Title: INTRINSIC SAFETY MADE EASY

By:
TH Kuan
KL Automation Engineering Sdn. Bhd.
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Profile of Kuan Teik Hua

Mr. Kuan is a Director for KL Automation Engineering Sdn Bhd. He has 19 years of working experience in Ex'i protection. Prior to his current position he was working for a reputable German company for 16 years from an engineer position to the head of company in various countries in Asia Pacific. Mr. Kuan has traveled extensively in the AP region in promoting Intrinsic Safety since 1987. He also stationed in Korea for 8 years in building up the awareness on Intrinsic Safety in the mentioned country. Mr. Kuan has presented a number of technical papers in various International Conferences such as ChemAsia/InstrumentAsia in Singapore, International Seminar on Emerging trend in Offshore Technology & Safety in India, Sino-China explosion Protection Conference in China and a lot more.
Mr. Kuan graduated in Electronics Engineering at French-Singapore Institute (Part of Nanyang Polytechnics, Singapore) under EDB scholarship and Sales and Marketing at National Productivity Board of Singapore.
Mr. Kuan has spent a considerable amount of time in Germany and UK in learning various explosion protection techniques.

ABSTRACT

This paper aims to provide a quick understanding on the concept of Intrinsically Safe, various available intrinsically safe products and their technologies used including HART and Foundation Fieldbus (FISCO solution and Fieldbus Barrier).

The paper begins by introducing the origin and how the concept of Intrinsically Safe (I.S.) is started then it move on to explain how the zener and galvanical/isolation barriers are designed and its working principles with the famous ignition curves.

It then attempt to provide a brief comparison on conventional point to point DIN rail mounting barrier solution to a system approach solution.

The paper also provides some background on HART and points to take note when using HART and HART Mutiplexer as HART protocol has been available for quite some time.

Foundation Fieldbus is a hot topic as a number of recent projects in Malaysia applied foundation Fieldbus technology. This paper outline the concept of Foundation Fieldbus and explain the different between FISCO and Fieldbus Barrier and also point to take note when selecting them.

HOW THE CONCEPT OF INTRINSIC SAFETY WAS STARTED

The concept of intrinsic safety was originated in England during the year of 1913. On 14th October 1913, a serious explosion in the Senghenydd Colliery, Glamorganshire, South Wales, led to about 439 Welsh miners losing their lives. The official report on the incident gave the cause as explosion firedamp ignited by sparking from Leclanche signaling bell. Investigation by the British Home Office Experimental Station at Eskmeals showed that the sparking occurred when the circuit contacts inside the bell were separated or shorted. Further investigations by the same authority with the cooperation of Durham University in 1915 and 1916 showed that the sparking was due to the energy stored in the inductive solenoid of the bell but this could be reduced to a safe level by suppressing the coil, that is limiting the supply voltage to about 24 volts and restricting the energizing current by a non-inductive resistor. This lead to the evolution of INTRINSIC SAFETY.

Newspaper Cutting On the Incident


The Daily Mirror

20 Pages

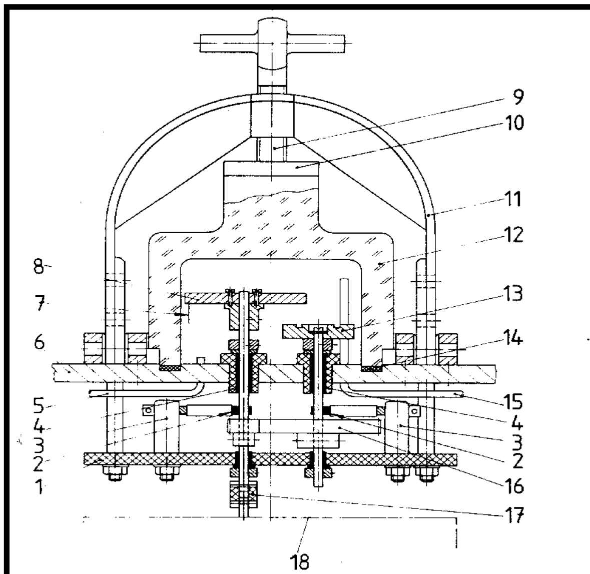
THE MORNING JOURNAL WITH THE SECOND LARGEST NET SALE.

WEDNESDAY, OCTOBER 15, 1913

TRAPPED IN A BLAZING MINE: "WORST DISASTER IN THE HISTORY OF THE WELSH COALFIELDS."

IGNITION CURVES

Ever since the incident happened, there are now huge volume of experimental work being carried out all over the world by using specialized apparatus which is known as "SPARK TEST APPARATUS" (refer to BS 5501 Part 7 EN 50 020). The studies have produced general agreed "IGNITION CURVES". These are the curves where the designers could use with suitable safety factors added to design intrinsically safe circuit.



1 Insulating plate	10 Pressure plate
2 Current connection	11 Clamp
3 Insulated bolt	12 Chamber
4 Insulated bearing	13 Contact disc
5 Gas outlet	14 Rubber seal
6 Base plate	15 Gas inlet
7 Contact wire	16 Gear wheel drive 50 : 12
8 Contact holder	17 Insulated coupling
9 Clamping screw	18 Drive motor with reduction gears 80 rev/min

Figure B4. Example of a practical design of spark test apparatus

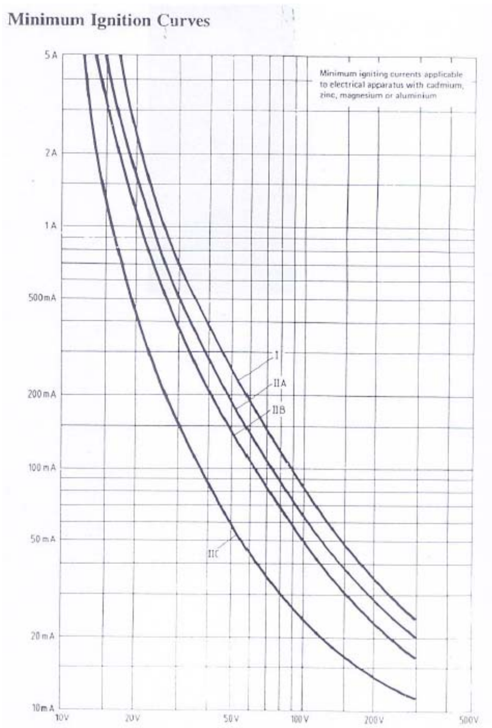


Figure1 – Resistive Ignition Curve

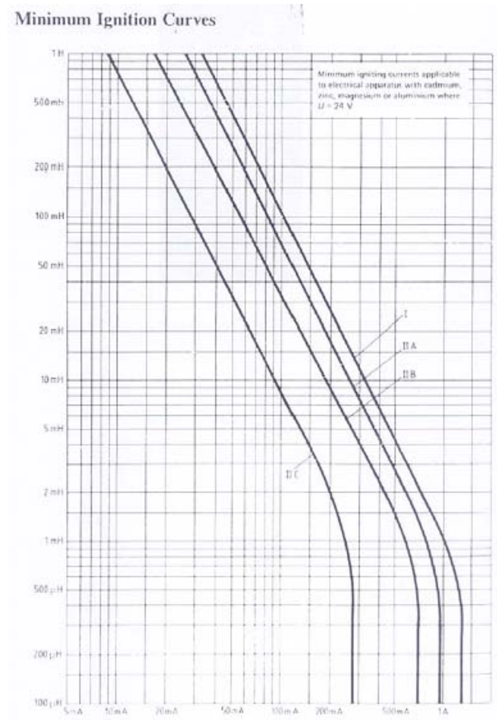


Figure 2 – Inductive Ignition Curve

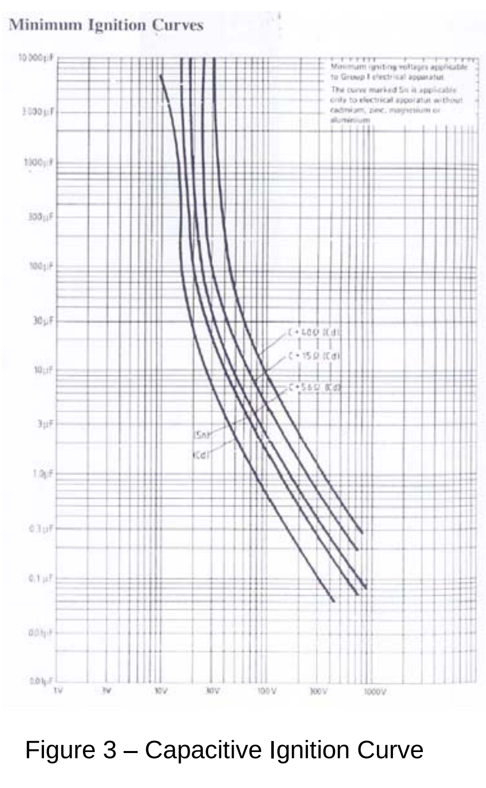


Figure 3 – Capacitive Ignition Curve

HOW SHUNT ZENER BARRIER IS DESIGN

From the ignition curve in figure 1, for a particular gas group, any combination of the current and voltage which falls below the curve will not likely to cause an ignition and values above the curve are capable of causing ignition. A circuit is intrinsically safe if the short circuit current and the open circuit voltage form a pair of values which plotted on the ignition curve, lies below the curve by a safety factor of 1.5. Shunt zener barriers are designed base on this principle behind.

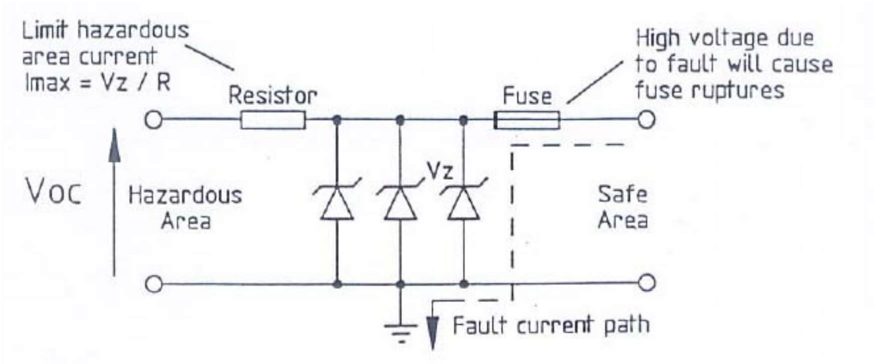


Figure 4 Typical Shunt Zener Barrier

A conventional shunt zener barrier as shown in figure 4 consists of a series of zener diodes, a resistor and fuse. These components prevent excessive voltages and currents developing in the safe area from faults in the system from entering the hazardous area.

These faults may exceed the rating of the fuse which will likely cause it to open, rendering the barrier inoperable.

The function of each component used in the conventional shunt zener barrier is briefly explained as below:

1. Fuse – to limit the maximum current that flow through the diodes
2. Resistor – to limit the maximum current entering the hazardous area
3. Zener diodes – to limit the voltage between the earth (ground) and the signal line or the open circuit voltage to the hazardous area

HOW GALVANICAL ISOLATION BARRIER IS DESIGN

Many early practical applications of intrinsic safety as a form of protection of electrical equipment in hazardous areas for surface industries depend on the use of Shunt Zener Barriers. It has been proven successful in these applications but Shunt Zener Barriers do carry some basic limitations such as:

1. They require a high integrity intrinsically safe earth connection to divert fault currents and they may connect the hazardous and safe area circuit together and to earth, putting constrains on the rest of the system.
2. The high integrity intrinsic safety earth must not be more than one ohm of resistance with respect to the installation main earth point. It must be regularly checked and maintained
3. In general, field devices are required to be insulated to 500Vrms, to prevent sparks due to differences in earth potential. Similarly, safe area circuits must usually be free from earth so that they can be earthed at the barrier without creating operationally undesirable earth loops
4. A regulated and approved power supply must be utilized. This will prevent the possibility of voltage rising too high, causing the fuse to open, or falling too low preventing the minimum voltage from reaching the field device.

The limitations of Shunt Zener Barriers are often not significant but where they are, they can often be overcome by ISOLATION BARRIERS. Isolation barriers offer three port isolation (input, output and power supply isolation) and reduced earth requirement. Together with the concept that each unit performances a complete signal conditioning function, this leads to much easier application and use of intrinsic safety as a protection technique.

Very often, isolated barrier contain a certified transformer which provides complete isolation between the safe and hazardous areas. There is no wired connection between the primary and secondary of the transformer. A simplified diagram is shown in figure 5.

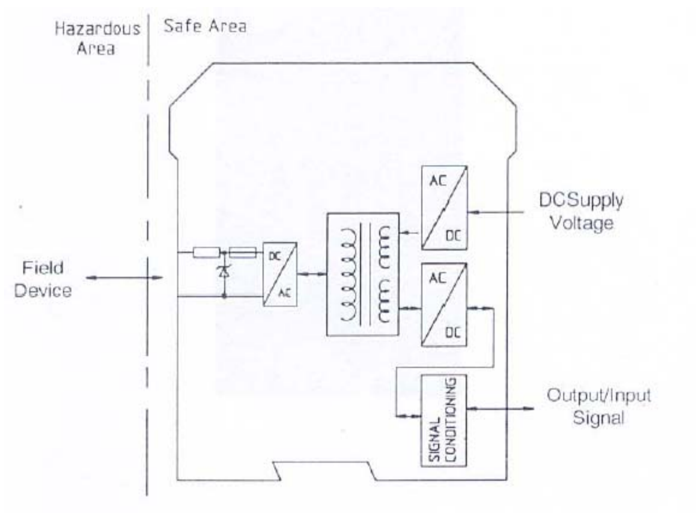


Figure 5 – Simplified diagram on Isolated Barrier

The isolated barrier contains a zener barrier for the voltage and current limitation, however it does not required an IS earth connection.

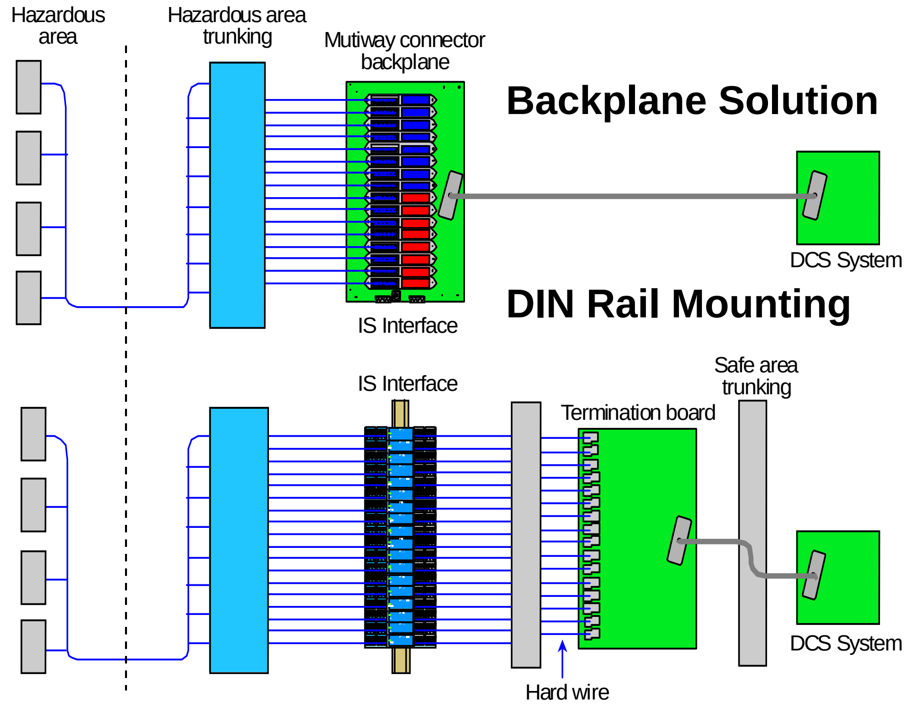
It is frequently asked how signals may be passed from the D.C. power supply through the transformer, since transformers will only pass A.C power and block D.C. This is because the barrier contains a static inverter which converts the D.C. to A.C., passes it through the transformer and then converts A.C. back to D.C.

BACKPLANE SOLUTION

Quite often users, consultants and engineering houses would like to take the system building approach into their design consideration. This approach is known as BACKPLANE SOLUTION. Backplane solutions give the vendors and users of the process control and safety systems the opportunity to integrate directly into their system without additional termination board or terminal block for cross wiring. As a result it has the following advantages:

Cost savings
Space efficiency
Easy to specify
System integration
High reliability

Below is a direct comparison for backplane solution and DIN Rail mounting solution.



HART CONNECTION IN I.S.
Background on HART

HART stands for **H**IGHWAY **A**DDRESSABLE **R**EMOTE **T**RANSDUSER.
HART is an open protocol that was originally developed in the late 1980's by Fisher Rosemount to communicate with their range of Smart field devices. Over the years it has become a de facto standard for communicating with SMART devices in the process industry. Over 100 manufacturers utilize the HART protocol in over 560 different products, from simple temperature transmitters to gas detectors.
The HART protocol is a powerful communication technology used to realize the full potential of digital field devices whilst preserving the traditional 4-20mA signal.

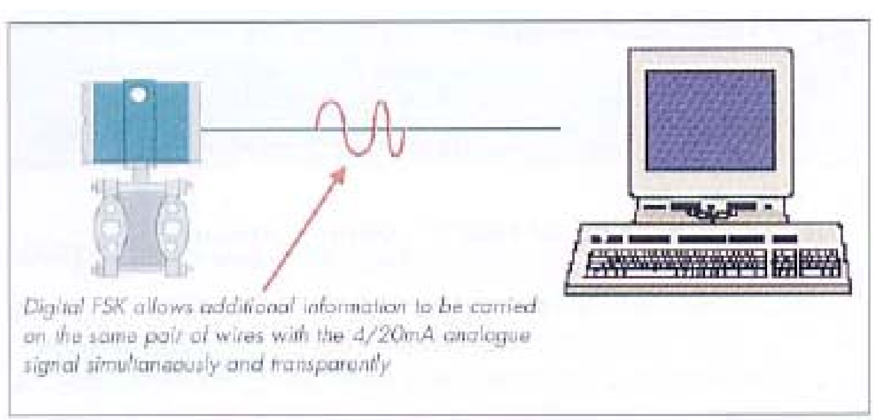


Figure 6 – Digital FSK allows additional information to be carried on the same pair of wires with the 4-20mA analogue signal simultaneously and transparently

HART is backward compatible with currently installed instrumentation. This ensures that investments in existing cabling and current control strategies remain secure into the future.

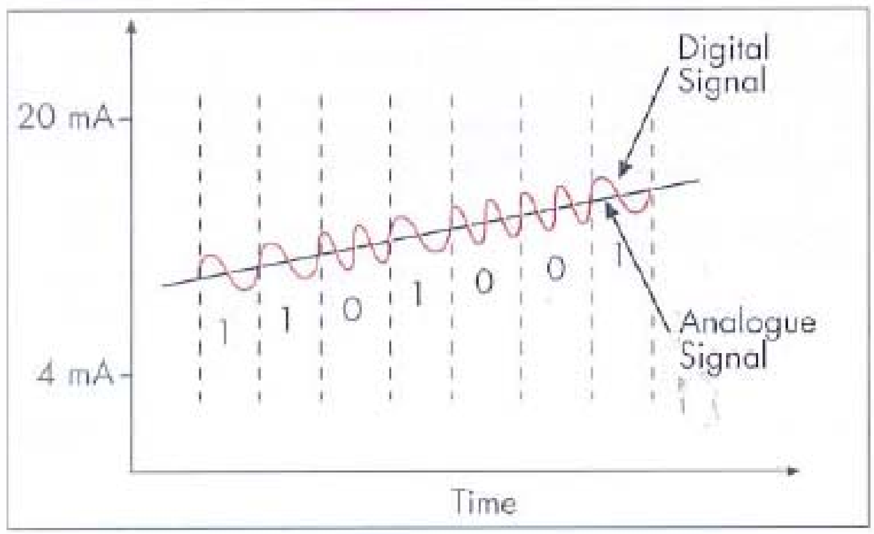


Figure 7 – Digital signal superimposed on the standard 4 to 20mA

HART digital signal is superimposed onto the standard 4-20mA signal. It uses Bell 202 standard Frequency Shift Keying (FSK) signal to communicate at 1200 baud. The digital signal is made up of two frequencies, 1200Hz and 2200Hz, representing bits 1 and 0 respectively. Sine waves of these two frequencies are superimposed onto the analogue signal cables to give simultaneous analogue and digital communications. As the average value of the FSK signal is always zero there is no effect on the 4-20mA analogue signal. A minimum loop impedance of 230 ohms is required for communication.
HART is a master-slave protocol – this means that a field device only replies when it is spoken to. Up to two masters can connect to each HART loop. The primary master is usually the DCS, the PLC or a PC. The secondary master can be a hand held configurator or another PC running an instrument maintenance software package (instrument management software). Slave devices include transmitters, actuators and controllers that respond to commands from the primary or secondary master.

The digital communication signal has a response time of approximately 2 to 3 updates per second without interrupting the analogue signal.

HART with I.S. Barrier

As described above, HART is a digital signal (1200Hz and 2200Hz) superimposed onto the standard 4 to 20mA. When selecting a barrier for HART, user will have to take note on the safety barrier so that the HART signal can be passes through the barriers in both direction (the design of the transformer in galvanical/isolation barrier must allow 1200Hz and 2200Hz to pass through). The 230 ohms resistor requirement for HART is automatically fulfill when barrier is used as all barrier for HART application has a resistor which is more than 230 ohms.

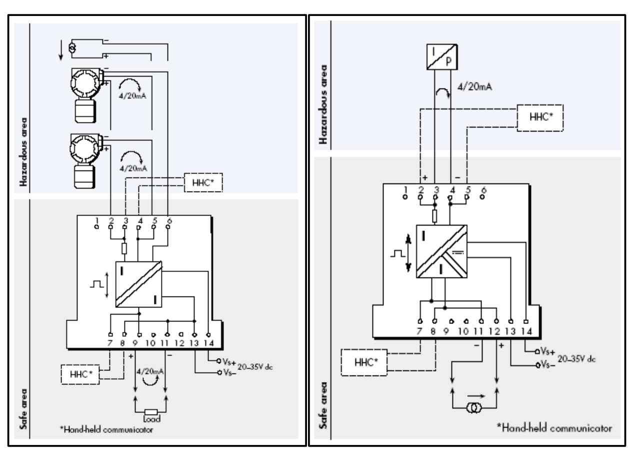


Figure 8 – Typical AI and AO barriers for HART application

HART Multiplexer

For DCS or controllers which do not have HART pass through capability require a HART Multiplexer. HART Multiplexer strips the HART digital signal from the 4-20mA signal (which passes to the control system unscathed) and sends it directly to a maintenance PC, thus giving access to the benefits offered by the latest powerful configuration and predictive maintenance software. Figure 9 is a typical HART Multiplexer system, its show a mix I.S. and general purposes (non-IS) application on HART Multiplexer.

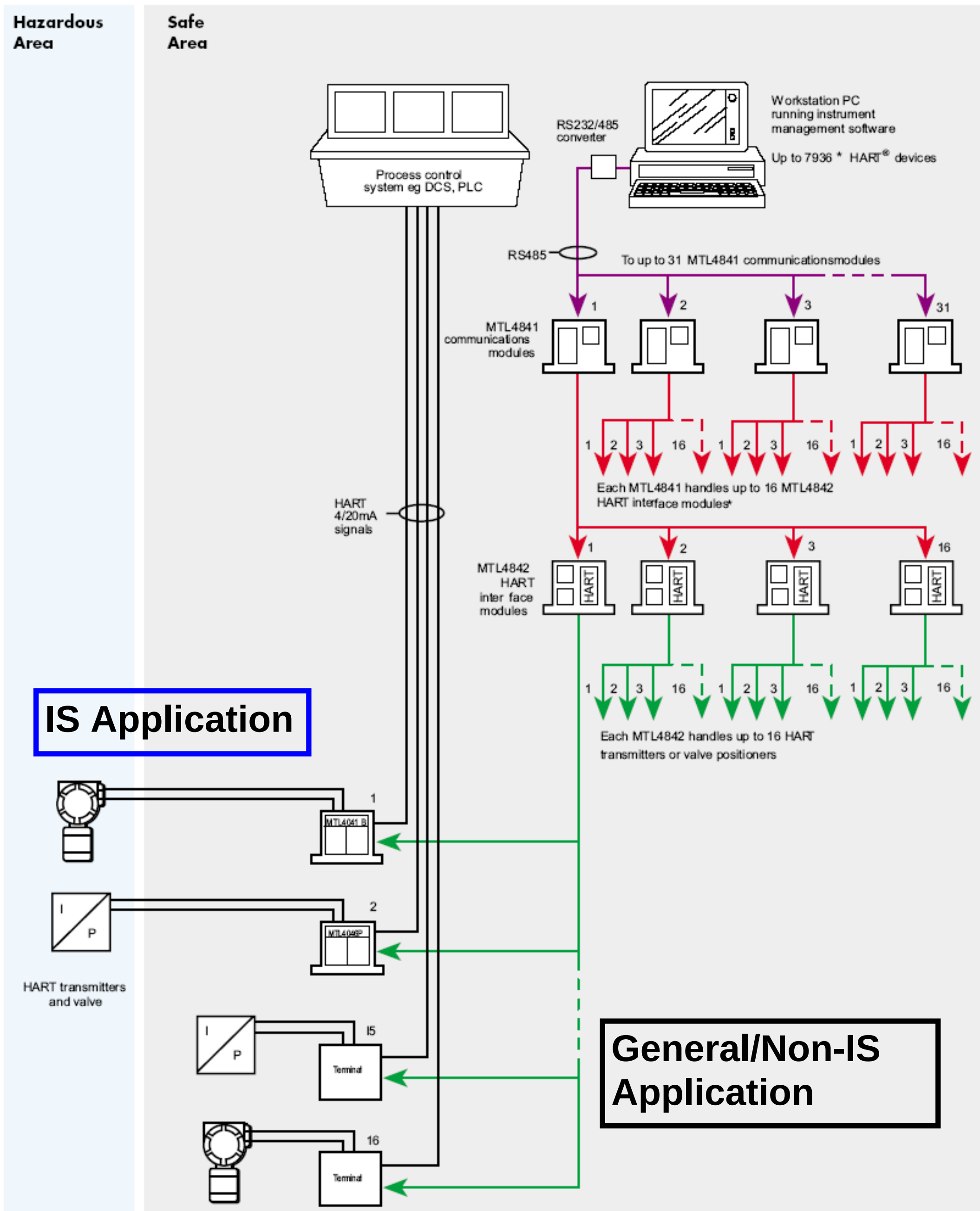


Figure 9 - show a mix IS and general purposes application for HART Multiplexer

FOUNDATION FIELDBUS IN I.S.

Fieldbus is a Local Area Network for process control that uses shared wiring for powering devices and carrying signals between devices (sensors, actuators and control devices). A power supply and a power conditioner are needed to provide Fieldbus power. A common type of Fieldbus configuration is show below. Two terminators are required.

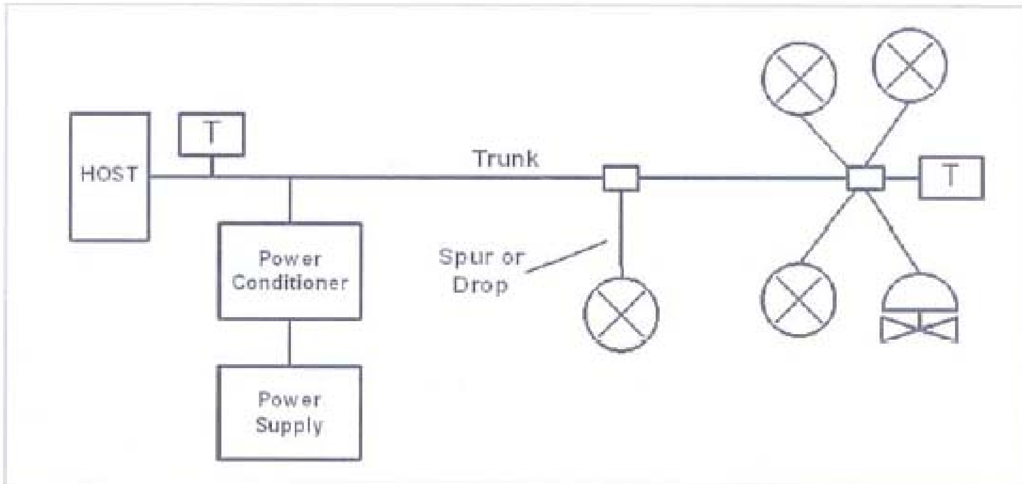


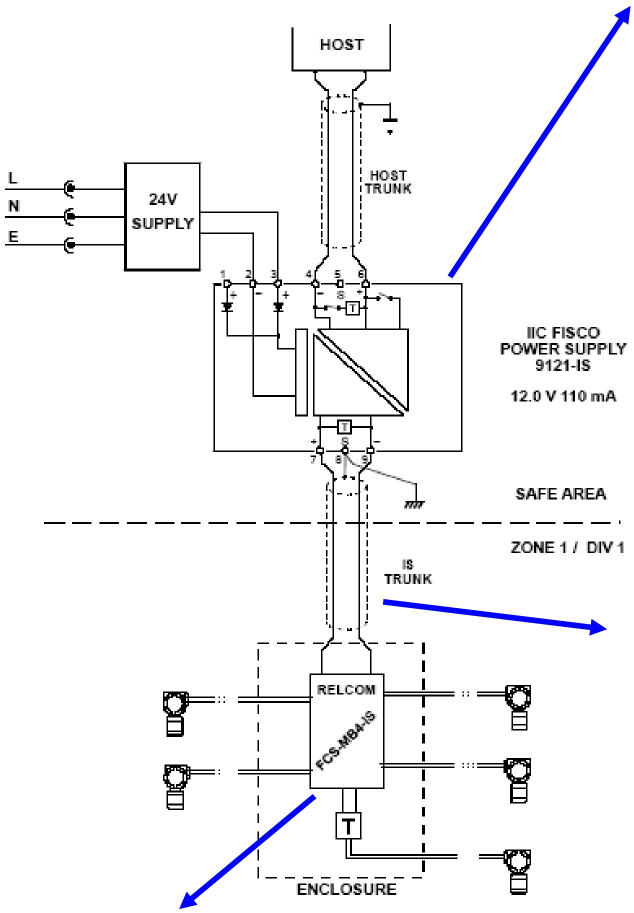
Figure 10 – typical Fieldbus configuration

*F*ieldbus *I*ntrinsically *S*afe *CO*ncept – FISCO

*F*ieldbus *I*ntrinsically *S*afe *CO*ncept – FISCO is to create an intrinsically Fieldbus system which can be safely created without a detailed safety analysis and permits the addition of further devices without having to reconsider that analysis.

FISCO is evolving based on experimental evidence and theoretical analysis done by German certification body PTB prompted by the practical limitation of the “Entity” concept when applied to a ‘low’ frequency (31.25 kbits/s) intrinsically safe bus systems.

An explanation on each of the functional block is give on the next page.

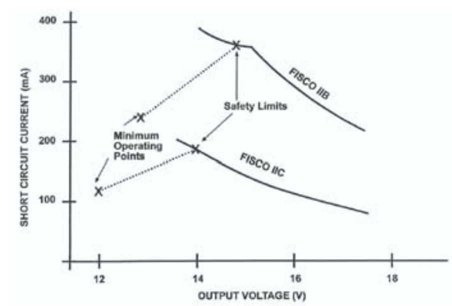


Wiring Hub (Megablock)

Usually, field device is connected to the system via spurs from the IS trunk so that any of the device can be removed or replaced without interrupting the operation of the whole system. 'Daisy-chain' connections and the use of more than one wire per terminal are not the recommended practice for both serviceability and reliability reasons. Another reason, wiring hub is required with built in short protection which prevent a short circuit in any of the individual field device or spur cable runs from bringing the whole Fieldbus segment down. For that purpose, MTL Megablock with SpurGuard™ could be used.

FISCO Power Supply / Fieldbus Power Supply

The FISCO standard utilizes recent work on the ignition capability of constant current power supplies to prose acceptable levels of power for supplies with a 'rectangular' characteristic (opposed to the resistor limited characteristic – linear power supply). This permits a greater useable power for the IS trunk, particularly if less sensitive gas group IIB satisfies the installation requirements.

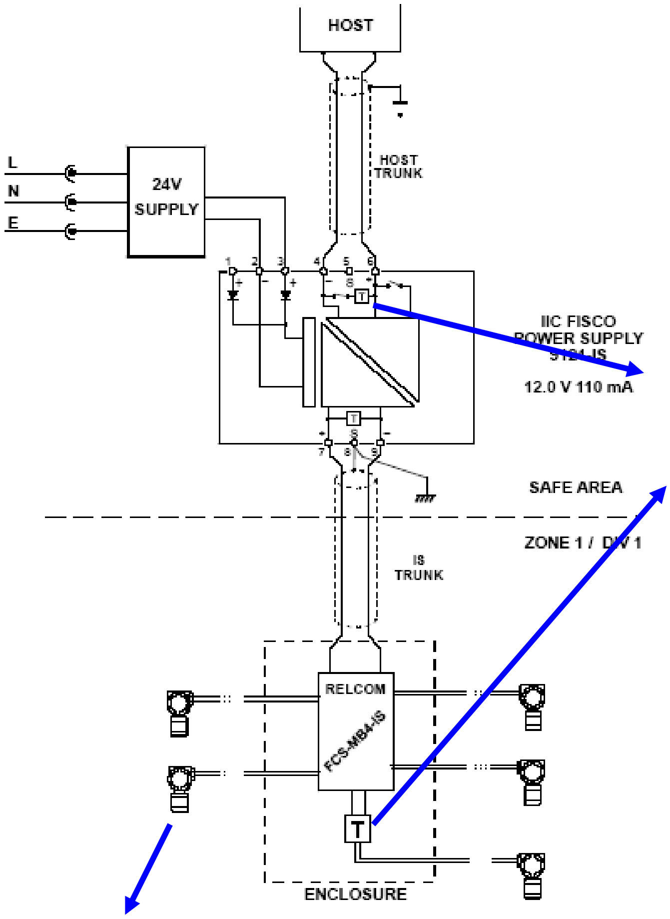


Permitted Safety Description For FISCO Power Supply

Cables

Experimental work demonstrate that, provided the inductance and capacitance per unit length of field cables are within defined limits, the risk of spark ignition does not increase with the total length. These findings have been used to simplify the design and documentation of IS fieldbuses.
Experimental work covers only a limited range of cable parameters, circuit voltage and current. Therefore the permitted specification of cables in the FISCO standard is as follows:

Parameter	Valve
Loop resistance	15 to 150 ohms/Km
Loop inductance	0.4 to 1mH/Km
Capacitance	80 to 200 nF/Km
Maximum length of each spur	60m in IIC & IIB
Maximum length of each trunk	1Km in IIC & 5Km in IIB



Terminators

The purpose of the terminator is to present a 100 ohms impedance at the trunk so as to match the cable impedance and to avoid reflections. A 1uf capacitor is connected in series to prevent continuous current drain. Adding a capacitor means that the terminator has to be certified. Normally, one terminator is come together with the FISCO power supply (switchable) and the other one can be build in together with the wiring hub or mount externally

Field Devices

The number of field devices, which can be connected to a FISCO power supply, is determined by the total quiescent current required by the field devices being not greater than the useable output current of the FISCO power supply.
The maximum permitted trunk length is then determined by the requirement to have a minimum of 9V available at the field device terminals. The trunk length is then determined by applying Ohm's law to the combination of cable resistance (Type =44 ohms/Km, for easy calculation many people used 50 ohms/Km), current flowing and the minimum power supply voltage.
The specification of the Fieldbus field devices is determined by the requirement to be compatible with the FISCO power supplies so that additional device can be added to a system without having to reconsider the system safety. Field device has to be certified to IIC and having the following input parameters: voltage, Ui 17.5V, current, Ii 380mA, power, Pi 5.32W, capacitance, Ci 5nF and inductance, Li 10uH. Devices may have any temperature classification.

Documentation

A major advantage of the FISCO concept is the reduction of safety documentation requirement as it is no necessity to carry out the apparatus compatibility checks or to calculate the safety parameters in the same way as for the entity concept and further additional field devices do not require a revaluation of the whole system. The gas group of the system is determined by the FISCO power supply, the temperature classification of the field devices by its certification. Hence, the documentation is only a list of connected devices. This could be done electronically (using available ‘asset management’ program) and can readily cross reference to the certification documents of the connected field devices.

ALTERNATION TECHNOLOGY – Non-Intrinsically Safe Trunk, Intrinsically Safe Spurs (Fieldbus Barrier)

Fully intrinsically safe bus segment (FISCO) offer full accessibility to the connected field devices while the bus is energized. The number of devices that may be supported on the bus is determined by the available current and voltage. For functional reasons of the physical layer, the maximum number of devices is limited to 32; in practice the limitation is determined by the available current and the capability of the DCS (presently, most DCS H1 card is cater for 16 devices). This current is derived from intrinsic safety ignition curves (see figure 1, 2 and 3 above) of the Fieldbus power supply by testing during certification process.

Fieldbus barrier use a method of protection other than intrinsic safety for the Fieldbus trunk. This has the benefit of delivery a higher current to the segment than is possible with intrinsic safety (scarifying live maintenance – trunk cable). Two type of Fieldbus Barriers available now, they are bus powered (figure 11) and separate powered (figure 12).

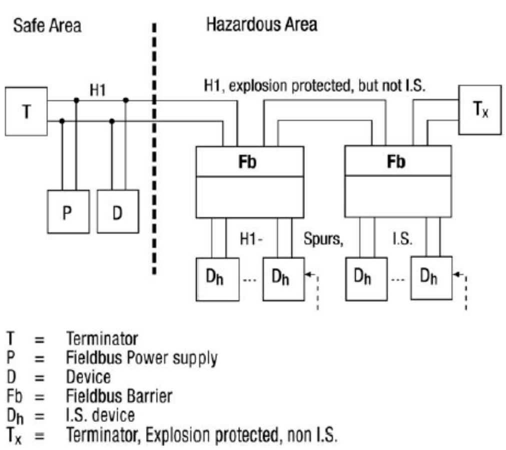


Figure 11: Bus powered Fieldbus Barrier

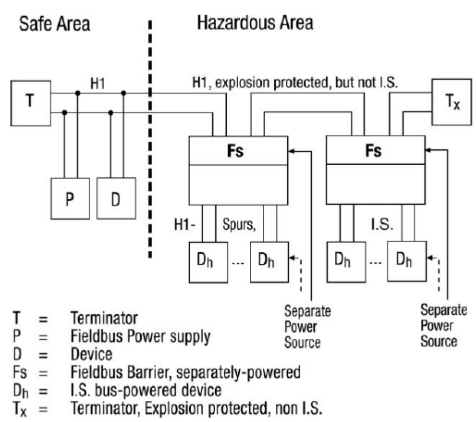


Figure 12: Separate powered Fieldbus Barrier

Intrinsically safe spurs may be generated by including voltage, current, power limiting components and limiting the internal capacitance and inductance within (see figure 13) the field mounted Fieldbus Barrier (Arguably on the life time as electronics are putting in the field).

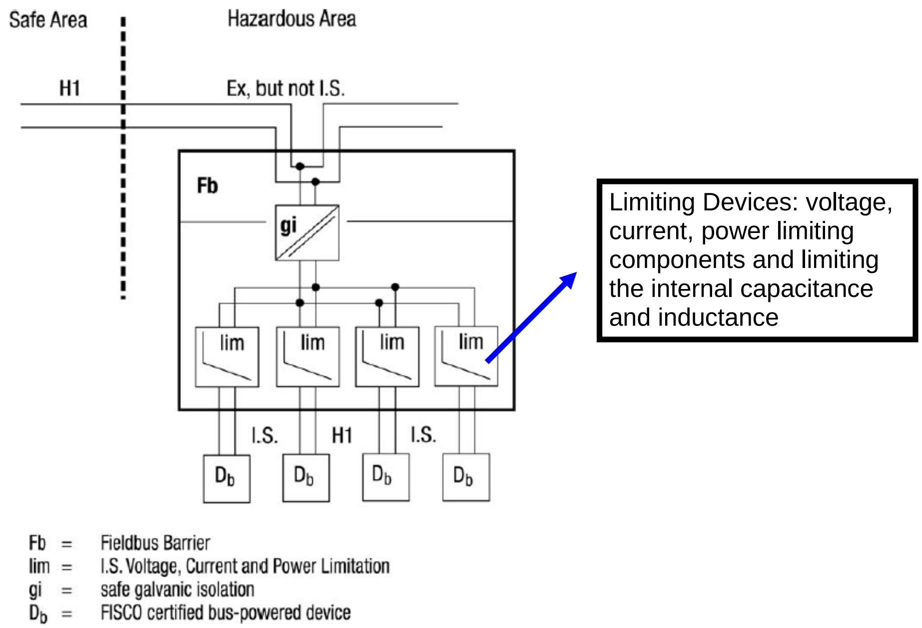


Figure 13: Fieldbus Barrier for Ex e trunk with I.S. Devices

When Fieldbus Barrier is use, the Fieldbus trunk must not be interrupted while energized in the hazardous area, unless proven to be gas free (example by gas detector) or by suitable certified connectors designed for live disconnection may be used, for example MTL951 Hazardous Area Connector.

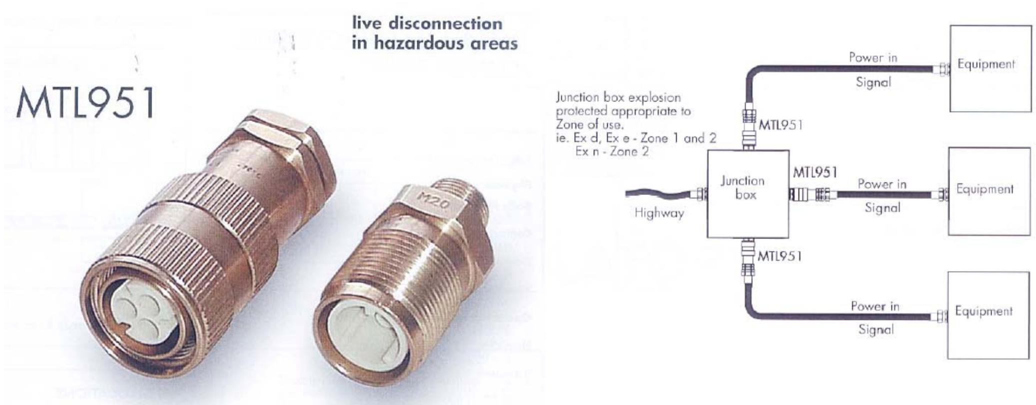


Figure 14: Connector - Live Disconnection in Hazardous Area

Fieldbus Power Supply For Fieldbus Barrier

Fieldbus power supply normally installed in the safe area which does not need to be explosion protected. If located in the hazardous area, the Fieldbus power supply must be suitably certified.

Reference and further reading:

1. Electrical Apparatus and Hazardous Areas by Robin Garside
2. EN 50 020: 2002, Electrical apparatus for potentially explosive atmospheres – Intrinsic Safety 'i'
3. IEC 60079-11: 1999, Electrical apparatus for explosive gas atmospheres – Part 11: Intrinsic Safety 'i'
4. IEC/TS 60079-27: 2002, Electrical apparatuses for explosive gas atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO)
5. Foundation Fieldbus Application Guide, AG 163 Revision 2.0
6. Foundation Fieldbus Application Guide, AG 140 Revision 1.0
7. Application and Specification Guide 9009001 – 2 Wire Transmitter by Kuan Teik Hua
8. Application note, AN9026 by MTL