Device bus? Sensor bus? Field bus?...or a broad-scope control bus? A view from a hazardous area

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Introduction

It is widely accepted that bus communication systems potentially offer many benefits in a wide variety of applications. This paper looks at the choice of bus systems from a particular point of view: that of the engineer who has to deal with hazardous locations – areas with potentially explosive gas mixtures present.

Hazardous areas have the same needs for monitoring inputs, controlling outputs, reading sensors and controlling processes as anywhere else. The benefits of using bus systems are just as great for hazardous areas. The difference when working with hazardous areas is that there are extra restrictions and costs of conforming to an approved methodology suitable for the hazards present.

This paper presents: the desires of plant engineer and instrument design engineer; an overview of alternative safety strategies; a review of bus systems available for use in hazardous areas and finally a comparison of the alternatives in the light of users' requirements.

From the point of view of a plant engineer

What does an instrument engineer want from a bus system in a hazardous area? Ideally to be able to deal with as many things in the hazardous area exactly as in the rest of his plant. He wants network configuration, data logging, high level diagnostics, inputs, outputs, control and so on. Just because the equipment is in a hazardous location, apart from keeping to the required safety regulations why should anything be different? A temperature in a hazardous location is just the same as a temperature anywhere else.

The engineer wants to be able to have a common man-machine interface to deal with the whole of his plant. He wants to deal as if it were a single network, not as a collection of different, application specific protocols. Benefits of such a network system include savings on training, installation and commissioning, spares holding and maintenance.

Perhaps this is being too idealistic? There are circumstances in which such a 'broad-scope' control bus may not be the best solution.

Perhaps the broad-scope control bus just does not have the required speed. In intrinsic safety (IS) everything is limited by the power available and a speed problem like this is more likely to be solved by using some solution other than a bus system (although as technology advances the question of what is high speed keeps changing).

Alternatively, an extension to an established plant without replacing the control system may be required. Perhaps some of the benefits of a bus system can be introduced by accepting a gateway between the old and the new. Even if the whole instrumentation system is to be replaced, the motivation may be to communicate more information on existing cabling.

If a broad-scope control bus satisfies the majority of user-requirements, but will not completely satisfy a small number of specialist needs this places an extra requirement on such a broad-scope control bus. To succeed, it must offer a straightforward capability of interfacing with busses that satisfy requirements it cannot, such as for high speed automation or management information.

From the point of view of an instrument design engineer

The designer and manufacturer don't want to have to work with many different version of the same product–with different protocols and different hardware but all doing the same thing. The designer's specialisation is the physical measurement, the analogue I/O and the hardware of the instrument, not in translating code between the different processors required for the various bus systems. Different hardware is particularly a problem when designing for hazardous locations because each of the different versions needs to be certified and this seriously affects speed to market with new products. You may argue that one bus suits a particular application and so one bus system can be adopted for each type of instrument – but the market has many different applications and opinions.

What is the solution for the instrument manufacturer? It is a versatile bus that customers can configure easily to suit their applications. Ideally this configuration should be carried out in the field. This would give a single variant of each type of instrument, reduced development, certification and stock-holding costs. The processor and communications could be common between different instruments and the designer could purchase ready certified components and concentrate resources on the areas in which they have expertise.

Whichever bus system is chosen, it must give the confidence that it is technically stable and that it will be available for at least a long enough period that any investment in development will be adequately recovered before technology moves on. Ideally the chosen bus system must be able to develop with technical advances.

The continuing demand for better performance and lower costs is most likely to be best achieved by a single bus technology for the majority of applications. A common bus technology with alternative communication media offers economies of scale in terms of development tools and expertise as well as in the cost of silicon.

Review of safety methodologies suitable for bus systems

Explosionproof, IS, encapsulation, powder filling and purging/pressurisation are the main explosion-protection methodologies used for electrical circuits in hazardous areas. The prevalence of their use varies both by type of application, power level required, and by geographical location (because of different regulatory regimes). Of the alternatives listed, explosionproof and intrinsic safety are the two most appropriate to consider for a bus communication system.

The explosionproof technique works by containing electrical equipment in robust, usually metal, enclosures. The enclosure is designed so that even if an explosion occurs inside there is no risk of an explosive mixture outside the enclosure igniting. Equipment using this technique is heavy and is expensive over the lifetime of a system. Live maintenance is not allowed – which is very restricting when considering a bus system. The whole section of bus connected together in a hazardous area must be isolated before any maintenance can be performed, even for the connection of an extra instrument. The main benefit of explosionproof as a technique is the level of power that can be used, although a secondary benefit is that safe area equipment has no restrictions or requirements for certification.

Intrinsic safety takes a completely different approach to making electrical circuits safe in the presence of explosive mixtures. IS works by limiting the energy that can be present to levels sufficiently low that even in the event of faults within the electrical equipment, it is impossible for ignition to occur. IS has three particular benefits: live maintenance is permitted; it is acceptable in even the most hazardous of locations and it is the most internationally standardised technique. Devices must be certified to meet IS standards and manufacturers are audited to ensure standards are complied with. IS offers great flexibility. The greatest challenge of IS is working within the limited power available. For bus system applications this power must be shared between all of the devices connected directly together. (Appendix A gives some details of the constraints.)

Many of the benefits offered by bus systems, especially in installation and maintenance, come from working on the network while it is live. For this reason, IS is the only feasible methodology for hazardous area bus systems.

What are the main consequences of IS constraints on bus system design? The most significant constraint is that of the power available to each device. If the total power on a bus segment to which many devices are the be connected (and from which they are to take power) is to be less than 1.2W (see Appendix A) then the number of devices is limited and the power overhead required by each device to operate to the bus protocol is a significant factor in determining this number. With current technology, whichever alternative bus system is considered, the number of nodes that can be connected together on one IS circuit is sufficiently small that the cost/benefit balance makes bus devices for single simple sensors or actuators not an attractive option. A far more practical solution is to share both the cost and power overheads of connecting to the bus between multiple I/O points.

The technical capabilities of the device which handles the bus protocol are typically far greater than previously have been located in hazardous areas. Any spare capacity may be used to increase the functionality of the hazardous area mounted device. A logical step to take, if it is efficient to connect multiple I/O to a single device is to group I/O that interact and to distribute into the field device at least some control or sequencing functionality.

What IS bus solutions for hazardous areas are available and how do they compare?

The list of IS bus systems looked at in historical order starts with a variety of proprietary systems (which are not going to be considered further because they are not “open”), HART, IEC1158-2 (used by Fieldbus Foundation, WorldFip, Profibus-PA) and IS-78 LonWorks®. IS-78 is currently the fastest open IS communication available.

It is debatable whether HART is a bus. When used in the mode in which digital communication is superimposed on a 4/20mA analogue signal it offers useful benefits, particularly for maintenance. Communication is slow, especially when used in multi-drop format, and HART does not really have the capabilities to satisfy the broader requirements of bus systems.

IEC1158-2 and IS-78 have similar capabilities of delivering power to hazardous locations, but IS-78 has a bit rate 2.5 times faster.

IEC1158-2 is a specification for physical communication. It is used by three alternative (competitive) protocols which are field busses (Fieldbus Foundation, WorldFip and Profibus-PA). They are all at various states of (in)completion. Trials of different elements of the protocols have taken place, but devices for these various protocols are not generally available commercially yet.

IS-78 is part of a complete, interoperable system which offers ready certified and proven performance. Transceivers and control modules are designed with and programmed in just the same way as corresponding safe area modules. They offer the same if not greater reductions in product development lead times to those offered for safe area developments because the components already meet IS requirements. Inevitably there are limitations introduced by the restrictions of IS, particularly the power available. However, IS-78 is versatile and it can be used to communicate to multiple devices in a hazardous areas, across hazardous areas, to devices in explosionproof enclosures. Dual redundant communication to hazardous area devices is also available. (See Appendix B for more details of IS-78 LonWorks.)

Where does IS-78 fit in terms of device bus, sensor bus, field bus or broad-scope control bus? Perhaps the best way to answer this question is to review a collection of typical applications:

- A system to monitor the strain in mooring hawsers for ocean-going tankers while they are being loaded. Each node monitors up to 8 load cells with a cycle time faster than one second. Measurements from more than 250 load cells are collected and processed. The benefits of using a bus system include a significant cable saving. A saving of cable gives a saving of weight, and of material and installation costs.

- Aerosol filling machinery. The traditional way uses PLCs with many discrete I/O, IS barriers and slip-rings. A bus system immediately offers some potential cost savings. A simple approach is to connect a controller to IS multi-channel input or output devices via a bus system. Operation is moderately fast, so if every switch closure generates a bus communication then care must be taken that the bus system is not overloaded. Perhaps a more attractive solution is for an IS multi-channel device to control much of the sequencing of the operation. This approach would greatly reduce the number of messages required and possibly could even eliminate the PLC!

- I/O for well-head operations. In its simplest form multi-channel discrete I/O devices could be used for valve limit switch monitoring and local indication of status. Further benefits could be added by connecting various other I/O such as pulse counters, analogue I/O and an operator interface to the same bus system. Benefits of using a bus system in this case include cable saving and the versatility of being able to connect a variety of different devices to the same bus system.

- Gas bottle filling machinery. This is quite similar to aerosol filling but is somewhat slower, with the extra complication of a variable tare for the gas bottles. Such a system requires a combination of operator terminal or bar-code reading for tare entry, various discrete inputs and outputs for bottle routing and load cell measurement for monitoring the filling operation. Such a filling line probably needs some overall controller to co-ordinate which filling head fills which bottle and ensure the correct tare value is used, although with careful design control could probably be distributed to the various I/O devices.

Conclusions

Considered from the point of view of both instrument manufacturer and end user there are strong benefits offered by having one bus system satisfy most applications – a broad-scope control bus system. A device bus, a sensor bus or a field bus triggers the question of "but how do I connect this to the rest of my system?" However, the market is not going to adopt just one bus system for every application for a variety of reasons: historical, political, technical and economic. If a broad-scope control bus, which is capable of satisfying most requirements, is also capable of interfacing successfully both to existing established systems and to complementary systems required for particular applications then a very attractive solution has been identified. Such a solution is likely to succeed provided the links to the other bus systems are available and do not introduce undue cost and performance handicaps.
In hazardous areas the choice of bus systems available is greatly restricted. However, by choosing IS as the safety methodology, many of the benefits of using bus systems are still available.

The applications discussed above illustrate just a few of the variety of different operations that can be interconnected on the same network. A broad-scope control bus offers a great opportunity for those who appreciate the flexibility of such a system. This is especially the case if the system offers rapid product development. The examples discussed above are all niche applications which offer significant cost savings from using a bus based solution. There are many more applications just waiting to benefit from a bus based solution. The challenge to maximise the benefit of using broad-scope control bus is to rethink systems completely and not just to think of the bus as a cable saving multiplexing system.

Appendix A: IS restrictions for bus systems

The laws of physics do not vary just because different circuits in hazardous areas are of different complexity or have different applications. Therefore, the overall restrictions imposed by intrinsic safety upon any circuit are similar whether it is a single instrument or a complete bus of sophisticated devices. There are constraints on voltage, current, power, inductance and capacitance. All of these must be satisfied to eliminate the risk of ignition. Every circuit must be protected in such a way so that even in the presence of prescribed faults in either equipment or interconnecting cables the combination is incapable of causing ignition.

Research and experience of testing with spark-ignition test apparatus have produced sets of minimum ignition curves which are used by national and international standards for IS. These curves show the limiting combinations of voltage with current, capacitance with voltage and inductance with current for safety and define which combinations can be used.

Contact with a hot surface is an alternative cause of ignition. The relevant parameter influencing this for hazardous-area installations is the worst-case electrical power transfer (the matched power). The higher the matched power, the greater the surface temperature that can be caused under fault conditions. when it is assumed that the maximum possible power is dissipated in individual components. Smaller components can be used if the matched power connected to the device is limited. This is a significant advantage because there are internationally agreed relaxations of the testing of designs to achieve a T4 temperature classification provided the power supplied does not exceed 1.3W for a maximum ambient temperature of 40 C, (with corresponding figures of 1.2W at 60 C and 1.0W at 80C). A T4 temperature classification covers the vast majority of industrial gases. These testing relaxations apply to all components with a surface area between 20mm^2 and 10cm^2 . While offering a significant advantage and simplification in the design and certification of equipment, the benefit is somewhat restricted when using surface mount technology because many common SMT packages have a surface area of less than 20mm^2.

Inevitably, the different constraints pull against each other and choosing the appropriate values for any particular system is an exercise of optimising a

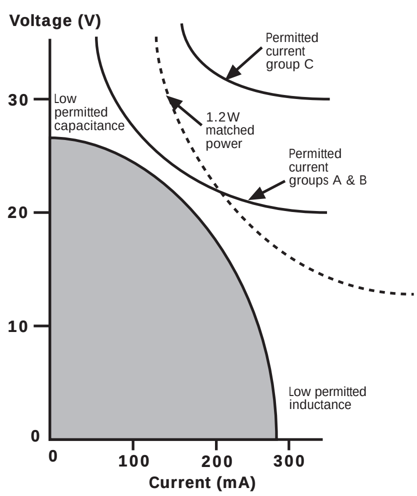

Figure 1: IS practical operating region

compromise. As is shown in Figure 1, the practical operating region is voltage-limited by the reduction of allowed capacitance, and current-limited by the reduction in allowed inductance (remember the cable itself contributes capacitance and inductance).

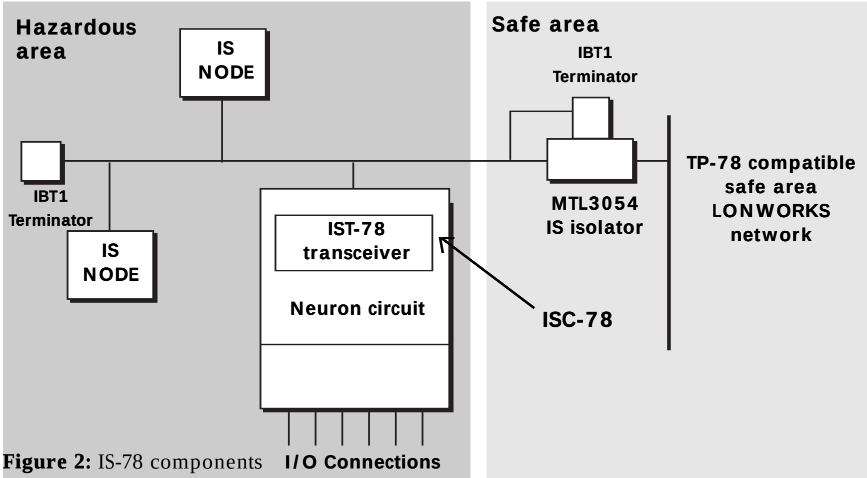

Figure 2: IS-78 components

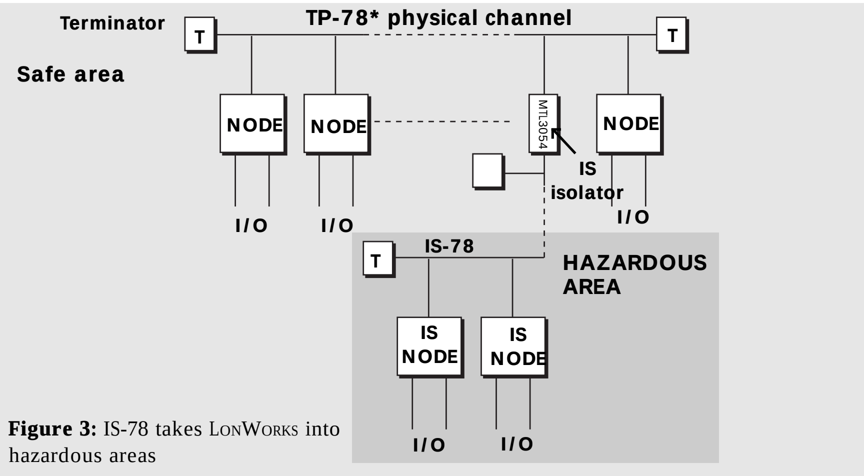

Figure 3: IS-78 takes LONWORKS into hazardous areas

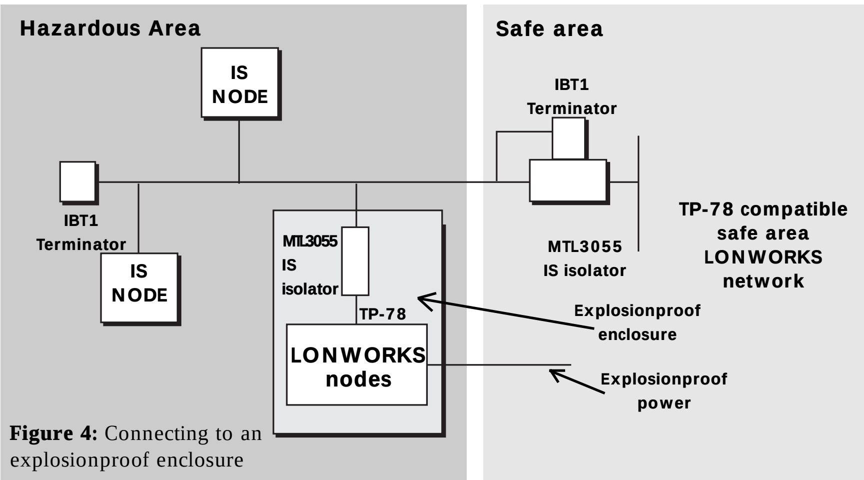

Figure 4: Connecting to an explosionproof enclosure

Appendix B: IS-78: IS communication for LONWORKS® networks

IS-78 follows the same principal aims of LONWORKS when it is in hazardous areas: an open bus system with proven, interoperable components freely available to any designer offering fast product development and guaranteed operation with other compatible LONWORKS devices. Figure 2 shows how a transceiver (IST-78) combines with a Neuron® circuit to form a control module (ISC-78) and this interfaces to application circuitry to form a device (a node). A number of nodes may be connected together on the same pair of wires in the hazardous area, the number only limited by the power that is available. In fact, with IS-78 there are additional benefit to the user of components in that they are pre-certified as components to be IS and so accelerated certification complements the accelerated product development.

IS-78 in the hazardous area connects to a standard safe area physical communication format through an IS isolator which performs three functions: guaranteed electrical limiting to ensure safety; conversion of signal form between safe and hazardous areas and the supply of power to the hazardous area bus devices (Figure 3).

As far as the network is concerned, the fact that part of the network is located in a hazardous area is (almost) transparent. The difference is only the same as a change between other different communications media (such as twisted pair, powerline or radio frequency) and in many applications even this will not be apparent to the user.

One of the major limitations of IS is the low level of power that is available in the hazardous are. Explosionproof, on the other hand allows much greater power to be used. The two techniques may be used together by using IS techniques to communicate across hazardous areas to devices mounted in explosionproof enclosures (Figure 4).

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