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31.25 kbit/s Intrinsically Safe Systems

Application Guide

FOUNDATION™ fieldbus

Compliments of:

FOUNDATION Fieldbus Application Guide

31.25 kbit/s Intrinsically Safe Systems

AG-163 Revision 1.0

This application guide has been prepared to aid understanding of the application considerations of the FOUNDATION fieldbus.

The booklet begins with a brief overview of 31.25 kbit/s intrinsically safe systems and their important parameters, followed by an outline of the specifications of devices and other related equipment.

The main portion of the booklet provides guidance on certifying equipment for use in these systems, and offers advice on sound design and installation practices.

I sincerely hope that this information proves useful to you. Please contact the Fieldbus Foundation if you need additional information about this exciting new technology.

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1.0 INTRODUCTION AND SCOPE

This application note relates only to FOUNDATION fieldbus equipment and systems operating at a 31.25 kbit/s data rate and conforming to the specifications and recommended parameters in the FOUNDATION 31.25 kbit/s Physical Layer Profile Specification, FF-816 Revision 1.0 May 13,1996. The advice given is not intended to apply to other fieldbus systems operating to different device specifications or data rates, and could lead to a potentially unsafe system if used in that way.

The intention of this application note is fourfold:

- Explain the basic concepts of intrinsically safe systems, and their important parameters;
- Outline the specifications of devices and other related equipment for use on FOUNDATION 31.25 kbit/s intrinsically safe fieldbus systems in hazardous areas;
- Provide guidance on certifying equipment for use in these systems;
- Offer advice to installers and users of these systems on good design and installation practice.

2.0 REFERENCE DOCUMENTS

Fieldbus Standards

IEC 1158-2 : 1993 *Fieldbus Standard for Use in Industrial Control Systems.*

Part 2 : Physical Layer Specification and Service Definition.

ISA-S50.02-1992 *Fieldbus Standard for Use in Industrial Control Systems.*

Part 2: Physical Layer Specification and Service Definition.

ISA dS50.02, Part 2 Draft Standard *Fieldbus Standard for Use in Industrial Control Systems*.

Part 2: Physical Layer Specification and Service Definition, Amendment to Clause 22 (Formerly Clauses 11 and 24).

FOUNDATION Specification

FOUNDATION Specification : *31.25 kbit/s Physical Layer Profile*

DOCUMENT	*FF-816*
REVISION:	*1.0*
DATE:	*May 13, 1996*

Intrinsic Safety Standards

IEC 79-4 : 1975 (Second edition) *Electrical Apparatus for Explosive Gas Atmospheres.*
Part 4 : Method of Test for Ignition Temperature.

IEC 79-11 : 1991 (Third edition) *Electrical Apparatus for Explosive Gas Atmospheres.*
Part 11 : Intrinsic Safety "i".

CENELEC EN 50014 : 1992 *Electrical Apparatus for Potentially Explosive Atmospheres - General Requirements*.

CENELEC EN 50 020 : 1977 (First edition) *Electrical Apparatus for Potentially Explosive Atmospheres - Intrinsic Safety "i".*

CENELEC EN 50020 : 1994 (Second edition) *Electrical Apparatus for Potentially Explosive Atmospheres - Intrinsic Safety "i".*

CENELEC EN 50 039 : 1982 *Electrical Apparatus for Potentially Explosive Atmospheres - Specification for Intrinsically Safe Electrical Systems "i".*

Factory Mutual Approval Standard. Class Number 3610, October 1988. *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division 1 Hazardous (Classified) Locations.*

Codes of Installation Practice

IEC Publication 79-14 : 1984 (First edition) - IEC Report. *Electrical Apparatus for Explosive Gas Atmospheres.*

Part 14 : Electrical Installations in Explosive Gas Atmospheres (other than mines).

British Standard BS 5345 : Part 4 : 1977. *Code of Practice for Selection, Installation and Maintenance of Electrical Apparatus for Use in Potentially Explosive Atmospheres (other than mining applications or explosive processing and manufacture).*

Part 4 : Installation and Maintenance Requirements for Electrical Apparatus with Type of Protection "i". Intrinsically Safe Electrical Apparatus and Systems.

ISA RP12.6, Recommended Practice, 1987. *Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations.*

3.0 GLOSSARY

For the purpose of this Application Note the following definitions (taken largely from CENELEC standards EN 50014 and EN 50020) apply:

associated apparatus Electrical apparatus which contains both intrinsically safe circuits and non-intrinsically safe circuits and is constructed so that the non-intrinsically safe circuits cannot adversely affect the intrinsically safe circuits.

NOTE – Associated apparatus may be either:

a) electrical apparatus which has an alternative type of protection for use in the appropriate explosive gas atmosphere or:

b) electrical apparatus not so protected and which therefore shall not be used within an explosive gas atmosphere: for example, a recorder which is not itself in an explosive gas atmosphere, but is connected to a thermocouple situated within an explosive atmosphere where only the recorder input circuit is intrinsically safe.

electrical apparatus Assembly of electrical components, electrical circuits or parts of electrical circuits normally contained in a single enclosure.

explosive gas atmosphere A mixture with air, under atmospheric conditions, of flammable substances in the form of gas vapor or mist in which after ignition combustion spreads throughout the unconsumed mixture.

fault Any defect of any component, separation, insulation or connection between components, not defined as infallible, upon which the intrinsic safety of a circuit depends.

fuse rating (I_n) The current rating of a fuse according to its manufacturer's specification.

ignition temperature of an explosive gas atmosphere The lowest temperature of a heated surface at which, under specified conditions according to IEC 79-4, the ignition of a flammable substance in the form of a gas or vapor mixture with air will occur.

infallible component or infallible assembly of components Component or assembly that is not likely to become defective, in service or in storage, in such a manner as to invalidate intrinsic safety.

infallible separation or insulation Separation or insulation between electrically conductive parts that is not considered as becoming short circuited in service or storage and therefore will not be considered to fail for the purposes of fault analysis and the application of the spark test apparatus.

intrinsically safe apparatus Electrical apparatus in which all the circuits are intrinsically safe circuits.

intrinsically safe circuit Circuit in which any spark or any thermal effect produced in the conditions specified in this standard, which include normal operation and specified fault conditions, is not capable of causing ignition of a given explosive gas atmosphere.

maximum external capacitance (C_o) Maximum capacitance in an intrinsically safe circuit that can be connected to the connection facilities of the apparatus without invalidating intrinsic safety.

maximum external inductance (L_o) Maximum value of inductance in an intrinsically safe circuit that can be connected to the connection facilities of the apparatus without invalidating intrinsic safety.

maximum external inductance to resistance ratio (L_o/R_o) Ratio of inductance (L_o) to resistance (R_o) of any external circuit that can be connected to the connection facilities of the electrical apparatus without invalidating intrinsic safety.

maximum input current (I_i) Maximum current (peak a.c. or d.c.) that can be applied to the connection facilities for intrinsically safe circuits without invalidating intrinsic safety.

maximum input power (P_i) Maximum input power in an intrinsically safe circuit that can be dissipated within an apparatus when it is connected to an external source without invalidating intrinsic safety.

maximum input voltage (U_i) Maximum voltage (peak a.c. or d.c.) that can be applied to the connection facilities for intrinsically safe circuits without invalidating intrinsic safety.

maximum internal capacitance (C_i) Total equivalent internal capacitance of the apparatus which is considered as appearing across the connection facilities of the apparatus.

maximum internal inductance (L_i) Total equivalent internal inductance of the apparatus which is considered as appearing at the connection facilities of the apparatus.

maximum internal inductance to resistance ratio (L_i/R_i) Ratio of inductance (L_i) to resistance (R_i) which is considered as appearing at the external connection facilities of the electrical apparatus.

maximum output current (I_o) Maximum current (peak a.c. or d.c.) in an intrinsically safe circuit that can be taken from the connection facilities of the apparatus.

maximum output power (P_o) Maximum electrical power in an intrinsically safe circuit that can be taken from the apparatus.

maximum output voltage (U_o) Maximum output voltage (peak a.c. or d.c.) in an intrinsically safe circuit that can appear under open circuit conditions at the connection facilities of the apparatus at any applied voltage up to the maximum voltage, including U_m and U_i.

> NOTE – where there is more than one applied voltage, the maximum output voltage is that occurring under the most onerous combination of applied voltages.

maximum r.m.s. a.c. or d.c. voltage (U_m) Maximum voltage that can be applied to the non-intrinsically safe connection facilities of associated apparatus without invalidating intrinsic safety.

> NOTE – the value of U_m may be different at different sets of connection facilities.

maximum surface temperature The highest temperature which is attained in service under the most adverse conditions (but within the recognized tolerances) by any part or surface of an electrical apparatus, which would be able to produce an ignition of the surrounding explosive atmosphere.

minimum igniting current (*MIC*) Minimum current in resistive or inductive circuits that causes the ignition of the explosive test mixture in the spark test apparatus.

minimum igniting voltage (*MIV*) Minimum voltage of capacitive circuits that causes the ignition of the explosive test mixture in the spark test apparatus.

normal operation Operation of intrinsically safe apparatus or associated apparatus such that it conforms electrically and mechanically with the design specification produced by its manufacturer.

potentially explosive atmosphere An atmosphere which could become explosive (the danger is a potential one).

rated value A quantity value assigned generally by the manufacturer, for a specified operating condition of a component, device or apparatus.

simple apparatus An electrical component or combination of components of simple construction with well defined electrical parameters which is compatible with the intrinsic safety of the circuit in which it is used.

type of protection The specific measures applied to electrical apparatus to avoid ignition of a surrounding explosive atmosphere.

4.0 PRINCIPLES OF INTRINSIC SAFETY APPLIED TO FOUNDATION FIELDBUS

Intrinsic Safety (I.S.) is a method of ensuring the safety of electrical equipment where flammable materials are present. The areas at risk are known as *Hazardous Areas* and the materials that are commonly involved include crude oil and its derivatives, alcohols, natural and synthetic process gases, metal dusts, carbon dust, flour, starch, grain, fiber and flyings. To protect both plant and personnel, precautions must be taken to ensure that these atmospheres cannot be ignited.

There are several ways this can be achieved: by enclosing the electrical equipment in a heavy, robust *Flameproof* enclosure designed to contain any explosion which occurs; by preventing access for the flammable atmosphere to the equipment using techniques such as sand or oil filling; by encapsulating the equipment in an epoxy resin; or by pressurizing the equipment so that the flammable atmosphere cannot enter. It is obvious that application of any of these techniques results in increased equipment size and weight, and does not allow live working when any degree of hazard is present. Some of the techniques also make the equipment completely impossible to service or repair.

I.S. assumes a different approach. The flammable atmosphere is allowed to come in contact with the electrical equipment without introducing a potential hazard. This is possible because the system (including both the *I.S. apparatus* in the hazardous area and the safe area *associated apparatus* directly connected to it) has been designed to be incapable of causing an ignition in that atmosphere, even with faults applied either to it or the interconnecting cables. The electrical energy available in hazardous area circuits is restricted to a level such that any sparks or hot surfaces which occur as a result of electrical faults are too weak to cause ignition. This approach allows measurements to be made on the equipment (using suitably approved test equipment) and adjustments to be carried out during live operation.

Similarly, equipment can be removed or replaced while the system is operating. I.S. can be applied only to low voltage, low power equipment (up to a few Watts) but is the favored approach for instrumentation, where its operational benefits are significant. It is also a technique where, unlike most of the alternatives mentioned, there is a large degree of international standardization. This makes it possible for the same equipment and systems to be certified and installed in most areas of the world.

4.1 Classifying Hazardous Areas and Flammable Atmospheres

Hazardous areas are classified by their degree of hazard *(Area Classification)* and the gases that are present *(Gas Group)*. Area classification categorizes areas according to the probability that an explosive atmosphere is present, and this dictates whether or not a particular explosion protection technique can be used. I.S. is internationally recognized as the technique offering the highest degree of safety and in most countries is specified as the only one allowed for use in the highest degree of hazard.

Unfortunately there are two different approaches to area classification. Most countries have adopted the IEC 79 *Zone* classifications, while the USA and Canada have a *Division* classification system. The European CENELEC standards follow the IEC approach. The two systems are summarized in Table 1, where it can be seen that the North American Division 1 encompasses the IEC Zones 0 and 1, while Division 2 is almost identical to IEC Zone 2. This equivalence is not exact and any designer, installer or user of equipment should make himself familiar with the detailed requirements of the standards and process. The 1996 US National Electrical Code recognizes the IEC Zone classification, opening the way for further adoption of IEC designations in the USA. It is expected that equivalent changes to the Canadian Electrical Code will follow soon.

The position relating to dust hazards is less standardized and general advice cannot easily be given here. Potential users are advised to consult authorities in the country where the equipment will be installed.

Table 1 – Area Classifications

IEC & CENELEC	USA & Canada
Zone 0: Explosive gas-air mixture continously present, or present for long periods. **Zone 1:** Explosive gas-air mixture is likely to occur in normal operation.	**Division 1:** Hazardous concentrations of flammable gases or vapors - or combustible dusts in suspension - continuously, intermittently or periodically present under normal operating conditions.
Zone 2: Explosive gas-air mixture not likely to occur and, if it occurs, it will exist only for a short time.	**Division 2:** Volatile flammable liquids or flammable gases present but normally confined within closed containers or systems from which they can escape only under abnormal operating or fault conditions. Combustible dusts not normally in suspension nor likely to be thrown into suspension.

The IEC standard defines two categories of I.S. system, dependent upon the number of component or other faults (1 or 2) that can be present while the equipment remains safe; the North American standards define only a single category of equipment that is safe with up to two faults introduced, as indicated in Table 2.

Table 2 – I.S. Equipment Categories

IEC & CENELEC	USA & Canada
Ex ia : Explosion protection maintained with up to two component or other faults. I.S. apparatus may be located in, and associated apparatus may be connected into Zone 0, 1 and 2 hazardous areas (Germany requires galvanic isolation and a system certificate for Zone 0). **Ex ib :** Explosion protection maintained with up to one component or other fault. I.S. apparatus may be located in, and associated apparatus may be connected into Zone 1 and 2 hazardous areas.	**One category only :** Safety maintained with up to two component or other faults. I.S. apparatus may be located in, and associated apparatus may be connected into Division 1 and 2 hazardous locations.

Gases are classified according to the spark energy needed to ignite them. All I.S. equipment is designed and certified as being safe for a particular group of gases, although in practice most I.S. systems are designed to be safe with all the gas groups normally encountered - while a few employ more power in particular defined environments. Again, there is a different classification of gases between IEC and North America, as shown in Table 3.

Table 3 – Gas Classifications

IEC & CENELEC	USA & Canada
Flammable gases, vapors and mists are classified according to the spark energy required to ignite the most easily ignitable mixture with air. Apparatus is grouped according to the gases that it may be used with.	Flammable gases, vapors and mists and ignitable dusts, fibers and flyings are classified according to the spark energy required to ignite the most easily ignitable mixture with air.
Surface industries	*Surface industries*
Group IIC : acetylene **Group IIC :** hydrogen **Group IIB :** ethylene **Group IIC :** propane (↑ more easily ignited)	**Class I, Group A :** acetylene **Class I, Group B :** hydrogen **Class I, Group C :** ethylene **Class I, Group D :** propane (↑ more easily ignited)
Dusts Under consideration	**Class II, Group E :** metal dust **Class II, Group F :** carbon dust **Class II, Group G :** flour, starch, grain **Class III :** fibers and flyings
Mining industry **Group 1 :** methane (firedamp)	*Mining industry* **Unclassified :** methane (firedamp)

The Temperature Classification of a piece of hazardous area equipment is defined by the highest surface temperature reached within any part of it when a specified amount of power is supplied to it under fault conditions (at an ambient temperature of 40° C unless otherwise stated). Fortunately there is international agreement on temperature classifications, and these are given in Table 4. There is no correlation between the spark energy required to ignite a gas mixture and its susceptibility to ignition by hot surfaces. For example, hydrogen is easily ignited by spark energy (19 mJ) but requires a surface temperature in excess of 560° C to produce ignition. All gases (with the exception of carbon disulphide) are covered by a T4 temperature classification, and this is the normal design level. Fortunately, within I.S. there are international agreements between certification bodies that allow a T4 classification to be assigned to most components within equipment without testing. These agreements only apply if the supplied power from the associated safe area apparatus under fault conditions, does not exceed 1.3 W at 40° C (equivalent figures are 1.2 W at 60° C and 1.0 W at 80° C ambient). Although this agreement excludes very small components, it can greatly simplify and shorten the task of certifying I.S. equipment.

Table 4 – Temperature Classification

Hazardous area apparatus is classified according to the maximum surface temperature produced under fault conditions at an ambient temperature of 40° C, or as otherwise specified.	
T1	450° C
T2	300° C
T3	200° C
T4	135° C
T5	100° C
T6	85° C

4.2 Ignition Curves

The energy required to ignite the most easily ignitable mixture of a given gas with air is called the *Minimum Ignition Energy* of that gas. The current required to sustain ignition varies with the voltage level in the circuit. Curves of permitted voltage and current for each gas group in a purely resistive circuit are published as *Ignition Curves* in each of the intrinsic safety standards. They result from experiments over several years and the results are agreed upon internationally. Typical curves (taken from the CENELEC standard EN 50 020) are shown in Figure 1. A 1.5 factor of safety has to be applied to the currents shown in these curves when they are applied in practice. Although the curves cover a considerable range of voltages and currents, the choice of operating region for an I.S. fieldbus is limited. This choice is determined by several factors:

- A low open circuit operating voltage to allow a large permitted system capacitance in the most hazardous gas group, IIC (North American Groups A & B);
- A short circuit current low enough to allow a usable system inductance under similar conditions;
- A peak output power from the safe area equipment that will minimize the design and certification problems for equipment vendors.

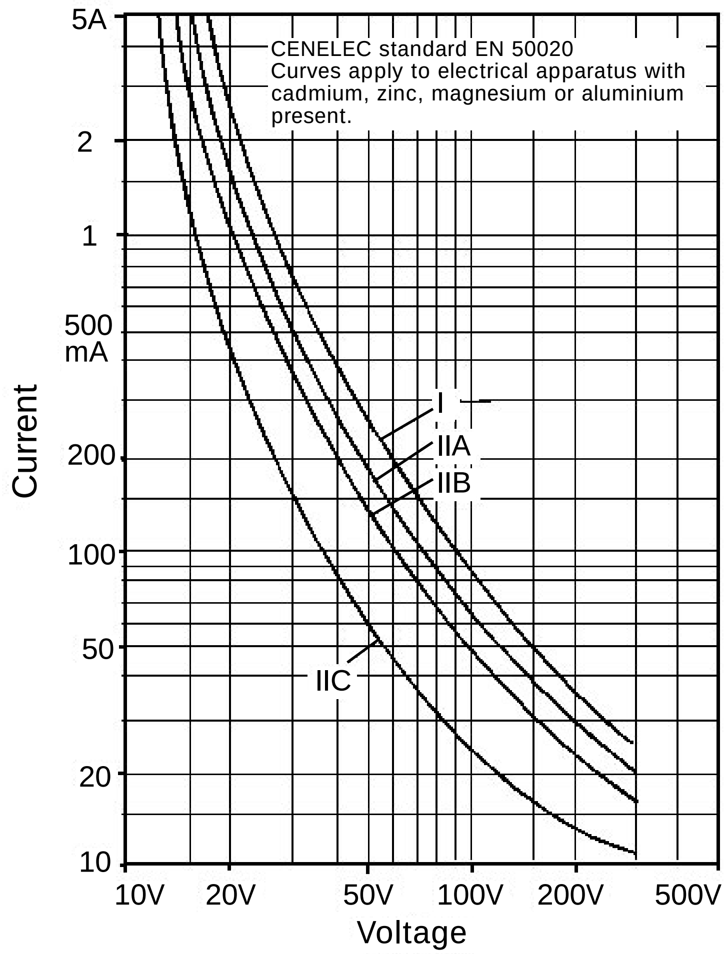


Figure 1 – Ignition Curves

These factors define an operating region below about 30 V, 300 mA and 1.2 W at 60° C, as shown in Figure 2 (which includes the required 1.5 factor of safety on the ignition curves). Capacitance is treated as a lumped parameter and its permitted value reduces sharply as the system voltage is increased. This proves to be a stronger defining effect than the reduction of permitted inductance as the current increases. This is because the increased inductance of long system cables is always accompanied by an increased series resistance which reduces its effect. Any item of I.S. associated apparatus normally has maximum specified values for permitted capacitance, inductance and inductance-to-resistance (L/R) ratio that may be safely connected to its I.S. terminals. Cables may be specified by their L/R ratio, as an alternative to a simple inductance parameter, which can make system inductance a less significant factor.

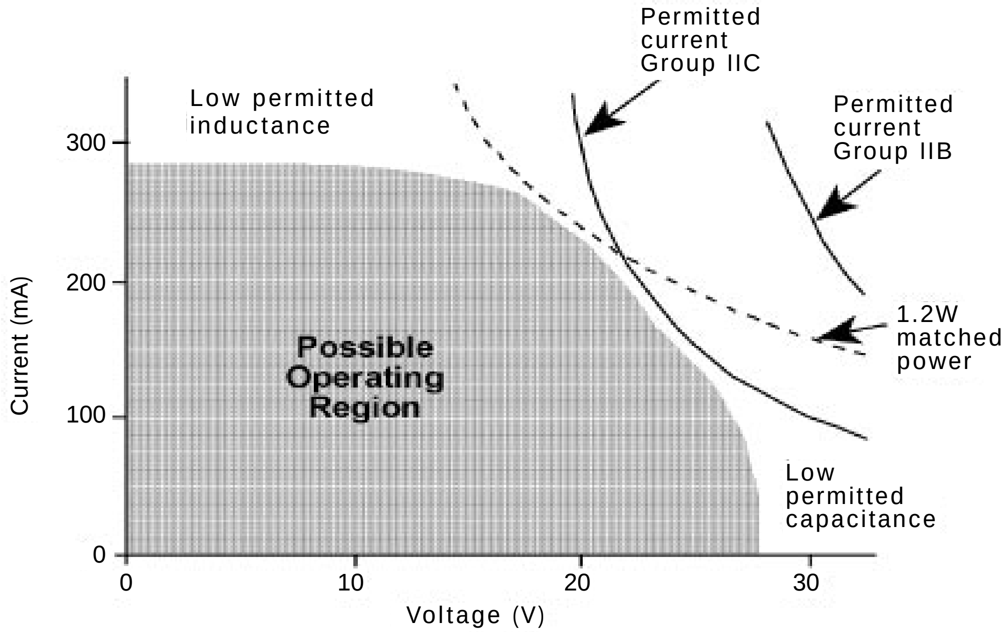


Figure 2 – Practical Operating Region

5.0 CERTIFYING EQUIPMENT FOR INSTALLATION IN HAZARDOUS AREAS

Equipment of various different types has been certified for hazardous area use over many years. The added factor that fieldbus introduces is the need for equipment from different manufacturers to be certified in a compatible way for connection onto a common bus. This is essential to the success of fieldbus in hazardous area applications, otherwise a common communication standard will not be translated into installed, multi-vendor hazardous area systems. Previously each manufacturer has specified the safety parameters of their hazardous area products (together with their own associated safe area equipment or those of a specialist manufacturer) in a way that suited them, without reference to other manufacturers or competitors.

This approach is not sufficient for fieldbus. For this reason, the FOUNDATION 31.25 kbit/s Physical Layer Profile Specification has established some recommended certification parameters for communicating devices and accessory items. If followed, these will lead to equipment from different manufacturers being able to connect together on FOUNDATION fieldbus in a demonstrably safe manner.

This profile specification, derived from the IEC/ISA Fieldbus Physical Layer Standard IEC 1158-2 : 1993 (ISA standard ISA - S50.02 - 1992 has identical English text) Clause 11 and draft Clause 22, defines eight profiles for communicating fieldbus device types. Of these, four are specified as suitable for connection to an I.S. fieldbus within a hazardous area. These profile types, with their FOUNDATION type designations, are:

Type 111 – standard-power signaling, bus powered, I.S.
Type 112 – standard-power signaling, separately powered, I.S.
Type 121 – low-power signaling, bus powered, I.S.
Type 122 – low-power signaling, separately powered, I.S.

These types are distinguished from the remaining ones as being suited for hazardous area use by their property of introducing no electrical energy onto the fieldbus during either reception or transmission of signals. This is because their *Medium Attachment Unit (MAU)* is specified as current sinking at all times; at no time during operation does it supply current to the fieldbus.

The remaining device profile types either employ transformer coupling of signals onto the fieldbus, in which case energy is supplied to the bus during half of each transmitted bit time, or do not include the internal energy limiting under fault conditions needed to obtain an I.S. certification.

The I.S. approach is inherently a system concept. All sources of possible energy into the flammable atmosphere must be considered and limited. It would be possible for a particular system including transformer coupled devices to be certified, but not in any generalized way or in an acceptable timescale. The FOUNDATION Physical Layer Profile Specification therefore specifies devices and accessory equipment for use on an I.S. fieldbus where the hazardous area equipment is supplied by one single source of power (from an I.S. power supply or through an I.S. interface of some type - see Section 6).

To achieve compatible device certifications, the Physical Layer Profile Specification recommends minimum input voltage, current and power levels with which hazardous area devices should be certified to operate. These are listed in Table 5. An *"ia"* certification (IEC designation, see Table 2) is recommended since this meets the requirements for international acceptance and ensures that systems can be analyzed without the need for repeated testing at each certification authority. Provided manufacturers certify devices to comply with at least these minimum levels, it should be possible safely and legally to connect certified devices from different manufacturers to the same fieldbus.

Also included in Table 5 is a recommended T4 device temperature classification. This will be required for operation with the majority of applications. The significance of the recommended device maximum residual capacitance and inductance parameters, also shown in Table 5, may not be immediately apparent, but these are explained more fully in Section 8.

Table 5 – Recommended I.S. Parameters For Hazardous Area Devices

Parameter	Recommended Value
Device approval voltage	24 V min.
Device approval current	250 mA min.
Device input power	1.2 W min.
Device residual capacitance	< 5 nF
Device residual inductance	< 20 mH
I.S. classification	Ex ia, IIC (gas groups A & B), T4

Individual manufacturers can choose to certify their equipment at figures higher than the minimum levels shown. There are good reasons to do this for particular applications, but they should be aware that if the field-bus is powered in a way to take advantage of the increased specifications (usually by increasing the levels of short circuit current and maximum transferred power from the safe area) then only equipment certified to the higher levels can be connected to that bus. Also, the manufacturer should not under-estimate the difficulty of maintaining a T4 temperature classification with increased power levels supplied to the device, or the time needed to achieve device certification.

Any combination of device profile *Types 111, 112, 121* and *122* can be connected to a powered I.S. fieldbus. The FOUNDATION Profile Specification defines a fieldbus capable of operating with both standard-power and low-power signaling devices present (due to the chosen characteristics of power supply and terminators – see Section 4 for more details) and any combination of these four types of bus powered and separately powered units.

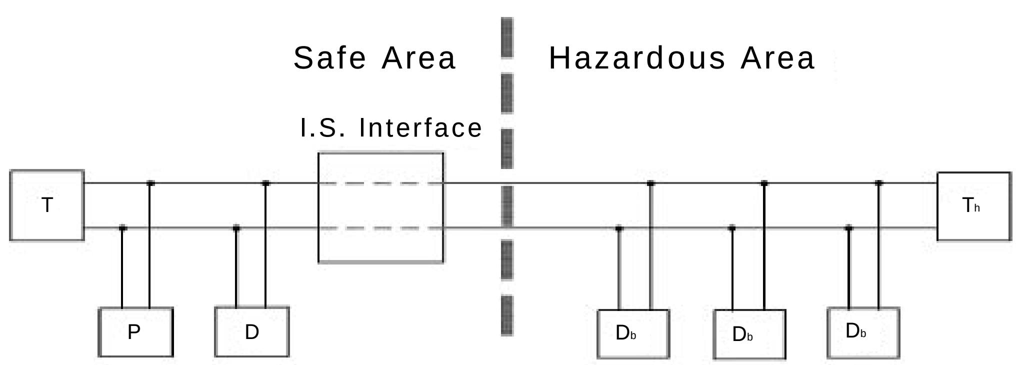
Any of the device profiles specified for hazardous operation can, as an alternative, be connected to a non-I.S. segment of a fieldbus, or to a totally safe area fieldbus, operating to FOUNDATION specifications. The only requirement is that the bus must be powered (even for separately powered Types 112 and 122 devices).

NOTE – As with existing analog installations, care must be exercised in the installation and use of I.S. apparatus in a hazardous area if it has previously been connected into a non-I.S. system.

5.1 Bus Powered Devices (Profile Types 111 and 121)

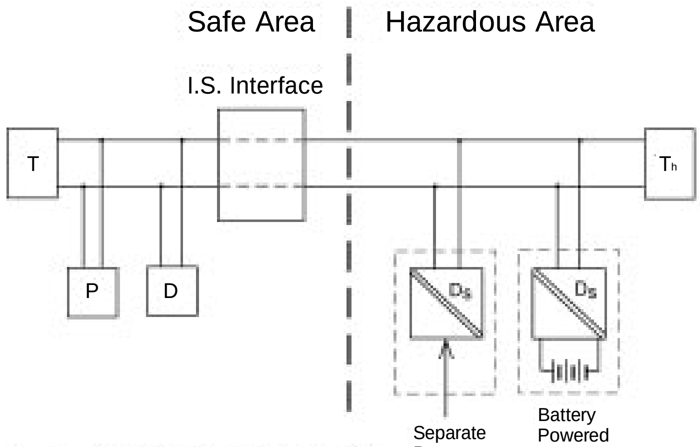
These are devices whose only source of electrical power is the fieldbus itself. A typical system might be as shown in Figure 3. The device MAU performs the dual function of regulating power from the fieldbus to the device and signaling onto the bus.

For the manufacturer, the major design challenges are to minimize the current drawn by each device – since the total current supplied to an I.S. fieldbus is limited (see Section 4) – and ensuring that only very low levels of unsuppressed capacitance and inductance can be measured external to the device. Recent emphasis on the immunity aspects of Electromagnetic Compatibility (EMC) makes the fitting of transient suppression components in the input of each device almost essential, but these present a problem in minimizing the residual reactive elements from an I.S. viewpoint.



P = Fieldbus power supply (*Type 131*)
T = Terminator
D = Device (any profile *Type*)
D_b = I.S. certified bus-powered device (*Type 111 or 121*)
T_h = I.S. certified terminator

Figure 3 – I.S. Fieldbus with Bus-Powered Devices



P = Fieldbus power supply (*Type 131*)
T = Terminator
D = Device (any profile *Type*)
D_s = I.S. certified separately-powered device (*Type 112 or 122*)
T_h = I.S. certified terminator

NOTE: A Type 112 or 122 device will use I.S. in combination with other explosion protection techniques. The external power source or internal battery must be galvanically isolated from the fieldbus MAU.

Figure 4 – I.S. Fieldbus with Separately-Powered Devices

5.2 Separately Powered Devices (Profile Types 112 and 122)

These device types have one or more sources of electrical power in addition to the power supplied from the fieldbus itself. An example of such a device is an analyzer where the application circuitry requires higher levels of power than can be obtained from an I.S. fieldbus, or a battery powered hand-held unit. These types of equipment, and their power supplies, would be designed to use another form of explosion protection, but the fieldbus communication element may still be required to connect to an I.S. fieldbus. An example system is shown in Figure 4.

The MAU within the device is, in this case, required to provide power only to the fieldbus communications circuit itself. This is one application where the use of low-power signaling (device *Type 122*) has an immediate advantage in reducing the current drawn from the fieldbus, but a standard-power signaling *Type 112* device can be used as an alternative. In either case, the MAU requirements completely mirror those of the corresponding bus powered device profile, and the certification parameters (Table 5) and operating characteristics are independent of the powering arrangements.

The major design requirement for I.S. fieldbus devices including separate sources of power is to ensure the complete separation of these sources from the fieldbus itself. This will normally involve some form of galvanic isolation to I.S. standards, with the communication signals being transferred across suitable opto-couplers or transformers. For connection to the FOUNDATION profile I.S. fieldbus this complete separation of power sources is an essential requirement.

5.3 Fieldbus Terminators

The FOUNDATION Physical Layer Profile (Section 12.4) defines the recommended I.S. parameters for a terminator certified for installation in a hazardous area, as listed in Table 6. All FOUNDATION fieldbus segments require two bus terminators to be present. For an I.S. fieldbus, at least one of these will be mounted in the hazardous area (see Figures 3 and 4). Any terminator designed for possible installation in a hazardous area must be formally certified since it includes a resistive-capacitive circuit which cannot be evaluated from standardized reference curves. The minimum I.S. parameters recommended in the FOUNDATION Physical Layer Profile Specification are compatible with those of devices and other equipment and, provided these are complied with, will allow

Parameter	Value
Mounting	Zone 0 (US Div. 1)
Gas group	IIC (US Groups A & B)
Input voltage	24 V min.
Input current	250 mA min.
Input power	1.2 W min.

Table 6 – Recommended I.S. Parameters for Hazardous Area Mounted Terminator

hazardous area fieldbus systems to be constructed. Some certification authorities may assign an equivalent unprotected capacitance to a particular manufacturer's terminator. In this case, the allocated capacitance value will be marked on the unit and should be taken into account when assessing available cable parameters, as outlined in Section 8.

The FOUNDATION terminator profile is derived from draft Clause 22 of the IEC/ISA Fieldbus standard, for reasons explained in Section 6.1. Bus terminators with other impedance characteristics should not be used on FOUNDATION fieldbus systems, as the transient response of the system could be adversely affected when different device profile types are added to the fieldbus.

6.0 CERTIFYING ASSOCIATED EQUIPMENT FOR INSTALLATION IN THE SAFE AREA

It is clear from the previous section that the only source of power to a FOUNDATION hazardous area fieldbus is that from the I.S. power source installed in the safe area. All safe area mounted equipment connected directly to wiring or equipment in the hazardous area that is part of an I.S. system must be formally certified compatible with its intended application. Such equipment is classed as *Associated Apparatus*. In the fieldbus case the power comes from an I.S. power supply which can be a separate item of equipment, may be included in an I.S. galvanic isolator, or can be formed by a general purpose fieldbus power supply used in conjunction with an I.S. barrier. The FOUNDATION Physical Layer Profile Specifications for these items include recommended I.S. parameters, as listed in Table 7.

Parameter	Value
Location of hazardous area apparatus	Zone 0 (US Div. 1)
Gas group	IIC (US Groups A & B)
Open circuit output voltage	24 V max.
Short circuit output current	250 mA max.
Matched output power	1.2 W max.

Table 7 – Recommended I.S. Parameters for Fieldbus I.S. Power Sources

The 24 V maximum output voltage specification in Table 7 is determined by two main factors:

- The requirement in the IEC/ISA fieldbus standard to operate with 1900m of a defined (Type "A") cable having 24 Ω/km DC resistance (each conductor). This introduces a 92 Ω cable loop resistance on a 1900m long fieldbus. When this resistance is consid ered together with

a) the minimum operating voltage specification for field devices (9 V);

b) the rapidly reduced permitted current level allowed by the ignition curves as the voltage rises, and

c) the required restriction of transferred power level (1.2 W max.),

a supply voltage below 24 V maximizes the current available to fieldbus devices.

- The rapid decrease in permitted system capacitance as the system voltage increases much above 20 V (This is normally only a practical problem in the most hazardous gas group and is discussed more fully in Section 8).

A plot of the maximum current available to field devices as the certified voltage of the I.S. power source varies is shown in Figure 5. This confirms that there is no advantage to be gained from operating an I.S. fieldbus at voltages above 24 V.

The recommended maximum short circuit current and transferred power specifications from the safe area power source are chosen to be compatible with the minimum current and power levels recommended in the I.S. device profiles listed in Table 5.

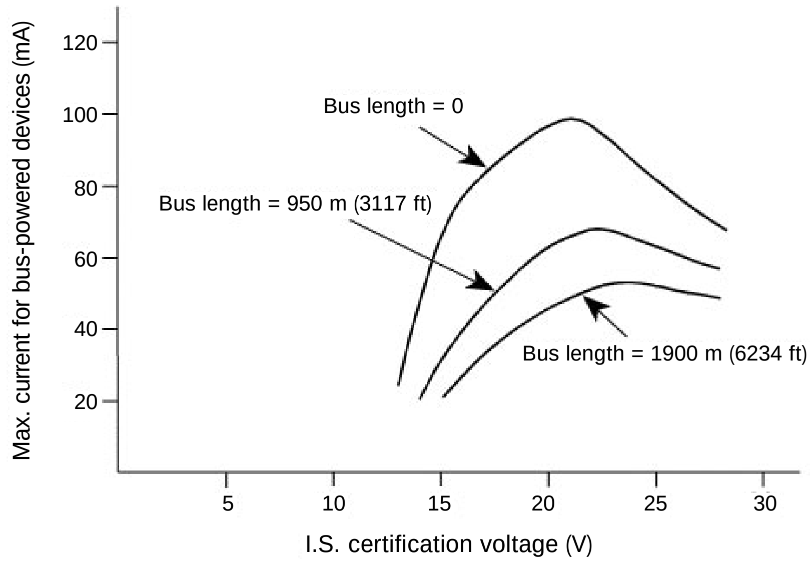


Figure 5 – Variation Of Available Device Current With I.S. Source Voltage

The current available to hazardous area devices on an I.S. fieldbus also varies with the length of the hazardous area bus. This is simply due to an increasing DC loss in the cable resistance as the bus length increases. Figure 6 shows a typical characteristic, based on an assumption that the I.S. interface is designed for about the optimum voltage indicated in Figure 5 and that all the hazardous area devices are connected at the far end of the fieldbus.

NOTE – Figures 5 and 6 as based on the following assumptions:

1. Type "A" cable characteristics, from the IEC/ISA Physical Layer fieldbus standard. This cable is nominal 0.8 mm^2 (#18 AWG). Results will be different with other wire sizes.
2. An I.S. fieldbus with a power supply voltage 3 V below the shown certification voltage. This figure is made up of a 2 V difference between certification and operating voltages, plus an additional 1 V peak signal excursion on the bus (which can occur when one bus terminator is removed).
3. All devices located at the far end of the bus and operating with a minimum device voltage of 9 V.
4. Figure 6 assumes I.S. certification parameters of 22 V, 214 mA and a 19 V power supply voltage.

A practical system may comprise equipment with operating characteristics different from these assumptions.

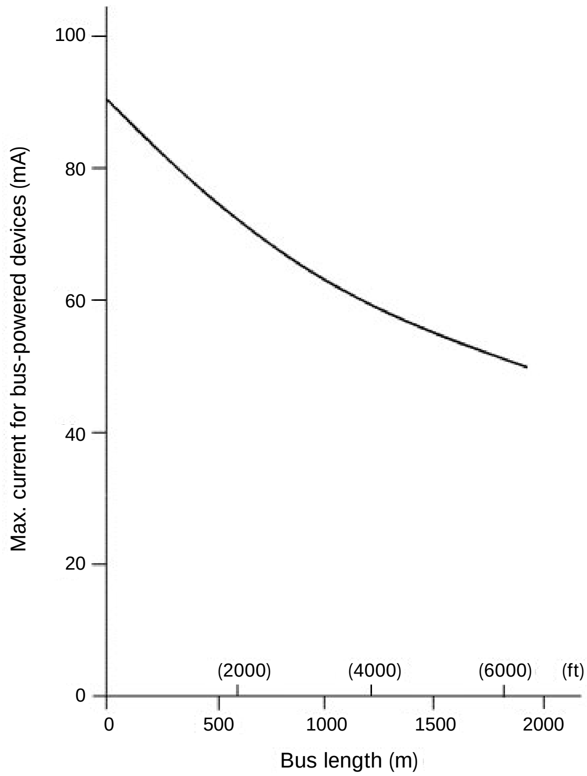


Figure 6 – Variation Of Available Device Current With Bus Length

Apparatus connected to the safe area terminals of associated apparatus does not need to be certified, but must comply with certain requirements outlined in Section 6.4.

6.1 Fieldbus Power Supplies

The FOUNDATION Physical Layer Profile Specification (Section 12.1) includes a *Type 133* I.S. power supply. This unit is specified, including recommended I.S. parameters as given in Table 7, such that it can be connected directly to an I.S. fieldbus circuit in a hazardous area. In such an application it is likely to be associated with an I.S. galvanic isolator (carrying communications between safe area and hazardous area mounted devices, see Section 6.3) designed and certified as providing negligible additional power to the hazardous area system.

An alternative application is where the whole fieldbus is contained in the hazardous area, with no communication to or from safe area devices. The power supply and one bus terminator are then the only items mounted outside the hazardous area. This type of application does not occur very often.

A *Type 133* fieldbus power supply suitable for direct connection to the hazardous area wiring of an I.S. system will be marked with its safety parameters. If these are not clear and understood, or if there is any doubt regarding the safety characteristics of an item of fieldbus equipment that is part of an I.S. system, then full data should be requested from the manufacturer or his authorized local representative.

NOTE – Only I.S. power supplies with linear output characteristics are discussed here, but the use of resistively limited power supplies having a non-linear output characteristic is not precluded.

The impedance characteristic of all the fieldbus power supplies defined in the FOUNDATION Physical Layer Profile Specification is chosen to conform with the requirements of draft Clause 22 of the IEC/ISA Fieldbus standard, rather than the characteristic defined by Clause 11 of that standard. This is important since it allows devices employing both standard-power and low-power signaling to be present on the same system in any combination without degrading signal waveforms. This is possible because the FOUNDATION fieldbus network as specified has a flat frequency response characteristic over a wide frequency range, achieved by tailoring the inductive reactance of the power supply to offset the capacitive reactance of the specified terminator. Before the advent of low-power signaling devices this did not appear very important, but these devices introduce current changes on the network at both bit and frame data rates and a flat characteristic is necessary to guarantee acceptable communication along the bus under all conditions.

The impedance of fieldbus cables and resistive elements in I.S. interface equipment (and even component tolerances in the fieldbus power supplies and terminators) degrade the flatness of this overall system frequency characteristic somewhat, but the specified test conditions in the draft Clause 22 of the standard ensure acceptable limits are maintained. Power supply characteristics other than those specified in the Physical Layer Profile Specification should not be used on FOUNDATION I.S. fieldbus networks.

When considering the current required by devices on a hazardous area I.S. fieldbus compared with that available from the power supply it is important to remember that there are two classes of device in this respect:

a) Devices whose average current draw remains constant between receiving and transmitting (These may be a Type 111, 112, 121 or 122 device);

b) Devices whose current draw increases when they are transmitting (These will be a Type 121 or 122 device).

When considering the first class of device it is sufficient to sum the current taken by all devices and compare this with the available current in the particular system configuration. This is calculated from the power supply voltage, the device minimum operating voltage (9 V), and all the resistive elements present in the particular system (power supply, cables and I.S. interface).

With the second class of device the quiescent current (during reception) of each device is again summed, but an additional current equal to the highest current difference between receiving and transmitting of any device in the system must then be added to this figure.

In either case it may be considered prudent to allow for the additional current taken during device start-up or by, for example, a portable bus analyzer that may be required on the system occasionally during operation. If this margin is not available reliable bus communication could be affected during these periods.

6.2 I.S. Barriers

The FOUNDATION Physical Layer Profile Specification (Section 12.2) includes an I.S. barrier. Such barriers are intended for mounting in the safe area only (unless their certification expressly allows installation in a hazardous areas using additional protection techniques). A typical I.S. barrier comprises a simple network of shunt-connected zener diodes, series current limiting resistors and protection fuses. The barrier performs its function by diverting excessive voltage or current surges or overloads safely to the system earth (or *ground* in North American parlance) before they can cause ignition of the hazardous atmosphere. The existence of a properly rated, high integrity connection from the barrier to earth is therefore a primary safety requirement when using a barrier-protected fieldbus in a hazardous area. Most national installation codes require that the earth cable has a DC resistance of <1 Ω between the barrier earth terminal and the system safety earth (normally the connection to the neutral point of the power distribution system). An I.S. barrier intended for operation with a safety earth must never be operated without the safety earth properly installed and connected.

The topic of earthing requirements for I.S. systems is too large to cover in any depth here. FOUNDATION I.S. fieldbus systems must obey the same well established general earthing principles as other I.S. systems. If installers have any doubt about what the system requires they are advised, before installing it, to consult published material from specialist I.S. suppliers (or speak directly to them) regarding specific installation requirements for their products. Some general points to take note of are:

- The selected safety earth connection point should be free from the possibility of invasion by other large fault currents (such as those from a large electric motor, for example);
- The safety earth connection should not carry any significant current during normal operation (except, for instance, the noise current present in cable screens);

  NOTE – The IEC/ISA Fieldbus Physical Layer Standard precludes the use of the cable screen as a power conductor.
- The safety earth cable should be clearly identified, and checked regularly for mechanical damage and integrity;
- For testing purposes, the fitting of two safety earth cables in parallel is recommended by some authorities. This facilitates the periodic measurement of resistance to earth (by disconnecting one cable and measuring the loop resistance).

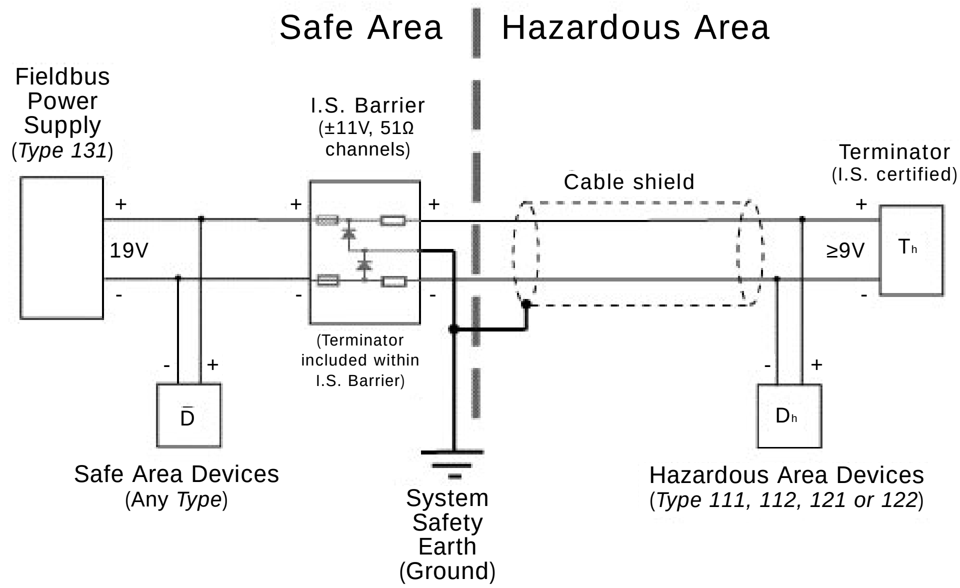


Figure 7 – Fieldbus With Earthed I.S. Barrier

The IEC/ISA Physical Layer Standard requires that the fieldbus is operated in a balanced mode with respect to earth. Barriers to the FOUNDATION I.S. barrier profile must maintain this balanced operation. This will normally require a dual channel I.S. barrier with equal positive and negative channel voltages. Usually it will be supplied from a FOUNDATION *Type 131* power supply, as illustrated in Figure 7. For correct fieldbus operation, the output voltage of the power supply must match the specified *Working Voltage* of the I.S. barrier.

This working voltage will normally be lower than the certified output voltage (*safety voltage*) of the barrier – by perhaps as much as 2 V. In addition to this, an allowance of 1 V needs to be made for the maximum excursion of the signal voltage on the fieldbus (which occurs if one bus terminator is removed). If an attempt is made to operate the system with a power supply voltage rating which results in voltages greater than its working voltage being applied to the barrier, fieldbus communications will be disrupted (by turning on of the internal barrier diodes). This may eventually result in permanent damage to the barrier by blowing its internal protection fuses. The values shown on Figure 7 are simply examples on a typical system. Other measured values may be equally valid with a particular manufacturer's equipment.

The I.S. barrier represents a significant lumped impedance in each fieldbus line (perhaps up to 80 Ω, depending on its characteristics). The IEC/ISA Physical Layer Standard (Clauses 11.7.5 and 22.7.5) requires a terminator to be placed at both ends of the fieldbus trunk cable. An impedance discontinuity, such as that introduced by an I.S. barrier, constitutes one end of the fieldbus trunk. The IEC/ISA Physical Layer Standard (Clauses 11.8.2 and 22.8.2) specifies a maximum cable length of 100 m (328 ft) between an I.S. barrier and the nearest terminator. Wiring from the barrier to any equipment in the safe area should therefore be treated as a spur cable, and limited in length by the recommendations in Annex B of the IEC Physical Layer Standard (printed as Annex C in ISA-S50.02-1992).

Some barrier manufacturers may therefore choose, for user convenience, to include a fieldbus terminator within the I.S. barrier. Users should check whether a particular I.S. barrier is specified as having an integral terminator, or requires an external terminator suitably certified for connection to hazardous area circuits.

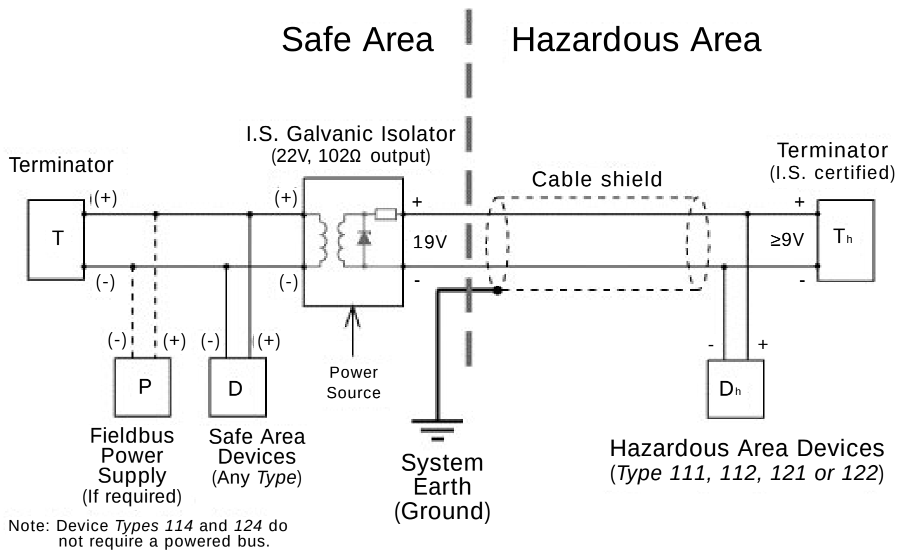


Figure 8 – Fieldbus With I.S. Galvanic Isolator

6.3 I.S. Galvanic Isolators

The FOUNDATION Physical Layer Profile Specification (Section 12.3) includes an I.S. galvanic isolator. This type of unit, in contrast to an I.S. barrier, maintains safety by having high integrity isolation that prevents the transmission of electrical surges or overloads from the safe to the hazardous area. Transmission of electrical power and signals through the isolator is achieved using specially designed components such as transformers and opto-couplers with guaranteed minimum segregation and isolation characteristics. Voltage and current limiting is then applied before signals are transmitted to the hazardous area circuit, defining the isolator hazardous area output characteristic as in the case of an I.S. barrier. When using an I.S. galvanic isolator a safety earth connection to the unit is therefore not required (in contrast to the I.S. barrier equivalent), since surge currents are no longer diverted to earth. It is, however, still necessary to provide a system earth for the proper termination of cable shields. I.S. galvanic isolators are intended for safe area mounting only (unless their certification expressly allows installation in a hazardous area using additional protection techniques).

One advantage of the I.S. galvanic isolator over the I.S. barrier is that it has a hazardous area circuit which is fully isolated from earth, making it easier to ensure the fieldbus is operated in a balanced mode with respect to earth. The active circuitry employed in the galvanic isolator also makes it possible for the isolator to present a reduced effective impedance in each fieldbus line (compared with the I.S. barrier) at the signaling frequencies. Manufacturers who implement this reduction technique within their I.S. galvanic isolator products will probably choose not to include a bus terminator within the unit, since the bus segments on both sides of the isolator may be considered as a single continuous bus. However, it is recommended in all cases to check the manufacturer's documentation regarding placement of bus terminators.

An I.S. galvanic isolator to the FOUNDATION Physical Layer Profile Specification is likely to include the equivalent of a *Type 133* fieldbus power supply. An example system is shown in Figure 8. Alternatively, it may be specified to operate in conjunction with an external fieldbus power supply of this same type. In either case, the characteristics of the galvanic isolator and power supply elements must be considered together when assessing the overall safety parameters represented by the combination. Where these are separate items, both units will be marked with their certified safety parameters.

6.4 Requirements For Other Safe Area Equipment Connected To The Fieldbus

By employing a suitably certified I.S. barrier or galvanic isolator, most of the restrictions are removed from equipment mounted in the safe area and connected to the safe area terminals of these devices. However, one significant requirement remains: no supply or source of generated voltage over 250 V RMS AC or DC may be present in any of the equipment connected to the safe area fieldbus. Most of this equipment will employ low voltage circuits and have no problems in complying. However, a personal computer (used as part of a fieldbus communications analyzer, for instance) or a DCS visual display system often contain high voltage circuits driving the CRT display. These technically invalidate the I.S. certification of the barrier or isolator unit (because the protection fuses in them can be bypassed by arcing from high input voltages) but, for personnel safety reasons, these types of equipment normally include a large separation between their high voltage circuits and the fieldbus or other user-accessible ports. Where there is any doubt that this is the case, the problem can normally be overcome by interposing a surge protection device between the equipment containing the high voltage circuitry and the associated safe area apparatus of the I.S. fieldbus.

7.0 ANALYZING THE SAFETY OF A FOUNDATION I.S. FIELDBUS SYSTEM

Requirements for formal third-party certification of a planned fieldbus system before installation vary between different countries. In the UK there is no legal requirement to obtain this certification, whereas in some other European countries it is required under some conditions. In France and Germany, for example, a system certification is specifically required when the hazard includes Zone 0. In Japan, at the present time, a systems certificate is a mandatory requirement.

North America has pioneered the acceptance of an *Entity Concept*. This is a system that assigns safety parameters to both power sourcing and receiving equipment in an I.S. system, allowing competent users to analyze the suitability and safety of any proposed system by comparing assigned device parameters. An extension of this approach is very suited to the analysis of a multi-vendor fieldbus system using equipment complying with the FOUNDATION Physical Layer Profile Specification. This could be a safety evaluation by the system designer, or for presentation of the results in an easily analyzed form to a third-party certification body. Although system certification is not a legal requirement in many countries, as outlined above, many major users still require it as an additional safeguard that the system installed is safe to operate. Where this system certification is needed, authorities will require each item of equipment to be completely defined.

The entity concept approach compares directly the parameters of equipment providing energy to the I.S. fieldbus system with those that receive it. With compatible equipment, certified to the recommended I.S. parameters contained in the FOUNDATION Physical Layer Profile Specification, adequate safety can quite easily be demonstrated. This must always be done prior to installation, whether or not a third-party system certification is required.

The recommended procedure consists of listing details for each piece of apparatus (both associated safe area apparatus and hazardous area mounted items) in a structured format as shown in Figure 9. Relevant information for each piece of equipment includes the following items:

For all items of equipment:
- Details of manufacturer
- Manufacturer's type reference
- Certification body
- Certification standard
- Certificate or file reference number
- Certification category : Ex ia or Ex ib (Class 1)
- Permitted gas group(s) : IIA, IIB, IIC (Groups A, B, C, D)

For intrinsically safe, hazardous area apparatus:
- Maximum certified input voltage, U_i (Vmax)
- Maximum certified input current, I_i (Imax)
- Maximum certified input power, P_i (Pmax)
- Temperature classification, T
- Residual device capacitance, C_i
- Residual device inductance, L_i

For associated safe area apparatus:
- Maximum certified open circuit output voltage, U_o (Voc, see Note 2)
- Maximum certified short circuit output current, I_o (Isc, see Note 2)
- Maximum transferred output power, P_o (Pm)
- Maximum permitted capacitance, C_o (Ca)
- Maximum permitted inductance, L_o (La)
- Maximum permitted inductance to resistance ratio, L_o/R_o (L/R)

NOTES

1. The symbols normally used for these parameters are shown here (and in figures 9 through 11) in IEC terminology. Where the equivalent North American symbol is different it is shown in parentheses after the IEC symbol.
2. When these entity parameters result from the combination of several I.S. sources they are designated as Vt and It, rather than Voc and Isc, in North American terminology.

The relevant information is required for each item present in the planned system. If there is any doubt about the parameters for a piece of equipment these should be obtained in writing from the manufacturer or his authorized local representative. Where compliance with any special conditions is required as part of the equipment certification these should be particularly noted. When all the information has been gathered, the table format of Figure 9 can be completed in detail, as illustrated in Figure 10. This has been completed for equipment certified to IEC categories, but can easily be translated to North American categories where equipment is certified to these standards. It is generally not possible to mix equipment certified to different (not fully compatible) standards in a single I.S. system.

NOTE – The data shown in Figure 10 is for illustration purposes only and does not indicate anything about the existence or suitability of the particular equipment listed.

Intrinsic Safety Approval Standard:

Associated Apparatus (Safe Area)

Man.	Type Ref.	Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Uo (Voc)	Io (Isc)	Po (Pm)	Co (Ca)	Lo (La)	Lo/Ro (L/R)

I.S. Apparatus (Hazardous Area)

Man.	Type Ref.	Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Temp. Class	Ui (Vmax)	Ii (Imax)	Pi (Pmax)	Ci	Li

Complete System

Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Temp. Class	Uo (Voc)	Io (Isc)	Po (Pm)	Max. C for Cable	Max. L for Cable, or	Max. L/R for Cable

Figure 9– Recommended Table For System Safety Analysis

For a safe system, the following conditions must apply for each piece of apparatus on the intended fieldbus network:

Ui ≥ Uo (Vmax ≥ Voc)
Ii ≥ Io (Imax ≥ Isc)
Pi ≥ Po (Pmax ≥ Pm)

These conditions are clearly met in the example system shown in Figure 10.

Intrinsic Safety Approval Standard: CENELEC EN 50 020 (First Edition, 1977)

Associated Apparatus (Safe Area)

Man.	Type Ref.	Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Uo (Voc)	Io (Isc)	Po (Pm)	Co (Ca)	Lo (La)	Lo/Ro (L/R)
ABC Ltd.	B791	BAS	BAS27	ia	IIC	22.0 V	214 mA	1.19 W	165 nF (IIC) 1.14mF (IIB)	0.35 mH (IIC) 1.04 mH (IIB)	31 mH/Ω (IIC) 93 mH/Ω (IIB)

I.S. (Hazardous Area)

Man.	Type Ref.	Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Temp. Class	Ui (Vmax)	Ii (Imax)	Pi (Pmax)	Ci	Li
ABC Ltd.	FBT1	BAS	BAS45	ia	IIC	T4 at 60° C Amb.	30.0 V	300 mA	1.2 W	0	0
DE Inc.	DP 04	LCIE	L9506	ia	IIC	T4 at 60° C Amb.	25.0 V	300 mA	1.2 W	2 nF	10 mH
FGH GmbH	TT9	PTB	PTB92	ia	IIC	T4 at 60° C Amb.	24.0 V	350 mA	1.6 W	5 nF	10 mH
JJ Inc.	IP956	PTB	PTB97	ia	IIC	T4 at 60° C Amb.	24.0 V	300 mA	1.2 W	5 nF	20 mH
KL Ltd.	Valve type 7P	BAS	BAS72	ia	IIC	T4 at 60° C Amb.	25.0 V	250 mA	1.2 W	3 nF	10 mH

Complete System

Certn. Auth.	Cert. No.	Certn. Cat.	Gas Group	Temp. Class	Uo (Voc)	Io (Isc)	Po (Pm)	Max. C for Cable	Max. L for Cable, or	Max. L/R for Cable
		ia	IIC	T4 at 60° C Amb.	22.0 V	214 mA	1.19 W	150 nF (IIC) 1.12 mF (IIB)	0.30 mH (IIC) 0.99 mH (IIB)	31 mH/Ω (IIC) 93 mH/Ω (IIB)

Figure 10– Example of A System Safety Analysis

The overall system takes the lowest certification category and gas group of any of the apparatus present in the system. In Figure 10 the overall system is Ex ia IIC, as all the individual pieces of equipment listed have been certified to the recommended FOUNDATION I.S. parameters. However, if any of the items of equipment had been certified as category ib, or for use in less hazardous gas groups IIB or IIA then the overall system certification would be limited to these categories. The overall temperature classification of the system is defined by the several pieces of equipment as T4 at up to 60° C ambient temperature.

The interpretation of capacitance and inductance figures will be dealt with in Section 8.

A completed form such as Figure 10, together with a generic diagram of the system layout (known as a *Control Drawing* in North America) similar to that shown in Figure 11, and supporting documentation for each piece of equipment, should be sufficient to enable system certification to be obtained efficiently from any recognized I.S. certification body.

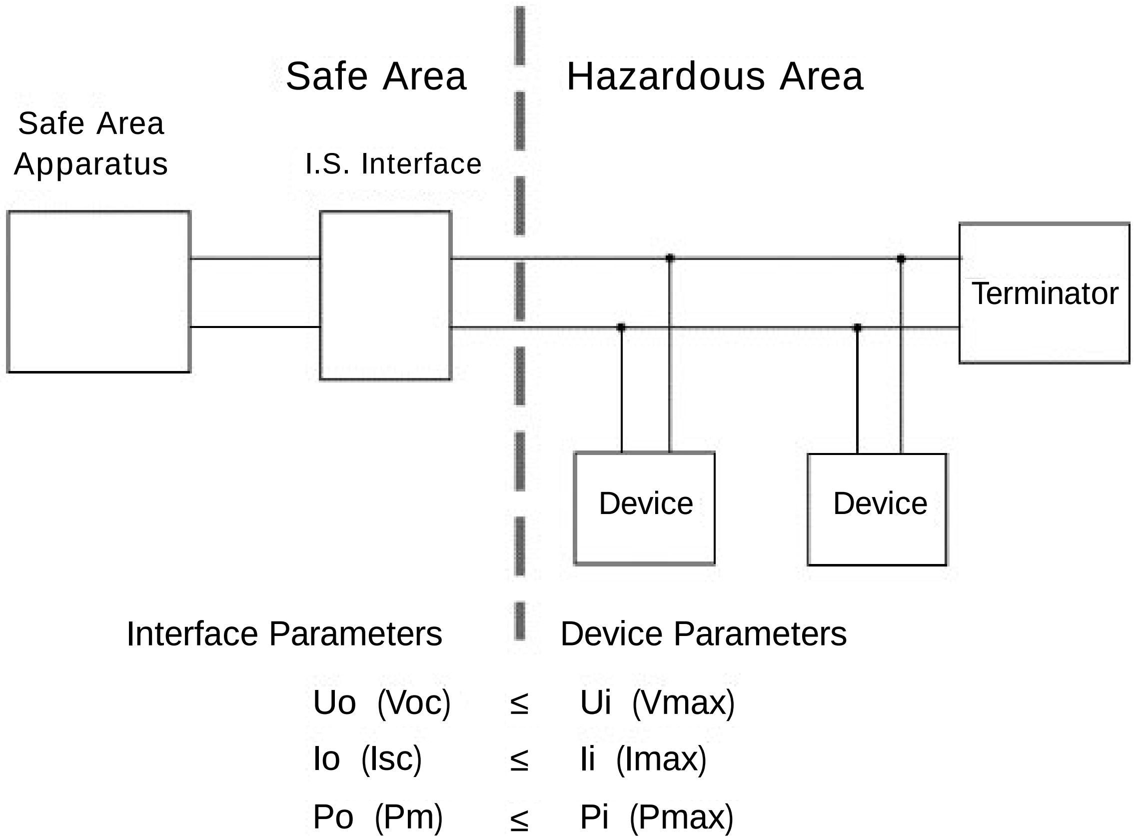


Figure 11– Example Of A System Control Drawing

8.0 SYSTEM CABLES

The structured table of system equipment with its safety parameters, as shown in Figures 9 and 10, also allows the maximum values of permitted capacitance and inductance in the hazardous area fieldbus cables to be determined easily. These parameters are important since they represent sources of stored energy present in the hazardous area that could be released by open circuiting or short circuiting the hazardous area field cables. The certification of an item of associated safe area I.S. apparatus will define maximum permitted values for the capacitance and inductance that may be connected to its hazardous area terminals. These permitted values are different for each gas group, the lowest ones being for IIC (North American Groups A & B) gases.

The maximum capacitance allowed for cables is calculated by subtracting the sum of all residual device capacitances from the capacitance permitted for the safe area associated apparatus. What remains is available for the cables. Similarly, the maximum inductance allowed for cables is calculated by subtracting the sum of all residual device inductances from the inductance permitted for the safe area associated apparatus. For the example system shown in Figure 10, the permitted cable capacitance is calculated for IIC gases as:

$$\text{Ccable max.} = 165\ \text{nF} - (2 + 5 + 5 + 3)\ \text{nF} = 150\ \text{nF}$$

and the permitted inductance as:

$$\text{Lcable max.} = 350\ \text{mH} - (10 + 10 + 20 + 10)\ \text{mH} = 300\ \text{mH}$$

With some types of cable this capacitance value could restrict the length of fieldbus permitted in the hazardous area.

Most practical restrictions arising from the maximum permitted inductance parameter can be overcome by using the allowed alternative L/R ratio parameter (mentioned in Section 4.2). A maximum permitted L/R ratio for cables connected to the hazardous area terminals of a piece of safe area associated apparatus will normally be assigned by the authority that certifies it. This parameter can be complied for cables as an alternative to meeting the permitted inductance figure. For the example IIC system in Figure 10 this means cables having an L/R ratio of up to 31 mH/Ω may be used – which covers most cable constructions that are normally used in I.S. systems. This overcomes any problem with the low allowed inductance figure.

Cable parameters are really only of concern in IIC (North American Groups A & B) applications. The greatly increased permitted maximum cable capacitance and inductance values, shown in Figure 10, for operation in a IIB (North American Group C) gas atmosphere are high enough not to impose any practical limitation on an I.S. fieldbus system. Corresponding values for a IIA (North American Group D) gas atmosphere are even higher. Work is underway within the IEC committee on I.S. to simplify further the assessment of cable parameters in I.S. systems, but it is likely to be several years before any general changes are introduced

Where it is necessary to determine the capacitance and inductance of an already installed cable, a first approach should be to contact the particular cable manufacturer for specified values corresponding to the installed cable type. Often these are not readily available but if they are it provides the easiest solution. If they cannot be obtained this way then the parameters of a known length of the installed cable can be measured using an LCR bridge. The highest capacitance value from measurements made core-to-core and core(s)-to-shield should be used. Alternatively, typical values can be used. Most of the types of cables normally used to interconnect instrument systems have L/R ratios below 25 mH/Ω and capacitances below 200 pF/m.

The maximum allowable length of a hazardous area fieldbus is determined by taking the calculated maximum permitted cable capacitance for the system and gas group (from Figure 10) and dividing this by the measured or estimated capacitance per unit length of the cable being used. For example, with a cable having a capacitance value of 140 pF/m the maximum length of fieldbus in a IIC hazardous area would be limited to 1071 m (3515 ft) - this is derived from 150 nF ÷ 140 pF/m. Using the same cable in a IIB hazardous area, the permitted length increases to 8035 m (26,363 ft).

Most national installation codes require segregation between wires carrying I.S. circuits and other cables within equipment racks or cubicles. Normal good practice is to run the two cable types in separate, clearly labeled cable ducts. Field wiring within a particular multicore cable will also normally be required to carry either all I.S. circuits or all non-I.S. circuits. The two types cannot usually be mixed within a single cable. Practice varies between different countries on whether multicore cables of these two types may be carried within a common cable duct or conduit, and users are advised to check on local practice before installation. It is also normally required to run I.S. circuits through separate field junction boxes from non-I.S. wiring.