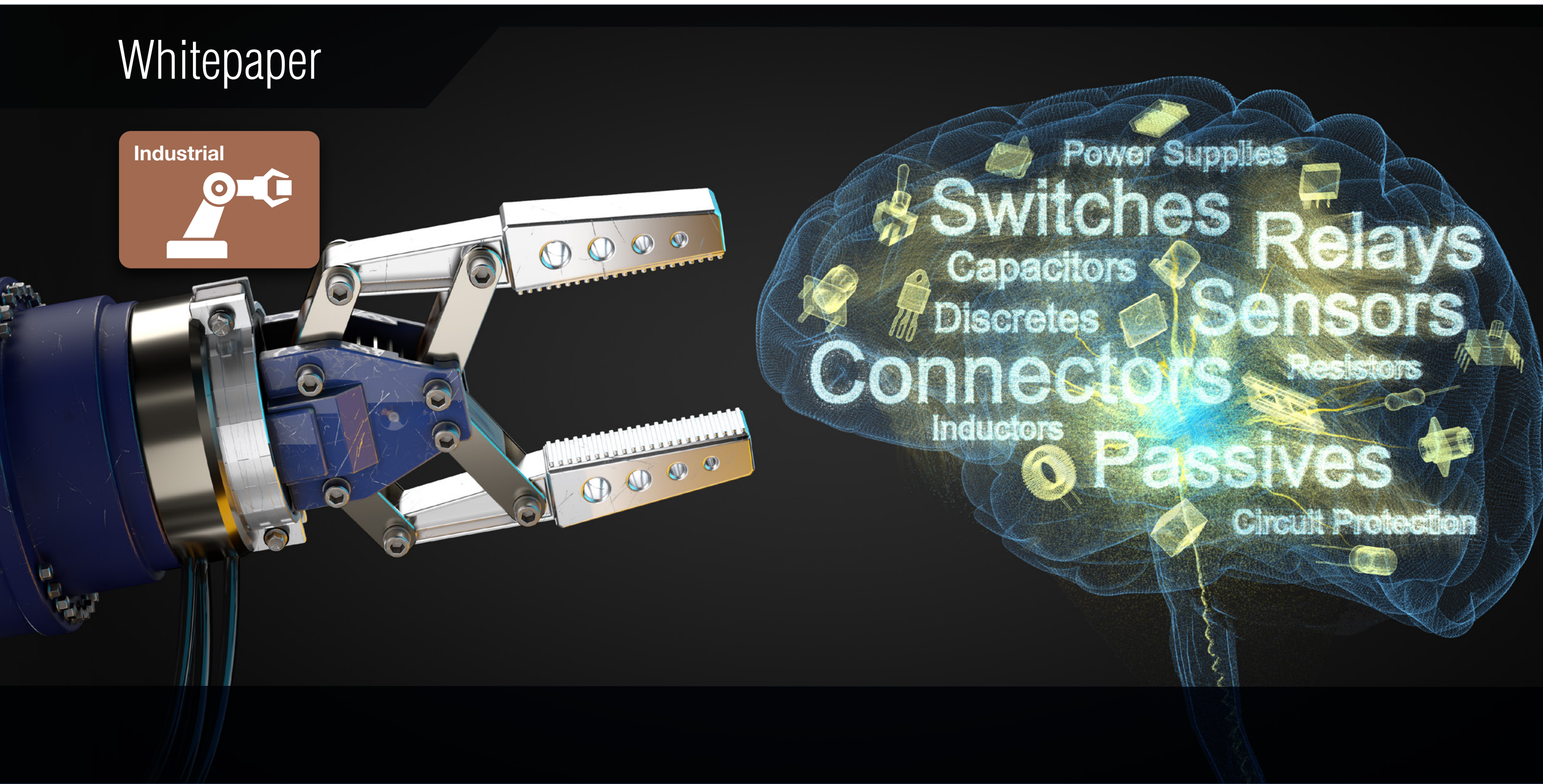
Whitepaper

Industrial



Choosing the right surge protection for industrial automation equipment

Executive Summary

The current trends of Industry 4.0 and the Industrial Internet of Things are behind many new industrial automation deployments. Keen to take advantage of the manufacturing productivity and improved agility that these initiatives offer, manufacturing organizations are looking to a broad range of suppliers to implement them. As such more and more electronics-based equipment is being installed factory-wide in control systems and sensors of various types. At the same time most industrial manufacturing facilities contain heavy-duty equipment such as pumps, arc-welding machines and high performance AC and DC motors along with a variety of electrically controlled actuators. This equipment typically consumes high levels of current and creates voltage transients during operation, particularly at start-up and shut-down, creating the potential to interfere with, or even damage, sensitive sensors and electronic control equipment located in the vicinity.

In this whitepaper we highlight the need to employ circuit protection devices within equipment used in the industrial automation environment. With an emphasis more on the aspects of ESD rather than EMC/EMI, we highlight the possible causes of surges and the different types of protection devices available to incorporate in control systems and their associated network interfaces (CAN, Ethernet etc.). In highlighting the different types of circuit protection available, a small selection of applications are discussed, along with specific products examples.

Industry 4.0 Background and trends

The term "Industry 4.0", originates from a project in the high-tech strategy of the German government promoting the computerization of manufacturing and is based on the 4 principles of Interconnection, Information Transparency, Technical Assistance and Decentralize decision-making.

Within the industry 4.0 or "smart" factory, cyber-physical systems communicate with each other and with humans using advanced Information Communication Technology, (ICT). Automated control systems and sensors enable smart machines to continually share information on parameters such as stock levels and operational status, including problems and faults, and machines within the factory are networked with production control systems using a range of communications protocols which are progressively becoming Ethernet based.

These increased levels of factory automation are facilitated by advances in semiconductor technology, such as nmCMOS, enabling more computing power to be deployed in smaller and smaller packages.

However, factory environments tend to be hostile as far as sensitive electronics are concerned, with a number of factors, including temperature, dust, vibration and transient overload voltages, or surges, posing threats to their operation. As the consequences of failure of factory control systems are significant, including lost production, financial loss, customer dis-satisfaction and even loss of life, rigorous measures must be taken to protect and safeguard their operation.

Transient over-voltages, or surges, constitute a specific category of threat to electronics in the factory environment, particularly as semi-conductor devices become smaller and more densely packed, and we now look at this category in more detail.

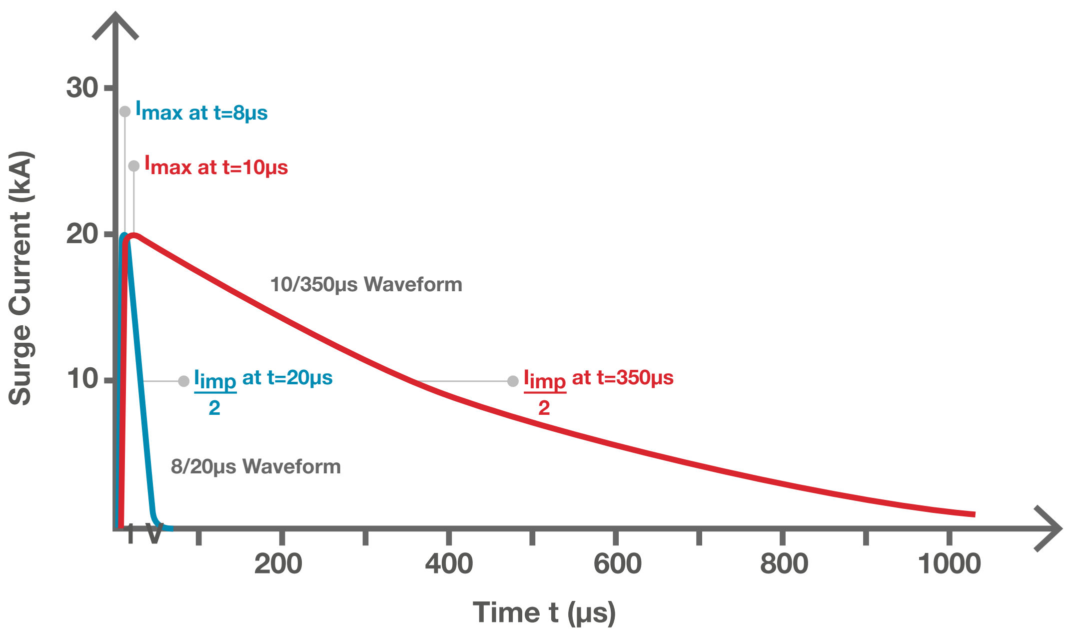
Electrical Surges in the factory environment

A surge, or transient overvoltage is a short duration increase in voltage, measured between two conductors, which can have a duration of anything from a few microseconds up to milliseconds with an amplitude of a few volts or many thousands of volts. Surges are everyday occurrences within the factory environment and can be caused by a number of sources:

Lightning Strikes

Lightning can strike a building directly, can strike a service to the building, (telephone line, water pipe, etc.) or can strike the ground nearby or even discharge in the atmosphere. Each scenario is capable of generating significant transient over-voltages affecting the equipment within the building. For the purposes of testing and rating SPD, specific waveforms are used, (figure 1), as defined in EN (IEC) 61643. Direct lightning strikes are characterized by the 10/350 waveform, where the maximum current from the strike occurs at 10 microseconds and the current value has decayed by 50% after 350 microseconds. Similarly indirect strikes are characterized by the 8/20 waveform. Due to its longer decay period the 10/350 waveform contains more electrical energy than the 8/20 and is more dangerous to structures and equipment.

Figure 1: Waveforms used to characterize surges (Source: BEAMA)



Transient Switching Operations

Shutdowns of high amperage equipment such as large motors or other heavy factory equipment can generate significant overvoltage levels. In most cases the shutdown of the equipment does not occur at the same time as the alternating current supply is at zero, leading to very fast changes of current, from a high value to zero. The resulting transient over-voltages can affect electronic equipment via conductive, inductive or capacitive means.

ESD

Static electricity is caused by tribocharging, the separation of electric charges that occurs when two materials are brought into contact and then separated. Familiar examples include walking on a rug, rubbing a balloon against a sweater and getting out of a car with a fabric car seat. The breaking of contact between the two materials results in tribocharging, creating a difference of electrical potential leading to an ESD discharge. Electronic components are particularly sensitive to ESD and must be appropriately protected during manufacture and also operation.

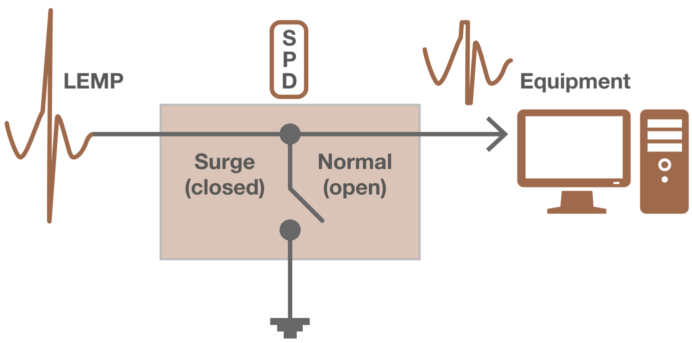
Faulty Switching

Significant over-voltages can be caused by issues in the electric mains supply such as failed Power Supply Units or Faulty wiring.

Transient over-voltages can occur between live conductors, or between a live conductor and the neutral conductor, in which case they are called transverse or symmetric surges. They can also occur between the live/neutral and earth conductors, when they are called longitudinal or asymmetric surges. Electronic equipment such as signaling terminals, transceivers, etc. may therefore require protection against both types of surge – i.e. the mains supply to the devices must be protected as well as the signaling lines.

Surge Protection Measures, (SPM), must therefore be taken to protect electrical installations or equipment and Surge Protection Devices (SPDs), Figure 2, are designed to divert surge currents to earth, thereby limiting the over-voltages to levels that are less likely to cause damage.

Figure 2: Basic SPM operation (Source: BEAMA)



There are a number of different types of SPD in common use, the main ones being:

Metal oxide varistor (MOV): A bulk semiconductor material (typically sintered granular zinc oxide) capable of conducting large currents when presented with a voltage above its rated voltage. MOVs typically limit voltages to about 3 to 4 times the normal circuit voltage by diverting surge current away from the protected load.

Transient voltage suppression (TVS) diode: A type of Zener diode which can limit voltage spikes. TVS diodes provide the fastest limiting action of protective components (theoretically in picoseconds), but have a relatively low energy absorbing capability. Voltages can be clamped to less than twice the normal operation voltage. If current impulses remain within the device ratings, life expectancy is exceptionally long. If component ratings are exceeded, the diode may fail as a permanent short circuit; in such cases, protection to their relatively limited current capacity, TVS diodes are often restricted to circuits with smaller current spikes.

Thyristor surge protection device (TSPD): A solid-state electronic device used in crowbar circuits to protect against overvoltage conditions. Thyristor-family devices can be viewed as having characteristics much like a spark gap but can operate much faster. They are related to TVS diodes, but can "break over" to a low clamping voltage analogous to an ionized and conducting spark gap. After triggering, the low clamping voltage allows large current surges to flow while limiting heat dissipation in the device.

Gas discharge tube (GDT): A sealed glass-enclosed device containing a special gas mixture trapped between two electrodes, which conducts electric current after becoming ionized by a high voltage spike. GDTs can conduct more current for their size than other components. Like MOVs, GDTs have a finite life expectancy, and can handle a few very large transients or a greater number of smaller transients. The typical failure mode occurs when the triggering voltage rises so high that the device becomes ineffective, although lightning surges can occasionally cause a dead short.

Standards and definitions

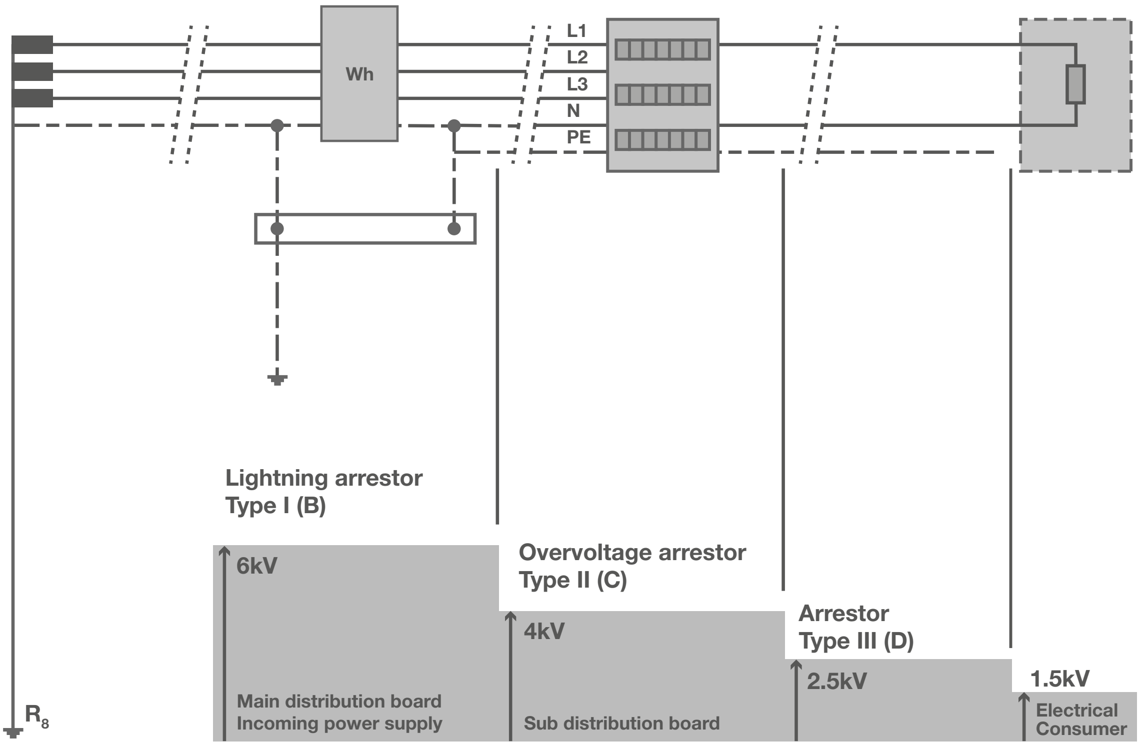
Various standards cover lightning protection and installation and product selection of surge protection devices, and a selection of those which are relevant to this discussion are listed in Table 1, below.

Application	Relevant Standards
Specifications for Electromagnetic compatibility (emission standards, immunity, installation, testing and measurement techniques must be considered.	EN (IEC) 61000
Protection of structures, their contents, persons and livestock against lightning	EN (IEC) 62305 parts 1 - 4
Electrical requirements and required test performance of SPDs for AC mains protection of 50/60 Hz low-voltage systems with a nominal voltage of up to 1000 V RMS AC and 1500 V DC	EN (IEC) 61643-11
Electrical requirements and required test performance of SPDs for telecommunications and signalling networks, low-voltage data systems, measurement and control circuits, and voice transmission networks with nominal voltages up to 1000 V RMS AC and 1500 V DC	EN (IEC) 61643 - 21
Technical specification providing recommendations for selection and installation of SPDs for AC mains protection of 50/60 Hz low-voltage systems with a nominal voltage of up to 1000 V RMS AC and 1500 V DC	EN (IEC) 61643 -12
Technical specification providing recommendations for selection and installation of SPDs connected to telecommunications and signalling networks, low-voltage data systems, measurement and control circuits, and voice transmission networks with nominal voltages up to 1000 V RMS AC and 1500 V DC	EN (IEC) 61643 - 22

Table 1: Selection of Standards and Specifications Relating to Surge Protection

EN 62305 describes techniques for protecting internal systems against Lightning Electromagnetic Impulse, (LEMP) and introduces Lightning Protection Zones, (LPZ), Figure 3, where the building is divided into a number of zones according to the level of threat, defined by withstand voltage - the maximum value of surge voltage which does not cause permanent damage through breakdown or sparkover of insulation. The principle behind zones is that the equipment to be protected should be located within an LPZ with compatible electromagnetic characteristics. The higher the zone number, the lower the expected electromagnetic effects and sensitive electronic equipment should be housed in higher numbered LPZs.

Figure 3: Lightning Protection Zones (Source: Weidmueller)



EN (IEC) 62305 also introduces the principle of coordinated SPDs, where the service entrance SPD handles the majority of surge energy and prevents flashover whilst the downstream transient overvoltage SPDs – installed between successive LPZs - ensure equipment protection by sufficiently limiting the over-voltages. SPDs are classified as Type 1, 2 or 3 and their electrical specifications and test requirements are defined in EN (IEC) 61643, as summarized in Table 2.

	LPZ 0/1	LPZ 1/2	LPZ 2/3
Typical SPD Installation Point	Service Entrance (e.g. Main Dist Board or Telecom NTP)	Sub-dist board or telecom PBX frame	Terminal Equipment (e.g. socket outlet)
SPD Type	Type 1	Type 2	Type3
SPD Technology	Spark Gap	Metal Oxide Varistor	Various
Test Waveform	10/350	8/20	Combination 8/20 and 1.2/50
Typical Peak Test Current	2.5kA	2.0kA	0.5kA
Notes	Capable of discharging partial lightning current	Prevents spread of over-voltages to electrical installations and connected equipment	Low discharge capacity, should always be installed as a supple-ment to Type 2 SPD

Table 2: SPD Types and test requirements (Adapted from Table2, BEAMA guide)

Examples of SPDs and Applications

The Industry 4.0 smart factory is heavily dependent upon networking technologies to enable communication between the various controllers and sensors or "things" which are increasingly embedded in modern factory equipment. Over the years, a number of networking standards have emerged in the industrial environment with Industrial Ethernet, Power over Ethernet, (PoE), CAN bus and Profibus among the more popular . Each of these standards have different transmission characteristics and topologies and SPD devices must be chosen and deployed accordingly.

Ethernet networks are the most widely installed in the modern factory and a number of SPD solutions exist for protecting indoor long-haul Ethernet data lines against lightning, ESD, EFT, and power faults. Figure 4 shows one such approach using LC03 and SP3051 TVS diode arrays from Littelfuse.

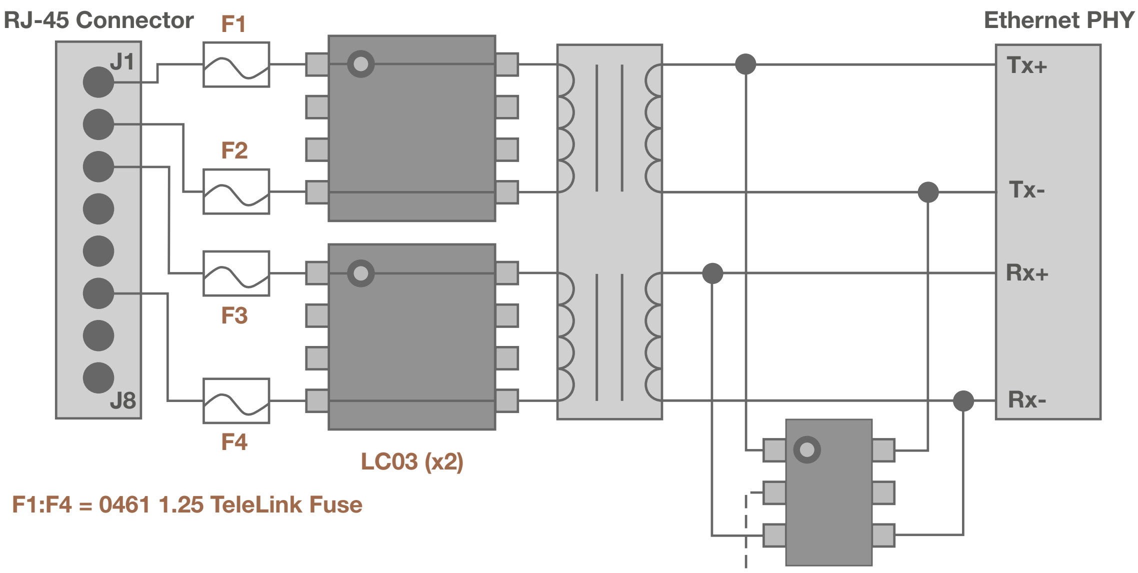


Figure 4: Ethernet Protection Solution (Source: Littelfuse)

TVS diode arrays are ideally suited for high speed data applications, such as Ethernet, owing to their very low capacitance. In this solution the four data lines shown (Tx± and Rx±) are protected against intra-building lightning transients by the LC03 TVS diode array which diverts the majority of energy away from the transformer. Any common mode energy which may be coupled across the transformer inter-winding capacitance is diverted to GND by the SP3051 TVS diode.

Controller Area Network (CAN bus) is another commonly used protocol in factory networks and Figure 5 shows an EPD solution for CAN bus using the Bourns® Model CDSOT23-T24CAN* dual TVS diode array.

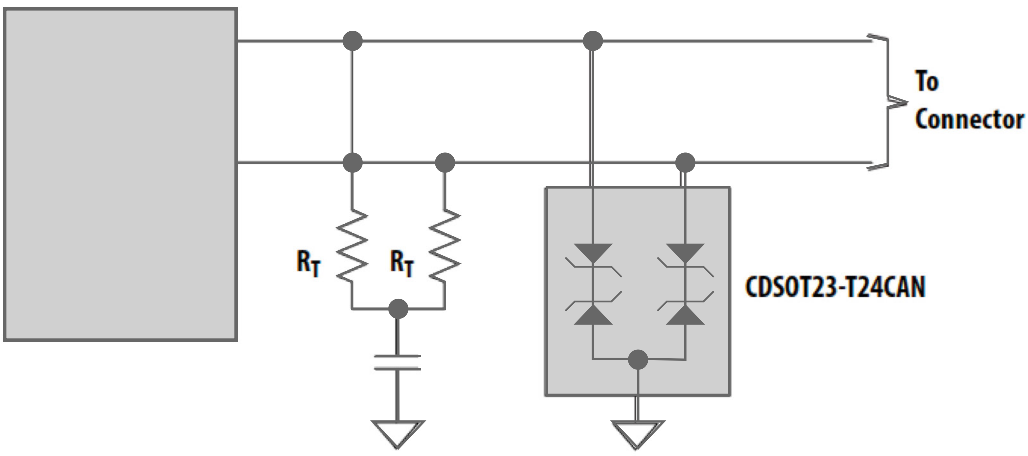


Figure 5: CANbus Protection circuit using CDSOT23-T24CAN TVS diode array (Source: Bourns)

The Bourns® Model CDSOT23-T24CAN dual TVS diode array is designed to protect a CANbus transceiver against surge events as per IEC 61000-4-5 (Level 1). The device is designed to be compatible with transceivers that have internal protection against 24 VDC being connected to either CAN input/output (I/O) due to a wiring error. The CDSOT23-T24CAN can be connected on a double-sided Printed Circuit Board (PCB) design and should be placed as close to the bus connector as possible with short traces to the signal lines.

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Telecoms networks are key services to modern buildings, including factories and, by nature of their provision, whether by overhead or underground cable, they are particularly sensitive to lightning strikes. Manufacturers of telecom equipment such as main distribution frames, subscriber terminal boxes, DSL and cable modems are increasingly using gas discharge tubes to protect against transient over-voltages.

Figure 6 shows the SMD gas discharge surge arrester range from TDK which can be deployed in a range of telecoms applications, including DSL line cards, cable modems, data lines, Ethernet ports and antennae.

Applications
S20/S30
Miniature 2-electrode SMD surge arrester designed for data lines and Ethernet ports

S50
Miniature 2-electrode SMD surge arrester with medium current handling capability for cable modems, DSL line cards etc.

S80
Miniature 2-electrode SMD surge arrester with high current handling capability for i.e. antenna protection.

TG30
Miniature 3-electrode SMD surge arrester designed for data lines and Ethernet ports

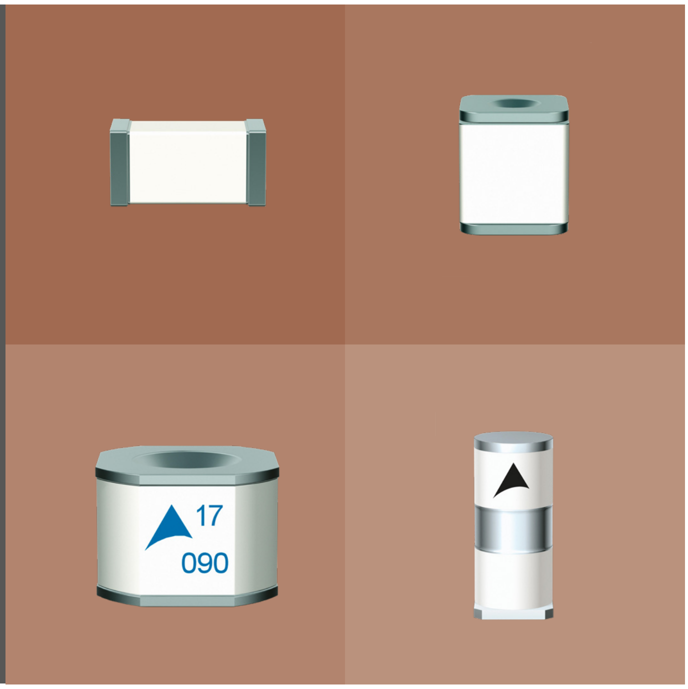

Figure 6: SMD Gas Discharge Surge Arrester family from TDK (Source: TDK: EPCOS)

Conclusion

Current trends in industrial automation have led to the advent of the smart factory where sophisticated electronic control systems exist side-by-side with the large, high amperage machines and equipment that they are designed to manage. Communications networks using a wide range of protocols are an integral part of this environment, enabling machines and controllers to share a wide range of data and information.

Surges or transient over-voltages are common within the industrial environment, whether caused by lightning strikes, transient voltages resulting from operation of machinery or wiring issues and these surges present a real threat to electronic systems.

Surge Protection Measures are used to minimize the threat caused by surges, thereby reducing the threat of expensive shut-downs caused by failure of automation systems.

This whitepaper has taken a closer look at the causes of surges along with current recommended procedures and technologies for the implementation of surge protection measures. Specific applications have been examined and sample Surge Protection Devices discussed.

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