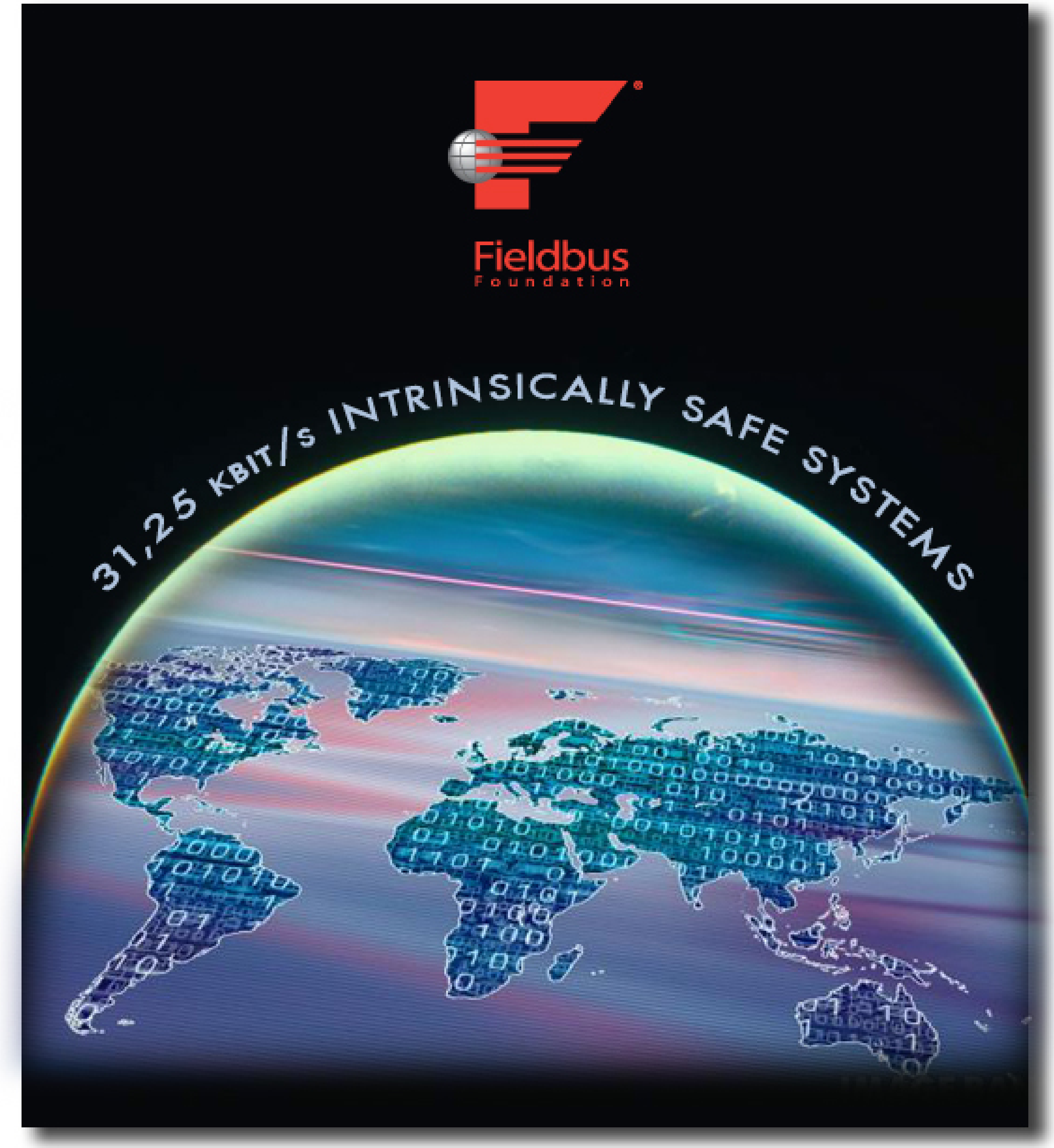
Fieldbus
Foundation
31,25 KBIT/S INTRINSICALLY SAFE SYSTEMS

FOUNDATION Fieldbus Application Guide
31,25 kbit/s Intrinsically Safe Systems
AG-163 Revision 2.0

This application guide has been prepared to aid understanding of the application considerations of FOUNDATION™ Fieldbus. It addresses both developers and users.

The booklet provides an overview of 31,25 kbit/s intrinsically safe Fieldbus Systems, followed by an outline of the specifications of field devices and other related equipment. The updates in revision 2.0 follow the actual state of the art of intrinsically safe fieldbus technology. The booklet provides guidance on certifying equipment and offers advice on sound design and installation practices. Having read the Introduction and Fundamentals of Part 1, the reader will follow the Entity model in Part 2 or alternatively the FISCO model in Part 3. Part 4 deals with fieldbus installation and shows other variants of explosion protected fieldbus systems that include Intrinsic Safety, such as the IIB/IIC split architecture concept and the field bus barrier concept.

The Foundation wishes to acknowledge the active commitment of the following companies without whose dedication this guide would not have been possible:

ABB	Pepperl+Fuchs
Endress+Hauser	Turck
Hawke	Stahl
MTL	VEGA

We express our special thanks to Dr. Ulrich Johannsmeyer from the Physikalisch Technische Bundesanstalt PTB for his contribution to this application guide.

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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Restriction of Liability

In addition to the recommendations included in this document, users are reminded that they must take account of valid international and local standards and regulations that apply in the country of installation.

Caution

The use of this guide may involve hazardous materials, operations or equipment. The guide cannot anticipate all possible applications or address all possible safety issues associated with use in hazardous conditions. The user of this guide must exercise sound professional judgment concerning its use and applicability under the user's particular circumstances and according to their established corporate policies and procedures. The user must also consider the applicability of any governmental regulatory limitations and established safety and health practices before implementing this standard.

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Table of Contents

4. INSTALLATION

1. INTRODUCTION AND FUNDAMENTALS

1.1 Introduction and Scope

This application guide 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 IEC 61158-2: 2003 standard “Fieldbus for use in industrial control systems - Part 2: Physical Layer specification”, type 1. 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.

This revised version includes FISCO (Fieldbus Intrinsically Safe Concept) and other variants of intrinsically safe fieldbus systems.

The intention of this application note is fourfold:

4 Explain the basic concepts of intrinsically safe systems, and their important parameters.

5 Outline the specifications of devices and other related equipment for use in FOUNDATION 31,25 kbit/s intrinsically safe fieldbus systems in hazardous areas.

6 Provide guidance on certifying equipment for use in these systems.

7 Offer advice to developers, installers and users of these systems on good design and installation practice.

1.2 Reference Documents

EN 50 020:
2002, Electrical apparatus for potentially explosive atmospheres - Intrinsic safety 'i'

EN 50281:
1998, Electrical apparatus for use in the presence of combustible dust

FF-816, Section 4.4 Fieldbus Foundation Physical Layer Profile Specification

IEC 60079-10:
2002, Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas

IEC 60079-11:
1999, Electrical apparatus for explosive gas atmospheres - Part 11: Intrinsic safety 'i'"

IEC 60079-14:
2002, Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)

IEC/TS 60079-27:
2002, Electrical apparatus for explosive gas atmospheres - Part 27: Fieldbus intrinsically safe concept (FISCO)

IEC 61158-2:
2003, Fieldbus for use in industrial control systems - Part 2: Physical Layer specification

IEC 61241:
1999, Electrical apparatus for use in the presence of combustible dust

NEC Article 500 – Hazardous (classified) Locations, Classes I, II, and III; Divisions 1 and 2

NEC Article 501 – Class I Locations

PTB-Report PTB-ThEx-10e
"Interconnection of non-linear and linear intrinsically safe circuits"

PTB-Report PTB-W-53e, Investigations into the Intrinsic Safety of fieldbus systems

1.3 Glossary

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Application Guide

area classification
The classification of areas according to the probability that an explosive atmosphere is present.

apparatus group
Gas Group.

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.*

barrier
Intrinsically safe barrier in the sense of this application guide. See I.S.

CENELEC
European Committee for Electrotechnical Standardization

earthing
Connection of an electrical circuit or a shield to earth or ground. In intrinsically safe fieldbus systems the earthing and shielding of a fieldbus installation has to take account of safety, explosion protection, electromagnetic compatibility (EMC) and functional requirements.

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

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

EN
European Standard

encapsulation, Ex m
Explosion protection according to IEC 60079-18 by encapsulation in epoxy resin.

Entity
The Entity model or concept defines one way in which intrinsically safe fieldbus systems are certified.

Ex d
Explosion proof, flame proof

Ex e
Increased safety, protected by Increased safety

Ex i
Intrinsic safety, intrinsically safe

Ex m
Encapsulation, encapsulated

Ex o
Oil filling, enclosed in oil filling

Ex p
Pressurizing, enclosed in pressurized enclosures

Ex q
Powder filling, sand filling, enclosed in powder or sand filling

explosionproof
North American explosion protection that encloses the electrical equipment in a heavy, robust enclosure designed to contain any explosion which occurs. It is similar in principle to the European flameproof technique.

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.

Faraday cage
Room with a closed metallic surface, where any external electrical charge has no influence on anything enclosed within this room. Attributed to the physicist Michael Faraday.

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

FF
Fieldbus Foundation

field device
A sensor, actuator or equipment installed in the field. In this guide it is understood that the field device is attached to the fieldbus.

fieldbus barrier
A device connected on one side to the bus by another protection method than intrinsic safety, by this providing high power to the fieldbus barrier. On the other side a fieldbus barrier provides intrinsically safe loops to connect intrinsically safe field devices.

fieldbus terminator
Resistor-Capacitor network to terminate the bus cable with the appropriate wave resistance.

FISCO
Fieldbus Intrinsically Safe Concept or model according to IEC/TS 60079-27:2002, which defines an alternative way in which intrinsically safe fieldbus systems are certified.

flameproof
Explosion protection according to IEC 60079-1 by enclosing the electrical equipment in a heavy, robust enclosure designed to contain any explosion which occurs. Similar in principle to the North American explosionproof technique.

Gas Group
Hazardous areas are classified by their degree of hazard (Area Classification) and the gases that are present (Gas Group).

grounding
Connection of an electrical circuit or a shield to ground or earth. In intrinsically safe fieldbus systems the grounding and shielding of a fieldbus installation has to take account of safety, explosion protection, electromagnetic compatibility (EMC) and functional requirements.

Hazardous Area
Area containing a potentially flammable or explosive gas or dust.

I.S.
Intrinsic Safety, intrinsically safe

I.S. Barrier

Limits voltage, current and power in an electrical circuit to values according to the Intrinsic Safety.

IEC
International Electrotechnical Commission

ignition test
Experimental ignition testing of intrinsically safe electrical circuits using a spark test apparatus.

ignition curves
Curves of permitted voltage and current for each Gas Group.

ignition temperature
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.

increased safety Ex e
Explosion protection method according to IEC 60079-7 for products in which arcs and sparks do not occur in normal operation nor under fault conditions and in which surface temperatures are controlled below incentive values. Increased Safety is achieved by enhancing insulation values and creepage and clearance distances above those required for normal service.

intrinsic safety, Ex i
Explosion protection method according to IEC 60079-11, which allows the flammable atmosphere to come in contact with the electrical equipment without introducing a potential hazard. The electrical energy available in intrinsically safe 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 gives access to the equipment during live operation. Intrinsic Safety can be applied only to low voltage, low power equipment (up to a few Watts) but is the favored approach for instrumentation.

intrinsically safe
protected by Intrinsic Safety

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

intrinsically safe circuit
Electrical circuit protected by Intrinsic Safety

MAU, medium attachment unit
Component that couples fieldbus circuitry to the fieldbus physical layer.

Maximum external capacitance C_o / residual lumped capacitance C_a
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 / residual lumped capacitance L_a
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 AC or DC), 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 AC or DC), 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 output current I_o
Maximum current (peak AC or DC) 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 AC or DC) in an intrinsically safe circuit, that can appear under open circuit conditions at the connection facilities of the apparatus.

maximum surface temperature
The highest temperature which is attained in operation 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 ignition energy
The energy required to ignite the most easily ignitable mixture of a given gas.

NEC, National Electrical Code
Standards used in North American and Canada

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.

oil Filling, Ex o
Explosion protection according to IEC 60079-6 by oil immersion.

potentially explosive atmosphere
An atmosphere which could become explosive.

powder Filling, sand Filling, Ex q
Explosion protection according to IEC 60079-5 by embedding the electrical circuits in powder or sand.

pressurizing, pressurized enclosures, Ex p
Explosion protection according to IEC 60079-2 by enclosing the electrical equipment in a pressurized enclosure.

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

repeater
Signal booster. May be used to enlarge a network.

residual lumped capacitance C_a / 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.

residual lumped capacitance L_a / 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.

sand Filling, powder Filling, Ex q
Explosion protection according to IEC 60079-5 by embedding the electrical circuits in powder or sand.

segment
A section of a fieldbus that is terminated in its characteristic impedance, meaning a cable and devices installed between a pair of terminators. Segments can be linked by repeaters to form a longer fieldbus.

shielding
Protection of electrical circuits in a cable against electrostatic and electromagnetic interference by means of a metal cover around the wires, which has the effect of a Faraday cage.

shunt zener diode barrier

zener diode barrier

simple apparatus
Electrical component or combination of components of simple construction with well defined electrical parameters, which is compatible with the intrinsic safety.

splice
Spur with length less than 1 m.

spur
Cable that connects a device to the trunk.

trunk
The longest cable path between any two devices on the fieldbus network. This is the main fieldbus communication cable.

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

zener diode barrier
Assembly of components that limit the voltage, current and power in an electrical circuit to values according to the requirements of Intrinsic Safety. The barrier diverts excessive voltage or current surges or overloads safely to the system earth or ground, before they can cause ignition of the hazardous atmosphere. A safety earth or ground is required.

1.4 Models of Intrinsic Safety – ENTITY and FISCO

Intrinsic Safety (I.S.) is a method of ensuring the safety of electrical equipment where flammable materials are present. 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. Intrinsic Safety allows the flammable atmosphere to come in contact with the electrical equipment without introducing a potential hazard. This is possible because the system 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.

In conventional non-fieldbus systems, typically only two devices are connected together; the intrinsically safe apparatus in the hazardous area and the associated apparatus in the safe area, for example, a transmitter and a power supply. In standard applications, an intrinsically safe 4 to 20 mA signal provides enough electrical power to supply the transmitter in the field.

In a fieldbus system a number of devices are connected together. The IEC 61158-2: 2000 Physical Layer Standard defines that several field devices could be supplied from one fieldbus power supply via one bus line. To achieve Intrinsic Safety, voltage, current and power on the bus cable have to be limited to a safe value. The intrinsically safe apparatus and the associated apparatus have to be designed, certified and applied taking into account the requirements for Intrinsic Safety.

The ENTITY concept defined the way in which intrinsically safe fieldbus systems have been certified. The new development of FISCO – Fieldbus Intrinsically Safe Concept – defines special requirements for an intrinsically safe fieldbus system with a physical layer according to IEC 61158-2: 2000. FISCO leads to easier planning, application and documentation of intrinsically safe bus circuits. In addition, higher supply current is permitted on the intrinsically safe bus than with conventional ENTITY circuits.

For a description of intrinsically safe fieldbus systems according to the ENTITY model refer to sections 2 and 4.

For a description of intrinsically safe fieldbus systems according to the FISCO model refer to sections 3 and 4.

2. ENTITY MODEL

2.1 Principles of Intrinsic Safety Applied to FOUNDATION Fieldbus – ENTITY

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 / Explosionproof* 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 *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.

2.1.1 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.

There are two different systems in use for area classification. These are the *Zone* classification system, as defined by IEC 60079-10, and the *Division* classification system, as recognised by the North American and Canadian National Electrical Codes (NEC). The European CENELEC standards follow the IEC approach. In addition, Zone classifications are also recognised in North America and Canada, as an alternative to Division classifications. In fact, new installations in Canada must be classified according to the Zone system. European countries follow the IEC system, but some non-European countries may follow the Division system or in some cases both systems.

The two systems are summarised in Table 2.1.1.1. The equivalence is not exact, and any designer, installer or user of equipment should make himself familiar with the detailed requirements of the standards and codes of practice for the country of use. Inside Europe the dust hazards are standardized (IEC 61241, EN 50281-1-2). In any case potential users are advised to consult authorities in the country where the equipment will be installed.

Table 2.1.1.1: Area Classifications

IEC & CENELEC	NEC (USA & Canada)
Zone 0: Explosive gas-air mixture continuously present, or present for long periods. Common understanding: more than 1000 h/a. **Zone 1:** Explosive gas-air mixture is likely to occur in normal operation. Common understanding: 10 to 1000 h/a.	**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. Common understanding: less than 10 h/a.	**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 independent faults introduced, as indicated in Table 2.1.1.2.

Table 2.1.1.2: I.S. Equipment Categories

IEC & CENELEC	USA & Canada
Ex ia: Explosion protection maintained with up to two faults in components upon which the safety depends. I.S. apparatus may be located in, and associated apparatus may be connected into Zone 0, 1 and 2 hazardous areas. **Ex ib:** Explosion protection maintained with up to one fault in components upon which the safety depends. 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 faults in components upon which the safety depends. 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 2.1.1.3.

Table 2.1.1.3: 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. ***Surface industries*** **Group IIC:** acetylene more **Group IIC:** hydrogen easily **Group IIB:** ethylene ignited **Group IIA:** propane ***Dusts*** metal carbon flour, starch fibers, flyings, grain ***Mining industry*** **Group I:** methane (firedamp)	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*** **Class I, Group A:** acetylene more **Class I, Group B:** hydrogen easily **Class I, Group C:** ethylene ignited **Class I, Group D:** propane **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* **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 ºC unless otherwise stated). There is international agreement on temperature classifications given in Table 2.1.1.4. 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 μJ) but requires a surface temperature in excess of 560 ºC 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.

Table 2.1.1.4: Temperature Classifications

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

2.1.2 Ignition Curves for ENTITY Model

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 IEC 60079-11) are shown in Figure 2.1.2.1. A 1,5 factor of safety has to be applied to the currents shown in these curves when they are applied in practice.

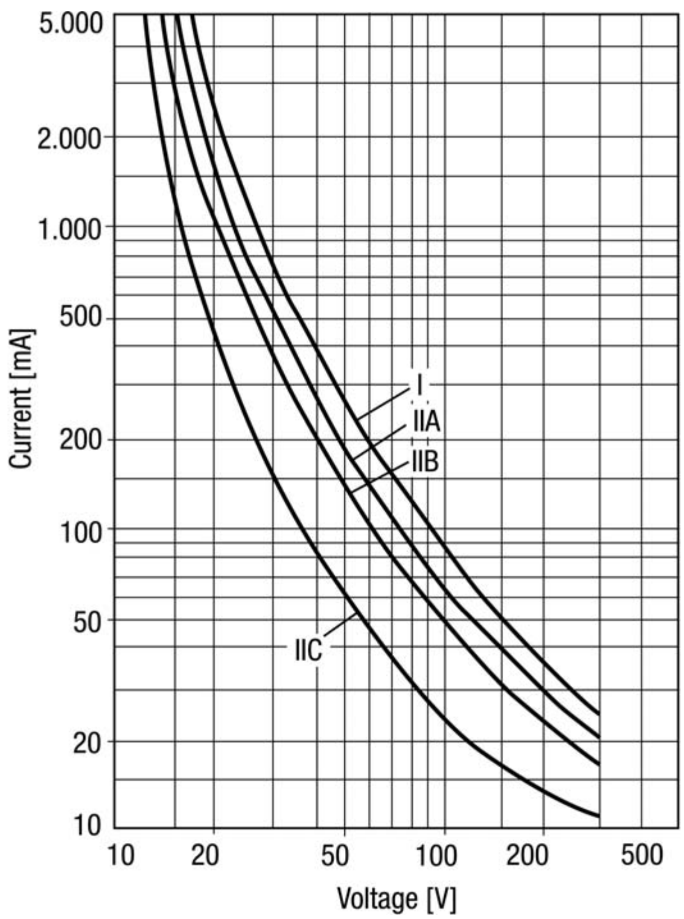


Figure 2.1.2.1: Ignition Curves

In circuits containing inductance and/or capacitance additional curves have to be applied. The curves of Figure 2.1.2.1 are applicable only for linear circuits (i.e. those in which current-limiting is achieved by means of a resistor), as shown in Figure 2.1.2.2. In practice non-linear circuits for voltage and current limitation are also used, as shown in Figures 2.1.2.3 and 2.1.2.4. In this case the curves in Figure 2.1.2.1 must not be used. There are several possible ways to determine the permitted values of voltage and current for a given circuit. These are for example computer simulation or ignition tests. It is well-advised to contact the local certification authority for the accepted method of specifying the limiting values.

Note that for fieldbus systems conforming to the Entity model, the power supply must be category Ex ia, meaning that it must comply with the linear or trapezoidal output characteristics. Electronically limited Ex ib power supplies with a rectangular output are not permitted.

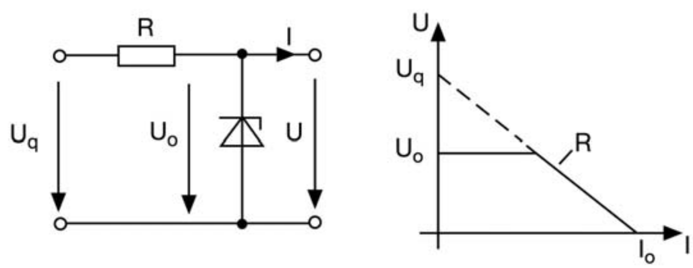


Figure 2.1.2.2: Linear Limitation

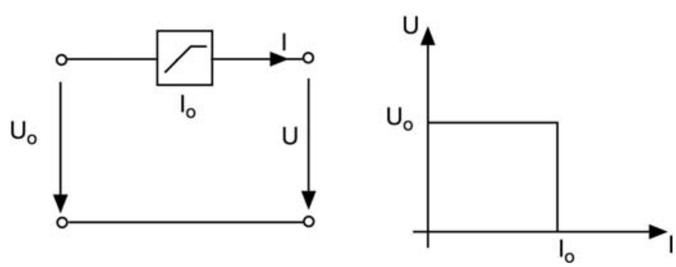


Figure 2.1.2.3: Trapezoidal Limitation

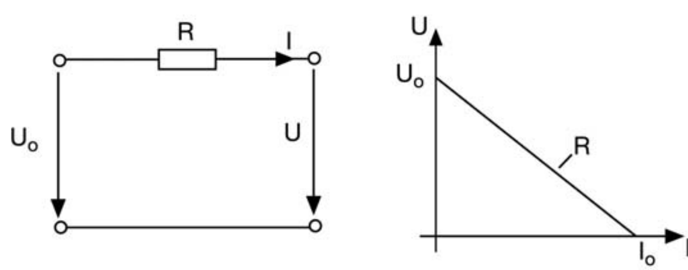


Figure 2.1.2.4: Rectangular Limitation

These factors typically restrict the operating region to below about 30 V and 300 mA, as shown in Figure 2.1.2.5 (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.

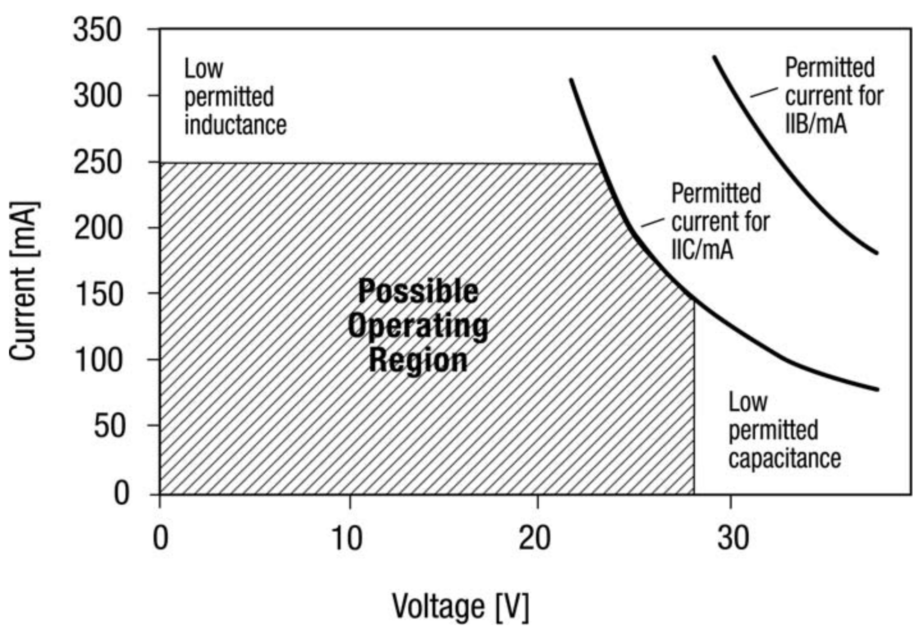


Figure 2.1.2.5: Practical Operating Region

2.2 Certifying Equipment for Installation in Hazardous Areas – ENTITY

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, as defined by clauses 11 and 22 of Physical Layer Standard IEC 61158-2: 2003, defines profiles for communicating fieldbus device types. Of these, four are specified as suitable for connection to an I.S. fieldbus within a hazardous area following the Entity model. These profile types, with their FOUNDATION type designations, are:

Type 111 — standard-power signaling, bus powered, Entity model I.S.

Type 112 — standard-power signaling, separately powered, Entity model I.S.

Type 121 — low-power signaling, bus powered, Entity model I.S.

Type 122 — low-power signaling, separately powered, Entity model I.S.

These types are distinguished from the remaining ones as being suited for hazardous area use following the Entity model 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 I.S. approach is inherently a system concept: Following IEC 61158-2 there is only one source of possible energy into the flammable atmosphere, which is the power supply. All other devices and accessory equipment must not put energy onto the bus.

To achieve compatible device certifications in an Entity certified fieldbus system, the Physical Layer Profile Specification (FF-816, Section 4.4) recommends minimum input voltage, current and power levels with which hazardous area devices should be certified to operate. These are listed in Table 2.2.1. An "*ia*" certification (IEC designation, see Table 2.1.1.2) 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 2.2.1 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 internal capacitance and inductance parameters also shown in Table 2.2.1 may not be immediately apparent, but these are explained more fully in Section 2.4.

Table 2.2.1: 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 max.
Device residual inductance	20 μH max.
I.S. classification	Ex ia IIC (gas groups A & B) T4

Individual manufacturers can choose to certify their field devices at figures for voltage, current or power higher than the minimum levels shown. For example, a manufacturer may wish to certify apparatus in such a way that it is compliant with both the Entity and FISCO concepts. In this case, the manufacturer will wish to choose a higher value of the device approval current and power and reduce L to the value specified for FISCO systems.

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) and any combination of these four types of bus powered and separately powered units.

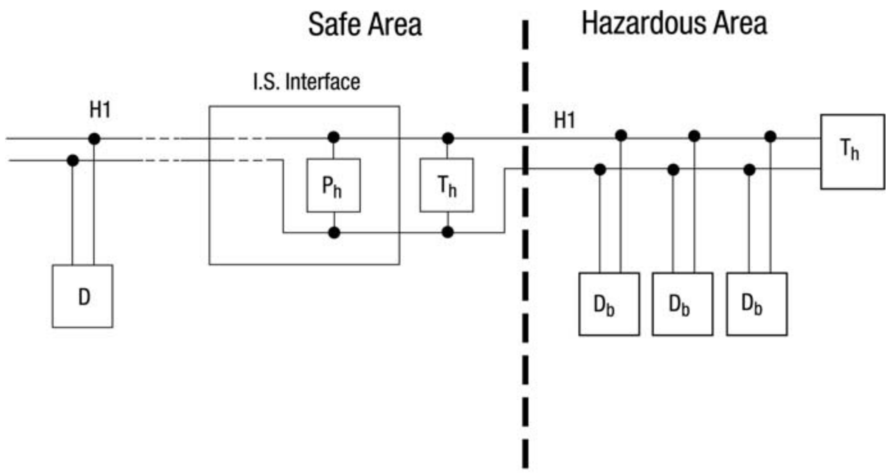
Any of the device profiles specified for hazardous operation can as an alternative be connected to a non-I.S. segment of a fieldbus, or to a totally safe area fieldbus, operating to FOUNDATION specifications. The only requirement is that the bus must be powered (even for separately powered *Types 112*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

NOTE: 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.

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 2.2.1.

The device MAU performs the dual function of regulating power from the fieldbus to the device and signaling onto the bus.



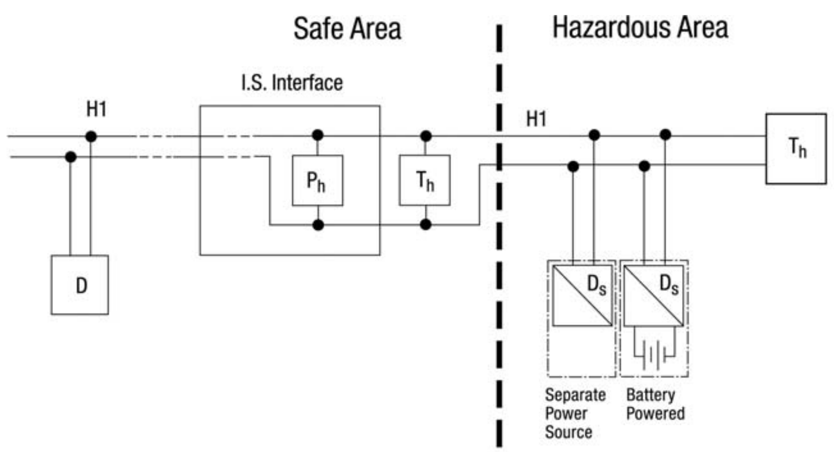
D = Device (any profile type)
P_h = Fieldbus power supply with I.S. output circuit
D_b = I.S. certified bus-powered device *(Type 111 or 121)*
T_h = I.S. certified terminator

Figure 2.2.1: I.S. Fieldbus with Bus-Powered Devices

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. Examples of such a device are 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, could utilise another form of explosion protection, but the bus terminals must remain passive, i.e. the terminals shall not be a source of energy to the system except for a leakage current not greater than 50 µA. The bus terminals must be galvanically isolated from the additional sources of electrical power. An example system is shown in Figure 2.2.2.

The MAU within the device performs in this case only the function of signaling onto the bus. 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 2.2.1) and operating characteristics are independent of the powering arrangements.



D = Device (any profile type)
P_h = Fieldbus power supply with I.S. output circuit
D_s = I.S. certified separately-powered device *(Type 112 or 122)*
T_h = FISCO 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 2.2.2: I.S. Fieldbus with Bus-Powered Devices

Fieldbus Terminators

The FOUNDATION Physical Layer profile defines the recommended I.S. parameters for a terminator like in Figure 2.2.3 certified according to the Entity Concept for installation in a hazardous area, as listed in Table 2.2.2. All FOUNDATION fieldbus segments require two bus terminators to be present. For an I.S. fieldbus, in common applications at least one of these will be mounted in the hazardous area (see Figures 2.2.1 and 2.2.2). Any terminator designed to be connected in an intrinsically safe circuit 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 for devices and other equipment and, provided these are complied with, these will allow 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 2.4 below.

Table 2.2.2: Recommended I.S. Parameters for Hazardous Area Mounted Terminator

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.

The FOUNDATION terminator profile is derived from Clause 11.7.5 of the IEC/61158-2:2000 Fieldbus standard, for reasons explained in Section 2.3 below. 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.

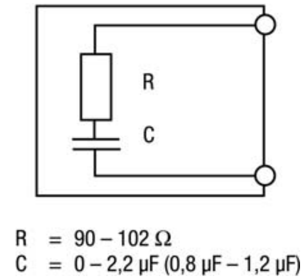


Figure 2.2.3: I.S. Fieldbus Terminator

2.3 Certifying Associated Equipment – ENTITY

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. It may be located in a safe (non-hazardous) area or, if protected according to a recognised method of protection, may also be in the hazardous 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 2.3.1.

Table 2.3.1: Recommended I.S. Parameters for Fieldbus I.S. Power Sources

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.

NOTE: There are technologies to operate the trunk with IIB protection and connect the field devices that need to be IIC protected by definition via special arrangements.

The selection of the open circuit output voltage and short circuit output current is determined by:

- the Intrinsic Safety Ignition Curves,
- the number of field devices,
- the minimum operating voltage specified for field devices (9 V),
- the cable length and resistance,

In addition the matched output power, both the inductance and the capacitance of the whole system have to be considered.

The current available to hazardous area devices on an I.S. fieldbus is related to the I.S. certification voltage U_o of the bus power supply, because of the relationship between voltage and current in the ignition curves. A lower voltage leads to a higher current and vice versa. However a higher current on the bus results in a higher voltage drop because of the resistance of the bus cable. Therefore the limits given by the Intrinsic Safety and the function will lead to an optimal point of operation.

The relationship between bus length (L), current and voltage can been seen for a special circuitry in the following example:

The example is based on the following assumptions:

1. Type "A" cable characteristics, from the IEC 61158-2 Physical Layer fieldbus standard. This cable is nominal 0,8 mm^2 (#18 AWG) with 44 Ω/km per loop (R_c). Results will be different with other wire sizes. The influence of temperature upon the cable resistance is not considered.
2. The diagram refers to functional supply voltages U_f, currents I_f, powers P_f and resistances R_f. In a practical power supply the certified voltage U_o, current I_o and power P_o as well as the value for the current limiting resistance for Intrinsic Safety R will be higher than the functional values.
3. All devices located at the far end of the bus and operating with a minimum device voltage of 9 V.
4. The spurs are considered to have a length of 30 m and lead to an additional voltage drop of < 30 mV, when carrying 20 mA, which is small enough to be ignored.
5. Results will be different for other circuitries.
6. A practical system may comprise equipment with operating characteristics different from these assumptions.

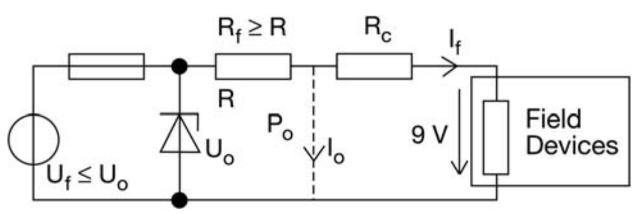


Figure 2.3.1: Circuitry to supply an Intrinsically Safe Fieldbus Trunk

$$L = \frac{U_f - R_f * I_f - 9V}{R_C * I_f}$$

Table 2.3.2: Example – Functional and I.S. Values

Unit	Example 1	Example 2	Example 3	
U_f (V)	12,80	15,00	19,00	Functional Values
I_f max (mA)	167,0	169,00	154,00	
P_f max (W)	0,54	0,64	0,73	
R_f (Ω)	78,50	88,50	123,40	
U_o (V)	15,80	18,00	22,00	I.S. Values
I_o (W)	248,00	244,00	214,00	
P_o (W)	0,98	1,10	1,18	
R / Ω	63,70	73,80	102,80	
R_o (Ω/km)	44,00	44,00	44,00	Cable

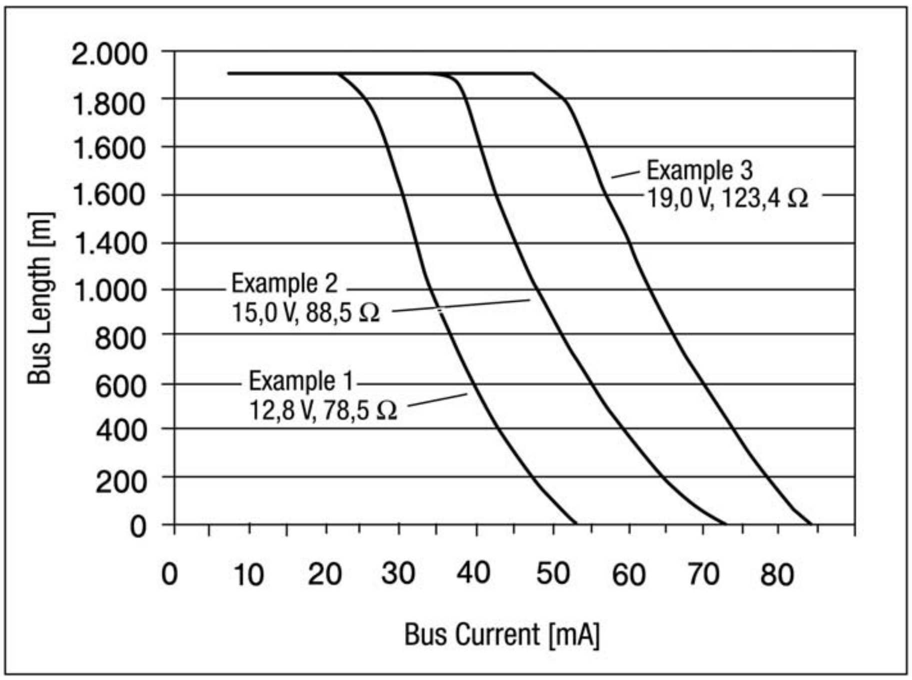


Figure 2.3.2: Variation of possible Bus length with total Device Current on Bus for different Supply Voltages

Fieldbus Power Supplies

The FOUNDATION Physical Layer Profile Specification includes a *Type 133* I.S. power supply. This unit is specified, including recommended I.S. parameters as given in Table 2.3.1, such that it can be connected directly to an I.S. fieldus 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 hazarous area mounted devices, see Section below). Depending on additional explosion protection methods applied to the Fieldbus power supply and the Fieldbus terminator, the power supply and the terminator may be installed in the safe (non hazardous) area or inside the hazardous area. 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. The full data regarding the safety characteristics 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 fieldbus power supplies defined in the FOUNDATION Physical Layer Profile Specification is chosen to conform with the requirements of Clause 22 the IEC 61158-2 Fieldbus standard rather than the characteristic defined by clause 11 of the 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 Clause 22 of the IEC 61158-2 Fieldbus 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:

1. Devices whose average current draw remains constant between receiving and transmitting (These may be a *Type 111*or *112*, device);
2. Devices whose current draw increases when they are transmitting (These may 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.

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 area 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 or ground is therefore a primary safety requirement when using a barrier-protected fieldbus in a hazardous area. Most national installation codes require that the earth (ground) cable has a DC resistance of <1 Ω between the barrier earth (ground) terminal and the system safety earth or ground (normally the connection to the neutral point of the power distribution system). An I.S. barrier intended for operation with a safety earth or ground must never be operated without the safety earth or ground properly installed and connected.

The IEC 61158-2 standard requires that the fieldbus is operated in a balanced mode with respect to earth or ground. 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.

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 2.3.3 are simply examples on a typical system, other measured values may be equally valid with a particular manufacturer's equipment.

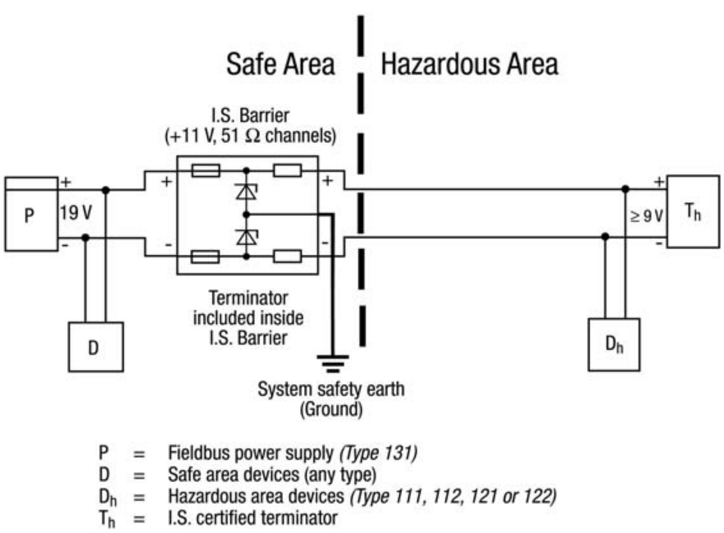


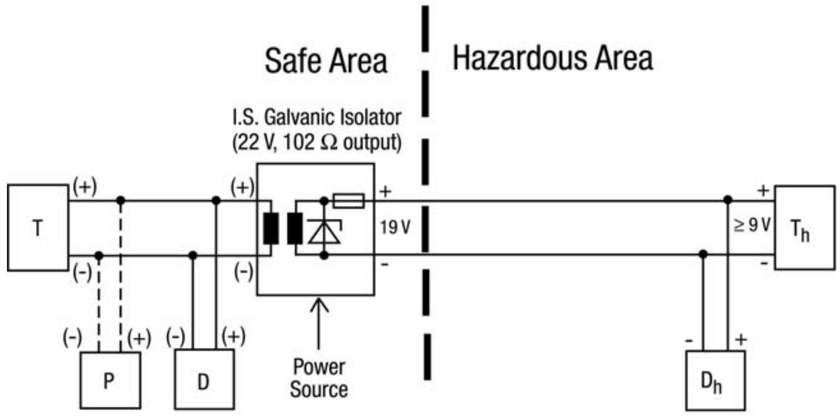
Figure 2.3.3: Fieldbus with Earthed (grounded) I.S. barrier

The I.S. barrier represents a significant lumped impedance in each fieldbus line (perhaps up to 80 Ω, depending on its characteristics). The IEC 61158-2 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 61158-2 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 61158-2 Physical Layer Standard.

I.S. Galvanic Isolators

The FOUNDATION Physical Layer Profile Specification (Section 16.4) 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 or ground connection to the unit is therefore not required, since surge currents are no longer diverted to earth or ground. For functional purposes it is however still necessary to provide a system earth or ground 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 methods).

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 or ground, making it easier to ensure the fieldbus is operated in a balanced mode with respect to earth or ground. 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 signalling 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.



T = Terminator
P = Fieldbus power supply (if required)
D = Safe area devices (any Type, device Types 114 and 124 do not require a power bus)
D_h = Hazardous area devices *(Type 111, 112, 121 or 122)*
T_h = I.S. certified terminator

Note: The values given in the figure are an example.

Figure 2.3.4: Fieldbus with I.S. galvanic isolator

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 2.3.4. 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.

2.4 System Cables – ENTITY

The structured table of system equipment with its safety parameters, as shown in Figures 2.5.1 and 2.5.2, 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 or short circuiting the hazardous area field cables. The certification of an item of associated 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 internal device capacitances from the capacitance permitted for the associated apparatus. What remains is available for the cables. Similarly, the maximum inductance allowed for cables is calculated by subtracting the sum of all internal device inductances from the inductance permitted for the associated apparatus. For the example system shown in Figure 2.5.1, the permitted cable capacitance is calculated for IIC gases as

C_C max. = 165 nF -(2 + 5 + 5 + 3) nF
= 150 nF

and the permitted inductance as

L_C max. = 0,35 mH - (10+10+20+10) µH
= 0,3 mH

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

The cables must be specified for the operating temperatures in the plant. According to the specification (IEC 61158-2), twisted pair cables with overall shield are prescribed. The cable and the cable length must fulfil the functional requirements of IEC 61158-2 specification and the requirements of Intrinsic Safety.

Where the cable parameters are not known, they may be determined in accordance with the Annex C of IEC 60079-14. The capacitance of the cable is calculated as

$C_C = C_{Conductor/Conductor} + 0,5 * C_{Conductor/Shield}$

if the bus is isolated from the earthed or grounded screen

$C_C = C_{Conductor/Conductor} + C_{Conductor/Shield}$

if the screen is connected with one pole of the supply unit

where $C_{Conductor/Conductor}$ is the capacitance between both cable wires and $C_{Conductor/Shield}$ is the capacitance between cable wire and shield.

In the example above using a cable with the bus isolated from the earthed or grounded screen:

48,2 Ω/km, 0,62 mH/km, 102,3 nF/km

$C_{Conductor/Conductor}$ = 56,4 nF/km

$C_{Conductor/Shield}$ = 91,8 nF/km

This results in

Capacitance per km = 102,3 nF/km

Capacitance for a cable of 400 m length
= 40,9 nF

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 2.1 above). A maximum permitted L/R ratio for cables connected to the hazardous area terminals of a piece of associated apparatus will normally be assigned by the authority that certifies it. This parameter can be complied with for cables as an alternative to meeting the permitted inductance figure. For the example IIC system in Figure 2.5.1 this means cables having an L/R ratio of up to 31 μH/Ω may be used — which covers most cable constructions that are normally used in I.S. systems. This over-comes any problem with the low allowed inductance figure.

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 2.5.1) and dividing this by the capacitance per unit length of the cable being used. For example, with a cable having a capacitance value of 102,3 nF/km the maximum length of fieldbus in a IIC hazardous area would be limited to 1,466 km (4.810 ft) - this is derived from 150 nF ÷ 102,3 nF/km.

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.

2.5 Analyzing the Safety of an I.S. FOUNDATION Fieldbus System – ENTITY

Requirements for formal third-party certification of a planned fieldbus system before installation vary between different countries. The Entity Concept 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. 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 2.5.1. 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
- Internal device capacitance, C_i
- Internal 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 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), if specified

NOTES:

1. *The symbols normally used for these parameters are shown here (and in Figures 2.5.1 and 2.5.2) in IEC terminology. Where the equivalent North American symbol is different*

this is shown in parentheses behind 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 in Figure 2.5.1 can be completed in detail. This has been completed for equipment certified to IEC categories, but can easily be translated to North American categories. 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 2.5.1 is for illustration purposes only and does not indicate anything about the existence or suitability of the particular equipment listed.

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

U_i	$\geq$	U_o	(Vmax$\geq$	Voc)
I_i	$\geq$	I_o	(Imax $\geq$	Isc)
P_i	$\geq$	P_o	(Pmax$\geq$	Pm)

These conditions are clearly met in the example system shown in Figure 2.5.1.

Intrinsic Safety Approval Standard: CENELEC EN 50 020

Associated Apparatus (Safe Area)

Func-tion	Type Ref.	Man.	Cert. No.	Classi-fication	Uo (Voc)	Io (Isc)	Po (Pm)	Co (Ca)	Lo (La)	Lo/Ro (L/R)
I.S. Inter-face	B791	ABC Ltd.	BASEx 02ATE X9999	[EEx ia] IIC	22,0 V	214 mA	1,19 W	165 nF (IIC) *)	0,35 mH (IIC) *)	31 µH/Ω (IIC) *)

I.S. Apparatus (Hazardous Area)

Func-tion	Type Ref.	Man.	Cert. No.	Classi-fication	Ui (Vmax)	Ii (Imax)	Pi (Pmax)	Ci	Li
Fieldbus Termi-nator	TRM2	Finito	CESI01 ATEX99 99	EEx ia IIC T4	30,0 V	300 mA	1,2 W	0	0
Pre-ssure Trans-mitter	DP 04	Wolf-boro	L9506	EEx ia IIC T4	25,0 V	300 mA	1,2 W	2 nF	10 µH
Level Probe	TT9	F+I GmbH	PTB 02 ATEX 9999	EEx ia IIC T4	24,0 V	350 mA	1,6 W	5 nF	10 µH
Temperature Transmitter	IP956	Money-bell Inc.	PTB 97 C9999	EEx ia IIC T4	24,0 V	300 mA	1,2 W	5 nF	20 µH
Sole-noid Valve	Valve type 7P	Tap Plc	BASEx 01ATEX 9999	EEx ia IIC T4	25,0 V	250 mA	1,2 W	3 nF	10 µH

Fieldbus Cable

Type Ref.	Man.	Max. Opera-ting Temp.	Length	Capacitance per km **)	Inductance per km	C_C **)	L_C
Bus02	Hooku p Inc	105 °C	400 m	102,3 nF/km	0,62 mH/km	40,9 nF	0,248 mH

Complete System

Classification	Uo (Voc)	Io (Isc)	Po (Pm)	Max. C for Cable	Max. L for Cable	Alternatively max. L/R for Cable
EEx ia IIC T4	22,0 V	214 mA	1,19 W	150 nF (IIC) *)	0,30 mH (IIC) *)	31 µH/Ω (IIC) *)

The system is intrinsically safe.

*NOTES: *) If the system is to be installed in a IIB or IIA Gas Group, then the applicable values for permitted capacitance and inductance in that Gas Group may be used.*

***) Calculation of the capacitance see 2.4*

Figure 2.5.1: 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 2.5.1 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 60º C ambient temperature.

The interpretation of capacitance and inductance figures has been dealt with in Section 2.4.

A completed form such as Figure 2.5.1, together with a generic diagram of the system layout (known as a *Control Drawing* in North America) similar to that shown in Figure 2.5.2, 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.

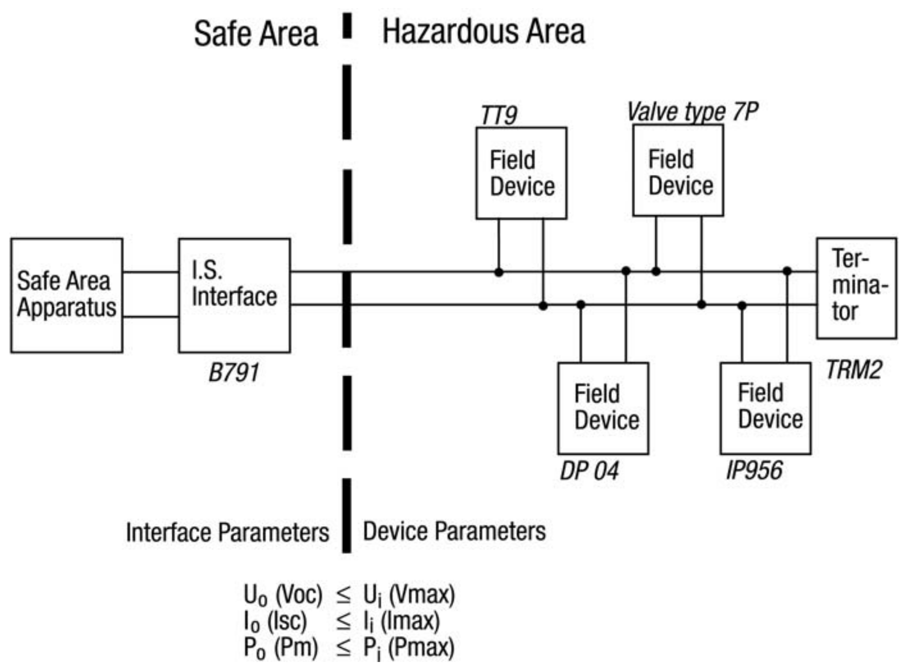


Figure 2.5.2: Example of a System Control Drawing

3. FISCO MODEL

3.1 Principles of Intrinsic Safety Applied to FOUNDATION FIELDBUS – FISCO

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 / Explosion proof* 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 *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.

3.1.1 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.

There are two different systems in use for area classification. These are the *Zone* classification system, as defined by IEC 60079-10, and the *Division* classification system, as recognised by the North American and Canadian National Electrical Codes (NEC). The European CENELEC standards follow the IEC approach. In addition, Zone classifications are also recognised in North America and Canada, as an alternative to Division classifications. In fact, new installations in Canada must be classified according to the Zone system. European countries follow the IEC system, but some non-European countries may follow the Division system or in some cases both systems.

The two systems are summarised in 3.1.1.1. The equivalence is not exact, and any designer, installer or user of equipment should make himself familiar with the detailed requirements of the standards and codes of practice for the country of use. Inside Europe the dust hazards are standardized (IEC 61241, EN 50281-1-2). In any case potential users are advised to consult authorities in the country where the equipment will be installed.

Table 3.1.1.1: Area Classifications

IEC & CENELEC	NEC (USA & Canada)
Zone 0: Explosive gas-air mixture continuously present, or present for long periods. Common understanding: more than 1000 h/a. Zone 1: Explosive gas-air mixture is likely to occur in normal operation. Common understanding: 10 to 1000 h/a.	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. Common understanding: less than 10 h/a.	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 independent faults introduced, as indicated in Table 3.1.1.2.

Table 3.1.1.2: I.S. Equipment Categories

IEC & CENELEC	USA & Canada
Ex ia: Explosion protection maintained with up to two faults in components upon which the safety depends. I.S. apparatus may be located in, and associated apparatus may be connected into Zone 0, 1 and 2 hazardous areas. Ex ib: Explosion protection maintained with up to one fault in components upon which the safety depends. 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 faults in components upon which the safety depends. 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. Again, there is a different classification of gases between IEC and North America, as shown in 3.1.1.3. All I.S. equipment is designed and certified as being safe for a particular group of gases. With the FISCO model, all field devices must be certified for installation in IIC (North American Groups A-D) gases, but power supplies may be certified for connection into IIC (Groups A-D) or IIB (Groups C,D).

Table 3.1.1.3: 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. *Surface industries* Group IIC: acetylene — more Group IIC: hydrogen — easily Group IIB: ethylene — ignited Group IIA: propane *Dusts* metal carbon flour, starch fibers, flyings, grain *Mining industry* Group I: methane (firedamp)	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* Class I, Group A: acetylene — more Class I, Group B: hydrogen — easily Class I, Group C: ethylene — ignited Class I, Group D: propane 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* 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 ºC unless otherwise stated). There is international agreement on temperature classifications given in Table 3.1.1.4. 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 μJ) but requires a surface temperature in excess of 560 ºC 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.

Table 3.1.1.4: Temperature Classifications

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

3.1.2 Ignition Curves for FISCO

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. The type of ignition curves that are used depends on the method that is used for current limitation in the power supply. Typical curves for resistor limited power supplies (taken from IEC 60079-11:1999) are shown in Figure 3.1.2.1. A 1,5 factor of safety has to be applied to the currents shown in these curves when they are applied in practice.

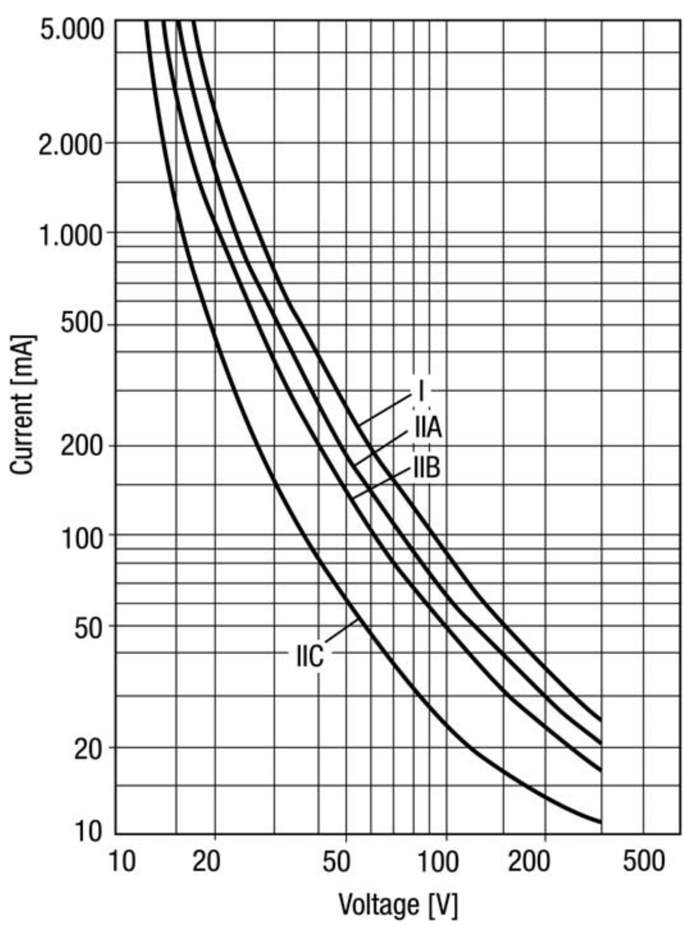


Figure 3.1.2.1: Ignition Curves

In circuits containing inductance and/or capacitance, additional curves have to be applied. The curves of Figure 3.1.2.1 are applicable only for linear circuits (i.e. those in which current-limiting is achieved by means of a resistor), as shown in Figure 3.1.2.2. In practice, non-linear circuits for voltage and current limitation are also used, as shown in Figures 3.1.2.3 and 3.1.2.4. In this case the curves in Figure 3.1.2.1 must not be used. There are several possible ways to determine the permitted values of voltage and current for a given circuit. These are for example computer simulation or ignition tests.

Note that for fieldbus systems conforming to the FISCO model, the power supply may be category Ex ia, meaning that it has linear or trapezoidal output characteristics, or Ex ib, having an electronically limited output with rectangular characteristic.

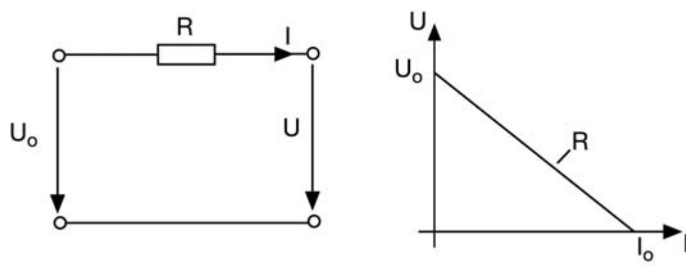


Figure 3.1.2.2: Linear Limitation

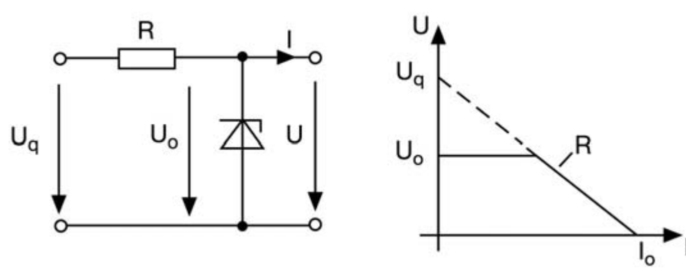


Figure 3.1.2.3: Trapezoidal Limitation

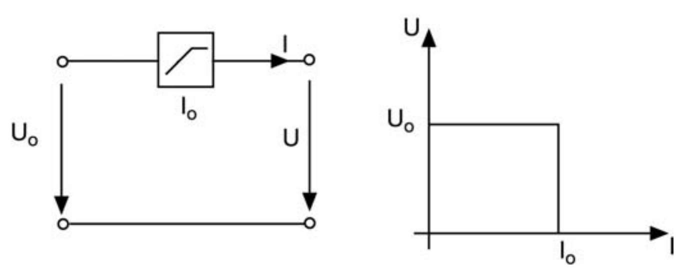


Figure 3.1.2.4: Rectangular Limitation

Prompted by manufacturers of fieldbus devices PTB (Physikalisch-Technische Bundesanstalt, Braunschweig, Germany) investigated the ignition behaviour of fieldbus systems based on the IEC 61158-2 physical layer. These investigations are documented in the PTB Report PTB-W-53e. The most important result of this study is, that using only one active power supply on the bus line under certain conditions the cable parameters and internal capacitances and inductances of the devices have no negative influence on the intrinsic safety of the system and therefore can be neglected. They called this model FISCO "Fieldbus Intrinsically Safe COncept". There is an IEC standard, which describes this concept: IEC/TS 60079-27: 2002 "Electrical apparatus for explosive gas atmospheres: Fieldbus intrinsically safe concept (FISCO)" (additional information: PTB-Report PTB-W-53e "Investigations into the Intrinsic Safety of fieldbus systems", PTB-Report PTB-ThEx-10e "Interconnection of non-linear and linear intrinsically safe circuits").

The following conditions must be met for a FISCO compliant FF-System:

Table 3.1.2.1: Specified Values for FISCO

	Gas Group IIB	Gas Group IIC
U_o	14...17,5 V	
I_o	In accordance to IEC 60079-11 but not exceeding 380 mA	
P_o	In accordance to IEC 60079-11 but not exceeding 5,32 W	
U_i	17,5 V min.	
I_i	380 mA min.	
P_i	5,32 W min.	
Cable length, trunk	1.900 m max. *(limited by FF specification)*	1.000 m max.
Cable length, spur	30 m max. [Note 1]	
Cable length, splice	1 m max.	
Loop resistance R	15...150 Ω/km	
Loop inductance L	0,4...1 mH/km	
Loop Capacitance C	80...200 nF/km [Note 1]	
Internal capacitance of field devices	5 nF max.	
Internal inductance of field devices	10 µH max.	
Terminator	90...102 Ω *0,8µF...1,2µF (limited by FF specification)*	
Maximum number of field devices	32	

Note: At the time of writing, these may change to 60 m spur length and 45…200 nF/km capacitance

3.2 Certifying Equipment for Installation in Hazardous Areas – FISCO

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. 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.

The FISCO approach is inherently a system concept: There is only one source of possible energy into the flammable atmosphere, which is the power supply. All other devices and accessory equipment must not put energy onto the bus.

The IEC/TS 60079-27: 2002 Technical Specification states minimum input voltage, current and power levels with which FISCO field devices and accessories must be certified. These are listed in Table 3.2.1.

Also included in Table 3.2.1 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 3.2.1 may not be immediately apparent, but these are explained more fully in Section 3.5 below.

Table 3.2.1: I.S. Parameters For Hazardous Area Devices with FISCO certification

Parameter	Required Value
Device approval voltage	17,5 V min.
Device approval current	380 mA min.
Device input power	5,32 W min.
Device residual capacitance	5 nF max.
Device residual inductance	10 µH max.
I.S. classification	Ex ia IIC or Ex ib IIC (Gas Groups A & B), T4 (*Note 1)*

Note: The T4 Temperature Classification is recommended, not mandatory

Individual manufacturers can choose to certify their equipment at figures higher than the minimum levels shown. For example, a manufacturer may wish to certify apparatus in such a way that it is compliant with both the FISCO and Entity concepts. In this case, the manufacturer will wish to choose a higher value of the device approval voltage.

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 3.3 for more details) and any combination of these 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 requirements is that the bus must be powered (even for separately powered devices).

NOTE: 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.

3.2.1 Bus Powered Devices

These are devices whose only source of electrical power is the fieldbus itself. A typical system might be as shown in Figure 3.2.1.1.

The device MAU performs the dual function of regulating power from the fieldbus to the device and signaling onto the bus.

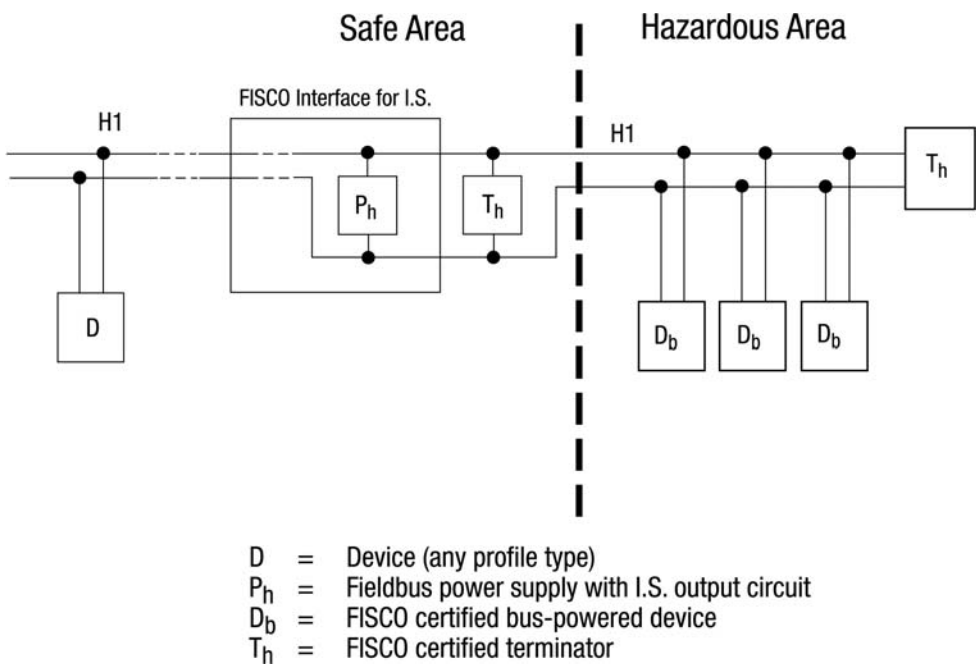


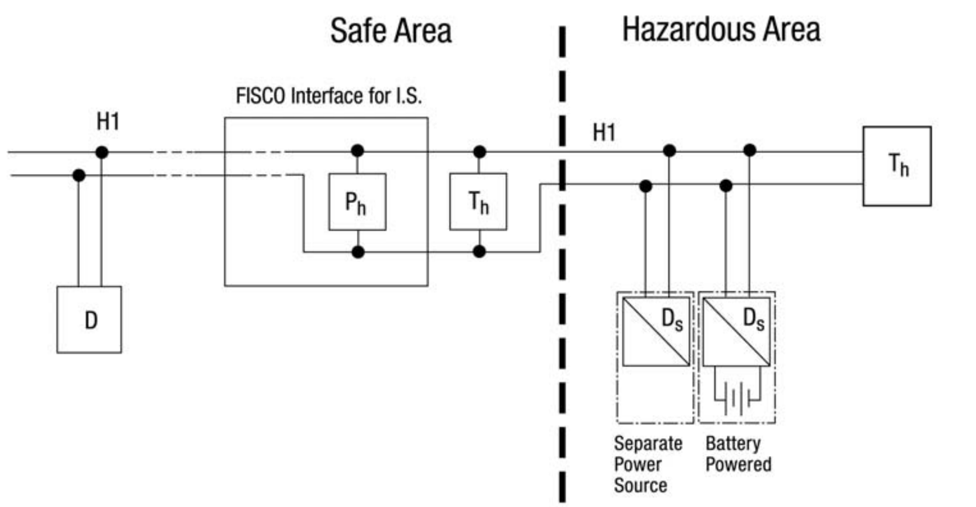
Figure 3.2.1.1.: I.S. Fieldbus with Bus-Powered Devices and Associated Apparatus

Note: I.S. Fieldbus with Bus-Powered Devices and Associated Apparatus shown installed in the safe area may be located in the hazardous area if protected by an appropriate method of protection.

3.2.2 Separately Powered Devices

These device types have one or more sources of electrical power in addition to the power supplied from the fieldbus itself. Examples of such a device are an analyser 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, could utilise another form of explosion protection, but the bus terminals must remain passive, i.e. the terminals shall not be a source of energy to the system except for a leakage current not greater than 50 µA. The bus terminals must be galvanically isolated from the additional sources of electrical power. An example system is shown in Figure 3.2.2.1.

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 has an immediate advantage in reducing the current drawn from the fieldbus, but a standard-power signaling 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 3.2.1) and operating characteristics are independent of the powering arrangements.



D = Device (any profile type)
P_h = Fieldbus power supply with I.S. output circuit
D_s = FISCO certified separately-powered device
T_h = FISCO certified terminator

Note: A separately-powered 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 3.2.2.1: I.S. Fieldbus With Separately Powered Devices

3.2.3 Fieldbus Terminator

The IEC/TS 60079-27: 2002 Technical Specification defines the required FISCO parameters for a terminator certified for installation in a hazardous area, as listed in Table 3.2.3.1. All FOUNDATION fieldbus segments require two bus terminators to be present. In common applications at least one of these will be mounted in the hazardous area (see Figures 3.2.1.1 and 3.2.2.1). Any terminator that is part of the hazardous area circuit must be formally certified since it includes a resistive-capacitive circuit.

Table 3.2.3.1: I.S. Parameters for Hazardous Area Mounted Terminator

Parameter	**Value**
Mounting	Ex ia IIC or Ex ib IIC (gas groups A & B), T4 (Note 1)
Gas Group	IIC (US Groups. A & B)
Input voltage	17,5 V min.
Input current	380 mA min.
Input power	5,32 W min.

Note: The T4 Temperature Classification is recommended, not mandatory

The FOUNDATION terminator profile is derived from Clause 11.7.5 of the IEC/61158-2:2003 Fieldbus standard, for reasons explained in Section 3.3.1 below. 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.

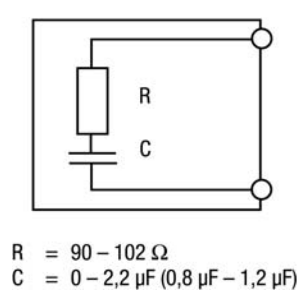


Figure 3.2.3.1: I.S. Fieldbus Terminator

3.3 Certifying Associated Equipment for Installation in the Safe Area – FISCO

3.3.1 Introduction

In an intrinsically safe system according to IEC 61158-2 and IEC/TS 60079-27: 2002 must be only one source of power onto the bus. For FISCO, this is the fieldbus power supply. In Intrinsic Safety terms, the power supply is classed as *Associated Apparatus*.

The requirements for FISCO power supplies, as defined in Clause 3 of Technical Specification IEC/TS 60079-27: 2002, are given in Table 3.3.1.1. Power supplies designed and certified in accordance with these values will be compatible with FISCO field instruments and accessories.

Table 3.3.1.1: Requirements for FISCO power supplies

Parameter	**Value**
Output voltage, U_o	14 … 17,5 V
Output current, I_o	In accordance to IEC 60079-11, but not exceeding 380 mA
Output power, P_o	In accordance to IEC 60079-11, but not exceeding 5,32 W
Internal capacitance, C_i	5 nF max.
Internal inductance, L_i	10 µH max.
Maximum permitted external capacitance, C_o	No specification required
Maximum permitted external inductance, L_o	No specification required

3.3.2 Compatibility with 'Entity' certified devices

It may be desirable to make the final output parameters of a FISCO power supply compatible with field devices that have been certified under the 'Entity' concept. In this case, the maximum values for U_o, I_o and P_o must be compatible with those given in Table 2.3.1 *(refer to "Certifying Associated Equipment for Installation in the Safe Area – Entity")*. Comparing both tables the lowest values for voltage, current and power have to be applied. Note however that such a circuit comprising a FISCO power supply and 'Entity' certified field devices will not comply with FISCO rules unless the field devices meet the FISCO requirements stated in Table 3.2.1. In particular, the unprotected residual inductance, L_i and capacitance, C_i of 'Entity' certified field devices may not comply with FISCO requirements.

Mixing FISCO and Entity components in the same segment is possible if special precautions are taken to ensure the compatibility of their safety parameters. The mixed segment will not be a FISCO system. A particular requirement may be to connect an Entity certified field device to a FISCO power supply. In this case a converter may be available, which has the function of making the safety description of an individual spur connection compatible with that of an Entity certified device.

In all situations, care should be taken to follow the manufacturer's instructions.

Some apparatus may be 'dual certified' for Entity and FISCO. For example, a field device may have safety parameters that permit its use with either an Entity or FISCO certified power supply. In practical terms, such a device must have minimum input parameters U_i > 24 V, I_i > 380 mA and P_i > 5,32 W, but these may be stated in the approvals documentation as separate sets of figures for Entity and FISCO. Similarly, a fieldbus power supply, or the spur connections of a wiring component, may have output safety parameters that fall below the maximum values for both Entity and FISCO. In this case the output parameters of the power supply must have maximum values U_o < 17,5 V, I_o < 250 mA and P_o < 1,2 W.

3.3.3 Gas Group

The power supply manufacturer must decide whether to design and certify the unit for Group IIC (US Groups A & B) or for less easily ignitable gases Group IIB (US Groups C & D). This choice will determine the levels of voltage, current and power that will be available in the hazardous area, but under no circumstances must the output safety parameters be higher than those given in Table 3.3.1.1.

At a given output safety voltage, a power supply designed for Group IIB (US Groups C & D) will typically have more output current than a supply designed for Group IIC (US Groups A & B). It will therefore be able to support more field devices on the hazardous area trunk, but the location of the trunk is restricted to the lower Gas Group, even though the field devices may be certified for more easily ignitable gases.

3.3.4 Intrinsic Safety category

The output current of a FISCO power supply may be limited by a conventional resistor circuit or by an electronic circuit. When the design is submitted for hazardous area certification, the certifying authority will assess the safety of the chosen current-limiting method and Gas

Group. Resistive circuits will be assessed against published ignition curves, and electronic circuits will be assessed either by comparison with published data or by spark ignition testing.

In accordance with conventional intrinsic safety practice, resistor-limited power supplies may be awarded an [Ex ia] certification code for connection to field instruments in Zone 0. Note that field instruments installed inside Zone 0 must be certified Ex ia. Electronically limited power supplies will be awarded an [Ex ib] code for connection to field instruments inside Zone 1, which may be certified Ex ib or Ex ia. For North American approvals, electronically limited power supplies may be approved for connection into Class I, Division 1 hazardous areas, at the discretion of the certifying authority.

3.3.5 Location of the FISCO power supply

Figures 3.2.1.1 and 3.2.2.1 are block diagrams of FISCO systems.

The power supply may be located in a safe (non-hazardous) area or, if protected according to a recognised method of protection, may also be in the hazardous area.

3.3.6 Galvanically isolated and shunt zener diode barriers

The I.S. protection in a FISCO power supply may be achieved using galvanically isolated or conventional shunt zener diode circuitry. Shunt zener barriers will typically require a high integrity earth or ground connection in order to divert fault currents.

3.3.7 Interaction between output voltage and current

The power supply manufacturer has some flexibility in choosing the usable output voltage and current values, but there is an interaction between them that is defined by the ignition curves. Careful attention must therefore be paid to selecting these values, in order to ensure that the power supply is capable of being used in a practical fieldbus system. In general, increasing the output voltage will result in a decrease in the available current, but the relationship is non-linear and the reduction in current is more exaggerated at higher voltages. In a typical installation, the output voltage from a FISCO power supply will determine the maximum length of the trunk cable. This is because the cable resistance will generate a voltage-drop along its length, while it is necessary to ensure a minimum of 9 V at the most distant field instrument. The output current will determine the number of field devices that can be supported.

Figure 3.3.7.1 illustrates an example of the relationship between the output voltage of the fieldbus power supply, the number of fieldbus devices supported and the maximum cable length. In this instance, the number of field devices has been first calculated from the permissible current as determined from the ignition curves for power supplies with rectangular outputs. The maximum cable length was then derived, assuming all the devices are located at the end of the trunk cable. This gives the most pessimistic result for cable length and number of devices. Note that the output current from a practical power supply will be less than the theoretical values used in this example.

The graph is also based on the following assumptions:

- All the field devices are bus-powered.

- The power supply is designed for IIC gases, category EEx ib.
- The cable has a loop resistance of 50 Ω/km.
- Each field device requires a supply current of 12 mA.
- The power supply has to provide the sum of the device currents plus 9 mA for modulation.
- Each field device has a minimum operating voltage of 9 V.

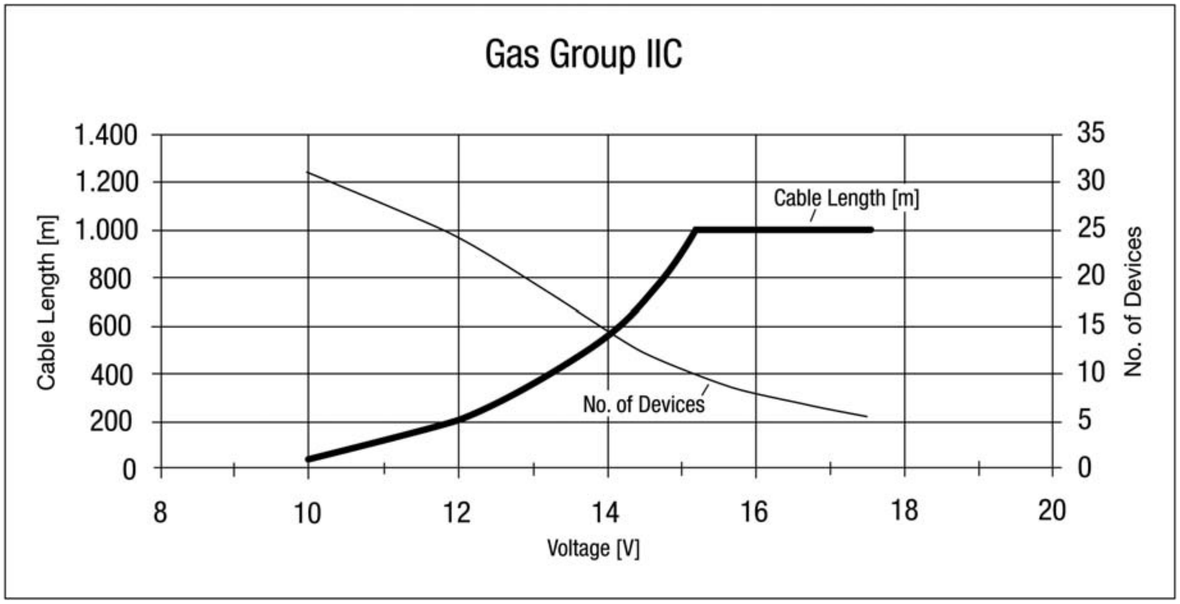


Figure 3.3.7.1: Number of bus-powered field devices as a function of supply voltage

Notes:
The output voltage of practical FISCO power supplies is restricted by the safety voltage range of 14…17,5 V
The maximum cable length for FISCO systems is limited to 1.000 m in IIC and 1.900 m in IIB gases.

3.3.8 Marking for certified FISCO apparatus

The requirements for marking of certified items of FISCO apparatus are defined in Clause 7 of Technical Specification IEC/TS 60079-27: 2002. These requirements include the following:

- The word "FISCO"
- An indication of the function of the apparatus, for example 'FISCO Power supply' or 'FISCO Field device'
- A statement for the certification code, for example 'EEx ia IIC'
- The manufacturer's name
- The model number of the apparatus, which should be sufficient to uniquely identify it.
- The certificate number

3.4 System Cables – FISCO

System cables for FISCO must comply with the functional requirements of the IEC 61158-2 standard and with the safety requirements of IEC/TS 60079-27: 2002.

The IEC 61158-2 standard states that a twisted pair cable with overall shield is used as transmission medium for the Fieldbus, transmitting the communication together with the supply for bus powered field devices. The cable parameters influence the performance that can be achieved by the Fieldbus.

The cables must also be specified for the operating temperatures in the plant.

The parameters of cables for FISCO applications are given in Table 3.4.1. Where the cable parameters are not known, they may be determined in accordance with the Annex C of IEC 60079-14. The capacitance of the cable is calculated as

$$C_c = C_{Conductor/Conductor} + 0,5 * C_{Conductor/Shield}$$

if the bus is isolated from the earthed or grounded screen

$$C_c = C_{Conductor/Conductor} + C_{Conductor/Shield}$$

if the screen is connected to one pole of the supply unit where $C_{Conductor/Conductor}$ is the capacitance between both cable wires and $C_{Conductor/Shield}$ is the capacitance between cable wire and shield.

The manufacturer of a cable complying to the FISCO parameters may mark it as 'FISCO'. If such a cable is used, the safety of the overall FISCO system can be easily demonstrated.

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 labelled 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 should not 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. FISCO cables should be identified as intrinsically safe.

FISCO conditions related to cable parameters: See Table 3.4.1.

Table 3.4.1: Cable parameters in accordance with IEC/TS 60079-27 (FISCO)

	Gas Group IIB	**Gas Group IIC**
Cable length including trunk length and total length of all spurs	1.900 m max. *(limited by FF specification)*	1.000 m max
Cable length spur	30 m max. for FISCO, but refer to other limitations defined by FF AG 140 [Note 1]	
Loop resistance R_c	15...150 Ω/km	
Loop inductance L_c	0,4...1 mH/km	
Loop Capacitance C_c	80...200 nF/km	

NOTE: At the time of writing, these may change to 60 m spur length and 45…200 nF/km capacitance

Table 3.4.2: Types of cable in accordance with IEC 61158-2 standard

These conditions are clearly met in the example system shown in the Figure 3.4.2.

	Type A (Reference)	**Type B**
Cable design	Twisted pair, individual shield	Multiple twisted pair, overall shield
Maximum conductor cross section (nominal)	0,8 mm² (AWG 18)	0,32 mm² (AWG 22)
Loop resistance (DC)	44 Ω/km	112 Ω /km
Impedance (31,25 kHz)	100 Ω ± 20 %	100 Ω ± 30 %
Attenuation (39 kHz)	3 dB/km	5 dB/km
Capacitive asymmetry	2 nF/km	2 nF/km
Max. propagation delay change (7,9 to 39 kHz)	1,7 µs/km	Not specified
Max. shield coverage	90 %	Not specified
Recommended extent of network (including spurs]	1.900 m	1.200 m

The reference cable (i.e. type A) must be used for conformance tests. When new systems are installed, cables that meet the minimum requirements of types A or B should be used. When multi-pair cables (i.e. type B) are used, several fieldbuses (31,25 kbit/s) may be operated in one cable. The inclusion of other non fieldbus circuits in the same cable should be avoided.

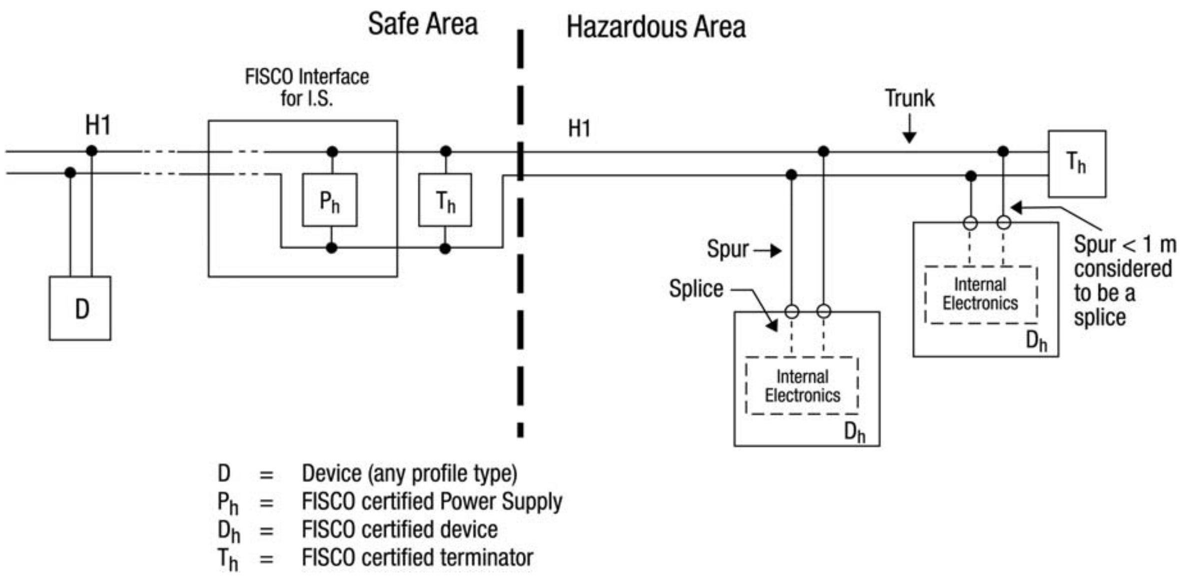


Figure 3.4.1: Cable Topology

Trunk, Main cable: Longest piece of cable between both terminating resistors.

Spur, Branch cable: All other connections to the trunk except splices. A spur which is less than 1 m long may be considered to be a splice.

Splice, Connection element: Any part of the network in which the characteristic impedance of the network cable is not preserved. Used to connect the circuitry of a field device to the trunk or a spur. Because of their short lengths, splices are not considered to affect the Intrinsic Safety according to FISCO.

Although IEC 61158-2 permits different cable types to be mixed in one network segment, this should be avoided. Determining the maximum cable lengths for such mixed structures is more time consuming and less accurate than using structures consisting of only one type of cable.

The network can be enlarged with repeaters. The above limit values then apply to each individual network segment, and only the maximum signal delay has to be calculated for the total network. Refer to the data sheets and manuals of the manufacturers of these repeaters.

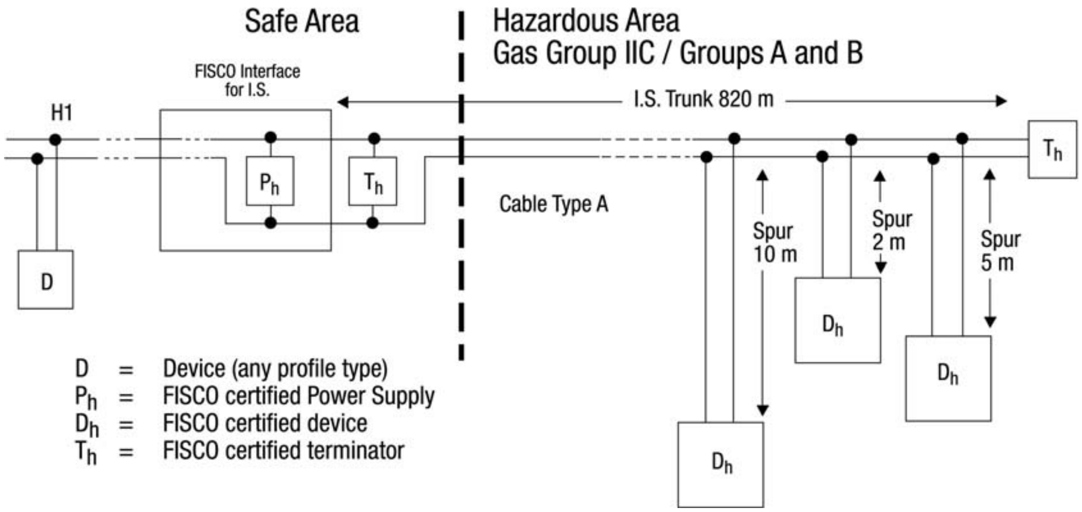


Figure 3.4.2: Example for Cable Topology

Trunk length (I.S): 820 m

Total cable length (I.S): 837 m = 10 m + 2 m + 5m + 820 m

Permitted cable length for Type A cable for Gas Group II C: 1.000 m

Permitted length of each spur: 30 m

The circuit is intrinsically safe.

3.5 Analyzing the Safety of an Intrinsically Safe FOUNDATION FIELDBUS System – FISCO

One of the merits of FISCO compared with the Entity model is the simplification of the safety analysis. Where each item of apparatus in a FISCO system complies with the requirements of IEC/TS 60079-27: 2002, the safety documentation may be simply a list of the separate items. It is not necessary to establish compatibility between the electrical parameters of each field device and the source of power, or to calculate cable parameters. Apparatus which complies with IEC/TS 60079-27: 2002 may be identified because it carries the 'FISCO' name as part of its marking.

An exception to this rule is for apparatus that was certified before IEC/TS 60079-27: 2002 was published. Such apparatus may be marked 'Suitable for FISCO systems' or 'in accordance with the FISCO model (field bus)' and with the values for U_i, I_i, P_i, C_i and L_i. If this kind of apparatus is to be included in a FISCO system, it is necessary to establish that its electrical parameters are compatible with those of other parts of the system. For example, the values U_i, I_i, and P_i for a field device must be compatible with U_o, I_o, P_o of the source of supply [Note 1].

An example of the safety documentation that may be used for a typical FISCO system is given in Figure 3.5.1. The table and corresponding analysis

should be done prior to installation. The example uses apparatus that is certified and marked in accordance with IEC practice; for North American practice, the Gas Group and intrinsic safety category may be presented in accordance with national standards.

The relevant information is required for each item in the planned system. If there is any doubt about the certification status for a piece of apparatus, this should be obtained from the manufacturer or his representative. Where compliance with any special conditions is required as part of the certification, these should be noted.

The table includes the following information for each item of apparatus:

- Name of manufacturer
- Manufacturer's model number
- Certificate or file reference number
- Intrinsic safety category: EEx ia or EEx ib
- Gas Group(s): IIA, IIB, IIC
- (Groups A, B, C, D)
- Temperature classification, where appropriate
- Operating ambient temperature range

Associated Apparatus

Item No.	FISCO	Device Type	Description	Manufacturer	Type No.	Classification	Certificate No.	Temperature Range
1	Yes	FISCO Power Supply	FISCO supply	ABC GmbH	B9121	[EEx ib] IIC	PTB 02 ATEX 9999	-40 ^{o}C to +70 ^{o}C

Field devices, Terminator and Cable

Item No.	FISCO	Device Type	Description	Manufacturer	Type No.	Classification	Certificate No.	Temperature Range
1	Yes	FISCO Terminator	Terminator	Schwarzen-egger plc	PRS-1	EEx ia IIC T4	Baseefa 02 ATEX 9999	-40 ^{o}C to +70 ^{o}C
2	Yes	FISCO Field device	Tempera-ture Transmitter	Fingaburn Ltd	999C	EEx ia IIC T4	SIRA 02 ATEX 9999	-40 ^{o}C to +85 ^{o}C
3	Yes	FISCO Field device	Pressure Transmitter	Bars	B52	EEx ia IIC T4	PTB 02 ATEX 9999	-40 ^{o}C to +85 ^{o}C
5	Yes	FISCO Field device	Flow Transmitter	Swirlwing Sarl	H2O	EEx ia IIC T4	INERIS 01 ATEX 9999	-45 ^{o}C to +80 ^{o}C
6	Yes	FISCO Field device	Valve positioner	Mountflower Inc	V55	EEx ia IIC T4	CESI 02 ATEX 9999	-35 ^{o}C to +85 ^{o}C
7	Yes	FISCO Cable	Cable	Hotstring Co.	Bus99	--	--	-45 ^{o}C to +85 ^{o}C
8	Yes	Cable	Cable Note 3	Wetstring Co.	Bus66	--	--	-45 ^{o}C to +85 ^{o}C

Figure 3.5.1: Example Safety Documentation of FISCO System

Notes

1. The symbols given here are in IEC terminology. The equivalent North American symbols are Vmax, Imax, Pmax and Voc, Ioc, Pm.

2. The data shown in the table is for illustration purposes only and does not indicate anything about the existence or suitability of any item listed.

3. It has to be proved that the cable parameters are according FISCO.

3.5.1 Classification of the complete System

3.5.1.1 Gas Group

In most cases, the Gas Group of the complete system will be determined by that of the power supply. In the example given, the Gas Group of the fieldbus power supply and all other items is IIC. If however the power supply was certified for IIB, then the overall system would be classified IIB.

3.5.1.2 Intrinsic Safety Category and Temperature Classification

The intrinsic safety category will be determined by that of the field devices, terminators and power supply. Note however that IEC/TS 60079-27: 2002 permits sub-systems to have a different category from that of the main system. For example, an 'ia' spur may be created from an 'ib' trunk by the insertion of a suitably certified interface.

The temperature classification of each piece of field-mounted apparatus will be determined by its certification.

3.5.1.3 Operating Temperature Range

It is necessary to ensure that the operating temperature range of each item of apparatus, including the cable, is suitable for its location; hence the inclusion of this information in the table.

For the example given, the overall system is classified Ex ib IIC T4.

3.5.2 Cable

The cable must comply with FISCO requirements, as defined in table 3.1.2.1.

3.6 FISCO segment design – worked examples

The following worked examples show how to design a FISCO fieldbus segment, taking into account the steady state operational parameters of the fieldbus power supply, field devices, interconnecting cable and wiring components. In a practical design, the safety analysis described in Section 3.5 should also be taken into account.

Two examples are presented. The first is for an application in which the Gas Group is IIB (Group C), and the second is for Gas Group IIC (Group A). In the second example, an active wiring component with spur short-circuit protection is also included. In both cases the following design requirements apply:

Minimum voltage required at fieldbus devices	9 V Note 1
Cable cross-sectional area	0,8 mm^2 (18 AWG)
Cable resistance	44 Ω/km per loop (i.e. outward and return conductors) The influence of temperature upon the cable resistance is not considered.

Example 1: IIB (Group C) Gas Group

Consider a typical IS fieldbus segment illustrated in Figure 3.6.1 and having the following additional requirements:

Number of fieldbus devices	10, with spare capacity for a further 2
Total trunk cable length	250 m
Spur cable length	30 m
Average current drawn by each fieldbus device	20 mA
Gas Group	IIB / Groups C, D

Five of the fieldbus devices are located at a distance of 150 m from the power supply, and the remaining five at a further distance of 100 m. The two additional (spare) devices are assumed to be located at the end of the trunk

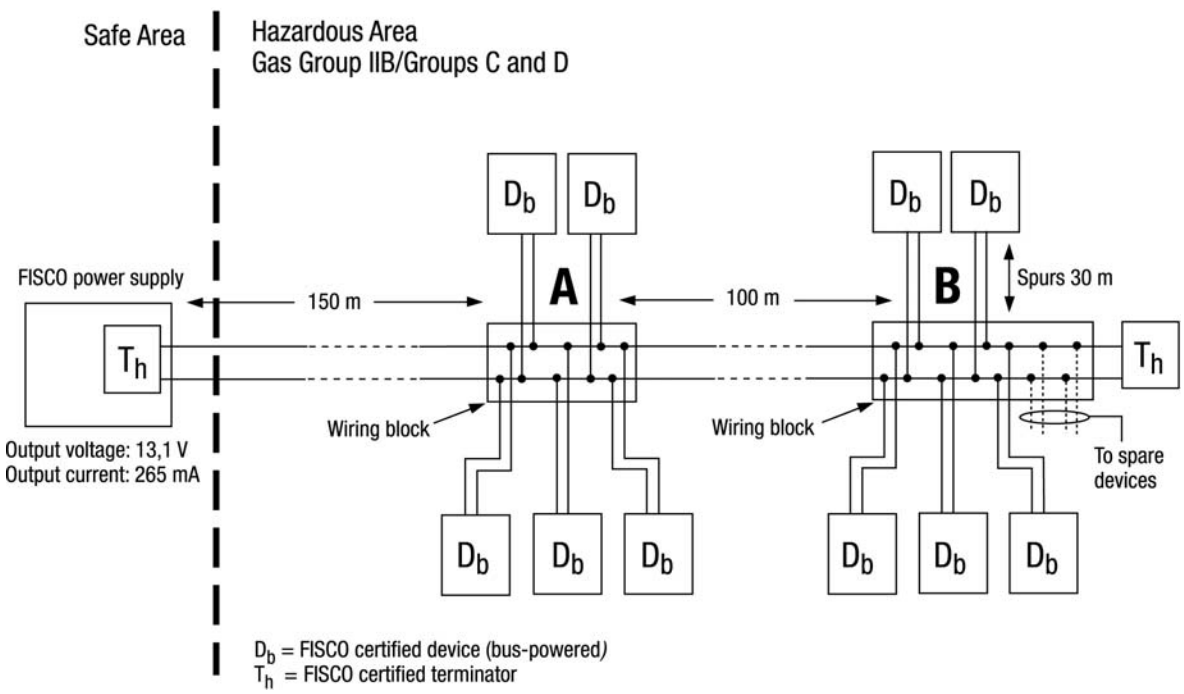


Figure 3.6.1: Example FISCO installation, IIB (Group C) Gas Group

The FISCO power supply is approved for connection into IIB / Group C, D hazardous areas, and has the following operational parameters Note 2:

Minimum output voltage	13,1 V
Minimum output current	265 mA

The first requirement is to ensure that the output of the FISCO power supply will provide the total current required by the fieldbus devices. The design must also take account of the spare capacity, so the number of devices for the design study is 12. Therefore, the operating current required is 12 x 20 mA = 240 mA, which is within the output capability of the power supply.

The second requirement is to ensure that all field devices have a minimum of 9 V at their terminals, allowing for the voltage drop in the cables. The voltage drop is calculated according to the current flowing and the resistance of the fieldbus cable, as follows:

- Voltage drop in first 150 m trunk length = $\Sigma I_{devices} \times R_{cable}$

  = (12 x 20 mA) x 0,15 km x 44 Ω/km = 1,58 V

- Voltage at point A (first wiring block) = 13,1 V – 1,58 V = 11,52 V

- Voltage drop in second 100 m trunk length = $\Sigma I_{devices} \times R_{cable}$

  = (7 x 20 mA) x 0,1 km x 44 Ω/km = 0,62 V

- Voltage at point B (second wiring block) = 11,52 V – 0,62 V = 10,9 V

The spurs have a length of 30 m and hence have a resistance of less than 1,5 Ω. This produces a voltage drop of only 30 mV when carrying 20 mA, which is small enough to be ignored.

The conclusion is therefore that these operational requirements of the proposed FISCO segment are met.

Example 2: IIC (Group A) Gas Group

Consider a typical IS fieldbus segment illustrated in Figure 3.6.2 and having the following requirements:

Number of fieldbus devices	6
Total trunk cable length	400 m
Spur cable length	30 m
Average current drawn by each fieldbus device	15 mA
Spur current drawn by wiring component when spur in short circuit	40 mA [Note 2]
Trunk to spur voltage drop	0,1 V [Note 2]
Gas Group	IIB / Groups C, D

The fieldbus devices are located at a distance of 400 m from the power supply. In this example they are connected to a suitably certified wiring block that has active short-circuit protection on the spur connections. The electrical characteristics of the block, as published by the manufacturer, must be taken into account to ensure correct operation of the fieldbus network.

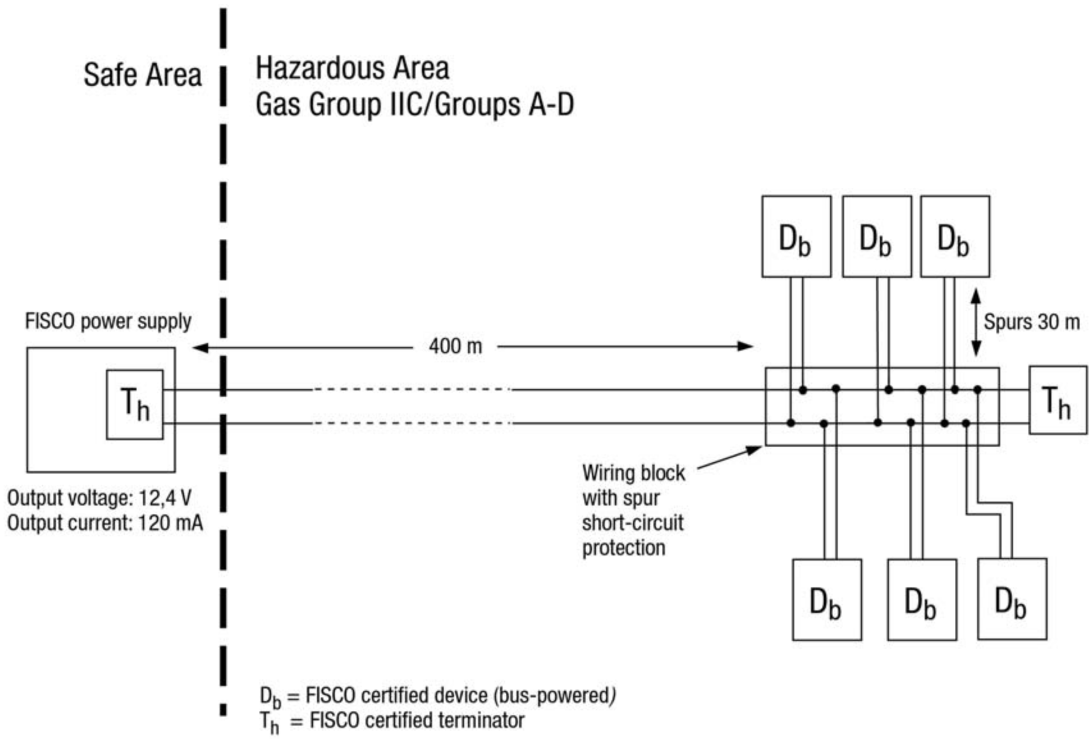


Figure 3.6.2: Example FISCO installation, IIC (Group A) Gas Group

The FISCO power supply is approved for connection into IIC / Group A, B hazardous areas, and has the following operational parameters [Note 2]:

Minimum output voltage	12,4 V
Minimum output current	120 mA

The first requirement is to ensure that the output of the FISCO power supply will provide the total current required by the fieldbus devices. The operating current required is 6 x 15 mA = 90 mA. An allowance must also be made for any additional current that is drawn when a spur is in short circuit. Note 3 The total design current is therefore 5 x 15 mA + 1 x 40 mA = 115 mA, which is within the output capability of the power supply.

♦ The second requirement is to ensure that all field devices have a minimum of 9 V at their terminals, allowing for the voltage drop in the cables. This voltage must be maintained even when a single spur is in short circuit, in accordance with the stated design requirements. The voltage drop is calculated according to the current flowing and the resistance of the fieldbus cable, as follows:

♦ Voltage drop in the 400 m trunk length = $\Sigma I_{devices} \times R_{cable}$

115 mA x 0,4 km x 44 Ω/km = 2,02 V

♦ Voltage at wiring block trunk connection
= 12,4 V – 2,02 V = 10,38 V

♦ Voltage at wiring block spur connection
= 10,38 V – 0,1 V = 10,28 V

The spurs have a length of 30 m and hence have a resistance of less than 1,5 Ω. This produces a voltage drop of only 23 mV when carrying 15 mA, which is small enough to be ignored.

The conclusion is therefore that these operational requirements of the proposed FISCO segment are met.

Notes
The addition of a voltage margin to the 9 V FF specification is at the discretion of the system designer.

Example values only; refer to the manufacturer's specifications.

It is normal to take into account a single spur in short circuit condition. Consideration of more than one spur in short circuit condition is at the discretion of the system designer.

4. INSTALLATION

4.1 Wiring Components

In a practical fieldbus installation, it is probable that the field devices will be connected to the fieldbus trunk using spurs, so that the removal of an individual device does not interrupt the operation of the whole system. 'Daisy chain' connections and the use of more than one wire per terminal are not recommended practice. Additional wiring components will therefore be required. These may take the form of conventional DIN-rail mounted terminals in suitable housings or wiring hubs specifically designed for fieldbus applications. Such components may also include additional facilities such as spur short-circuit protection, surge protection, or additional voltage and current limiting components that may form part of the overall intrinsically safe protection scheme. A fieldbus terminator may also be incorporated.

Wiring blocks that contain energy-storing components may be certified, if they are to be included in an intrinsically safe fieldbus system. In this case, the input values U_i, I_i and P_i of the wiring block must be compatible with the output parameters of the fieldbus power supply, and the residual lumped capacitance, C_i and inductance, L_i must be taken into account as part of the safety assessment. Note that the safety parameters of the spur connections may be different to those of the trunk, and compatibility with those of the field instruments must be established.

Wiring devices often contain only passive components or other components with well-defined parameters such as terminals plugs, sockets and switches. These devices may be considered to be 'simple apparatus', as defined in IEC 60079-11 and they do not need to be certified or marked. However they are part of the analysis of the intrinsic safety carried out as described in chapter 2.5 and 3.5.

Additional requirements for FISCO systems:

The FISCO technical specification IEC/TS 60079-27: 2002 makes no specific reference to wiring components, but their influence on the overall safety of the system should be considered. Where certified wiring components are included, they should comply with the requirements for FISCO field devices and be marked in accordance with the specification. Each component having non-zero values of C_i and L_i should comply with the FISCO specification for field devices. Certified wiring components should be included in the list of items as part of the safety documentation. If a terminator is incorporated, it must comply with the requirements of IEC/TS 60079-27: 2002.

4.2 Repeaters in Intrinsically Safe fieldbus applications

In general terms, active repeaters may be used to extend the length of a fieldbus trunk beyond that of a single segment, as permitted by the network configuration rules. Repeaters may be used in hazardous area applications provided they are appropriately certified. For example, if a repeater is to be connected in an intrinsically safe circuit, it must be certified in accordance with intrinsic safety rules and must comply with the requirements of the physical layer specification (Entity or FISCO).

Some intrinsically safe fieldbus power supply / conditioners may incorporate a repeater function. In this case, the fieldbus trunk on both sides of the power supply may extend to the full 1.900 m limit unless otherwise constrained. Since there is no deterioration of the fieldbus signal across the repeater, immunity to electrical noise may also be improved. Where required, more than one repeating power supply may be connected in parallel to a single host fieldbus, thereby creating multiple trunk circuits.

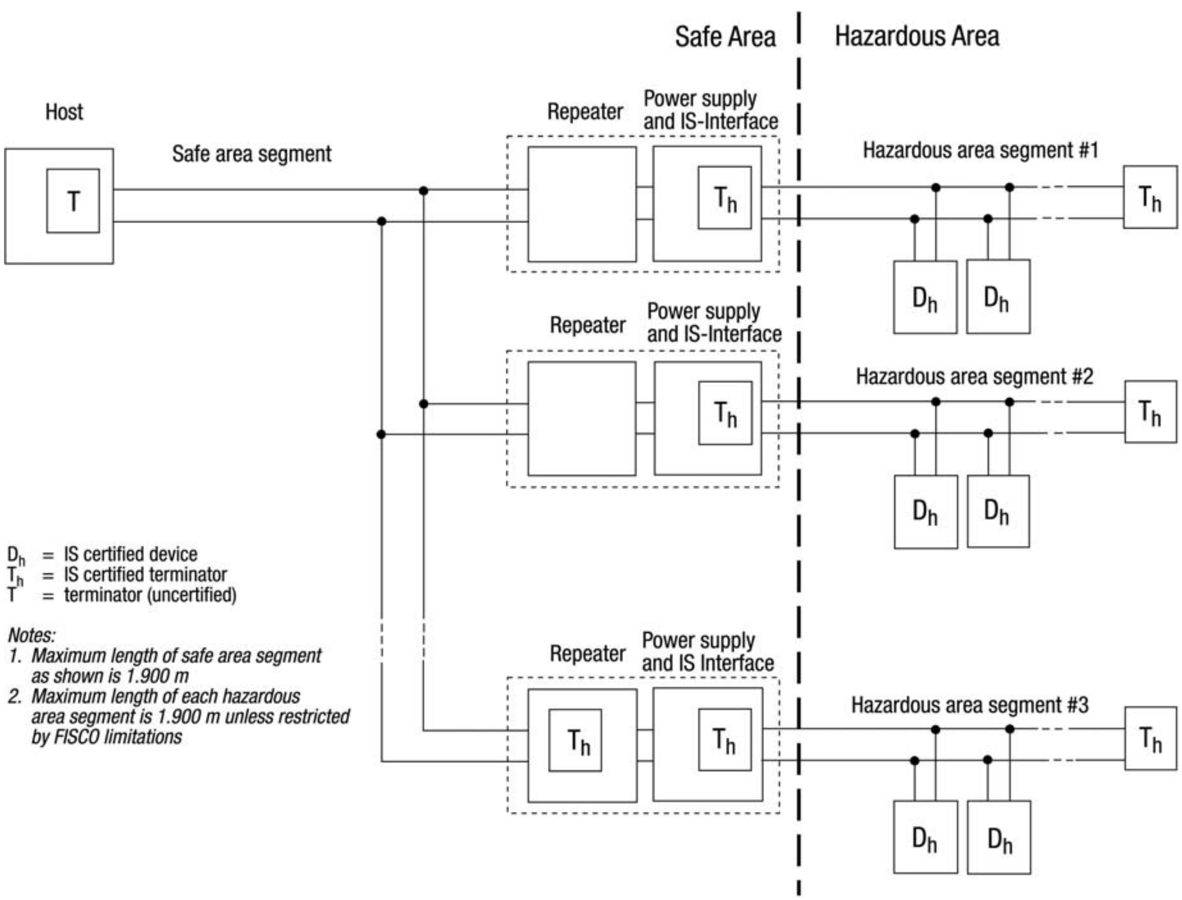


Figure 4.2.1: Fieldbus Topology with Repeaters

4.3 Alternative Technologies

4.3.1 Non-intrinsically Safe Trunk, Intrinsically Safe Spurs (Fieldbus Barrier)

Fully intrinsically safe bus segments offer full accessibility to connected field devices while the bus is energized. The trunk and spurs are live-workable, and field devices can be connected or disconnected to the bus even under power. The number of devices that may be supported on the bus is determined by the available current. For functional reasons of the physical layer the maximum number of devices per segment is limited to 32; in practice the limitation is determined by the available current. This current is derived from the intrinsic safety ignition curves of the fieldbus power supply or by testing during the certification process.

An alternative architecture is to use a method of protection other than intrinsic safety for the fieldbus trunk. This has the benefit of delivering a higher level of current to the segment than is possible with intrinsic safety. Intrinsically safe spurs may be generated by including voltage, current and power limiting components and limiting the internal capacitance and inductance within a field-mounted Fieldbus Barrier. The box may also perform the function of a junction box for connecting the spur cables.

This technology gives full access to the field devices even when they are energized inside the hazardous area, although an increased amount of supply power is available. However, the fieldbus trunk must not be interrupted while energised in the hazardous area, unless proven to be gas free for example by means of gas detection. Alternatively, suitably certified connectors designed for live disconnection may be used.

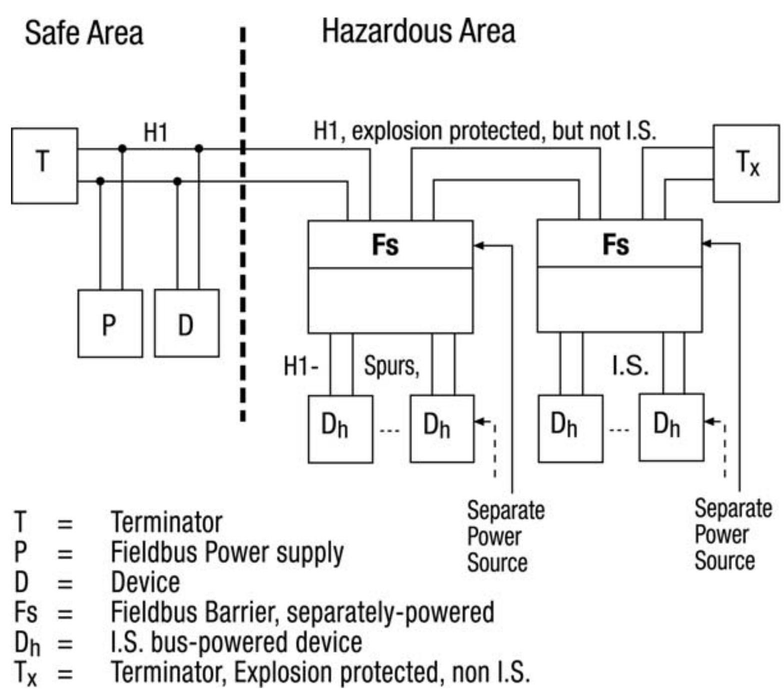


Figure 4.3.1.1: Fieldbus Barrier

The fieldbus power supply will normally be installed in the safe area, in which case it does not need to be explosion protected. If located in the hazardous area, the power supply must be suitably certified. Another alternative is to use separately powered Fieldbus Barriers

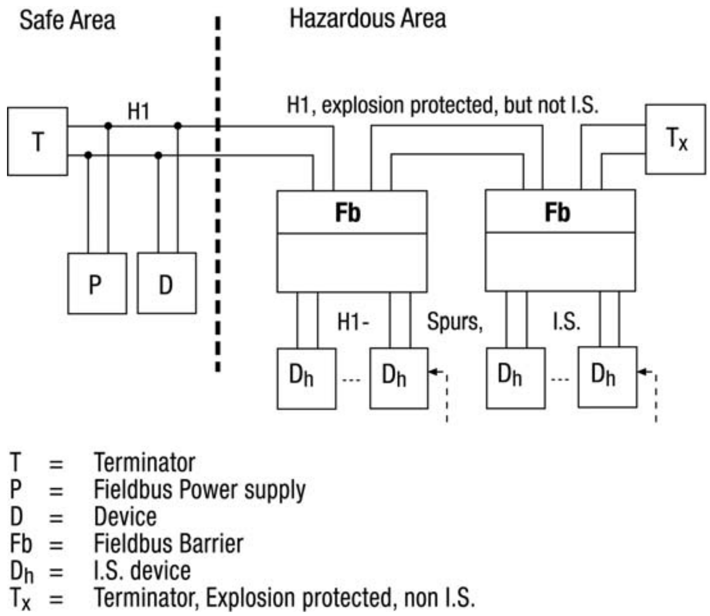


Figure 4.3.1.2: Fieldbus Barrier, separately-powered

The Fieldbus Barrier must be certified for installation within the hazardous area. If located in an IEC Zone 1 area, suitable explosion protection methods include flameproof / explosionproof (Exd), increased safety (Exe), encapsulation (Ex m) and intrinsic safety (Exi). For example, following the European rules the Fieldbus Barrier could be classified as Ⓔx II 2 (1) G EEx me [ia] IIC T4.

For installations in accordance with IEC practice, the bus cable must be suitable for Zone 1. Connections to the Fieldbus Barrier may be in accordance with increased safety requirements.

Note that the some explosion protection methods such as increased safety are not recognised for installation in Division 1 areas in countries following NEC practice. In this case, alternative protection methods must be employed, and the fieldbus trunk must be installed in accordance with Division 1 wiring methods. Such methods include rigid metal conduit. Installation in Division 2 hazardous areas may also be permitted, if the Fieldbus Barrier is suitably certified. Refer to Figures 4.3.1.3 and 4.3.1.4.

The intrinsically safe spurs may be designed in accordance with the Entity or FISCO concepts, and may include short-circuit protection such that the bus segment is not affected by a short-circuit on a spur. Intrinsic safety protection for the spurs may be implemented using either galvanically isolated or shunt zener diode barriers. Zener diode barriers must have quasi-floating channels. The installer has the responsibility to provide potential equalisation in accordance with Section 2.3.

If the bus trunk is terminated in the hazardous area, an explosion protected fieldbus terminator must be used. Its certification must be suitable for installation inside the hazardous area and for connection to a non-intrinsically safe circuit. If the terminator is included inside the Fieldbus Barrier and is intended to be switched on and off in the hazardous area, the manufacturer must ensure that the arrangement is suitably protected.

The individual connections to the field devices are spurs and therefore are not required to be terminated.

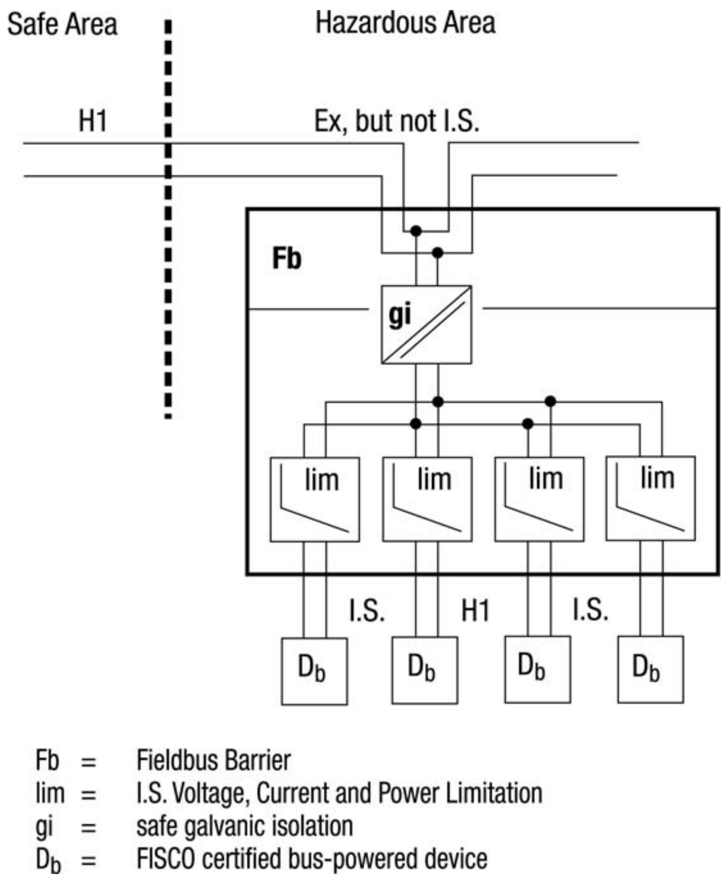


Figure 4.3.1.3: Fieldbus Barrier for Ex e Trunk with I.S. Devices (Example)

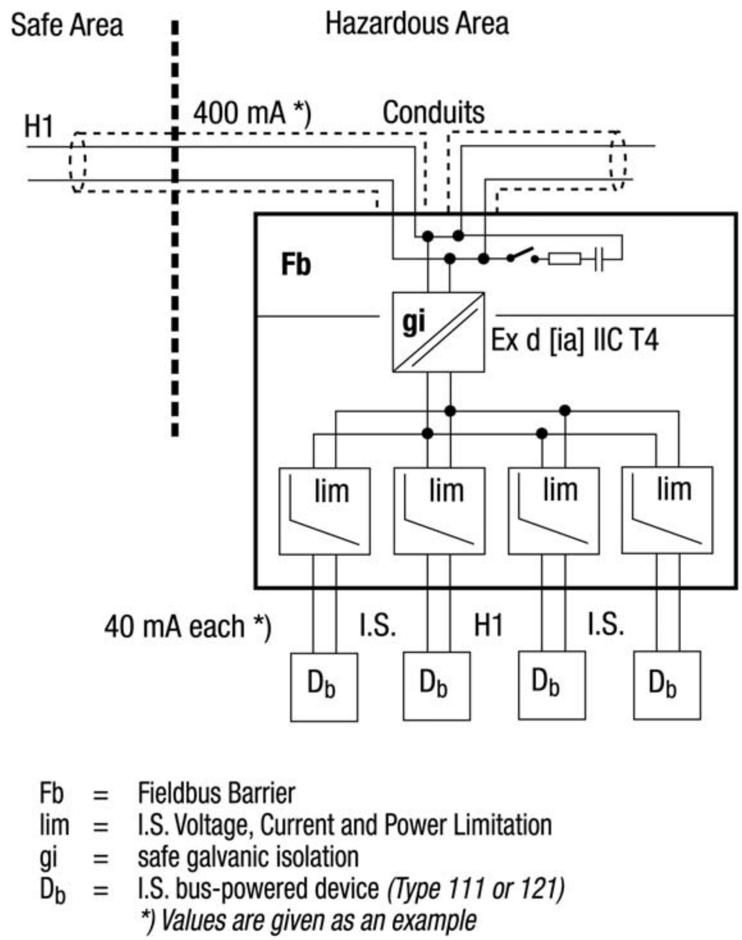


Figure 4.3.1.4: Fieldbus Barrier for Conduit-protected Trunk and I.S. devices (Example)

4.3.2 IIB/IIC Split Architecture

Depending upon the gases present in different hazardous areas lower or higher currents are permitted in intrinsic safe circuits. The allowed current for gas group IIB (and IIA) is higher than for IIC. By this a higher fieldbus supply current, as well as a higher power, can be transferred to this area.

An intrinsically safe power supply rated for one Gas Group IIB (IIA) can feed field devices, which are installed in a IIC area and are connected to a field junction box with further energy limitation installed in a IIB (IIA) area. The total fieldbus segment current flows through a lower series resistance than in IIC area. The spur connecting the field device to the junction box carries the current

for this field device only and it runs over a shorter distance. These effects lead to a lower voltage drop via the cable, by this enabling higher functional currents.

The architecture uses standard design techniques for intrinsically safe power supplies and so permits approval for device location in Zone 0. The selection of intermediate approval for the intrinsically safe power supply means the trunk and the field junction box are not themselves suitable for location in the most hazardous gas atmospheres. But the field devices and spur wiring may be installed in any gas group, if certified for IIC.

The terminator may be an independent component, in which case it must be approved for connection to the intrinsically safe power supply, taking into account the higher-than-normal available fault current and power. If the terminator is part of an approved field junction box, no separately approved terminator is needed.

Device selection

The system documentation will define the approval parameters in order to allow selection of compatible field devices. Comment: It is also possible to build a split-architecture system with FISCO.

In conventional installations, cable parameters must be assessed per installation. However, in this type of system, each spur is treated as an independent circuit as far as allowable capacitance is concerned (each spur has its own current limiting component), but all cables (trunk plus spurs) must be lumped together when considering allowable inductance or the alternative L/R ratio.

Segment capacity may be determined from Ohm's law calculations as for all fieldbus applications, but in this configuration, the total voltage drop is composed of that related to trunk cable and source impedance, plus that related to one spur. The following equation may be used to determine permissible cable resistance and hence length:

$$R_c = \frac{U_s - (\sum I_d \times R_1) - (I_d \times R_2) - U_d}{(\sum I_d)}$$

where U_d = Device Voltage
U_s = Source Voltage
R_1 = Source Resistance
R_2 = Spur Resistance
R_c = Cable Resistance
I_d = Nominal Device Current

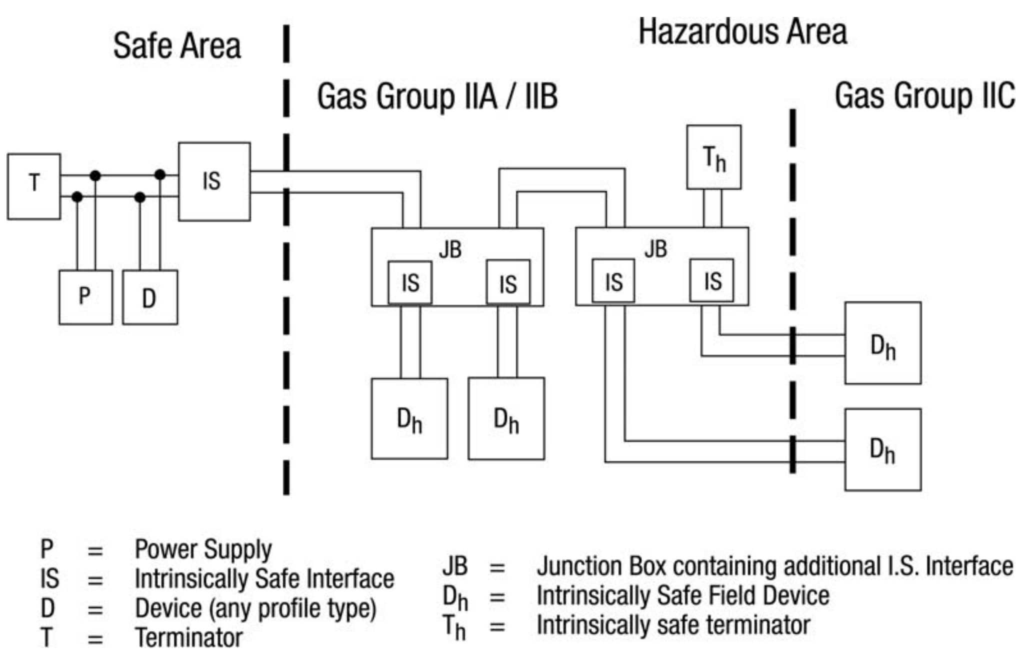


Figure 4.3.2.1: IIB/IIC Split Architecture

4.4 Earthing and Shielding

The earthing or grounding and shielding of a fieldbus installation has to take account of safety, explosion protection, electromagnetic compatibility (EMC) and functional requirements.

The IEC 61158-2 Standard requires that the fieldbus is operated in a balanced mode with respect to earth or ground. The manufacturer of the fieldbus devices should ensure that this balance is within the limits defined in the standard. Neither conductor of the fieldbus cable should be connected to earth or ground.

There are three methods of shielding in principle. Most common is to earth or ground the shield at one end of the cable only, usually inside the control room. This approach is derived from conventional point to point wiring practice as used for 4 to 20 mA signals.

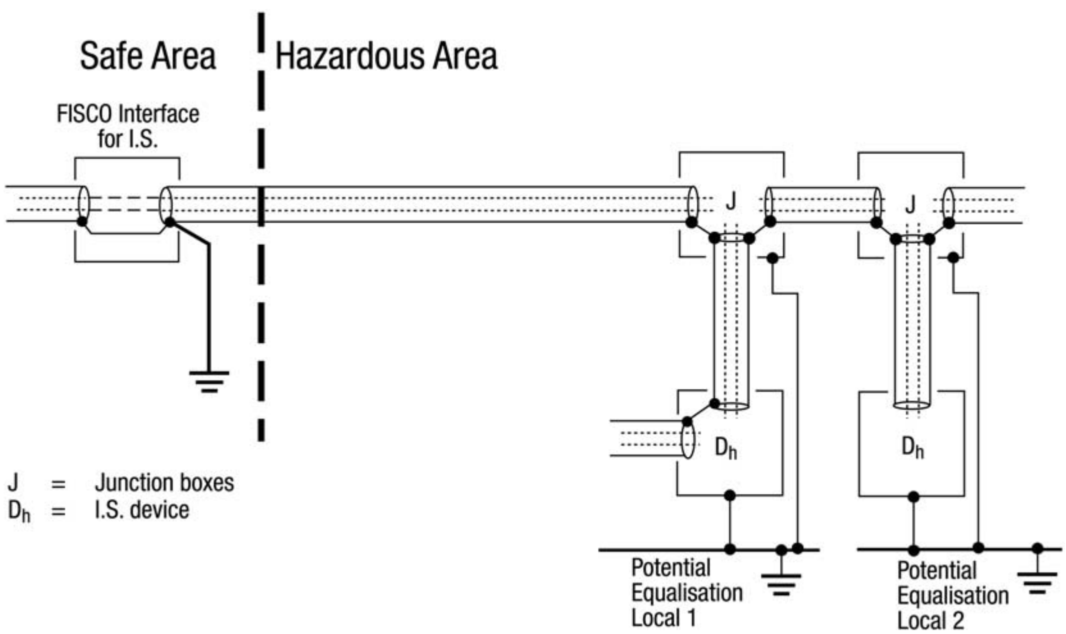


Figure 4.4.1: Fieldbus System with shields, shield connected to earth or ground on one side in the control room

NOTE: In addition to grounding of the fieldbus cable shield, installation regulations normally require that metal housings are connected to local earth or ground.

In situations where higher levels of interference could affect the operation of the fieldbus system, alternative shielding arrangements may be considered. Fieldbus systems in accordance with IEC 61158-2 operate with AC signal transmission, which can be influenced mostly by electromagnetic fields. Ideally a Faraday cage should be built up by proper grounding of the whole system including cables, junction boxes and field devices etc. This could result in the need for a closed shielding arrangement with the cable shields connected to ground at both ends. Because of the demands of the explosion protection, in this case the potential of the ground has to be the same on both ends of the shield. For example DC or low frequency AC leakage currents of electrical machines could raise the earth or ground potential in the field by driving a current through the cable shield. As this current would be limited only by the shield resistance, the explosion protection could be violated. To avoid this, a safe and reliable potential equalisation according to the requirements of intrinsic safety must be installed.

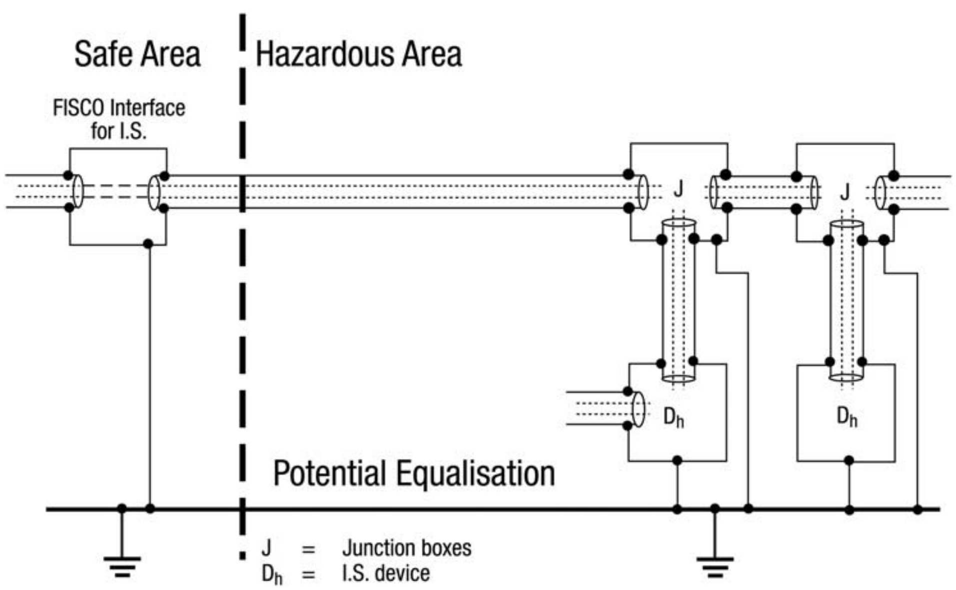


Figure 4.4.2: Fieldbus System with shields, shield connected to earth or ground on both ends

The third method is to connect the shield directly to earth or ground only one end (for example in the field) and introduce a capacitive earthing or grounding at the other end (for example in the safe area). The shields of cables and the devices in the hazardous area are connected onto the local potential equalisation of the plant according to the requirements of intrinsic safety. High level circular currents are prevented, because the capacitance blocks DC and low frequency AC currents. Higher frequency currents are led to earth or ground through the capacitor providing a closed shield for EMC. The capacitor must not be permitted to fail to short circuit, because in this case the requirements of intrinsic safety would be violated.

The specification of the shield capacitor should be

- solid dielectric
- capacitance max. 10 nF
- test voltage min. 1.500 V
- the connection of the capacitor to the shield and earth or ground should have a low impedance for frequencies higher than 32,15 kHz.

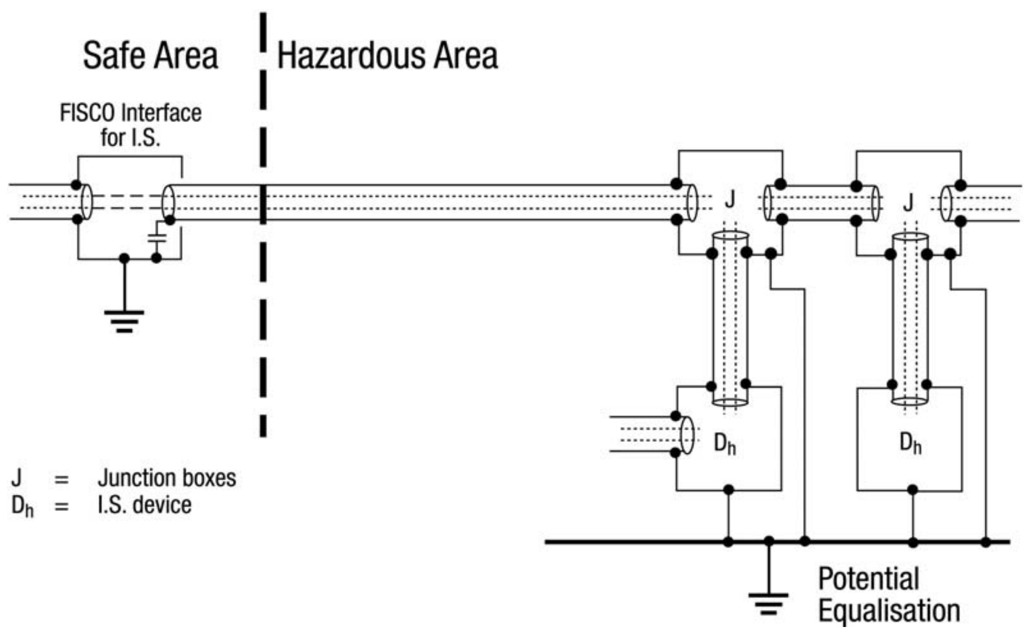


Figure 4.4.3: Fieldbus System with shields, shield connected to earth or ground in the field and capacitive earthing or grounding in the safe area

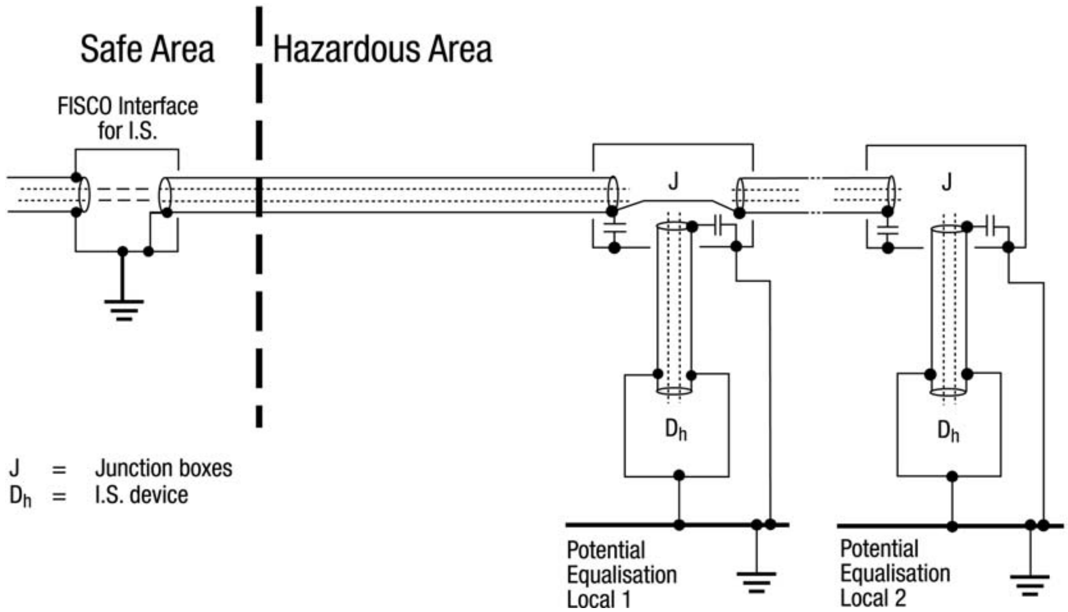


Figure 4.4.4: Distributed Fieldbus System with shields. Shield connected to earth or ground in the field, partially capacitive earthing or grounding in the field connected to one local potential equalization and capacitive earthing or grounding in the safe area.

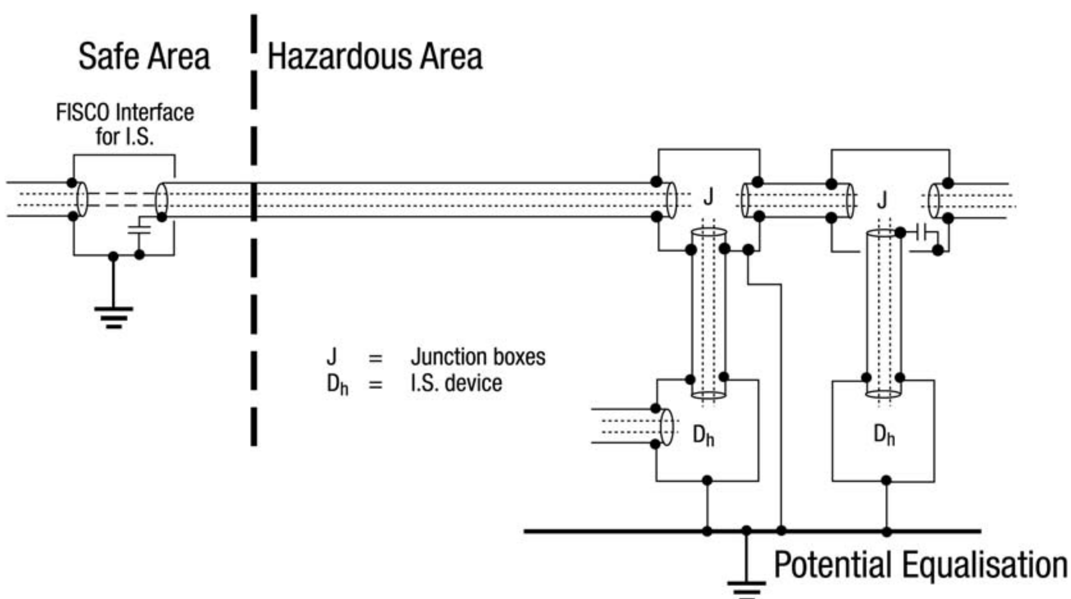


Figure 4.4.5: Distributed Fieldbus System with Shields. Partially capacitive earthing or grounding in the field connected to different local potential equalisations and hard earthing or grounding in the safe area.

All three principal concepts for shielding are in accordance with intrinsic safety following the entity concept as well as FISCO.