Report</td>
<td>.227</td>
</tr>
<tr>
<td>CE Marking</td>
<td>.227</td>
</tr>
<tr>
<td>China Compulsory Certification</td>
<td>.228</td>
</tr>
<tr>
<td>Electrical Safety Testing</td>
<td>.228</td>
</tr>
<tr>
<td>EMC Testing</td>
<td>.228</td>
</tr>
<tr>
<td>Energy Efficiency Testing</td>
<td>.229</td>
</tr>
<tr>
<td>Environmental Simulation Testing</td>
<td>.229</td>
</tr>
<tr>
<td>EuP Directive Compliance</td>
<td>.230</td>
</tr>
<tr>
<td>GOST R certification</td>
<td>.230</td>
</tr>
<tr>
<td>Green Energy Compliance</td>
<td>.230</td>
</tr>
<tr>
<td>GS Mark Certification</td>
<td>.230</td>
</tr>
<tr>
<td>Halogen Testing</td>
<td>.230</td>
</tr>
<tr>
<td>Lithium-Ion Battery Testing</td>
<td>.230</td>
</tr>
<tr>
<td>Marine Electronics Testing</td>
<td>.230</td>
</tr>
<tr>
<td>Nationally Recognized Testing Laboratory (NRTL)</td>
<td>.230</td>
</tr>
<tr>
<td>Network Equipment Building System (NEBS) Testing</td>
<td>.230</td>
</tr>
<tr>
<td>Product Pre-Compliance Testing</td>
<td>.231</td>
</tr>
<tr>
<td>Product Safety Testing</td>
<td>.231</td>
</tr>
<tr>
<td>Radio Performance &amp; Functionality Testing</td>
<td>.232</td>
</tr>
<tr>
<td>RoHS Directive Compliance</td>
<td>.232</td>
</tr>
<tr>
<td>Standards Council of Canada Certification Body</td>
<td>.232</td>
</tr>
<tr>
<td>Telecommunication Certification Approval</td>
<td>.232</td>
</tr>
</tbody>
</table>
Associations, Education & Training

Associations
A2LA .......................... 301-644-3204  
EDS Association .................. 315-339-6937  
iNARTE at RABQSA International .......................... 800-89-NARTE  
NTS Albuquerque .................. 505-821-4740  
RABQSA International .................. 888-722-2440  
Trace Laboratories, Inc. .................. 410-584-9099

Books
Books, EMI/EMC
D. C. Smith Consultants .......... 800-323-3956  
Henry Ott Consultants ............. 973-992-1793  
Montrose Compliance Services ........................................ 408-247-5715  
Phoenix Technical Group ........... 919-535-3662  
Wurth Electronics Midcom. ........ 800-643-2661

Books, ESD
D. C. Smith Consultants .......... 800-323-3956

Books, Product Safety
Phoenix Technical Group .......... 919-535-3662

Codes, Standards and Regulations
Abstraction Engineering Inc ........ 408-258-3282  
Aum Electro Technology Pvt Ltd .............................................. 00912512871365  
Clarion Safety Systems ............. 800-748-0241  
Don HEIRMAN Consultants .......... 732-741-7723  
Eisner Safety Consultants ........ 503-244-6151  
Lewis Bass International .......... 808-942-8000  
MC Global Access ................. 760-696-3700  
VEROCH ............................................. 954-990-7544

Education
Agilent Technologies ............. 800-829-4444  
American Certification Body, Inc. ........................................... 703-847-4700  
Clarion Safety Systems ............. 800-748-0241  
D. C. Smith Consultants .......... 800-323-3956  
Eisner Safety Consultants ........ 503-244-6151  
ESD Association .................. 315-339-6937  
ETS-Lindgren ....................... 512-531-6400  
iNARTE at RABQSA International ............................................. 800-89-NARTE  
Jastech EMC Consulting LLC ........ 248-876-0481

Montrose Compliance Services .............................................. 408-247-5715  
Oxford University Technology .................. 44 (0)1865 286958  
RMV Technology Group, LLC ......... 650-964-4792

UL Knowledge Services ............. 888-503-5536  
Wurth Electronics Midcom. ........ 800-643-2661  
Zone Safe Solutions .................. 775-622-0400

Publications
Agilent Technologies ............. 800-829-4444  
André Consulting, Inc. ............ 206-406-8371  
ANDRO Computational Solutions .............................................. 315-334-1163  
ARC Technical Resources, Inc. .............................................. 806-263-6486  
BestESD Technical Services ......... 831-824-4052  
CKC Laboratories, Inc. ............ 800-500-4362  
Compatible Electronics, Inc. ........ 650-417-EMC1 (3621)  
CST of America ..................... 508-665-4400  
D. C. Smith Consultants .......... 800-323-3956  
D.L.S. Electronic Systems, Inc. .............................................. 847-537-6400

Don HEIRMAN Consultants .......... 732-741-7723  
Eisner Safety Consultants ........ 503-244-6151  
EMCC DR. RASEK .................. 49-9194-9016  
ESD Association .................. 315-339-6937  
ETS-Lindgren ....................... 512-531-6400  
F2 Labs ............................................. 877-405-1580  
G&M Compliance, Inc. ............ 714-628-1020  
Henry Ott Consultants ............. 973-992-1793  
Hoolihan EMC Consulting ........ 651-213-0966  
Jastech EMC Consulting LLC ........ 248-876-0481

Kimmel Gerke Associates, Ltd. .... 888-EMI-GURU

Montrose Compliance Services .............................................. 408-247-5715  
Narda Safety Test Solutions ........ 631-231-1700  
NCE Labs ............................................. 888-567-6860  
NTS Pittsfield ....................... 800-270-2516  
Oxford University Technology .............................................. 44 (0)1865 286958  
Phoenix Technical Group ........... 919-535-3662  
Prostat Corporation .................. 630-238-8883  
Reliant EMC LLC .................. 408-600-1472  
Retif Testing Laboratories ........ 631-737-1500 x111  
RMV Technology Group, LLC ......... 650-964-4792  
RTF Compliance .................. 949-813-6095  
SIEMIC ............................................. 408-526-1188  
SILENT Solutions LLC .................. 603-578-1842 x203  
Spectrum EMC Consulting, LLC ....... 651-688-0634

Videos
Agilent Technologies ............. 800-829-4444  
D. C. Smith Consultants .......... 800-323-3956  
Espresso Engineering ............. 703-847-4700

Chambers, Antennas & Accessories
Absorbers
EMC Absorbers
ARC Technologies, Inc. ........... 978-388-2993  
Carden Shielding Systems .......... 918-624-2888  
Cuming-Lehman Chambers, Inc. .............................................. 717-263-4101  
DWM Electronics .................. 866-DWM-EMC  
DMAS ............................................. 0831-0715012526  
Electronic Instrument Associates .............................................. 630-924-1600  
EMC Technologists .................. 732-919-1100  
ETS-Lindgren ....................... 512-531-6400  
Microwave Vision Group .......... 678-797-9172  
Panashield, Inc. .................. 203-866-5888  
TDK Corporation .................. 512-258-9478  
TechDream, Inc. .................. 808-400-7362

Honeycomb RF Absorbers
ARC Technologies, Inc. ........... 978-388-2993  
Carden Shielding Systems .......... 918-624-2888  
EMC Technologists .................. 732-919-1100  
ETS-Lindgren ....................... 512-531-6400  
Panashield, Inc. .................. 203-866-5888  
TDK Corporation .................. 512-258-9478

Low Frequency Absorbers
ARC Technologies, Inc. ........... 978-388-2993  
Cuming-Lehman Chambers, Inc. .............................................. 717-263-4101  
DWM Electronics .................. 866-DWM-EMC  
EMC Technologists .................. 732-919-1100  
ETS-Lindgren ....................... 512-531-6400  
Microwave Vision Group .......... 678-797-9172  
Panashield, Inc. .................. 203-866-5888  
TDK Corporation .................. 512-258-9478
Microwave Absorbers
ARC Technologies, Inc. ........................................ 978-388-2993
Cuming-Lehman Chambers, Inc. ........................................ 717-263-4101
Djem Electronics ............................................... 866-DJM-ELEC
DMAS ........................................................................ 0031-0715012526
EMC Technologists .................................................. 732-919-1100
Microwave Vision Group ........................................ 678-797-9172
Panashield, Inc. ..................................................... 203-866-5888
Tdk Corporation .................................................. 512-258-9478

Anechoic Materials
Braden Shielding Systems ............................... 918-624-2888
Cuming-Lehman Chambers, Inc. ........................................ 717-263-4101
DMAS ........................................................................ 0031-0715012526
EMC Technologists .................................................. 732-919-1100
Ets-Lindgren ......................................................... 512-531-6400
Microwave Vision Group ........................................ 678-797-9172
Panashield, Inc. ..................................................... 203-866-5888
Tdk Corporation .................................................. 512-258-9478
Techdream, Inc. ................................................... 408-800-7362

Antenna Couplers
Tdk Corporation .................................................. 512-258-9478
Teseq Inc. ......................................................... 732-417-0501

Antenna Masts
ARC Technologies, Inc. ........................................ 978-388-2993
Braden Shielding Systems ............................... 918-624-2888
Com-Power Corporation ........................................ 714-528-8800
Electronen Instrument Associates ......................... 630-924-1600
Ets-Lindgren ......................................................... 512-531-6400
Inco System GmbH ............................................. 0049 9435 301659 0
Lionheart Northwest ............................................ 425-882-2587
Sunol Sciences Corporation .................................. 925-833-9936

Antennas
Biconical Antennas
A.H. Systems, Inc. ................................................ 818-998-0223
Com-Power Corporation ........................................ 714-528-8800
Em Software & Systems-S.A. ...................................... 732-21831500
Ets-Lindgren ......................................................... 512-531-6400
Microwave Vision Group ........................................ 678-797-9172
Reliant EMC LLC ............................................. 408-600-1472
Teseq Inc. ......................................................... 732-417-0501

Broadband Antennas
A.H. Systems, Inc. ................................................ 818-998-0223
Applied EM Technology ........................................ 410-326-6728
Ar RF/Microwave Instrumentation ....................... 888-933-8181
Arc Technical Resources, Inc. .............................. 408-263-6486

Com-Power Corporation ........................................ 714-528-8800
Em Software & Systems-S.A. ...................................... 732-21831500
Ets-Lindgren ......................................................... 512-531-6400
Microwave Vision Group ........................................ 678-797-9172
Reliant EMC LLC ............................................. 408-600-1472
Teseq Inc. ......................................................... 732-417-0501
Test Equipment Connection ..................................... 800-615-8378

EMI Test Antennas
A.H. Systems, Inc. ................................................ 818-998-0223
Applied EM Technology ........................................ 410-326-6728
Ar RF/Microwave Instrumentation ....................... 888-933-8181
dB Instruments Co. ................................................ 508-238-1303
Electronic Instrument Associates .......................... 630-924-1600
Em Software & Systems-S.A. ............................... 732-21831500
Ets-Lindgren ......................................................... 512-531-6400
Em Software & Systems-S.A. ............................... 732-21831500
Ets-Lindgren ......................................................... 512-531-6400
Fil-Coil ................................................................. 631-467-5328
Lionheart Northwest ............................................ 425-882-2587
Microwave Vision Group ........................................ 678-797-9172
Noise Laboratory Co (Noiisken) .............................. 81(0)427120251
Sunol Sciences Corporation .................................. 925-833-9936
Tdk Corporation .................................................. 512-258-9478
Techdream, Inc. ................................................... 408-800-7362

Nonionizing Radiation Hazard Antennas
Em Software & Systems-S.A. ...................................... 2718311500

Loop Antennas
A.H. Systems, Inc. ................................................ 818-998-0223
Ar RF/Microwave Instrumentation ....................... 888-933-8181
Com-Power Corporation ........................................ 714-528-8800
Ets-Lindgren ......................................................... 512-531-6400
Em Software & Systems-S.A. ............................... 732-21831500
Fair-Rite Products Corp. ....................................... 888-324-7748
Reliant EMC LLC ............................................. 408-600-1472

Tunable Dipole Antennas
A.H. Systems, Inc. ................................................ 818-998-0223
Com-Power Corporation ........................................ 714-528-8800
Ets-Lindgren ......................................................... 512-531-6400
MI Technologies .................................................. 678-475-8345
Microwave Vision Group ........................................ 678-797-9172
Teseq Inc. ......................................................... 732-417-0501

Whip Antennas
A.H. Systems, Inc. ................................................ 818-998-0223
Com-Power Corporation ........................................ 714-528-8800
Em Software & Systems-S.A. ............................... 732-21831500
Laird Technologies ............................................... 636-898-6215

Cells
Cells, Gtem
Ar RF/Microwave Instrumentation ....................... 888-933-8181
Arc Technical Resources, Inc. .............................. 408-263-6486
Em Software & Systems-S.A. ............................... 732-21831500
Ets-Lindgren ......................................................... 512-531-6400
Reliant EMC LLC ............................................. 408-600-1472
Cells, TEM & Strip Line
ARC Technical Resources, Inc. ........................................ 408-263-6486
Instruments For Industry, Inc. ........................................ 631-467-8400

Chambers
Chambers, Anechoic
ARC Technical Resources, Inc. ........................................ 408-263-6486
Audivo GmbH. ......................................................... 49 9435 5419 0
Braden Shielding Systems ............................................. 918-624-2888
Cuming-Lehman Chambers, Inc. ...................................... 717-263-4101
DMAS ................................................................. 0031-(0)715012526
Electronic Instrument Associates ..................................... 630-924-1600
EMC Technologists ................................................... 732-919-1100
ETS-Lindgren ....................................................... 512-531-6400
Innco Systems GmbH ............................................... 49 9435 301659 0
Lionheart Northwest ................................................... 425-882-2587
MI Technologies ...................................................... 678-475-8345
Microwave Vision Group ............................................ 678-797-9172
ANTS Rockford ....................................................... 800-270-2516
Panashield, Inc. ....................................................... 203-866-5888
Sprinkler Innovations ................................................ 800-850-6692

Helmholtz Coils
ETS-Lindgren ....................................................... 512-531-6400

Injection Clamps
ETS-Lindgren ....................................................... 512-531-6400
Mag Daddy ............................................................. 847-719-5600

Sensors/Transducers, RF Field
Test Equipment Connection ......................................... 800-615-8378

Shielded Buildings
Audivo GmbH. ......................................................... 49 9435 5419 0
Braden Shielding Systems ............................................. 918-624-2888
Cuming-Lehman Chambers, Inc. ...................................... 717-263-4101
Fil-Coil ................................................................. 631-467-5328
Microwave Vision Group ............................................ 678-797-9172
Panashield, Inc. ....................................................... 203-866-5888
Raymond EMC Enclosures Ltd. ...................................... 800-362-1495

Shielded Rooms/Chambers
ARC Technical Resources, Inc. ........................................ 408-263-6486
Audivo GmbH. ......................................................... 49 9435 5419 0
Braden Shielding Systems ............................................. 918-624-2888
Cuming-Lehman Chambers, Inc. ...................................... 717-263-4101
DJM Electronics ...................................................... 866-DJM-ELEC
Electronic Instrument Associates .................................... 630-924-1600
EMC Technologists ................................................... 732-919-1100
ETS-Lindgren ....................................................... 512-531-6400
Magnetic Shield Corporation ........................................ 888-766-7800
MI Technologies ...................................................... 678-475-8345
Microwave Vision Group ............................................ 678-797-9172
ANTS Rockford ....................................................... 800-270-2516
ANTS Tinton Falls .................................................... 732-936-0800
Panashield, Inc. ....................................................... 203-866-5888
Raymond EMC Enclosures Ltd. ...................................... 800-362-1495

Fire Protection
Cuming-Lehman Chambers, Inc. ...................................... 717-263-4101
EMC Technologists ................................................... 732-919-1100
Microwave Vision Group ............................................ 678-797-9172
Panashield, Inc. ....................................................... 203-866-5888

Turntables
Braden Shielding Systems ............................................. 918-624-2888
ETS-Lindgren ....................................................... 512-531-6400
Innco Systems GmbH ............................................... 49 9435 301659 0
Mag Daddy ............................................................. 847-719-5600
ANTS Newark .......................................................... 877-245-7800
Sunol Sciences Corporation ......................................... 925-833-9936

Consulting & Services

Calibration & Repair Services
Aum Electro Technology Pvt Ltd ..................................... 09912512871365
Dynamic Sciences International ..................................... 800-966-3713
Ergonomics, Inc. ...................................................... 800-862-0102
ESDEMC Technology LLC .......................................... 877-864-8479
ETI Conformity Services ............................................ 877-468-6384
ETS-Lindgren ....................................................... 512-531-6400
HCT Co., Ltd. .......................................................... 82-31-645-6454
Liberty Labs, Inc. ....................................................... 712-773-2199
Noise Laboratory Co (NoiseKen) ..................................... 81 (0) 42 712 2051
Prostat Corporation ................................................... 630-238-8883
Reliant EMC LLC .................................................... 408-600-1472
Restor Metrology ...................................................... 877-220-5554
SE Laboratories ....................................................... 800-939-CALS
Teseq Inc. .............................................................. 732-417-0501
Thermo Fisher Scientific .............................................. 972-409-4519

Panashield, Inc. ....................................................... 203-866-5888
Raymond EMC Enclosures Ltd. ...................................... 800-362-1495
Select Fabricators, Inc. ............................................... 888-599-6113
TDK Corporation ..................................................... 888-599-6113

Universal Shielding ................................................... 800-645-5578

2013 Annual Guide  In Compliance  209
## Conductive Painting Services

**Protective Industrial Polymers**  
866-361-3331

**Staticworx Flooring**  
888-STATICWORX

## Consultants

### Conductive Painting Services

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>JDM LABS LLC</td>
<td>847-630-2769</td>
</tr>
<tr>
<td>Kimmel Gerke Associates, Ltd.</td>
<td>888-EMI-GURU</td>
</tr>
<tr>
<td>LCR Electronics, Inc.</td>
<td>800-527-4362</td>
</tr>
<tr>
<td>Lewis Bass International</td>
<td>408-942-8000</td>
</tr>
<tr>
<td>LS Research</td>
<td>262-375-4400</td>
</tr>
<tr>
<td>Montrose Compliance Services</td>
<td>408-247-5715</td>
</tr>
</tbody>
</table>

### Consultants, EMC

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced ESD Services</td>
<td>607-759-8133</td>
</tr>
<tr>
<td>Alion Science and Technology</td>
<td>610-825-1960</td>
</tr>
<tr>
<td>American Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>André Consulting, Inc.</td>
<td>206-406-8371</td>
</tr>
<tr>
<td>ARC Technical Resources, Inc.</td>
<td>408-263-6486</td>
</tr>
<tr>
<td>Atlas Compliance &amp; Engineering</td>
<td>866-573-9742</td>
</tr>
<tr>
<td>BestESD Technical Services</td>
<td>831-824-4052</td>
</tr>
<tr>
<td>Braden Shielding Systems</td>
<td>918-624-2888</td>
</tr>
<tr>
<td>CKC Laboratories, Inc.</td>
<td>800-500-4362</td>
</tr>
<tr>
<td>Compatible Electronics, Inc.</td>
<td>650-417-EMC1 (3621)</td>
</tr>
<tr>
<td>Compliance &amp; More, Inc.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>D. C. Smith Consultants</td>
<td>800-323-3956</td>
</tr>
<tr>
<td>D.L.S. Electronic Systems, Inc.</td>
<td>847-537-6400</td>
</tr>
<tr>
<td>Dayton T. Brown, Inc.</td>
<td>800-TEST-456</td>
</tr>
<tr>
<td>Design Chain Associates, LLC</td>
<td>866-322-7676 x 2</td>
</tr>
<tr>
<td>DNB Engineering, Inc.</td>
<td>714-870-7781</td>
</tr>
<tr>
<td>Don HEIRMAN Consultants</td>
<td>732-741-7723</td>
</tr>
<tr>
<td>Electronics Test Centre</td>
<td>613-599-6800</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>EMC Compliance</td>
<td>256-650-5261</td>
</tr>
<tr>
<td>EMC Testing Laboratories, Inc.</td>
<td>770-475-8819</td>
</tr>
<tr>
<td>EMCC DR. RASEK</td>
<td>49-9194-9016</td>
</tr>
<tr>
<td>EMplus LLC</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>EMS Solutions</td>
<td>949-206-9960</td>
</tr>
<tr>
<td>ESDEMCM Technology LLC</td>
<td>877-864-8479</td>
</tr>
<tr>
<td>F2 Labs.</td>
<td>877-405-1580</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Go Global Certification Inc.</td>
<td>408-416-3772</td>
</tr>
<tr>
<td>H.B. Compliance Solutions</td>
<td>480-684-2969</td>
</tr>
<tr>
<td>Henry Ott Consultants</td>
<td>973-992-1793</td>
</tr>
<tr>
<td>Hoolihan EMC Consulting</td>
<td>651-213-0966</td>
</tr>
<tr>
<td>International Certification Services, Inc.</td>
<td>888-286-6888</td>
</tr>
<tr>
<td>IQS, a Division of CMG</td>
<td>508-460-1400</td>
</tr>
<tr>
<td>Jastech EMC Consulting LLC</td>
<td>248-876-4810</td>
</tr>
</tbody>
</table>

### Consultants, GOST

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>CQC Co Ltd</td>
<td>48 509959591</td>
</tr>
<tr>
<td>CSIA, LLC</td>
<td>503-489-8006</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Go Global Certification Inc.</td>
<td>408-416-3772</td>
</tr>
<tr>
<td>MC Global Access</td>
<td>760-696-3700</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>TestingPartners.com</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>Versus Global Certifications Pty Ltd.</td>
<td>27 83 5140709</td>
</tr>
</tbody>
</table>

### Consultants, Lightning Protection

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>André Consulting, Inc.</td>
<td>206-406-8371</td>
</tr>
<tr>
<td>D. C. Smith Consultants</td>
<td>800-323-3956</td>
</tr>
<tr>
<td>Dayton T. Brown, Inc.</td>
<td>800-TEST-456</td>
</tr>
<tr>
<td>DNB Engineering, Inc.</td>
<td>714-870-7781</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>EMI Solutions</td>
<td>949-206-9960</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>NTS Northeast</td>
<td>800-723-2687</td>
</tr>
<tr>
<td>NTS Pittsfield</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>Spectrum EMC Consulting, LLC</td>
<td>651-688-0634</td>
</tr>
<tr>
<td>WEMS Electronics</td>
<td>310-962-4410</td>
</tr>
</tbody>
</table>

### Consultants, Medical Device

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberi EcoTech</td>
<td>702-677-6923</td>
</tr>
<tr>
<td>Atlas Compliance &amp; Engineering</td>
<td>866-573-9742</td>
</tr>
<tr>
<td>Compliance &amp; More, Inc.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>CQC Co LTD</td>
<td>48 509959591</td>
</tr>
<tr>
<td>CSIA, LLC</td>
<td>503-489-8006</td>
</tr>
<tr>
<td>D.L.S. Electronic Systems, Inc.</td>
<td>847-537-6400</td>
</tr>
<tr>
<td>Design Chain Associates, LLC</td>
<td>866-322-7676 x 2</td>
</tr>
<tr>
<td>EMC Testing Laboratories, Inc.</td>
<td>770-475-8819</td>
</tr>
<tr>
<td>H.B. Compliance Solutions</td>
<td>480-684-2969</td>
</tr>
<tr>
<td>Ergonomics, Inc.</td>
<td>800-862-0102</td>
</tr>
<tr>
<td>H.B. Compliance Solutions</td>
<td>480-684-2969</td>
</tr>
<tr>
<td>International Certification Services, Inc.</td>
<td>888-286-6888</td>
</tr>
<tr>
<td>IQS, a Division of CMG</td>
<td>508-460-1400</td>
</tr>
<tr>
<td>LS Research</td>
<td>262-375-4400</td>
</tr>
<tr>
<td>Montrose Compliance Services</td>
<td>408-247-5715</td>
</tr>
<tr>
<td>NCEE Labs.</td>
<td>888-567-6860</td>
</tr>
<tr>
<td>NTS Rockford</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>O’Brien Compliance Management</td>
<td>978-970-0525</td>
</tr>
<tr>
<td>Phoenix Technical Group</td>
<td>919-535-3662</td>
</tr>
<tr>
<td>Pulver Laboratories Inc.</td>
<td>800-635-3050</td>
</tr>
<tr>
<td>SIEMIC</td>
<td>408-526-1188</td>
</tr>
<tr>
<td>Spectrum EMC Consulting, LLC</td>
<td>651-688-0634</td>
</tr>
<tr>
<td>Technology Forecasters Inc.</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>Versus Global Certifications Pty Ltd.</td>
<td>27 83 5140709</td>
</tr>
</tbody>
</table>

### Consultants, GOSL

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>CQC Co Ltd</td>
<td>48 509959591</td>
</tr>
<tr>
<td>CSIA, LLC</td>
<td>503-489-8006</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Go Global Certification Inc.</td>
<td>408-416-3772</td>
</tr>
<tr>
<td>MC Global Access</td>
<td>760-696-3700</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>TestingPartners.com</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>Versus Global Certifications Pty Ltd.</td>
<td>27 83 5140709</td>
</tr>
</tbody>
</table>
Consulting & Services

Alberi EcoTech ........................ 702-677-6923
American Certification Body, Inc. ........................ 703-847-4700
CASE Forensics ........................ 877-736-1106
Design Chain Associates, LLC ......................... 866-322-7676 x2
Eisner Safety Consultants ......................... 503-244-6151
Ergonomics, Inc. ........................ 800-862-0102
NTS Newark ................................ 877-245-7800
O’Brien Compliance Management ............... 978-970-0525
Pulver Laboratories Inc. ..................... 800-635-3050
Raytheon EMC Enclosures Ltd. .................. 800-362-1495
Test Site Services Inc. ........................ 508-962-1662
Trace Laboratories, Inc. ....................... 410-584-9099
UTente, a Division of NQA .................. 800-998-9395

Consultants, Quality

Alberi EcoTech ........................ 702-677-6923
American Certification Body, Inc. ........................ 703-847-4700
CASE Forensics ........................ 877-736-1106
Design Chain Associates, LLC ......................... 866-322-7676 x2
Eisner Safety Consultants ......................... 503-244-6151
Ergonomics, Inc. ........................ 800-862-0102
NTS Newark ................................ 877-245-7800
O’Brien Compliance Management ............... 978-970-0525
Pulver Laboratories Inc. ..................... 800-635-3050
Trace Laboratories, Inc. ....................... 410-584-9099

Consultants, Telecom

CSIA, LLC ........................ 503-489-8006
CV DIMULTI ........................ 6221132608337
D. C. Smith Consultants .................. 800-323-3956
D.L.S. Electronic Systems, Inc. ............... 847-537-6400

Elite Electronic Engineering ................ 800-ELITE-11
EMC Testing Laboratories, Inc. ............... 770-475-8819
Garwood Laboratories ..................... 888-427-4111

Go Global Compliance Inc.

.............................................. 408-416-3772
MC Global Access ........................ 760-696-3700
Nemko Canada ........................ 613-737-9680

NTS - Corporate HQ

.............................................. 800-270-2516
NTS Newark ................................ 877-245-7800

SIEMIC ................................. 408-526-1188
Test Site Services Inc. ..................... 508-962-1662
Versus Global Certifications Pty Ltd. ......... 27 83 5140787

Consultants, Telecom

American Certification Body, Inc. ........................ 703-847-4700
André Consulting, Inc. ..................... 206-406-8371
Braiden Shielding Systems ................ 918-624-2888
Dayton T. Brown, Inc. .................... 800-TEST-456
General Dynamics C4 Systems ......... 480-441-5321
NexTek, Inc. ..................... 978-486-0582
Raymond EMC Enclosures Ltd. .......... 800-362-1495

Consultants, Transients

American Certification Body, Inc. ........................ 703-847-4700
BestESD Technical Services ................ 831-824-4052
D. C. Smith Consultants .................. 800-323-3956
D.L.S. Electronic Systems, Inc. ............... 847-537-6400
DNB Engineering, Inc. ........................ 714-870-7781
Kimmel Gerke Associates, Ltd. ............... 888-EMI-GURU
NexTek, Inc. ..................... 978-486-0582
Pulver Laboratories Inc. ..................... 800-635-3050
SILENT Solutions LLC ..................... 603-578-1842 x203
Spectrum EMC Consulting, LLC ......... 651-688-0634
WEMS Electronics ........................ 310-962-4410

Consultants, VCCI

American Certification Body, Inc. ........................ 703-847-4700
Atlas Compliance & Engineering ................ 866-573-9742
Compliance & More, Inc .................. 303-663-3396
Compliance Management Group .......... 508-281-5985
CSIA, LLC ........................ 503-489-8006
D.L.S. Electronic Systems, Inc. ............... 847-537-6400
EMCplus LLC ........................ 303-663-3396

2013 Annual Guide  In Compliance  211
Design Services

American Certification Body, Inc. ........................................ 703-847-4700
BestESD Technical Services ........................................... 831-824-4052
Bittele Electronics ...................................................... 416-800-7540
CKC Laboratories, Inc. .................................................. 800-500-4362
D.L.S. Electronic Systems, Inc. ......................................... 847-537-6400
DDB Unlimited, Inc. ..................................................... 800-753-8459
DNB Engineering, Inc. .................................................. 714-870-7781
EMC Compliance .......................................................... 256-650-5261
F2 Labs. ....................................................................... 877-405-1580
High Voltage Maintenance ............................................... 866-486-8326
IQS, a Division of CMG .................................................. 508-460-1400
Jastech EMC Consulting LLC ............................................ 248-876-4810
K-Form, Inc. .................................................................. 703-450-4401
Keystone Compliance ..................................................... 724-657-9940
LCR Electronics, Inc. ...................................................... 800-527-4362
LS Research ................................................................. 262-375-4400
MAJR Products, Inc. ....................................................... 877-625-7776
Montrose Compliance Services ......................................... 408-247-5715
NCEE Labs. ................................................................... 888-567-6860
Nexlogic Technologies, Inc. ............................................... 866-845-1197
NexTek, Inc. ................................................................. 978-486-0582
NTS Albuquerque ........................................................... 505-821-4740
NTS Northeast ............................................................. 800-723-2687
Pulver Laboratories Inc. .................................................... 800-635-3050
SILENT Solutions LLC .................................................. 603-578-1842
TestingPartners.com ..................................................... 862-243-2329
Vermillion, Inc. ............................................................. 305-968-5981
VEROCH ..................................................................... 954-990-7544
WEMS Electronics .......................................................... 310-962-4410

Equipment Rental & Leasing

Dynamic Sciences International ......................................... 800-966-3713
EMCC DR. RASEK ........................................................ 49-9194-9016
Ergonomics, Inc. ........................................................... 800-862-0102
Thermo Fisher Scientific .................................................. 978-275-0800 x2302

Manufacturers’ Representatives

Comply Tek, Inc. ............................................................ 858-674-6155

Shielded Enclosure Design, Relocation Services

André Consulting, Inc. ..................................................... 206-406-8371
ARC Technical Resources, Inc. ....................................... 408-263-6486
DDB Unlimited, Inc. ..................................................... 800-753-8459
K-Form, Inc. ................................................................. 703-450-4401
Magnetic Shield Corporation ......................................... 888-766-7800
MAJR Products, Inc. ...................................................... 877-625-7776
Microwave Vision Group ............................................. 678-797-9172
The MuShield Company Inc. ......................................... 888-669-3539

Raymond EMC Enclosures Ltd. ................................. 800-362-1495
Universal Shielding ...................................................... 800-645-5578

Site Attenuation Testing Services

Alien Science and Technology ........................................ 610-825-1960
ETS-Lindgren ............................................................... 512-531-6400
Raymond EMC Enclosures Ltd. ........................................ 800-362-1495
Retlif Testing Laboratories ........................................... 631-737-1500 x111
TestingPartners.com .................................................... 862-243-2329
Universal Shielding ...................................................... 800-645-5578

Site Survey Services

Alien Science and Technology ......................................... 610-825-1960
ARC Technical Resources, Inc. ....................................... 408-263-6486
D. C. Smith Consultants ................................................ 800-323-3956
Dayton T. Brown, Inc. .................................................... 800-TEST-456
DNB Engineering, Inc. .................................................. 714-870-7781
etl Conformity Services ............................................... 877-468-6384
F2 Labs. ........................................................................ 877-405-1580
Garwood Laboratories .................................................. 888-427-4111
High Voltage Maintenance ........................................... 866-486-8326
Magnetic Shield Corporation ......................................... 888-766-7800
Raymond EMC Enclosures Ltd. ................................... 800-362-1495
Retlif Testing Laboratories ........................................... 631-737-1500 x111
RMV Technology Group, LLC ....................................... 650-964-4792
Stephen Halperin & Associates ..................................... 630-238-8883
TestingPartners.com .................................................... 862-243-2329

Electrical & Electronic Components

Adapters

Admired Services Components ....................................... 727-346-5157
Americor Electronics Ltd. ............................................. 800-830-5337
Conec Corporation ...................................................... 919-460-8800
Global Test Equipment ................................................... 866-409-0400
Instruments For Industry, Inc. ....................................... 631-467-8400

Backplanes

Schurter Inc. ............................................................... 800-848-2600

Backshells

Admired Services Components ....................................... 727-346-5157
Conec Corporation ...................................................... 919-460-8800
Power Dynamics, Inc. ................................................ 973-560-0019
Sabritec ........................................................................ 949-250-1244

Air Filters

EMI Air Filters

Alco Technologies, Inc. ................................................... 310-328-4770
JEMIC Shielding Technology ........................................... 717-232-1030
MAJR Products, Inc. ..................................................... 877-625-7776

Shielded Air Filters

Alco Technologies, Inc. ................................................... 310-328-4770

JEMIC Shielding Technology ........................................... 717-232-1030
MAJR Products, Inc. ..................................................... 877-625-7776

Attenuators

BMI Surplus ................................................................ 781-871-8868
Global Test Equipment ................................................... 866-409-0400
Instruments For Industry, Inc. ....................................... 631-467-8400

Backplanes

Schurter Inc. ............................................................... 800-848-2600

Backshells

Admired Services Components ....................................... 727-346-5157
Conec Corporation ...................................................... 919-460-8800
Power Dynamics, Inc. ................................................ 973-560-0019
Sabritec ........................................................................ 949-250-1244

Alco Technologies, Inc. ................................................... 310-328-4770
JEMIC Shielding Technology ........................................... 717-232-1030
MAJR Products, Inc. ..................................................... 877-625-7776
**Electrical & Electronic Components**

**Bluetooh Modules**
Laird Technologies ................. 636-898-6215
LS Research ..................... 262-375-4400
Mag Daddy ....................... 847-719-5600
Murata Electronics ............... 800-554-4070

**Breakers**
Clarion Safety Systems ............. 800-748-0241
eti Conformity Services ......... 877-468-6384
Mag Daddy ....................... 847-719-5600

**Cabinets/Enclosures**
Clarion Safety Systems ............. 800-748-0241
DBB Unlimited, Inc ............... 800-753-8459
K-Form, Inc ..................... 703-450-4401

**Cable Assemblies**
Americor Electronics Ltd ........... 800-830-5337
Bittele Electronics ............... 416-800-7540
CMD Ltd ......................... 441709829511
Global Test Equipment ............ 866-409-0400
Lionheart Northwest ............... 425-882-2587
Mag Daddy ....................... 847-719-5600
Michigan Scientific Corporation 248-685-3939 x111
Vermillion, Inc ................. 305-968-5981

**Circuit Breakers**
Bittele Electronics ................ 416-800-7540
eti Conformity Services ......... 877-468-6384
Interpower Corporation .......... 800-662-2290
Schurter Inc ..................... 800-848-2600
Texas Spectrum Electronics .... 972-296-3699

**Connectors**
Admired Services Components .... 727-346-5157
Amphenol Canada Corp .......... 416-754-5688
API Technologies Corp ........... 855-294-3800
ARC Technologies, Inc ........... 978-388-2993
Conex Corporation ............... 919-460-8800
EMI Solutions ................... 949-206-9960
eti Conformity Services ......... 877-468-6384
Global Test Equipment .......... 866-409-0400
Interpower Corporation ........ 800-662-2290
LCR Electronics, Inc ............ 800-527-4362
Mag Daddy ....................... 847-719-5600
Power Dynamics, Inc ............. 973-560-0019
Sabritec ......................... 949-250-1244
Schurter Inc ..................... 800-848-2600
Wurth Electronics Midcom .... 800-643 2661

**Couplers**
AR RF/Microwave Instrumentation . 888-933-8181
BMI Surplus ..................... 888-933-8181
Conex Corporation ............... 919-460-8800

**EM TEST USA** 
Instruments For Industry, Inc.
858-450-0085

**Fuses**
Admired Services Components .... 727-346-5157
etif Conformity Services ......... 877-468-6384
Interpower Corporation ........ 800-662-2290
Schurter Inc ..................... 800-848-2600

**Grounding Rods**
Mag Daddy ....................... 847-719-5600

**Impedance Matching Networks**
AR RF/Microwave Instrumentation . 888-933-8181

**Inductors**
EMI/RFI Inductors
Americor Electronics Ltd ........ 800-830-5337
André Consulting, Inc .......... 206-406-8371
Fair-Rite Products Corp ......... 888-324-7748
LCR Electronics, Inc ............ 800-527-4362
TDK-EPC Corporation ........... 800-888-7728
WEMS Electronics ............... 310-962-4410
Wurth Electronics Midcom .... 800-643 2661

**Liquid Crystal Display (LCD) Modules**
Mag Daddy ....................... 847-719-5600

**Military (MIL-SPEC) Connectors**
Admired Services Components .... 727-346-5157
André Consulting, Inc .......... 206-406-8371
API Technologies Corp ........... 855-294-3800
BMI Surplus ..................... 781-871-8868
EMC Technologists ............... 732-919-1100
LCR Electronics, Inc ............ 800-527-4362
Mag Daddy ....................... 847-719-5600

**Oscillators**
API Technologies Corp ........... 855-294-3800
Applied EM Technology .......... 410-326-6728
Giga-tronics Incorporated ...... 800-277-9764

**Potentiometers**
API Technologies Corp .......... 855-294-3800
Global Test Equipment .......... 866-409-0400
Murata Electronics .............. 800-554-4070

**Resonators**
Admired Services Components .... 727-346-5157
TDK-EPC Corporation ............ 800-888-7728

**RF Frequency Converters**
API Technologies Corp .......... 855-294-3800
Global Test Equipment .......... 866-409-0400
Oak-Mitsui Technologies ....... 518-686-4961
Test Equipment Connection ...... 800-615-8378

**Solid State Relays**
Americor Electronics Ltd ........ 800-830-5337
Global Test Equipment .......... 866-409-0400

**Surge Suppressors**
CITE, Inc ....................... 800-248-3548
Fil-Coil ......................... 631-467-5328
Fischer Custom Communications 310-303-3300
Murata Electronics .............. 800-554-4070
Okay Electric America, Inc .... 800-852-0122

**LEDs and Displays**
Admired Services Components .... 727-346-5157
Audio GmbH ...................... 49 9435 5419 0
Mag Daddy ....................... 847-719-5600
Okay Electric America, Inc .... 800-852-0122
<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surge Suppressors continued</strong></td>
</tr>
<tr>
<td>TDK-EPC Corporation ........ 800-888-7728</td>
</tr>
<tr>
<td>Texas Spectrum Electronics . 972-296-3699</td>
</tr>
<tr>
<td>WEMS Electronics ............. 310-962-4410</td>
</tr>
<tr>
<td><strong>Switches</strong></td>
</tr>
<tr>
<td>Admired Services Components ........................................... 727-346-5157</td>
</tr>
<tr>
<td>eti Conformity Services .... 877-468-6384</td>
</tr>
<tr>
<td>Interpower Corporation ..... 800-662-2290</td>
</tr>
<tr>
<td>The MuShield Company Inc. .................................................. 888-669-3539</td>
</tr>
<tr>
<td>Schurter Inc. .................. 800-848-2600</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td><strong>Terminal Blocks</strong></td>
</tr>
<tr>
<td>Americor Electronics Ltd .... 800-830-5337</td>
</tr>
<tr>
<td>Curtis Industries ............... 800-657-0853</td>
</tr>
<tr>
<td>eti Conformity Services .... 877-468-6384</td>
</tr>
<tr>
<td>Global Test Equipment ........ 866-409-0400</td>
</tr>
<tr>
<td>Interpower Corporation ..... 800-662-2290</td>
</tr>
<tr>
<td>Mag Daddy ..................... 847-719-5600</td>
</tr>
<tr>
<td>Texas Spectrum Electronics .. 972-296-3699</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td><strong>Thyristors</strong></td>
</tr>
<tr>
<td>Admired Services Components ........................................... 727-346-5157</td>
</tr>
<tr>
<td><strong>Transformers</strong></td>
</tr>
<tr>
<td>Transformers, Power Line Isolation</td>
</tr>
<tr>
<td>Clarion Safety Systems .... 800-748-0241</td>
</tr>
<tr>
<td>Elna Magnetics .................. 800-553-2870</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td>Transformers, Signal Line Isolation</td>
</tr>
<tr>
<td>Elna Magnetics .................. 800-553-2870</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td>Transformers, Telecommunications</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td>Transformers, Third-Party Approved, EU</td>
</tr>
<tr>
<td>Americor Electronics Ltd .... 800-830-5337</td>
</tr>
<tr>
<td>Clarion Safety Systems .... 800-748-0241</td>
</tr>
<tr>
<td>eti Conformity Services .... 877-468-6384</td>
</tr>
<tr>
<td>Transformers, Toroidal</td>
</tr>
<tr>
<td>The MuShield Company Inc. .............................................. 888-669-3539</td>
</tr>
<tr>
<td><strong>Pearson Electronics, Inc.</strong></td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td><strong>Varistors</strong></td>
</tr>
<tr>
<td>BMI Surplus .................... 781-871-8868</td>
</tr>
<tr>
<td>TDK-EPC Corporation ........ 800-888-7728</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td><strong>EMC/EMI Control</strong></td>
</tr>
<tr>
<td><strong>Air Cooling Systems</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>DDB Unlimited, Inc .......... 800-753-8459</td>
</tr>
<tr>
<td>HM Cragg ....................... 800-672-7244</td>
</tr>
<tr>
<td>Parker Hannifin, Chomerics Div ........................................ 781-935-4850</td>
</tr>
<tr>
<td><strong>Architectural Shielding Products</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>Fil-Coil ........................ 631-467-5328</td>
</tr>
<tr>
<td><strong>Arrestors, Lightning and Surge</strong></td>
</tr>
<tr>
<td>NTS Pittsfied .................. 800-270-2516</td>
</tr>
<tr>
<td>Okay Electric America, Inc .. 800-852-0122</td>
</tr>
<tr>
<td>Texas Spectrum Electronics .. 972-296-3699</td>
</tr>
<tr>
<td><strong>Braid, Bonding, and Grounding Accessories</strong></td>
</tr>
<tr>
<td>DDB Unlimited, Inc .......... 800-753-8459</td>
</tr>
<tr>
<td><strong>Capacitors, Mains (X and Y)</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>Americor Electronics Ltd .... 800-830-5337</td>
</tr>
<tr>
<td>Captor Corporation .......... 937-667-8484</td>
</tr>
<tr>
<td>LCR Electronics, Inc. ...... 800-527-4362</td>
</tr>
<tr>
<td>Oak-Mitsui Technologies .... 518-686-4961</td>
</tr>
<tr>
<td><strong>Capacitors, Planar Array</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>Amphenol Canada Corp. ...... 416-754-5688</td>
</tr>
<tr>
<td>Oak-Mitsui Technologies .... 518-686-4961</td>
</tr>
<tr>
<td><strong>Capacitors, Tantalum</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td><strong>Chokes</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>Adams Magnetic Products .... 800-275-6312</td>
</tr>
<tr>
<td>André Consulting, Inc .. 206-406-8371</td>
</tr>
<tr>
<td>Captor Corporation .......... 937-667-8484</td>
</tr>
<tr>
<td>Corcom/Tyco Electronics .... 847-573-6504</td>
</tr>
<tr>
<td>Elna Magnetics ................. 800-553-2870</td>
</tr>
<tr>
<td>Fair-Rite Products Corp. .... 888-324-7748</td>
</tr>
<tr>
<td>LCR Electronics, Inc. ...... 800-527-4362</td>
</tr>
<tr>
<td>Murata Electronics .......... 800-554-4070</td>
</tr>
<tr>
<td>Schaffner EMC Inc. ..........</td>
</tr>
<tr>
<td>Schurter Inc. .................. 800-848-2600</td>
</tr>
<tr>
<td>TechDream, Inc. ............... 408-800-7362</td>
</tr>
<tr>
<td>WEMS Electronics ............. 310-962-4410</td>
</tr>
<tr>
<td>Wurth Electronics Midcom .. 800-643 2661</td>
</tr>
<tr>
<td><strong>Conductive Materials</strong></td>
</tr>
<tr>
<td><strong>Conductive Additives</strong></td>
</tr>
<tr>
<td>Parker Hannifin, Chomerics Div ........................................ 781-935-4850</td>
</tr>
<tr>
<td><strong>Conductive Adhesive</strong></td>
</tr>
<tr>
<td>Parker Hannifin, Chomerics Div ........................................ 781-935-4850</td>
</tr>
<tr>
<td><strong>Conductive Epoxy</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>Parker Hannifin, Chomerics Div ........................................ 781-935-4850</td>
</tr>
<tr>
<td>Protective Industrial Polymers 866-361-3331</td>
</tr>
<tr>
<td>VTI Vacuum Technologies, Inc. 800-482-1941</td>
</tr>
<tr>
<td><strong>Conductive Foam</strong></td>
</tr>
<tr>
<td>3Gmetalworx Inc. .. 888-965-3634</td>
</tr>
<tr>
<td>JEMIC Shielding Technology ............................................. 717-232-1030</td>
</tr>
<tr>
<td>Leader Tech ................... 866-TECH EMI</td>
</tr>
<tr>
<td>Orbel Corporation .......... 610-829-5000</td>
</tr>
<tr>
<td>Parker Hannifin, Chomerics Div ........................................ 781-935-4850</td>
</tr>
<tr>
<td>Tech-Etch ..................... 508-747-0300</td>
</tr>
</tbody>
</table>
Conductive Laminates
JEMIC Shielding Technology .................................................. 717-232-1030
Conductive Lubricants
Parker Hannifin, Chomerics Div ........................................... 781-935-4850
Conductive Plastics
Parker Hannifin, Chomerics Div ........................................... 781-935-4850
Connector Fingers
Alco Technologies, Inc ....................................................... 310-328-4770
East Coast Shielding .......................................................... 908-852-9160
Fontaf ................................................................. 773-463-6211
Ja-Bar Silicone Corp ......................................................... 973-786-5000
Leader Tech .......................................................... 866-TECH-EMI
Orbel Corporation ......................................................... 610-829-5000
Tech-Etch .......................................................... 508-747-0300
Wurth Electronics Midcom ........................................... 800-643 2661
Cord Sets, EMI
3Gmetalworx Inc ................................................... 888-965-3634
Americor Electronics Ltd .................................................. 800-830-5337
Captor Corporation ......................................................... 937-667-8484
EMC Technologists .................................................. 732-919-1100
LCR Electronics, Inc .................................................. 800-527-4362
Power Dynamics, Inc .................................................. 973-560-0199
Schurter Inc .......................................................... 800-848-2600
Ferrite Beads, Rods and Forms
Adams Magnetic Products ............................................... 800-275-6312
André Consulting, Inc .................................................. 206-406-8371
Dexter Magnetic Technologies ........................................... 800 317 2537
Elna Magnetics .......................................................... 800-553-2870
Fair-Rite Products Corp .................................................. 888-324-7748
Ferrite Shield .......................................................... 866-TECH-EMI
Intermark USA, Inc ...................................................... 408-971-2055
Laird Technologies ...................................................... 636-898-6215
Leader Tech .......................................................... 866-TECH-EMI
MAJ Products Inc ...................................................... 877-625-7776
Murata Electronics ...................................................... 800-554-4070
TechDream, Inc ......................................................... 408-800-7362
Wurth Electronics Midcom ........................................... 800-643 2661
Filter Coils
Captor Corporation ......................................................... 937-667-8484
Fil-Coil .............................................................. 631-467-5328
LCR Electronics, Inc ...................................................... 800-527-4362
Texas Spectrum Electronics ........................................... 972-296-3699
WEMS Electronics ...................................................... 310-962-4410
Filter Pins
EMI Solutions ......................................................... 949-206-9960
Quell Corporation ......................................................... 505-243-1423
Filtered Connectors
EMI Solutions ......................................................... 949-206-9960
Quell Corporation ......................................................... 505-243-1423
Filters
Filters, Absorptive
Captor Corporation ......................................................... 937-667-8484
Filters, Antenna
Captor Corporation ......................................................... 937-667-8484
Murata Electronics ...................................................... 800-554-4070
Oak-Mitsui Technologies .................................................. 518-686-4961
WEMS Electronics ...................................................... 310-962-4410
Filters, EMC and RFI
André Consulting, Inc .................................................. 206-406-8371
API Technologies Corp .................................................. 855-294-3800
Curtis Industries ......................................................... 800-657-0853
DJM Electronics ........................................................ 866-DJM-ELEC
EMI Solutions ......................................................... 949-206-9960
ETS-Lindgren .......................................................... 512-531-6400
Filconn Inc .............................................................. 480 222 3565
Genisco Filter Corp ...................................................... 858-565-7405
Jastech EMC Consulting LLC ........................................... 248-876-4810
LCR Electronics, Inc ...................................................... 800-527-4362
NexTek, Inc .............................................................. 978-486-0582
Oak-Mitsui Technologies .................................................. 518-686-4961
Parker Hannifin, Chomerics Div ........................................... 781-935-4850
Schaffner EMC Inc ...................................................... 800-848-2600
Schurter Inc .............................................................. 978-486-0582
Solar Electronics Company ........................................... 800-952-5302
Spira Manufacturing Corporation ........................................... 888-98-SPIRA
Tri-Mag, Inc .............................................................. 559-651-2222
WEMS Electronics ...................................................... 310-962-4410
Filters, EMC Test Chamber
Captor Corporation ......................................................... 937-667-8484
Corcom/Tyco Electronics ................................................. 847-573-6504
Curtis Industries ......................................................... 800-657-0853
DNB Engineering, Inc ...................................................... 714-870-7781
ETS-Lindgren .......................................................... 512-531-6400
Genisco Filter Corp ...................................................... 858-565-7405
LCR Electronics, Inc ...................................................... 800-527-4362
Murata Electronics ...................................................... 800-554-4070
NexTek, Inc .............................................................. 978-486-0582
Okaya Electric America, Inc .............................................. 800-852-0122
OnFILTER, Inc .......................................................... 831-824-4052
Panashield, Inc .......................................................... 203-866-5888
Reliant EMC LLC ......................................................... 408-600-1472
Schaffner EMC Inc ...................................................... 800-848-2600
Spira Manufacturing Corporation ........................................... 888-98-SPIRA
TDK Corporation ......................................................... 512-258-9478
Filters, Power Line
Captor Corporation ......................................................... 937-667-8484
Corcom/Tyco Electronics ................................................. 847-573-6504
Curtis Industries ......................................................... 800-657-0853
DNB Engineering, Inc ...................................................... 714-870-7781
ETS-Lindgren .......................................................... 512-531-6400
Genisco Filter Corp ...................................................... 858-565-7405
LCR Electronics, Inc ...................................................... 800-527-4362
Murata Electronics ...................................................... 800-554-4070
NexTek, Inc .............................................................. 978-486-0582
Okaya Electric America, Inc .............................................. 800-852-0122
OnFILTER, Inc .......................................................... 831-824-4052
Panashield, Inc .......................................................... 203-866-5888
Reliant EMC LLC ......................................................... 408-600-1472
Schaffner EMC Inc ...................................................... 800-848-2600
Spira Manufacturing Corporation ........................................... 888-98-SPIRA
TDK Corporation ......................................................... 512-258-9478
Filters, RF and Microwave
API Technologies Corp .................................................. 855-294-3800
ESDEM Technology LLC .................................................. 877-864-8479
Filconn Inc .............................................................. 480 222 3565
Lionheart Northwest ...................................................... 425-882-2587
Oak-Mitsui Technologies .................................................. 518-686-4961
Filters, Shielded Air
- Alco Technologies, Inc. .................................. 310-328-4770
- Parker Hannifin, Chomerics Div .......................... 781-935-4850
  Prismaier .................................................. 630-592-4515
  TechDream, Inc. ......................................... 408-800-7362

Filters, Shielded Room
- Alco Technologies, Inc. .................................. 310-328-4770
- Captor Corporation ....................................... 937-667-8484
- DJM Electronics .......................................... 866-DJM-ELEC
- ETS-Lindgren .............................................. 512-531-6400
- Genisco Filter Corp ....................................... 858-565-7405
- NexTek, Inc. ................................................ 978-486-0582
- WEMS Electronics ........................................ 310-962-4410

Filters, Signal Line
- Amphenol Canada Corp .................................. 416-754-5668
- Captor Corporation ....................................... 937-667-8484
- Corcom/Tayo Electronics ................................ 847-573-6504
- DJM Electronics .......................................... 866-DJM-ELEC
- DNB Engineering, Inc. ................................... 714-870-7781
- EMI Solutions ............................................. 949-206-9960
- Genisco Filter Corp ....................................... 858-565-7405
- LCR Electronics, Inc. ..................................... 800-527-4362
- Oak-Mitsui Technologies ................................ 518-686-4961
- Quell Corporation ......................................... 505-243-1423
- Reliant EMC LLC .......................................... 408-600-1472
- Solar Electronics Company ............................... 800-952-5302
- TDK Corporation ........................................... 512-258-9478
- Texas Spectrum Electronics .............................. 972-296-3699
- WEMS Electronics ........................................ 310-962-4410

Filters, Third-Party Approved, EU
- LCR Electronics, Inc. ..................................... 800-527-4362

Filters, Third-Party Approved, US/Canada
- LCR Electronics, Inc. ..................................... 800-527-4362

Finger Stock
- Laird Technologies ......................................... 636-898-6215
- Leader Tech ................................................ 866-TECH EMl
- Orbel Corporation .......................................... 610-829-5000
- P & P Technology Ltd ..................................... 44 (0)1376 550525

Foils, Shield Tape
- Advance Magnetics ....................................... 574-223-3158
- André Consulting, Inc. ................................... 206-406-8371
- East Coast Shielding ..................................... 908-852-9160
- JEMIC Shielding Technology ............................. 717-232-1030
- The Mushiild Company Inc. .............................. 888-669-3539

Gaskets
- 3Gmetalworx Inc. ......................................... 888-965-3634
- Alco Technologies, Inc. .................................. 310-328-4770
- East Coast Shielding ...................................... 908-852-9160
- Fotofab ..................................................... 773-463-6211
- Intermark USA, Inc. ....................................... 408-971-2055
- Ja-Bar Silicone Corp ....................................... 973-786-5000
- JEMIC Shielding Technology .............................. 717-232-1030
- Laird Technologies ......................................... 636-898-6215
- Leader Tech ................................................ 866-TECH EMl
- MAJR Products, Inc. ....................................... 888-625-7776
- Metal Textiles Corporation ............................... 732-287-0800
- Omega Shielding Products, Inc. ......................... 800-828-5784
- Orbel Corporation .......................................... 610-829-5000
- P & P Technology Ltd ..................................... 44 (0)1376 550525

Shielded Connectors
- 3Gmetalworx Inc. ......................................... 888-965-3634
- Adv-ance Magnetics ...................................... 574-223-3158
- Alco Technologies, Inc. .................................. 310-328-4770
- API Technologies Corp. .................................. 855-294-3800
- East Coast Shielding ...................................... 908-852-9160
- Ja-Bar Silicone Corp ....................................... 973-786-5000
- Prismaier ................................................... 630-592-4515
- Schurter Inc. .............................................. 800-848-2600
- Spira Manufacturing Corporation .................... 888-98-SPIRA

Resistors
- Americor Electronics Ltd. ............................... 800-830-5337

Shielded Cable Assemblies and Harnesses
- Alco Technologies, Inc. .................................. 310-328-4770
- Bittele Electronics ........................................ 416-800-7541
- Electri-Flex Company ..................................... 800-323-6174
- Vermillion, Inc. ........................................... 305-968-5981

Shielded Cable, Assemblies and Harnesses
- Americor Electronics Ltd. ............................... 800-830-5337
- Electri-Flex Company ..................................... 800-323-6174
- Magnetic Shield Corporation ............................ 888-766-5981

Shielded Conduit
- Americor Electronics Ltd. ............................... 800-830-5337
- Electri-Flex Company ..................................... 800-323-6174
- Magnetic Shield Corporation ............................ 888-766-5981

Shielded Tube, Umbilical
- Americor Electronics Ltd. ............................... 800-830-5337
- Electri-Flex Company ..................................... 800-323-6174
- Magnetic Shield Corporation ............................ 888-766-5981
Shielded Wire and Cable
Alco Technologies, Inc. …… 310-328-4770
Electri-Flex Company …… 800-323-6174
EMC Technologies …… 732-919-1100
Magentic Shield Corporation …… 888-766-7800

The MuShield Company Inc.
Verdimill, Inc. …… 305-968-5981
W. L. Gore & Associates, Inc.
Zero Ground LLC …… 866-937-4643

Shielding Coatings
Magnetic Shield Corporation …… 888-766-7800
Parker Hannifin, Chomerics Div. …… 781-935-4850
VTI Vacuum Technologies, Inc. …… 800-482-1941

Shielding Compounds
3Gmetalworx Inc. …… 888-965-3634
Parker Hannifin, Chomerics Div. …… 781-935-4850

Shielding Material
Shielding Material, EMI/RFI
3Gmetalworx Inc. …… 888-965-3634
Ad-Vance Magnetics …… 574-223-3158
Alco Technologies, Inc. …… 310-328-4770
André Consulting, Inc. …… 206-406-8371
DDB Unlimited, Inc. …… 800-753-8459
Dexmet Corporation …… 203-294-7867
East Coast Shielding …… 908-852-9160
Electri-Flex Company …… 800-323-6174
FerrShield …… 866-TECH-EMI
Fotofab …… 773-463-6211
Intermark USA, Inc. …… 408-971-2055
Ja-Bar Silicone Corp …… 973-786-5000
JEMIC Shielding Technology …… 717-232-1030
Leader Tech …… 866-TECH-EMI
Magnetic Shield Corporation …… 888-766-7800
MAJR Products, Inc. …… 877-625-7776
Microwave Vision Group …… 678-797-9172
The MuShield Company Inc. …… 888-669-3539
Omega Shielding Products, Inc. …… 800-828-5784
Orbel Corporation …… 610-829-5000
P & P Technology Ltd. …… 44 (0)1376 550525
Panahseld, Inc. …… 203-866-5888
PRISMIER …… 630-592-4515
Pulver Laboratories Inc. …… 800-635-3050
Raymond EMC Enclosures Ltd. …… 800-362-1495
SAS Industries, Inc. …… 631-727-1441 x302
Schiegel Electronic Materials, Inc. …… 800-204-0863
Spira Manufacturing Corporation …… 888-98-SPIRA
Tech-Etch …… 508-747-0300
TechDream, Inc. …… 408-800-7362
Vermillion, Inc. …… 305-968-5981
VTI Vacuum Technologies, Inc. …… 800-482-1941
W. L. Gore & Associates, Inc.
Wurth Electronics Midcom …… 800-643 2661
Zero Ground LLC …… 866-937-4643

Shielding Material, Magnetic Field
3Gmetalworx Inc. …… 888-965-3634
Ad-Vance Magnetics …… 574-223-3158
André Consulting, Inc. …… 206-406-8371
Dexmet Corporation …… 203-294-7867
FerrShield …… 866-TECH-EMI
Fotofab …… 773-463-6211
Magentic Shield Corporation …… 888-766-7800
MAJR Products, Inc. …… 877-625-7776
Microwave Vision Group …… 678-797-9172
The MuShield Company Inc. …… 888-669-3539
Orbel Corporation …… 610-829-5000
P & P Technology Ltd. …… 44 (0)1376 550525
Panahseld, Inc. …… 203-866-5888
PRISMIER …… 630-592-4515
Pulver Laboratories Inc. …… 800-635-3050
Raymond EMC Enclosures Ltd. …… 800-362-1495
SAS Industries, Inc. …… 631-727-1441 x302
Schiegel Electronic Materials, Inc. …… 800-204-0863
Spira Manufacturing Corporation …… 888-98-SPIRA
Tech-Etch …… 508-747-0300
TechDream, Inc. …… 408-800-7362
Vermillion, Inc. …… 305-968-5981
VTI Vacuum Technologies, Inc. …… 800-482-1941
W. L. Gore & Associates, Inc.
Wurth Electronics Midcom …… 800-643 2661
Zero Ground LLC …… 866-937-4643

ESD Equipment & Products
Air Ionizers
3M Electronic Solutions …… 512-984-6747
MKS ION Systems …… 800-367-2452
TREK, INC. …… 800-FOR-TREK

ESD Tape
Mag Daddy …… 847-719-5600
Polyonics …… 603-352-1415

Meters
Meters, Static Charge
ESDEMC Technology LLC …… 877-864-8479
Megalin Source International …… 886-2-8698-4181
MKS ION Systems …… 800-367-2452
Monroe Electronics, Inc. …… 585-765-2254
Prostat Corporation …… 630-238-8883
Staticworx Flooring …… 888-STATICWORX
TREK, INC. …… 800-FOR-TREK

Simulators
Simulators, EMP
EM TEST USA …… 858-450-0085
Teseq Inc. …… 732-417-0501

Simulators, ESD
Advanced Test Equipment Rentals
ARC Technical Resources, Inc. …… 408-263-6486
Barth Electronics, Inc. …… 702-293-1576
EM TEST USA …… 858-450-0085
ESDEMC Technology LLC …… 877-864-8479
Grund Technical Solutions, LLC …… 510-453-2617
HV TECHNOLOGIES, Inc. …… 703-365-2330
Noise Laboratory Co (NoiseKen) …… 81 (0) 42 712 2051
Teseq Inc. …… 732-417-0501
Thermo Fisher Scientific …… 978-275-0800 x2302

Suppressors
Suppressors, Transient
Captor Corporation …… 937-667-8484
NexTek, Inc. …… 978-486-0582
Okaya Electric America, Inc. …… 800-852-0122
Texas Spectrum Electronics . 972-296-3699
WEMS Electronics …… 310-962-4410
Simulators, Lightning

Advanced Test Equipment Rentals ........................................ 858-558-6500
EM TEST USA ................................................................. 858-450-0085

Haefely EMC Technology .................................................... 845-279-3644 x240
HV TECHNOLOGIES, Inc .................................................... 703-365-2330
Mag Daddy ................................................................. 847-719-5600
Noise Laboratory Co (NoiseKen) ........................................ 81 (0) 42 712 2051
NTS Pittsfield ................................................................. 800-270-2516
Teseq Inc ................................................................. 732-417-0501
Thermo Fisher Scientific .................................................. 866-361-3331

Static Control

Static Control Containers
3M Electronic Solutions .................................................... 512-984-6747

Static Control Flooring
3M Electronic Solutions .................................................... 512-984-6747
Protective Industrial Polymers ........................................... 866-361-3331

Static Control Footwear
Staticworx Flooring ....................................................... 888-STATICWORX

Static Control Garments
3M Electronic Solutions .................................................... 512-984-6747
ESDEMC Technology LLC ............................................... 877-864-8479
Prostat Corporation ....................................................... 630-238-8883

Static Control Mats
3M Electronic Solutions .................................................... 512-984-6747
ESDEMC Technology LLC ............................................... 877-864-8479
Prostat Corporation ....................................................... 630-238-8883

Static Control Monitoring Equipment
3M Electronic Solutions .................................................... 512-984-6747
MKS ION Systems .......................................................... 800-367-2452
TREK, INC ................................................................. 800-FOR-TREK

Static Control Packaging
3M Electronic Solutions .................................................... 512-984-6747

Static Control Workstations
3M Electronic Solutions .................................................... 512-984-6747

Static Control Wrist Straps
3M Electronic Solutions .................................................... 512-984-6747
ESDEMC Technology LLC ............................................... 877-864-8479
Prostat Corporation ....................................................... 630-238-8883

Transient Detectors and Suppressors
D. C. Smith Consultants ..................................................... 800-323-3956
EMI Solutions ............................................................... 949-206-9960
ESDEMC Technology LLC ............................................... 877-864-8479
MKS ION Systems .......................................................... 800-367-2452
Quell Corporation ............................................................ 505-243-1423
Texas Spectrum Electronics ........................................... 972-296-3699
WEMS Electronics ......................................................... 310-962-4410

Coatings
Master Bond ................................................................. 201-343-8983
Krefine Co.Ltd ............................................................... 520-838-0548
Polyonics ................................................................. 603-352-1415
Protective Industrial Polymers ....................................... 886-361-3331
Staticworx Flooring ...................................................... 888-STATICWORX
TestingPartners.com ...................................................... 862-243-2329
VTI Vacuum Technologies, Inc ....................................... 800-482-1941

Foams and Foam Materials
Krefine Co.Ltd ............................................................... 520-838-0548
Laird Technologies ......................................................... 636-898-6215
TechDream, Inc ............................................................. 408-800-7362
W. L. Gore & Associates, Inc ........................................... 866-680-1555

Insulation
Polyonics ................................................................. 603-352-1415

Powders
Lubrizol Conductive Polymers ...................................... 866-680-1555

Resins and Compounds
Krefine Co.Ltd ............................................................... 520-838-0548
Lubrizol Conductive Polymers ...................................... 866-680-1555
RTP Company ............................................................... 800-433-4787

Sealants
Master Bond ................................................................. 201-343-8983
W. L. Gore & Associates, Inc. ........................................... 866-680-1555

Silicone Conductive Sponge
Ja-Bar Silicone Corp ...................................................... 973-786-5000
JEMIC Shielding Technology ........................................... 717-232-1030
P & P Technology Ltd .................. .................................. 44 (0)1376 550525

Thermally Conductive Silicone Materials
Ja-Bar Silicone Corp ...................................................... 973-786-5000
Laird Technologies ......................................................... 636-898-6215
TechDream, Inc ............................................................. 408-800-7362

Thermoplastic Components
Lubrizol Conductive Polymers ...................................... 866-680-1555

Thermoplastics and Thermoplastic Materials
Dexmet Corporation ....................................................... 203-294-7867
Krefine Co.Ltd ............................................................... 520-838-0548
Power & Power Management

Overvoltage Protection

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>CITEL, Inc.</td>
<td>800-248-3548</td>
</tr>
<tr>
<td>NexTek, Inc.</td>
<td>978-486-0582</td>
</tr>
<tr>
<td>Okaya Electric America, Inc.</td>
<td>800-852-0122</td>
</tr>
</tbody>
</table>

Power Amplifier

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE Techron, Inc.</td>
<td>574-295-9495</td>
</tr>
</tbody>
</table>

Power Converters

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associated Power Technologies</td>
<td>877-322-7693</td>
</tr>
<tr>
<td>Chroma Systems Solutions, Inc.</td>
<td>949-600-6400</td>
</tr>
</tbody>
</table>

Power Cords

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americor Electronics Ltd.</td>
<td>800-830-5337</td>
</tr>
<tr>
<td>Mag Daddy</td>
<td>847-719-5600</td>
</tr>
<tr>
<td>OPHIR RF</td>
<td>310-306-5556</td>
</tr>
<tr>
<td>Schurter Inc.</td>
<td>800-848-2600</td>
</tr>
</tbody>
</table>

Power Distribution Systems

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Technologies Corp.</td>
<td>855-294-3800</td>
</tr>
<tr>
<td>Captor Corporation</td>
<td>937-667-8484</td>
</tr>
<tr>
<td>CMD Ltd</td>
<td>441709829511</td>
</tr>
<tr>
<td>HM Cragg</td>
<td>800-672-7244</td>
</tr>
<tr>
<td>IQS, a Division of CMG</td>
<td>508-460-1400</td>
</tr>
<tr>
<td>Oak-Mitsui Technologies</td>
<td>518-686-4961</td>
</tr>
<tr>
<td>Schurter Inc.</td>
<td>800-848-2600</td>
</tr>
</tbody>
</table>

Power Generators

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarion Safety Systems</td>
<td>800-748-0241</td>
</tr>
<tr>
<td>Laird Technologies</td>
<td>636-898-6215</td>
</tr>
</tbody>
</table>

Power Line Conditioning Equipment

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mag Daddy</td>
<td>847-719-5600</td>
</tr>
<tr>
<td>OPHIR RF</td>
<td>310-306-5556</td>
</tr>
<tr>
<td>Schurter Inc.</td>
<td>800-848-2600</td>
</tr>
</tbody>
</table>

Power Supplies

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE Techron, Inc.</td>
<td>574-295-9495</td>
</tr>
<tr>
<td>Americor Electronics Ltd.</td>
<td>800-830-5337</td>
</tr>
<tr>
<td>API Technologies Corp.</td>
<td>855-294-3800</td>
</tr>
<tr>
<td>Associated Power Technologies</td>
<td>877-322-7693</td>
</tr>
<tr>
<td>Chroma Systems Solutions, Inc.</td>
<td>949-600-6400</td>
</tr>
<tr>
<td>DDB Unlimited, Inc.</td>
<td>800-753-8459</td>
</tr>
<tr>
<td>HM Cragg</td>
<td>800-672-7244</td>
</tr>
<tr>
<td>Murata Electronics</td>
<td>800-554-4070</td>
</tr>
<tr>
<td>Test Equipment Connection</td>
<td>800-615-8378</td>
</tr>
<tr>
<td>TREK, INC</td>
<td>800-FOR-TREK</td>
</tr>
<tr>
<td>Tri-Mag, Inc.</td>
<td>559-651-2222</td>
</tr>
</tbody>
</table>
Switch Mode Power Supply
AE Techron, Inc. .......................... 574-295-9495
Associated Power Technologies
............................................. 877-322-7693
Chroma Systems Solutions, Inc.
............................................. 949-600-6400
Tri-Mag, Inc. ............................. 559-651-2222

Switching Power Supplies
Americor Electronics Ltd. ......... 800-830-5337
Associated Power Technologies
............................................. 877-322-7693
Chroma Systems Solutions, Inc.
............................................. 949-600-6400
Interpower Corporation ............ 800-662-2290
Tri-Mag, Inc. ............................. 559-651-2222

Software Suppliers
3D Simulation Software
CST of America ....................... 508-665-4400

Anechoic Chamber Software
EM Software & Systems (USA) Inc
............................................. 800-419-5566 (FEKO)
EM Software & Systems-S.A.
............................................. 27 21 831 1500
EMSS Consulting ...................... 27 2188 01880

EMC Simulation Software
ANDRO Computational Solutions
............................................. 315-334-1163
CST of America ......................... 508-665-4400
Delcross Technologies, LLC ......... 217-363-3396
EM Software & Systems (USA) Inc
............................................. 800-419-5566 (FEKO)
EM Software & Systems-S.A.
............................................. 27 21 831 1500

EMC/EMI Software
AR RF/Microwave Instrumentation
............................................. 888-933-8181
ARC Technical Resources, Inc.
............................................. 408-263-6486
CST of America ......................... 508-665-4400
Delcross Technologies, LLC ......... 217-363-3396
EM Software & Systems (USA) Inc
............................................. 800-419-5566 (FEKO)
MossBay EDA ......................... 206-779-5345
NEC Corporation ..................... 408-600-1472
Reliant EMC LLC ..................... 408-800-7362

ESD, Static Control Software
CST of America ......................... 508-665-4400
MKS ION Systems ..................... 800-367-2452

EM Software & Systems (USA) Inc
............................................. 800-419-5566 (FEKO)

Delcross Technologies, LLC ......... 217-363-3396

EMC/EMI Software
AR RF/Microwave Instrumentation
............................................. 888-933-8181
ARC Technical Resources, Inc.
............................................. 408-263-6486
CST of America ......................... 508-665-4400
Delcross Technologies, LLC ......... 217-363-3396
EM Software & Systems (USA) Inc
............................................. 800-419-5566 (FEKO)
MossBay EDA ......................... 206-779-5345
NEC Corporation ..................... 408-600-1472
Reliant EMC LLC ..................... 408-800-7362
TechDream, Inc. ....................... 408-800-7362

Standards Suppliers
Clarion Safety Systems ............... 800-748-0241
EMC Compliance ..................... 256-650-5261
ESD Association ....................... 315-339-6937
Hoolihan EMC Consulting ............ 651-213-0966
Trace Laboratories, Inc. ............. 410-584-9099

Test & Measurement Equipment
Amplifiers
Amplifiers, Low Noise
A.H. Systems, Inc ....................... 818-998-0223
Advanced Test Equipment Rentals
............................................. 858-558-6500
AE Techron, Inc. ......................... 574-295-9495
Agilent Technologies ................. 800-829-4444
API Technologies Corp. .............. 855-294-3800
AR RF/Microwave Instrumentation
............................................. 888-933-8181
Avalon Equipment Corporation ....... 888-542-8256
Com-Power Corporation .............. 714-542-8256
Dynamic Sciences International .. 800-696-3713
Electro Rent Corporation ............ 800-688-1111
Giga-tronics Incorporated .......... 800-277-9764
Instruments For Industry, Inc. ...... 631-467-5556
OPHIR RF ................................ 310-306-6556
Teseq Inc. ............................... 732-417-0501
### Amplifiers, Power

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>AE Techron, Inc.</td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td><strong>AR RF/Microwave Instrumentation</strong></td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td>Com-Power Corporation</td>
</tr>
<tr>
<td>CPL, Inc.</td>
</tr>
<tr>
<td>Electronic Instrument Associates</td>
</tr>
<tr>
<td>Giga-tronics Incorporated</td>
</tr>
<tr>
<td><strong>HV TECHNOLOGIES, Inc.</strong></td>
</tr>
<tr>
<td>Instruments For Industry, Inc.</td>
</tr>
<tr>
<td>Lionheart Northwest</td>
</tr>
<tr>
<td>MILMEGA Ltd.</td>
</tr>
<tr>
<td><strong>OPHIR RF</strong></td>
</tr>
<tr>
<td>Rohde &amp; Schwarz, Inc.</td>
</tr>
<tr>
<td>Solar Electronics Company</td>
</tr>
<tr>
<td><strong>Vectawave Technology, Ltd.</strong></td>
</tr>
</tbody>
</table>

### Amplifiers, RF

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td>API Technologies Corp.</td>
</tr>
<tr>
<td><strong>AR RF/Microwave Instrumentation</strong></td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td><strong>HV TECHNOLOGIES, Inc.</strong></td>
</tr>
<tr>
<td>Instruments For Industry, Inc.</td>
</tr>
<tr>
<td>Lionheart Northwest</td>
</tr>
<tr>
<td>MILMEGA Ltd.</td>
</tr>
<tr>
<td><strong>OPHIR RF</strong></td>
</tr>
<tr>
<td>Rohde &amp; Schwarz, Inc.</td>
</tr>
<tr>
<td>Solar Electronics Company</td>
</tr>
<tr>
<td><strong>Vectawave Technology, Ltd.</strong></td>
</tr>
</tbody>
</table>

### Analyzers

#### Analyzers

**Analyzers, EMI/EMC Spectrum**

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td>ARC Technical Resources, Inc.</td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td>Com-Power Corporation</td>
</tr>
<tr>
<td>Dynamic Sciences International</td>
</tr>
<tr>
<td>Electro Rent Corporation</td>
</tr>
<tr>
<td>Electronic Instrument Associates</td>
</tr>
<tr>
<td><strong>GAUSS INSTRUMENTS</strong></td>
</tr>
<tr>
<td><strong>MADE IN JAPAN</strong></td>
</tr>
<tr>
<td><strong>MetaGeek</strong></td>
</tr>
<tr>
<td><strong>Reliant EMC</strong></td>
</tr>
<tr>
<td><strong>Test Equipment Connection</strong></td>
</tr>
<tr>
<td><strong>Teseq Inc.</strong></td>
</tr>
</tbody>
</table>

#### Analyzers, Flicker

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td>ARC Technical Resources, Inc.</td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td>Com-Power Corporation</td>
</tr>
<tr>
<td>Dynamic Sciences International</td>
</tr>
<tr>
<td>Electro Rent Corporation</td>
</tr>
<tr>
<td><strong>MetaGeek</strong></td>
</tr>
<tr>
<td><strong>Reliant EMC</strong></td>
</tr>
</tbody>
</table>

#### Analyzers, Harmonics

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td>ARC Technical Resources, Inc.</td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td>Electro Rent Corporation</td>
</tr>
<tr>
<td><strong>EM TEST USA</strong></td>
</tr>
<tr>
<td>Lionheart Northwest</td>
</tr>
<tr>
<td><strong>Reliant EMC</strong></td>
</tr>
</tbody>
</table>

#### Analyzers, Network

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td><strong>BG ELECTRONIC</strong></td>
</tr>
<tr>
<td><strong>BMR ELECTRONIC</strong></td>
</tr>
<tr>
<td><strong>DYNAMIC SCIENCES</strong></td>
</tr>
<tr>
<td><strong>ELECTRONIC</strong></td>
</tr>
<tr>
<td><strong>TESEQ INC.</strong></td>
</tr>
<tr>
<td><strong>TESEQ</strong></td>
</tr>
</tbody>
</table>

#### Analyzers, Power Quality

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Test Equipment Rentals</strong></td>
</tr>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td>Agilent Technologies</td>
</tr>
<tr>
<td>ARC Technical Resources, Inc.</td>
</tr>
<tr>
<td>Avalon Equipment Corporation</td>
</tr>
<tr>
<td><strong>BG ELECTRONIC</strong></td>
</tr>
<tr>
<td><strong>BMR ELECTRONIC</strong></td>
</tr>
<tr>
<td><strong>DYNAMIC SCIENCES</strong></td>
</tr>
<tr>
<td><strong>ELECTRONIC</strong></td>
</tr>
<tr>
<td><strong>TESEQ INC.</strong></td>
</tr>
<tr>
<td><strong>TESEQ</strong></td>
</tr>
</tbody>
</table>

### Automatic Test Sets

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td><strong>Adaptive Test Solutions</strong></td>
</tr>
<tr>
<td><strong>ARC Technical Resources, Inc.</strong></td>
</tr>
<tr>
<td><strong>Aum Electro Technology Pvt Ltd</strong></td>
</tr>
<tr>
<td><strong>Chroma Systems Solutions, Inc.</strong></td>
</tr>
<tr>
<td><strong>Hermon Laboratories TI</strong></td>
</tr>
<tr>
<td><strong>Innco Systems GmbH</strong></td>
</tr>
<tr>
<td><strong>Reliant EMC LLC</strong></td>
</tr>
</tbody>
</table>

### Test Equipment Connection

<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeroflex</td>
</tr>
<tr>
<td><strong>Agilent Technologies</strong></td>
</tr>
<tr>
<td>EmTech, Inc.</td>
</tr>
<tr>
<td><strong>Flicker Test Equipment</strong></td>
</tr>
<tr>
<td><strong>Global Test Equipment</strong></td>
</tr>
<tr>
<td><strong>Giga-tronics Incorporated</strong></td>
</tr>
<tr>
<td><strong>HV TECHNOLOGIES, Inc.</strong></td>
</tr>
<tr>
<td><strong>Instruments For Industry, Inc.</strong></td>
</tr>
<tr>
<td><strong>Lionheart Northwest</strong></td>
</tr>
<tr>
<td><strong>MetaGeek</strong></td>
</tr>
<tr>
<td><strong>MOLOCK</strong></td>
</tr>
<tr>
<td><strong>MetaGeek</strong></td>
</tr>
<tr>
<td><strong>Telescop</strong></td>
</tr>
<tr>
<td><strong>TESOCH</strong></td>
</tr>
<tr>
<td><strong>Teseq Inc.</strong></td>
</tr>
<tr>
<td><strong>Test Equipment Connection</strong></td>
</tr>
<tr>
<td><strong>Veralco</strong></td>
</tr>
<tr>
<td><strong>VEROCH</strong></td>
</tr>
</tbody>
</table>
Avionics Test Equipment
AE Techtron, Inc. 574-295-9495
Aeroflex 800-835-2352
Avalon Equipment Corporation 888-542-8256
Dayton T. Brown, Inc. 800-TEST-456
EM TEST USA 858-450-0085
HV TECHNOLOGIES, Inc. 703-365-2330
MI Technologies 678-475-8345
Narda Safety Test Solutions 631-231-1700
Thermo Fisher Scientific 978-275-0800 x2302
Buildings, EMC Testing
Audivo GmbH 49 9435 5419 0
Cuming-Lehman Chambers, Inc. 717-263-4101
Narda Safety Test Solutions 631-231-1700
Burn-in Test Equipment
VEROCH 954-990-7544
Calibration & Repair Services
Aeroflex 800-835-2352
Agilent Technologies 800-829-4444
Avalon Equipment Corporation 888-542-8256
EM TEST USA 858-450-0085
ESDEM Technology LLC 877-864-8479
eti Conformity Services 877-468-6384
Fischer Custom Communications 310-303-3300
GAUSS INSTRUMENTS 49-89-5404699-0
Global Test Equipment 866-409-0400
Liberty Labs, Inc. 712-773-2199
MI Technologies 678-475-8345
Prostat Corporation 630-238-8883
Restor Metrology 877-220-5554
VEROCH 954-990-7544
World Cal, Inc. 712-764-2197
Current Leakage Testers
Advanced Test Equipment Rentals 858-558-6500
Associated Research, Inc. 800-858-8378
Chroma Systems Solutions, Inc. 949-600-6400
ED&D Inc. 800-806-6236
Ergonomics, Inc. 800-862-0102
Slaughter Company, Inc. 800-504-0055
Vitrek Corporation 858-689-2755
Data Acquisition Monitoring Systems
3M Electronic Solutions 512-984-6747
Advanced Test Equipment Rentals 858-558-6500
Avalon Equipment Corporation 888-542-8256
Global Test Equipment 866-409-0400
MKS ION Systems 800-367-2452
NTS Albuquerque 505-821-4740
Dielectric Strength Testers
Advanced Test Equipment Rentals 858-558-6500
Associated Research, Inc. 800-858-8378
Chroma Systems Solutions, Inc. 949-600-6400
ED&D Inc. 800-806-6236
Ergonomics, Inc. 800-862-0102
Slaughter Company, Inc. 800-504-0055
Vitrek Corporation 858-689-2755
Electrical Safety Testers
Advanced Test Equipment Rentals 858-558-6500
AE Techtron, Inc. 574-295-9495
Associated Research, Inc. 800-858-8378
Avalon Equipment Corporation 888-542-8256
Chroma Systems Solutions, Inc. 949-600-6400
ED&D Inc. 800-806-6236
Ergonomics, Inc. 800-862-0102
Finero USA LLC 239-898-8487
Prostat Corporation 630-238-8883
Slaughter Company, Inc. 800-504-0055
VEROCH 954-990-7544
Vitrek Corporation 858-689-2755
EMC Testers
Advanced Test Equipment Rentals 858-558-6500
AE Techtron, Inc. 574-295-9495
Aeroflex 800-835-2352
Amber Precision Instruments, Inc. 408-752-0199 x102
Avalon Equipment Corporation 888-542-8256
D. C. Smith Consultants 800-323-3956
Electronic Instrument Associates 630-924-1600
EM TEST USA 858-450-0085
EMC Test Design, LLC 508-292-1833
EMSCAN 877-367-2261
GAUSS INSTRUMENTS 49-89-5404699-0
Haefely EMC Technology 845-279-3644 x240
HV TECHNOLOGIES, Inc. 703-365-2330
Noise Laboratory Co (NoiseKen) 81 (0) 42 712 2051
Reliant EMC LLC 408-600-1472
Rohde & Schwarz, Inc. 888-TEST-RSA
TectDrem, Inc. 408-800-7362
Teseq Inc. 732-417-0501
Test Equipment Connection 800-615-8378
Thermo Fisher Scientific 978-275-0800 x2302
TÜV SÜD America Inc. 800-888-0123
EMP Simulators
Dayton T. Brown, Inc. 800-TEST-456
EM TEST USA 858-450-0085
Fischer Custom Communications 310-303-3300
HV TECHNOLOGIES, Inc. 703-365-2330
Teseq Inc. 732-417-0501
Environmental Chambers
Advanced Test Equipment Rentals 858-558-6500
ED&D Inc. 800-806-6236
NTS Newark 877-245-7800
NTS Rockford 800-270-2516
Thermotron Industries 616-393-4580
TÜV SÜD America Inc. 954-990-7544
ÉVROCH 954-990-7544
Thermo Fisher Scientific 978-275-0800 x2302
AUdivo GmbH 49 9435 5419 0
Cuming-Lehman Chambers, Inc. 717-263-4101
Narda Safety Test Solutions 631-231-1700
VEROCH 954-990-7544
ESD Test Equipment

Generators

3M Electronic Solutions ........................................ 512-984-6747
Amber Precision Instruments, Inc. ........................................ 408-752-0199 x102
Avalon Equipment Corporation ........................................ 888-542-8256
Barth Electronics, Inc. ........................................ 702-293-1576
Electro Rent Corporation ........................................ 800-688-1111
Electronic Instrument Associates ........................................ 630-924-1600
ESDEMC Technology LLC ........................................ 877-864-8479
Grund Technical Solutions, LLC ........................................ 510-453-2617

HV TECHNOLOGIES, Inc. ........................................ 703-365-2330
Monroe Electronics, Inc. ........................................ 585-765-2254
Narda Safety Test Solutions ........................................ 631-231-1700
Magnetic Shield Corporation ........................................ 800-806-0102

Flow Meters

VEROCH ........................................ 954-990-7544

Gaussmeters

BMI Surplus ........................................ 781-871-8868
Ergonomics, Inc. ........................................ 800-862-0102
Magnetic Shield Corporation ........................................ 888-766-7800
Narda Safety Test Solutions ........................................ 631-231-1700

Generators, Arbitrary Wave Form

Aeroflex ........................................ 800-835-2352
Electro Rent Corporation ........................................ 800-688-1111
Rigol Technologies ........................................ 877-474-4651
Tektronix, Inc. ........................................ 800-833-9200
Test Equipment Connection ........................................ 800-615-8378

Generators, ESD

EM TEST USA ........................................ 858-450-0085
Haefely EMC Technology ........................................ 845-279-3644 x240
HV TECHNOLOGIES, Inc. ........................................ 703-365-2330
Teseq Inc. ........................................ 732-417-0501
Thermo Fisher Scientific ........................................ 978-275-0800 x2302

Generators, Fast/Transient Burst

Advanced Test Equipment Rentals ........................................ 858-558-6500
Electro Rent Corporation ........................................ 800-688-1111
EM TEST USA ........................................ 858-450-0085
Fischer Custom Communications ........................................ 310-303-3300
Haefely EMC Technology ........................................ 845-279-3644 x240
HV TECHNOLOGIES, Inc. ........................................ 703-365-2330
Noise Laboratory Co (NoiseKen) ........................................ 81 (0) 42 712 2051
Thermo Fisher Scientific ........................................ 978-275-0800 x2302

Generators, Impulse

Applied EM Technology ........................................ 410-326-6728
Electro Rent Corporation ........................................ 800-688-1111
EM TEST USA ........................................ 858-450-0085
Haefely EMC Technology ........................................ 845-279-3644 x240
Noise Laboratory Co (NoiseKen) ........................................ 81 (0) 42 712 2051
Thermo Fisher Scientific ........................................ 978-275-0800 x2302

Generators, Interference

Electro Rent Corporation ........................................ 800-688-1111
Noise Laboratory Co (NoiseKen) ........................................ 81 (0) 42 712 2051

Generators, Lightning

EM TEST USA ........................................ 858-450-0085
Haefely EMC Technology ........................................ 845-279-3644 x240
HV TECHNOLOGIES, Inc. ........................................ 703-365-2330
Solar Electronics Company ........................................ 800-952-5302
Thermo Fisher Scientific ........................................ 978-275-0800 x2302

Generators, Signal

Aeroflex ........................................ 800-835-2352
Agilent Technologies ........................................ 800-829-4444
AR RF/Microwave Instrumentation ........................................ 888-933-8181
Electro Rent Corporation ........................................ 800-688-1111
Giga-tronics Incorporated ........................................ 800-277-9764
Global Test Equipment ........................................ 866-409-0400
Reliant EMC LLC ........................................ 408-600-1472
Rigol Technologies ........................................ 877-474-4651
Rohde & Schwarz, Inc. ........................................ 888-TEST-RSA
Tektronix, Inc. ........................................ 800-833-9200
Test Equipment Connection ........................................ 800-615-8378

Ground Bond Testers

Associated Research, Inc ........................................ 800-858-8378
Chroma Systems Solutions, Inc. ........................................ 949-600-6400

Ground Resistance Testers

Associated Research, Inc ........................................ 800-858-8378
Chroma Systems Solutions, Inc. ........................................ 949-600-6400

Hipot Testers

Associated Research, Inc ........................................ 800-858-8378
Avalon Equipment Corporation ........................................ 888-542-8256
Chroma Systems Solutions, Inc. ........................................ 949-600-6400

Product/Service Directory
<table>
<thead>
<tr>
<th>Product/Service Directory</th>
</tr>
</thead>
</table>

## Meters

### Megohmmeters
- Chroma Systems Solutions, Inc. 949-600-6400
- Finero USA LLC. 239-898-8487
- **Monroe Electronics, Inc.** 585-765-2254
- Staticworx Flooring . 888-STATICWORX
- Vitrek Corporation . 858-689-2755

### Meters, Field Strength
- **AR RF/Microwave Instrumentation** 888-933-8181
- EMC Test Design, LLC . 508-292-1833
- Ergonomics, Inc. . 800-862-0102
- **ETS-Lindgren** 512-531-6400
- Magnetic Shield Corporation . 888-766-7800
- Narda Safety Test Solutions . 631-231-1700
- TREK, INC . 800-FOR-TREK

### Meters, Magnetic Field
- EMC Test Design, LLC . 508-292-1833
- Ergonomics, Inc. . 800-862-0102
- Magnetic Shield Corporation . 888-766-7800
- Narda Safety Test Solutions . 631-231-1700

### Meters, Radiation Hazard
- EMC Test Design, LLC . 508-292-1833
- **ETS-Lindgren** 512-531-6400
- Narda Safety Test Solutions . 631-231-1700

### Meters, RF Power
- Aeroflex . 800-835-2352
- **Agilent Technologies** 800-829-4444
- **AR RF/Microwave Instrumentation** 888-933-8181
- BML Surplus . 781-871-8686
- Electro Rent Corporation . 800-688-1111
- EMC Test Design, LLC . 508-292-1833
- Giga-tronics Incorporated . 800-277-9764
- Global Test Equipment . 866-409-0400
- MetaGeek . 208-639-3140

### Meters, Static Charge
- **Monroe Electronics, Inc.** 585-765-2254
- Prostat Corporation . 630-238-8883
- Staticworx Flooring . 888-STATICWORX
- TREK, INC . 800-FOR-TREK

### Meters, Static Decay
- **Monroe Electronics, Inc.** 585-765-2254
- Prostat Corporation . 630-238-8883
- Staticworx Flooring . 888-STATICWORX

## Monitors

### Monitors, Current
- 3M Electronic Solutions . 512-984-6747
- **Pearson Electronics, Inc.** 650-494-6444

### Monitors, EMI Test
- 3M Electronic Solutions . 512-984-6747
- EMC Test Design, LLC . 508-292-1833
- MKS ION Systems . 800-367-2452
- Test Equipment Connection . 800-615-8378

### Monitors, ESD
- 3M Electronic Solutions . 512-984-6747
- MKS ION Systems . 800-367-2452
- Noise Laboratory Co (NoiseKen) . 81 (0) 42 712 2051
- TREK, INC . 800-FOR-TREK

### Monitors, Ionizer Balance
- MKS ION Systems . 800-367-2452

### Monitors, Static Voltage
- MKS ION Systems . 800-367-2452
- TREK, INC . 800-FOR-TREK

## Oscilloscopes and Transient Recorders
- Aeroflex . 800-835-2352
- **Agilent Technologies** 800-829-4444
- Aum Electro Technology Pvt Ltd . 00912512871365
- Avalon Equipment Corporation . 888-542-8256
- BML Surplus . 781-871-8686
- D. C. Smith Consultants . 800-323-3956
- Electro Rent Corporation . 800-688-1111
- GAUSS INSTRUMENTS . 49-89-5404699-0
- Global Test Equipment . 866-409-0400
- Lionheart Northwest . 425-882-2587
- MetaGeek . 208-639-3140
- Rigol Technologies . 877-474-4651
- Tektronix, Inc . 800-833-9200
- Test Equipment Connection . 800-615-8378

## Probes, Electric Field
- **Agilent Technologies** 800-829-4444
- Amber Precision Instruments, Inc. . 408-752-0199 x102
- **AR RF/Microwave Instrumentation** 888-933-8181
- Com-Power Corporation . 714-528-8800
- D. C. Smith Consultants . 800-323-3956
- Electronic Instrument Associates . 630-924-1600
- EMC Test Design, LLC . 508-292-1833
- ESD EMC Technology LLC . 877-864-8479
- **ETS-Lindgren** 512-531-6400
- Test Equipment Connection . 800-615-8378
- Van Doren Company . 573-341-4097

## Probes, Voltage
- **Agilent Technologies** 800-829-4444
- ARC Technical Resources, Inc. . 408-263-6486
- Barth Electronics, Inc. . 702-293-1576
- BML Surplus . 781-871-8668
- D. C. Smith Consultants . 800-323-3956
- Fischer Custom Communications . 310-303-3300
- Global Test Equipment . 866-409-0400
- Reliant EMC LLC . 408-600-1472
- Tektronix, Inc . 800-833-9200
- Test Equipment Connection . 800-615-8378
- VEROCH . 954-990-7544

## Receivers

### Receivers, EMI/EMC
- **Advanced Test Equipment Rentals** . 858-558-6500
- **Agilent Technologies** 800-829-4444
- API Technologies Corp. . 855-294-3800
- **AR RF/Microwave Instrumentation** 888-933-8181
- Com-Power Corporation . 714-528-8800
- Dynamic Sciences International . 800-966-3713
- Electro Rent Corporation . 800-688-1111
- EMI Testing Instruments . 805-835-8547
- GAUSS INSTRUMENTS . 49-89-5404699-0
- Reliant EMC LLC . 408-600-1472
- Rohde & Schwarz, Inc. . 888-TEST-RSA
- TechDream, Inc. . 408-800-7362
Receivers, RF

- Agilent Technologies ........................................ 800-829-4444
- API Technologies Corp. ........................................ 855-294-3800
- Dynamic Sciences International ........................................ 800-966-3713
- Electro Rent Corporation ........................................ 800-688-1111
- GAUSS INSTRUMENTS ........................................ 49-89-5404699-0
- Global Test Equipment ........................................ 866-409-0400
- MI Technologies ........................................ 678-475-8345

RF Leak Detectors

- AR RF/Microwave Instrumentation ........................................ 888-933-8181
- ETS-Lindgren ........................................ 512-531-6400
- MetaGeek ........................................ 208-639-3140
- Narda Safety Test Solutions ........................................ 631-231-1700
- Test Equipment Connection ........................................ 800-615-8378

Safety Test Equipment

- Associated Research, Inc........................................ 800-858-8378
- Avalon Equipment Corporation ........................................ 888-542-8256
- Chroma Systems Solutions, Inc ........................................ 949-600-6400
- Com-Power Corporation ........................................ 714-528-8800
- ED&D Inc ........................................ 800-806-6236
- EMC Technologists ........................................ 732-919-1100
- Ergonomics, Inc ........................................ 800-862-0102
- Finero USA LLC ........................................ 239-898-8487
- Narda Safety Test Solutions ........................................ 631-231-1700
- Slaughter Company, Inc ........................................ 800-504-0055
- VEROCH ........................................ 954-990-7544

Shock & Vibration Testing Shakers

- Aum Electro Technology Pvt Ltd ........................................ 00912512871365
- Dayton T. Brown, Inc ........................................ 800-TEST-456
- NTS Newark ........................................ 877-245-7800
- NTS Santa Clarita ........................................ 800-270-2516
- Thermotron Industries ........................................ 616-393-4580
- TÜV SÜD America Inc ........................................ 800-888-0123

Susceptibility Test Instruments

- AE Technon, Inc ........................................ 574-295-9495
- Amber Precision Instruments, Inc ........................................ 408-752-0199 x102
- AR RF/Microwave Instrumentation ........................................ 888-933-8181
- ARC Technical Resources, Inc ........................................ 408-263-6486
- Com-Power Corporation ........................................ 714-528-8800
- Electronic Instrument Associates ........................................ 630-924-1600
- EM TEST USA ........................................ 858-450-0085
- EMC Test Design, LLC ........................................ 508-292-1833
- Narda Safety Test Solutions ........................................ 631-231-1700
- NexTek, Inc ........................................ 978-486-0582
- Solar Electronics Company ........................................ 800-952-5302
- Thermo Fisher Scientific ........................................ 978-275-0800 x2302

Telecom Test Equipment

- AE Technon, Inc ........................................ 574-295-9495
- Aeroflex ........................................ 800-835-2352
- ED&D Inc ........................................ 800-806-6236
- Electro Rent Corporation ........................................ 800-688-1111
- Electronic Instrument Associates ........................................ 630-924-1600
- EM TEST USA ........................................ 858-450-0085
- Gaia Global Test Equipment ........................................ 866-409-0400
- Haefely EMC Technology ........................................ 845-279-3644 x240
- Hermon Laboratories TI ........................................ 972-4-6268401
- HV TECHNOLOGIES, Inc ........................................ 703-365-2330
- MetaGeek ........................................ 208-639-3140
- NTS Newark ........................................ 877-245-7800
- NTS Tinton Falls ........................................ 732-936-0800
- Test Equipment Connection ........................................ 800-615-8378
- Thermo Fisher Scientific ........................................ 978-275-0800 x2302

Temperature Cycling Systems

- ED&D Inc ........................................ 800-806-6236

Used & Refurbished Test Equipment

- A.H. Systems, Inc ........................................ 818-998-0223
- AR RF/Microwave Instrumentation ........................................ 888-933-8181
- Avalon Equipment Corporation ........................................ 888-542-8256
- BML Surplus ........................................ 781-871-8868
- Giga-technics Incorporated ........................................ 800-277-9764
- Global Test Equipment ........................................ 866-409-0400
- Test Equipment Connection ........................................ 800-615-8378
- TÜV SÜD America Inc ........................................ 800-888-0123
- VEROCH ........................................ 954-990-7544

Testing Services

Accredited Registrar

- CKC Laboratories, Inc ........................................ 800-500-4362
- CSA Group ........................................ 866-463-1785
- Curtis-Straus (Bureau Veritas) ........................................ 877-277-8880
- Electro Magnetic Test, Inc ........................................ 650-965-4000
- Nemko Canada ........................................ 613-737-9680
- Nemko USA - SouthEast ........................................ 813-662-4606
- NQA Canada ........................................ 514-242-2655
- NQA Indiana ........................................ 800-398-8282
- NQA West Coast ........................................ 888-734-4476
- NQA, USA ........................................ 800-649-5289
- Parker Hannifin, Chomerics Div ........................................ 781-935-4850
- TÜV Rheinland of North America ........................................ 1-TUV-RHEINLAND
- TÜV SÜD America Inc ........................................ 800-888-0123

CE Competent Body

- Abstraction Engineering Inc ........................................ 408-258-3282
- American Certification Body, Inc ........................................ 703-847-4700
- CKC Laboratories, Inc ........................................ 800-500-4362
- Compatible Electronics, Inc ........................................ 650-417-EMC1 (3621)
- Compliance Management Group ........................................ 508-281-5985
- CSA Group ........................................ 866-463-1785
- Curtis-Straus (Bureau Veritas) ........................................ 877-277-8880
- D.L.S. Electronic Systems, Inc ........................................ 847-537-6400
- Elite Electronic Engineering ........................................ 800-ELITE-11
- EMCC DR, RASEK ........................................ 49-9194-9016
- G&M Compliance, Inc ........................................ 714-628-1020
- LS Research ........................................ 262-375-4400
- Nemko Canada ........................................ 613-737-9680
- Nemko USA - SouthEast ........................................ 813-662-4606
- Parker Hannifin, Chomerics Div ........................................ 781-935-4850
- SIEMIC ........................................ 408-526-1188
- Test Site Services Inc ........................................ 508-962-1662
- TÜV Rheinland of North America ........................................ 1-TUV-RHEINLAND
- TÜV SÜD America Inc ........................................ 800-888-0123
- UL LLC

CE Notified Body

- American Certification Body, Inc ........................................ 703-847-4700
- CKC Laboratories, Inc ........................................ 800-500-4362
- Compatible Electronics, Inc ........................................ 650-417-EMC1 (3621)
- CSA Group ........................................ 866-463-1785
- Curtis-Straus (Bureau Veritas) ........................................ 877-277-8880
- D.L.S. Electronic Systems, Inc ........................................ 847-537-6400
- Elite Electronic Engineering ........................................ 800-ELITE-11
- EMCC DR, RASEK ........................................ 49-9194-9016
- G&M Compliance, Inc ........................................ 714-628-1020
- HS Research ........................................ 262-375-4400
- Nemko Canada ........................................ 613-737-9680
- Nemko USA - SouthEast ........................................ 813-662-4606
- Parker Hannifin, Chomerics Div ........................................ 781-935-4850
- SIEMIC ........................................ 408-526-1188
- Test Site Services Inc ........................................ 508-962-1662
- TÜV Rheinland of North America ........................................ 1-TUV-RHEINLAND
- TÜV SÜD America Inc ........................................ 800-888-0123
- UL LLC

2013 Annual Guide  In Compliance 225
Product/Service Directory

CE Notified Body continued

NTS Newark ...................... 877-245-7800
SGS Consumer Testing Services ........................................ 800-777-TEST (8378)
SIEMIC ................................... 408-526-1188
Test Site Services Inc. ................................................. 508-962-1662
TÜV Rheinland of North America ....................................... 1-TUV-RHEINLAND
TÜV SÜD America Inc. ................................. 800-888-0123
UL LLC

Environmental Testing and Analysis Services

ACS - Boca Raton, FL ............................................ 561-961-5585
Alberi EcoTech ............................................. 702-677-6923
Cascade TEK - Oregon ............................................ 888-835-9250
Cascade TEK - Colorado ............................................ 888-835-9250
CertifiGroup Inc .............................................. 800-422-1651
Core Compliance Testing ............................................ 603 889-5545
CSA Group .................................................. 866-463-1785
CS2 Testing Services ............................................... 513-793-7774
D.L.S. Electronic Systems, Inc. ....................................... 847-537-6400
EMC Testing Laboratories, Inc. ...................................... 770-475-8819
G&M Compliance, Inc. ........................................... 714-628-1020
Garwood Laboratories ............................................... 888-427-4111
Garwood Laboratories Inc. SC ...................................... 888-427-4111
Green Mtn. Electromagnetics ........................................... 802-388-3390
Keystone Compliance ............................................... 724-657-9940
LabTest Certification Inc. ........................................... 604-247-0444
NTS Santa Clarita .................................................. 800-270-2516
Staticworx Flooring .................................................. 888-STATICWORX
Test Site Services Inc. .............................................. 508-962-1662
TestingPartners.com .................................................. 862-243-2329
Thermotron Industries .................................................. 616-393-4580
VEROCH ...................................................... 954-990-7544

Homologation Services

ACS - Atlanta, GA ............................................. 770-831-8048
ACS - Boca Raton, FL ............................................ 561-961-5585
ACS - Melbourne, FL .............................................. 321-951-1710
Amedican Certification Body, Inc. ..................................... 703-847-4700
CertifiGroup Inc .................................................. 800-422-1651
CSIA, LLC ..................................................... 503-489-8006
Curtis-Straus (Bureau Veritas) ........................................ 877-277-8880
Dayton T. Brown, Inc. ............................................. 800-TEST-456
Electro Magnetic Test, Inc. .......................................... 650-965-4000
H.B. Compliance Solutions ............................................. 480-684-2969
IQS, a Division of CMG ............................................ 508-460-1400
Jacobs Technology ..................................................... 248-676-1101
Lewis Bass International ............................................. 408-942-8000
Nemko Canada ...................................................... 613-737-9680
Nemko USA - SouthEast .............................................. 813-662-4606
O’Brien Compliance Management ..................................... 978-970-0525
SGS Consumer Testing Services ...................................... 800-777-TEST (8378)
SIEMIC ......................................................... 408-526-1188
Telcron LLC ....................................................... Test Site Services Inc .................................................. 508-962-1662
TestingPartners.com .................................................. 862-243-2329
Versus Global Certifications Pty Ltd. .................................. 27 83 5140709

Pre-Assessments

Abstraction Engineering Inc ........................................ 408-258-3282
ACS - Atlanta, GA ............................................. 770-831-8048
ACS - Boca Raton, FL ............................................ 561-961-5585
ACS - Melbourne, FL .............................................. 321-951-1710
Advanced ESD Services ............................................. 607-759-8133
Alberi EcoTech ..................................................... 702-677-6923
American Certification Body, Inc. ..................................... 703-847-4700
CASE Forensics .................................................... 877-736-1106
CertifiGroup Inc .................................................. 800-422-1651
Compatible Electronics, Inc. ......................................... 650-417-EMC1 (3621)
Corcom/Tyco Electronics ............................................. 847-573-6504
CSA Group ....................................................... 866-463-1785
Curtis-Straus (Bureau Veritas) ........................................ 877-277-8880
Electro Magnetic Test, Inc. .......................................... 650-965-4000
EMI Solutions ...................................................... 949-206-9960
G&M Compliance, Inc. ............................................. 714-628-1020
Garwood Laboratories Inc. SC ....................................... 888-427-4111
Jastech EMC Consulting LLC ....................................... 248-876-4810
Lewis Bass International ............................................. 408-942-8000
MI Technologies .................................................... 678-475-8345
Montrose Compliance Services ........................................ 408-247-5715
NCEE Labs. ....................................................... 888-567-6860
O’Brien Compliance Management ..................................... 978-970-0525
Product Safety Consulting ............................................ 877-804-3066
Pulver Laboratories Inc. .............................................. 800-635-3050
RF Exposure Lab .................................................... 760-475-8819
RMV Technology Group, LLC ........................................ 650-964-4792
SILENT Solutions LLC ............................................. 603-578-1842
Spectrum EMC Consulting, LLC ..................................... 651-688-0634
Stephen Halperin & Associates ....................................... 630-238-8883
Telcron LLC ....................................................... Test Site Services Inc .................................................. 508-962-1662
TestingPartners.com .................................................. 862-243-2329
TÜV Rheinland of North America ..................................... 1-TUV-RHEINLAND

Product and Component Testing Services

Abstraction Engineering Inc ........................................ 408-258-3282
ACS - Atlanta, GA ............................................. 770-831-8048
ACS - Boca Raton, FL ............................................ 561-961-5585
ACS - Melbourne, FL .............................................. 321-951-1710
Cascade TEK - Oregon ............................................. 888-835-9250
Cascade TEK - Colorado ............................................ 888-835-9250
CertifiGroup Inc .................................................. 800-422-1651
Compatible Electronics, Inc. ......................................... 650-417-EMC1 (3621)
CSA Group ....................................................... 866-463-1785
CSIA, LLC ....................................................... 503-489-8006
Electronics Test Centre - Airdrie ..................................... 403-912-0037
EMC Testing Laboratories, Inc. ...................................... 770-475-8819
EMI Solutions ...................................................... 949-206-9960
Ergonomics, Inc. .................................................... 800-862-0102
Garwood Laboratories ............................................... 888-427-4111
Garwood Laboratories Inc. SC ....................................... 888-427-4111
Jastech EMC Consulting LLC ....................................... 248-876-4810
Keystone Compliance ............................................... 724-657-9940
L-3 Communications Cincinnati ...................................... 800-543-8220
LabTest Certification Inc. ........................................... 604-247-0444
Lambda Calibration Ltd ................................................ 800-362-1495
LCR Electronics, Inc. ............................................. 800-527-4362
MI Technologies .................................................... 678-475-8345
Nexlogic Technologies, Inc. .......................................... 866-845-1197
Product Safety Consulting ............................................ 877-804-3066
Raymond EMC Enclosures Ltd. ....................................... 800-777-TEST (8378)
SGS Consumer Testing Services ...................................... 800-777-TEST (8378)
SIEMIC ......................................................... 408-526-1188
## Testing Services

**Testing Laboratories**

<table>
<thead>
<tr>
<th>Location</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telcron LLC</td>
<td>508-962-1662</td>
</tr>
<tr>
<td>Test Site Services Inc.</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>TestingPartners.com</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>UL LLC</td>
<td>862-243-2329</td>
</tr>
</tbody>
</table>

**Acoustical Testing**

**Compliance Worldwide, Inc.**
- 603-887-3903
- Core Compliance Testing: 603-889-5545
- Dayton T. Brown, Inc.: 800-TEST-456
- DNB Engineering, Inc.: 714-870-7781
- Ergonomics, Inc.: 800-862-0102
- ETS-Lindgren: 512-531-6400
- Flextronics: 613-895-2053
- Garwood Laboratories Inc. SC: 888-427-4111
- IDQ, a Division of CMG: 508-460-1400
- MET Laboratories: 410-354-3300
- NCE Labs: 888-567-6860
- NTS Fullerton: 800-677-2687
- NTS LAX: 800-559-3202
- NTS Northeast: 800-723-2687
- NTS Plano: 877-717-2687
- NTS Santa Clarita: 800-270-2516
- NTS Tempe: 480-966-5517
- NTS Tinton Falls: 732-936-0800
- Professional Testing: 800-695-1077
- Pulver Laboratories Inc.: 800-635-3050
- Retlif Testing Laboratories: 631-737-1500 x111

**BSMI Compliant Certification Testing**

**ACS - Atlanta, GA.**
- 770-831-8048

**ACS - Boca Raton, FL.**
- 561-961-5585

**ACS - Melbourne, FL.**
- 321-951-1710

**Atlas Compliance & Engineering**
- 866-573-9742

**Compliance Management Group**
- 303-663-3396

**Compliance & More, Inc.**
- 303-663-3396

**Compliance World Wide, Inc.**
- 603-887-3903

**Core Compliance Testing**
- 603-889-5545

**D.L.S. Electronic Systems, Inc.**
- 847-537-6400

**DNB Engineering, Inc.**
- 714-870-7781

**Electro Magnetic Test, Inc.**
- 650-965-4000

**EMCplus LLC.**
- 303-663-3396

**G&M Compliance, Inc.**
- 714-628-1020

**G&M Compliance, Inc.**
- 714-628-1020

**Nemko USA - SouthEast**
- 813-662-4606

**Nemko USA - SouthWest**
- 813-662-4606

**Northwest EMC Inc. - Minnesota**
- 888-364-2378

**Northwest EMC Inc. - California**
- 888-364-2378

**Northwest EMC Inc. - Washington**
- 888-364-2378

**Northwest EMC, Inc. - Oregon**
- 888-364-2378

**NTS Fremont**
- 877-245-7800

**SGS Consumer Testing Services**
- 800-777-TEST (8378)

## CB Test Report

**ACS - Atlanta, GA.**
- 770-831-8048

**ACS - Boca Raton, FL.**
- 561-961-5585

**ACS - Melbourne, FL.**
- 321-951-1710

**American Certification Body, Inc.**
- 703-847-4700

**Atlas Compliance & Engineering**
- 866-573-9742

**CertifiGroup Inc.**
- 800-422-1651

**CCHK Laboratories, Inc.**
- 800-500-4362

**Compatible Electronics, Inc.**
- 650-417-EMC1 (3621)

**Compliance & More, Inc.**
- 303-663-3396

**Compliance Management Group**
- 808-281-5985

**Compliance World Wide, Inc.**
- 603-887-3903

**Core Compliance Testing**
- 603-889-5545

**CSA Group**
- 866-463-1785

**CSIA, LLC**
- 503-489-8006

**Curtis-Straus (Bureau Veritas)**
- 877-277-8880

**DNB Engineering, Inc.**
- 714-870-7781

**Electro Magnetic Test, Inc.**
- 650-965-4000

**EMCplus LLC.**
- 303-663-3396

**G&M Compliance, Inc.**
- 714-628-1020

**G&M Compliance, Inc.**
- 714-628-1020

**Nemko USA - SouthEast**
- 813-662-4606

**Nemko USA - SouthWest**
- 813-662-4606

**Northwest EMC Inc. - Minnesota**
- 888-364-2378

**Northwest EMC Inc. - California**
- 888-364-2378

**Northwest EMC Inc. - Washington**
- 888-364-2378

**Northwest EMC, Inc. - Oregon**
- 888-364-2378

**NTS Fremont**
- 877-245-7800

**SGS Consumer Testing Services**
- 800-777-TEST (8378)

**UL LLC**
- 862-243-2329

## CE Marking

**ACS - Atlanta, GA.**
- 770-831-8048

**ACS - Boca Raton, FL.**
- 561-961-5585

**ACS - Melbourne, FL.**
- 321-951-1710

**American Certification Body, Inc.**
- 703-847-4700

**Atlas Compliance & Engineering**
- 866-573-9742

**CertifiGroup Inc.**
- 800-422-1651

**CCHK Laboratories, Inc.**
- 800-500-4362

**Compatible Electronics, Inc.**
- 650-417-EMC1 (3621)

**Compliance & More, Inc.**
- 303-663-3396

**Compliance Management Group**
- 808-281-5985

**Compliance World Wide, Inc.**
- 603-887-3903

**Core Compliance Testing**
- 603-889-5545

**CSA Group**
- 866-463-1785

**CSIA, LLC**
- 503-489-8006

**Curtis-Straus (Bureau Veritas)**
- 877-277-8880

**DNB Engineering, Inc.**
- 714-870-7781

**Electro Magnetic Test, Inc.**
- 650-965-4000

**EMCplus LLC.**
- 303-663-3396

**G&M Compliance, Inc.**
- 714-628-1020

**G&M Compliance, Inc.**
- 714-628-1020

**Nemko USA - SouthEast**
- 813-662-4606

**Nemko USA - SouthWest**
- 813-662-4606

**Northwest EMC Inc. - Minnesota**
- 888-364-2378

**Northwest EMC Inc. - California**
- 888-364-2378

**Northwest EMC Inc. - Washington**
- 888-364-2378

**Northwest EMC, Inc. - Oregon**
- 888-364-2378

**NTS Fremont**
- 877-245-7800

**SGS Consumer Testing Services**
- 800-777-TEST (8378)
### Product/Service Directory

**CE Marking continued**

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics Test Centre - Airdie</td>
<td>403-912-0037</td>
</tr>
<tr>
<td>Elite Electronic Engineering - 800-ELITE-11</td>
<td>877-277-1106</td>
</tr>
<tr>
<td>EMC Integrity Inc.</td>
<td>888-423-6275</td>
</tr>
<tr>
<td>EMC Testing Laboratories, Inc.</td>
<td>877-475-8819</td>
</tr>
<tr>
<td>EMCC DR. RASEK</td>
<td>49-9194-9016</td>
</tr>
<tr>
<td>EMCCplus LLC</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Ergonomics, Inc.</td>
<td>800-862-0102</td>
</tr>
<tr>
<td>F2 Labs.</td>
<td>877-405-1580</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Garwood Laboratories Inc. SC</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>Green Mtn. Electromagnetics</td>
<td>802-388-3390</td>
</tr>
<tr>
<td>H.B. Compliance Solutions</td>
<td>480-684-2969</td>
</tr>
<tr>
<td>HCT Co., Ltd.</td>
<td>82-31-645-6454</td>
</tr>
<tr>
<td>International Certification Services, Inc.</td>
<td>888-286-6888</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>Keystone Compliance</td>
<td>724-657-9940</td>
</tr>
<tr>
<td>LabTest Certification Inc.</td>
<td>604-247-0444</td>
</tr>
<tr>
<td>Lewis Bass International</td>
<td>408-942-8000</td>
</tr>
<tr>
<td>LS Research</td>
<td>262-375-4400</td>
</tr>
<tr>
<td>MET Laboratories</td>
<td>410-354-3300</td>
</tr>
<tr>
<td>Montrose Compliance Services</td>
<td>408-247-5715</td>
</tr>
<tr>
<td>NCEE Labs.</td>
<td>888-567-6860</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Minnesota</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - California</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Washington</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC, Inc. - Oregon</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>NTS Fremont</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Fullerton</td>
<td>800-677-2687</td>
</tr>
<tr>
<td>NTS Northeast</td>
<td>800-723-2687</td>
</tr>
<tr>
<td>NTS Rockford</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>O'Brien Compliance Management</td>
<td>978-970-0525</td>
</tr>
<tr>
<td>Product Safety Consulting</td>
<td>877-804-3066</td>
</tr>
<tr>
<td>Professional Testing</td>
<td>800-695-1077</td>
</tr>
<tr>
<td>Pulver Laboratories Inc.</td>
<td>800-635-3050</td>
</tr>
<tr>
<td>Radiometrics Midwest Corp.</td>
<td>815-293-0772</td>
</tr>
<tr>
<td>Retif Testing Laboratories</td>
<td>631-737-1500 x111</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
<tr>
<td>SIEMIC</td>
<td>408-526-1188</td>
</tr>
<tr>
<td>Test Site Services Inc.</td>
<td>508-962-1662</td>
</tr>
<tr>
<td>Thermo Fisher Scientific</td>
<td>978-275-0800 x2302</td>
</tr>
</tbody>
</table>

---

**TÜV Rheinland of North America**

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>TÜV SÜD America Inc.</td>
<td>800-888-0123</td>
</tr>
<tr>
<td>UL LLC</td>
<td></td>
</tr>
</tbody>
</table>

**China Compulsory Certification (CCC)**

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>Compliance &amp; More, Inc.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>CSA Group</td>
<td>866-463-1785</td>
</tr>
<tr>
<td>CSIA, LLC</td>
<td>503-489-8006</td>
</tr>
<tr>
<td>D.L.S. Electronic Systems, Inc.</td>
<td>847-537-6400</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-965-4000</td>
</tr>
<tr>
<td>EMC Integrity Inc.</td>
<td>888-423-6275</td>
</tr>
<tr>
<td>EMCCplus LLC</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Go Global Compliance Inc.</td>
<td>408-416-3772</td>
</tr>
<tr>
<td>HCT Co., Ltd.</td>
<td>82-31-645-6454</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>RTF Compliance</td>
<td>949-813-6095</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
<tr>
<td>SIEMIC</td>
<td>408-526-1188</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>1-TUV-RHEINLAND</td>
</tr>
<tr>
<td>TÜV SÜD America Inc.</td>
<td>800-888-0123</td>
</tr>
<tr>
<td>UL LLC</td>
<td></td>
</tr>
</tbody>
</table>

**Electrical Safety Testing**

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS - Atlanta, GA</td>
<td>770-831-8048</td>
</tr>
<tr>
<td>ACS - Boca Raton, FL</td>
<td>561-961-5585</td>
</tr>
<tr>
<td>ACS - Melbourne, FL</td>
<td>321-951-1710</td>
</tr>
<tr>
<td>American Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>CASE Forensics</td>
<td>877-736-1106</td>
</tr>
<tr>
<td>CertifiGroup Inc.</td>
<td>800-422-1651</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>Core Compliance Testing</td>
<td>603 889-5545</td>
</tr>
<tr>
<td>CSA Group</td>
<td>866-463-1785</td>
</tr>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>D.L.S. Electronic Systems, Inc.</td>
<td>847-537-6400</td>
</tr>
<tr>
<td>DNB Engineering, Inc.</td>
<td>714-870-7781</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-965-4000</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>EMCC DR. RASEK</td>
<td>49-9194-9016</td>
</tr>
<tr>
<td>eti Conformity Services</td>
<td>877-468-6384</td>
</tr>
<tr>
<td>F2 Labs.</td>
<td>877-405-1580</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>Green Mtn. Electromagnetics</td>
<td>802-388-3390</td>
</tr>
<tr>
<td>HCT Co., Ltd.</td>
<td>82-31-645-6454</td>
</tr>
<tr>
<td>High Voltage Maintenance</td>
<td>866-486-8326</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>LabTest Certification Inc.</td>
<td>604-247-0444</td>
</tr>
<tr>
<td>Lewis Bass International</td>
<td>408-942-8000</td>
</tr>
<tr>
<td>MET Laboratories</td>
<td>410-354-3300</td>
</tr>
<tr>
<td>NCEE Labs.</td>
<td>888-567-6860</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>NTS Fremont</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Fullerton</td>
<td>800-677-2687</td>
</tr>
<tr>
<td>NTS Tinton Falls</td>
<td>732-936-0800</td>
</tr>
<tr>
<td>Product Safety Consulting</td>
<td>877-804-3066</td>
</tr>
<tr>
<td>Professional Testing</td>
<td>800-695-1077</td>
</tr>
<tr>
<td>Pulver Laboratories Inc.</td>
<td>800-635-3050</td>
</tr>
<tr>
<td>Retif Testing Laboratories</td>
<td>631-737-1500 x111</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
<tr>
<td>Test Site Services Inc.</td>
<td>508-962-1662</td>
</tr>
<tr>
<td>TestingPartners.com</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>Trace Laboratories, Inc.</td>
<td>410-584-9099</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>1-TUV-RHEINLAND</td>
</tr>
<tr>
<td>TÜV SÜD America Inc.</td>
<td>800-888-0123</td>
</tr>
<tr>
<td>UL LLC</td>
<td></td>
</tr>
<tr>
<td>Ultratech EMC Lab.</td>
<td>905-829-1570</td>
</tr>
</tbody>
</table>

**EMC Testing**

<table>
<thead>
<tr>
<th>Company</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS - Atlanta, GA</td>
<td>770-831-8048</td>
</tr>
<tr>
<td>ACS - Boca Raton, FL</td>
<td>561-961-5585</td>
</tr>
<tr>
<td>ACS - Melbourne, FL</td>
<td>321-951-1710</td>
</tr>
<tr>
<td>Alion Science and Technology</td>
<td>610-825-1960</td>
</tr>
<tr>
<td>Amber Precision Instruments, Inc.</td>
<td>408-752-0199 x102</td>
</tr>
<tr>
<td>American Certification Body, Inc.</td>
<td>703-847-4700</td>
</tr>
<tr>
<td>Americor Electronics Ltd.</td>
<td>800-830-5337</td>
</tr>
<tr>
<td>Company Name</td>
<td>Phone Number</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Atlas Compliance &amp; Engineering</td>
<td>866-573-9742</td>
</tr>
<tr>
<td>CKC Laboratories, Inc.</td>
<td>800-500-4362</td>
</tr>
<tr>
<td>Compatible Electronics, Inc.</td>
<td>650-417-EIMC1 (3621)</td>
</tr>
<tr>
<td>Compliance &amp; More, Inc.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td><strong>Compliance Worldwide, Inc.</strong></td>
<td>603-887-3903</td>
</tr>
<tr>
<td>Core Compliance Testing</td>
<td>603 889-5545</td>
</tr>
<tr>
<td>CSIA, LLC</td>
<td>503-489-8006</td>
</tr>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>D.L.S. Electronic Systems, Inc.</td>
<td>847-537-6400</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-983-6012</td>
</tr>
<tr>
<td><strong>Electronics Test Centre</strong></td>
<td>613-599-6800</td>
</tr>
<tr>
<td>Electro Magnetic Test Centre - Airdrie</td>
<td>403-912-0037</td>
</tr>
<tr>
<td>Elite Electronic Engineering . . . . . . . . . .</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>EMC Compliance</td>
<td>256-650-5261</td>
</tr>
<tr>
<td>EMC Integrity Inc.</td>
<td>888-423-6275</td>
</tr>
<tr>
<td>EMC Testing Laboratories, Inc.</td>
<td>770-475-8819</td>
</tr>
<tr>
<td>EMCC DR. RASEK</td>
<td>49-9194-9016</td>
</tr>
<tr>
<td>EMCplus LLC</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>eti Conformity Services</td>
<td>877-468-6384</td>
</tr>
<tr>
<td>F2 Labs.</td>
<td>877-405-1580</td>
</tr>
<tr>
<td>Flextronics</td>
<td>613-895-2053</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Garwood Laboratories SC</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>General Dynamics C4 Systems</td>
<td>480-441-5321</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>Green Mtn. Electromagnetics</td>
<td>802-388-3390</td>
</tr>
<tr>
<td>H.B. Compliance Solutions.</td>
<td>480-684-2969</td>
</tr>
<tr>
<td>HCT Co., Ltd</td>
<td>82-31-645-6454</td>
</tr>
<tr>
<td>International Certification Services, Inc.</td>
<td>888-286-6888</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>Jacobs Technology</td>
<td>248-676-1101</td>
</tr>
<tr>
<td>Keystone Compliance</td>
<td>724-657-9940</td>
</tr>
<tr>
<td>L-3 Communications Cincinnati</td>
<td>800-543-8220</td>
</tr>
<tr>
<td>LabTest Certification Inc.</td>
<td>604-247-0444</td>
</tr>
<tr>
<td>LCR Electronics, Inc.</td>
<td>800-527-4362</td>
</tr>
<tr>
<td>Lewis Bass International</td>
<td>408-942-8000</td>
</tr>
<tr>
<td>LS Research</td>
<td>262-375-4400</td>
</tr>
<tr>
<td>MET Laboratories</td>
<td>410-354-3300</td>
</tr>
<tr>
<td>Microwave Vision Group</td>
<td>678-797-9172</td>
</tr>
<tr>
<td>Montrose Compliance Services</td>
<td>408-247-5715</td>
</tr>
<tr>
<td>NCEE Labs.</td>
<td>888-567-6860</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>NexTek, Inc.</td>
<td>978-486-0582</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Minnesota</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - California</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Washington</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Oregon</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>NTS Corporate HQ</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>NTS Europe GmbH</td>
<td>49 89 787475 160</td>
</tr>
<tr>
<td>NTS Fremont</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Fullerton</td>
<td>800-677-2687</td>
</tr>
<tr>
<td>NTS Newark</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Northeast</td>
<td>800-723-2687</td>
</tr>
<tr>
<td>NTS Plano</td>
<td>877-717-2687</td>
</tr>
<tr>
<td>NTS Rockford</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>NTS Temple</td>
<td>480-966-5517</td>
</tr>
<tr>
<td>NTS Tinton Falls</td>
<td>732-936-0800</td>
</tr>
<tr>
<td><strong>Professional Testing</strong></td>
<td>800-695-1077</td>
</tr>
<tr>
<td>NTS - Corporate HQ</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>NTS Europe GmbH</td>
<td>49 89 787475 160</td>
</tr>
<tr>
<td>NTS Fremont</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Fullerton</td>
<td>800-677-2687</td>
</tr>
<tr>
<td>NTS Newark</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Northeast</td>
<td>800-723-2687</td>
</tr>
<tr>
<td>NTS Plano</td>
<td>877-717-2687</td>
</tr>
<tr>
<td>NTS Rockford</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>NTS Temple</td>
<td>480-966-5517</td>
</tr>
<tr>
<td>NTS Tinton Falls</td>
<td>732-936-0800</td>
</tr>
<tr>
<td><strong>Professional Testing</strong></td>
<td>800-695-1077</td>
</tr>
<tr>
<td><strong>Professional Testing</strong></td>
<td>800-695-1077</td>
</tr>
<tr>
<td><strong>Professional Testing</strong></td>
<td>800-695-1077</td>
</tr>
<tr>
<td><strong>Professional Testing</strong></td>
<td>800-695-1077</td>
</tr>
<tr>
<td><strong>Professional Testing</strong></td>
<td>800-695-1077</td>
</tr>
<tr>
<td><strong>Energy Efficiency Testing</strong></td>
<td></td>
</tr>
<tr>
<td>ACS - Atlanta, GA.</td>
<td>770-831-8048</td>
</tr>
<tr>
<td>ACS - Boca Raton, FL.</td>
<td>561-961-5585</td>
</tr>
<tr>
<td>ACS - Melbourne, FL.</td>
<td>321-951-1710</td>
</tr>
<tr>
<td>CSA Group</td>
<td>866-463-1785</td>
</tr>
<tr>
<td>CSIA, LLC.</td>
<td>503-489-8006</td>
</tr>
<tr>
<td>G&amp;M Compliance, Inc.</td>
<td>714-628-1020</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>MET Laboratories</td>
<td>410-354-3300</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>Pulver Laboratories Inc.</td>
<td>800-635-3050</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
<tr>
<td><strong>TÜV Rheinland of North America</strong></td>
<td></td>
</tr>
<tr>
<td><strong>TÜV SÜD America Inc.</strong></td>
<td>800-888-0123</td>
</tr>
<tr>
<td>UL LLC</td>
<td></td>
</tr>
<tr>
<td>Ultratech EMC Lab</td>
<td>905-829-1570</td>
</tr>
<tr>
<td>Yazaki Testing Center</td>
<td>734-983-6012</td>
</tr>
<tr>
<td><strong>Environmental Simulation Testing</strong></td>
<td></td>
</tr>
<tr>
<td>ACS - Atlanta, GA.</td>
<td>770-831-8048</td>
</tr>
<tr>
<td>ACS - Boca Raton, FL.</td>
<td>561-961-5585</td>
</tr>
<tr>
<td>ACS - Melbourne, FL.</td>
<td>321-951-1710</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>Core Compliance Testing</td>
<td>603 889-5545</td>
</tr>
<tr>
<td>CSZ Testing Services</td>
<td>513-793-7774</td>
</tr>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>Dayton T. Brown, Inc.</td>
<td>800-TEST-456</td>
</tr>
<tr>
<td>DNB Engineering, Inc.</td>
<td>714-870-7781</td>
</tr>
<tr>
<td>Electronics Test Centre - Airdrie</td>
<td>808-777-TEST (8378)</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
</tbody>
</table>
### Environmental Simulation Testing

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMCC DR. RASEK</td>
<td>49-9194-9016</td>
</tr>
<tr>
<td>Flextronics</td>
<td>613-895-2053</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Garwood Laboratories SC</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>Keystone Compliance</td>
<td>724-657-9940</td>
</tr>
<tr>
<td>L-3 Communications Cincinnati</td>
<td>800-543-8220</td>
</tr>
<tr>
<td>MET Laboratories</td>
<td>410-354-3300</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>NTS Europe GmbH</td>
<td>49 89 787475 160</td>
</tr>
<tr>
<td>NTS Fullerton</td>
<td>800-677-2687</td>
</tr>
<tr>
<td>NTS LAX</td>
<td>800-559-3202</td>
</tr>
<tr>
<td>NTS Northeast</td>
<td>800-723-2687</td>
</tr>
<tr>
<td>NTS Plano</td>
<td>877-717-2687</td>
</tr>
<tr>
<td>NTS Santa Clarita</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>NTS Tempe</td>
<td>800-962-1662</td>
</tr>
<tr>
<td>NTS Tinton Falls</td>
<td>732-936-0800</td>
</tr>
<tr>
<td>Professional Testing</td>
<td>800-695-1077</td>
</tr>
<tr>
<td>Qualtest Inc.</td>
<td>407-313-4230</td>
</tr>
<tr>
<td>Retilf Testing Laboratories</td>
<td>631-737-1500 x111</td>
</tr>
<tr>
<td>Trace Laboratories, Inc.</td>
<td>410-584-9099</td>
</tr>
<tr>
<td>TÜV SÜD America Inc.</td>
<td>800-888-0123</td>
</tr>
<tr>
<td>Testing Partn ers.com</td>
<td>862-243-2329</td>
</tr>
</tbody>
</table>

### EuP Directive Compliance

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-965-4000</td>
</tr>
<tr>
<td>EMCplus LLC.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>1-TUV-RHEINLAND</td>
</tr>
</tbody>
</table>

### GS Mark Certification

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compliance &amp; More, Inc</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-965-4000</td>
</tr>
<tr>
<td>EMCplus LLC.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>1-TUV-RHEINLAND</td>
</tr>
</tbody>
</table>

### Halogen Testing

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Safety Consulting</td>
<td>877-804-3066</td>
</tr>
<tr>
<td>RTF Compliance</td>
<td>949-813-6095</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
</tbody>
</table>

### Lithium-Ion Battery Testing

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascade TEK - Oregon</td>
<td>888-835-9250</td>
</tr>
<tr>
<td>Cascade TEK - Colorado</td>
<td>888-835-9250</td>
</tr>
<tr>
<td>CASE Forensics</td>
<td>877-736-1106</td>
</tr>
<tr>
<td>Dayton T. Brown, Inc.</td>
<td>800-TEST-456</td>
</tr>
<tr>
<td>DNB Engineering, Inc.</td>
<td>714-870-7781</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Garwood Laboratories Inc. SC</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Intertek</td>
<td>800-WORLDLAB</td>
</tr>
<tr>
<td>Nemko USA - SouthEast</td>
<td>813-662-4606</td>
</tr>
</tbody>
</table>

### Marine Electronics Testing

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascade TEK - Oregon</td>
<td>888-835-9250</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>Dayton T. Brown, Inc.</td>
<td>800-TEST-456</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-965-4000</td>
</tr>
<tr>
<td>Flextronics.</td>
<td>613-895-2053</td>
</tr>
</tbody>
</table>

### Network Equipment Building System (NEBS) Testing

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascade TEK - Oregon</td>
<td>888-835-9250</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>Curtis-Straus (Bureau Veritas)</td>
<td>877-277-8880</td>
</tr>
<tr>
<td>Dayton T. Brown, Inc.</td>
<td>800-TEST-456</td>
</tr>
<tr>
<td>Electro Magnetic Test, Inc.</td>
<td>650-965-4000</td>
</tr>
<tr>
<td>Flextronics.</td>
<td>613-895-2053</td>
</tr>
</tbody>
</table>
# Product/Service Directory

## Testing Services

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-3 Communications Cincinnati</td>
<td>800-543-8220</td>
</tr>
<tr>
<td>LCR Electronics, Inc.</td>
<td>800-527-4362</td>
</tr>
<tr>
<td>Lewis Bass International</td>
<td>408-942-8000</td>
</tr>
<tr>
<td>LS Research</td>
<td>262-375-4400</td>
</tr>
<tr>
<td>Montrose Compliance Services</td>
<td>408-247-5715</td>
</tr>
<tr>
<td>NCEE Labs</td>
<td>888-567-6860</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Minnesota</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - California</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Washington</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC, Inc. - Oregon</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>NTS Fremont</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Plano</td>
<td>877-717-2687</td>
</tr>
<tr>
<td>NTS Rockford</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>O'Brien Compliance Management</td>
<td>978-970-0525</td>
</tr>
<tr>
<td>Parker Hannifin, Chromics Div</td>
<td>781-935-4850</td>
</tr>
<tr>
<td>Product Safety Consulting</td>
<td>877-804-3066</td>
</tr>
<tr>
<td>Professional Testing</td>
<td>800-695-1077</td>
</tr>
<tr>
<td>Pulver Laboratories Inc.</td>
<td>800-635-0350</td>
</tr>
<tr>
<td>Qualtest Inc.</td>
<td>407-313-4230</td>
</tr>
<tr>
<td>Radiometrics Midwest Corp.</td>
<td>815-293-0772</td>
</tr>
<tr>
<td>Retlif Testing Laboratories</td>
<td>631-737-1500 x111</td>
</tr>
<tr>
<td>RF Exposure Lab</td>
<td>760-471-2100</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
<tr>
<td>Stephen Halperin &amp; Associates</td>
<td>630-238-8883</td>
</tr>
<tr>
<td>Test Site Services Inc.</td>
<td>508-962-1662</td>
</tr>
<tr>
<td>TestingPartners.com</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>Trace Laboratories, Inc.</td>
<td>410-584-9099</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>1-TUV-RHEINLAND</td>
</tr>
<tr>
<td>UL Verification Services</td>
<td>.86 20 28667188</td>
</tr>
<tr>
<td>Ultraceh EM Lab.</td>
<td>905-829-1570</td>
</tr>
<tr>
<td>Wyatt Technical Services LLC</td>
<td>877-443-9275</td>
</tr>
</tbody>
</table>

## Product Safety Testing

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS - Atlanta, GA</td>
<td>770-831-8048</td>
</tr>
<tr>
<td>ACS - Boca Raton, FL</td>
<td>561-961-5585</td>
</tr>
<tr>
<td>ACS - Melbourne, FL</td>
<td>321-951-1710</td>
</tr>
<tr>
<td>Atlas Compliance &amp; Engineering</td>
<td>866-573-9742</td>
</tr>
<tr>
<td>Cascade TEK - Colorado</td>
<td>888-835-9250</td>
</tr>
<tr>
<td>CASE Forensics</td>
<td>877-736-1106</td>
</tr>
<tr>
<td>CertifGroup Inc</td>
<td>800-422-1651</td>
</tr>
<tr>
<td>CKC Laboratories, Inc.</td>
<td>800-500-4362</td>
</tr>
<tr>
<td>Compatible Electronics, Inc.</td>
<td>650-417-EMC1 (3621)</td>
</tr>
<tr>
<td>Compliance &amp; More, Inc.</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Compliance Management Group</td>
<td>508-281-5985</td>
</tr>
<tr>
<td>Elite Electronic Engineering</td>
<td>800-ELITE-11</td>
</tr>
<tr>
<td>EMC Integrity Inc.</td>
<td>888-423-6275</td>
</tr>
<tr>
<td>EMCC DR. RASEK</td>
<td>49-9194-9016</td>
</tr>
<tr>
<td>EMCCplus LLC</td>
<td>303-663-3396</td>
</tr>
<tr>
<td>Ergonomics, Inc.</td>
<td>800-862-0102</td>
</tr>
<tr>
<td>eti Conformity Services</td>
<td>877-468-6384</td>
</tr>
<tr>
<td>F2 Labs.</td>
<td>877-405-1580</td>
</tr>
<tr>
<td>Flextronics</td>
<td>613-895-2053</td>
</tr>
<tr>
<td>Garwood Laboratories</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Garwood Laboratories Inc. SC</td>
<td>888-427-4111</td>
</tr>
<tr>
<td>Global EMC Inc.</td>
<td>888-441-7337</td>
</tr>
<tr>
<td>H.B. Compliance Solutions</td>
<td>480-684-2969</td>
</tr>
<tr>
<td>International Certification Services, Inc.</td>
<td>888-286-8888</td>
</tr>
<tr>
<td>Keystone Compliance</td>
<td>724-657-9940</td>
</tr>
<tr>
<td>L-3 Communications Cincinnati</td>
<td>800-543-8220</td>
</tr>
<tr>
<td>LCR Electronics, Inc.</td>
<td>800-527-4362</td>
</tr>
<tr>
<td>Lewis Bass International</td>
<td>408-942-8000</td>
</tr>
<tr>
<td>LS Research</td>
<td>262-375-4400</td>
</tr>
<tr>
<td>Montrose Compliance Services</td>
<td>408-247-5715</td>
</tr>
<tr>
<td>NCEE Labs</td>
<td>888-567-6860</td>
</tr>
<tr>
<td>Nemko Canada</td>
<td>613-737-9680</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Minnesota</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - California</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC Inc. - Washington</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>Northwest EMC, Inc. - Oregon</td>
<td>888-364-2378</td>
</tr>
<tr>
<td>NTS Fremont</td>
<td>877-245-7800</td>
</tr>
<tr>
<td>NTS Plano</td>
<td>877-717-2687</td>
</tr>
<tr>
<td>NTS Rockford</td>
<td>800-270-2516</td>
</tr>
<tr>
<td>O’Brien Compliance Management</td>
<td>978-970-0525</td>
</tr>
<tr>
<td>Parker Hannifin, Chromics Div</td>
<td>781-935-4850</td>
</tr>
<tr>
<td>Product Safety Consulting</td>
<td>877-804-3066</td>
</tr>
<tr>
<td>Professional Testing</td>
<td>800-695-1077</td>
</tr>
<tr>
<td>Pulver Laboratories Inc.</td>
<td>800-635-0350</td>
</tr>
<tr>
<td>Qualtest Inc.</td>
<td>407-313-4230</td>
</tr>
<tr>
<td>Radiometrics Midwest Corp.</td>
<td>815-293-0772</td>
</tr>
<tr>
<td>Retlif Testing Laboratories</td>
<td>631-737-1500 x111</td>
</tr>
<tr>
<td>RF Exposure Lab</td>
<td>760-471-2100</td>
</tr>
<tr>
<td>SGS Consumer Testing Services</td>
<td>800-777-TEST (8378)</td>
</tr>
<tr>
<td>Stephen Halperin &amp; Associates</td>
<td>630-238-8883</td>
</tr>
<tr>
<td>Test Site Services Inc.</td>
<td>508-962-1662</td>
</tr>
<tr>
<td>TestingPartners.com</td>
<td>862-243-2329</td>
</tr>
<tr>
<td>Trace Laboratories, Inc.</td>
<td>410-584-9099</td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>1-TUV-RHEINLAND</td>
</tr>
<tr>
<td>UL Verification Services</td>
<td>.86 20 28667188</td>
</tr>
<tr>
<td>Ultraceh EM Lab.</td>
<td>905-829-1570</td>
</tr>
<tr>
<td>Wyatt Technical Services LLC</td>
<td>877-443-9275</td>
</tr>
</tbody>
</table>

## Additional Resources

- Curtis-Straus (Bureau Veritas) | 877-277-8880 |
- D.L.S. Electronic Systems, Inc. | 847-537-6400 |
- Dayton T. Brown, Inc. | 800-TEST-456 |
- Electro Magnetic Test, Inc. | 650-965-4000 |
- Electronics Test Centre - Airdrie | 403-912-0037 |
- Elite Electronic Engineering | 800-ELITE-11 |
- EMC Integrity Inc. | 888-423-6275 |
- EMCC DR. RASEK | 49-9194-9016 |
- EMCCplus LLC | 303-663-3396 |
- Ergonomics, Inc. | 800-862-0102 |
- eti Conformity Services | 877-468-6384 |
- F2 Labs. | 877-405-1580 |
- Flextronics | 613-895-2053 |
- Garwood Laboratories | 888-427-4111 |
- Garwood Laboratories Inc. SC | 888-427-4111 |
- Global EMC Inc. | 888-441-7337 |
- Green Mtn. Electromagnetics | 802-388-3390 |
- H.B. Compliance Solutions | 480-684-2969 |
- HCT Co., Ltd. | 82-31-645-6454 |
- High Voltage Maintenance | 866-486-8326 |
- Intertek | 800-WORLDLAB

---

**2013 Annual Guide In Compliance**
Product/Safety/Service Directory

Product/Safety/Service Directory

Product Safety Testing continued

NTS Newark 877-245-7800
NTS Northeast 800-723-2687
NTS Pittsfield 800-270-2516
NTS Plano 877-717-2687
NTS Tempe 480-966-5517
NTS Tinton Falls 732-936-0800
O’Brien Compliance Management 978-970-0525
Product Safety Consulting 877-804-3066
Professional Testing 800-695-1077
Pulver Laboratories Inc. 800-635-3050
SGS Consumer Testing Services 800-777-TEST (8378)
SIEMIC 408-526-1188
Test Site Services Inc. 508-962-1662
TestingPartners.com 862-243-2329
Trace Laboratories, Inc. 410-584-9099
TÜV Rheinland of North America 1-TUV-RHEINLAND
TÜV SÜD America Inc. 800-888-0123
UL LLC

Radio Performance & Functionality Testing

ACS - Atlanta, GA. 770-831-8048
ACS - Boca Raton, FL 561-961-5585
ACS - Melbourne, FL 321-951-1710
Compliance Worldwide, Inc. 603-887-3903
Curtis-Straus (Bureau Veritas) 877-277-8880
D.L.S. Electronic Systems, Inc. 847-537-6400
Dayton T. Brown, Inc. 800-TEST-456
Electro Magnetic Test, Inc. 650-965-4000
Elite Electronic Engineering. 800-ELITE-11
Flextronics 613-895-2053
Garwood Laboratories 888-427-4111
Garwood Laboratories Inc. SC 888-427-4111
Green Mtn. Electromagnetics 802-388-3390
H.B. Compliance Solutions 480-684-2969
Intertek 800-WORLDLAB
Keystone Compliance 724-657-9940
LS Research 262-375-4400
Microwave Vision Group 678-797-9172
Nemko Canada - SouthEast 813-662-4606
NTS Fremont 877-245-7800
Professional Testing 800-695-1077
RF Exposure Lab. 760-471-2100
SGS Consumer Testing Services 800-777-TEST (8378)
SIEMIC 408-526-1188
Ultratech EMC Lab. 905-829-1570
RoHS Directive Compliance

Alberi EcoTech 702-677-6923
G&M Compliance, Inc. 714-628-1020
Garwood Laboratories 888-427-4111
Intertek 800-WORLDLAB
Nemko Canada 613-737-9680
Product Safety Consulting 877-804-3066
Professional Testing 800-695-1077
Pulver Laboratories Inc. 800-635-3050
RTF Compliance 949-813-6095
SGS Consumer Testing Services 800-777-TEST (8378)
TestingPartners.com 862-243-2329
Trace Laboratories, Inc. 410-584-9099
TÜV Rheinland of North America 1-TUV-RHEINLAND
UL LLC

Standards Council of Canada Certification Body

ACS - Atlanta, GA. 770-831-8048
ACS - Boca Raton, FL 561-961-5585
ACS - Melbourne, FL 321-951-1710
Compliance Management Group 508-281-5985
CSA Group 866-463-1785
Curtis-Straus (Bureau Veritas) 877-277-8880
Electronics Test Centre 613-599-6800
Intertek 800-WORLDLAB
LabTest Certification Inc. 604-247-0444
MET Laboratories 410-354-3300
Nemko USA - SouthEast 813-662-4606
Northwest EMC Inc. - Minnesota 888-364-2378
Northwest EMC Inc. - California 888-364-2378
Northwest EMC Inc. - Oregon 888-364-2378
NTS - Corporate HQ 800-270-2516
NTS Fremont 888-270-7800
NTS Fremont 800-723-2687
Professional Testing 800-695-1077
Retlif Testing Laboratories 631-737-1500 x111
SGS Consumer Testing Services 800-777-TEST (8378)
SIEMIC 408-526-1188
TÜV Rheinland of North America 1-TUV-RHEINLAND
TÜV SÜD America Inc. 800-888-0123
UL LLC

Telecommunication Certification Approval

ACS - Atlanta, GA. 770-831-8048
ACS - Boca Raton, FL 561-961-5585
ACS - Melbourne, FL 321-951-1710
Compatible Electronics, Inc. 650-417-EMC1 (3621)
CSIA, LLC 503-489-8006
Curtis-Straus (Bureau Veritas) 877-277-8880
D.L.S. Electronic Systems, Inc. 847-537-6400
DNB Engineering, Inc. 714-870-7781
Electro Magnetic Test, Inc. 650-965-4000
Elite Electronic Engineering 800-ELITE-11
G&M Compliance, Inc. 714-628-1020
Garwood Laboratories 888-427-4111
Garwood Laboratories Inc. SC 888-427-4111
Go Global Compliance Inc. 408-416-3772
H.B. Compliance Solutions 480-684-2969
Intertek 800-WORLDLAB
MET Laboratories 410-354-3300
Microwave Vision Group 678-797-9172
Nemko Canada 613-737-9680
Nemko USA - SouthEast 813-662-4606
Northwest EMC Inc. - Minnesota 888-364-2378
Northwest EMC Inc. - California 888-364-2378
Northwest EMC Inc. - Oregon 888-364-2378
NTS - Corporate HQ 800-270-2516
NTS Fremont 888-270-7800
NTS Fremont 800-723-2687
Professional Testing 800-695-1077
Retlif Testing Laboratories 631-737-1500 x111
SGS Consumer Testing Services 800-777-TEST (8378)
SIEMIC 408-526-1188
TÜV Rheinland of North America 1-TUV-RHEINLAND
TÜV SÜD America Inc. 800-888-0123
UL LLC

Ultratech EMC Lab. 905-829-1570
A.H. Systems manufactures a complete line of affordable, reliable, individually calibrated EMC Test Antennas, Preamplifiers, Current Probes and Low-Loss, High-Frequency Cables that satisfy FCC, MIL-STD, VDE, IEC and SAE testing standards. We also provide tripods and accessories that complement other EMC testing equipment used to complete your testing requirements.

We provide rental programs for our equipment and offer recalibration services for Antennas, Preamplifiers, Current Probes and Cables, including other manufacturers worldwide.

A.H. Systems provides next-day, on-time delivery for a fast turn around schedule to help minimize any down time the customer may be experiencing during testing. Manufacturing high quality products at competitive prices with immediate shipment plus prompt technical support are goals we strive to achieve at A.H. Systems.

Abstraction Engineering Inc
6590 Felter Road
San Jose, CA 95132-3410 USA
tel: 408-258-3282
eugeneheil@abstractionengineering.com
http://www.abstractionengineering.com

Abstraction Engineering is professional engineering for safe machinery. We provide CE Mark (LVD-MD-EMC), SEMI S2 and tracer gas, RIA R15.0 robot, hazard labels and manuals, field labels (Silicon Valley, Oregon, Minnesota, and other locations), and factory safety including arc flash, LOTO, and QEW training. Give us a call today.

Abstraction Engineering has a reputation for competent fast service without the hassle. Checklists and reports are easy to read. Our certifications are accredited by many top tier companies in your industry. We have well known affiliations including Montrose Compliance (EMC), LaCroix-Davis (tracer gas), PSL (power testing), and others.

A2LA
5301 Buckeystown Pike, Suite 350
Fredrick, MD 21704 USA
tel: 301-644-3204
fax: 301-662-2974
info@A2LA.org
http://www.A2LA.org

A2LA is professional engineering for safe machinery. We provide CE Mark (LVD-MD-EMC), SEMI S2 and tracer gas, RIA R15.0 robot, hazard labels and manuals, field labels (Silicon Valley, Oregon, Minnesota, and other locations), and factory safety including arc flash, LOTO, and QEW training. Give us a call today.

A2LA has a reputation for competent fast service without the hassle. Checklists and reports are easy to read. Our certifications are accredited by many top tier companies in your industry. We have well known affiliations including Montrose Compliance (EMC), LaCroix-Davis (tracer gas), PSL (power testing), and others.

3Gmetalworx Inc.
90 Snow Boulevard
Concord, ON L4K 2C6 Canada
tel: 905-998-0223
toll free: 888-998-6892
sales@3gmetalworx.com
http://www.3gmetalworx.com

3Gmetalworx Inc. is professional engineering for safe machinery. We provide CE Mark (LVD-MD-EMC), SEMI S2 and tracer gas, RIA R15.0 robot, hazard labels and manuals, field labels (Silicon Valley, Oregon, Minnesota, and other locations), and factory safety including arc flash, LOTO, and QEW training. Give us a call today.

3Gmetalworx has a reputation for competent fast service without the hassle. Checklists and reports are easy to read. Our certifications are accredited by many top tier companies in your industry. We have well known affiliations including Montrose Compliance (EMC), LaCroix-Davis (tracer gas), PSL (power testing), and others.

A.H. Systems, Inc.
9710 Cozycroft Avenue
Chatsworth, CA 91311 USA
tel: 818-998-0223
toll free: 818-998-6892
sales@ahsystems.com
http://www.ahsystems.com

A.H. Systems manufactures a complete line of affordable, reliable, individually calibrated EMC Test Antennas, Preamplifiers, Current Probes and Low-Loss, High-Frequency Cables that satisfy FCC, MIL-STD, VDE, IEC and SAE testing standards. We also provide tripods and accessories that complement other EMC testing equipment used to complete your testing requirements.

We provide rental programs for our equipment and offer recalibration services for Antennas, Preamplifiers, Current Probes and Cables, including other manufacturers worldwide.

A.H. Systems provides next-day, on-time delivery for a fast turn around schedule to help minimize any down time the customer may be experiencing during testing. Manufacturing high quality products at competitive prices with immediate shipment plus prompt technical support are goals we strive to achieve at A.H. Systems.

3M Electronic Solutions
926 JR Industrial Drive
Sanford, NC 27332 USA
tel: 512-984-6747
3MStaticInfo@mmm.com
http://www.3MStatic.com

3M Electronic Solutions is professional engineering for safe machinery. We provide CE Mark (LVD-MD-EMC), SEMI S2 and tracer gas, RIA R15.0 robot, hazard labels and manuals, field labels (Silicon Valley, Oregon, Minnesota, and other locations), and factory safety including arc flash, LOTO, and QEW training. Give us a call today.

3M Electronic Solutions has a reputation for competent fast service without the hassle. Checklists and reports are easy to read. Our certifications are accredited by many top tier companies in your industry. We have well known affiliations including Montrose Compliance (EMC), LaCroix-Davis (tracer gas), PSL (power testing), and others.
Agilent Technologies
5301 Stevens Creek Boulevard
Santa Clara, CA 95051 USA
tel: 800-829-4444
toll free: 800-829-4444
fax: 800-829-4433
contact_us@agilent.com
http://www.agilent.com/find/emc
Agilent Technologies Inc. (NYSE: A) is the world’s premier measurement company and a technology leader in chemical analysis, life sciences, diagnostics, and electronic measurement.
Agilent offers EMI measurement solutions for compliance and precompliance testing. The CISPR-compliant MXE EMI receiver delivers outstanding measurement accuracy and sensitivity as well as extensive diagnostic tools. To ensure successful compliance testing, Agilent’s EMC measurement application can perform precompliance measurements with any X-Series signal analyzer. Through Agilent Solutions Partners, combine Agilent products with value-added integration, software, probes, antennas, chambers, and more for a complete solution that meets MIL-STD and commercial specifications.

Aeroflex
10200 W York Street
Wichita, KS 67215 USA
tel: 316-522-4981
toll free: 800-835-2352
fax: 316-524-2623
info-test@aeroflex.com
http://www.aeroflex.com

American Certification Body, Inc.
6731 Whittier Avenue, Suite C110
McLean, VA 22101 USA
tel: 703-847-4700
fax: 703-847-6888
sales@acbcert.com
http://www.acbcert.com

Amphenol Canada Corp.
605 Milner Avenue
Toronto, ON M1B 5X6 Canada
tel: 416-754-5688
fax: 416-292-0647
philb@amphenolcanada.com
http://www.amphenolcanada.com

André Consulting, Inc.
12812 NE 185th Court
Bothell, WA 98011-3121 USA
tel: 206-406-8371
fax: 425-485-8153
pat@andreconsulting.com
http://www.andreconsulting.com

ANDRO Computational Solutions
7902 Turin Road, Suite 2-1
Rome, NY 13440 USA
tel: 315-334-1163
fax: 315-334-1397
tcox@androcs.com
http://www.androcs.com

API Technologies Corp.
4705 S. Apopka Vineland Road, Suite 210
Orlando, FL 32819 USA
tel: 855-294-3800
sales@apitech.com
http://www.apitech.com

Applied EM Technology
Post Office Box 1437
Solomons, MD 20688-1437 USA
tel: 410-326-6728
info@AppliedEMtech.com
http://www.AppliedEMtech.com

ARC Technical Resources, Inc.
2006 Lockwood Drive
San Jose, CA 95132 USA
tel: 408-263-6486
info@arctechnical.com
http://www.arctechnical.com

Agilent Technologies
5301 Stevens Creek Boulevard
Santa Clara, CA 95051 USA
tel: 800-829-4444
toll free: 800-829-4444
fax: 800-829-4433
contact_us@agilent.com
http://www.agilent.com/find/emc
Agilent Technologies Inc. (NYSE: A) is the world’s premier measurement company and a technology leader in chemical analysis, life sciences, diagnostics, and electronic measurement.
Agilent offers EMI measurement solutions for compliance and precompliance testing. The CISPR-compliant MXE EMI receiver delivers outstanding measurement accuracy and sensitivity as well as extensive diagnostic tools. To ensure successful compliance testing, Agilent’s EMC measurement application can perform precompliance measurements with any X-Series signal analyzer. Through Agilent Solutions Partners, combine Agilent products with value-added integration, software, probes, antennas, chambers, and more for a complete solution that meets MIL-STD and commercial specifications.

Aeroflex
10200 W York Street
Wichita, KS 67215 USA
tel: 316-522-4981
toll free: 800-835-2352
fax: 316-524-2623
info-test@aeroflex.com
http://www.aeroflex.com

American Certification Body, Inc.
6731 Whittier Avenue, Suite C110
McLean, VA 22101 USA
tel: 703-847-4700
fax: 703-847-6888
sales@acbcert.com
http://www.acbcert.com

Amphenol Canada Corp.
605 Milner Avenue
Toronto, ON M1B 5X6 Canada
tel: 416-754-5688
fax: 416-292-0647
philb@amphenolcanada.com
http://www.amphenolcanada.com

André Consulting, Inc.
12812 NE 185th Court
Bothell, WA 98011-3121 USA
tel: 206-406-8371
fax: 425-485-8153
pat@andreconsulting.com
http://www.andreconsulting.com

ANDRO Computational Solutions
7902 Turin Road, Suite 2-1
Rome, NY 13440 USA
tel: 315-334-1163
fax: 315-334-1397
tcox@androcs.com
http://www.androcs.com

API Technologies Corp.
4705 S. Apopka Vineland Road, Suite 210
Orlando, FL 32819 USA
tel: 855-294-3800
sales@apitech.com
http://www.apitech.com

Applied EM Technology
Post Office Box 1437
Solomons, MD 20688-1437 USA
tel: 410-326-6728
info@AppliedEMtech.com
http://www.AppliedEMtech.com

ARC Technical Resources, Inc.
2006 Lockwood Drive
San Jose, CA 95132 USA
tel: 408-263-6486
info@arctechnical.com
http://www.arctechnical.com
AR RF/Microwave Instrumentation
160 School House Road
Souderton, PA 18964 USA
tel: 215-723-8181
toll free: 888-933-8181
info@arworld.us
http://www.arworld.us
AR is your one source for
RF/Microwave amplifiers, amplifier
modules, complete EMC test systems,
EMI receivers and more.
The parent company consists of
AR RF/Microwave Instrumentation,
AR Modular RF, AR Receiver Systems
and AR Europe.
AR RF/Microwave Instrumentation –
Souderton, PA
• RF Power Amplifiers, 1 – 50,000
  watts, dc – 1 GHz
• Microwave Amplifiers, 1 – 10,000
  watts, 0.8 – 45 GHz
• Hybrid Power Modules, 1-6 & 4 – 18
  GHz and custom design
• RF Conducted Immunity Generators
• Radiated Immunity Test Systems
• EMC Test Software
• EMC and RF Test Accessories

 associated research, Inc.
13860 W. Laurel Drive
Lake Forest, IL 60045 USA
tel: 847-971-9743
toll free: 866-573-9742
fax: 408-971-9783
info@asresearch.com
http://www.asresearch.com

AR RF/Microwave Instrumentation

Atlas Compliance & Engineering
1792 Little Orchard Street
San Jose, CA 95125 USA
tel: 408-971-9743
toll free: 866-573-9742
fax: 408-971-9783
info@atalsce.com
http://www.atalsce.com
Atlas Compliance & Engineering,
located in San Jose, California, is an
accredited test lab which has been
in business since 1997. We specialize
in EMC testing for North America,
Europe, Japan, Korea and many other
markets. We also provide In Situ and
Product Safety testing. Our solutions
support your business during the
complete product development cycle,
from design to production, ensuring
consistent compliance, accelerating
market access. We are very
reasonable in our prices and we offer
many benefits as an engineering
focused laboratory. Scheduling
is quick and we work with you to
accommodate your needs. We are a
service organization and as such we
understand your need to have the
process of regulatory compliance to
be as smooth and quick as possible.

associated power Technologies
1142 S. Diamond Bar Boulevard #106
Diamond Bar, CA 91765 USA
tel: 909-860-1646
toll free: 877-322-7693
jimk@aspowertechnologies.com
http://www.aspowertechnologies.com

BMI Surplus
149 King Street
Hanover, MA 02339 USA
tel: 781-871-8868
toll free: 781-871-7412
sales@bmius.com
http://www.bmius.com

AR RF/Microwave Instrumentation

Arc Technologies, Inc.
11 Chestnut Street
Amesbury, MA 01913 USA
tel: 978-388-2993
fax: 978-388-6866
sales@arc-tech.com
http://www.arc-tech.com

Associated Power Technologies
1142 S. Diamond Bar Boulevard #106
Diamond Bar, CA 91765 USA
tel: 909-860-1646
toll free: 877-322-7693
jimk@aspowertechnologies.com
http://www.aspowertechnologies.com

Aum Electro Technology Pvt Ltd
D-22 Phase 2, MIDC Dombivli East
Thane, Maharashtra 421203 India
tel: 91 2512871365
contact@aumtech.in
http://www.aumtech.in

Avalon Equipment Corporation
2453 Cades Way, Building B
Vista, CA 92081 USA
tel: 760-536-0191
toll free: 888-542-8256
fax: 760-536-0184
smcilhon@avalontest.com
http://www.avalontestequipment.com

Audivo GmbH
Irrenloher Damm 17
Schwarzenfeld, D 92521 Germany
tel: 49-9435-5419-0
fax: 49-9435-5419-19
info@audiwo.com
http://www.audiwo.com

Barth Electronics, Inc.
1589 Foothill Drive
Boulder City, NV 89005 USA
tel: 702-293-1576
fax: 702-293-7024
beisales@barthelectronics.com
http://www.BarthElectronics.com

BestESD Technical Services
P.O. Box 5146
Santa Cruz, CA 95063 USA
tel: 831-824-4052
fax: 206-350-7458
vkraz@bestesd.com
http://www.bestesd.com

Bittele Electronics
250 Consumers Road, Suite 202
North York, Ontario M2J 4V6 Canada
tel: 416-800-7540
info@7pcb.com
http://www.bittele.com

BRADEN SHIELDING SYSTEMS
9260 Broken Arrow Expressway
Tulsa, OK 74145 USA
tel: 918-624-2886
info@bradenshielding.com
http://www.bradenshielding.com
Vendor Directory

Captor Corporation
5040 S. County Road
Tipp City, OH 45371 USA
tel: 937-667-8484
gail@captorcpr.com
http://www.captorcpr.com

Cascade TEK - Oregon
5245 NE Elam Young Parkway
Hillsboro, OR 97124 USA
tel: 503-648-1818
toll free: 888-835-9250
gail@captorcpr.com
http://www.cascadetek.com/product-testing-services

Cascade TEK - Colorado
150 Vista View Drive
Longmont, CO 80504 USA
tel: 720-340-7810
toll free: 888-835-9250
gail@captorcpr.com
http://www.cascadetek.com/product-testing-services

CASE Forensics
4636 N Williams Avenue
Portland, OR 97217 USA
tel: 503-736-1106
toll free: 877-736-1106
gail@captorcpr.com
http://www.cascadetek.com/product-testing-services

CertifiGroup Inc
901 Sheldon Drive
Cary, NC 27513 USA
tel: 800-422-1651
toll free: 800-422-1651
gail@captorcpr.com
http://www.certifigrou.com

Chroma Systems Solutions, Inc.
19772 Pauling
Foothill Ranch, CA 92610 USA
tel: 949-600-6400
gail@captorcpr.com
http://www.captorcpr.com

CITE, Inc.
11381 Interchange Circle South
Miramar, FL 33025 USA
tel: 954-430-6310
toll free: 800-248-3548
gail@captorcpr.com
http://www.cite.com

Compliance More, Inc
1076 Deer Clover Way
Castle Rock, CO 80108 USA
tel: 303-663-3396
gail@captorcpr.com
http://www.compliance-more.com

Compliance Management Group
202 Forest Street
Marlborough, MA 01752 USA
tel: 508-281-5985
gail@captorcpr.com
http://www.cmgroup.net

Compliance Worldwide, Inc.
357 Main Street
Sandown, NH 03873 USA
tel: 603-887-3903
gail@captorcpr.com
http://www.cmworldwide.com

Comply Tek, Inc.
13114 Lomas Verdes Drive
Poway, CA 92064 USA
tel: 858-674-6155
gail@captorcpr.com
http://www.complytek.com

Conec Corporation
343 Technology Drive
Garner, NC 27529 USA
tel: 919-460-8800
gail@captorcpr.com
http://www.conec.com

Corcom/Tyco Electronics
620 S. Butterfield Road
Mundelein, IL 60060 USA
tel: 847-573-6504
gail@captorcpr.com
http://www.corcom.com

Core Compliance Testing
79 River Road
Hudson, NH 03051 USA
tel: 603-889-5545
gail@captorcpr.com
http://www.corecomplianttesting.com
CST of America
492 Old Connecticut Path, Suite 500
Framingham, MA 01701 USA
tel: 508-665-4400
fax: 508-665-4401
events@ cst.com
http://www. cst.com
CST develops and markets high performance EM field simulation software. Its products allow you to characterize, design and optimize electromagnetic devices before going into the lab or measurement chamber. This can help save substantial costs especially for new or cutting edge products, reduce design risk, and improve overall performance and profitability. CST STUDIO SUITE® enables the fast and accurate electromagnetic simulation of high frequency devices and the analysis of emissions or susceptibility of electromagnetic systems (including cables) in the time and frequency domain. CST’s customers operate in industries as diverse as Telecommunications, Defense, Automotive, Electronics, and Medical Equipment.

CPI, Inc.
45 River Drive
Georgetown, ON L7G 2J4 Canada
tel: 905-877-0161
fax: 905-877-5327
tom.sertic@ cpii.com
http://www. cpii.com/emc

CQC Co LTD
Subislawa 23m/13
Gdansk, Pomorskie 80-180 Poland
tel: 48 509595919
dima@certificator.eu
http://www.certificator.eu

CSA Group
8501 E Pleasant Valley Road
Cleveland, OH 44131-5516 USA
tel: 216-524-4990
toll free: 866-463-1785
cert.sales@csagroup.org
http://csagroup.org

CSIA, LLC
61535 SW Highway 97, Suite 9635
Bend, OR 97702 USA
tel: 503-489-8006
gpeschka@csiasassoc.com
http://www.csiasassoc.com

CSZ Testing Services
11901 Mosteller Road
Cincinnati, OH 45241 USA
tel: 513-793-7774
fax: 513-793-7277
testing@ cszinc.com
http://www.csztesting.com

Cuming-Lehman Chambers, Inc.
5800 Cumberland Highway
Chambersburg, PA 17202 USA
tel: 717-263-4101
fax: 717-263-4102
sales@cuminglehman.com
http://www. cuminglehman.com

Curtis Industries
2400 S. 43rd Street
Milwaukee, WI 53219 USA
tel: 414-649-4200
toll free: 800-657-0853
fax: 414-649-4279
sales@curtisind.com
http://www. curtisind.com

Curtis-Straus (Bureau Veritas)
One Distribution Center Circle, Suite 1
Littleton, MA 01460 USA
tel: 978-486-8880
toll free: 877-277-8880
fax: 978-486-8828
electricalmail@ bureauveritas.com
http://www. bureauveritas.com/ee

CV DIMULTI
JL Swatantra V, Villa Andalusia No.9
Jatirasa, Jatiash
Bekasi, Jawa Barat 17424 Indonesia
tel: 62 12132608337
fax: 62 2182415949
narmadi@typeapprovalindonesia.com
http://www.dimulti.co.id

D.L.S. Electronic Systems, Inc.
1250 Peterson Drive
Wheeling, IL 60090 USA
tel: 847-537-6400
fax: 847-537-6488
jblack@dlsemc.com
http://www.dlsemc.com
D.L.S. Electronic Systems, Inc. offers EMC, Product Safety, Wireless, and Environmental compliance testing and consulting services for electric and electronic equipment and devices for the Military, Avionics, Commercial, Medical, and Industrial marketplace, including MIL STD, RTCA, FCC, IC, CE, IEC, ETSLEN, UL-c, UL and other global standards. D.L.S. is a NVLAP Accredited and iNARTE certified organization, is accredited to the UL third party testing program, and is a Notified Body for EMC and RTTE Directives. D.L.S. offers design seminars on a regular basis, including proprietary design software and a hands-on workshop.

D. C. Smith Consultants
1305 Arizona Street
Boulder Dam Hotel, Suite 101
Boulder City, NV 89050 USA
tel: 702-570-6108
toll free: 800-323-3956
doug@dsmith.org
http://emcesd.com

dB Instruments Co.
22 Berwick Road
Easton, MA 02375 USA
tel: 508-238-1303
fax: 508-238-6098
Dougdr@msn.com
Dayton T. Brown, Inc.
1195 Church Street
Bohemia, NY 11716 USA
tel: 631-589-6300
toll free: 800-TEST-456
fax: 631-589-3648
test@dtbtest.com
http://www.dtbtest.com
Dayton T. Brown, Inc. is an A2LA/NVLAP accredited independent engineering and testing lab. Please see our website for our scopes of accreditation. DTB offers environmental, vibration, EMI/EMC and structural testing to a host of international standards, including commercial and military requirements. We also provide engineering analysis to our customers for both physical and electrical characteristics, as well as, for dimensional and material inspection, failure analysis and reverse engineering. Tap into our experience, flexibility, reduced time-to-test and low set up costs, to satisfy your most demanding test objective. Ask about our new T5500, 3 inch displacement, vibration facility or our new 100 meter indoor ballistics range.

DDB Unlimited, Inc
8445 Highway 77N
Wynnewood, OK 73098 USA
tel: 800-753-8459 ext 2828
toll free: 800-753-8459
fax: 405-665-9995
sales@ddbunlimited.com
http://www.ddbunlimited.com

Delcross Technologies, LLC
3015 Village Office Place
Champaign, IL 61822 USA
tel: 217-363-3396
contact@delcross.com
http://www.delcross.com

Design Chain Associates, LLC
5 3rd Street, Suite 732
San Francisco, CA 94103 USA
tel: 415-904-8330
toll free: 866-322-7676 x2
info@designchainassociates.com
http://www.DesignChainAssociates.com

Dexmet Corporation
22 Barnes Industrial Road South
Wallingford, CT 06492 USA
tel: 203-294-7867
fax: 203-294-7898
k.mull@dexmet.com
http://www.dexmet.com

Dexter Magnetic Technologies
1050 Morse Avenue
Elk Grove Village, IL 60007 USA
tel: 847-956-1140
toll free: 800-317-2537
fax: 847 956 8205
info@dextermag.com
http://www.dextermag.com

DJM Electronics
2907 Shelter Island Drive #105-138
San Diego, CA 92106 USA
tel: 619-299-6090
toll free: 866-DJM-ELEC
fax: 619-299-6090
sales@djmelectronics.com
http://www.djmelectronics.com

DMAS
Industrieweg 12
Zoeterwoude 2382NV The Netherlands
tel: 31 715012526
bkdegroot@dmas.eu
http://www.dmas.eu

DNB Engineering, Inc.
3535 W. Commonwealth Avenue
Fullerton, CA 92835 USA
tel: 714-870-7781
fax: 714-870-5081
tonyp@dnbenginc.com
http://www.dnbenginc.com

Don HEIRMAN Consultants
143 Jumping Brook Road
Lincolft, NJ 07738-1442 USA
tel: 732-741-7723
fax: 732-530-5695
d.heirman@ieee.org
http://www.donheirman.com

Dynamic Sciences International
6130 Variel Avenue
Woodland Hills, CA 91304 USA
tel: 818-226-6262
toll free: 800-966-3713
fax: 818-226-6247
market@dynamicsciences.com
http://www.dynamicsciences.com

ED&D Inc.
901 Sheldon Drive
Cary, NC 27513 USA
tel: 919-469-9434
toll free: 800-806-6236
fax: 919-469-5743
info@productsaft.com
http://www.ProductSafeT.com
World leading manufacturer of Product Safety test equipment, including Hipot, ground continuity, leakage current, access probes, impact testers, burn test equipment, ingress protection equipment, cable and cord testers, and everything else. ISO 17025 accredited.

East Coast Shielding
37 Route 46
Hackettstown, NJ 07840 USA
tel: 908-852-9160
fax: 908-852-9163
mike@eastcoastshielding.com
http://www.eastcoastshielding.com

Eisner Safety Consultants
3331 SW Seymour Street
Portland, OR 97239 USA
tel: 503-244-6151
fax: 503-244-6152
Leo@EisnerSafety.com
http://www.EisnerSafety.com

Electri-Flex Company
222 W. Central Avenue
Roselle, IL 60172 USA
tel: 630-529-2920
toll free: 800-323-6174
fax: 630-529-0482
mktg@electriflex.com
http://www.electriflex.com

Electro Magnetic Test, Inc.
1547 Plymouth Street
Mountain View, CA 94043 USA
tel: 650-965-4000
fax: 650-965-3000
jgandhi@emtlabs.com
http://www.emtlabs.com
Electronics Test Centre
302 Legget Drive
Kanata, ON K2K 1Y5 Canada
tel: 613-599-6800
fax: 613-599-7614
lynn.diggins@etc-mpb.com
http://www.etc-mpb.com

The Electronics Test Centre brings compliance and certification services, as well as, customized test and engineering to the Aeronautical, Automotive, Medical, Military and Telecommunications industries. We are NVLAP accredited and experienced in a broad spectrum of standards, including Commercial, Military, and Aerospace. Additional services offered include mechanical engineering, consultation and custom fabrication.

Electro Rent Corporation
6060 Sepulveda Boulevard
Van Nuys, CA 91411 USA
tel: 800-688-1111
toll free: 800-688-1111
fax: 818-374-7399
sales@electrorent.com
http://www.ElectroRent.com

Electronic Instrument Associates
PO Box 6487
Bloomingdale, IL 60108 USA
tel: 630-924-1600
fax: 630-477-0321
info@electronicinstrument.com
http://www.electronicinstrument.com

Electronics Test Centre - Airdrie
27 East Lake Hill
Airdrie, AB T4A 2K3 Canada
tel: 403-912-0037
fax: 403-912-0083
mmediboina@etc-mpbtech.com
http://www.etc-mpb.com

Elite Electronic Engineering
1516 Centre Circle
Downers Grove, IL 60515 USA
tel: 630-495-9770
toll free: 800-ELITE-11
sglaya@elitetest.com
http://www.elitetest.com

Elite Electronic Engineering is the premiere accredited independent test laboratory in North America. Experts in the fields of EMC, Environmental stress testing and electrical products and components testing and certification since 1954. Elite caters to the automotive, aerospace, military, medical, and commercial electrical products industries. With an extensive 45,000 square foot facility conveniently located in Chicago, Elite offers efficient, effective and inexpensive testing and consulting to suit the gamut of testing needs.

EM Software & Systems (USA) Inc
100 Exploration Way, Suite 310-B
Hampton, VA 23666 USA
tel: 757-224 0548
toll free: 800-419-5566 (FEKO)
fax: 757-282 5897
feko@emssusa.com
http://www.feko.info

FEKO: Comprehensive Electromagnetic Simulation Tool
EM Software & Systems (USA) Inc is established to distribute and support FEKO in the United States, Canada, Mexico and Central America. FEKO is a leading CEM code for the analysis of: antennas (wire antennas, patch antennas, horn antennas, integrated antenna systems, etc.), antenna placement on electrically small and large structures, electromagnetic compatibility, microstrip circuits and antennas in stratified media and dielectric bodies.

Elna Magnetics
203 Malden Turnpike
Saugerties, NY 12477 USA
tel: 845-247-2000
toll free: 800-553-2870
fax: 845-247-0196
info@elnamagnetics.com
http://www.elnamagnetics.com

EMC Integrity Inc.
1736 Vista View Drive
Longmont, CO 80504 USA
tel: 303-776-7249
toll free: 888-423-6275
fax: 303-776-7314
guyd@emcintegrity.com
http://www.emcintegrity.com

EMC Technologists
5033 Industrial Road, Building. 6
Farmingdale, NJ 07727 USA
tel: 732-919-1100
fax: 732-919-7196
sales@emctech.com
http://www.emctech.com

EM Software & Systems-S.A.
32 Techno Avenue
Stellenbosch, 7600 South Africa
tel: 27 21 831 1500
fax: 27 21 880 1936
feko@emss.co.za
http://www.feko.info

EM Compliance
P.O. Box 14161
Huntsville, AL 35815-0161 USA
tel: 256-650-5261
ken.javor@emccompliance.com
http://www.emccompliance.com

Electronics Test Centre
39 West Lake Hill
Airdrie, AB T4A 2K3 Canada
tel: 403-912-0037
fax: 403-912-0083
mmediboina@etc-mpbtech.com
http://www.etc-mpb.com
EM TEST USA
9250 Brown Deer Road
San Diego, CA 92121 USA
tel: 858-450-0085
fax: 858-458-0267
tom.revesz@ametek.com
http://www.emtest.com

EM Test manufactures simulators and generators to meet international, national and corporate EMC requirements for virtually all industries including Automotive, Avionics, Consumer Electronics, Industrial Controls, Medical, Military, Telecom, and others. We provide test solutions for ESD, Surge, Fast Transients, Conducted RF, and a wide variety of AC and DC power mains tests, including many specialized requirements in the automotive and avionics fields.

EMC Test Design, LLC
P.O. 600532
Newton, MA 02460 USA
tel: 508-292-1833
exid@emctd.com
http://www.emctd.com

EMC Testing Laboratories, Inc.
2100 Brandon Trail
Alpharetta, GA 30004 USA
tel: 770-475-8819
fax: 770-475-2011
gbailey@emctesting.com
http://emctesting.com

EMCC DR. RASEK
Moggast, Boelwiese 4 - 8
Ebermannstadt, 91320 Germany
tel: 49-9194-9016
fax: 49-9194-8125
i.helldoerfer@emcc.de
http://www.emcc.de

EMCplus LLC
1076 Deer Clover Way
Castle Rock, CO 80108 USA
tel: 303-663-3396
fax: 303-663-5545
doug@emcplus.com
http://emcplus.com

EMSCAN
#1, 1715-27 Avenue N.E.
Calgary, AB T2E 7E1 Canada
tel: 403-291-0313
fax: 403-250-8786
info@emscan.com
http://www.emscan.com

EMSCAN is a world-leading developer of real-time magnetic very-near-field measurement solutions. We provide real-time visual test Solutions for antenna and PCB designers and verification engineers. We have two product portfolios:

RFxpert is the only real-time, compact, bench-top antenna measurement equipment that calculates accurate far-field patterns and radiated power levels based on near-field measurements. Immediate access to FF data saves time and cost by reducing reliance upon time consuming and costly anechoic chambers. Unique NF data provides insight into root cause of problems.

EMxpert is a real-time, compact, bench-top EMC/EMI diagnostic tool enabling designers to rapidly diagnose and solve EMC/EMI problems in a single design cycle.

EMI Instrumentation
650 Rogers Circle
Folsom, CA 95630 USA
tel: 805-835-8547
steven.souther@emi-i.com
http://emi-i.com

• IV-Curve TLP Systems up to 30A (TLP/VFTLP), customize up to 10kV/200A for bench top or 60kV/1200A for rack mount
• HV RF Pulse Attenuators up to 5kV/4GHz
• ESD Simulators up to 30kV (300kV for military use)
• ESD Calibration Kits up to 4GHz
• Cable Discharge Event Testers
• HV DC Supply Modules
• HV Measurements up to 120kV
• IC Stripline TEM Cells up to 5.5GHz
• Customized RF System Design up to 30GHz

EMI Solutions
13805 Alton Parkway #B
Irvine, CA 92618 USA
tel: 949-206-9960
fax: 949-206-9983
Bob@4emi.com
http://www.4EMI.com

ESDEMC Technology LLC
4000 Enterprise Drive, Suite 103
Rolla, MO 65401 USA
toll free: 877-864-8479
info@esdemc.com
http://www.esdemc.com

• IV-Curve TLP Systems up to 30A (TLP/VFTLP), customize up to 10kV/200A for bench top or 60kV/1200A for rack mount
• HV RF Pulse Attenuators up to 5kV/4GHz
• ESD Simulators up to 30kV (300kV for military use)
• ESD Calibration Kits up to 4GHz
• Cable Discharge Event Testers
• HV DC Supply Modules
• HV Measurements up to 120kV
• IC Stripline TEM Cells up to 5.5GHz
• Customized RF System Design up to 30GHz

ESDEMC Technology designs, manufactures and markets ESD and EMC related products. We are devoted to delivering creative, flexible and cost effective ESD and EMC solutions and top-level consulting services. We offer customized design services to satisfy all of our customers.

EMSS Consulting
3 Meson Avenue
Stellenbosch, 7600 South Africa
tel: 27 21 880 1880
bboesch@emss.co.za
http://www.emssixus.com

Ergonomics, Inc.
324 Second Street Pike Unit 3
Southampton, PA 18966 USA
tel: 215-357-5124
toll free: 800-862-0102
fax: 215-364-7582
info@ergonomicsusa.com
http://www.ergonomicsusa.com
ETS-Lindgren
1301 Arrow Point Drive
Cedar Park, TX 78613 USA
tel: 512-531-6400
info@ets-lindgren.com
http://www.ets-lindgren.com

ETS-Lindgren is a leading manufacturer of turn-key systems and components for EMC, Wireless, Acoustic, and RF testing. We adapt new technologies and apply proven engineering principles to create value-added solutions for our customers. Our well-known products include antennas, field probes and monitors, positioners, RF and microwave absorbers, shielded enclosures, and anechoic chambers, to name a few. Innovative software offered includes TILE!™ for EMC test lab management and EMQuest™ for antenna pattern measurement. ETS-Lindgren provides expert calibration services at our A2LA accredited calibration lab. Based in Cedar Park, Texas, ETS-Lindgren has facilities in North America, South America, Europe and Asia. For more information visit www.ets-lindgren.com

ESD Association
7900 Turin Road, Building 3
Rome, NY 13440-2069 USA
tel: 315-339-6937
fax: 315-339-6793
info@esda.org
http://www.esda.org

Espresso Engineering
6731 Whittier Avenue, Suite C110
McLean, VA 22101 USA
tel: 703-847-4700
fax: 703-847-6888
info@espressoengineering.tv
http://espressoengineering.tv

eti Conformity Services
8760 Orion Place, Suite 110
Columbus, OH 43240 USA
tel: 877-468-6384
fax: 614-410-8500
info@electricalreliability.com
http://www.eticonformity.com

Fair-Rite Products Corp.
1 Commercial Row
Wallkill, NY 12589 USA
tel: 845-895-2055
toll free: 888-324-7748
fax: 845-895-2629
ferrites@fair-rite.com
http://www.fair-rite.com

For over fifty years Fair-Rite Products Corp. has been the first choice in cost effective ferrite components. We offer a comprehensive product line that includes a wide range of materials and geometries for EMI Suppression, Power Applications, and RFID Antennas. We place the highest value on quality, engineering, service, and continual improvement. Fair-Rite Products Corp. supplies a wide variety of standard catalog ferrite parts to thousands of customers worldwide. Many commonly used ferrite parts are stocked by our distributors, who offer prompt deliveries. In addition to our standard product offering, Fair-Rite can provide custom designs and shapes to meet your specific requirements. We have an experienced team of engineers to assist you with new design and technical support.

F2 Labs
26501 Ridge Road
Damascus, MD 20872 USA
tel: 440-632-5541 x208
toll free: 877-405-1580
fax: 440-632-5542
elittell@f2labs.com
http://www.f2labs.com

FerriShield
12420 Race Track Road
Tampa, FL 33626 USA
tel: 813-855-6921
toll free: 866-TECH-EMI
fax: 813-855-3291
sales@leadertechinc.com
http://www.ferrishield.com

F2 Labs
26501 Ridge Road
Damascus, MD 20872 USA
tel: 440-632-5541 x208
toll free: 888-324-7748
fax: 845-895-2629
elittell@f2labs.com
http://www.fair-rite.com

FerriShield
12420 Race Track Road
Tampa, FL 33626 USA
tel: 813-855-6921
toll free: 866-TECH-EMI
fax: 813-855-3291
sales@leadertechinc.com
http://www.ferrishield.com

Fil-Coil
77-18 Windsor Place
Cenral Islip, NY 11722 USA
tel: 631-467-5328
fax: 631-467-5066
sales@cuwstompowersystem.com
http://custompowersystem.com

Filconn Inc.
3324 N. San Marcos Place
Chandler, AZ 85225 USA
tel: 480-222-3565
fax: 480-222-3567
sales@filconn.com
http://www.filconn.com

Finero USA L.L.C.
3009 Lake Manatee Court
Cape Coral, FL 33909 USA
tel: 239-898-8487
sales@qacontrol.com
http://www.qacontrol.com

Fischer Custom Communications
20603 Earl Street
Torrance, CA 90503 USA
tel: 310-303-3300
fax: 310-371-6268
sales@fischercc.com
http://www.fischercc.com

Flextronics
21 Richardson Side Road
Ottawa, ON K4A 3H6 Canada
tel: 613-895-2053
fax: 613-271-2581
philippe.boisvert@ca.flextronics.com
http://www.flexdvc.com

Fotofab
3758 W. Belmont Avenue
Chicago, IL 60618 USA
tel: 773-463-6211
fax: 773-463-3387
sales@fotofab.com
http://www.fotofab.com

ETS-Lindgren is a leading manufacturer of turn-key systems and components for EMC, Wireless, Acoustic, and RF testing. We adapt new technologies and apply proven engineering principles to create value-added solutions for our customers. Our well-known products include antennas, field probes and monitors, positioners, RF and microwave absorbers, shielded enclosures, and anechoic chambers, to name a few. Innovative software offered includes TILE!™ for EMC test lab management and EMQuest™ for antenna pattern measurement. ETS-Lindgren provides expert calibration services at our A2LA accredited calibration lab. Based in Cedar Park, Texas, ETS-Lindgren has facilities in North America, South America, Europe and Asia. For more information visit www.ets-lindgren.com
Vendor Directory

G&M Compliance, Inc.
154 South Cypress Street
Orange, CA 92866 USA
tel: 714-628-1020
fax: 714-628-1021
katy@gmcompliance.com
http://www.gmcompliance.com

Garwood Laboratories
7829 Industry Avenue
Pico Rivera, CA 90660 USA
tel: 562-949-2727
toll free: 888-427-4111
fax: 562-949-8757
sales@garwoodlabs.com
http://www.garwoodlabs.com

Garwood Laboratories Inc. SC
143 Calle Iglesia
San Clemente, CA 92672 USA
tel: 949-361-9189
toll free: 888-427-4111
fax: 949-361-9597
frankd@garwoodlabs.com
http://www.garwoodlabs.com/gsc

GAUSS INSTRUMENTS
Agnes-Pockels-Bogen 1
Muenchen, 80992 Germany
tel: 49-89-54-04-699-0
braun@tdemi.com
http://www.tdemi.com

General Dynamics C4 Systems
8201 E McDowell Road
Scottsdale, AZ 85257 USA
tel: 480-441-5321
harry.gaul@gdc4s.com
http://www.gdc4s.com

Genisco Filter Corp
5466 Complex Street, Suite 207
San Diego, CA 92123 USA
tel: 858-565-7405
fax: 858-565-7415
sales@genisco.com
http://www.genisco.com

Giga-tronics Incorporated
4650 Norris Canyon Road
San Ramon, CA 94583 USA
tel: 925-328-4650
toll free: 800-277-9764
fax: 925-328-4700
inquiries@gigatronics.com
http://www.gigatronics.com

Grund Technical Solutions, LLC
5932 Amapola Drive
San Jose, CA 95129 USA
tel: 510-453-2617
fax: 408-446-4061
support@grundtech.com
http://www.grundtech.com

At GTS our constant commitment is to provide for all your ESD device characterization needs. We do this by developing cutting edge equipment with features you won‘t find anywhere else. Whether you‘re a designer, technician, or program manager we have the products and expertise to solve the problems you face.

Our products fall into three main categories, stress generation, stress delivery, and stress measurement. This means we can offer you a fully integrated solution that can not only generate the standards compliant waveforms to qualify your devices, but deliver them to your part without distortions, while showing you what stress was provided to your part measured at your part.

Go Global Compliance Inc.
4454 Crabapple Court
Tracy, CA 95377 USA
tel: 408-416-3772
peter@goglobalcompliance.com
http://www.goglobalcompliance.com

Green Mtn. Electromagnetics
219 Blake Roy Road
Middlebury, VT 05753 USA
tel: 802-388-3390
fax: 802-388-6279
gme@gmelectro.com
http://www.gmelectro.com

H.B. Compliance Solutions
5005 S. Ash Avenue, Suite #A-10
Tempe, AZ 85282 USA
tel: 480-684-2969
hoosam@hbcompliance.com
http://www.hbcompliance.com

Haefely EMC Technology
1650 Route 22 N.
Brewster, NY 10509 USA
tel: 845-279-3644 x240
fax: 845-279-2467
emcsales@hipotronics.com
http://www.haefelyemc.com

HCT Co., Ltd.
105-1 Jangam-ri, Majang-myeon
Icheon, Gyeonggi 467-811 South Korea
tel: 82-31-645-6454
fax: 82-31-645-6401
alarcon@hct.co.kr
http://www.hct.co.kr

Henry Ott Consultants
48 Baker Road
Livingston, NJ 07039-2502 USA
tel: 973-992-1793
fax: 973-533-1442
h.ott@verizon.net
http://www.hottconsultants.com

Hermon Laboratories TI
Hatachana Street
Binyamina, 30500 Israel
tel: 972-4-6268401
fax: 972-4-6288277
sales-tca@hermonlabs.com
http://www.hermonlabs.com

At GTS our constant commitment is to provide for all your ESD device characterization needs. We do this by developing cutting edge equipment with features you won‘t find anywhere else. Whether you‘re a designer, technician, or program manager we have the products and expertise to solve the problems you face.

Our products fall into three main categories, stress generation, stress delivery, and stress measurement. This means we can offer you a fully integrated solution that can not only generate the standards compliant waveforms to qualify your devices, but deliver them to your part without distortions, while showing you what stress was provided to your part measured at your part.
High Voltage Maintenance  
5100 Energy Drive  
Dayton, OH 45414 USA  
tel: 937-278-0811  
toll free: 866-486-8326  
fax: 937-278-7791  
info@hvmcorp.com  
http://www.hvmcorp.com

HM Cragg  
7674 Washington Avenue South  
Eden Prairie, MN 55344 USA  
tel: 952-884-7775  
toll free: 800-672-7244  
fax: 952-884-7739  
yvette@hmcragg.com  
http://www.hmcragg.com

In Compliance Magazine  
531 King Street, Suite 5  
Littleton, MA 01460 USA  
tel: 978-486-4684  
fax: 978-486-4691  
directory@incompliancemag.com  
http://www.incompliancemag.com

iNARTE at RABQSA International  
600 N. Plankinton Ave., Suite 301  
Milwaukee, WI 53201 USA  
tel: 414-272-3937  
toll free: 800-89-NARTE  
minman@rabqsa.com  
http://www.narte.org

WE GET YOU RECOGNIZED  
iNARTE is credentialing brand offered by RABQSA International, a non-profit, credentialing body. We offer validation of professional credentials for Engineers and Technicians through a number of certification programs in Telecommunications, Electromagnetic Compatibility, Electrostatic Discharge Control and Product Safety Engineering. Whether just starting out, or widely experienced, iNARTE Certification can get your career on the Fast Track.

Innco Systems GmbH  
Erlenweg 12  
Schwarzenfeld, D-92521 Germany  
tel: 49-9435-301659-0  
fax: 49-9435-301659-99  
info@inncosystems.com  
http://www.inncosystems.com

Intermark USA, Inc.  
1310 Tully Road, Suite 117  
San Jose, CA 95122 USA  
tel: 408-971-2055  
fax: 408-971-6033  
sales@intermark-usa.com  
http://www.intermark-usa.com

Interpower Corporation  
PO Box 115  
Oskaloosa, IA 52577 USA  
tel: 800-662-2290  
info@interpower.com  
http://www.interpower.com

iNARTE at RABQSA International  
600 N. Plankinton Ave., Suite 301  
Milwaukee, WI 53201 USA  
tel: 414-272-3937  
toll free: 800-89-NARTE  
minman@rabqsa.com  
http://www.narte.org

Instruments For Industry, Inc.  
903 South Second Street  
Ronkonkoma, NY 11779 USA  
tel: 631-467-8400  
fax: 631-467-8558  
cschlie@ifi.com  
http://www.ifi.com

Intermark USA, Inc.  
1310 Tully Road, Suite 117  
San Jose, CA 95122 USA  
tel: 408-971-2055  
fax: 408-971-6033  
sales@intermark-usa.com  
http://www.intermark-usa.com

Interpower Corporation  
PO Box 115  
Oskaloosa, IA 52577 USA  
tel: 800-662-2290  
info@interpower.com  
http://www.interpower.com

Intertek  
70 Codman Hill Road  
Boxborough, MA 01719 USA  
tel: 800-WORLDLAB  
icenter@intertek.com  
http://www.intertek.com

IQS, a Division of CMG  
257 Simarano Drive  
Marlborough, MA 01752 USA  
tel: 508-460-1400  
fax: 508-460-7979  
kwhitten@iqscorp.com  
http://www.iqscorp.com
Ja-Bar Silicone Corp
252 Brighton Road
Andover, NJ 07821 USA
tel: 973-786-5000
fax: 973-786-5546
mcruz@ja-bar.com
http://jabar.com
Ja-Bar specializes in silicone and elastomeric materials for electromagnetic shielding. Products include Electrically Conductive particle filled elastomers, Wire oriented in silicone, Elastomer filled metallic sheeting, BeCu fingers, Shielding Vents and Windows, manufactured to Military, Federal, AMS, SAE and customer specifications.

Jacobs Technology
3300 General Motors Road
MC-483-340-145
Milford, MI 48380 USA
tel: 248-676-1101
fax: 248-676-1135
debra.stefanik@jacobs.com
http://www.jacob.com

Jastech EMC Consulting LLC
47523 Clipper Street
Plymouth, MI 48170 USA
tel: 248-876-4810
fax: 866-790-9081
Jim@jastech-EMC.com
http://www.jastech-EMC.com

JDM LABS LLC
430 Weidner Road
Buffalo Grove, IL 60089 USA
tel: 847-630-2769
jerrymeyerhoff@ieee.org

JEMIC Shielding Technology
1160 South Cameron Street
Harrisburg, PA 17104 USA
tel: 717-232-1030
dietrich@jemic.com
http://jemic.com

K-Form, Inc.
9A Acacia Lane
Sterling, VA 20166 USA
tel: 703-450-4401
fax: 703-894-9194
kform@kform.com
http://www.kform.com

Keystone Compliance
131 Columbus Inner Belt
New Castle, PA 16101 USA
tel: 724-657-9940
fax: 724-657-9920
sam@keystonecompliance.com
http://www.keystonecompliance.com

Kimmel Gerke Associates, Ltd.
628 LeVander Way
South Street, PA 55075 USA
tel: 651-457-3715
toll free: 888-EMI-GURU
fax: 651-457-4139
bkimmel@emiguru.com
http://www.emiguru.com

Krefine Co.Ltd.
420 Lexington Avenue, Suite 2525
New York, NY 10170 USA
tel: 520-838-0548
fax: 520-838-0548
Dotson@Kureha.com
http://www.Krefine.com

L-3 Communications Cincinnati
7500 Innovation Way
Mason, OH 45040 USA
tel: 513-573-6809
toll free: 800-543-8220
fax: 513-573-6499
EnvSvcsSales@L-3Com.com
http://www.cinele.com/
environmental.html

LabTest Certification Inc.
3133 - 20800 Westminster Highway
Richmond, BC V6V2W3 Canada
tel: 604-247-0444
fax: 604-247-0442
colin.kooner@labtestcert.com
http://www.labtestcert.com

Laird Technologies
3481 Rider Trail South
Earth City, MO 63045 USA
tel: 636-898-6215
fax: 636-898-6100
dlmarcom@lairdtech.com
http://www.lairdtech.com

Lambda Calibration Ltd
Stump Lane
Chorley, Lancs PR6 0BL
United Kingdom
jenster@email.com
http://www.lambda-cal.co.uk

LCR Electronics, Inc.
9 South Forest Avenue
Norristown, PA 19401 USA
tel: 610-278-0840
toll free: 800-527-4362
fax: 610-278-0935
sales@lcrcal.com
http://www.lcr-cal.com

Leader Tech
12420 Race Track Road
Tampa, FL 33626 USA
tel: 813-855-6921
toll free: 866-TECH-EMI
fax: 813-855-3291
sales@leadertechinc.com
http://www.leadertechinc.com

Lewis Bass International
1250 Ames Avenue
Milpitas, CA 95035 USA
tel: 408-942-8000
fax: 408-957-9621
sandeep.bendale@lewisbass.com
http://www.lewisbass.com

Liberty Labs, Inc.
1346 Yellowwood Road
Kimballton, IA 51543 USA
tel: 712-773-2199
fax: 712-773-2299
info@liberty-labs.com
http://www.liberty-labs.com
Lionheart Northwest
15874 NE 93rd Way
Redmond, WA 98052 USA
tel: 425-882-2587
fax: 425-952-8739
sales@lionhearthnw.com
http://www.lionhearthnw.com

LS Research
W66 N220 Commerce Court
Cedarburg, WI 53012 USA
tel: 262-375-4400
fax: 262-375-4248
sales@lsr.com
http://www.lsr.com

Lubrizol Conductive Polymers
9911 Brecksville Road
Cleveland, OH 44141 USA
tel: 866-680-1555
toll free: 866-680-1555
fax: 216-447-5750
stat-rite@lubrizol.com
http://www.stat-rite.com

Mag Daddy
1155 Rose Road
Lake Zurich, IL 60047 USA
tel: 847-719-5600
Lperrault@termax.com
http://www.magdaddyusa.com

MAJR Products, Inc.
17540 State Highway 198
Saegertown, PA 16433 USA
tel: 814-763-3211
toll free: 877-625-7776
fax: 814-763-2952
sales@majr.com
http://www.majr.com

Master Bond
154 Hobart Street
Hackensack, NJ 07601 USA
tel: 201-343-8983
fax: 201-343-2132
hevans@masterbond.com
http://www.masterbond.com

MC Global Access
Carlsbad Boulevard
Carlsbad, CA 92008 USA
tel: 760-696-3700
mcassidy@mcglobalaccess.com
http://www.mcglobalaccess.com

Lionheart Northwest
15874 NE 93rd Way
Redmond, WA 98052 USA
tel: 425-882-2587
fax: 425-952-8739
sales@lionhearthnw.com
http://www.lionhearthnw.com

LS Research
W66 N220 Commerce Court
Cedarburg, WI 53012 USA
tel: 262-375-4400
fax: 262-375-4248
sales@lsr.com
http://www.lsr.com

Lubrizol Conductive Polymers
9911 Brecksville Road
Cleveland, OH 44141 USA
tel: 866-680-1555
toll free: 866-680-1555
fax: 216-447-5750
stat-rite@lubrizol.com
http://www.stat-rite.com

Mag Daddy
1155 Rose Road
Lake Zurich, IL 60047 USA
tel: 847-719-5600
Lperrault@termax.com
http://www.magdaddyusa.com

MAJR Products, Inc.
17540 State Highway 198
Saegertown, PA 16433 USA
tel: 814-763-3211
toll free: 877-625-7776
fax: 814-763-2952
sales@majr.com
http://www.majr.com

Master Bond
154 Hobart Street
Hackensack, NJ 07601 USA
tel: 201-343-8983
fax: 201-343-2132
hevans@masterbond.com
http://www.masterbond.com

MC Global Access
Carlsbad Boulevard
Carlsbad, CA 92008 USA
tel: 760-696-3700
mcassidy@mcglobalaccess.com
http://www.mcglobalaccess.com

Magnetic Shield Corporation
740 N. Thomas Drive
Bensenville, IL 60106 USA
tel: 630-766-7800
toll free: 888-766-7800
fax: 630-766-2813
shields@magnetic-shield.com
http://www.magnetic-shield.com

Since 1941, Magnetic Shield Corporation has provided magnetic shielding materials and custom fabrications for OEM customers, worldwide. Today, we offer our proprietary brands of high permeability alloys as magnetic shields, for EMI shielding of sensitive electrical & electronic components and equipment. Our brands of MuMETAL®, CO-NETIC®, and NETIC® alloys are used Worldwide. Our other popular, specialty electrical/electronics shielding for wiring applications include INTER-8® Weave Cable, Spira-Shield flexible conduit, and CO-NETIC® Braided Sleevings, and are used to shield sensitive circuits in many industries and market segments. Our engineering staff will work closely with you to design custom solutions, and address your specific interference problem. We will then execute your design to fabricate your shields in a timely fashion with superior quality - our hallmark for over 70 years.

Metal Textiles Corporation
970 New Durham Road
Edison, NJ 08818 USA
tel: 732-287-0800 x150
fax: 732-287-8546
sales@metexcorp.com
http://www.metexcorp.com

Metal Textiles has been a manufacturer of standard & custom EMI/RFI Shielding products for over 50 years, serving Military, government, automotive, manufacturing, and commercial electronic industries. Our line of products include Wire mesh tape, wire mesh gasketing, combine strips, metalized fabric over foam, conductive elastomers, vent panels, conductive gaskets, fingerstock, & EMI windows.

As an ISO/TS 16949 Registered & ISO 3001 Registered company, we offer solid technical and customer support while also giving competitive pricing and outstanding delivery.

Megaline Source International
3F-6 Sec.1 Xin-Tai-Wu Road
Si-Chi District, New Taipei City, 221
Taiwan
tel: 86-2-8698-4181
fax: 86-2-8698-4197
sales@megalinsource.com
http://www.megalinsource.com

MET Laboratories
914 W. Patapsco
Baltimore, MD 21230 USA
tel: 410-354-3300
fax: 410-354-3313
info@metlabs.com
http://www.metlabs.com

MetaGeek
10147 Emerald Street, Suite 150
Boise, ID 83704 USA
tel: 208-639-3140
Lperrault@termax.com
http://www.metageek.net

MI Technologies
1125 Satellite Boulevard, Suite 100
Suwanee, GA 30024-4629 USA
tel: 678-475-8345
fax: 678-542-2601
marketing@mi-technologies.com
http://www.mi-technologies.com

Microwave Vision Group
2105 Barrett Park Drive, Suite 104
Kennesaw, GA 30044 USA
tel: 678-797-9172
jestrada@satimo.com
http://www.microwavevision.com
Michigan Scientific Corporation
321 East Huron Street
Milford, MI 48381 USA
tel: 248-685-3939
fax: 248-684-5406
http://www.michsci.com

Michigan Scientific Corporation (MSC) is the leading manufacturer of Fiber-Optic Systems that provide RF immunity for signals that are linked to/from equipment under test during automotive component and full-scale vehicle electromagnetic compatibility (EMC) engineering and testing.

MSC Fiber-Optic Systems have earned a reputation for superior stability and immunity that is necessary for Monitoring/Sourcing signals To/From any DUT/EUT located in high-field areas such as anechoic chambers. This is especially true when seeking certification with the Automotive Electromagnetic Compatibility Laboratory Recognition Program (AEMCLRP). MSC F-O Links are also compatible with BCI testing when used as recommended.

MILMEGA Ltd
Park Road
Ryde, Isle of Wight PO33 2BE
United Kingdom
tel: 44 1983 618004
fax: 44 1983 811521
sales@milmega.co.uk
http://www.milmega.com

MKS ION Systems
1750 North Loop Road
Alameda, CA 94502 USA
tel: 510-217-0600
toll free: 800-367-2452
fax: 510-217-0484
info@ion.com
http://www.mksinst.com

Monroe Electronics, Inc.
100 House Avenue
Lyndonville, NY 14098 USA
tel: 585-765-2254
electrostatics@monroe-electronics.com
http://www.monroe-electronics.com

Montrose Compliance Services
2353 Mission Glen Drive
Santa Clara, CA 95051-1214 USA
tel: 408-247-5715
fax: 408-247-5715
mark@montrosecompliance.com
http://www.montrosecompliance.com

MossBay EDA
23889 NE 112th Circle #2
Redmond, WA 98053 USA
tel: 425-779-5345
gene@mossbayeda.com
http://www.mossbayeda.com

Muranita Electronics
2200 Lake Park Drive
Smyrna, GA 30080 USA
tel: 770-433-5782
toll free: 800-554-4070
fax: 770-436-3030
chayden@murata.com
http://www.murata.com

The MuShield Company Inc.
9 Ricker Avenue
Londonderry, NH 03053 USA
tel: 603-666-4433 x21
toll free: 888-669-3539
fax: 603-666-4013
lukeg@mushield.com
http://www.mushield.com

Narda Safety Test Solutions
435 Moreland Road
Hauppauge, NY 11788 USA
tel: 631-231-1700
fax: 631-231-1711
nardasts@L-3com.com
http://www.narda-sts.us

NEC Corporation
7-1, Shiba 5-chome, Minato-ku
Tokyo, 108-8001 Japan
sales@emistream.jp.nec.com
http://www.nec.com

NCEE Labs
4740 Discovery Drive
Lincoln, NE 68521 USA
tel: 402-323-6233
toll free: 888-567-6860
fax: 402-323-6238
executivedirector@nceelabs.com
http://www.nceelabs.com

NCEE Labs is an A2LA accredited testing facility offering EMC, Environmental, Safety testing and consulting which gives us the flexibility to develop the testing program that’s right for you.

Our 15,700 square foot state-of-the-art facility houses one of the nation’s few public 10-m semi-anechoic chambers as well as a 3-m chamber, so we can handle products of a variety of shapes and sizes.

Nemko Canada
303 River Road
Ottawa, ON K1V 1H2 Canada
tel: 613-737-9680
fax: 613-737-9691
sim.jagpal@nemko.com
http://www.nemko.com

Nemko USA - SouthEast
Tampa Sales Office
Tampa, FL 33511 USA
tel: 813-662-4606
andrew.robbins@nemko.com
http://www.nemko.com

Nexlogic Technologies, Inc.
2085 Zanker Road
San Jose, CA 95131 USA
tel: 408-436-8150
toll free: 866-845-1197
fax: 408-436-8156
sales@nexlogic.com
http://www.nexlogic.com
Vendor Directory

NexTek, Inc.
2 Park Drive, Building #1
Westford, MA 01886 USA
tel: 978-486-0582
fax: 978-486-0583
sales@nexteklightning.com
http://www.nexteklightning.com

NQA Canada
7 Donat
Valleyfield, QC J6S 6C9 Canada
tel: 514-242-2655
fax: 450-373-1835
info@nqa-usa.com
http://www.nqacanada.ca

NQA Indiana
700 E. Beardsley Avenue
Elkhart, IN 46514 USA
tel: 574-264-0745
toll free: 800-398-8282
fax: 574-264-0740
info@nqa-usa.com
http://www.nqa-usa.com

NQA West Coast
3639 Harbor Boulevard, Suite 202
Ventura, CA 93001 USA
tel: 805-644-8476
toll free: 800-734-4476
fax: 805-644-8451
info@nqa-usa.com
http://www.nqa-usa.com

NQA, USA
4 Post Office Square
Acton, MA 01720 USA
tel: 978-635-9256
toll free: 800-649-5289
fax: 978-263-0785
info@nqa-usa.com
http://www.nqa-usa.com

NTS - Corporate HQ
24007 Ventura Boulevard
Calabasas, CA 91302 USA
tel: 800-270-2516
toll free: 800-270-2516
sales@nts.com
http://www.nts.com

NTS Albuquerque
3801 Academy Parkway, North, NE
Albuquerque, NM 87109 USA
tel: 505-821-4740
fax: 505-821-5210
sales@nts.com
http://www.nts.com

NTS Europe GmbH
Hofmannstr. 50
Munich, D-81379 Germany
tel: 4-89-787475-160
sales@nts.com
http://www.nts.com/locations/europe

NTS Fremont
41039 Boyce Road
Fremont, CA 94538 USA
tel: 510-578-3500
toll free: 877-245-7800
fax: 510-440-9525
sales@nts.com
http://www.nts.com

NTS Fullerton
1536 East Valencia Drive
Fullerton, CA 92831 USA
tel: 714-879-6110
toll free: 800-677-2687
fax: 714-879-6117
sales@nts.com
http://www.nts.com

NTS LAX
5320 West 104th Street
Los Angeles, CA 90045 USA
tel: 310-348-0900
toll free: 800-559-3202
fax: 310-670-7556
sales@nts.com
http://www.nts.com/locations/los_angeles

NTS Newark
38995 Cherry Street
Newark, CA 94560 USA
tel: 510-578-3500
toll free: 877-245-7800
fax: 510-440-9525
sales@nts.com
http://www.nts.com

NTS Northeast
1146 Massachusetts Avenue
Boxborough, MA 02109 USA
tel: 978-266-1001
toll free: 800-723-2687
fax: 978-266-1073
sales@nts.com
http://www.nts.com
NTS Pittsfield
10 Downing Industrial Parkway
Pittsfield, MA 01201-3890 USA
tel: 413-499-2135
toll free: 800-270-2516
fax: 413-499-2503
sales@nts.com
http://www.nts.com

NTS Plano
1701 East Plano Parkway, Suite 150
Plano, TX 75074 USA
tel: 972-509-2566
toll free: 877-717-2687
fax: 972-509-0073
sales@nts.com
http://www.nts.com

NTS Rockford
3761 South Central Avenue
Rockford, IL 61102 USA
tel: 815-315-9250
toll free: 800-270-2516
fax: 815-489-9561
sales@nts.com
http://www.nts.com

NTS Santa Clarita
20970 Centre Pointe Parkway
Santa Clarita, CA 91350 USA
tel: 661-259-8184
toll free: 800-270-2516
fax: 661-254-4814
sales@nts.com
http://www.nts.com

NTS Tempe
1155 West 23rd Street, Suite 11A
Tempe, AZ 85282 USA
tel: 480-966-5517
fax: 480-966-5525
sales@nts.com
http://www.nts.com

NTS Tinton Falls
36 Gilbert Street South
Tinton Falls, NJ 07724 USA
tel: 732-936-0800
fax: 732-936-0700
sales@nts.com
http://www.nts.com

O’Brien Compliance Management
12 Stedman Street
Chelmsford, MA 01824 USA
tel: 978-970-0525
fax: 978-970-0526
fobrien@obcompmam.com
http://www.obcompmam.com

O'Malley Technologies
80 First Street
Hoosick Falls, NY 12090 USA
tel: 518-686-4961
fax: 518-686-8080
sales@oakmitsui.com
http://www.oakmitsui.com

O'Malley Shielding Products, Inc.
9 Emery Avenue
Randolph, NJ 07869 USA
tel: 973-366-0080 x21
toll free: 800-828-5784
fax: 973-366-8232
sales@omegashielding.com
http://www.omegashielding.com

P & P Technology Ltd
1-3 Finch Drive
Springwood Industrial Estate
Braintree, Essex CM7 2SF
United Kingdom
tel: 44 1376 550525
fax: 44 1376 552389
info@p-p-t.co.uk
http://www.p-p-t.co.uk

Okaya Electric America, Inc.
52 Marks Road, Suite 1
Valparaiso, IN 46383 USA
tel: 219-477-4488
toll free: 800-852-0122
fax: 219-477-4856
sales@okaya.com
http://www.okaya.com
Okaya Electric is a manufacturer of Noise and Surge Suppression devices. Okaya is the world’s leading manufacturer of X-capacitors and a leading manufacturer of Surge suppressors including AC and DC Power line, Electrostatic and Network line and SMD TVSS gas tubes. Other products include EMI-RFI Filters, Single Phase, Three Phase, IEC Inlet and PCB Style, Lightning arrestors, Gas Discharge Tubes, Spark Quenchers and High Pulse and Snubber Caps. Okaya also offers a complete line of LCD, TFT and OLED displays.

OnFILTER, Inc.
3601-B Caldwell Drive
Soquel, CA 95073 USA
tel: 831-824-4052
fax: 206-350-7458
info@onfilter.com
http://www.onfilter.com

OPHIR RF
5300 Beethoven Street
Los Angeles, CA 90066 USA
tel: 310-306-5556
fax: 310-821-7413
sales@ophirrf.com
http://www.ophirrf.com

Orbel Corporation
2 Danforth Drive
Easton, PA 18045 USA
tel: 610-829-5000
fax: 610-829-5050
sales@orbel.com
http://www.orbel.com

Oxford University Technology
CPD Centre, 1 Wellington Square
Oxford, Oxfordshire OX1 2JA United Kingdom
tel: 44 1865 286958
technology@conted.ox.ac.uk
http://www.conted.ox.ac.uk/courses/professional/staticdetails.php?course=202

Parker Hannifin, Chomerics Div
77 Dragon Court
Woburn, MA 01801 USA
tel: 781-935-4850
fax: 781-933-4318
chomailbox@parker.com
http://www.chomerics.com

Okaya Electric is a manufacturer of Noise and Surge Suppression devices. Okaya is the world’s leading manufacturer of X-capacitors and a leading manufacturer of Surge suppressors including AC and DC Power line, Electrostatic and Network line and SMD TVSS gas tubes. Other products include EMI-RFI Filters, Single Phase, Three Phase, IEC Inlet and PCB Style, Lightning arrestors, Gas Discharge Tubes, Spark Quenchers and High Pulse and Snubber Caps. Okaya also offers a complete line of LCD, TFT and OLED displays.
Panashield, Inc.
185R West Norwalk Road
Norwalk, CT 06850-4312 USA
tel: 203-866-5888
fax: 203-866-6162
help@panashield.com
http://www.panashield.com
Panashield provides facility solutions for global electromagnetic compatibility (EMC), by creating controlled electromagnetic environments necessary for testing electronic devices in today’s world. These controlled environments include radio-frequency (RF) shielded enclosures and RF/Anechoic test chambers, to meet global RF/EMC standards for Immunity and Emissions testing of electronic products; Free Space Simulation for Antenna and RCS measurements; Industrial and Medical RF protection; TEMPEST Security; and HEMP protection.
Panashield Inc. was founded by a team of knowledgeable personnel in the RF and RF/Anechoic industry in 1989, and is located in Norwalk, Connecticut. Panashield, Inc. is a Small Business Concern and a Woman-Owned business. Panashield (UK) Ltd. was established in Surrey, England in 1996 to provide direct service to the European market.

Product Safety Consulting
605 Country Club Drive
Bensenville, IL 60106 USA
tel: 630-238-0188
toll free: 877-804-3066
fax: 630-238-0269
info@productsafetyinc.com
http://www.productsafetyinc.com
Product Safety Consulting, now in its 25th year, has been providing product developers and manufacturers with expert advice and testing services, so they confidently secure product safety and regulatory compliance in the least time, and for the least expense (UL, ETL, CSA, CE, etc.). From consumer products to lighting fixtures, to motor controllers and medical devices, they have helped more than 3,000 customers in over 35 countries. No other consultancy can this breadth of experience. They’ve trademarked Design for Safety Approvals – DFS™. Get them involved early in your process and you’ll benefit with smoother, faster and less expensive Certification projects. Some of their clients include Colgate Palmolive, Hewlett-Packard, Johnson Controls, Acuity Lighting, EcoLab, Hamilton Sundstrand, Bissel, SC Johnson & Son, Dell, and many more.

Pearson Electronics, Inc
4009 Transport Street
Palo Alto, CA 94303 USA
tel: 650-494-6444
fax: 650-494-6716
sales@pearsonelectronics.com
http://www.pearsonelectronics.com

Polyonics
28 Industrial Park Drive
Westmoreland, NH 03467 USA
tel: 603-352-1415
fax: 603-352-1936
info@polyonics.com
http://www.polyonics.com

Phoenix Technical Group
PO Box 522
Cary, NC 27512 USA
tel: 919-535-3662
askus@phoenixtechnicalgroup.com
http://www.phoenixtechnicalgroup.com

Power Dynamics, Inc
145 Algonquin Parkway
Whippany, NJ 07981 USA
tel: 973-560-0019
fax: 973-560-0076
sales@powerdynamics.com
http://www.powerdynamics.com

Protective Industrial Polymers
7875 Bliss Parkway
North Ridgeville, OH 44039 USA
tel: 440-327-0015
toll free: 866-361-3331
fax: 440-353-0549
info@protectcpoly.com
http://www.protectcpoly.com
http://www.inhibistat.com
A facility’s flooring plays a vital role in the success of any robust ESD-Control program. Protective Industrial Polymers is dedicated to providing fully compliant, turn-key ESD flooring solutions that provide peace of mind both today and in the future. PIP’s InhibiStat line of polymer ESD-Control Flooring Systems are designed to meet and exceed current performance standards, assuring the end-user the most comprehensive ESD flooring product range, combined with expert consultation, superior installation, certification and ongoing compliance support.

PRISMIER
10216 Werch Drive, Suite 118
Woodridge, IL 60517 USA
tel: 630.592.4515
toll free: 877-804-3066
fax: 630-214-4099
mtummillo@prismier.com
http://prismier.com

Professional Testing
1601 North A.W. Grimes Boulevard, Suite B
Round Rock, TX 78665 USA
tel: 512-244-3371
toll free: 800-695-1077
fax: 512-244-1846
jmunsch@ptitest.com
http://www.ptitest.com

Prostat Corporation
1072 Tower Lane
Bensenville, IL 60106 USA
tel: 630-238-8883
fax: 630-238-9717
kbecker@prostatcorp.com
http://www.prostatcorp.com
Pulver Laboratories Inc.
320 North Santa Cruz Avenue
Los Gatos, CA 95030-7243 USA
tel: 408-399-7000
toll free: 800-635-3050
fax: 408-399-7001
Los.Gatos@PulverLabs.com
http://www.PulverLabs.com

Qualtest Inc.
5325 Old Winter Garden Road
Orlando, FL 32811 USA
tel: 407-313-4230
fax: 407-313-4234
chebda@qualtest.com
http://www.qualtest.com

Quell Corporation
5639 Jefferson NE
Albuquerque, NM 87109 USA
tel: 505-243-1423
fax: 505-243-9772
EESeal@Quell.US
http://www.eeseal.com

RABQSA International
600 N Plankinton Avenue
Milwaukee, WI 53201 USA
tel: 414-272-3937
toll free: 888-722-2440
mrehm@rabqsa.com
http://www.rabqsa.com

Radiometrics Midwest Corp.
12 East Devonwood
Romeoville, IL 60446 USA
tel: 815-293-0772
fax: 815-293-0820
info@radiomet.com
http://www.radiomet.com

Raymond EMC Enclosures Ltd.
5185 Dolman Ridge Road
Ottawa, ON K1C 7G4 Canada
tel: 613-841-1663
toll free: 800-362-1495
fax: 613-841-0456
sales@raymondemc.ca
http://www.raymondemc.ca

Reliant EMC LLC
6501 Crown Boulevard, Suite 106A9
San Jose, CA 95120 USA
tel: 408-600-1472
bruce@reliantemc.com
http://www.reliantemc.com
Reliant EMC offers World Class turn-key systems for EMC and RF Emissions and Immunity testing. By applying proven engineering principles to create value-added EMC solutions for our customers; Reliant EMC becomes your top source for CE and FCC, Automotive, Solar MIL and Aerospace Electromagnetic Compliance (EMC). Our product line includes Test Cells, Antennas, Filters, LISNs, Analyzers, Synthesizers, RF-Amplifiers, Calibrators and Comb/Noise Generators. Based in San Jose, California, Reliant EMC provides expert advice on test requirements and products. Reliant EMC exclusively distributes products from York EMC, Laplace Instruments, Spitzenberger & Spies and OnFILTER. For additional information, visit our website at www.ReliantEMC.com.

Restor Metrology
921 Venture Avenue
Leesburg, FL 34748 USA
tel: 877-220-5554
eric.egler@restormetrology.com
http://www.restormetrology.com

Rigol Technologies
7401 First Place, Suite N
Oakwood Village, OH 44146 USA
tel: 877-474-4651
fax: 440-232-4488
sales@rigoltech.com
http://www.rigoltech.com

RMV Technology Group, LLC
NASA Ames Research Park
Moffett Field, CA 94035 USA
tel: 650-964-4792
fax: 650-964-1268
bob@esdrmv.com
http://www.esdrmv.com

Rohde & Schwarz, Inc.
8661 A Robert Fulton Drive
Columbia, MD 21046 USA
tel: 410-910-7800
toll free: 888-TEST-RSA
fax: 410-910-7801
info@rsa.rohde-schwarz.com
http://www.rohde-schwarz.com

RTF Compliance
22431 Antonio Parkway #B160-698
Rancho Santa Margarita, CA 92688 USA
tel: 949-813-6095
fax: 949-271-4016
randy.flinders@rtfcomp.com
http://www.rtfcomp.com

RTP Company
580 East Front Street
Winona, MN 55987 USA
tel: 507-474-5472
toll free: 800-433-4787
fax: 507-454-2041
rtp@rtpcompany.com
http://www.rtpcompany.com
Vendor Directory

Schlegel Electronic Materials, Inc.
1600 Lexington Avenue, Suite 236A
Rochester, NY 14606 USA
tel: 585-643-2010
toll free: 800-204-0863
fax: 585-427-7216
haydee.dibble@schlegelemi.com
http://www.schlegelemi.com

Schurter Inc.
447 Aviation Boulevard
Santa Rosa, CA 95403 USA
tel: 707-636-3000
toll free: 800-848-2600
fax: 707-636-3033
info@schurterinc.com
http://www.schurterinc.com

Select Fabricators, Inc.
5310 North Street, Building 5
Canandaigua, NY 14424-0119 USA
tel: 585-393-0650
toll free: 888-599-6113
fax: 585-393-1378
contactus@select-fabricators.com
http://www.select-fabricators.com

SGS Consumer Testing Services
620 Old Peachtree Road, Suite 100
Suwanee, GA 30024 USA
tel: 770-570-1800
toll free: 800-777-TEST (8378)
fax: 770-277-1240
uscts.inquiries@sgs.com
http://www.us.sgs.com/cts

SIEMIC
775 Montague Expressway
Midpitas, CA 95035 USA
tel: 408-526-1188
fax: 408-526-1088
mark.maynard@siemic.com
http://www.siemic.com

SILENT Solutions LLC
10 Northern Boulevard, Suite 1
Amherst, NH 03031 USA
tel: 603-578-1842 x203
fax: 603-578-1843
lhill@silent-solutions.com
http://www.silent-solutions.com

Slaughter Company, Inc.
28105 N. Keith Drive
Lake Forest, IL 60045 USA
tel: 847-932-3662
toll free: 800-504-0055
jimk@hipot.com
http://www.hipot.com

Solar Electronics Company
10866 Chandler Boulevard
North Hollywood, CA 91601 USA
tel: 818-755-1700
toll free: 800-952-5302
fax: 818-755-0078
sales@solar-emc.com
http://www.solar-emc.com

Southwest Research Institute
6220 Culebra Road, P.O. Drawer 28510
San Antonio, TX 78228-0510 USA
tel: 210-522-2122
fax: 210-522-3496
bd@swri.org
http://www.swri.org

Spectrum EMC Consulting, LLC
3238 Black Oak Drive
Eagan, MN 55121 USA
tel: 651-688-0634
dzimmerman@spectrumemc.com
http://www.spectrumemc.com

Spira Manufacturing Corporation
12721 Saticoy Street South
North Hollywood, CA 91605 USA
tel: 818-764-8222
toll free: 888-98-SPIRA
fax: 818-764-9880
sales@spira-emi.com
http://www.spira-emi.com

Sprinkler Innovations
95 Ledge Road, Suite 4
Seabrook, NH 03874 USA
tel: 978-375-2302
toll free: 800-850-6692
fax: 603-468-1031
jbeers@sprinklerinnovations.com
http://www.sprinklerinnovations.com

SE Laboratories
1065 Comstock Street
Santa Clara, CA 95954 USA
tel: 408-727-3286
toll free: 800-939-CALS
fax: 408-988-6186
sales@selabs.com
http://www.selabs.com

Founded in 1978, SE Laboratories is the leading independent metrology lab in the Western US, committed to providing the industry with quality test equipment calibration, repair, and preventative maintenance. Since its founding, SE Laboratories has grown with the demands of the market. Today we offer services across a wide range of equipment types in the compliance market.

Sabritec
17550 Gillette Avenue
Irvine, CA 92614 USA
tel: 949-250-1244
fax: 949-250-1009
sdurr@sabritec.com
http://www.sabritec.com

Same Page Publishing, LLC
531 King Street, Suite 5
Littleton, MA 01460 USA
tel: 978-486-4684
fax: 978-486-4691
info@incompliancemag.com

SAS Industries, Inc.
939 Wading River Manor Road
Manville, NY 11949 USA
tel: 631-727-1441 x302
fax: 631-727-1387
mstecis@sasindustries.com
http://www.sasindustries.com

Schaffner EMC Inc.
52 Mayfield Avenue
Edison, NJ 08837 USA
usasales@schaffner.com
http://www.schaffnerusa.com

Founded in 1978, SE Laboratories is the leading independent metrology lab in the Western US, committed to providing the industry with quality test equipment calibration, repair, and preventative maintenance. Since its founding, SE Laboratories has grown with the demands of the market. Today we offer services across a wide range of equipment types in the compliance market.

Sabritec
17550 Gillette Avenue
Irvine, CA 92614 USA
tel: 949-250-1244
fax: 949-250-1009
sdurr@sabritec.com
http://www.sabritec.com

Same Page Publishing, LLC
531 King Street, Suite 5
Littleton, MA 01460 USA
tel: 978-486-4684
fax: 978-486-4691
info@incompliancemag.com

SAS Industries, Inc.
939 Wading River Manor Road
Manville, NY 11949 USA
tel: 631-727-1441 x302
fax: 631-727-1387
mstecis@sasindustries.com
http://www.sasindustries.com

Schaffner EMC Inc.
52 Mayfield Avenue
Edison, NJ 08837 USA
usasales@schaffner.com
http://www.schaffnerusa.com
Staticworx Flooring
124 Watertown Street
Watertown, MA 02472 USA
tel: 617-923-2000
toll free: 888-STATICWORX
fax: 617-923-2009
info@staticworx.com
http://www.staticworx.com

Stephen Halperin & Associates
1072 Tower Lane
Bensenville, IL 60106 USA
tel: 630-238-8883
fax: 630-238-9717
kbecker@halperinassoc.com
http://www.halperinassoc.com

Sunol Sciences Corporation
6780 Sierra Court, Suite R
Dublin, CA 94568 USA
tel: 925-833-9936
fax: 925-833-9059
emc@sunolsciences.com
http://www.sunolsciences.com

TDK-EPC Corporation
485B Route 1 South, Suite 200
Iselin, NJ 08830 USA
tel: 732-906-4327
toll free: 800-888-7728
joseph.pulomena@epcos.com
http://www.epcos.com

Tech-Etch
45 Aldrin Road
Plymouth, MA 02360 USA
tel: 508-747-0300
fax: 508-746-9639
sales@tech-etch.com
http://www.tech-etch.com

TechDream, Inc.
19925 Stevens Creek Boulevard
Cupertino, CA 95014 USA
tel: 408-800-7362
US_Sales@tech-dream.com
http://www.tech-dream.com

Technology Forecasters Inc.
2000 Santa Clara Avenue
Alameda, CA 94105 USA
info@techforecasters.com
http://www.techforecasters.com

TDK Corporation
1101 Cypress Creek Road
Cedar Park, TX 78613 USA
tel: 512-258-9478
fax: 512-258-0740
info@tdkrf.com
http://tdkrfsolutions.com
TDK RF Solutions is a world leader in the design, development, and manufacture of technical solutions for the electromagnetic compatibility testing industry.
We offer a complete range of solutions, including automated test systems, TDK anechoic chambers, software antennas and a wide range of test products. We call it Total System Technology.

Tektronix, Inc.
14150 SW Karl Braun Drive
Beaverton, OR 97077 USA
toll free: 800-833-9200
email-marketing@tektronix.com
http://www.tek.com

Telcron LLC
Bloomfield, NJ 07003 USA
info@telcron.net
http://www.telcron.net

Test Equipment Connection
30 Skyline Drive
Lake Mary, FL 32746 USA
tel: 407-804-1299
toll free: 800-615-8378
fax: 407-804-1277
business@testequipmentconnection.com
http://www.TestEquipmentConnection.com

Test Site Services Inc
30 Birch Street
Milford, MA 01757 USA
tel: 508-962-1662
fax: 508-634-0388
slp5@verizon.net
http://www.testsiteservices.com

TestingPartners.com
8440 East Washington Street #207
Chagrin Falls, OH 44023 USA
tel: 862-243-2329
info@testingpartners.com
http://www.testingpartners.com

Texas Spectrum Electronics
120 Regency Drive
Wylie, TX 75098 USA
tel: 972-296-3699
fax: 972-296-7881
sales@texasspectrum.com
http://www.texasspectrum.com

Thermo Fisher Scientific
200 Research Drive
Wilmington, MA 01887 USA
tel: 978-275-0800 x2302
fax: 978-275-0850
william.obrien@thermofisher.com
http://www.thermo.com/esd
## TÜV Rheinland of North America

1300 Massachusetts Avenue  
Boxborough, MA 01719 USA  
tel: 1-TUV-RHEINLAND  
fax: 203-426-3293  
info@us.tuv.com  
http://www.us.tuv.com

## TÜV SÜD America Inc.

10 Centennial Drive  
Peabody, MA 01960 USA  
tel: 978-573-2500  
toll free: 800-888-0123  
fax: 978-977-0159  
info@tuvam.com  
http://www.TUVamerica.com

## UL Verification Services

25, South HuanShi Avenue  
Nansha District  
Guangzhou, 511453 China  
tel: 86-20-28667188  
jerry.mai@ul.com  
http://www.ul.com/verification

## THERMOTRON INDUSTRIES

291 Kollen Park Drive  
Holland, MI 49418 USA  
tel: 616-393-4580  
info@thermotron.com  
http://www.thermotron.com

## Trace Laboratories, Inc.

5 North Park Drive  
Hunt Valley, MD 21030 USA  
tel: 410-584-9099  
fax: 410-584-9117  
info@tracelabs.com  
http://www.tracelabs.com

## TREK, INC.

11601 Maple Ridge Road  
Medina, NY 14103 USA  
tel: 585-798-3140  
toll free: 800-FOR-TREK  
fax: 585-798-3106  
sales@trekinc.com  
http://www.trekinc.com

## Trace Laboratories, Inc.

5 North Park Drive  
Hunt Valley, MD 21030 USA  
tel: 410-584-9099  
fax: 410-584-9117  
info@tracelabs.com  
http://www.tracelabs.com

## UL Knowledge Services

333 Pfingsten Road  
Northbrook, IL 60062 USA  
tel: 888-503-5536  
ulknowledge@ul.com  
http://www.ulknowledge@ul.com

UL Knowledge Services is one of UL’s five strategic business units, providing training and advisory services designed to help make people and the companies they work for smarter, safer, more efficient and more effective. We recognize that knowledge creates new opportunities, better business results, a stronger workforce and a true sense of accomplishment. Through our services your organization can access first-hand, real-time, industry-critical information that not only covers UL Standards, but also addresses specific topics intended to help you create and/or install safe products, increase efficiency and realize improved speed to market.

## COMMITMENT. COMMUNITY. COMPLIANCE.

EMC / EMI • PRODUCT SAFETY • ESD • ENVIRONMENTAL

In Compliance is committed to the community of compliance engineering professionals who make up our readership.

You can turn to us as your #1 source for all your compliance news - in our magazine, at events and online.

Sign up for FREE subscriptions at www.incompliancemag.com/subscribe
UL
333 Pfingsten Road
Northbrook, IL 60062 USA
tel: 877-UL-HELPS (877-854-3577)
fax: 360-817-6278
cec.us@us.ul.com
www.ul.com/appliances
UL is a premier global independent safety science company with more than 118 years of history. Employing more than 10,000 professionals with customers in over 100 countries, UL has five distinct business units – Product Safety, Environment, Life & Health, Knowledge Services, to meet the expanding needs of our customers and to deliver on our public safety mission. For more information on UL’s family of companies and network of 95 laboratory, testing, and certification facilities, go to UL.com.

Universal Shielding
20 West Jefryn Boulevard
Deer Park, NY 11729 USA
tel: 631-667-7900
toll free: 800-645-5578
fax: 631-667-7912
info@universalshielding.com
http://www.universalshielding.com
Universal Shielding Corp. was established in 1972 and is a pioneer in providing pre-fabricated shielded enclosures for the military, commercial, and medical industries. USC has the capabilities to provide a shielded enclosure of any size; from the smallest prefabricated unit for an R & D lab to the largest and most complex installations for a computer or communications center. USC offers a full range of RF Shielded Enclosures, RF Shielded Doors, RF Shielded Cabinets, Exterior Doors and RF Shielding Accessories.

Vanguard Products Corporation
87 Newtown Road
Danbury, CT 06810 USA
tel: 203-744-7265
fax: 203-798-2351
sales@vanguardproducts.com
http://www.vanguardproducts.com

Vectawave Technology, Ltd.
Street. Cross Business Park
Newport, Isle of Wight PO30 5XW
United Kingdom
tel: 44 1983 821818
fax: 44 1983 532737
sales@vectawAvenueuco.uk
http://www.vectawAvenuecom

Vermillion, Inc.
4754 S. Palisade
Wichita, KS 67217 USA
tel: 305-968-5981
fax: 316-524-2011
bprice@vermillioninc.com
http://www.vermillioninc.com

VTI Vacuum Technologies, Inc.
1215 Industrial Avenue
Reedsburg, WI 53959 USA
tel: 608-524-9822
toll free: 800-482-1941
fax: 608-524-9722
VITIsales@vactecinc.com
http://www.vactecinc.com
VTI Vacuum Technologies Inc. supplies EMI/RFI/ESD Shielding and Form-In-Place Gasketing solutions for medical, defense, aerospace and industrial devices. VTI utilizes a vacuum deposition process for selectively shielding plastic electronic enclosures against electromagnetic interference, radio frequency interference and electrostatic discharge. The company robotically dispenses conductive and environmental Form-In-Place (FIP) Gaskets for sealing on plastic or metal components. VTI is an ISO 9001:2008 certified, ITAR compliant and veteran owned small business established in 1993.

Universal Shielding Corp. was established in 1972 and is a pioneer in providing pre-fabricated shielded enclosures for the military, commercial, and medical industries. USC has the capabilities to provide a shielded enclosure of any size; from the smallest prefabricated unit for an R & D lab to the largest and most complex installations for a computer or communications center. USC offers a full range of RF Shielded Enclosures, RF Shielded Doors, RF Shielded Cabinets, Exterior Doors and RF Shielding Accessories.

VERSCHN

Universal Shielding
20 West Jefryn Boulevard
Deer Park, NY 11729 USA
tel: 631-667-7900
toll free: 800-645-5578
fax: 631-667-7912
info@universalshielding.com
http://www.universalshielding.com

Universal Shielding Corp. was established in 1972 and is a pioneer in providing pre-fabricated shielded enclosures for the military, commercial, and medical industries. USC has the capabilities to provide a shielded enclosure of any size; from the smallest prefabricated unit for an R & D lab to the largest and most complex installations for a computer or communications center. USC offers a full range of RF Shielded Enclosures, RF Shielded Doors, RF Shielded Cabinets, Exterior Doors and RF Shielding Accessories.

VERSCHN

Universal Shielding
20 West Jefryn Boulevard
Deer Park, NY 11729 USA
tel: 631-667-7900
toll free: 800-645-5578
fax: 631-667-7912
info@universalshielding.com
http://www.universalshielding.com

Universal Shielding Corp. was established in 1972 and is a pioneer in providing pre-fabricated shielded enclosures for the military, commercial, and medical industries. USC has the capabilities to provide a shielded enclosure of any size; from the smallest prefabricated unit for an R & D lab to the largest and most complex installations for a computer or communications center. USC offers a full range of RF Shielded Enclosures, RF Shielded Doors, RF Shielded Cabinets, Exterior Doors and RF Shielding Accessories.

VERSCHN

Universal Shielding
20 West Jefryn Boulevard
Deer Park, NY 11729 USA
tel: 631-667-7900
toll free: 800-645-5578
fax: 631-667-7912
info@universalshielding.com
http://www.universalshielding.com

Universal Shielding Corp. was established in 1972 and is a pioneer in providing pre-fabricated shielded enclosures for the military, commercial, and medical industries. USC has the capabilities to provide a shielded enclosure of any size; from the smallest prefabricated unit for an R & D lab to the largest and most complex installations for a computer or communications center. USC offers a full range of RF Shielded Enclosures, RF Shielded Doors, RF Shielded Cabinets, Exterior Doors and RF Shielding Accessories.

VERSCHN

Universal Shielding
20 West Jefryn Boulevard
Deer Park, NY 11729 USA
tel: 631-667-7900
toll free: 800-645-5578
fax: 631-667-7912
info@universalshielding.com
http://www.universalshielding.com

Universal Shielding Corp. was established in 1972 and is a pioneer in providing pre-fabricated shielded enclosures for the military, commercial, and medical industries. USC has the capabilities to provide a shielded enclosure of any size; from the smallest prefabricated unit for an R & D lab to the largest and most complex installations for a computer or communications center. USC offers a full range of RF Shielded Enclosures, RF Shielded Doors, RF Shielded Cabinets, Exterior Doors and RF Shielding Accessories.
<table>
<thead>
<tr>
<th>Vendor</th>
<th>Address</th>
<th>Phone</th>
<th>Fax</th>
<th>Email</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>W. L. Gore &amp; Associates, Inc.</td>
<td>380 Starr Road, Landenberg, PA 19350 USA</td>
<td>tel: 610-388-1600</td>
<td>fax: 610-388-1685</td>
<td><a href="mailto:electronics.usa@wlgore.com">electronics.usa@wlgore.com</a></td>
<td><a href="http://gore.com">http://gore.com</a></td>
</tr>
<tr>
<td>Yazaki Testing Center</td>
<td>6800 N. Haggerty Road, Canton, MI 48187 USA</td>
<td>tel: 734-983-6012</td>
<td>fax: 734-983-6013</td>
<td><a href="mailto:scott@yazakiemc.com">scott@yazakiemc.com</a></td>
<td><a href="http://www.yazakiemc.com">http://www.yazakiemc.com</a></td>
</tr>
<tr>
<td>Washington Laboratories</td>
<td>7560 Lindbergh Drive, Gaithersburg, MD 20879 USA</td>
<td>tel: 301-216-1500</td>
<td>fax: 301-417-9069</td>
<td><a href="mailto:mikev@wll.com">mikev@wll.com</a></td>
<td><a href="http://www.wll.com">http://www.wll.com</a></td>
</tr>
<tr>
<td>WEMS Electronics</td>
<td>4650 West Rosecrans Avenue, Hawthorne, CA 90250-6898 USA</td>
<td>tel: 310-962-4410</td>
<td>fax: 310-644-5334</td>
<td><a href="mailto:jobrien@wems.com">jobrien@wems.com</a></td>
<td><a href="http://www.wems.com">http://www.wems.com</a></td>
</tr>
<tr>
<td>Wurth Electronics Midcom</td>
<td>121 Airport Drive, Watertown, SD 57201 USA</td>
<td>tel: 605-886-4385</td>
<td>toll free: 800-643-2661</td>
<td><a href="mailto:midcom@we-online.com">midcom@we-online.com</a></td>
<td><a href="http://www.we-online.com">http://www.we-online.com</a></td>
</tr>
<tr>
<td>Zero Ground LLC</td>
<td>3392 Hillside Court, Woodridge, IL 60517 USA</td>
<td>tel: 630-401-377-8389</td>
<td>toll free: 866-937-6463</td>
<td><a href="mailto:service@zero-ground.com">service@zero-ground.com</a></td>
<td><a href="http://www.dbzshield.com">http://www.dbzshield.com</a></td>
</tr>
<tr>
<td>Wyatt Technical Services LLC</td>
<td>56 Aspen Drive, Woodland Park, CO 80863 USA</td>
<td>tel: 719-310-5418</td>
<td>toll free: 877-443-9275</td>
<td><a href="mailto:ken@emc-seminars.com">ken@emc-seminars.com</a></td>
<td><a href="http://www.emc-seminars.com">http://www.emc-seminars.com</a></td>
</tr>
<tr>
<td>Zone Safe Solutions</td>
<td>1601 North A.W. Grimes Boulevard, Suite B, Round Rock, TX 78665 USA</td>
<td>tel: 775-622-0400</td>
<td><a href="mailto:info@zonesafesolutions.com">info@zonesafesolutions.com</a></td>
<td><a href="http://www.zonesafesolutions.com">http://www.zonesafesolutions.com</a></td>
<td></td>
</tr>
</tbody>
</table>

Visit INCOMPLIANCE Magazine's Online Directory: www.incompliance.com/directory
<table>
<thead>
<tr>
<th>Advertiser</th>
<th>Page</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 Minnesota EMC Event</td>
<td>195</td>
<td><a href="http://www.mnemcevent.com">www.mnemcevent.com</a></td>
</tr>
<tr>
<td>35th Annual EOS/ESD Symposium &amp; Exhibits</td>
<td>257</td>
<td><a href="http://www.esda.org">www.esda.org</a></td>
</tr>
<tr>
<td>A2LA</td>
<td>198</td>
<td><a href="http://www.A2LA.org">www.A2LA.org</a></td>
</tr>
<tr>
<td>Abstraction Engineering Inc</td>
<td>198</td>
<td><a href="http://www.abstractionengineering.com">www.abstractionengineering.com</a></td>
</tr>
<tr>
<td>Advanced Test Equipment Rentals</td>
<td>35, 199</td>
<td><a href="http://www.atecorp.com">www.atecorp.com</a></td>
</tr>
<tr>
<td>Agilent Technologies</td>
<td>11</td>
<td><a href="http://www.agilent.com/find/emc">www.agilent.com/find/emc</a></td>
</tr>
<tr>
<td>AMTA 2013</td>
<td>89</td>
<td><a href="http://www.amta2013.org">www.amta2013.org</a></td>
</tr>
<tr>
<td>André Consulting, Inc.</td>
<td>196</td>
<td><a href="http://www.andreconsulting.com">www.andreconsulting.com</a></td>
</tr>
<tr>
<td>AR</td>
<td>Gate Fold, 199</td>
<td><a href="http://www.arworld.us">www.arworld.us</a></td>
</tr>
<tr>
<td>ARC Technologies, Inc.</td>
<td>51</td>
<td><a href="http://www.arc-tech.com">www.arc-tech.com</a></td>
</tr>
<tr>
<td>Captor Corporation</td>
<td>199</td>
<td><a href="http://www.captorcorp.com">www.captorcorp.com</a></td>
</tr>
<tr>
<td>Chomerics, a division of Parker Hannfin</td>
<td>79, 199</td>
<td><a href="http://www.chomerics.com">www.chomerics.com</a></td>
</tr>
<tr>
<td>Compliance Worldwide, Inc.</td>
<td>14/15, 189, 199</td>
<td><a href="http://www.cw-inc.com">www.cw-inc.com</a></td>
</tr>
<tr>
<td>CST of America</td>
<td>199</td>
<td><a href="http://www.cst.com">www.cst.com</a></td>
</tr>
<tr>
<td>Don Heirman Consultants, LLC</td>
<td>196</td>
<td><a href="http://www.donheirman.com">www.donheirman.com</a></td>
</tr>
<tr>
<td>Dutch Microwave Absorber Solutions (DMAS)</td>
<td>77</td>
<td><a href="http://www.dmas.eu">www.dmas.eu</a></td>
</tr>
<tr>
<td>E. D. &amp; D., Inc.</td>
<td>129, 200</td>
<td><a href="http://www.ProductSafeT.com">www.ProductSafeT.com</a></td>
</tr>
<tr>
<td>Electronics Test Centre</td>
<td>47, 200</td>
<td><a href="http://www.etc-mpb.com">www.etc-mpb.com</a></td>
</tr>
<tr>
<td>EM Test USA</td>
<td>83, 200</td>
<td><a href="http://www.emtest.com">www.emtest.com</a></td>
</tr>
<tr>
<td>ETS-Lindgren</td>
<td>16/17, C3, 200</td>
<td><a href="http://www.ets-lindgren.com">www.ets-lindgren.com</a></td>
</tr>
<tr>
<td>Fair-Rite Products Corp., Inc.</td>
<td>93</td>
<td><a href="http://www.fair-rite.com">www.fair-rite.com</a></td>
</tr>
<tr>
<td>Go Global Compliance, Inc.</td>
<td>195</td>
<td><a href="http://www.goglobalcompliance.com">www.goglobalcompliance.com</a></td>
</tr>
<tr>
<td>Haefely EMC Technology</td>
<td>37, 200</td>
<td><a href="http://www.haefelyemc.com">www.haefelyemc.com</a></td>
</tr>
<tr>
<td>Henry Ott Consultants</td>
<td>9, 195, 196</td>
<td><a href="http://www.hottconsultants.com">www.hottconsultants.com</a></td>
</tr>
<tr>
<td>Hoolihan EMC Consulting</td>
<td>196</td>
<td><a href="http://www.emcxpert.com">www.emcxpert.com</a></td>
</tr>
<tr>
<td>HV TECHNOLOGIES, Inc.</td>
<td>3, 18/19, 200</td>
<td><a href="http://www.hvtechnologies.com">www.hvtechnologies.com</a></td>
</tr>
<tr>
<td>IEEE EMC 2013 Symposium</td>
<td>55</td>
<td><a href="http://www.emc2013.org">www.emc2013.org</a></td>
</tr>
<tr>
<td>IEEE Symposium on Product Compliance Engineering</td>
<td>131</td>
<td><a href="http://www.psessymposium.org">www.psessymposium.org</a></td>
</tr>
<tr>
<td>Intermark USA, Inc.</td>
<td>95</td>
<td><a href="http://www.intermark-usa.com">www.intermark-usa.com</a></td>
</tr>
<tr>
<td>Interpower Corporation</td>
<td>81</td>
<td><a href="http://www.interpower.com">www.interpower.com</a></td>
</tr>
<tr>
<td>Kimmel Gerke Associates, Ltd.</td>
<td>197</td>
<td><a href="http://www.emiguru.com">www.emiguru.com</a></td>
</tr>
</tbody>
</table>
35th Annual EOS/ESD Symposium & Exhibits

September 8-13, 2013
Rio All Suites, Las Vegas, NV

Benchmark your companies operation against the practices of other companies. Solve business challenges in Controlling ESD by Networking with other ESD professionals and industry experts to learn best practices and technology advances for ESD Control.

Join ESD professionals from around the world for the latest information on controlling electrostatic discharge!

- Over 37 Tutorials with New or Revised classes!
- Technical Sessions
  Over 50 Exciting ESD Presentations. Workshops and Exhibits
  - For stimulating your ESD programs.
  - Exhibitors “Showcase” ESD technologies with 8 minute presentations during technical sessions.
  - Two “Year in Review” sessions of factory standards and device standards.

For more information please visit www.esda.org

Setting the Global Standards for Static Control!

EOS/ESD Association Inc. 7900 Turin Rd Bld 3 • Rome NY 13440
Phone 315-339-6937 • Fax 315-339-6793
info@esda.org • www.esda.org • Join our EOS/ESD Symposium Group on LinkedIn
## Advertiser Index

<table>
<thead>
<tr>
<th>Advertiser</th>
<th>Page</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCR Electronics, Inc.</td>
<td>57, 201</td>
<td><a href="http://www.lcr-inc.com">www.lcr-inc.com</a></td>
</tr>
<tr>
<td>Liberty Labs/World Cal Inc.</td>
<td>53</td>
<td><a href="http://www.liberty-labs.com">www.liberty-labs.com</a></td>
</tr>
<tr>
<td>Magnetic Shield Corporation</td>
<td>201</td>
<td><a href="http://www.magnetic-shield.com">www.magnetic-shield.com</a></td>
</tr>
<tr>
<td>MI Technologies</td>
<td>87</td>
<td><a href="http://www.mi-technologies.com">www.mi-technologies.com</a></td>
</tr>
<tr>
<td>Monroe Electronics</td>
<td>195</td>
<td><a href="http://www.monroe-electronics.com">www.monroe-electronics.com</a></td>
</tr>
<tr>
<td>Montrose Compliance Services, Inc.</td>
<td>197</td>
<td><a href="http://www.montrosecompliance.com">www.montrosecompliance.com</a></td>
</tr>
<tr>
<td>The MuShield Company, Inc.</td>
<td>49, 201</td>
<td><a href="http://www.mushield.com">www.mushield.com</a></td>
</tr>
<tr>
<td>Northeast Product Safety Society Vendors’ Night</td>
<td>195</td>
<td><a href="http://www.nepss.net/">www.nepss.net/</a></td>
</tr>
<tr>
<td>NTS</td>
<td>20/21, 73</td>
<td><a href="http://www.nts.com">www.nts.com</a></td>
</tr>
<tr>
<td>Oak-Mitsui Technologies</td>
<td>67</td>
<td><a href="http://www.faradflex.com">www.faradflex.com</a></td>
</tr>
<tr>
<td>Okaya Electric America, Inc.</td>
<td>201</td>
<td><a href="http://www.okaya.com">www.okaya.com</a></td>
</tr>
<tr>
<td>Panashield, Inc.</td>
<td>22/23, 65, 201</td>
<td><a href="http://www.panashield.com">www.panashield.com</a></td>
</tr>
<tr>
<td>Pearson Electronics, Inc.</td>
<td>63</td>
<td><a href="http://www.pearsonelectronics.com">www.pearsonelectronics.com</a></td>
</tr>
<tr>
<td>Professional Testing</td>
<td>24/25, 59, 202</td>
<td><a href="http://www.ptitest.com">www.ptitest.com</a></td>
</tr>
<tr>
<td>Quell Corporation</td>
<td>7, 202</td>
<td><a href="http://www.eeseal.com">www.eeseal.com</a></td>
</tr>
<tr>
<td>Radiometrics Midwest Corporation</td>
<td>91</td>
<td><a href="http://www.radiomet.com">www.radiomet.com</a></td>
</tr>
<tr>
<td>Reliant EMC LLC</td>
<td>202</td>
<td><a href="http://www.reliantemc.com">www.reliantemc.com</a></td>
</tr>
<tr>
<td>Rohde &amp; Schwarz GmbH &amp; Co.</td>
<td>5</td>
<td><a href="http://www.rohde-schwarz.com">www.rohde-schwarz.com</a></td>
</tr>
<tr>
<td>RTF Compliance</td>
<td>197</td>
<td><a href="http://www.rtfcomp.com">www.rtfcomp.com</a></td>
</tr>
<tr>
<td>Schlegel Electronic Materials Inc.</td>
<td>75</td>
<td><a href="http://www.schlegelemi.com">www.schlegelemi.com</a></td>
</tr>
<tr>
<td>Schurter Inc.</td>
<td>69</td>
<td><a href="http://www.schurterinc.com">www.schurterinc.com</a></td>
</tr>
<tr>
<td>Spira Manufacturing Corporation</td>
<td>28/29, 45, 202</td>
<td><a href="http://www.spira-emi.com">www.spira-emi.com</a></td>
</tr>
<tr>
<td>Sprinkler Innovations</td>
<td>39, 202</td>
<td><a href="http://www.sprinklerinnovations.com">www.sprinklerinnovations.com</a></td>
</tr>
<tr>
<td>TDK RF Solutions</td>
<td>202</td>
<td>tdkrfsolutions.com</td>
</tr>
<tr>
<td>Teseq</td>
<td>203, C4</td>
<td><a href="http://www.teseq.com">www.teseq.com</a></td>
</tr>
<tr>
<td>Tri-Mag, Inc.</td>
<td>85</td>
<td><a href="http://www.tri-mag.com">www.tri-mag.com</a></td>
</tr>
<tr>
<td>TÜV Rheinland of North America</td>
<td>26/27, 33, 203</td>
<td><a href="http://www.us.tuv.com">www.us.tuv.com</a></td>
</tr>
<tr>
<td>TÜV SÜD America Inc.</td>
<td>30/31, 41, 203</td>
<td><a href="http://www.TUVamerica.com">www.TUVamerica.com</a></td>
</tr>
<tr>
<td>UL LLC</td>
<td>203</td>
<td><a href="http://www.ul.com/appliances">www.ul.com/appliances</a></td>
</tr>
<tr>
<td>Universal Shielding Corporation</td>
<td>203</td>
<td><a href="http://www.universalshielding.com">www.universalshielding.com</a></td>
</tr>
<tr>
<td>Washington Laboratories Ltd.</td>
<td>61</td>
<td><a href="http://www.wll.com">www.wll.com</a></td>
</tr>
<tr>
<td>Wyatt Technical Services LLC</td>
<td>197</td>
<td><a href="http://www.emc-seminars.com">www.emc-seminars.com</a></td>
</tr>
</tbody>
</table>
ETS-U 2013 Class Schedule:

- **EMC Fundamentals**
  February 5 – 7, May 14 – 16
- **MIL-STD 461F**
  March 12 – 14, October 15 – 17
- **Overview of Radiated Immunity/Emissions Test Facilities**
  June 11 – 13
- **Wireless / OTA**
  September 16 – 20

Course Benefits:

- Classroom study with hands-on lab sessions
- Taught by experienced engineers
- Low student to instructor ratio
- Courses may qualify for CEU credit
- Course study guide included

Our training facilities include an A2LA accredited calibration lab, CTIA CATL, and NVLAP accredited acoustic lab.

For more information:
www.ets-lindgren.com/learning

---

**Experience Hands-On Learning in a Lab**

Get practical real-world training from experts!
NSG 3040 MULTIFUNCTION GENERATOR – GOOD THINGS COME IN SMALL PACKAGES

Small and smart, the NSG 3040 features a high-contrast 7” touchscreen color display and rotary wheel for quick input with appealing ease of operation. With its open modular architecture, the NSG 3040 is the ideal immunity test system for smaller engineering labs – with amazing capacities for demanding EMC testing companies and for easy integration into the production process. The electromagnetic pulses generated from this multipurpose unit are especially tailored for CE marking requirements and other national and international standards. Like its big brother, NSG 3060 (6.6 kV), the NSG 3040 also has a SD memory card where test files can be saved easily and expanded at any time.

NSG 3040 at a glance:
- Modular, expandable system
- Surge voltage to 4.4 kV
- EFT/Burst to 4.8 kV/1 MHz
- Dip/Interrupt to 16 A/260 VAC & DC
- Easy-to-operate 7” touchscreen color display
- Quickly launch tests from extensive Standards Library or User Test folders
- Parameters can be changed during test