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HORIZONS

A new approach to surge suppression

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A new type of surge-suppression technology, recently introduced by RCA Solid State, has been developed to protect sophisticated electronic circuits from rapid, high-voltage power surges that conventional surge suppressors cannot handle.

This new surge protector, called a Surgector™, is really a two-in-one device combining two proven components—a zener diode and a thyristor—in a single unit.

Because it combines the continuous voltage protection of the zener with the thyristor's ability to handle high current, the Surgector provides instantaneous protection against fast-rising, high-voltage pulses—pulses that are too rapid or too powerful for conventional devices (such as gas tubes, MOV's, air gap carbon blocks, or stand-alone zeners) to block.

As a result, the Surgector provides much-needed secondary surge protection for telecommunications circuitry, data links, and other sensitive electronic circuits that are especially susceptible to damage from transient voltage.

A Look at the Problem

The need for a new type of surge suppressor stems from the increasing sophistication of today's electronics. In the telecommunications industry, for example, the trend is toward increasing use of medium scale integrated (MSI) and very large scale integrated (VLSI) circuits. These circuits, used in equipment that transmits, processes, codes, switches, and stores data, have multifunction capability but are intolerant of voltage overloads.

The most common device used to protect these circuits is the gas discharge tube; air gap carbon blocks are also frequently employed for surge suppression. While these devices can handle extremely high currents, they do not switch rapidly enough to catch the fast-peaking pulses characteristic of lightning, electrostatic discharges, load changes, commutation spikes, and switching transients. Hence, a secondary surge suppressor—one that reacts quickly enough to clamp the fastest pulses—is needed to provide complete continuous protection. And that is where the Surgector comes in.

How It Works

The Surgector is a monolithic device. It consists of an SCR-type thyristor whose gate region contains a special diffused section that acts as a zener diode. The zener portion of the Surgector provides continuous protection of the circuit, just as a stand-alone zener would.

Here's how it works:

The Surgector allows normal operation of the circuit as long as the voltage does not exceed a certain maximum value (V_{DM}). RCA currently manufactures Surgectors rated at 30, 60, 100, and 230 volts.

When a transient pulse hits the line, voltage begins to rise—often at an extremely rapid rate. Lightning, for example, can cause a voltage rise in excess of 1000 volts per microsecond.

A gas tube or carbon block cannot act rapidly enough to block such a pulse, but the Surgector can. As soon as the voltage reaches the avalanche breakdown voltage, the zener instantly "clamps" the voltage. The voltage can rise above its normal value for the circuit, but only by a small amount; the Surgector ensures that the protected circuit never sees a voltage greater than 110 percent of the zener avalanche operating voltage.

This is where the thyristor portion of the Surgector comes into play. A normal stand-alone zener diode maintains a constant voltage for the duration of the pulse and can quickly burn out from this energy overload. But in the Surgector, current flows from the zener region into the thyristor gate, switching on the thyristor in nanoseconds. The thyristor drops to low voltage, creating a low impedance in the circuit, and shunts the excess energy from the zener region to the ground.

In effect, the thyristor draws energy away from the zener, allowing it to survive the transient. Because of this, the Surgector can handle about ten times more current than a stand-alone zener.

While the transient is on the line, the Surgector remains in the ON state, and the voltage across the circuit is low. Its precise value depends on the type of pulse and the type of Surgector being used.

Eventually, the pulse passes, and the current begins to drop. When it reaches a certain minimum value, known as the "holding current," the Surgector

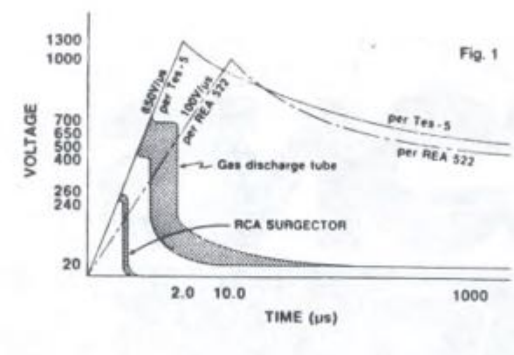

Fig. 1

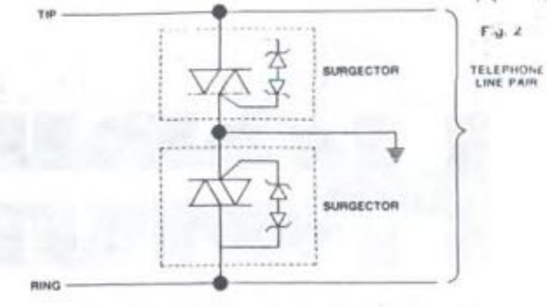

Fig. 2

To protect delicate telecommunications equipment, two bidirectional SURGECTORS are placed between the tip and ring lines just after these lines enter the telephone.

automatically shuts off, and normal circuit operation resumes, with the zener section of the Surgector again providing continuous protection.

Performance Characteristics

The Surgector has been throughly tested, using a KeyTek (Burlington, MA) surge tester, for a number of industry-standard pulses.

These pulses are usually described by two time intervals. The first number is the time in microseconds it takes the pulse to reach peak current. The second number is the time in microseconds it takes for the current pulse to decay to 50% of its peak value. For example, a 1×2 pulse reaches peak current in 1 microsecond, and the current delays to 50% of its peak value in 2 microseconds.

Three of the standard pulses used to rate surge suppression devices today are 1×2, 10×560, and 10×1000. The 1×2 pulse is used to simulate fast risetime lightning impulses. A standard value for voltage rise is 1.5 kV/µs. The 10×560 pulse is often specified by the FCC for communications equipment. A 10×1000 pulse is specified by IEEE and the Rural Electrification Administration for characterization of telephone protection.

Presently announced Surgectors have ratings for transient peak surge current of 300 amperes for a 1×2 pulse and appropriately scaled currents at 10×560 and 10×1000. These rated surges can be applied to the Surgectors repeatedly without degradation.

The overshoot ratio of the Surgector is the ratio of the highest voltage encountered by the protected circuit (during a 100-V/microsecond pulse) over the zener voltage of the Surgector. The Surgector's clamping ratio is 1.1. The Surgector has the lowest overshoot ratio of any surge-suppression technology on the market today, which means it suppresses transient voltage more effectively than gas tubes, MOVs, or carbon blocks.

Many surge-suppression devices are characterized by the speed at which they switch on. A gas discharge tube, in which gas must ionize before the device can function, takes microseconds to become operational.

But this specification is meaningless for the Surgector, because the Surgector provides instantaneous and continuous protection. The zener section of the Surgector always clamps voltage when the value reaches a certain minimum zener voltage for which the device is rated. It is simply impossible for the voltage in the line to exceed a value equal to the breakover voltage multiplied by the 1.1 overshoot ration (unless the device is operated beyond its specifications).

Figure 1 illustrates this point. The Surgector type SGT23U13, which is rated at 230 volts, clamps the transient voltage the instant it reaches the zener voltage—and the voltage never rises beyond 110 percent of this value. Within nanoseconds, the thyristor switches on and drops the voltage to just a few volts. (The voltage will remain at this low value until the surge passes and the current drops below the holding current.)

The gas discharge tube, on the other hand, is slow to ionize. By the time it becomes operational, a circuit hit with the 1 kV/microsecond pulse sees anywhere from 400 to 1500 volts. Such a voltage overload could easily damage or destroy the circuit.

As stated, the Surgector can handle peak currents up to 300 amps, depending on the type of pulse. But, like any electronic device, the Surgector will eventually fail if pushed beyond its specifications. However, the Surgector is designed not to fail open on a 1×2 pulse below 450 A.

This is an important feature, especially in telecommunications applications. *If a device fails to open*, the circuit remains unprotected until the device is replaced. And open failures on the line are not easily detected. A short, on the other hand, provides continuous protection against surges (although it prevents operation of the circuit) and is easy to locate for repair or replacement.

Aside from failure due to operating beyond the device's specifications, the Surgector has no inherent wearout mechanism. Performance is consistent and does not degrade with repeated use or time. And there is no inherent limit on the Surgector's operating life. We predict the Surgector will have a life comparable to RCA transistors, which last for 20 years or more. By comparison, MOVs and carbon blocks have wearout mechanisms.

Surgectors are usually used in conjunction with primary protection devices, and therefore should rarely see currents exceeding their rated capacities. When operated within their specifications, Surgectors automatically switch to their OFF state once the pulse passes and the current drops below the holding current. The holding current of the Surgector must be greater than the normally available current in the circuit to insure that the Surgector will return to the OFF state when the transient has passed and allow normal circuit opera-

Design considerations

Here are some factors to consider when designing surge protection into a circuit:

Line voltage

Select a device that will remain in the OFF-state under the normal operating voltage of the circuit. Surgector model SGT06U13, for example, should not be used with a line voltage above 58 V.

Maximum voltage

Determine the maximum voltage your electronics can handle, then choose surge protection to ensure that the circuit never sees a voltage exceeding this upper limit.

The SGT06U13 is guaranteed not to exceed 65 volts with a 100-V/µs transient. This value is safe up to the full current capability of the Surgector. All Surgectors are rated for this important characteristic.

Polarity

A line that requires protection from a single polarity can be sufficiently protected with a unidirectional Surgector. Lines that require protection in both polarities will need a bidirectional Surgector (or a unidirectional Surgector in combination with diodes).

Location

The Surgector should be located near the electronics it is intended to protect. An ideal place is on the front of the circuit board where the input wires enter. By incorporating the Surgector into the board itself, you take advantage of the ease of repair and replacement inherent in today's "modular" electronic system designs. Also, the impedance at any interconnection limits the current supplied to the Surgector.

When designing, keep in mind that the impedance through the Surgector to the ground must be lower than the impedance from the circuit to the ground. Otherwise, some transient energy may flow through the circuit during a transient impulse.

A major application of the Surgector is in telecommunications. Surgectors can protect a wide variety of equipment, including telephone handsets, headsets, "intelligent" telephones, PBXs, and central office equipment. Here, the Surgector protects the expensive electronics from damage while ensuring that service is not interrupted by transient voltage.

In a typical telephone application, the Surgector would be placed between the tip and ring lines. Several different configurations are possible. In the bridge circuit, six diodes and one unidirectional Surgector are placed between the two lines, right after they enter the telephone. The diodes "steer" the current in the right direction, enabling the single unidirectional Surgector to handle both positive and negative pulses.

An alternative approach is to replace the bridge circuit and unidirectional Surgector with two bidirectional Surgectors, one on the tip line and one on the ring line (Fig. 2). This provides the same protection as the bridge circuit but eliminates the need for diodes. Eliminating the diodes reduces the inductance and lowers the cost of the circuit.

Surgectors can also be used in computer equipment, especially in data communications links. Surgectors built directly into the modem protect volatile computer memories and the equipment itself.

Another use of the Surgector as a trigger is in "crowbar applications." Here, a single Surgector replaces the mass of extra circuitry normally required to trigger a larger SCR.

In addition, the continuous protection, small size, and low cost of Surgectors make them suitable for alarm systems, automobiles, television, outdoor lighting, CATV, and aircraft electronics.

tion to resume. Surgectors are designed with high holding currents, ranging from 100 to 250 milliamps, depending on the type. These ratings are sufficient to allow proper operation in most telecommunications circuits.

The Surgector's normal OFF condition is a state of high impedance, which prevents loading of the line. Leakage is extremely low: the Surgector passes less than 100 nanoamps versus milliamps for MOVs. The capacitance of Surgectors is also low, presenting about 100 pF for a bidirectional device in normal telecommunication circuits. This is low enough to allow high-speed data communications.

Choosing a technology

The Surgector represents a new standard in secondary surge protection. But the choice of which type of device to use is largely dependent on the requirements of your specific application.

Here are some of the other popular surge-protection technologies and how they compare and contrast with the Surgector.

Gas discharge tubes

These small, inert-gas-filled glass tubes are usually located where the lines enter the building. When there is a surge on the line, the gas ionizes, protecting the circuits inside.

Because they can shunt extremely high currents, gas tubes continue to be used as the primary protection for circuits. However, the gas is slow to ionize, so some form of faster-acting secondary protection is needed to protect delicate circuitry from fast transient voltages, such as those produced by lightning. Another problem with gas tubes is that they have a high overshoot voltage — the circuits they protect may be hit with voltage up to 10 times the normal operating voltage. Circuits that have a lower tolerance than this require secondary protection.

Carbon blocks

Air gap carbon blocks, once the most popular form of primary protection, are now being replaced by gas discharge tubes.

Carbon blocks have many inherent problems. Like gas tubes, they are slow to activate and therefore unable to suppress fast-rising voltages. Their overshoot ratio is high (on the order of 6.5) and varies as the block gets older. Leakage is initially low but increases with use. Furthermore, carbon blocks have a short life, necessitating frequent replacement.

Zeners

Zeners, used by themselves or with diodes, can be used for secondary surge protection.

Like the Surgector, the stand-alone zener immediately clamps the voltage when the transient reaches a certain breakover value.

Because the zener voltage remains high throughout the surge, its current handling capacity is reduced to a relatively low value. For a given size device, a Surgector can handle as much as 10 times more current than a zener. The overshoot ratio of zeners is greater than Surgectors because of the higher series resistance through which the high surge current must flow.

SCRs

A standard SCR used with a zener diode to provide transient surge protection has two problems. Because most SCRs turn on slowly, the dissipation in the zener prior to SCR condition is excessive for fast risetime transients, and the clamping ratio is high because the current through the zener is very high before the SCR turns on. The holding current on standard SCRs is not controlled tightly enough to insure that the device will always turn off when the transient is over.

A Surgector built as a gated three terminal device results in an SCR ideally suited to this type of service. This device provides the fast turn on and controlled holding current required. A three terminal device is valuable where transient voltage protection is required at voltages intermediate to those in the normal maxtrix. Care must be taken to limit the inductance in the voltage reference to avoid slowing the protection.

MOVs

The MOV, or metal oxide varistor, is widely used as a transient suppressor. It has several deficiencies. Since it is merely a resistor whose resistance is a function of the applied voltage, leakage is high (on the order of milliamperes) and the clamping ratio is also high (on the order of 1.7 for a 10-ampere pulse). MOVs also degrade with exposure to transient surges and become leakier.

The voltage across an MOV does not drop to a low value under high current conditions, causing high dissipation under high current conditions. The capacitance of MOVs is high (on the order of 2000 pF). This will often interfere with high data rate telecommunications.

Types Available

RCA manufacturers three types of Surgectors: unidirectional, bidirectional, and SCR.

The unidirectional Surgector is so named because it can handle only one polarity. A unidirectional Surgector and a diode are required to protect a steering circuit or multiple lines. The unidirectional Surgector is currently available in voltages of 30, 60, and 230 (types SGT03U13, SGT06U13, and SGT23U13 respectively). Holding current for the device is 130 milliamps.

A bidirectional Surgector, capable of handling surges in both polarities (positive and negative), is now being sampled by RCA and is scheduled for release in the third quarter of this year. The bidirectional Surgector has two terminals, and only one Surgector per line is required. Two initial versions are planned: models SGT20B10 (200 volts, 100 milliamps) and SGT23B25 (230 volts, 250 milliamps).

A third type, the SCR Surgector, is unidirectional but provides three terminals instead of two. The third terminal gives the user direct access to the SCR's gate region, so the Surgector can be triggered with an external voltage reference. The current SCR, called SGT10S10, is rated at 100 volts, but with the external gate-controlled circuitry, any voltage between 5 V and 100 V can trigger the device. The SGT10S10 also has a high holding current (100 milliamps) to allow rapid transition to the OFF-state.

The Surgector type numbers are easy to interpret. The first three characters — the letters "SGT" — stand for Surgector. Next comes two digits, which represent the maximum OFF-state voltage divided by 10. Following the voltage is a letter indicating either unidirectional (U), bidirectional (B), or SCR (S) type Surgector. Finally, the last two digits represent the holding current, in milliamps, divided by 10. Thus, SGT03U13 is a unidirectional Surgector with a maximum OFF-state voltage of 30 volts and a holding current of 130 milliamps.

All versions of the Surgector are housed in a modified TO-202 versatab plastic package. This is a single-in-line package, meaning that all leads come out of the same end and are parallel to one another. The advantage of single-in-line packaging is that it makes the Surgector easy to insert into a circuit or socket by automated methods.

Surgectors are shipped to the customer either in bulk or on plastic "sticks" designed for automated machinery. *The sticks are rectangular tubes that hold* 50 Surgectors apiece.

Proven technology

Although the Surgector is a new idea, it is based on two proven technologies: zener diodes and thyristors. RCA has been manufacturing thyristors for more than 20 years.

The Surgectors are manufactured on the same production lines used for producing bipolar transistors. Assembly, bonding, and packaging procedures are all standard; no new techniques or untested materials are used. Operating range is -40 to +85° C.

The cost of the Surgector varies, depending on the type number, but is approximately $1 each in quantities of 10,000. Low cost is an important advantage in the telecommunications equipment market, where the use of inexpensive components help manufacturers keep the price of their systems competitive.

For further information on the Surgector, contact John DeSantis, RCA Solid State, Route 202, Somerville, NJ 08876, (201) 685-6545.