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N91-32732

CIRCUIT PROTECTION DEVICES FOR TRANSIENT SUPPRESSION

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ABSTRACT

Electrical Overstress (EOS) transients - brief but powerful voltage surges - are a major threat to virtually all electronics equipment. As electronics equipment becomes denser, and as chip geometries shrink, the likelihood of EOS transients increases. Therefore, more designers are using transient suppressors to protect electrical circuits from damage due to EOS threats such as lightning, electrostatic discharge, and electromagnetic pulses.

Currently the major transient suppression devices are gas discharge tubes, metal-oxide varistors (MOVs), and zener diodes. The gas discharge tubes and varistors are designed to handle high energy transients while the zener diodes provide only low energy protection. Of these devices, no one type meets all the criteria of an ideal transient suppressor.

Electromer Corporation has developed a series of transient voltage suppression components based on a patented, specially formulated PolyClamp® material. PolyClamp® components are a new class of transient voltage surge suppressors that extend the range of protection offered by transients protectors. The PolyClamp® transient surge suppressors provide low capacitance, high energy capability, and packaging flexibility.

A wide variety of applications can be protected by PolyClamp®. A tube and ferrule configuration is designed to be used with MIL/Aerospace style connectors and is designed to meet the applicable environmental, mechanical, and electrical requirements as defined by SAE, and United States and European defense standards performance requirements. This paper compares PolyClamp® to current transient surge suppressors and describes typical performance and design.

INTRODUCTION

Transient suppressors of the type discussed above, as well as the Electromer PolyClamp® devices, operate by shunting the incoming EOS transient to ground, thereby clamping the circuit voltage to a tolerable level. The transient suppression device is in parallel with the electronics circuitry to be protected.

EOS transients can enter electronics equipment through several paths. Antenna cables and other signal lines are very susceptible to picking up EOS transients. Power supply lines, both AC and DC, are frequently carriers of the transients. In fact, virtually any cable or wire connected to the equipment is a potential path for transporting the EOS transient to the sensitive electronics. Therefore, transient suppression is necessary at practically all input/output lines to electronics equipment.

The ideal transient suppressor is at a very high or infinite resistance during normal operating conditions and is essentially electronically invisible to the other circuitry. The presence of an EOS transient causes the ideal transient suppressor to rapidly switch to a low resistance state, shunting the transient to ground and preventing the other electronics circuitry from experiencing damaging overvoltage conditions. The transient suppressor is said to clamp the transient voltage to a safe level. Gas discharge tubes clamp the transient voltage to a very low level by creating a virtual short circuit to ground. Varistors and zener diodes as well as PolyClamp®, have a specified voltage clamp level.

The ideal transient suppressor should have zero leakage current, very low capacitance, high energy handling capability, and response time in the sub-nanosecond range. PolyClamp® products can be tailored to very nearly meet these ideal specifications.

In addition to the performance benefits PolyClamp® components offer a packaging flexibility that is not available with gas discharge tubes, diodes, or varistors. PolyClamp® transient suppressors are moldable into many configurations including tubes and ferrules, pin and ferrules, and arrays. The packaging flexibility allows form, fit, or function customization for packaging and cost advantages.

PERFORMANCE OF POLYCLAMP® COMPONENTS

(a) Clamp Voltage

PolyClamp® clamp voltage, the voltage at which the device switches to a low resistance state, can be controlled both by formulation and by the dimensions of the device itself. Currently there are two PolyClamp® formulations available. These formulations, combined with precise dimensional control, allow a broad range of devices to be made over a wide range of clamp voltages, 30 to 1000 volts.

(b) Energy Capability

The typical energy handling capability of PolyClamp® devices is approximately 10 Joule/cc. For applications requiring large energy dissipation, the size of the PolyClamp® device can be increased to accommodate the specific requirement. The excellent energy handling characteristics of PolyClamp® make it a rugged device with broad applicability in transient suppression applications.

(c) Response Time

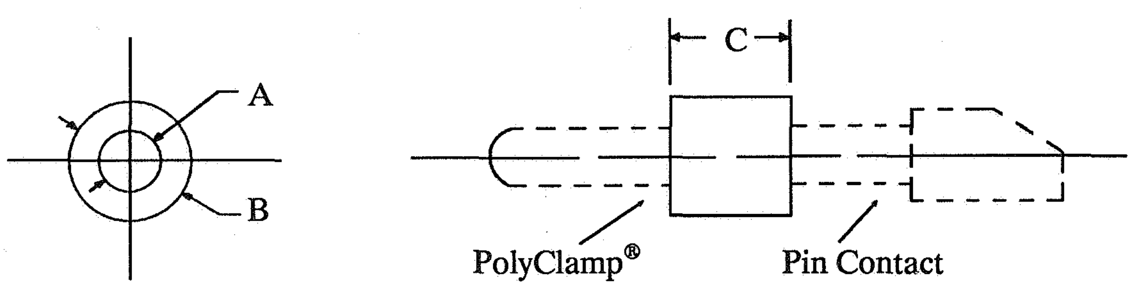
An important feature of any transient suppression device is the response time to an EOS transient. This is especially true for fast rising transients. The rise time of a transient pulse can be thought of as the time for the transient to rise from essentially zero volts to the peak amplitude of as many as several thousand of volts. Fast rise times are usually considered sub-nanosecond range. The nature of the PolyClamp® performance is that of a foldback device with response times less than 100 nanoseconds.

(D) Packaging Flexibility

PolyClamp® is a moldable plastic semiconductor device, and because PolyClamp® formulations are moldable, a wide variety of shapes and geometries can be fabricated. This is particularly desirable for nearly every application including connector inserts, printed circuit board traces, leaded devices, wire insulation, IC packaging, gaskets, housings, customer retrofit parts, etc. PolyClamp® offers many advantages in its manufacture. The raw materials are generally standard and easily obtainable. Processing of the PolyClamp® formulations is done by standard plastic processing technology. Finely divided powders are incorporated into a polymer matrix using Banbury or two-roll mill mixing. Curing of the polymer matrix is done according to usual procedures for the polymers used in the particular formulation. All materials are non-toxic and stable under widely varying conditions.

A typical tube and ferrule PolyClamp® specification and design follows:

Voltage Clamp Range	50-90 Volt
Response Time	$<$200 nanoSeconds
Energy Handling	$>$10 Joules/cc
Capacitance	$<$10 picoFarads
Off State Resistance	$>10^8$ ohms @ 100 volts
On State Resistance	$<$2 ohms
Operating Temp.	-55 to 155 °C



DIM:	Pin dia.	A dia.	B dia.	C
Size 22	0.030	.033	0.073	0.300
Size 20	0.040	0.043	0.118	0.300
Size 16	0.062	0.066	0.141	0.300
Size 12	0.094	0.098	0.170	0.300

DESCRIPTION OF EXISTING TRANSIENT SUPPRESSORS

Below is a detailed discussion of varistors, zener diodes, and gas discharge tubes.

Varistors

Varistors are ceramic devices formed by sintering together metal oxide powders at high temperatures. The resulting solid material is composed of individual metal oxide grains separated from each other by grain boundaries of finite thickness. These grain boundaries contain various impurities and dopants important to the varistor operation. It is the grain boundaries, generally characterized as a Schottky barriers, that give rise to the voltage clamping characteristics.

Because of the grain boundaries, varistors have inherently high capacitance, an undesirable feature for most applications. this high capacitance plus other factors cause varistors to have inadequate response times to fast rising EOS transients. The resulting voltage overshoot can be very damaging to the electronics equipment to be protected.

Zener Diodes

Zener Diodes are P-N semiconductor junctions which are specifically made to operate in the reverse breakdown mode in response to a voltage transient. Response times to EOS transients are generally quite fast. However a major problem is the energy handling capability. Because of its thickness and construction, the semiconductor junction of the zener diode has very low energy handling capability. Another consideration is the relatively high capacitance associated with the zener diode junction.

In comparison, the PolyClamp® conduction mechanism is a bulk effect and therefore PolyClamp® devices have substantially greater energy capability.

Gas Discharge Tubes

Gas discharge tubes are composed of a gas-filled tube enclosing two metallic conductors which are separated by a small gap. Under normal conditions the resistance between the two conductor is essentially infinite. When a large enough voltage is applied to the conductors, an arc is ignited across the gap and the conductors are virtually shorted together. The time to form and develop the arc can be quite long relatively to the rise time of an EOS transient, resulting in large voltage overshoots before the clamping effect takes place. The very slow response time renders gas discharge tubes inadequate for suppressing fast rising EOS transients.

Gas Discharge Tubes do not reset. This means that after triggering the internal electrical arc in response to an incoming transient, all power to the circuit must be removed in order to extinguish the arc and restore the Gas Discharge tube to its off state. PolyClamp® automatically resets to high resistance when the incoming transient is past.

General Description of PolyClamp® Devices

PolyClamp® Protection Devices are used as a parallel element in electrical circuits. A simple circuit diagram is shown below in Figure 1.

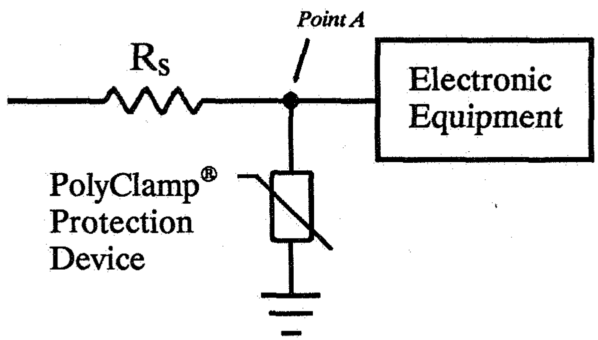


Figure 1 - Simplified Circuit Using Voltage Clamping Device

The source impedance R_S shown in Fig. 1 is present in all applications, although it may not be contained in a single circuit element as shown. For applications such as telephony, where long signal lines are involved, the source impedance is comprised of distributed resistance, capacitance, and inductance. For wiring in aircraft or buildings there are again distributed values which can effectively be combined into a single source impedance element for the present analysis.

The role of source impedance is not always fully appreciated when discussing voltage clamping elements such as PolyClamp® Protection Devices. The total voltage of the overvoltage transient is shared between the source impedance and the PolyClamp® Protection Device, the voltage clamping element. Example: using a PolyClamp Device with a rated clamping voltage of 30 volts, and an incoming overvoltage transient of 3000 volts magnitude, there would be a voltage of 30 volts at Point A in Figure 1. The rest of the transient voltage, 2970 volts, would be shared or dropped across the source impedance R_S. Thus the electronic equipment in Figure 1 is effectively protected from damaging exposure to excessive voltage levels. This example should help illustrate the role and importance of source impedance.

Response to Lightning

A typical lightning threat is illustrated in Figure 2. This pulse shape is described in ANSI/IEEE C62.41-1980 (formerly IEEE 587) and is often referred to as an 1.2x50 waveform. The voltage level can be as high as 6000 volts with up to 3000 amps of current. The 1.2x50 designation refers to a rise time of 1.2 microseconds and a fall time to 50% amplitude of 50 microseconds.

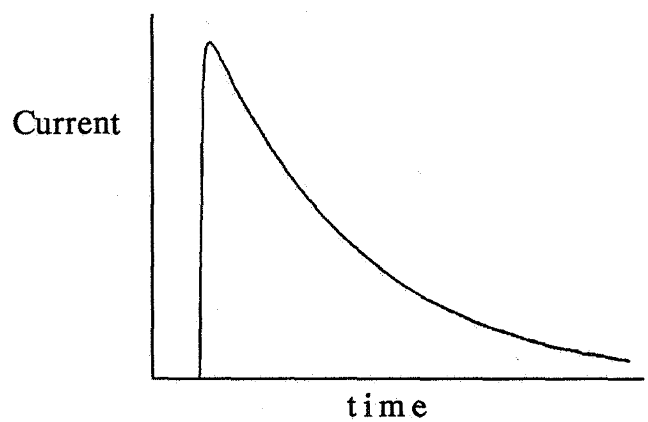


Figure 2 - 1.2x50 Lightning Pulse

Figure 3 below illustrates the response of an ideal voltage clamping device to the lightning threat of Figure 2. Note the sharp clamping action, primarily because the Ideal Device responds instantaneously. In addition, the Ideal Device has virtually no capacitance, has an infinite off-state resistance, and is capable of absorbing extremely large amounts of energy.

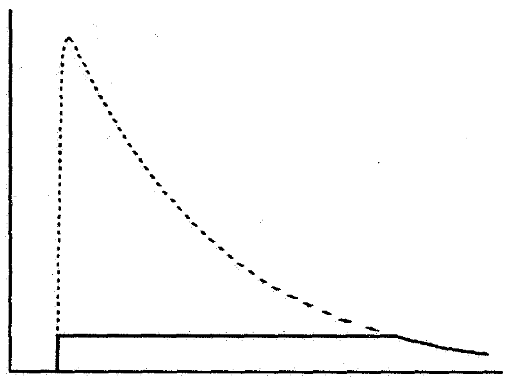


Figure 3 - Response of the Ideal Voltage Clamping Device

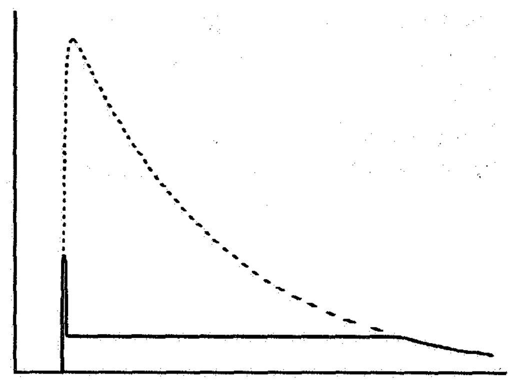
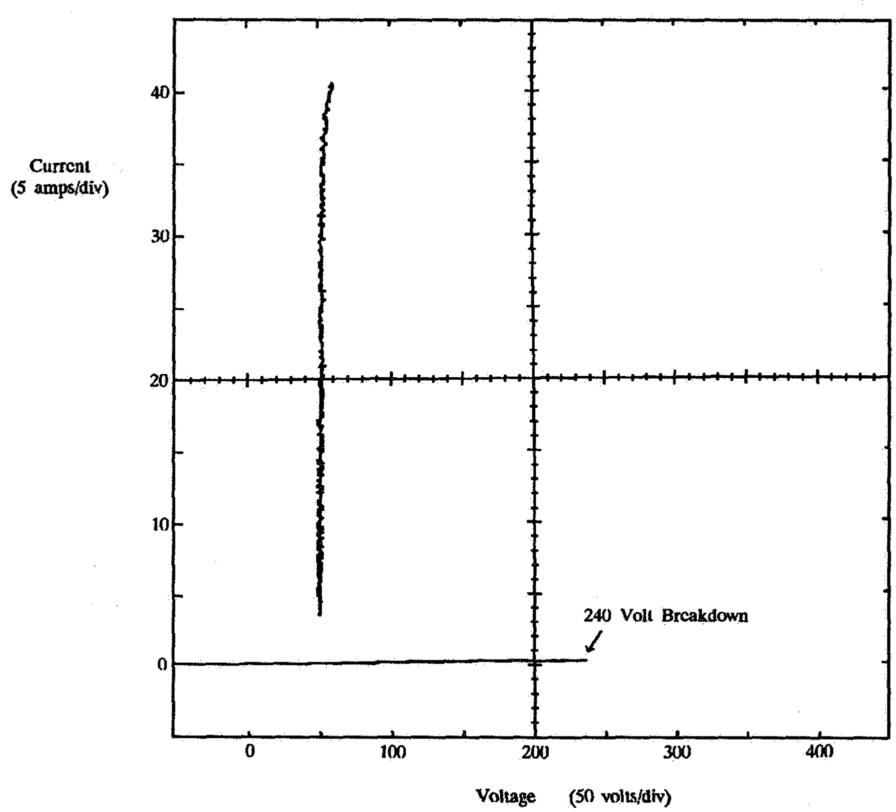


Figure 4 - Response of PolyClamp® Protection Device

Figure 4 above shows the response characteristics of the PolyClamp® Protection Devices to the lightning pulse of Figure 2. The PolyClamp® device is a foldback device with the I-V curve shown in Figure 5 below.



PolyClamp® Protection Devices have very low capacitance and handle large energy levels. Energy values of up to 10 joules per cc of material are within the capability of the devices. Depending on the device size, peak power levels of greater than 5000 watts are obtainable in connector applications.

The response of a PolyClamp® Device to longer lightning pulses, such as the 10x1000 pulse (10 microsecond risetime, 1000 microseconds to 50% amplitude) or the 50x500 pulse (e.g.) LEMP-EFA-1 requirement), is essentially the same as in Figure 4 except of course that the clamp region lasts for a much longer time period. Below in Figure 6 are actual voltage and current responses to a 6,000 volt 1.2x50 lightning pulse.

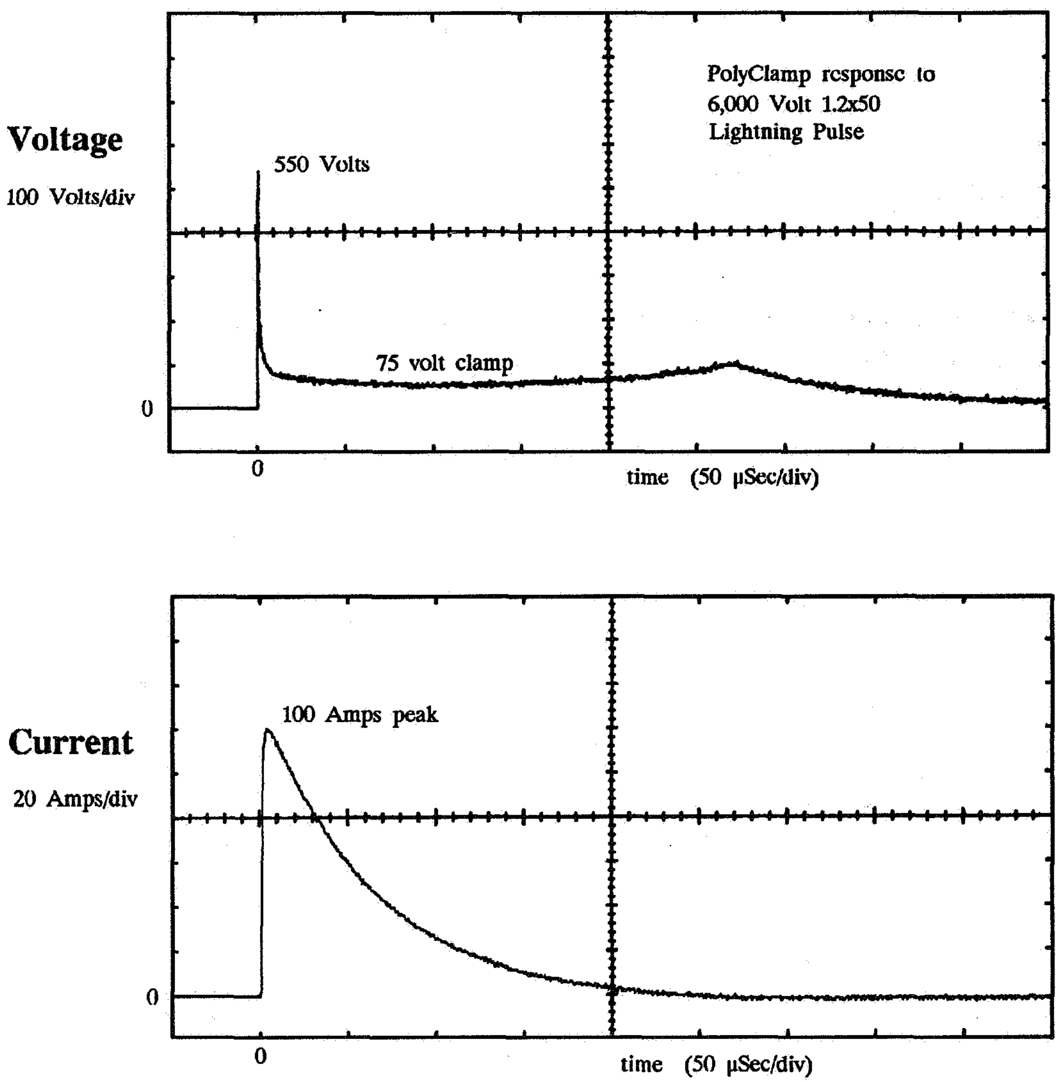


Figure 6 - PolyClamp® response to 1.2x50 Lightning Pulse.

Response to EMP/NEMP

The oscillatory pulse characteristic of induced transients from the NEMP-EFA-1 test waveform (DEF STAN 59-41) is illustrated in Figure 7. This waveform in this Figure is a damped 30 Mhz pulse of several thousand volts amplitude.

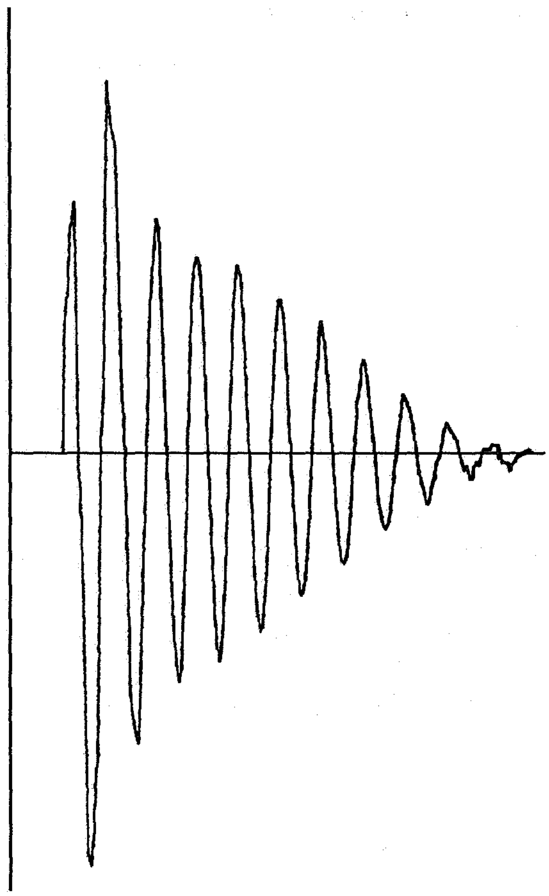


Figure 7 - EFA EMP/NEMP Pulse

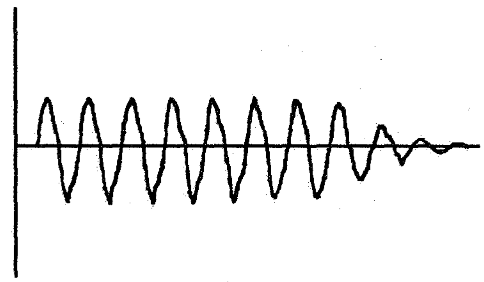


Figure 8 - Response of Ideal Voltage Clamping Device

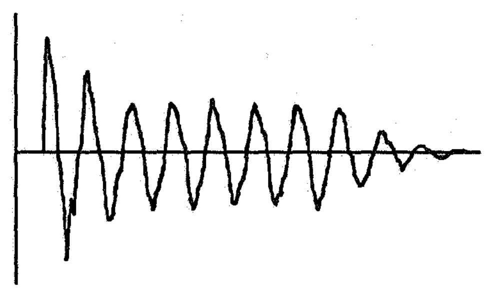


Figure 9 - Response of PolyClamp® Protection Device

The response of the Ideal Voltage Clamping Device is shown in Figure 8, and the response characteristics of the PolyClamp® Protection Device is shown in Figure 9.

The induced current with the PolyClamp® Protection Device in the circuit (Figure 9) was 30 amps. Note the PolyClamp® Device exhibits a small "overshoot" at the front of the waveform. The switching speed to reach rated clamp voltage is typically 1/4 microsecond.

Figure 9 illustrated the dramatic clamping action of the PolyClamp® #22 Tubular Protection Device designed for use in connector applications. The low capacitance and low insertion loss makes this product ideal for avionics electronics.

ADVANTAGES OF PolyClamp OVER EXISTING TRANSIENT SUPPRESSORS

Existing transient suppressors include varistors, gas discharge tubes, and zener diodes. The following Table compares the performance characteristics of existing transient suppressors with both the ideal device and with PolyClamp®.

Compared to Spark gaps, Zener diodes, and MOV's, PolyClamp® Products have:

-Packaging Flexibility

-Very High Energy Capability

-Low capacitance (pF)

-Highly reliable, rugged, single unit construction

SUMMARY

A wide variety of applications can be protected by PolyClamp® Transient Voltage Suppression devices. The extremely low capacitance of PolyClamp® devices makes them well suited for use with network and high-frequency applications. In addition, wide service range and high energy-handling capability make them useful for low level data signal and heavy duty power protection. Performance stability demonstrated during MILSPEC performance testing, temperature extremes, and mechanical testing ensure reliability of the material and product configuration.