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SURGE AND FILTER PROTECTION DEVICES AND APPLICATIONS

BULLETIN 4983 SURGE AND FILTER PRODUCTS

Sources and effects of transients and electrical noise and the surge and filter protection products and applications.



4983-DD



4983-DS



4983-DC

Filter and SPD
Combination



4983-DH



4983-PF Filter

Bulletin 4983 Surge Protection and Filter Products

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Key Terms

Transient (Surge)

A high voltage transient is a high energy, short term (1...10 μ s) deviation or change from desired voltage levels. It is an unwanted bundle of high electrical energy in the AC power line or communications line. The transient can be noted as a single overvoltage spike or a burst of spikes, sometimes followed by a ringing waveform.

Electrical Noise

Interfering and unwanted voltage and current anomalies in an electrical device or system; consists of undesirable frequencies above 60 Hz.

Surge Protective Device (SPD)

A general classification of a wide array of devices that are designed to react quickly to sudden and momentary overvoltage conditions, also referred to as a Transient Voltage Surge Suppressor (TVSS). The name changed from TVSS to SPD in revision 3 of UL 1449, Surge Protective Devices. According to UL1449, revision 3, Surge Protective Devices (SPD) are divided into 4 major types or categories: Type 1, Type 2, Type 3 and Type 4. IEC also divides SPD into types: Type 1, or Class I, Type 2, or Class II, and Type 3, or Class III. The rating depends on the intended areas of usage and the corresponding magnitude of surge suppression capabilities.

IEEE also specified location categories. Category C is Outdoor and Service Entrance. Category B is Service Entrance and Branch Panels. Category A is Equipment Level.

	Service Entrance		Branch Panel	Equipment Level	Test Requirements
	Line Side of Main Disconnect	Load Side of Main Disconnect			
	IEEE Category C Locations	IEEE Category B Locations	IEEE Category B and A Locations	IEEE Category A Locations	
UL 1449 Type 1	⊙				15 Pulses of 8/20 μ s waveform
UL 1449 Type 2		⊙	⊙		15 Pulses of 8/20 μ s waveform
UL 1449 Type 3				⊙	Combination Wave 6kV, 3kA
UL 1449 Type 4	⊙	⊙	⊙	⊙	Based on end application
IEC Type 1/ Class I	⊙				10/350 μ s waveform
IEC Type 2/ Class II		⊙	⊙		8/20 μ s waveform
IEC Type 3/ Class III				⊙	Hybrid Waveform — open voltage 1.2/50 μ s, short-circuit current 8/20 μ s

Filter

An electronic circuit that attenuates specific unwanted frequencies or frequency ranges and allows the desired signal to pass through with minimal disturbance. UL1283 is the standard that governs electro-magnetic filters.

Cascaded Architecture

Systematic approach of providing multiple points of transient protection with each successive downstream protection point using an SPD or filter with a lower energy rating. The goal is to provide the highest order of protection at the service entry points and lower-rated devices at the more protected sites, such as the output power distribution side of an electrical enclosure.

Sources of Transients and Electrical Noise

The key to understanding the different methods used to address transients and electrical noise is to gain an appreciation for the various sources. Some of the most prominent sources are created external to a facility: lightning, utility switching, capacitor switching, faults, and construction.

Lightning is the most recognizable and destructive form of high voltage transients. Direct hits can be extraordinarily powerful, and can deliver more than 100 million volts and more than 100 thousand amps. In addition, through the phenomenon of mutual inductance, any conductive circuit within several miles of a lightning strike can experience voltage transients of several thousand volts.

Utility companies can also create significant transients through their daily operations. With the dynamic nature of the demand for power, substations are switched in and out based on power needs. Each change is capable of generating a transient, often amounting to several thousand volts. In addition, power factor correction capacitors are commonly switched in and out of the power networks to compensate for highly inductive loads. Each time the capacitors are added or removed, a transient is generated.

An often overlooked source of transients is construction-related failures, i.e., those caused by component failures. Connections do age and break, and when they fail, transients are created. Construction-related failures can also be induced by commonly used equipment, such as arc welders. This sort of failure could cause a catastrophic failure of a phase-to-phase or phase-to-neutral/ground connection. In an ideal situation, this causes the circuit protection to operate instantly. When the fault occurs, the distribution voltage falls from the normal operating level to a near zero level until the system's fault current increases sufficiently to trip the circuit protection and clear the fault. Although the loads downstream of the fault experience a blackout, the loads upstream of the fault-clearing device can be subjected to substantial voltage transients.

Although these causes for transients are fairly common and can cause significant damage or destruction, it is important to know that the majority of transients that negatively affect equipment are created within the four walls of a factory environment. Some studies have

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shown that this number could be as high as 85%. For that reason, Rockwell Automation has chosen to focus its line of transient suppression and filter products on these main causes of transients.

Transients (surge spikes, swells, sags) and noise that is generated internal to a facility can be characterized by switching electric power sources on or off. Problematic industrial transients are known to be caused by the following sources:

- Starting motors or transformers
- Neon and sodium light starters
- Switching power networks
- Switch bounce in an inductive circuit
- Operation of fuses and circuit protection
- Operations of welders
- Operation of drives
- Starting computerized industrial loads
- Power factor correction capacitor bank

Transient and Electrical Noise Distribution

The two primary methods that distribute transients and electrical noise are conducted emissions and radiated emissions

Conducted transients are generated by motors or starters switching, power networks switching, the operation of a fuse or circuit breaker, etc. The transients are then carried or conducted to all devices sharing the same power lines or communications lines.

Radiated emissions are generated when the energy from the transients is converted to radio frequency energy, which is referred to as radio frequency interference (RFI). This energy radiates from the sources listed above in a radial pattern and is coupled into any cable, wire, or conductive device in close proximity. The longer the length of unprotected wire or cable, the more effective an antenna it makes. This phenomena explains why a sensitive piece of equipment, such as a computer, can be affected by a contactor or welder switching on and off, even when it resides in an isolated cell with no direct functional relationship to the computer. This also explains why it is important to place the transient protective and filtering devices in close proximity to whatever needs protecting. If the transient protective device or filter is placed too far from that which it is protecting, the effectiveness of the protective device will diminish.

Effects of Transients and Noise

Transients and noise can and do negatively affect electronic equipment. Some of the most common effects include the following:

Destruction:

- Voltage breakdown of semiconductor junctions
- Destruction of the bonding of components
- Destruction of printed circuit board (PCB) traces or contacts
- Destruction of triacs/thyristors due to excessive change in the voltage over time

Intermittent Operation

- Random operation of latches, thyristors / triacs
- Erasure or corruption of the memory in programmable logic controllers (PLC's), industrial computers, etc
- Program errors or computer system crashes
- Data and transmission errors

Premature Aging

Components exposed to repeat transients and/or noise can experience shortened operating life. Over time, these disturbances degrade equipment, which can cause intermittent operation or corrupted data. The effects of transients and noise are cumulative.

It is often challenging to identify when and where transient or noise conditions are occurring, which in turn can make it difficult to determine the root cause of a fault or failure. Did the component fail because it reached its end of life? Or did a transient that occurred in the first day of operation result in a 90% reduction in its operating life? Questions like this, and many others like it, point toward the value of integrating transient suppression products and filters within the initial installation. These devices can be extremely helpful in preventing faults, and evaluating them when they do occur.

Application of Surge and Protection and Filter Products

Implementation of the Cascade Approach

As mentioned above, transients and noise are generated everywhere, both internal and external to the facility. The key to controlling the intermittent operation and damage to electrical devices that occurs due to these power anomalies is to account for all possible sources inside the facility, and then limit or control each situation with a specific and structured solution.

A facility's first line of protection would most likely be a lightning arrester. Per UL, lightning arrestors must be in their own enclosure, and installed on the line side of the main disconnect. Rockwell Automation does not presently offer products to be used as lightning arrestors. The Bulletin 4983 family of surge protectors and filters are all meant to be installed on the load side of the main disconnect, and address the 85% of transients that are created inside a facility.

To address the transients as they enter the facility, an SPD should be used in the main power distribution panel, on the load side of the main disconnect. A standard-duty SPD (Bulletin 4983-DS) should be adequate here, although in geographical locations that have a significant amount of lightning, or where there are specific standards requirements (in some IEC regions), a heavy-duty SPD (Bulletin 4983-DH) should be used.

As power is distributed to electrical sub-distribution panels, or machine control panels, a standard-duty SPD (Bulletin 4983-DS) should be used at the front entrance of the panel.

If there is a particularly sensitive piece of electronic equipment, such as a computer or test stand that is located further down stream, consideration should be given to the use of a filter (Bulletin 4983-PF) or a combined SPD/filter product (Bulletin 4983-DC). In all cases, the closer the filter or SPD is to the device that is being protected, the more effective the SPD or filter will be. The power wire acts as an antenna. The longer the power wire, the better of an antenna it becomes. This creates more risk that a transient or noise could be induced or radiated onto the power line, causing damage to the sensitive electronic equipment. As a rule, the unprotected wire length should be limited to no longer than 2 feet.

Continuing downstream into the system configuration, consideration should be given to any wires connecting the sensitive devices and the communications networks. SPDs specifically designed for communications networks (Bulletin 4983-DD) should be positioned to protect every device that resides on these networks. In the simplistic case of a computer connected to a printer, both computer and printer should have an SPD protecting the network connection.

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Applying the cascade approach is important. Consider the following example:

A customer has made no efforts to protect a particular facility from transients or noise. The customer has an application where a new power supply has failed in the first few months of operation. When he replaced the power supply, it failed again after a few months. He decides to apply a single transient suppression device on the line side of the power supply. The newly installed transient protected power supply now operates without failure for extended periods of time, but the customer now finds that the PLC that the power supply is powering is experiencing intermittent operation. Other power supplies within the facility are now periodically failing. Then a new welder is installed and multiple power supply and PLC failures are being noted throughout the factory. Some are nuisance intermittent operations, but some are catastrophic failures. All of these failures are characteristic of transient and electrical noise related problems.

If a cascaded approach were used, many of the failures, if not all of them, could have been avoided.

AC Surge Protective Devices (4983- DS and 4983-DH)

The primary purpose of any SPD is to provide protection from transients and surges. The SPD does this by clamping the transient voltage as quickly as possible, limiting the high-voltage spikes to an acceptable level, and then diverting the transient energy in a non-destructive manner to ground. The expected energy then continues on its path. SPDs are wired in parallel and, much like circuit protective devices, they only activate when an event (a surge) occurs.

There are numerous guidelines and standards that govern SPDs.

Within UL1449 (Ed. 3), SPDs are divided into 4 categories. These ratings depend on the intended areas of usage and the corresponding magnitude of surge suppression capabilities. UL Type 1 products are those used at service entrances, on the line side of the main disconnect. UL type 2 products are those used at service entrances on the load side of the main disconnect, or in a branch panel. UL Type 3 products are used at equipment level. UL Type 4 products are component or component assembly, with no enclosure, and the rating is based on specific testing with the device that needs protecting.

IEC also divides SPDs into categories. These categories are based on the amount of surge impulse that the device has been tested to. IEC Class I/Type 1 devices are tested to a 10/350 μ s waveform, which means it is rated to handle a surge spike that reaches 90% of its peak in 10 μ s and diminishes to 50% of its peak in 350 μ s. IEC Class II/Type 2 surge protective devices are tested to a 8/20 μ s waveform, which means it is rated to handle a surge spike that reaches 90% of its peak in 8 μ s and diminishes to 50% of its peak in 20 μ s. IEC Class III/Type 3 surge protective devices are tested to a combination waveform, 1.2/50 μ s... 8/20 μ s.

IEEE defines location categories for SPDs. Category C is Outdoor and Service Entrance. Category B is Service Entrance and Branch Panels, and Category A is Equipment Level.

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Rockwell Automation offers products that can be used on the load side of the main disconnect at the service entrance, in branch panels, and on the equipment level.

Bulletin 4983-DH heavy-duty SPDs are extraordinarily robust, and can handle a significant amount of energy. This device is tested to a 10/350 μ s waveform which means it is rated to handle a surge spike that reaches 90% of its peak in 10 μ s and diminishes to 50% of its peak in 350 μ s. This waveform is meant to simulate a huge surge spike, similar to the energy created during direct lightning strike.

4983-DS Surge Protective Devices are standard duty SPDs and are meant to handle more common surges that are created inside a facility. This device is tested to a 8/20 μ s waveform, meaning it is rated to handle a surge spike that reaches 90% of its peak in 8 μ s and diminishes to 50% of its peak in 20 μ s. This waveform is meant to simulate a more typical surge spike, similar to that of an indirect lightning strike.

An SPD should be used in the main power distribution panel, on the load side of the main disconnect. In most cases a standard duty (4983-DS) is adequate. A heavy-duty SPD (4983-DH) should be used in locations that have a significant amount of lightning or have specific standards requirements (in some IEC regions).

As power is distributed into electrical sub-distribution panels, or machine control panels, a standard-duty SPD (4983-DS) should be used at the entrance of each specific panel.

Comparing Competitive Surge Protective Devices

When comparing competitive SPDs, it is important understand some of the different ratings. Most SPD data sheets are presented with an array of complex facts and figures that can be confusing. Some of these factors are more significant than others. This section will clarify some of the key parameters, discuss their significance and explain how they can be used to better understand the performance of an SPD.

A fundamental characteristic of any SPD is the time in which it responds to a transient. Most SPDs in the market today have very good response times. Due to the relative similarity of this feature, this is not a key differentiated in most cases.

One key parameter is the clamping voltage, which is denoted as the surge voltage rating (SVR). This is a clearly defined measurement, governed by UL1449, which can be used to compare competitive products. The lower the SVR, the better.

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Another important specification is the energy rating. This defines the amount of energy that the SPD can absorb, and is sometimes noted as the Joule rating (based on the unit of measurement).

The energy rating is calculated as follows:

Energy Rating = $V \times I \times T$, where

V = Surge voltage (or SVR) across the SPD (volts)

I = Surge current flowing through SPD (amps)

T = Duration of surge pulse (seconds)

The energy rating uses the Joule as the unit of measurement.

When selecting comparable technologies of surge devices, the energy rating can be quite useful. Since the purpose of an SPD is to clamp transient voltages and absorb energy, the calculation for the energy rating is a good indication of the effectiveness of the device. The higher the energy rating value, the better the product is perceived.

There are a number of different building block components for SPDs such as metal oxide varistors (MOVs), gas discharge tubes (GDTs), and silicon avalanche diodes (SADs). Due to the different characteristics of these components, the energy rating should only be used to distinguish between SPDs that are using similar technologies. Comparing the energy rating of a SPD that uses MOV technology to one that uses SAD technology could be misleading. The following example shows the some of the differences in the technology, how the calculation of the energy rating can be performed, and how the rating can be misleading:

The table below shows three different devices with identical Energy ratings, but diverging characteristics. These diverging characteristics can and do impact the functional abilities of SPDs.

Table 1

	Device 1 (GPT + Resistor)	Device 2 (SAD)	Device 3 (MOV)
SVR	15 000V	300V	300V
I	2500 A	2500 A	125 000 A
T	20 μ s	1000 μ s	20 μ s
Energy rating	750 J	750 J	750 J

When looking at the SVR the lower the values are better. As mentioned earlier, the SVR is the point in a voltage rise at which the device activates and begins clamping. Device 1 with a GDT and resistor has an extremely high SVR. GDTs alone, typically have very low SVRs, but the

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addition of the resistor makes the SVR for this device very high and, as such, is undesirable. Device 2, which has the SAD network, has an SVR that is much more reasonable, and will begin clamping the voltage at 300V. Device 3, MOVs also has a good SVR rating.

Identifying the current, I, that the device has been tested to, is also important. The higher the current rating, the more transient energy the device can absorb. In this example, both Device 1 (GDT & Resistor) and Device 2 (SAD) have been tested to a current of 2500 Amps. SADs in particular are not known for their energy absorption characteristics. MOV technology, included in Device 3, typically has very high energy absorption capabilities

It is also good to examine what type of surge waveform (indicated in time, T) the device has been tested to. Sometimes a 10 x 1000 μ s waveform is used, as in the example for Device 2, instead of the IEEE defined (typical) waveform for an indirect lightning strike, the 8 x 20 μ s waveform, or the waveform for a direct lightning strike, 10 x 350 μ s.

Situation 3 is clearly the highest performer, with its use of MOV technology. The SVR is low, which is highly desirable, and remains low during the duration of the surge pulse. The MOV can also accept the highest levels of surge current and is rated based on the IEEE pulse waveform, which is the most severe possible scenario. This evaluation effectively shows the MOV to be the clear winner among all technologies for surge suppression.

The Bulletin 4983 family of SPDs utilizes MOV technology as the primary internal component for surge protection. For example, the 4983-DS120-401 has an SVR of 0.5 kV. The MOV used in these products can accept 40 kA of surge current, and is rated based on the IEEE pulse waveform.

The Bulletin 4983-DH products use a combination of MOVs and GDTs. The Bulletin 4983-DH120-25 allows for an SVR of 0.4 kV with 70 kA of surge current. These products provide protection against almost any transient, and lead the industry in surge capabilities.

The Bulletin 4983-DD Dataline Surge products are designed to provide transient protection for communication devices, such as industrial processing equipment, I/O cards, transmissions systems, displays, etc. The devices are meant to protect 6V, 12V, and 24V DC applications.

These devices utilize GDTs to address incoming surges and a clamping diode network to attenuate any potential let-through voltages.

When applying these products, it is important to note that the wiring method for the 4983-DD products is different than most other SPDs.

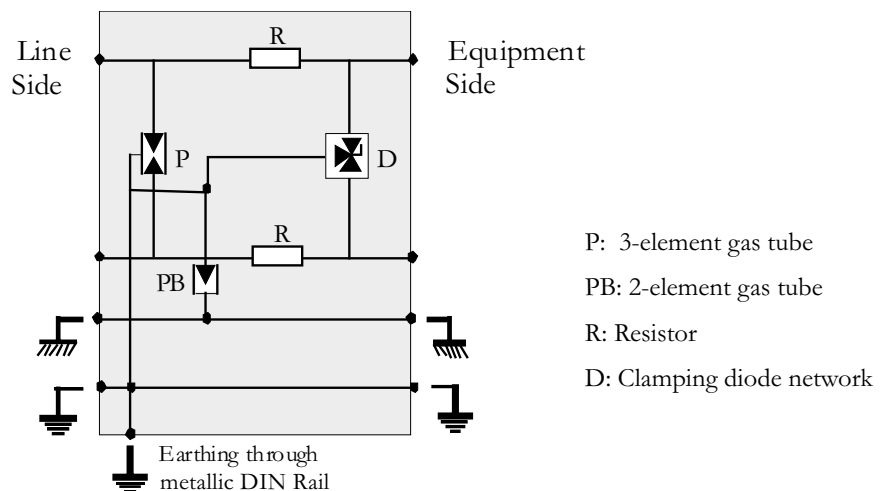
Communication Network Surge Protection Devices (4983- DD)

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A typical surge product in a pure power distribution application is connected in a parallel or shunted configuration. As such, there is no need to differentiate between the line and load side of the device when wiring, other than placing the surge device as close as possible to the piece of equipment that is being protected.

When wiring the 4983-DD, it is critical to understand that the line and equipment sides are not interchangeable. These devices need to be wired in series, and severe damage could occur to the dataline device if incorrectly wired (see Figure 1).

Figure 1.



The governing principle for the connection requirements is that the GDTs (*P* and *PB* in Diagram 1), need to be the first order of protection. The GDTs need to absorb the bulk of the transient energy before it reaches the diode network (*D* in Diagram 1). The diode network exhibits lower energy absorption characteristics than the GDTs. In the event that the connections to the dataline were reversed, the transient would first reach the diode network and the diodes would be destroyed, rendering the surge device useless for protection against future transients.

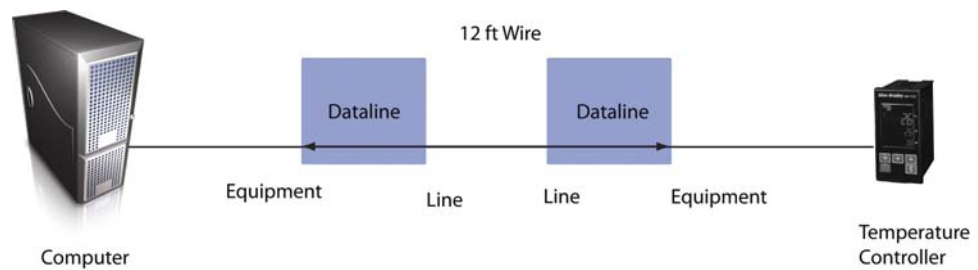
Example:

A typical application for the Bulletin 4983-DD device would be a single loop temperature controller connected to a computer. Information is transferred bi-directionally between the two, so the question becomes: How should the dataline device be wired? Which is the line side and which is the equipment side? How can it be ensured that both pieces of equipment, the temperature controller and the computer, receive adequate protection from transients?

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Both the computer and temperature controller need to be protected from a radiated transient that is picked up on a 12-foot length of RS232 cable running between the pieces of equipment. (See Figure 2)

Figure 2.



The first thought would be to place the 4983-DD device as close as possible to the equipment that needs protecting; in this case, the computer. As referenced in the Application Theory section, the equipment side of the dataline, should face towards the computer to ensure adequate protection. This results in the line side of the dataline device facing the remaining length of wire (from which the transient is traveling), as well as the temperature controller, which is at this point, essentially unprotected.

The naming of the connection as equipment makes sense here. The thing that may be confusing is the line designation, as there really is no line side with a communications setup.

Because the radiated transient has been picked up by the wire, it travels in both directions, and so is thus heading towards the temperature controller as well. The best thing to do here would be to place another dataline device next to the temperature controller, with the equipment side facing it.

The dataline products are now placed in a mirrored fashion, providing the best possible protection from any transients to both pieces of equipment in the communication network.

This example can be easily expanded to multiple products on any communications network.

The key is to place the dataline device as close to the piece of equipment that is being protected and make sure that the equipment side connection is facing that piece of equipment.

Filtering Devices (4983- PF and 4983-DC)

Filtering Devices protect sensitive electronic equipment from damaging transients and disruptive electrical line noise. These series-wired devices are constantly monitoring the AC power line, and ensuring that only clean power is getting to equipment. With today's highly sensitive digital equipment, clean power is more than desirable, it's a necessity.

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These filters reduce the stress on components of connected equipment by lowering the clamping voltage and the rate of voltage change by removing the high frequency elements of transients. They can and should be placed in front of PLCs, PanelViews, InViews, motion control systems, industrial computers, or any equipment with microprocessor-based technology.

The Bulletins 4983-PF and 4983-DC filters are built with Islatrol™ filter technology. Islatrol filtering technology continuously monitors and responds to unwanted disturbances to the input signal. This means that there is the same filtering at any point on the sine-wave, and whenever a disturbance comes through the input signal, the filter will respond appropriately, cleaning the wave of that disturbance. It is a filtering technique with the benefit of having very large decibel attenuation over the range, many competitors claim an attenuation range in the 40 dB range, Islatrol filtering technology provides an attenuation range to 90 dB.

These filters should be placed directly in front of the equipment that needs protecting. They are selected by the operating voltage of the system, and the ampacity of the equipment that needs protecting.

Rockwell Automation offers two main types of Allen-Bradley filtering devices. The 4983-PF filters are panel mount filters, rated to UL1283, and are designed to clean the AC power sine wave of lower level voltage transients and high frequency noise.

The other Allen-Bradley filtering product that is offered is the Bulletin 4983-DC. This device is both a filter with Islatrol technology, as well as an SPD. It is rated to both UL1283 and UL1449. This Din Rail-mounted device acts as both a filter, cleaning the wave of noise, and an SPD, shunting high-energy transients away from vulnerable equipment.

Summary

A common mistake in determining the total cost of a failure is to look only at the cost of the failed component. In reality, the analysis of the exact cost of a failure needs to take into account the down time costs associated with the loss of functionality as well as the repair labor time. In most cases, these costs far outweigh the cost of just replacing the damaged components. The costs associated with the prevention of even a single failure with the proper use of transient and noise suppression devices will be minimal compared to the actual costs of failure due to down time.

In addition to these losses, there can be huge losses associated with many intangible factors such as:

- Loss of productivity, idle workers, and equipment.
- Potential for overtime and additional labor expense
- Lost orders, lost good will, lost customers
- Lost revenue: no invoices generated, payments delayed, missed discounts, credit problems
- Customer/management dissatisfaction.

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- Penalties or fines, critical materials unavailable

Many significant, expensive problems can be avoided or mitigated with very little effort, time, and money. Transient protective devices and filters can be a great insurance policy for your sensitive equipment and systems. Consider using Rockwell Automation's Bulletin 4983 line of SPDs and filters to protect your investments.

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