

Lightning & surge protection for fieldbus systems



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1 INTRODUCTION

This application note discusses suitable surge protection techniques to protect electronic circuits and equipment within the fieldbus system and the associated fieldbus trunk from high voltages and surge currents induced by lightning and other forms of transient.

Most process control or telemetry installations are interconnected by power and signal cables and busses which run on trays, in ducting, underground or via overhead poles. Lightning strikes, static discharges and induction from power cabling are typical sources of transient voltages that can be coupled into signal cables and hence transmitted to electronic equipment. Field transmitters and computerised control equipment, etc. containing low-power semiconductor devices can be damaged by overvoltages of only tens of volts.

The longer the cables, the higher the magnitude of high voltage transients through shifts in earth potential, therefore devices controlling or monitoring events in remote locations are more likely to suffer from overvoltages and consequent component failures. Significant damage can also be found in equipment connected by relatively short cables if the circuits or components are particularly sensitive.

Electronic systems can be damaged or disrupted by what are referred to as "surges". These are voltages which are much greater than the normal working voltage and which appear in a system such as fieldbus for a short period of time, and hence are also sometimes referred to 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.

It is important to appreciate that although catastrophic damage can indeed result from a direct lightning strike to a building, this is relatively rare. More usually is the substantial damage to electronic components inflicted by a strike to ground within a distance in the order of a kilometre or so. 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 vapourised 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, there can be 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.

2 FIELDBUS BACKGROUND

Users of industrial process control systems are now able to specify proven and standardised fieldbus technology for their field instruments. Buses conveying both communication signal and power on the same pair of wires are among the most popular. An international standard physical layer used by Foundation Fieldbus and Profibus PA is specified by IEC 61158-2, (see section 6 of this document for further information).

A major influence on the economy of fieldbus installations is the number of field devices which can be connected on a single bus segment and hence to a single controller input/output (I/O) channel. In particular applications, users may choose to use only a small number of devices on a segment, in order to achieve faster scan cycles or for reasons of system integrity. In most cases, economic considerations lead to the desire to connect as many devices as possible on to a single cable and fieldbus port.

The IEC 61158-2 specification allows for up to 16 devices to be connected to the single pair of wires forming a bus segment (see Appendix 1, Table 1), most practical installations to date have between 6 and 12 bus-powered devices. There may be limitations depending on the design of the host system, but in practice, in IS (Intrinsically Safe) circuits the need to supply power to all of the devices limits the possible number of bus-powered devices on one segment.

DC voltage drop in the fieldbus cable reduces the supply voltage to the most remote devices (see Appendix 2, Table 2), and the situation requires greater consideration in Intrinsically Safe (IS) systems. Intrinsically Safe power supplies typically provide lower voltage and some versions include

current-limiting resistors which contribute significantly to the voltage drop. Section 5 shows where careful selection of surge protection devices increases the availability of the fieldbus system and reduces / eliminates the adverse effects of surges.

3 WHAT IS A SURGE PROTECTOR

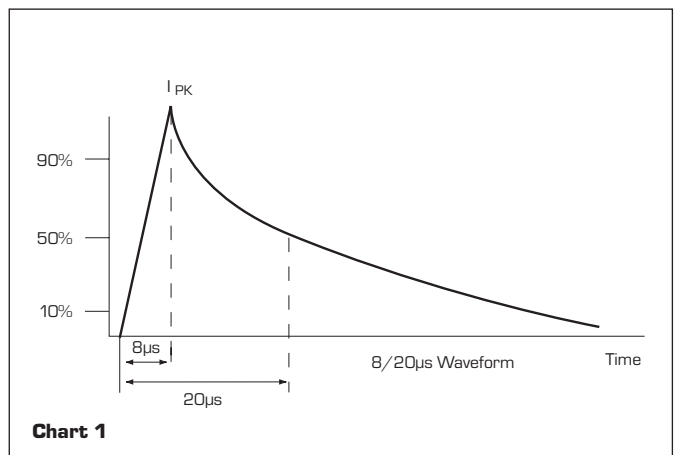
Electronic equipment can be protected from the potentially destructive effects of high-voltage transients. Protective devices, known by a variety of names (including 'lightning barriers', 'surge arrestors', 'lightning protection units', etc.) are available. The 'correct' name (accepted internationally) is 'surge protection devices' or 'SPDs' – and this nomenclature is used throughout this publication.

Surge protection devices should ideally operate instantaneously to divert a surge current to earth, and control voltage to a level, which will not damage the connected equipment. Once the surge current has subsided, the SPD should automatically restore normal operation and reset to a state ready to receive the next surge.

We specialise in the design and manufacture of SPDs. The range of products available includes models for virtually all applications. They are based on a combination of gas discharge tubes (GDTs), voltage-clamping diodes, and metal-oxide varistors (MOVs) which feature rapid operation, accurate voltage control and automatic resetting once the overvoltage has ceased.

The working voltage of a surge protection device is the normal working voltage of the application without affecting the circuit in which it is placed. It is also the maximum voltage between lines or from line to earth for the specified leakage current.

Limiting voltage is a measure of how good a surge protection device is at removing surges. Also known as '**Let-through Voltage**', this is the peak output voltage after injection of a test impulse from a 6kV/3kA 8/20µS combination waveform generator or some other specified voltage and current.



A good limiting voltage should be not much higher than the working voltage of the device. In general, however, it is usually around twice the working voltage

A correctly selected surge protection device should not change the characteristics or reliability of an application, whether it is for the protection of AC power systems, signal data systems such as fieldbus and 4-20mA, aerials (antennae) or telephony and communications systems.

The magnitude of lightning discharges around the world have been measured from 2kA to more than 200kA, with rise times to peak current of less than 10µs.

IEC 61024 gives the following data:-

- 1% of strokes exceed 200kA
- 10% of strokes exceed 80kA
- 50% of strokes exceed 28kA
- 90% of strokes exceed 8kA
- 99% of strokes exceed 3kA

4 THE NEED FOR SURGE PROTECTION

The fieldbus system by the very nature of the environment in which it will be placed, is at risk from surges that will be induced onto the trunk and AC or DC power supplies feeding the fieldbus system.

The units that can be affected include the controller and power supplies, the field devices, together with fieldbus terminators, spurs, expansion blocks and power conditioning modules.

Because the fieldbus system is controlling and handling the data transactions across a common trunk, the importance of safeguarding the integrity of the fieldbus system is paramount in order that the shutdown of multiple processes does not occur. This is particularly important in fieldbus process applications because of the possibility of injury to personnel and damage to process equipment and the environment. More information can be found in Section 5 on this topic.

If incorrect or inferior surge protection is fitted, then not only will the fieldbus sustain damage, but it could also cause the fieldbus to be affected adversely in that data communications is interrupted or the system is not able to support the required number of field instruments.

Considering these mechanisms in relation to process instrumentation, RFI rarely rises above the nuisance level.

Inductive effects require the close proximity of lightning currents to signal cables in order to achieve a measurable level of coupling. Generally, field signal cables are screened or shielded to reduce general RFI and noise pickup.

Twisted pair cables are normally used to reduce voltages between lines to levels that do not cause measurement errors. However, shifts in earth potential will still be generated and can cause component damage in sensitive systems.

The 'host end' of any fieldbus system must have maximum protection to ensure full operation of the site, therefore protection must be installed on both AC and DC power and fieldbus cables.

The AC power for a fieldbus system could be supplied from the control area or locally in the field. In either case, surge protection is required at the fieldbus system.

In addition to the AC power, the combined 24Vdc and signal output from the fieldbus power supply must also be protected. If the two wire Trunk cable is longer than 50 metres in the horizontal plane or 10 metres in the vertical plane, for example, a sensor / transmitter is positioned on a column stack, pole or pipe, then the fieldbus must have surge protection.

When considering surge suppression of the local field wiring, the requirement is to look for more obvious situations such as:

- a) The long cables reaching out to a single instrument. Anything longer than 50 metres should be considered, longer than 100 metres must be protected.
- b) Particular installations where lightning currents would preferentially flow. For example instruments mounted along a pipeline which crosses a non-conducting surface such as dry sand.
- c) Installations that involve considerable vertical distances on structures that may be struck by lightning. A wind speed indicator on the top of a tall structure is a classic example.
- d) Installations where sensors are associated with high voltage, high power electrical equipment, For example temperature sensors embedded in the windings of high voltage motors.

Suitable protection devices should be used for hazardous and non-hazardous areas. The protectors should not cause any attenuation and be of a mechanical design suitable for fitting to field devices.

In all cases, in a fieldbus installation, the trunk and the power supply to the nodes should be protected against lightning induced surges to provide reliability and system integrity.

Local fieldbus field wiring to adjacent equipment where the length of the spurs are normally quite short is less prone to damage from surges but should be surveyed.

More information can be found in Section 5 on this topic.

5 SOLUTIONS FOR FIELDBUS SYSTEMS

5.1 Requirements

When considering surge protection for an AC power system for use on the fieldbus system, the ability of the whole system to withstand voltage surges should be considered. The surge protection device (SPD) must be capable of limiting any surge voltages to a level considered safe for the most vulnerable part of the equipment served by the system. It must also be able to divert the maximum surge current likely to be experienced by the system it is protecting.

5.2 Power line protection

AC power protection is often overlooked when deciding a surge protection strategy. When providing protection, users are keen to apply surge protection devices to process signal lines, transmitters and other important equipment, as the source of surges is more obvious. However, a common source of surges is the AC power supply. It is important to note that any cable entering an electronic device is also an easy path for lightning induced current to enter and cause untold damage, the power supply is no exception.

Any devices should be selected with appropriate regard to the physical location and be suitable for that purpose, especially with regard to the mounting of equipment in hazardous areas

Generally, most low voltage power systems (240/415V) and the electronic and electrical equipment with which they are associated, can withstand voltage surges of two to three times their normal peak operating voltage for the duration of a typical lightning surge.

During a lightning surge, the voltage is well in excess of these values and therefore surge protection is required.

5.3 Data line protection

The fieldbus surge protection devices must be capable of limiting any surge voltages to a level considered safe for the most vulnerable piece of equipment served by the system. It must also be able to divert the maximum surge current likely to be experienced by the system it is protecting.

Transmitters on tall structures such as distillation columns are also vulnerable to high voltages between the case and the circuitry caused by lightning currents flowing down the structure. SPDs fitted to transmitters should attempt to provide a preferential breakdown path between lines and lines/earth so that any surge currents thus induced flow along that path rather than through the transmitter circuitry. The type of transient protection offered as an optional extra by most transmitter manufacturers generally consists of surge suppression diodes or, occasionally, varistors.

The former type provides protection only against low-voltage and the latter only against high-voltage surges. Devices incorporating hybrid circuits combining gas discharge tubes varistors and surge suppression diodes are the obvious answer but, until relatively recently, were not easy to implement on account of the physical difficulties of packaging the more complex network within the body of the transmitter. Due consideration should be given to the parameters such as capacitance and inductance and how this will affect the system.

The better solution is to use a 'dedicated' externally threaded SPD that has been designed specifically for easy and convenient use with field transmitters. This is a small unit that is mounted by screwing it into a spare 'cable entry' on the transmitter casing. Three flying leads are provided for connection to line 1 fieldbus +, line 2 fieldbus -, and earth. It is available both in a standard version and also in 'hazardous area' approved versions (i.e. Intrinsically Safe and explosionproof/flameproof). All versions are available with a variety of screw threads to suit virtually all currently available transmitters and can be retrofitted to existing installations without

affecting loop wiring or performance. The SPDs should provide protection against ALL surges up to 10kA and achieve 60V differential mode protection.

5.4 Fieldbus systems

Figure 1 below shows a simple fieldbus system that has three transmitters connected. The length of the spur S_j is less than 10 metres and therefore may not require surge protection. The two other transmitters have been protected both at the transmitter and the terminator for complete protection by using a TP32 (see figures 1 and 3).

Note: It should be stressed, if the two wire Trunk cable is longer than 100 metres in the horizontal plane or 10 metres in the vertical plane, for example, a sensor/transmitter is positioned on a column stack, pole or pipe, then the fieldbus must have surge protection.

Protection requirement:

Note: Protection at the host end of the Trunk is highly recommended.

- ◆ Use FP32 on Trunk at preferably at both ends.
- ◆ Use TP32-x, where x = thread type [see Appendix 3, Section 9.C] used on all transmitters with attached cables longer than 100 metres horizontal and 10 metres vertical.
- ◆ Use the MA4000 on AC power input at the host end.

The equation to evaluate the surge value on a length of conductor:-

$$V_{\text{surge}} = IL \frac{di}{dt}$$

Where V = voltage, L = inductance, I = length of cable and $\frac{di}{dt}$ = rate of change of current

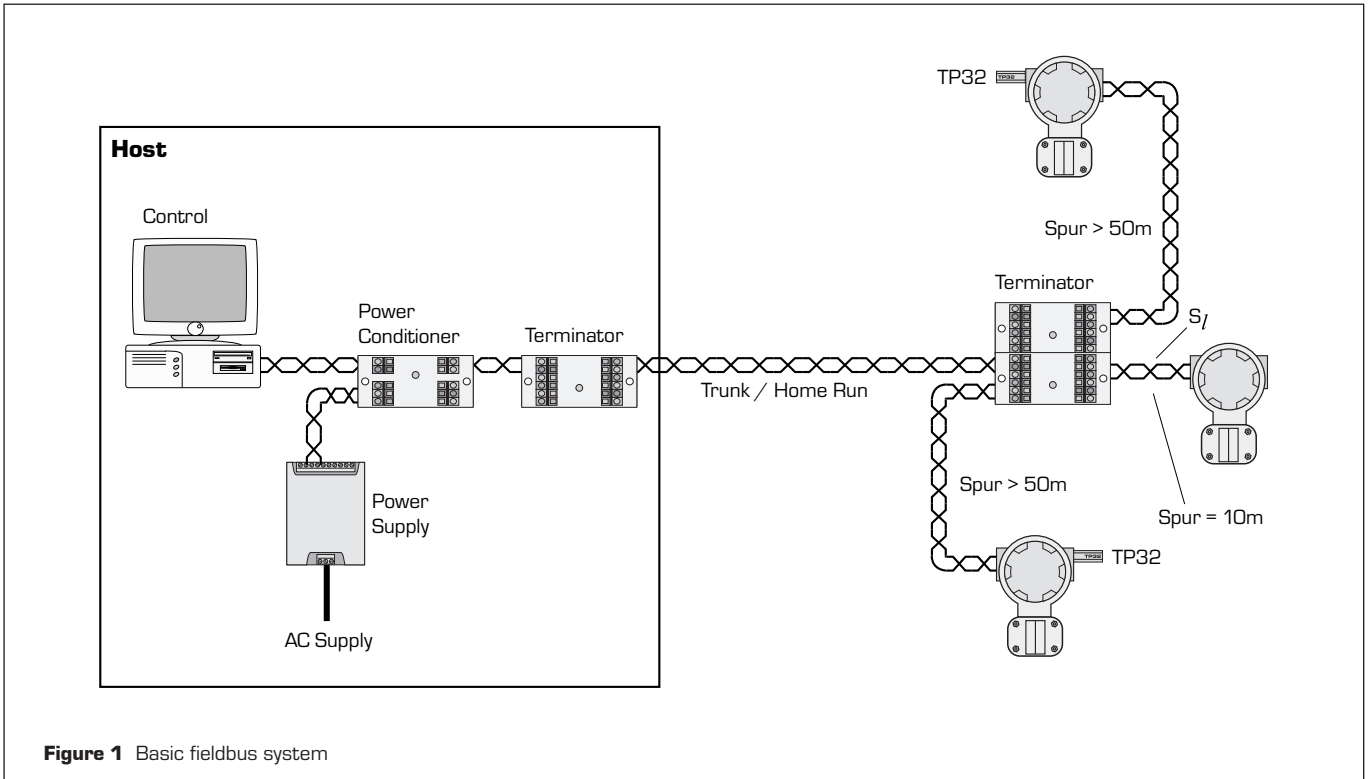


Figure 1 Basic fieldbus system

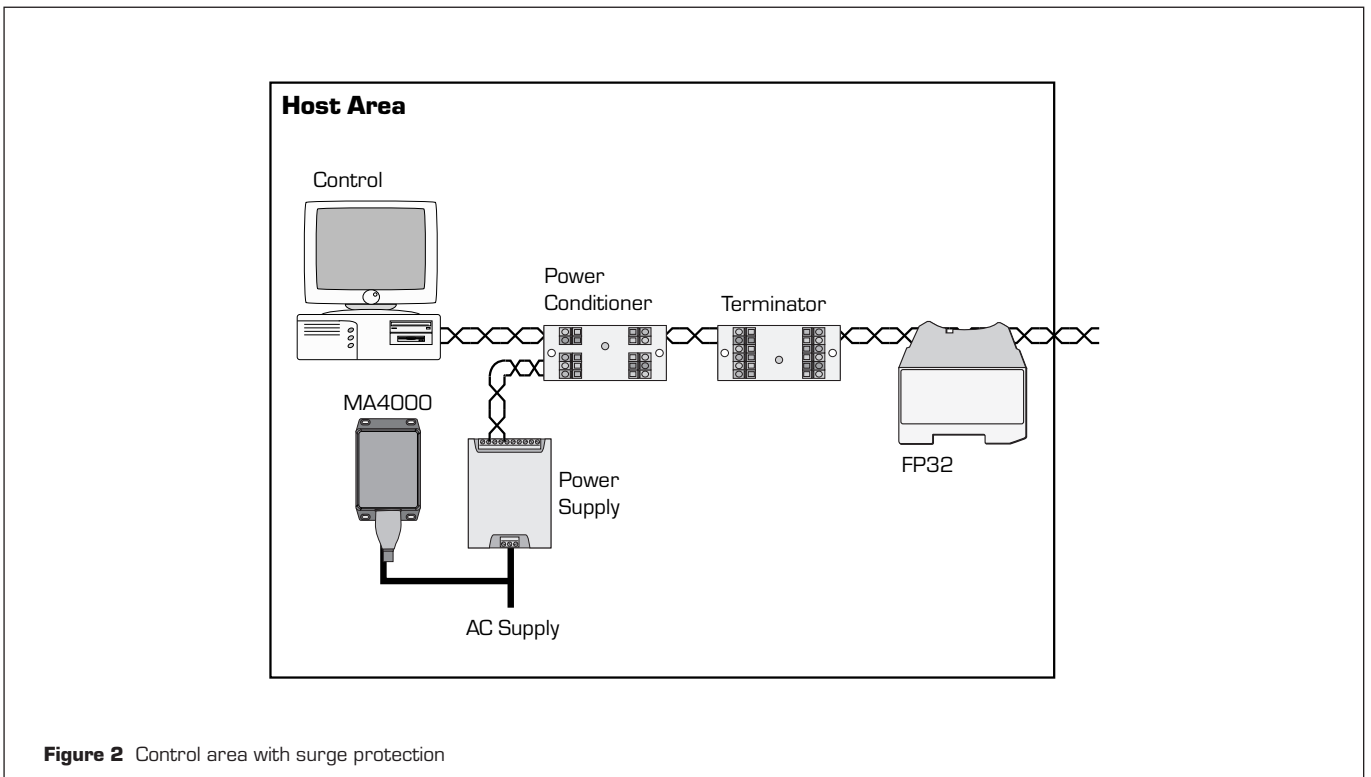


Figure 2 Control area with surge protection

Example:

Length of a fieldbus spur (l) = 100 metres
 The inductance (L) was 0.1µH per metre
 Surge current of 100kA
 Rise time of surge 10µS

The voltage value would be:

$$100 \times 0.1 \times 10^{-6} \times \frac{10^5}{10 \times 10^{-6}} = 10^5$$

Protection is always required at the host (see figure 2), as this could cause catastrophic damage from a single process failure to a total shutdown of the plant. An SPD must have been designed specifically with fieldbus systems in mind and should be a series device offering the lowest possible limiting voltage, to ensure that no damage occurs to the critical control systems.

As can be seen from figure 2, not only the data lines but also the AC power lines have been protected from injection of surges onto the control system equipment.

Figure 3 indicates where protection should be fitted to the trunk in order that the terminator is protected from surges that are induced onto the trunk.

The placement of the fieldbus control system may be installed in a control room building may be field mounted in order that the fieldbus system is sited close to the transmitter/sensors as shown in figure 4 section 5.5.1.

With this type of configuration, the AC (or DC) power feed is from the power distribution board in the control area to the fieldbus controller. Any surges that are induced onto the power cable from the field to the controller will be eliminated by the SPD in the power distribution board. Similarly, the AC power to the fieldbus system power supply in the field has also been protected.

5.5 Hazardous area surge protection configurations

5.5.1 Zone 2 / DIV 2 Non Arcing / Non incendive

For non-arcing and non incendive applications, the unit that is suitable for Zone 2 / Div 2 takes its description from the nature of the circuit being protected and is non incendive (nL) or non-arcing (nA), see figure 4.

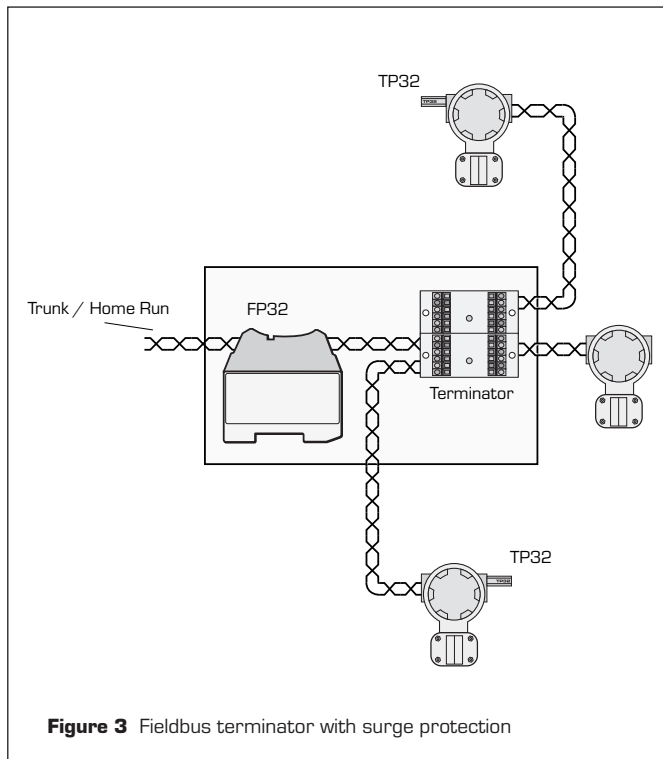


Figure 3 Fieldbus terminator with surge protection

Protection requirement:

Note: Protection at the host end of the Trunk is highly recommended.

- ◆ Use FP32 on Trunk at host end and TP32 at the field end terminator.
- ◆ Use FP32 on the input and the output of the junction box to protect the FISCO PSU.
- ◆ Use TP32-x, where x = thread type [see Appendix 3, Section 9.C] used on all transmitters with attached cables longer than 100 metres horizontal and 10 metres vertical.
- ◆ Use the MA4000 on AC power input at the host end and in the field mounted junction box.

In figure 4, below, where the fieldbus controller is situated in the Zone/ DIV 2 area, a standard transmitter protector TP32 may be used without adversely affecting the level of safety.

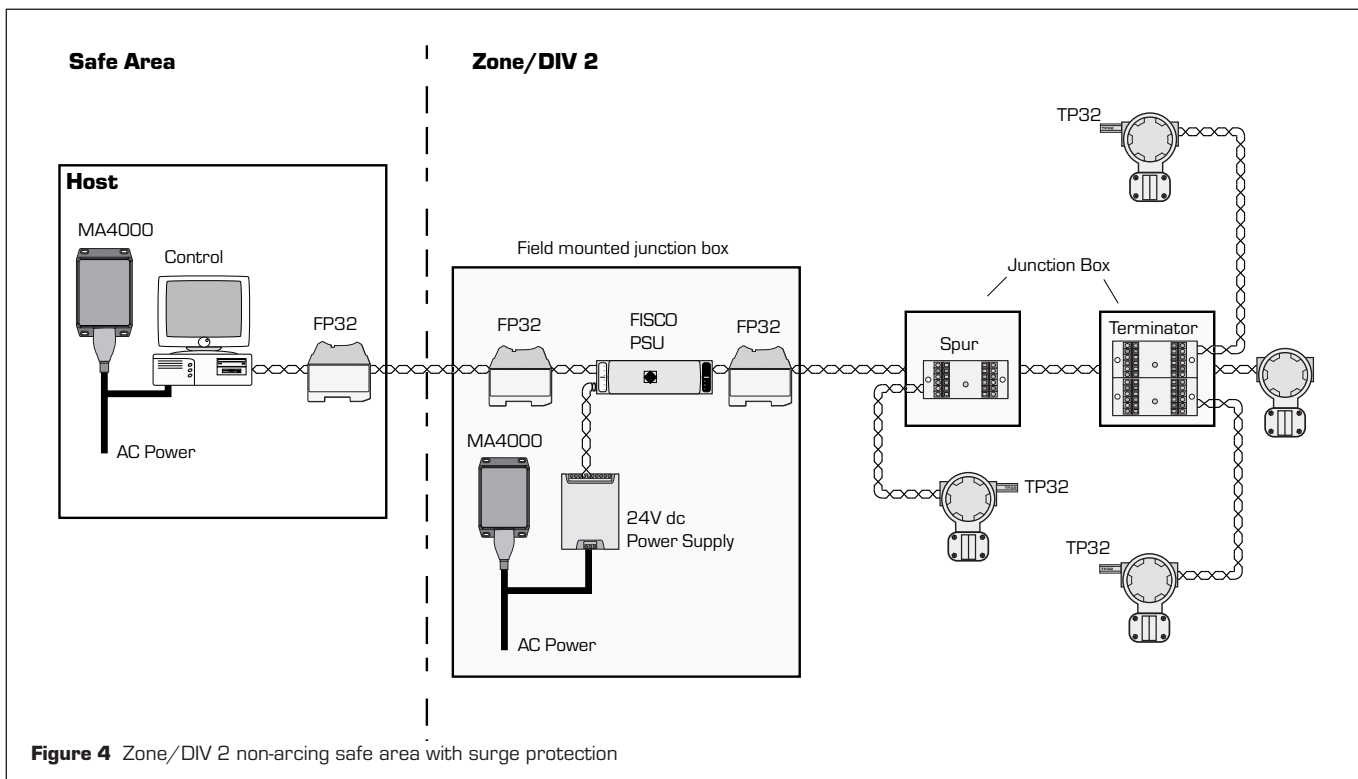


Figure 4 Zone/DIV 2 non-arcing safe area with surge protection

Surge protection is required at the Control building both for the fieldbus trunk and the AC power. The field based unit must duplicate this protection with trunk surge protection both into and out of the fieldbus enclosure/junction box. The AC power may be obtained from a local power source or from the control area must also be protected from the likelihood of damage from induced surges from nearby lightning strikes. Depending on the length of the spur, the field instruments may also require transmitter protection even though they do not have any form of connection to earth. This is because the insulation voltage of a typical unit is in the order of 500 to 1500 volts. If a nearby lightning strike occurs, this value will easily be exceeded and damage will occur to the equipment due to internal arcing within the electronics of the unit.

Protection requirement:

Note: Protection at the host end of the Trunk is highly recommended.

- ◆ Use FP32 on Trunk at host end and TP32 at the field end terminator.
- ◆ Use TP32-x-NDI, where x = thread type (see Appendix 3, Section 9.C) used on all transmitters with attached cables longer than 100 metres horizontal and 10 metres vertical.
- ◆ Use the MA4000 on AC power input at the host end.

For transmitter protection, the surge protector must be certified to Ex d if not enclosed in a suitable Ex d enclosure. The field mounted fieldbus controller system must also be housed within an Ex d enclosure as must the spur and termination fieldbus components.

5.5.2 Explosionproof / Flameproof / increased safety

For explosionproof / flameproof and increased safety in hazardous areas, Ex d cables and junction boxes must be used (see figure 5).

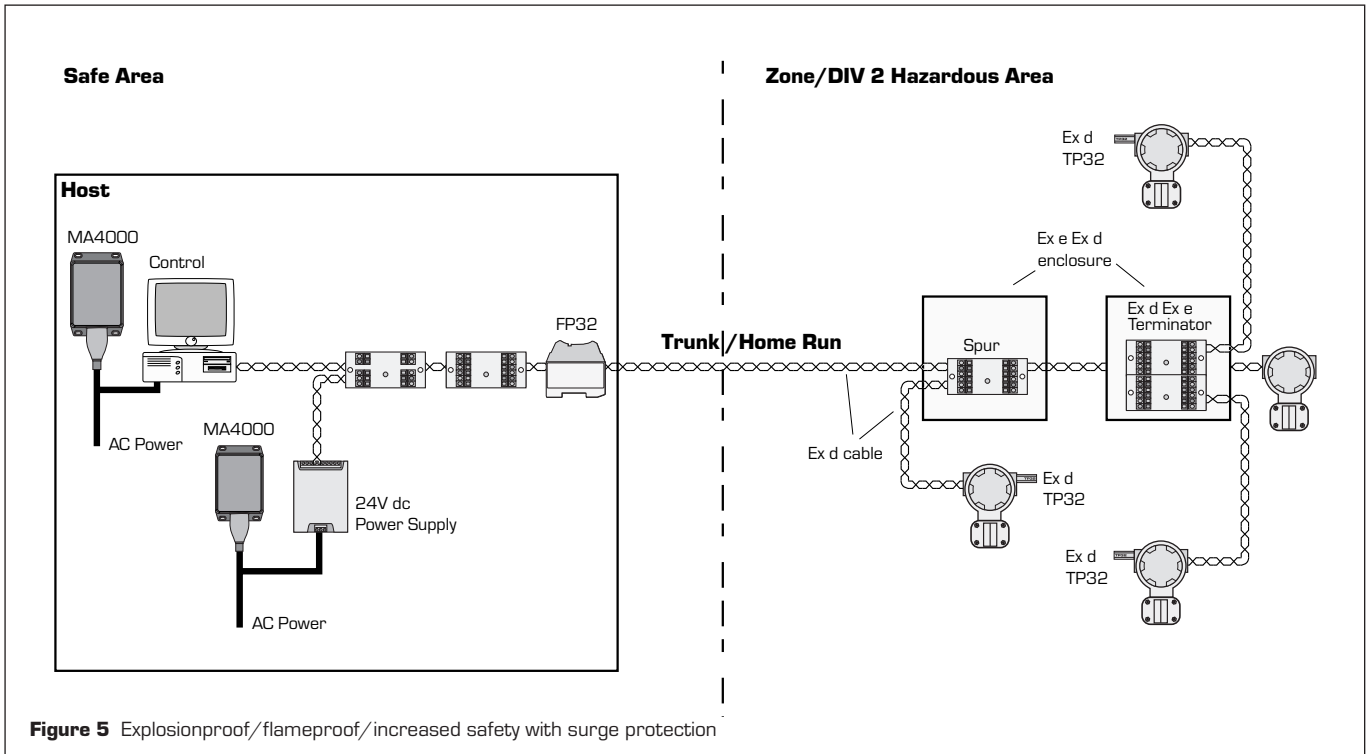


Figure 5 Explosionproof/flameproof/increased safety with surge protection

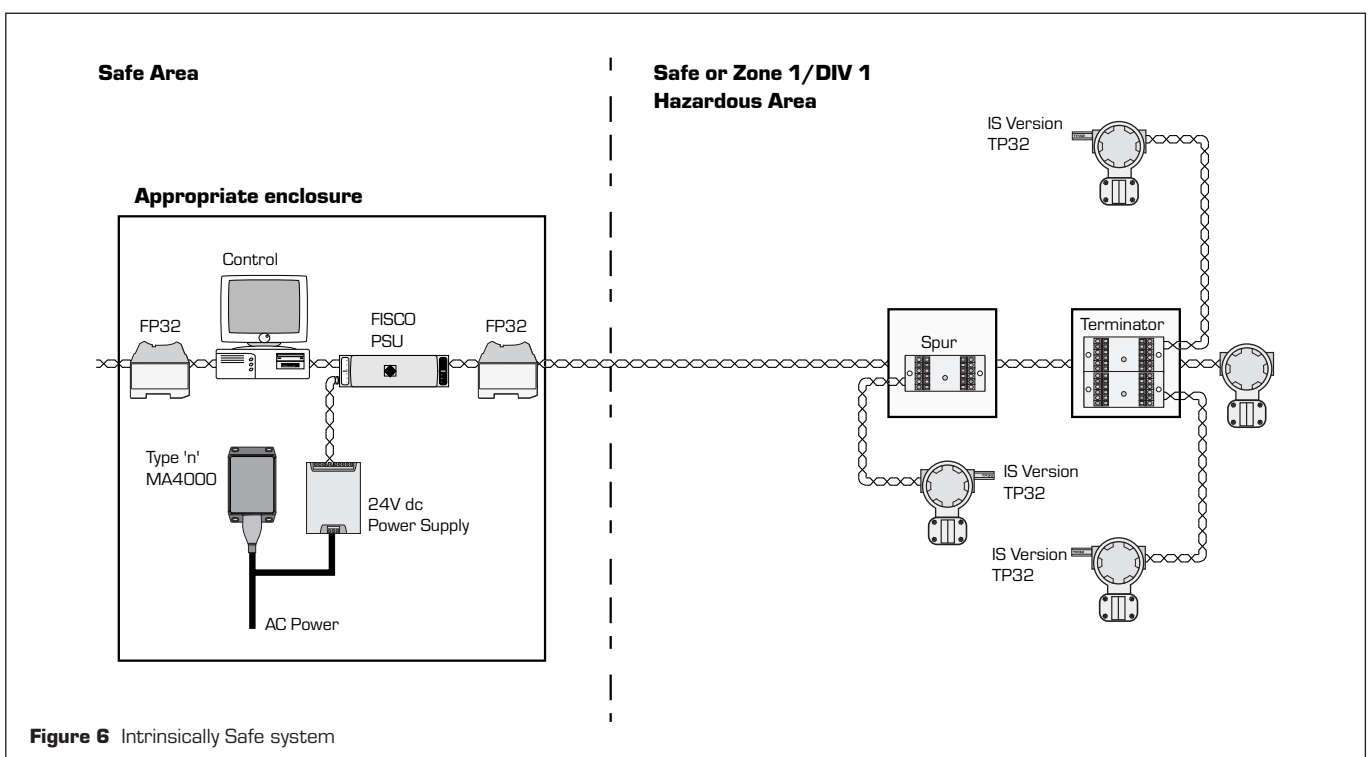


Figure 6 Intrinsically Safe system

5.5.3 Intrinsically Safe system

Intrinsic Safety (IS) is a protection concept employed in potentially explosive atmospheres. IS relies on the electrical apparatus being designed so that it is unable to release sufficient energy, by either thermal or electrical means to cause an ignition of flammable gas or dust.

The Fieldbus FOUNDATION FF816 physical layer profile defines two IS physical layer profiles, entity and FISCO (Fieldbus Intrinsically Safe COnccept). The SPDs should be certified to be compatible with both these profiles to allow flexibility in system installation.

Intrinsically Safe systems may be Ia or Ib. The surge protection is chosen in order that it does not affect the level of protection of the system (see figure 6).

Protection requirement:

Note: Protection at the host end of the Trunk is highly recommended.

- ◆ Use FP32 on Trunk at host end and at the input to the suitable enclosure.
- ◆ Use TP32-x-NDI, where x = thread type (see Appendix 3, Section 9.C) used on all transmitters with attached cables longer than 100 metres horizontal and 10 metres vertical.
- ◆ Use the MA4000 on AC power input at the host end and in the field mounted junction box.

The IS version of the TP32 Range is BASEEFA certified and may be supplied with various threads to suit the Transmitter glanding. If the TP32 version is not used, then the DIN rail version of the TP32 may be used, but must be installed within a suitable enclosure dependent upon the environmental conditions.

6 STANDARDS

6.1 Surge protection related standards

BS 6651 Appendix C

Code of practice for protection of structures against lightning.

ANSI/IEEE C62.41-1991

ANSI/IEEE Recommended Practice on Surge Voltages in Low-Voltage AC power circuits.

IEC 61000-4-5 - Electromagnetic compatibility (EMC) Part 4.

Testing and measurement techniques. Section 4. Electrical fast transient/burst immunity test - Basic EMC publication.

IEC/EN 60079-14 : 1997

Electrical apparatus for explosive gas atmospheres, Part 14. Electrical installations in hazardous areas (other than mines).

IEC 61024

Protection of structures against lightning, Part 1. General principles, section 1 : Guide A : selection of protection levels for lightning protection systems.

6.2 Fieldbus related standards

IEC 61158-2 : 1996

Fieldbus standard for use in industrial control systems - Part 2. Physical layer specification and service definition, amendment number 2.

CENELEC EN 50170

General purpose field communication systems EuroNorm EN 50170.

7 FIELDBUS FREQUENTLY ASKED QUESTIONS

We have never had any problems with surges, why do I need protection?

Lightning is not the only source of problematic surges.

Have you ever measured or analysed incidents of lightning/voltage transient?

Do you suffer unexplained or spurious failures rather than immediate failures? Electronic systems can suffer from long term gradual failures as a result of surge induced stress.

We don't get lightning here so we should not have a problem...

Does not need to be a local strike (can be up to 1Km away).

Lightning is not the only source of surges.

Does not need to be a direct strike.

Geographical lightning authenticity charts will indicate local incidence levels

Some of my equipment is inside a building, why do I need protection?

Protection for fieldbus systems needs installing on all cables carrying the following supply to and from the building

- ◆ Data
- ◆ Mains power
- ◆ Fieldbus trunks
- ◆ Fieldbus spurs that are longer than 50 metres

All of my I/O has isolation, why do I need protection?

Isolation is good up to a point/at a level (say 8-10kV) it is prone to breakdown.

Lightning generated voltages can run to 100's of kV.

Lose your isolation you've lost all or part of your fieldbus system.

The SPD's are more expensive than the equipment they are protecting, why should I bother to protect?

When deciding the cost of surge protection devices there are several things to take into consideration.

Safety aspects of plant and personnel.

How much does it cost to shut down an entire fieldbus system for a day?

How much business can you afford to lose if your computer system fails?

Surge protection devices can make your installation more reliable and you need to look at the whole cost not just the equipment cost.

Maintenance/service costs can be expensive and can mean extensive system downtime.

We have IS systems which do not allow an earth point in the hazardous area, and your SPD's need to be earthed at both ends of the loop, how can I use surge protection?

SPD's utilise earth connection in the event of a strike and are isolated from earth at other times. This point is clarified in MTL documentation and considered in the relevant code of practice IEC/EN 60079-14.

8 FIELDBUS GLOSSARY

Attenuation	Signal getting smaller as it travels on the cable
Cable	A number of wires and shielding in a single sheath
Daisy-chain	A wiring method where a number of devices are attached along the trunk cable
Device	A sensor, actuator or control equipment attached to the fieldbus
Fieldbus	A process control local area network defined by ISA standard SP50.02
Frame	A single transmission from a device
H1	The 31.25 kbit/second type of fieldbus
Intrinsic Safety	A low energy protection technique that cannot cause an explosive atmospheres to ignite.
IS barrier	A device used to keep voltages and currents on wires below the levels that can ignite an atmosphere
Reflection	An unwanted signal that results from a cable fault or improper termination
Segment	A part of a fieldbus network wiring that is electrically independent from other parts
Surge	A large unwanted voltage or current on wires generally caused by lightning or nearby heavy electrical power use
Surge Protection Device (SPD)	A device used to discharge surges to earth/ground
Terminator	A device used to correctly terminate at the end of a wire thus minimising reflections

9 APPENDICES

9.A Appendix 1 - Number of fieldbus devices on a spur

Number of Devices	Maximum total spur length
1-12	120 metres
13-14	90 metres
15-18	60 metres
19-24	30 metres
25-32	No spurs allowed, devices must be attached directly to the home run cable

Table 1 Number of fieldbus devices on a spur

These are only estimates. The quality of existing cable may vary a great deal. Some existing cable may be very good while other cable of the same type may be waterlogged, have deteriorated insulation or be mechanically damaged. The only real way to determine if existing cable is suitable for fieldbus or if new cable has been installed correctly is to use a fieldbus tester.

9.B Appendix 2 - Fieldbus cable lengths

The fieldbus standard contains estimates of how long a fieldbus cable can be and still get adequate signal quality. For the standard fieldbus cable, and some types of existing cables used for control applications, the limits are:

Cable type	Distance (metres/ feet)	Characteristic Impedance (Ohms)	Resistance (Ohms/Km)	Atten. (DB/Km)	Description
Type A	1900/6270	100	22	3	Each twisted pair has shield
Type B	1200/3960	100	56	5	Multiple twisted pairs with overall shield
Type C	400/1320	Unknown	132	8	Multiple twisted pairs, no shield
Type D	200/660	Unknown	20	8	Multiple conductor cable, no pairing of wires

Table 2 Fieldbus cable length standard

9.C Appendix 3 - TP32 thread information

The following thread types and sizes are available:

- ◆ N = 1/2 inch NPT
- ◆ I = 20mm ISO
- ◆ G = G 1/2 inch (BSP 1/2 inch)

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