

MTL Surge Technologies

Surge protection for Local Area Networks

Synopsis

This publication discusses ways in which Local Area Networks can be damaged by lightning-induced transients, and how they can be protected economically.

Application Note TAN 1007

Application Notes from MTL Surge Technologies

MTL Surge Technologies publish an increasing number of Application Notes providing easily understood information on various aspects of lightning and surge protection. At the date of publication of this Application Note, the list included:-

- TAN1001** Lightning surge protection for electronic equipment – *a practical guide*
A relatively brief and easy to understand introduction to the subject – an excellent starting point.
- TAN1002** Lightning and surge protection – *basic principles*
A more detailed account of the mechanism of lightning strikes and the measures needed to achieve an adequate level of protection.
- TAN1003** Earthing guide for surge protection
A detailed analysis of the subject of earthing for surge suppression purposes, this is both an easily understood exposition and a valuable reference document.
- TAN1004** Surge protection for intrinsically safe systems
A description of the best methods of combining surge protection and intrinsically safe systems.
- TAN1005** Surge protection for Zone 0 locations
A detailed analysis of this particular aspect of surge suppression in hazardous areas; complements TAN1004.
- TAN1006** Surge protection for weighing systems
Discusses, in some detail, the application of surge suppression to load-cell weighing systems.
- TAN1007** Surge protection for Local Area Networks
Discusses ways in which Local Area Networks can be damaged by lightning induced transients and how they can be protected economically.
- TAN1009** Surge protection for electrical power installations
Discusses aspects of how to protect and install mains power devices, with information on earthing and mains power systems. A guide to simple maintenance techniques for surge protection devices is included.

About MTL Surge Technologies

MTL Surge Technologies, the surge protection division of the MTL Instruments Group Plc, designs and manufactures a vast range of protection solutions for all your system surge protection requirements. Comprising of two independent but closely linked companies, Telematic and Atlantic Scientific Corporation, MTL Surge Technologies has a combined experience of nearly 50 years within the surge protection industry. MTL Surge Technologies supplies a wide range of Telematic and Atlantic Scientific surge protection devices offering solutions for all AC power, data and signal, telecom, network and wireless and HF systems.

The MTL Instruments Group has a strong and well respected presence within the Industrial Process market. This, combined with Telematic's close association with the Water Industry and Atlantic Scientific's presence in the Networks and Wireless Infrastructure market, means that MTL Surge Technologies is well placed to support a wide range of industries around the world.

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SURGE PROTECTION FOR LOCAL AREA NETWORKS

1 INTRODUCTION AND SCOPE

The purpose of this Guide is to describe the application of surge protection to local area networks (LANs), and to assist the reader in answering the following questions:

- ◆ What is surge protection?
- ◆ Is my network at risk - do I need surge protection?
- ◆ What are the costs and benefits of surge protection?
- ◆ Assuming I were to invest in surge protection, how would I apply it to my network?
- ◆ How do I choose surge protection products?

MTL Surge Technologies' principal area of expertise is in surge protection. This Guide does not attempt to be a treatise on networks, the subject being so vast, and some knowledge of networks and basic electrical theory is assumed. For those new to the subject, the further reading section contains some helpful references. Similarly, some of the surge protection topics covered are dealt with more fully in the other MTL Surge Technologies' publications listed.

The reader primarily interested in networks and coming new to surge protection may well discover that there is a need for surge protection at his site which extends beyond network protection. An example might be fax machine and modem connection to copper telephone cables. Should this be the case, Appendix G provides some guidance, MTL & Telematic staff will be pleased to assist further.

2 WHAT IS SURGE PROTECTION?

Electronic systems can be damaged or disrupted by what we refer to here as "surges". These are voltages which are much greater than the normal working voltage and which appear in a system such as a local area network for a short period of time, and hence are also sometimes referred to less succinctly as "transient over-voltages".

These surges can arise from switching of nearby heavy electrical equipment or from the clearance of an electrical short circuit fault (e.g. by a fuse blowing), but the most potent source is lightning. We shall be covering this in more detail, but it is important to appreciate that although catastrophic damage can indeed result from a direct lightning strike to one's building, this is relatively rare. Far commoner is the substantial damage to electronic components inflicted by a strike to ground within a distance of the order of a kilometre or so. As we shall see, this can produce a surge on cables feeding vulnerable electronic equipment, resulting in damage. Typical damage to a circuit board consists of such items as scorched and vaporized copper track, burned and open-circuit resistors, integrated circuits with part of their package blown away, and semiconductor junctions failed short-circuit.

At a lower level, but more insidious, is latent damage to semiconductors which subsequently fail perhaps months later, as can happen with electrostatic discharges.

Surge protection consists of the use of hardware devices, increasingly termed surge protection devices (SPDs, see glossary for other terms), which, correctly positioned and installed, limit surge voltages reaching protected equipment to a safe level. The operation of SPDs is covered briefly later for the interested reader.

2.1 How big are surges?

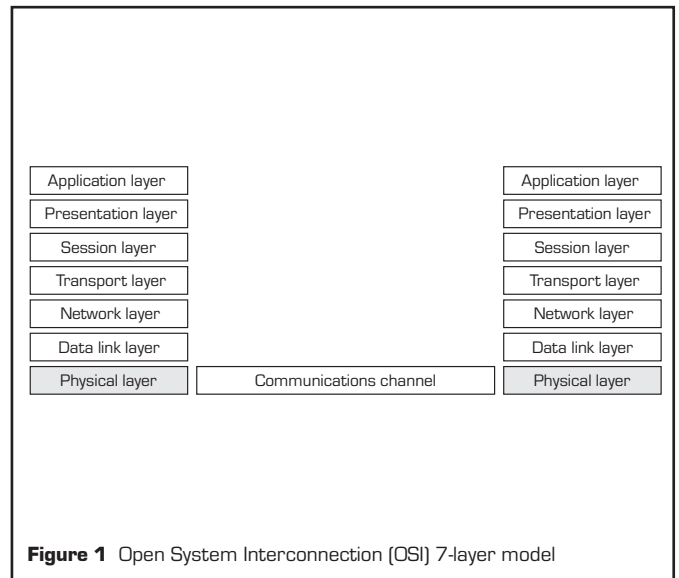
We can characterise lightning-induced surges by:

- Open-circuit voltage: the peak voltage which would be measured on a cable assuming no breakdown occurred
- Short-circuit current: the peak current flowing once breakdown has occurred, as commonly happens.
- Time: the time taken for the voltage or current pulse to rise to the peak and then decay. Lightning impulses have a fast rising edge, occupying a few microseconds, and a relatively slow decay of tens to hundreds of microseconds.

Experience of surge damage and the successful operation of surge protection devices indicates that one needs to be prepared to contend with voltages of the order of kilovolts to tens of kilovolts, and currents of kiloamps to low tens of kiloamps.

2.2 Surge protection and network layers

Fully defining a network is a huge undertaking. For those familiar with the Open System Interconnection (OSI) seven layer reference model employed for the task, and shown in figure 1, it is worth making the point that surge protection is concerned exclusively with the physical layer. This means that considerations for SPDs are with such things as signal voltages, impedances, losses and bandwidth, and with connectors and cable types.



SPDs are applied to network and other signal cables including telephone lines and the mains power supply.

Having discussed briefly what surge protection is, the next two sections outline some of the factors to be taken into account by the reader when considering investment in surge protection. The decision, which will inevitably be partly subjective, will be based on an assessment of the probability of damage, for which impartial assistance can be obtained, and the consequences of that damage, which the reader must assess for himself.

To give examples in a wider context, at one extreme might be a petrochemical plant in a lightning-prone area, handling potentially flammable and explosive liquids and gases. The loss of telemetry or control could have disastrous consequences. At the other extreme, a damaged TV set in an area of low lightning incidence may involve no more than a once-in-a-lifetime insurance claim and the purchase of a new TV!

3 RISK FACTORS

As with insurance, the only certainty with surge protection is the cost of obtaining it! The risks must be described in terms of probability only. It is entirely possible that in a given location, damage due to lightning may not occur for twenty years, and then twice in the same week.

A risk analysis can be undertaken using British Standard BS 6651: 1999, Appendix C, General advice on protection of electronic equipment within or on structures, against lightning, which is the best reference of which we are aware. This publication identifies risk factors which affect the probability of equipment suffering damage.

- ◆ Frequency of lightning strikes to ground.
- ◆ Size and exposure of building.
- ◆ Soil resistivity (the higher the resistivity, the greater the risk).
- ◆ Number and length of copper cables entering a building. These include mains power, telephone and data cables.
- ◆ Vulnerability of equipment.

Sample calculations are given in the standard.

4 ECONOMIC FACTORS

Even after deciding that the risk of damage might be great enough to warrant surge protection, there is still the hurdle of cost to be considered. The cost of a good SPD is of the order of tens of pounds (£), and installation work in addition may well cost much more. The cost of computing and networking hardware has fallen dramatically over recent years. The cost of providing surge protection may appear prohibitive, particularly for small networks with a few computers, relative to, say, replacing a damaged network card or PC.

However, the following need to be borne in mind:

- 1) Many businesses and organisations are now very reliant on their network. If the network is out of action, the business is paralysed. What is the cost to you of this “down-time”?
- 2) Restoring the network may not simply be a matter of quickly replacing an item of hardware because:
 - ◆ There may not be anyone with the required skills and confidence on site.
 - ◆ Identifying a single faulty item of hardware is not always straightforward.
 - ◆ There may be damage to more than one item, which will add to the difficulty of fault-finding.
 - ◆ Replacement hardware may not be readily available. Hardware, even though it may be performing an invaluable job for your business, becomes obsolete and hard to replace, remarkably quickly.
- 3) Can lost data be guaranteed to be retrieved?

Some insurance companies are now advising surge protection, and it is quite possible that this will become a factor in premiums and the willingness to cover a claim in the event of damage.

In summary, hardware can be insured and replaced easily and quickly. Data may be priceless, loss of data more than an inconvenience.

The next two sections are intended to give an insight into how surges infiltrate networks, and very briefly, how surge protection devices work. The reader lacking time or interest in these topics may wish to skip to the section on applying surge protection.

5 HOW SURGES THREATEN A NETWORK

In this section we deal with:

- 1) Ground potential surge due to a nearby lightning strike to ground, probably the greatest threat of damage to the largest number of networks.
- 2) Direct strike to a building housing a LAN, a severe threat to a relatively few.
- 3) Mains power supply transients due to lightning strikes to power lines, supply switching and faults, a moderate threat to an intermediate number of LANs.

Ground potential surge due to a nearby lightning strike to ground:

A lightning strike to ground consists of a number of strokes of differing intensity. Currents of typically tens of kiloamps (1 kiloamp = 1000 amp) flow through surface layers of e.g. soil, clay and rock in the process of discharging the electrostatic energy of the thundercloud. Figures of 100kA and 200kA are used to illustrate worst-case direct strikes.

Because the ground is an imperfect electrical conductor, these lightning currents can develop extremely large voltages (or “potentials”) between points on the earth’s surface. For instance, 100kA flowing through 10 ohm, not a particularly high value of ground resistance, develops 1 million volts (1 megavolt!) across metres or tens of metres of ground. This is the ground potential surge.

Two buildings in the vicinity of a nearby ground strike but separated by some distance, will experience different potential shifts, and their electrical earths, which are connected to their local ground via earth systems such as rods and mats, will briefly have a large potential difference between them. If the buildings’ electrical systems are contained entirely within their structure, this does not present a problem. If, however, a cable such as a LAN cable links the buildings, equipment in one will be subjected to the relative ground potential of the other, which may well be sufficient (kilovolts or greater) to cause damage when current (tens to thousands of amps) flows as a result of destructive breakdown within the LAN equipment. Figure 2 illustrates this. The surge voltage depends on the location of the lightning strike, its current, the ground resistivity, and the distance between the buildings.

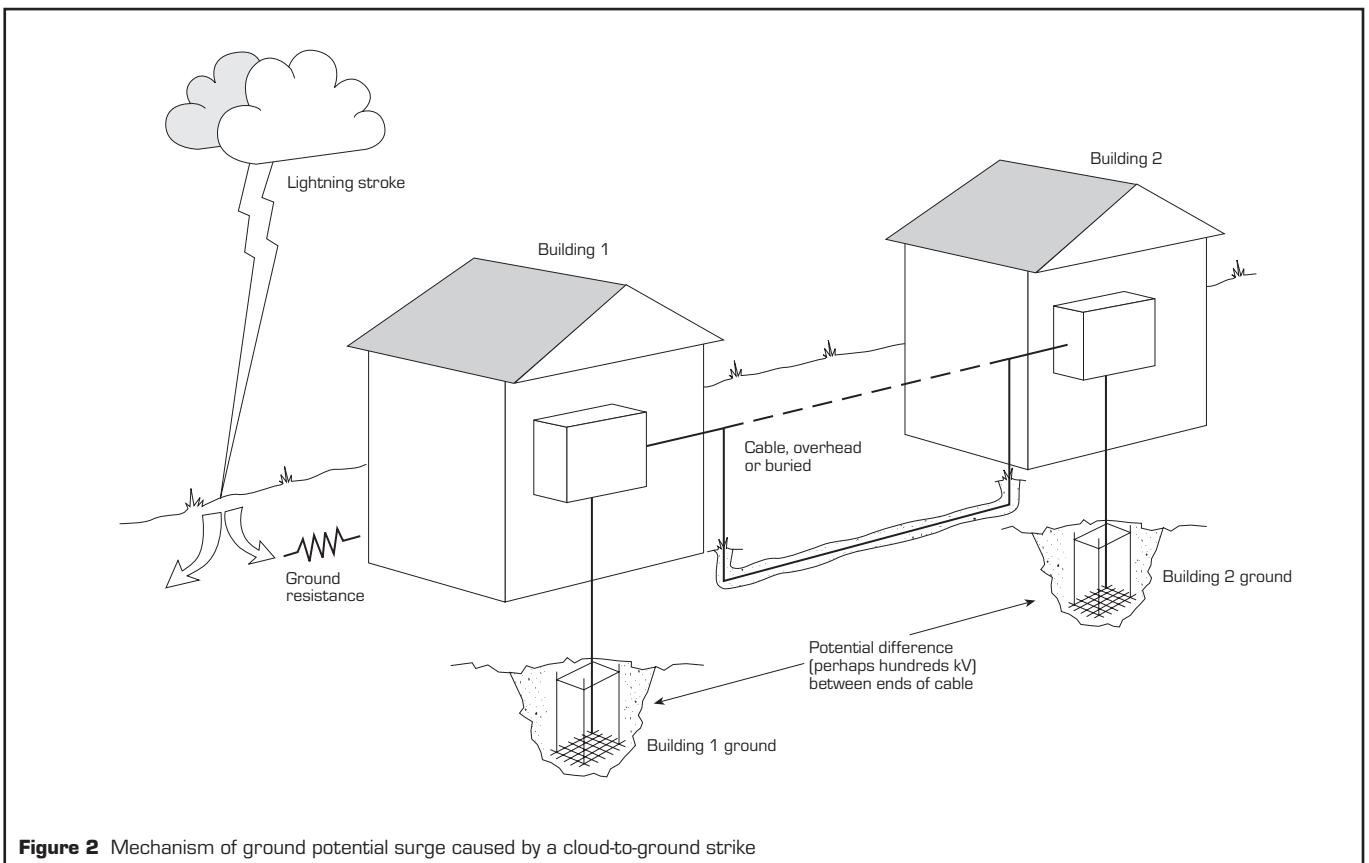


Figure 2 Mechanism of ground potential surge caused by a cloud-to-ground strike

It would be prudent to fit surge protection devices (SPDs) when cables longer than a few metres, link buildings. In effect, the external cable presents a large "capture area" for transients.

Although the focus of this Guide is on LANs, the wider context must not be neglected. The typical modern building is served by a number of cables carrying signals from points not tied to the building's electrical earth. These can include telephone lines, now commonly feeding fax machines and modems, antennas, video security camera links and external lighting cables. Each one carries the threat of damage from the ground potential surge, and surge protection should be considered for each (see the checklist in appendix 6).

Direct strike to a building

We have tended to play down the risk of direct strikes, because they affect relatively few people. Nevertheless, for tall buildings such as corporate offices exposed to lightning activity, the threat of direct strikes is very real, and the assumption must be made that it will happen. We consider here how a LAN in such a building can suffer damage.

In the event of a direct lightning strike, the full strike current flows through the building's lightning conductor system.

Figure 3 shows how side-flash can arise. Lightning strikes an air termination and travels down a conductor on the surface of the building. The voltage across a length of cable due to a rapidly changing current flowing through it depends on the rate of change of current and the cable's self-inductance. The calculation given in Appendix 1, based on BS 6651 information, shows that a voltage of 1.5 million volts (also written megavolts or MV) can be developed along a 30 metre lightning conductor.

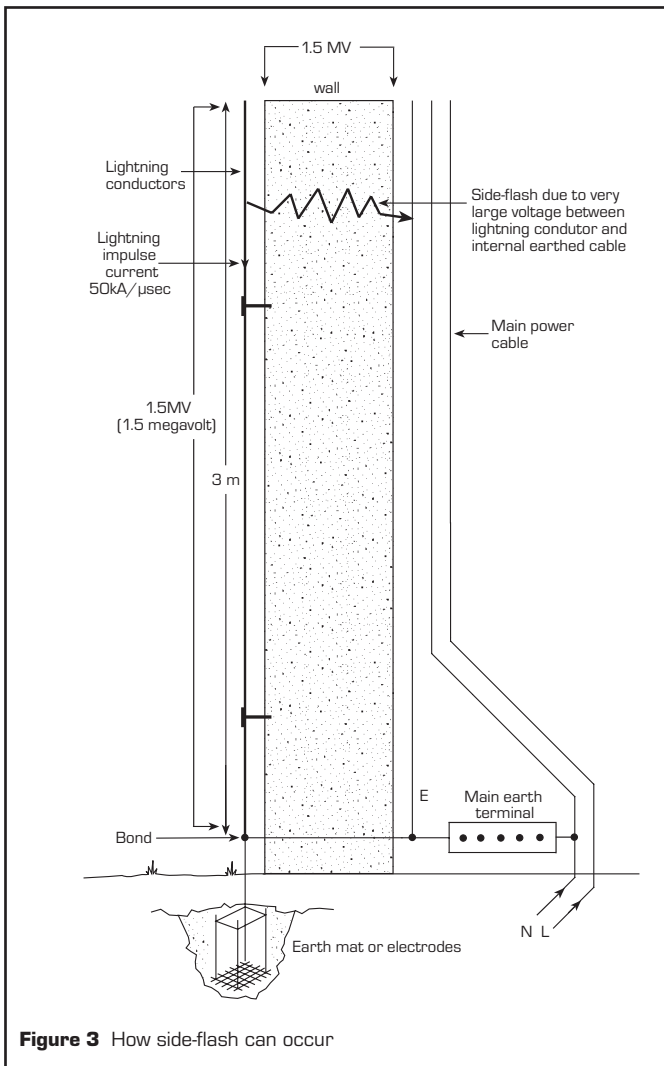


Figure 3 How side-flash can occur

If cables which are at the potential of the surrounding earth are run close to walls which are not metal clad, there may be side-flash. This is rather extreme and the ensuing current may cause severe damage. Modern building construction techniques with all structural metalwork bonded and earthed, should make this relatively rare.

A less extreme case involves voltages induced by capacitive or inductive coupling (see figure 4). Capacitively-induced voltages will be greatly reduced if the cables are run in earthed metal ducting.

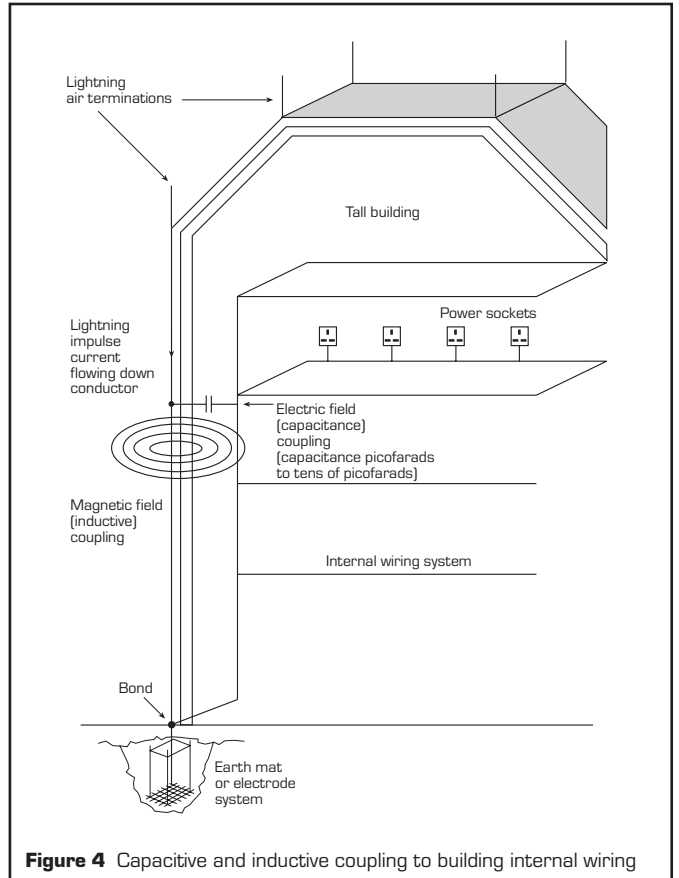


Figure 4 Capacitive and inductive coupling to building internal wiring

It is not easy to provide definitive information on the voltages expected within buildings struck by lightning. BS 6651 appendix C, figure C4 gives a figure of 1500V induced in a 2 metre high wiring loop when a direct strike current flows down a building's lightning conductor system, assuming a peak rate of current rise of 50kA/µsec. One difficulty in providing definitive figures is that although the purpose of the lightning conductor system is to provide, in effect, a screened enclosure for the building, in reality, this will be an approximation, and depends on the construction used. A metal-skinned building, with all parts bonded, can be very good. Those with large areas of glass may be another matter:

A calculation presented at the ERA Seminar on Lightning Protection (see ERA Report no. 87-0328) was that of the voltage across the ends of a large loop within a building, 1 metre from a current-carrying lightning conductor:

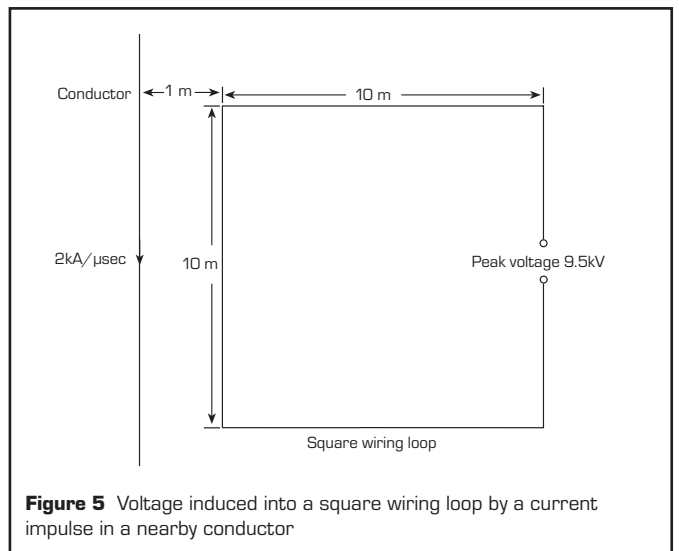


Figure 5 Voltage induced into a square wiring loop by a current impulse in a nearby conductor

The wiring loop could be a combination of mains power & network cabling, via computers. Note the modest figure of 2kA/µsec for the rate of rise of current.

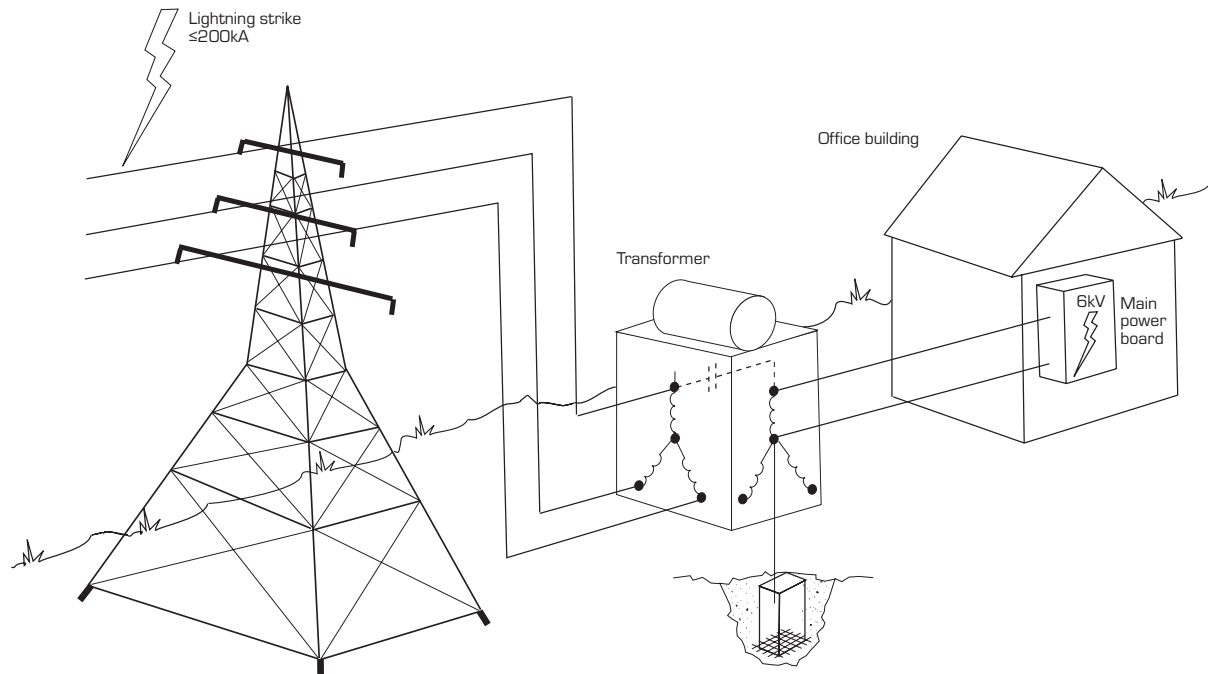


Figure 6 Capacitive coupling from a direct lightning strike on overhead cables

5.1 Reducing the risks

From BS 6651, Appendix C, "General advice on protection of electronic equipment within or on structures against lightning": To reduce the risk of damage to equipment within conventional modern metal framed buildings, section C.7.2.1 advises locating electronic equipment towards the centre of the building and avoiding the top floor, near air terminations. If possible, data and power lines should be run in adjacent ducts to minimise loop areas (figure C9 of the standard).

This section of necessity appears somewhat theoretical. It is difficult to assess how much damage of this sort is actually happening. A network being out of action is not something which companies are likely to publicise, and as noted earlier, some damage may be latent, occur later, and therefore not be associated with lightning. Anecdotally, the Financial Times once reported: "...Amstrad's design department found its machines reset when a horizontal bolt of lightning zipped past its windows...", though no damage was mentioned.

Mains power supply transients due to lightning strikes to power lines, supply switching and faults

We have concentrated primarily on surges which enter equipment via the LAN signal cables. However, the mains power supply presents another route. As shown in figure 6, a direct strike to a high voltage power line can, via capacitive coupling through transformers produce a mains power supply surge. Even though greatly attenuated from the original, this can be great enough to cause equipment damage.

Not all surges are caused by lightning. Some originate inside a building's electrical system as a result of the interruption of a large supply current. This could result from the switching of loads such as lifts and motors, or from fault currents, this being illustrated in figure 7 below. A fault develops which short-circuits the supply. When the short-circuit current is suddenly interrupted by the opening of a fuse or circuit-breaker, an inductive transient voltage is produced. The waveform will typically be a damped oscillation, the peak voltage being related to the rate of change of current and the inductance of the supply cable.

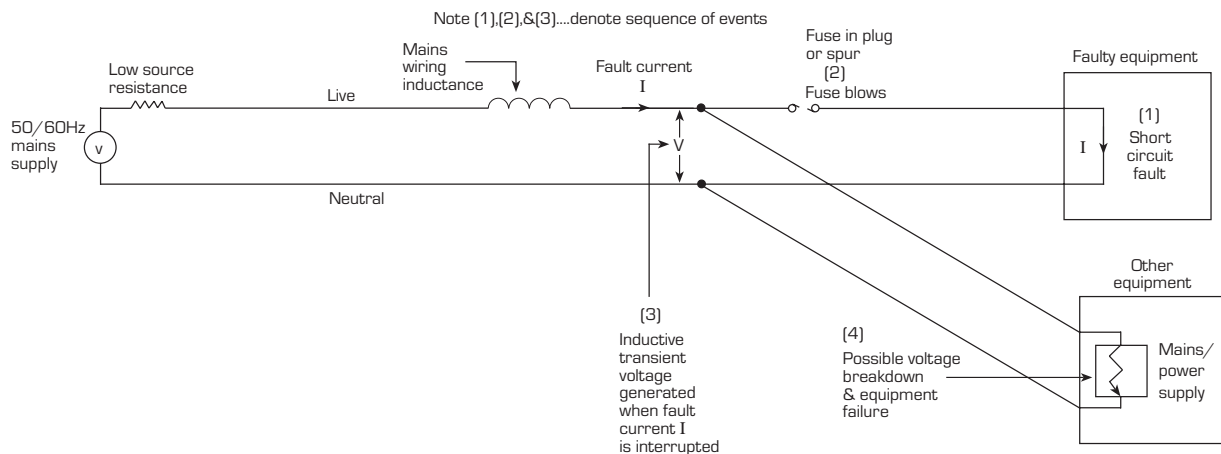


Figure 7 Generation of mains power supply surges due to fault current clearance

6 HOW SURGE PROTECTION DEVICES WORK

An SPD can helpfully be thought of as a switch which is normally open, but which closes when the voltage across it exceeds a threshold level. It is not intended to go into internal details here, merely to note that SPDs use components such as gas discharge tubes, diodes, resistors, inductors and metal oxide varistors.

A typical SPD for use in protecting data cables will limit the voltage between the conductors of the data cable ("difference mode") and between the conductors and earth ("common mode"). Common mode surges are more potent in terms of voltage and current, and are more difficult to deal with, since a low impedance earth connection is required. An SPD can only do its job if correctly installed, and this is the main theme of reference P2 (see Further reading). Figures 8 & 9, taken from this 'Earthing guide...', illustrate SPD operation.

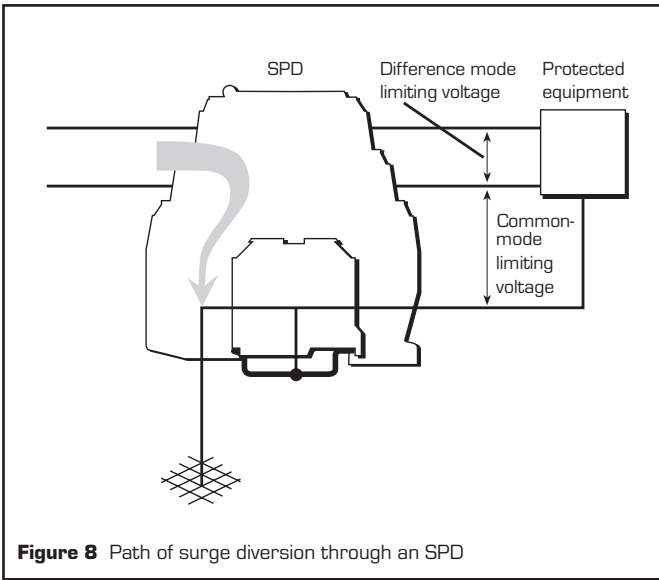


Figure 8 Path of surge diversion through an SPD

In acting as a switch, the SPD conducts very large transient currents with an output voltage low enough to avoid damage to the protected equipment. All the current flows through the SPD and none through the equipment.

The reader may at this point be wondering whether, given the need for an earth connection and a large, if brief, current flow, it would be a better idea to use a series protection device which goes open circuit during a surge. The "series isolation" protection can be effected by unplugging connectors (thereby losing the signal) before or during a storm, or more elegantly, by using optical fibres. However, surge voltages can be so huge a series device is simply not practical on a "copper" data cable. BS 6651 appendix C (see Further Reading) states that "high impedance isolation devices are not satisfactory on their own unless they have a withstand voltage greater than 100kV owing to the large potential difference occurring between unprotected buildings resulting from lightning current flow into the ground from one of them."

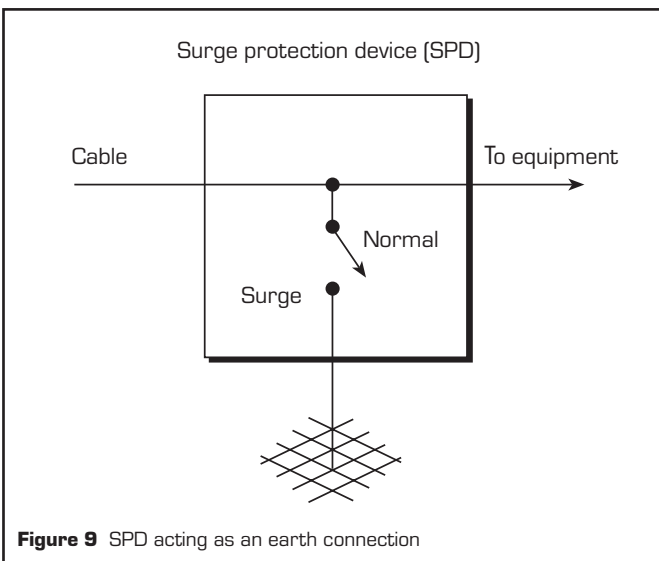


Figure 9 SPD acting as an earth connection

Note that for effective protection, mains power SPDs are needed in conjunction with network and other signal protectors, and are generally earthed via the electricity supply earth.

An SPD for use on a LAN, will have had the following factors taken into account:

- ◆ Cable and connector type
- ◆ Signal levels
- ◆ System impedance (e.g. 50 ohm for coaxial Ethernet™)
- ◆ Allowable attenuation and/or series resistance
- ◆ Bandwidth required, based on signalling speed
- ◆ Surge current handling
- ◆ System earthing arrangement
- ◆ Physical size constraints
- ◆ Method of installation

This accounts for the variety of products available.

It may appear that the maximum surge voltage which the LAN can withstand has been omitted. In practice, this is not always known and will vary as new equipment is added to the LAN, and in any case, the SPD is usually designed for the lowest possible limiting voltage, allowing a margin above the normal signal level, as illustrated by figure 10.

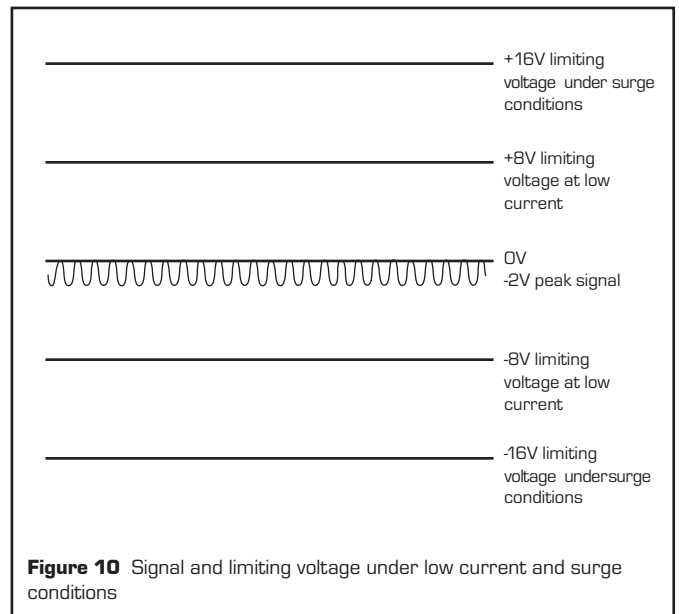


Figure 10 Signal and limiting voltage under low current and surge conditions

Note: 'Ethernet' is a trade mark of the Xerox Corporation.

7 APPLYING SURGE PROTECTION TO A LOCAL AREA NETWORK

Surge protection devices can only be effective if properly installed, and this section provides some basic guidelines. For the sake of brevity, it is somewhat prescriptive and Earthing guide... TAN1003 should be studied if an understanding of the reasoning is required. Some readers may be somewhat disheartened to find that practical considerations such as the routing of network cables mean that not all the guidelines can be followed. These concerns are at least partly addressed, and provided that limitations are recognised, a good level of protection for at least part of the system can be achieved - much better than doing nothing!

First, the guidelines for the case of a network where the LAN cables run between buildings which either have structural lightning protection fitted, or for which the risk of a direct strike is negligible:

- ◆ LAN cable routing: run the cables which pass between buildings close to the mains power distribution boards, from which the electrical supply earth for each building is derived.
- ◆ Fit a network SPD in the LAN cable close to the mains power distribution board in each building. Each building should be treated alike, since the concern is with potential differences between the two building earths.

- ◆ Earth the SPD at the mains power distribution board with the shortest possible length of cable with a minimum cross section of 2.5mm². Better still, use several cables electrically in parallel, spaced apart from each other. Best of all, fit the SPD on earthed metal panels if available.

Apart from a direct strike to the building, the result will be protection for the entire LAN cable in the building, using only one LAN SPD per building.

Suppose that the LAN cable cannot practically or economically be routed as described above? In this case, it is not possible to position a single LAN plus mains power SPD so as to protect the entire network with as great a confidence. Individual items of hardware can be fully protected, however, with lesser protection offered to the rest. While not wishing to dissuade from fitting SPDs to each item on the network (!), in practice it would be sensible to decide on the most strategically important, such as the file and application servers, and fit SPDs there. Figure 11 shows how this should be done, using short connections to the equipment earth point. (The need for a mains power as well as a LAN SPD is explained in TAN1003, section 7.4.)

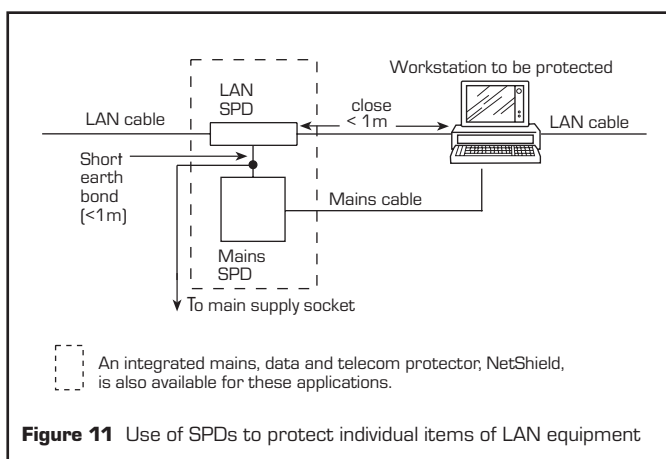


Figure 11 Use of SPDs to protect individual items of LAN equipment

The reason why this does not offer complete protection is shown in figure 12 below. When the LAN cable is subject to a surge, i.e. at a high voltage relative to the building's electrical supply earth, the SPDs operate and protect the equipment to which they are attached. However, depending on the layout of the wiring, the current pulse generates an inductive transient voltage which may be enough to break down insulation in other devices and cause damage. The energy in this transient depends on the inductance and the peak current. As this will be much lower than the energy in the original transient, the network will still have benefitted greatly from the fitting of even partial protection.

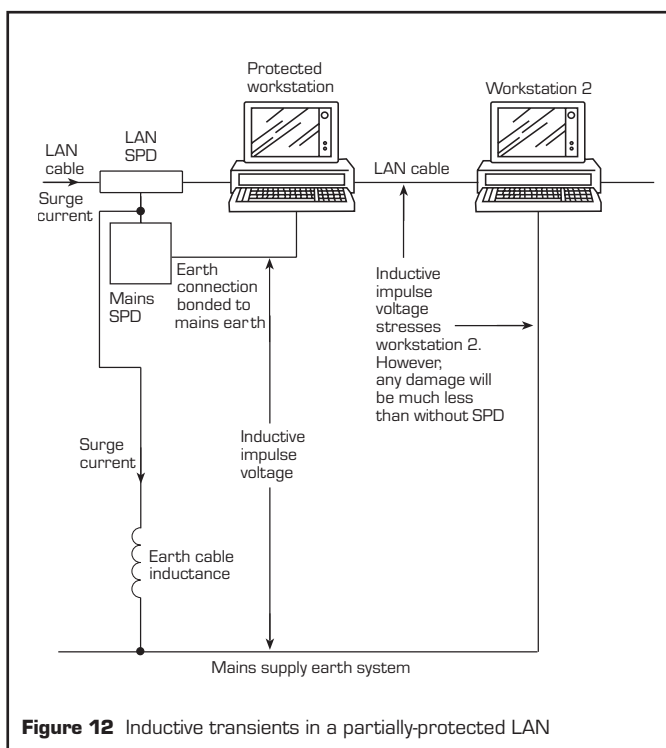


Figure 12 Inductive transients in a partially-protected LAN

We dealt earlier with the less well-defined threats to LANs in a single building. The advice in this situation is similar to the case of external cables which are non-ideally routed covered in the paragraphs immediately above. Identify the most strategically important items of equipment and fit protection locally to these.

8 SELECTING LAN SURGE PROTECTION HARDWARE

This section is intended to assist in choosing the appropriate network protection devices available from MTL Surge Technologies'. It is intended merely as a pointer, and the product literature should be consulted for full details. No comparisons are drawn with other manufacturers' offerings. However, the reader should be aware that the devices offered by MTL Surge Technologies' and other reputable companies, are designed to protect and survive repeated large surges. Low-cost LAN protection products are on the market which, while probably offering protection, are sacrificial and do not survive a significant surge. These are likely to give a false economy since their failure will stop the network functioning and this will absorb time and effort in fault-finding and re-ordering.

The main LAN types are briefly covered, with the SPDs suitable for the application. There is then a tabular summary covering a greater range of named networks. Yet again, the point needs to be stressed that full protection often requires additional SPDs on the mains power supply and, for instance, on telephone cables.

1) Newer, faster LANs:

Some computer applications, such as real-time video, require very large amounts of data to be transported around a network. This is especially so when images are involved. The volume of traffic can slow the network down. A lot of work has therefore been put into increasing the capacity of networks. One way of doing this is to use faster data rates. Fast (100Mbps or more) systems are now being installed which have a data rate along the cables ten times that of standard Ethernet. Some years ago, FDDI (Fibre Distributed Data Interface) using optical fibre and allowing up to 1km links, was promoted as the answer and predicted to overwhelm other systems, but cost of hardware and installation (requiring precision work with connectors) has prevented this. New systems using copper cable have been developed.

As usual, there is more than one competing system, the main contenders being Asynchronous Transfer Mode (ATM), versions of 100Mbps Ethernet such as 100Base-T, 100Base-T4 and 100VG-AnyLAN, and CDDI (C = Copper) i.e. FDDI using copper cables.

The defining standard for this too is ISO/IEC 8802-3, ANSI/IEEE 802.3 (S3, further reading)

Details of some articles on these and the related topic of structured cabling are given in the Further Reading section.

The Atlantic Scientific ZoneBarrier ZBS 24550 (with ASC 24500 rack mounting kit) and Telematic NET 905 are available for use on unshielded twisted pair cables carrying data at up to and beyond 100 Mbps. Protection is provided for all four pairs of standard cable, including category 5. The NET 905 is a single unit, protecting one cable, while ZBS 24550 is a 32-way rack-mountable unit protecting up to 64 cables.

A further product selection guide is given in appendix 5.

2) Twisted pair Ethernet 10Base-T (ISO/IEC 8802-3):

- ◆ Data rate 10 Mbps
- ◆ Cable type: unshielded twisted pair (UTP) or shielded twisted pair (STP). Two pairs are required, though the actual cable used commonly contains four pairs.
- ◆ Cable characteristic impedance 100 ohm.
- ◆ Connector type: RJ45.

The cabling used is relatively inexpensive and flexible. If a computer in an office is moved, it can be re-connected to the network on a new length of cable plugged into the hub without disrupting other users. With coaxial Ethernet systems, the cable has to be routed close to all workstations, and for instance, re-arranging an office, a popular modern pastime, could involve expensive re-cabling. Also, if the coaxial trunk cable is broken, the entire network, or network segment if repeaters are used, ceases to function.

The Atlantic Scientific ZoneBarrier 24540 or Interface Protector IP 70015 (which incorporates an RJ45 connection system) can be used to protect Token Ring networks. An alternative to the RJ45 connection system is an IP 70014 which employs a DB9 connection. IP Series devices provide in-line I/O port protection for RS232, RS423, 10Base-T and Token Ring, on DB9, DB15 and DB25 style connectors.

Products available from MTL Surge Technologies:

- ◆ Telematic NET 905 (4-pair protection, RJ 45 connectors, free-standing)
- ◆ Atlantic Scientific Zone Barrier ZBS 24550 (Protection for sixteen, 4-wire cables, RJ45 connectors, in ASC 24500 rack mounting kit)

3) IBM Token Ring (ISO/IEC 8802-5):

- ◆ Data rate 4 or 16 Mbps.
- ◆ ISO/IEC 8802-5 (ANSI/IEEE 802.5) standard specifies this type of token passing network.

Originally, a number of types of shielded twisted pair (STP) cables were specified, known as IBM type 1,2,6 or 9, with a 150 ohm characteristic impedance, produced in indoor and outdoor versions, and special connectors. More recently, unshielded twisted pair (UTP) 100 ohm cables have been adopted, using RJ45 connectors. Maximum cable length in the ring, depending on type, is 366 metres.

4) Thin Ethernet (10Base-5) summary:

- ◆ Coaxial cable characteristic impedance: 50 ohm.
- ◆ Typical coaxial cable: RG58
- ◆ Bit rate 10 megabits per second (10 Mbps)
- ◆ Connector type: BNC
- ◆ Maximum cable length per segment: 185 metres
- ◆ Repeaters allow cable segments to be added to extend the total length of the network
- ◆ Defining standards: ISO/IEC 8802-3, ANSI/IEEE 802.3 (S3, Further Reading)
- ◆ Appropriate Telematic SPDs: ZoneBarrier ZBS 24534

The Telematic building in Luton has a thin Ethernet network with one repeater, since more than 185 metres of cable is used.

Appendix 1: Surge voltage along a conductor

When a current flows in a conductor, a magnetic field appears around the conductor. If the current changes, the changing magnetic field is said to "induce" a voltage which appears along the length of the conductor. The polarity of the voltage is such as to oppose further change in the current. This property of a conductor of resisting the flow of a changing current is known properly as the "self-inductance", but more commonly as simply the "inductance". It is measured in units of henries and for conductors of about 2mm diameter with say a length of up to 100m would have a typical self-inductance value of 1µH/m (1 microHenry per metre).

The voltage produced across an inductance is given by:

$$V = L \frac{di}{dt}$$

where V is the voltage, L is the self-inductance and $\frac{di}{dt}$ the rate of change of current. The minus sign indicates that the voltage opposes the rate of change of current. It is commonly omitted when only the magnitude of the voltage is required.

Taking L = 50mH (for 50 metres of conductor on a moderately tall building,

assuming 1µH per metre) and $\frac{di}{dt} = 30kA/\mu\text{sec}$, a value for lightning stroke current quoted in BS 6651 appendix C, we get a voltage of 1.5MV (1.5 megavolts).

Note that the inductance value is a "rule of thumb" figure. As conductor length increases, the inductance increases somewhat faster than proportionally, so the voltage calculated above is an underestimate.

Appendix 2: Surge protection devices and LAN cable testers

When the installation of network cabling is complete, it is quite common for the installer to check the integrity of the cables sections and connectors using a cable tester. Some of these use a technique known as time domain reflectometry (TDR). In this, a pulse is sent down the cable, and the strength and delay of the return or echo signal is measured in a manner somewhat analogous to radar. A well-terminated cable in good condition should give a weak return signal, and therefore a high so-called "return loss".

The pulses used have very fast edges to allow accurate timing of the return signal, and very large bandwidths, of the order of several hundred megahertz (MHz) are needed to transmit the pulses without distortion, a condition met by good network cables.

However, an SPD with its protection components has a more limited bandwidth and appears to the cable tester using TDR as a low-pass filter, presenting a significant return signal that is, a low (poor) return loss, even though no fault exists.

For this reason, LAN cable testing using the TDR method should be carried out without any SPDs installed in the cabling.

Appendix 3: Structured cabling and surge protection devices

Traditionally, wiring within buildings has ended up as a mess, with telephone and computer network cables trailing all over the place. Structured cabling (or "wiring") is an attempt at an orderly solution, by wiring a building with an infrastructure of twisted pair cable and wall outlets (or "wallports"). The signals conveyed by the cabling can be voice or data, depending on the user's needs. If these needs change, there is no need to re-cable, which can be extremely expensive.

Cables and connection systems have been characterised according to their performance with frequency, the most demanding category currently installed being "category 5", which is specified up to 100MHz, a frequency most people would once have considered far too high to be transmitted along twisted pair cable looking superficially much like telephone cable.

In summary, the idea of structured cabling is to provide a flexible cable infrastructure through which a wide variety of signals can be passed. However, surge protection devices, are designed to protect specific types of equipment and should not be regarded as part of this infrastructure. For example, an SPD for analogue telephone signals will have a limiting voltage of the order of 200 volts to accommodate battery and ringing voltages, whereas an SPD for a LAN application will be designed with a limiting voltage of a few volts to give optimum protection.

Appendix 4: Case Study - Damage to a 10Base-5 LAN

Two 10Base-5 (Thick Ethernet) LANs, joined by a bridge, serve two factory buildings and an office, with the network cables linking the buildings as shown in figure below. Several transceivers (at positions A) have suffered damage.

Why the particular transceivers have suffered damage is a matter of conjecture. It may be that some are more robust than others, and that in failing, the damaged units saved the others.

The mains power supply is distributed from one point in each office and factory. We are not told whether the network cables pass close to the mains distribution board. The protection we apply depends on whether the network cables:

- 1) Run close to the distribution board, or can be re-routed to do so,
- or;
- 2) Are distant from this point.

In case (1) network surge protection devices (SPDs) type ZoneBarrier ZBS 24534 should be installed at positions B in figure A4.2, close to the mains power distribution board, and earthed there using as short a length of cable as possible, with a diameter of 2.5mm² or greater (length is much more important than diameter). To reduce the effect of cable inductance, several cables can be run electrically in parallel, but spaced apart physically. If earthed metal panels are available at the distribution board, these would offer further reduction in inductance, and better protection.

Mains power protection should also be considered, the minimum requirement being for a heavy duty protector located at the distribution board.

In case (2), it is not possible using as few SPDs to give full protection to the LANs. The decision must be made as to which network transceivers to protect. A ZoneBarrier ZBS 24534 should be installed close to each PC to be protected, and earthed at the same point as the PC, for instance at the supply socket into which the PC mains power cable is plugged. Again, the minimum length of earth cable must be used.

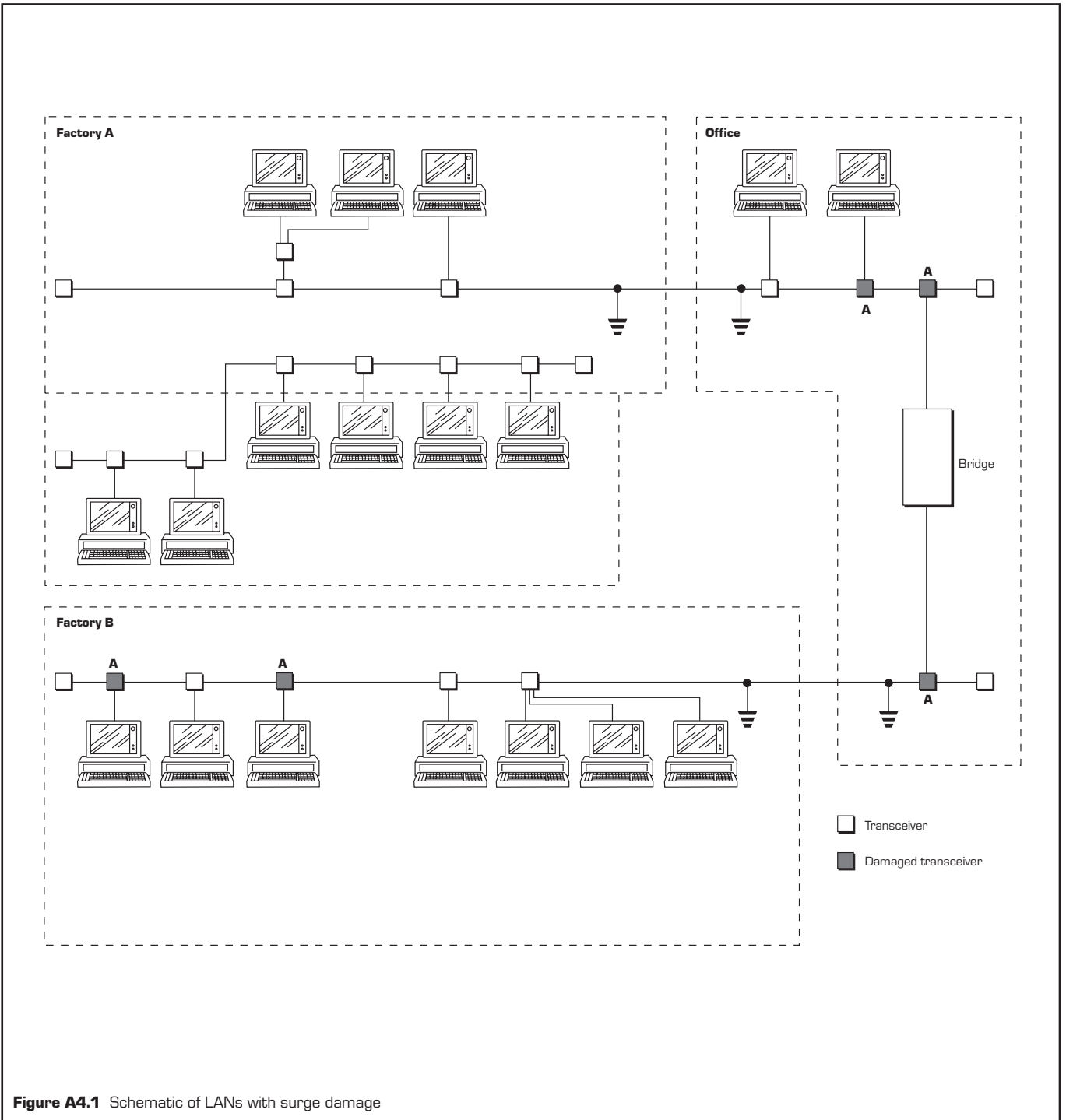


Figure A4.1 Schematic of LANs with surge damage

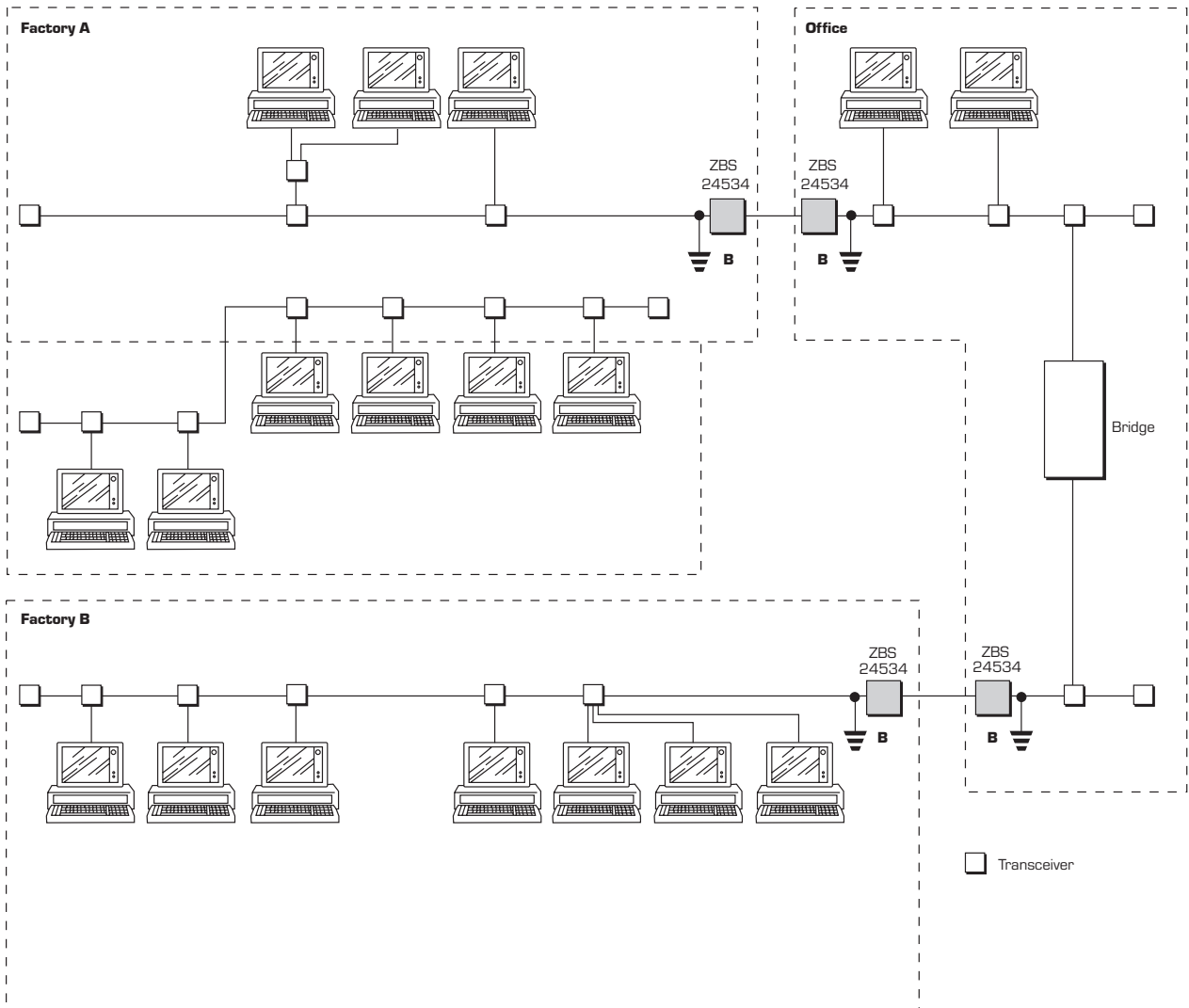


Figure A4.2 Recommended surge protection for the LAN

Appendix 5: Product selection guide

As the following guide shows, there is a large number of network types in existence. The table gives product suggestions for a number of these. Those in italics indicate products thought to be suitable for these LAN types less commonly encountered.

LAN	Product(s)
Thin Ethernet (10Base-2, IEC8802.3)	ZBS 24534
Twisted pair Ethernet (10Base-T, IEC8802.3)	ZBS 24534, NET 905 ZBS 24550 + ASC 24500
Fast (100Mbps) Ethernet (100Base-T)	ZBS 24534, NET 905 ZBS 24550 + ASC 24500
100VG-Anylan	ZBS 24534, NET 905 ZBS 24550 + ASC 24500

Token Ring (IEC8802.5)	ZBS 24540
ATM (Asynchronous Transfer Mode)	ZBS 24534, NET 905 ZBS 24550 + ASC 24500
StarLAN 1Mbps (1Base-5, IEC8802.3)	ZBS 24534, NET 905, ZBS 24550 + ASC 24500
Arcnet	ZBS 24537
Apple EtherTalk	ZBS 24534
Novell E-Net	ZBS 24534
Novell G-Net	ZBS 24534
Wangnet (Wang Laboratories)	ZBS 24534
Broadband Ethernet	ZBS 24540

New LAN surge protection applications

Telematic will be pleased to discuss other LAN applications. As noted earlier, although a vast amount of information is involved in defining a network, surge protection is concerned only with the physical layer. Selecting or designing a surge protection device requires the following information:

- ◆ Cable and connector type
- ◆ Signal levels
- ◆ System impedance (e.g. 50 ohm for coaxial Ethernet)
- ◆ Allowable attenuation and/or series resistance
- ◆ Data rate or bandwidth required - the SPD must have sufficient bandwidth to pass the wanted signals without undue loss or distortion.
- ◆ System earthing arrangement
- ◆ Physical size constraints
- ◆ Method of installation

Much of this information can usually be gleaned from published standards.

We also take a judgement on the likely exposure to surges.

Appendix 6: surge protection checklist

Whether to protect

The following factors would tend to favour fitting surge protection:

- ◆ Surge damage has been suffered, or is suspected.
- ◆ Surge damage has been suffered by other nearby organisations.
- ◆ A risk analysis has been carried out indicating a significant risk of damage.
- ◆ The consequences of surge damage are serious, despite a low probability.
- ◆ Surge protection is specified or recommended by an insurance company or parent organisation.
- ◆ Good experience of surge protection in a related field.

What to protect

Assuming that some form of surge protection is decided upon, it is important to take a broad view of the whole electrical installation, and at least consider fitting surge protection devices to the following cables, each of which, if present, can provide a means of coupling lightning-induced surges into the installation:

- ◆ Mains power electricity supply
- ◆ Telephone lines feeding fax machines & modems
- ◆ Data cables for local area networks
- ◆ Cables for telemetry and instrumentation & control
- ◆ Antenna cables
- ◆ Security camera cables
- ◆ Outdoor lighting cables

Note: mains power protection is generally recommended with any of the others.

Installation of SPDs

- a) Cables routed close to the building earth connection at the distribution board where the mains power electrical supply enters the building:
- ◆ Fit SPDs close to this earth connection, mounting on earthed metalwork if available.
 - ◆ Earth cable from SPD to the supply earth to be as short as possible, cross section 2.5mm² recommended.
- b) Cables routed remote from the building earth connection:

- ◆ Decide on which items of equipment are the most important and need fullest protection.
- ◆ Fit SPD(s) to the relevant cable(s) close the earth of this equipment. For a PC or fax machine, for instance, this will be the electrical supply earth of the socket into which it is plugged. Any SPD earth cable to be as short as possible, cross section 2.5mm² recommended.
- ◆ Fit a mains power SPD here.

The equipment should then be fully protected, the rest partially protected.

Periodic checks:

- ◆ The SPDs themselves should require no maintenance over a life of twenty years or so.
- ◆ Periodically check the installation to ensure that the SPD earth connections are intact and sound. An SPD requires a good earth connection in order to do its job.

Troubleshooting - hints for when things go wrong (fortunately rare):

- 1) SPD installed and network ceases to work. Possibilities are:
- ◆ Incorrect product selection.
 - ◆ Incorrect location, e.g. SPDs installed between trunk cable and PC, rather than in the trunk cable.
 - ◆ Faulty cables and/or connectors.
- 2) SPDs fitted but surge damage still occurs. SPD may also be damaged:
- ◆ A vital cable left unprotected.
 - ◆ SPD earth cable excessively long.
- Note that in general the failure mode for SPDs for data application fail short circuit i.e. they short out the signal, and the data cable remains protected (i.e. they "fail safe"). Such failure can generally be ascertained using a multimeter measuring resistance, preferably with a diode test function.
- 3) Mains power SPD damaged - protection components failed :
- ◆ Fault in installation causing prolonged over-voltage (SPDs are only designed to protect against transient over-voltages). Example: standby generator wrongly connected or with poor regulation.

Appendix 7: questions and answers

Q: My file server is protected by a UPS (Uninterruptible Power Supply). Why do I need a mains power SPD as well?

A: Not all UPSs are protected, or adequately protected, against lightning transients. The cheaper the UPS, the less likely it is to contain sufficiently robust protection.

Q: My connection to the outside world is via optical fibre cables. Surely I don't need any further protection?

A: Optical fibre cables remove the risk from surges that would be associated with a corresponding copper cable, provided that any metallic shield is stripped back at least one metre from where the fibre enters the building. Mains power transients may still be a problem and these can be dealt with by mains power SPDs. If data cabling within the building is copper, and there is a significant risk of direct strike to the building, then protection for this should be considered.

Q: My LAN tester gives a fail message on the TDR (time domain reflectometer) or return loss test when I test the cabling with SPDs installed. What should I do - are the SPDs faulty?

A: See appendix : TDR testing of the LAN cabling should be done with the SPDs removed.

Q: I've got a LAN and fax machine and modem. Why can't I use the same type of SPD for all of them?

A: SPDs designed to protect LANs have a low limiting voltage and will, in effect, short out battery and ringing voltages present on analogue telephone lines feeding fax machines and modems.

Q: The shortest earth wire I can use for the SPD is about ten metres. Is this ok?

A: In the event of even a moderate lightning surge, this is almost certainly much too long. We experienced such a case where the inductive transient developed across roughly this length of cable was sufficient to blow apart a ceramic capacitor on the network card, in addition to causing semiconductor damage. The LAN cable should be re-routed to allow an SPD earth of the order of 1 metre or less, or the SPDs should be fitted close to the most strategically important hardware. See section Applying surge protection

Q: Won't a longer earth cable be ok if I use, say 10mm² cable instead of 2.5mm²?

A: Unfortunately, no. The problem with a long earth cable for surge is almost entirely due to its inductance and not its resistance. Although a 10mm² cable will have only a quarter of the resistance of a 2.5mm² cable, the reduction in inductance is minor, and certainly not worth the additional awkwardness of installing it. Length is much more important than cross section.

Q: How many LAN SPDs can I use on my network?

A: Ethernet SPDs such as the ZBS 24534 have less than half ohm series resistance, however normally only 2 units are required (this will not affect the termination resistance of the network). SPDs designed for twisted pair, such as NET 905, do have some small loss and should probably be limited to two per radial cable. This is likely to be the most needed.

Q: I have a 10Base-2 (Thin Ethernet) LAN where the PC workstations are fed from taps on the trunk coaxial cable. Can I install a ZBS 24534 between the cable from the tap and the PCs?

A: No. The ZBS 24534 must be fitted in line with the coaxial trunk cable. The distance between the cable and the PC must be kept as short as possible, as specified in the standards e.g. IEC/ISO 8802.3, otherwise the network may not function.

Glossary

The computing and networking field has been a prodigious generator of terms and acronyms. A very small selection is covered here.

bridge	a device for linking two networks
Mbps	megabits (millions of bits) per second
PC	personal computer
repeater	a device for increasing allowable length of cable
SPD	surge protection device. Other terms for SPDs can be derived by combining any one of the words in the left hand column with any one in the right hand column!

surge	barrier
transient	protector
overvoltage	protection device
lightning	suppressor
spike	arrestor

Further Reading

Surge protection:

P1) Lightning surge protection for electronic equipment - a practical guide Application Note TAN1001, Telematic

P2) Earthing guide for surge protection Application Note TAN1003, Telematic

Networks & computer communications:

N1) Communications and networking for the PC, Larry Jordan & Bruce Churchill, New Riders Publishing

N2) Communication Network Protocols, 3rd ed, Brian W Marsden, Chartwell-Bratt, ISBN 0 86238 276 9

N3) '100Mbit/sec Ethernet'. An article by Systems Marketing of Compaq Computer Corporation, 22 May 1995

N4) 'Is your network cabling infrastructure cut out for fast Ethernet?', Personal Computer Magazine, June 1995

N5) 'Hundreds and Thousands', Personal Computer Magazine, April 1994.

N6) 'Categorical Imperatives', Datacom, July 1994

N7) 'Cabling strategies for high speed networks', Telecommunications, January 1993

Standards:

S1) BS ISO 10738: Token ring networks, unshielded twisted pair cable (UTP)

S2) BS ISO 9578: Connectors for communications interfaces

S3) ISO/IEC 8802-3 ANSI/IEEE Std 802.3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications

Includes 1Base-5, 10Base-2 ("thin Ethernet"), 10Base-5 ("thick Ethernet") & 10Base-T ("twisted pair Ethernet")

S4) ISO/IEC 8802-5: Token ring access method and physical layer specifications

S5) ECMA-80: Local area networks CSMA/CD baseband - coaxial cable system

Covers cabling and installation rules for 10 Mbit/sec systems

(ECMA = European Computer Manufacturers' Association)

S6) ECMA-81: Local area networks CSMA/CD baseband - physical layer

S7) ECMA TR/26: Local area networks CSMA/CD baseband - planning and installation guide

S8) BS 6651 : 1999 Code of practice for protection of structures against lightning

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