Application Notes

- IEC-61000-4 Requirements
- Turn On Time Characteristics of Multilayer Varistor
- The Impact of ESD on Insulated Portable Equipment
- TransGuard Motor and Relay Application Study
- Multilayer Varistors in Automobile MUX Bus Applications

WHAT IS IEC 61000-4?

The International Electrotechnical Commission (IEC) has written a series of specifications, IEC 61000-4, which man- date the performance of all electronic devices in a variety of transient and incident RF conditions. This specification requirement resulted as part of Europe's move toward a single market structure and a desire to formalize and harmonize current member countries' requirements. As of January 1, 1996, all electronic and electrical items sold to Europe must meet IEC 61000-4 series specifications.

WHY IS IEC 61000-4 REQUIRED BY EUROPE?

The various regulatory agencies within Europe feel that the IEC 61000-4 series of specifications is necessary to insure acceptable performance of electronic equipment in a world filled with increasingly more Electromagnetic Interference - EMI. Furthermore, as electronic systems become more portable, and the transient susceptibility of semiconductors increases, government regulations are essential to maintain a minimum level of performance in all equipment. Europe is so serious about the problem that they require that equipment be certified via testing to meet IEC 61000-4 series specifications after 1/1/96 to avoid fines and prosecution.

HOW DO COMPANIES SELLING ELECTRONIC SYSTEMS MEET IEC 61000-4 PARTS 2-5 SPECIFICATIONS?

Companies and design engineers must now use protective circuits or devices to meet these requirements. First, a description of IEC 61000-4/2-6 is in order:

IEC 61000-4-2 ESD TESTING REQUIREMENTS

All equipment destined for Europe must be able to withstand 10 strikes of ESD waveforms with Tr < 1ns in contact discharge mode (preferred) at pre-selected points accessible during normal usage or maintenance. Testing shall be performed at one or more of four (4) severity levels, depending upon equipment category.

Level	Contact Discharge[1] Mode Test Voltage kV	Air Discharge Mode Test Voltage kV
1	2	2
2	4	4
3	6	8
4	8	15

61000-4-2 Test Conditions

1Preferred mode of testing due to repeatability.

WAVEFORM PARAMETERS

Level	Test Voltage Level kV	First Peak of Discharge Current Amps ± 10%	TR nS	30 nS Current Amps ± 30%	60 nS Current Amps ± 30%
1	2	7.5	0.7 -1	4	2
2	4	15	0.7 -1	8	4
3	6	22.5	0.7 -1	12	6
4	8	30	0.7 -1	16	8

Upon completion of the test, the system must not experience upset (data or processing errors) or permanent damage. The waveforms are to be injected at or along the DUT's body which is accessible in normal set-up and operation.

IEC 61000-4-3 ELECTROMAGNETIC COMPATIBILITY IMPACT TESTING (EMC)

This test is concerned with the susceptibility of equipment when subjected to radio frequencies of 27 MHz to 500 MHz. The system must be able to withstand three (3) incident radiation levels:

Level 1 1V/m field strength

Level 2 3V/m field strength

Level 3 10V/m field strength

Level X User defined > 10V/m field strength

The system must not experience upset (data or processing errors) or permanent errors.

IEC 61000-4-4 ELECTRICAL FAST TRANSIENT (EFT) TESTING

The EFT test is modeled to simulate interference from inductive loads, relay contacts and switching sources. It consists of coupling EFT signals on I/O parts, keyboard cables, communication lines and power source lines. The system, depending upon appropriate severity level, must be able to withstand repetition rates of 2.5 kHz to 5 kHz for ≥ 1 minute as follows:

Open Circuit Output Voltage/10%

	On Power Supply	On I/O, Signal, Data, Control lines
Level 1	0.5kV	0.25kV
Level 2	1kV	0.5kV
Level 3	2kV	1kV
Level 4	4kV	2kV

IEC 61000-4-5 UNIDIRECTIONAL POWER LINE SURGE TEST

The details of this specification for high energy disturbances are being addressed in several drafts under discussion within the EC at this time.

IEC 61000-4-6 CONDUCTED RF TEST FROM 9KHZ TO 80MHZ

The details of this specification for conducted broad band RF signals are being addressed in a first edition draft within the EC at this time.

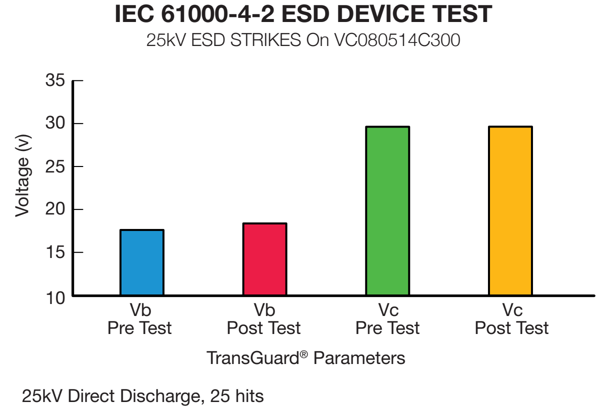
Designers have the option of using KYOCERA AVX TransGuards® to meet IEC 61000-4-2, 3 and 4.

In the case of IEC 61000-4-2 TransGuards® can be used to suppress the incoming Transient just like a Zener diode would. TransGuards®, however, exhibit bipolar characteristics, a faster turn-on-time (<1nS), a better repetitive strike capability and superior thermal stability to the Zener suppression device. Furthermore, TransGuards® are typically smaller and lighter when placed on SMT circuit boards. See Figure 1 for data illustrating IEC 61000-4-2 repetitive strike capability.

The TransGuards® effective capacitance allows the device to be used to meet IEC 61000-4-3 and 61000-4-4. The device's parallel capacitance can be used as effectively as a capacitor to block low level incident and conducted RF energy. If in the case of some levels of IEC 61000-4-3 and IEC 61000-4-4 when the intensity of pulse is greater than the device's breakdown capability it will then turn on and suppress via MOV means rather than capacitance (as in the small signal case). Effectiveness hinges upon the proper placement of the device within the PCB (which is usually easily accomplished since TransGuards® are so small).

SUMMARY

KYOCERA AVX TransGuards® are exceptionally suited to meet the defined portions of the IEC 61000-4 document. Experimentation is critical to proper choice and selection of devices to suppress 61000-4-3/4. Samples are available from your local sales representative.



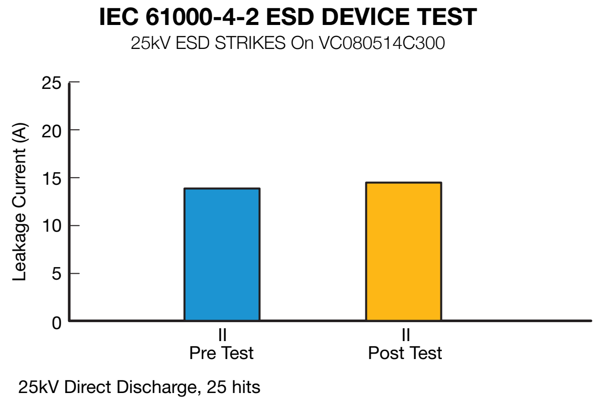


Figure 1

INTRODUCTION

Due to the growing importance of ESD immunity testing, as required by the EMC Directive, proper selection of voltage suppressor devices is critical. The proper selection is a function of the performance of the device under transient conditions. An ideal transient voltage suppressor would reach its “clamping voltage” in zero time. Under the conditions imposed by the 1991 version of IEC 61000-4-2, the actual turn-on-time must be less than one nanosecond to properly respond to the fast leading edge of the waveform defined in the standard.

It has been found during testing of transient suppressors that the response time is very closely dictated by the packaging of the device. Inductance that is present in the connection between the silicon die and the leads of the device creates an impedance in series with the suppressor device; this impedance increases the overall device response time, reducing the effectiveness of the suppressor device.

The purpose of this paper is to present the Turn on Time characteristics of Multilayer Varistors (MLVs) and to compare the MLV Turn on Time to that of various silicon transient voltage suppressors (SiTVs).

The Turn on Time of a transient voltage suppressor (TVS) is of growing importance since IEC 61000-4-2 now specifies ESD waveform with a rise time < 1 ns. Therefore, TVS’s must have a turn on time < 1 ns to effectively suppress ESD. In many, if not all, ESD suppression applications, TVS turn on time can be of more importance than absolute clamping voltage (Vc) of the TVS (assuming that the TVS clamping voltage is less than the damage voltage of the circuit or IC).

To measure the turn on time of today’s TVS’s, a broad cross section of MLVs and SiTVs were chosen. Only surface mount devices were chosen in order to best represent today’s TVS current usage/trends and to keep the test matrix to a reasonable level of simplicity. The following devices were tested:

TEST PROCEDURE

The TVS device under test (DUT) was placed on a PCB test fixture using SN60/40 solder. The test fixture (see Figure 1) was designed to provide an input region for an 8kV contact ESD discharge waveform (per IEC 61000-4-2 level 4 requirements). In addition, the fixture was designed to provide low impedance connections to the DUTs.

SMT MLV	SiTVS
	MA141WA
0603	BAV 99
0805	SOT 23 type
1206	SMB - 500W gull-wing SM device
1210	SMC - 1500W gull-wing SM device

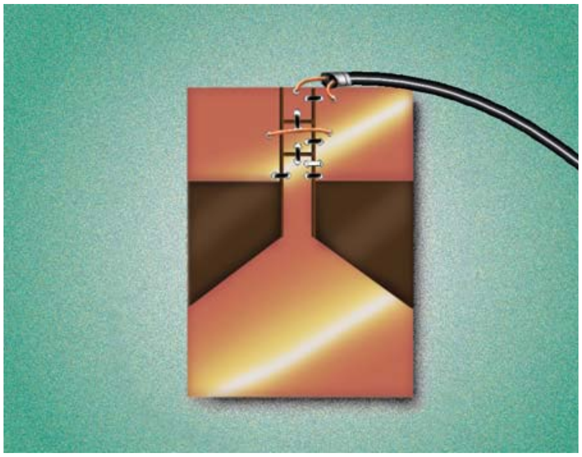


Figure 1. DUT Test Fixture

The ESD pulse was injected to the PCB from a Keytek minizap ESD simulator. Additionally, the fixture was to channel the ESD event to a storage oscilloscope to monitor the suppressor’s response. Six resistors were used on the PCB to provide waveshaping and an attenuated voltage to the storage scope (see Figure 2):

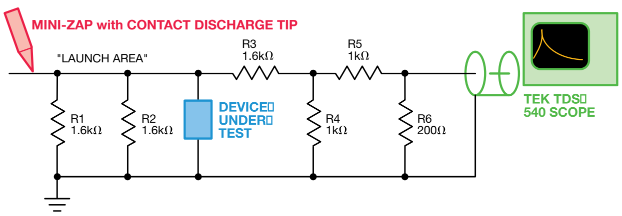


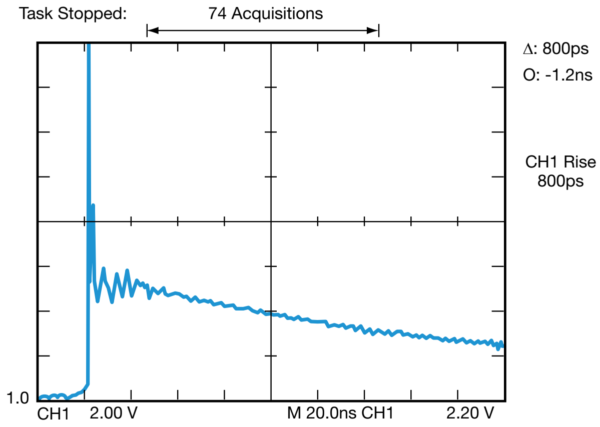
Figure 2. Schematic of Test Set Up

The functions of the resistors are as follows: The resistor values were adjusted in "open circuit" conditions to obtain best open circuit response.

R1, R2 (1.6K) - provide wave shaping during the ESD discharge event

R3 (1.6K), R4 (1K), R5 (1K) - Form a 60 dB Attenuator (1000:1 ratio) for input of Tektronix TDS 540 1 giga sample/second storage oscilloscope

R6 (200 Ω) - provides matching to the 50 ohm coax feeding the TDS 540 oscilloscope.



The open circuit response of the ESD test fixture with a 9kV ESD pulse is shown in Figure 3.

Figure 3. Open Circuit Response of Test Fixture to an Injected ESD Waveform

The graph shows the voltage attenuated by a factor of 1000, with a 800ps risetime for the ESD waveform (this agrees with typical data given by Keytek for equipment performance). It should be noted that only the positive polarity was tested. Prior testing showed turn on time was not dependent upon waveform polarity (assuming that DUTs are bidirectional).

TEST RESULTS

MLV TURN ON TIME TRANSGUARDS®

The turn on time test results for KYOCERA AVX TransGuards® showed that all case sizes were capable of a sub-nanosecond turn on response. This corresponds favorably with the calculated turn on time of less than 1 ns. Specific performance data follows:

TransGuard®	
CASE SIZE	TURN ON SPEED
0603	< 0.7 ns
0805	< 0.9 ns
1206	< 0.9 ns
1210	< 0.8 ns

TVS TURN ON TIME

Test results for SiTVs varied widely depending upon the physical size and silicon die mounting configuration of the device. The results agree with several SiTVs manufacturers papers indicating that the absolute response from the silicon die could be < 1 ns. However, when the die is placed in a package, the turn on time delay increases dramatically. The reason for this is the series inductance of the SiTVs packaging decreases the effective response time of the device. Reports of 1-5 ns are frequently referred to in SiTVs manufacturers publications. Further, the turn on times for SiTVs vary dramatically from manufacturer to manufacturer and also vary within a particular manufacturers lot. The data provided in the following table generally agreed with these findings:

SiTVS	
CASE SIZE	TURN ON SPEED
MA141WA	0.8ns
BAV 99	0.9ns to 1.2ns
SOT 23 Type	0.8ns
SMB	1.5ns to 2.2ns
SMC	1.5ns to 3ns

SUMMARY

This test confirms calculations that show that KYOCERA AVX TransGuards® have a true sub-nanosecond turn on time. Although the silicon die of a SiTVs has a sub-nanosecond response, the packaged SiTVs typically has a response time much slower than a TransGuard®. If the two devices were directly compared on a single graph (see Figure 4), it could be shown that the TransGuard® diverts significantly more power than even the fastest SiTVs devices. Additionally, TransGuards® have a multiple strike capability, high peak inrush current, high thermal stability and an EMI/RFI suppression capability which diodes do not have.

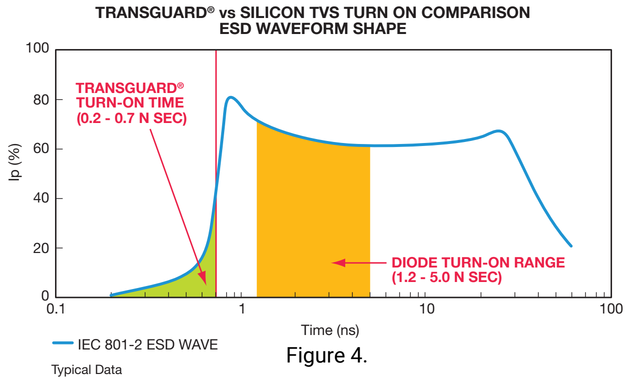


Figure 4.

Application Notes: The Impact of ESD on Insulated Portable Equipment

The purpose of this discussion is to recap the impact ESD has on portable, battery powered equipment. It will be shown that ESD can cause failures in “floating ground systems” in a variety of ways. Specifically, ESD induced failures can be caused by one or more of its complex components:

Predischarge - Corona Generated RF

Predischarge - E Field

Discharge - Collapsing E Field

Discharge - Collapsing H Field

Discharge - Current Injection...Voltage...Additional Fields

With this in mind it will be shown that the only way to insure equipment survivability to ESD is to use a Transient Voltage Suppressor (in addition to proper circuit layout, decoupling, and shielding).

In order to get a better understanding of what happens in an ESD event the charge developed by a human body should be defined. The ESD schematic equivalent of the human body model is shown in Figure 1. Typically, the charge developed on a person can be represented by a 150pF capacitor in series with a resistance of 330 ohms. The energy of an ESD waveform generated from this model is Q = 1/2 CV2 where Q = total energy in Joules, C = capacitance of the human body model in farads and V = charging voltage in volts.

Voltages can be as high as 25 kV, however typical voltages seen are in the 8 to 15 kV regions.

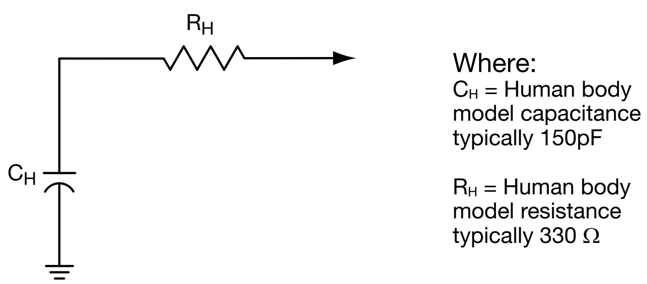


Figure 1. Human Body Model

PREDISCHARGE E FIELD FAILURES

Now that we have a definition of the basic ESD human body model we can discuss the predischarge E field failure mode.

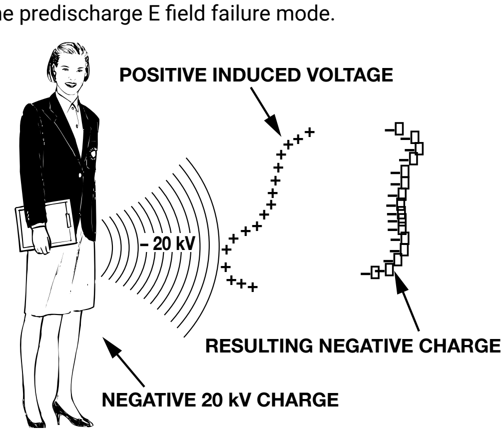


Figure 2. Pre-Discharge Scenario

In the predischarge scenario (Figure 2) a human charged to −20 kV may approach a battery powered “system” on a table. As the person reaches toward the system electrostatics dictate that the system will have an equal and opposite charge on the system’s surface nearest to the person. SInce the system we are approaching is isolated from ground, the charge is only redistributed among the device. (If the system were grounded a current would be generated by the loss of electrons to ground. The system would then become positive relative to ground). The rate of approach of the human body model affects the charging current to a small extent. However, most importantly, it is the electrostatic field and the unequal voltages which developed across the equipment that cause the destruction of components within the system. In general, unprotected IC’s (particularly CMOS) are susceptible to damage due to induced E field voltages. This problem is further complicated by the device type and complexity and the fact that the breakdown voltage of a generic IC will vary greatly from manufacturer to manufacturer (Figure 3). This brief discussion should be adequately convincing that electrostatically induced E field can impact system reliability. IC protection can be achieved by placing a transient suppressor on the most susceptible pins of the sensitive IC’s (e.g., Vcc and I/O pins, etc.).

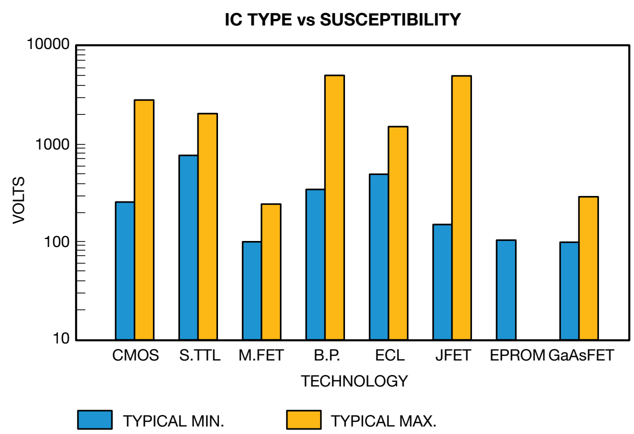


Figure 3. IC Type E Field Susceptibility

CONTACT DISCHARGE FAILURES

As the charged person gets closer to the system, the situation is more complex. First a much more detailed human body model is needed to represent the complex transmission line which will transport energy to the system (see Figure 4). In this discussion we will only consider the case of a single contact discharge. In the real world, however, multiple discharges will likely occur (possibly caused by a person’s hand reacting to an ESD spark and then touching the system again, etc.).

In contact discharge, when a charged person approaches the system, E fields are induced. As the person gets closer to the system, the field intensity becomes greater, eventually reaching a point large enough to draw an arc between the person and the system. In contrast to the noncontrast

E field example, the speed of approach is of great importance in the contact discharge model. A fast approach causes a more intensive discharge and faster current rise times and peaks.

The model shown on Figure 4 can be broken up into 4 sections for the sake of simplification. The first section is the human body model input voltage. This section is identical to the simplified human body model shown in Figure 1.

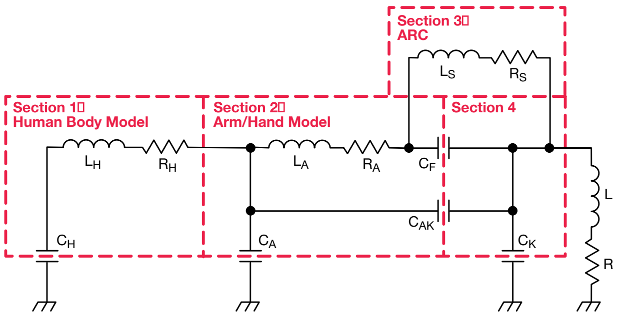
Section 2 takes into account how the human body model gets the energy to the system. This section considers the inductance, resistance and capacitance of the human's arm and finger and its capacitance relative to ground and the system.

The third section is the inductance and resistance of the arc which is created as section 2 approaches the system (Section 4).

Section four is the system itself.

The combination of the capacitances and inductances in these sections form a complex network of LC tank circuits which will inject a variety of waveforms (transients) into the system. These waveforms will range in frequency from very high (5 GHz) to high (100 MHz) to low (20-50 MHz) plus a variety of under damped and over damped waveforms.

Finally, in addition to current/voltage injection occurring as a result of the discharge, there will be collapsing E and H fields and significant high frequency RF waveforms. Many times these waveforms propagate into shielded equipment and cause system/device failures.



Where: C_H = Lumped capacitance between the human body and earth
R_H = Lumped resistance of the human body
L_H = Lumped inductance of the human body
C_A = Lumped capacitance between the person's arm and earth
C_{AK} = Lumped capacitance between the person's arm (and near portions of the body) and the keyboard
R_A = Lumped resistance of the person's arm's discharge path
L_A = Lumped inductance of the person's arm's discharge path
C_F = Capacitance between person's finger, hand, and the keyboard
C_K = Lumped capacitance keyboard to earth
R_K = Lumped resistance of the keyboard earth ground path
L_K = Lumped inductance of the keyboard earth ground path

Figure 4. Contact Discharge Model

SUMMARY

Designers may be inclined to think that E field variation due to near field electrostatics (as in the person being close to the system but not touching it) can be eliminated by shielding. This is usually not the case because it is difficult to get a tight columbic shield around internal circuitry without incurring significant additional manufacturing costs. Additionally, the shielding will likely have seams, ventilation holes, or I/O ports which represent a significant portion of a wavelength (at 5 GHz). Therefore, E fields and corona generated RF can be a problem. Finally, if the system has I/O connectors, keyboards, antennas, etc., care must be taken to adequately protect them from direct/indirect transients. The most effective resolution is to place a TransGuard® as close to the device in need of protection as possible. These recommendations and comments are based upon case studies, customer input and Warren Boxleitner's book Electrostatic Discharge and Electronic Equipment - A Practical Guide for Designing to Prevent ESD Problems.

PURPOSE

A significant number of end customers have experienced failures of circuitry in and around low voltage relays and motors. Additionally, EMI problems have been associated with running motors.

This study is aimed at evaluating how TransGuards® can reduce EMI from running motors and clamp transients generated from relays and motors during power off.

DESCRIPTION

Three different motors and two different relays were chosen to represent the wide range of possible devices used by designers. Device choices were as follows:

MOTORS

Cramer	8001 series Geared Motor 12V, 30rpm (4800 RPM armature speed) 170ma Start/Run Torque 30oz
Comair	Rotron DC Biscut Fan - 24V, 480ma
Comair	Rotron DC Biscut Fan - 12V, 900ma

RELAYS

Potter and Brumfield	24V Relay 1⁄3 HP 120V AC, 10A 240 VAC Rating
Potter and Brumfield	12V Relay 1⁄3 HP 120V AC, 10A 240 VAC Rating

A Tektronix TDS 784A four channel 1GHz 4G S/s digitizing storage scope was used to capture the -1⁄2 LI2 transient peak from the relays and motors.

A x10 probe was connected to the scope and one leg of the relay/motor coil; the probe's ground was connected to the other relay coil/motor wire. The scope was triggered on the pulse and waveforms printed.

When suppression was introduced into the circuit, it was placed directly on the relay coils/motor lead wires. The axial TransGuard® and capacitors had a 19mm (3⁄4") total lead length in each case. Upon careful consideration, it was determined that this was a fairly common lead length for such applications.

SUMMARY

GEARED MOTOR

The Cramer geared motor was tested while running (under load) to determine its "on state" noise as well as under loaded turn off conditions. Both TransGuards® and ceramic capacitors were tested to determine the level of protection they offer.

A 14V axial TransGuard® provided the best protection during running and turn off. The VA100014D300 TransGuard® cut the 60V unprotected turn off voltage spike to 30V. It also cut the on state noise to 4.0V pk-pk due to its internal capacitance. The following is a summary of measured voltages (scope traces are shown in Figures 1, 1A, 2, 2A).

Test Condition	Transient without Protection	Transient with .1μF cap	Transient with .01μF cap	Transient with 14v TransGuard®
Geared motor at turn off	60V	32V	48V	30V
Geared motor during running	12V pk-pk	4.0V pk-pk	4.0V pk-pk	4.0V pk-pk

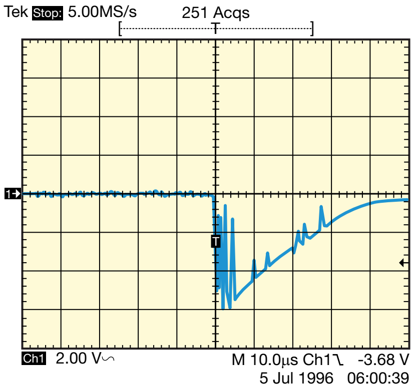


Fig. 1. Geared Motor Transient at Turnoff without protection 60 V Gear Motor 20 V/Division

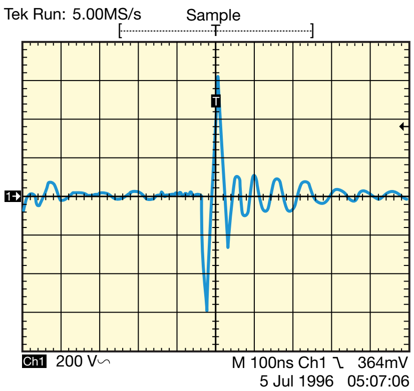


Fig. 2. Geared Motor Running noise without protection 12 V pk-pk 2 V/ Division

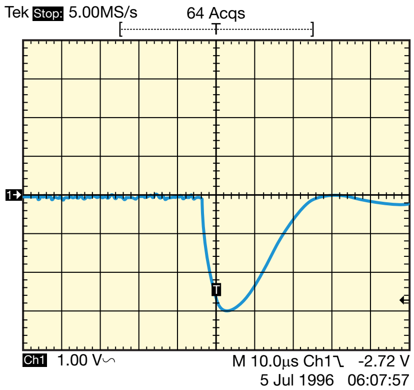


Fig. 1A. Geared Motor Transient at Turnoff with 14 V TransGuard® 30 V 10 V/Division

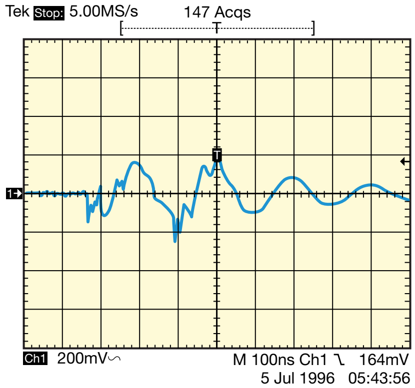


Fig. 2A. Geared Motor Running with 14 V TransGuard® 4 V pk-pk 2 V/ Division

BISCUT FAN

The Comair 24V and 12V biscut fans were tested only for transients at turn off. Results of those tests are shown in the table at the right (as well as slope traces 3, 3A, 4, 4A).

Motor Type	Transient without Protection	Transient with .1μF cap	Transient with .01μF cap	Transient with 14v TransGuard®
24V Fan	165V	120V	140V	65V(1)
12V Fan	60V	52V	64V	30V(2)

(1) VA100030D650 TransGuard® / (2) VA100014D300 TransGuard®

Fig. 3. 24 V Biscut Fan without protection 165 V Biscut 50 V/ Division

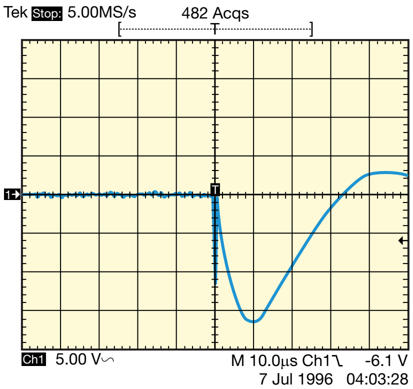


Fig. 3A. 24 V Biscut Fan with 30 V TransGuard® 65 V 50 V/Division

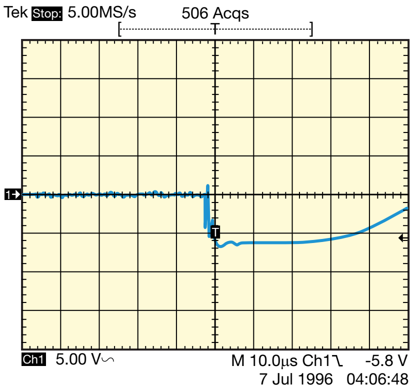


Fig. 4. 12 V Biscut Fan without protection 60 V 20 V/Division

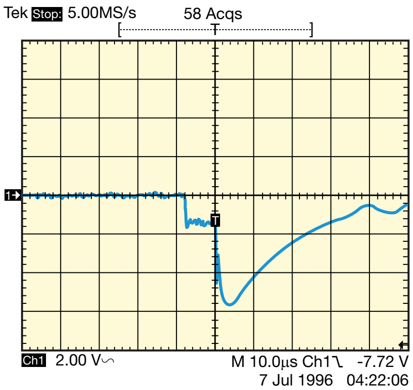
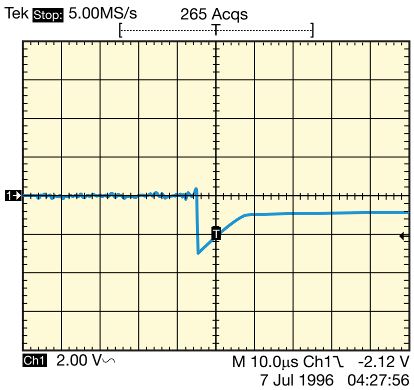


Fig. 4A. 12 V Biscut Fan with 14 V TransGuard® 30 V 20 V/Division



RELAYS

The 12V and 24V relays were tested only for transients at turn off. The results of those tests are shown in the table at the right (as well as scope traces 5, 5A, 6, 6A).

Relay Type	Transient without Protection	Transient with .1µF cap	Transient with .01µF cap	Transient with 14v TransGuard®
24V	44V	24V	28V	28V(3)
12V	105V	63V	100V	30V(4)

(3) VA100026D580 TransGuard® / (4) VA100014D300 TransGuard®

Fig. 5. 24 V Relay Transient without protection 44 V 10 V/Division

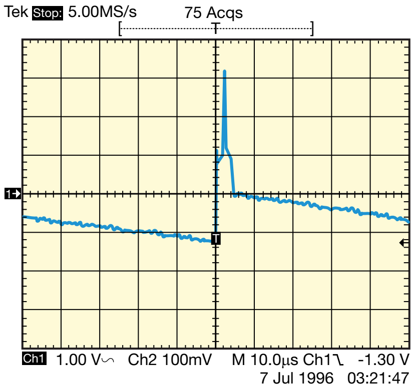


Fig. 5A. 24 V Relay Transient with 26 V TransGuard® 10 V/Division

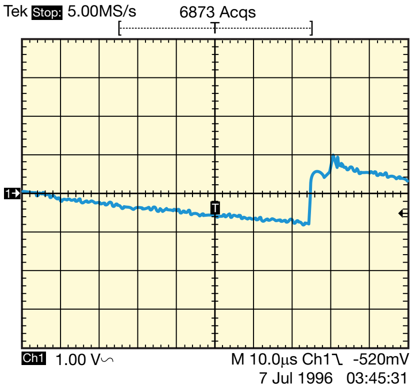


Fig. 6. 12 V Relay Transient without protection 105 V 50 V/Division

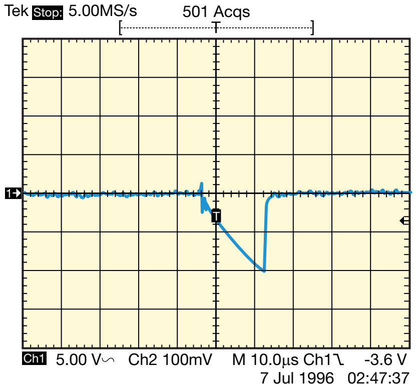
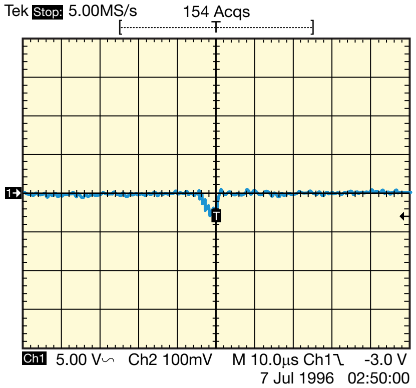


Fig. 6A. 12 V Relay Transient with 14 V TransGuard® 30 V 50 V/Division



CONCLUSIONS

TransGuards® can clamp the wide range of voltages coming from small/medium motors and relays due to inductive discharge. In addition, TransGuards® capacitance can help reduce EMI/RFI. Proper selection of the TransGuards® voltage is critical to clamping efficiency and correct circuit operation.

The current trend in automobiles is towards increased performance, comfort and efficiency. To achieve these goals, automobile companies are incorporating an ever increasing array of electronics into cars. As the electronic content within cars increases, auto manufacturers are utilizing multiplex bus designs to network all the sensors to a central point (usually the engine control unit [ECU]). Multiplex lines save wiring harness weight and decrease the harness' complexity, while allowing higher communication speeds. However, the multiplex structure tends to increase the occurrence and severity of Electromagnetic Interference (EMC) and Electrostatic Discharge (ESD).

Multilayer varistors (MLVs) are a single component solution for auto manufacturers to utilize on multiplex nodes to eliminate both ESD and EMC problems. MLVs also offer improved reliability rates (FIT rates <1 failure/ billion hours) and smaller designs over traditional diode protection schemes.

TYPICAL MUX NODE APPLICATION

There are a variety of SAE recommended practices for vehicle multiplexing (J-1850, J-1939, J-1708, J-1587, CAN). Given the number of multiplexing specifications, it is easy to understand that bus complexity will vary considerably.

Each node has an interface circuit which typically consists of a terminating resistor (or sometimes a series limiting resistor), back to back Zener diodes (for over voltage protection) and an EMC capacitor. Such a method is compared to that of a multilayer varistor in Figure 1.

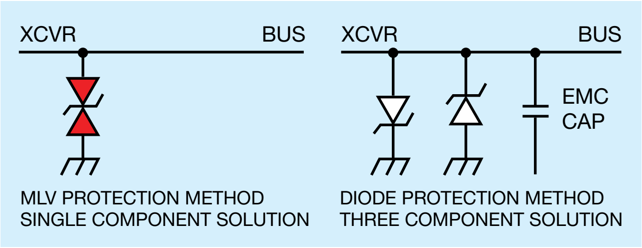


Figure 1. Comparison of past node protection methods to MLV node protection methods.

To more clearly understand the functional structure of a MLV, see the equivalent electrical model shown in Figure 2.

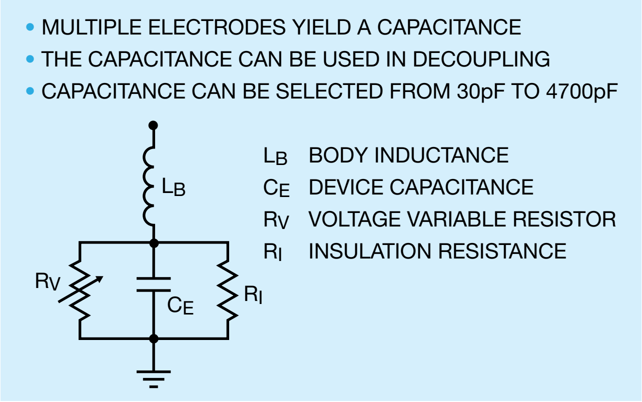


Figure 2. TransGuard® Equivalent Model.

As the schematic in Figure 1 illustrates, the implementation of MLV protection methods greatly simplifies circuit layout, saves PCB space and improves system reliability. The MLV offers many additional electrical improvements over the Zener/passive schemes. Among those advantages are higher multiple strike capability, faster turn on time and larger transient overstrike capability. Further clarification on the types of varistors compared to the performance of Zener diodes follows.

CONSTRUCTION AND PHYSICAL COMPARISON

The construction of Zinc Oxide (ZnO) varistors is a well known, relatively straightforward process in which ZnO grains are doped with cobalt, bismuth, manganese and other oxides. The resulting grains have a Schottky barrier at the grain interface and a typical grain breakdown voltage (Vb) of approximately 3.6V per grain.

Currently, there are two types of varistors. Single layer varistors (SLVs) – an older technology referred to as "pressed pill," typically are larger, radial leaded components designed to handle significant power. Multilayer varistors (MLVs) are a relatively new technology packaged in true EIA SMT case sizes.

Beyond the ZnO material system and grain breakdown similarity, MLVs and SLVs have little in common. That is, to design a low voltage SLV, the grains must be grown as large as possible to achieve a physically large enough part to be handled in the manufacturing process. Typically it is very difficult to obtain a consistent grain size in a low voltage SLV process.

The electrical performance of SLV is affected by inconsistent grain size in two ways. First, low voltage SLVs often exhibit an inconsistent Vb and leakage current (IL) from device to device within a particular manufacturing lot of a given rating. This contributes to early high voltage repetitive strike wear out.

Secondly, SLVs with similar voltage and energy ratings as MLVs typically exhibit a lower peak current capability due in part to increased resistance of the long current path of the large grains. This contributes to early repetitive high current wear out.

At higher voltages, the grain size variations within SLVs play a much smaller percentage role in Vb and leakage current values. As a result, SLVs are the most efficient cost effective way to suppress transients in high voltages (e.g., 115 VAC, 220 VAC).

MLV MANUFACTURE

The construction of a MLV was made possible by employing a variety of advanced multilayer chip capacitors (MLCC) manufacturing schemes coupled with a variety of novel and proprietary ZnO manufacturing steps. In the MLCC process, thin dielectrics are commonly employed to obtain very large capacitance values. It is that capability to design and manufacture multilayer structures with dielectric thicknesses of ≤1 mil that allows MLVs to be easily made with operating/ working voltages (Vwm) as low as 3.3V (for use in next generation silicon devices).

Once a particular working voltage has been determined (by altering the ZnO dielectric thickness), the multilayer varistor's transient energy capability is determined by the number of layers of dielectric and electrodes. It is, therefore, generally easy to control the grain size and uniformity within a MLV due to the relative simplicity of this process.

MLVs exhibit capacitance due to their multiple electrode design and the fact that ZnO is a ceramic dielectric. This capacitance can be utilized with the device's series inductance to provide a filter to help limit EMI/RFI. The equivalent model of a MLV is shown in Figure 2.

MLVs are primarily used as transient voltage suppressors. In their "on" state, they act as a back-to-back Zener, diverting to ground any excess, unwanted energy above their clamping voltage. In their "off" state, they act as an EMC capacitor (capacitance can be minimized for high speed applications). A single MLV, therefore, can replace the diode, capacitor and resistor array on multiplex node applications.

Any TVS will see a large number of transient strikes over its lifetime. These transient strikes will result from different events such as well known ESD HBM, IC MM, alternator field decay, load dump models and uncontrolled random events. It is because of the repetitive strikes that all TVS suppressors should be tested for multiple strike capability. Typically, a TVS will fail due to high voltage, high current or over-energy strikes.

High voltage repetitive strikes are best represented by IEC 61000-4-2 8kV waveforms. MLVs demonstrate a greatly superior capability to withstand repetitive ESD high voltage discharge without degradation.

High current repetitive strikes are represented by 8x20µs 150A waveforms. A comparison between MLVs, SLVs and SiTVS is shown in Figures 3A, B, C respectively.

SILICON TVS MANUFACTURE

The construction of a silicon TVS departs dramatically from that of either single layer varistor or multilayer varistor construction. Devices are generally produced as Zener diodes with the exception that a larger junction area is designed into the parts and additional testing was likely performed. After the silicon die is processed in accordance to standard semi-conductor manufacturing practice, the TVS die is connected to a heavy metal lead frame and molded into axial and surface mount (SMT) configuration.

MLVS COMPARED TO DIODES

The response time for a silicon diode die is truly sub-nanosecond. The lead frame into which the die is placed and the wire bonds used for die connections introduce a significant amount of inductance. The large inductance of this packaging causes a series impedance that slows the response time of SiTVS devices. A best case response time of 8nS on SOT23 and a 1.5nS to 5nS response time on SMB and SMC products respectively are rather typical. MLVs turn on time is <7nS. MLVs turn on time is faster than SiTVS and that fast turn on time diverts more energy and current away from the IC than any other protection device available.

CONCLUSION

The technology to manufacture MLVs exists and allows the manufacture of miniature SMT surge suppressors. MLVs do not have the wear out failure mode of first generation (single layer) varistors. In fact, MLVs exhibit better reliability numbers than that of TVS diodes. MLVs are a viable protection device for auto multiplex bus applications.

Written by Ron Demcko

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150 AMP Current Repetitive Strike Comparison

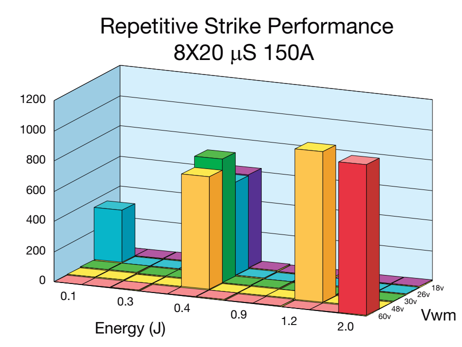

Figure 3A. Multilayer Varistor.

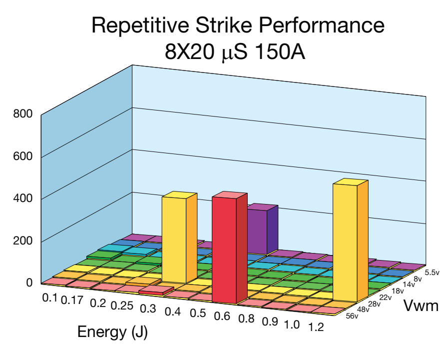

Figure 3B. Single Layer Varistor

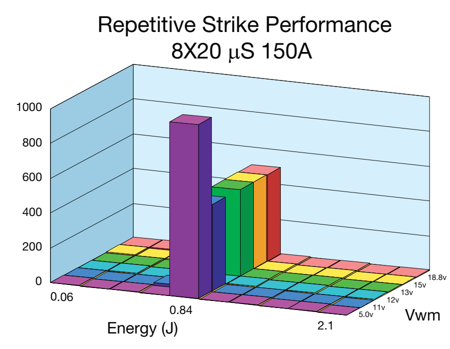

Figure 3C. Silicon TVS.