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ACHIEVING REDUNDANT INTRINSICALLY-SAFE FIELDBUS SEGMENTS FOR FISCO & ENTITY DEVICES

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During the last year or so, a variety of approaches have been released offering users new fieldbus segments with redundancy and FISCO device connectivity. This paper describes and compares those new designs with regard to segment capacity, MTBF, overall availability, installation areas and implementation cost. At first glance, fieldbus is mutually incompatible with intrinsic safety unless both compromise on segment design. Fieldbus works best when many devices are connected together on one segment and intrinsic safety is a design concept that minimises the available energy in any one cable. Many companies and approval bodies have collaborated to generate FISCO (Fieldbus Intrinsically-Safe Concept) designs but power supply redundancy as commonly used in non-intrinsically safe segments has not been possible. There are now new and novel designs that incorporate redundant I.S. power supplies, others that incorporate redundant power supplies with common I.S. sections, and still others that have redundant power with field-mounted I.S. interfaces. These complex products and designs need detailed comparison in order for users to make sense of the implications of any particular concept for their application.

Keywords: Fieldbus, Redundant, Intrinsic Safety, FISCO

1. Introduction

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2. Intrinsically Safe Fieldbus - AG163

With the active participation of a group of vendors and end-users, the Fieldbus Foundation has produced AG163 FOUNDATION Fieldbus Application Guide to 31.25Kb Intrinsically Safe Systems. AG163 Issue 2 provides considerable background to the development and performance of various intrinsically safe design concepts so only the overview will be described here. The output characteristics of the various intrinsically safe power supplies are shown in Figure 1.

2.1. 'Entity'

Entity systems may be described as 'classical intrinsic safety'; some sort of interface, (barrier or isolator) provides the source of power in the fieldbus segment, and the design has to take into account the fieldbus devices, the cable and all of their inherent capacitances and inductances in determining that the system is safe for the Gas Group and location required. Without describing the entire process, it is well documented that Entity systems initially used for fieldbus were only capable of delivering something like 80mA per segment. One significant advantage is that classical barriers used simple resistors as the current-limiting component and that design simplicity allows very high MTBF at little cost. The output characteristic is linear shown as Figure 1(a) and the systems architecture is shown as Figure 2(a).

2.2. FISCO

The Fieldbus Intrinsically Safe Concept (FISCO) initially established by PTB (Germany) replaces the traditional linear power supply with an electronic current-limiting power supply in order to allow more current into that segment. The output characteristic is either trapezoidal or rectangular, illustrated as Figure 1(b) or 1(c). Systems using electronic current limitation can only achieve Exib approval and are thus restricted to Zone 2 and Zone 1. Typical systems architecture is shown as Figure 2(b).

FISCO devices typically have parameters of at least 17.5V/380mA/5.32W. Commercially available FISCO power supplies can deliver 110mA in IIC and 265mA in IIB applications. Not only does FISCO allow more current into the segment, the design concept also allows the free use of cable and devices conforming to the FISCO specification with no regard to cable or device Entity parameters. This freedom is a consequence of an acceptance of a restriction in both cable type (see table) and of overall length (1000m total, 60m spurs). The use of electronic current limiting does lead to complex design and potentially expensive product, and also causes a very significant reduction in MTBF. Adding Entity devices (24V/250mA/1.2W) is also a problem, requiring an additional module per spur to incorporate further power limiting unless devices have an uncommon hybrid approval.

2.3. Split-Architecture

This design concept takes its lead from previous generations of panel-board instruments whereby front-of-panel indicators were married to back-of-panel control modules. In 'split-architecture', the conventional I.S. barrier resistive component is split into two pieces, one at the power supply end and the other in the field at the spur. This is particularly advantageous in fieldbus applications where the trunk carries current for all devices on the segment and each spur may be restricted to a single device at a time.

One commercially-available split-architecture design allows 350mA in the segment and each spur is intrinsically safe for IIC. Avoiding design complexity and retaining resistive limiting (albeit split into two pieces) keeps the system linear (and therefore suitable for Exia systems), avoids high cost and allows significantly enhanced MTBF compared to equivalent systems based on FISCO power supplies. A recent enhancement to this particular design is a revision to the certification allowing connection of FISCO devices to any spur, but without the limitations imposed by 'pure' FISCO systems (segment is still 1900m overall, spurs are still 120m each). A drawback is that the trunk cable and device coupler location is only IIB-approved though the device connections are all IIC – see Figure 2(c). This is overcome by a specific device coupler version which has Exe trunk terminals and thus allows IIC locations.

2.4. Fieldbarriers

These units are precisely that; I.S. barriers mounted in the field. An I.S. ground connection from a field enclosure is expensive and problematic even for experienced I.S. aficionados, so modern units replace the 'barrier' with the equivalent of a 'galvanic isolator'. The overall systems architecture (see figure 2(d)) therefore has one isolated power supply with fieldbus conditioning at the control panel with yet another isolated power supply with fieldbus conditioning in a box in the field. Since the field DC/DC isolator circuit has to be loop powered, this causes the minimum voltage for proper functionality to be raised, typically set at 16V for 10V at the spur. Overall, systems complexity is high, making for high cost and lower MTBF – 4-spur fieldbarriers are particularly disadvantaged. In general, fieldbarriers are approved such that the spur connections are suitable for both FISCO and Entity devices. One further issue not commonly disclosed is that each segment cannot have a large number of connected fieldbarriers without compromising the allowable segment 'jitter'; each fieldbarrier introduces a significant amount of jitter to that segment and the segment is allowed only 3.2µs before H1 communications become untenable.

3. Redundancy in Fieldbus

Standard fieldbus segments are based on multiple devices connected on one pair of wires, driven by a power supply and connected to a H1 card. The DCS vendors are generally delighted to offer dual H1 cards whereby the primary active H1 card has a low bus address and the secondary backup card is able to take over if that primary card fails. Similarly, there are fieldbus systems where the H1 communications cables are offered in redundant pairs such that communications, control and monitoring can be maintained should there be a cable failure. Making the fieldbus power supply redundant is simply a matter of connecting one or more power supplies together on the same fieldbus segment, at least, so long as the segment is not intrinsically safe.

Having two intrinsically safe power supplies connected to the same segment at the same time is not possible without severely restricting their capability; if an I.S. power supply can safely deliver 100mA, it is highly unlikely that 2 units in parallel making 200mA available will also be intrinsically safe. In the same vein, if it permitted to have 100mA in a particular configuration, then each power supply in a redundant pair for that configuration can only safely deliver 50mA and the segment designer can only count on 50mA for devices in his segment analysis.

There is another problem peculiar to FISCO; the FISCO design specifically allows only 1 active power supply in the segment, which makes redundant FISCO impossible to achieve with 2 permanently connected power supplies.

4. Practical solutions

There are several ways to get around these problems in allowing users of intrinsically safe segments the same confidence in their power supplies as non-intrinsically safe segment users. The following configurations are possible:

- redundant I.S. power supplies
- redundant power supplies with common I.S. section
- redundant power supplies with fieldbarriers

4.1. Redundant I.S. power supplies

As described above, it is not possible to have two I.S. power sources simultaneously connected to one segment. However, it is possible to have multiple I.S. power sources connected via a switch so that only one is allowed access to the segment at any one time. There is now a commercially available configuration of this type whereby two power supplies are made available for a segment, each unit controlled by an external module with 'hand-shaking' between the two units to ensure that only one power source can ever be connected to the segment – see Figure 3(a). In practice, the overall MTBF is only slightly improved because the linked control modules are not truly independent and clearly, the overall cost is quite high since the configuration requires both 2 power supplies and two control modules with the attendant demand for back-of-panel space and power. A consequence of this configuration is that the control modules must themselves be powered from the power available within the segment to avoid additional design complications and wiring, which still further saps the power available to the field.

4.2. Redundant power supplies with common I.S. section

In this configuration, the power supply can be whichever design is considered most appropriate; linear or switch-mode. They can be connected in parallel in the normal way and are then effectively load-sharing and hot-swappable pairs. One particular commercially available configuration uses conventional linear DC power supplies as the most cost effective design. The I.S. section is then made to be common to the two power supplies and here an Entity-type I.S. interface is the only practical solution – see Figure 3(b). This configuration achieves high MTBF performance by retaining the simple resistive element, further improved by having passive coil power conditioning and straight transformer isolation.

4.3. Redundant power supplies with fieldbarriers

In this configuration, the trunk is powered by redundant power supply modules, but there is no redundancy available at the fieldbarrier itself. Each fieldbarrier is in

actually a FISCO/ENTITY power supply located in the field and as far as is known, no one has yet attempted to provide multiple switched I.S. power supplies at that point. In all probability, it is not commercially feasible to do so and would make for a very complex systems design.

5. Architecture Comparison

Figure 3 compares the architecture of the two redundant I.S. systems described as 4.1 and 4.2 above. By adding the known MTBF's of the various components, the overall performance of each systems type can be evaluated - at time of writing, the MTBF of the Control Module in type 4.1 is estimated by the author, pending release of full information by that manufacturer.

Table 1 provides a detailed analysis of the various configurations. The segment capacity is calculated for 20mA devices (some vendors use 15mA device loads, mentioned in small print), and segment lengths are based on Type A 0.8mm² cable. Price data is taken from available List Prices.

Real life notes:

1. Most users stipulate that the minimum allowable segment voltage is at least 1V or 2V above the minimum 9V, which seriously penalises FISCO systems which tend to have low output voltage; 12.4V (IIC) to 13.1V (IIB).
2. The new FF standard to which fieldbus device couplers are being tested for registration (FF846-1) requires that the DUT minimum operational voltage must allow for reverse polarity diodes and other series components before the spur, and also include the effect of a single spur short-circuit on the segment; device couplers with 'current-limiting' designs lose another 40mA or so from the segment capacity, whereas device couplers with 'fold-back' spur short-circuit protection suffer no such loss.

6. Conclusion

Redundant intrinsically-safe fieldbus systems are now available in a variety of architectures. Comparisons between the various configurations clearly shows that the split-architecture approach has all the required characteristics of power supply redundancy and simplicity for high MTBF, has I.S. approval for both FISCO and ENTITY devices, and supports standard fieldbus cable lengths of 1900m total and 120m spurs at up to 350mA. What is somewhat surprising is that this system has been available since 2000 (FISCO connections added in 2008) and is already installed in over 100 locations across the world with (nearly) all DCS vendors. This widespread acceptance demonstrates that 'smart' design in fieldbus applications is finally able to overcome the dominance of the traditional I.S. interface suppliers.

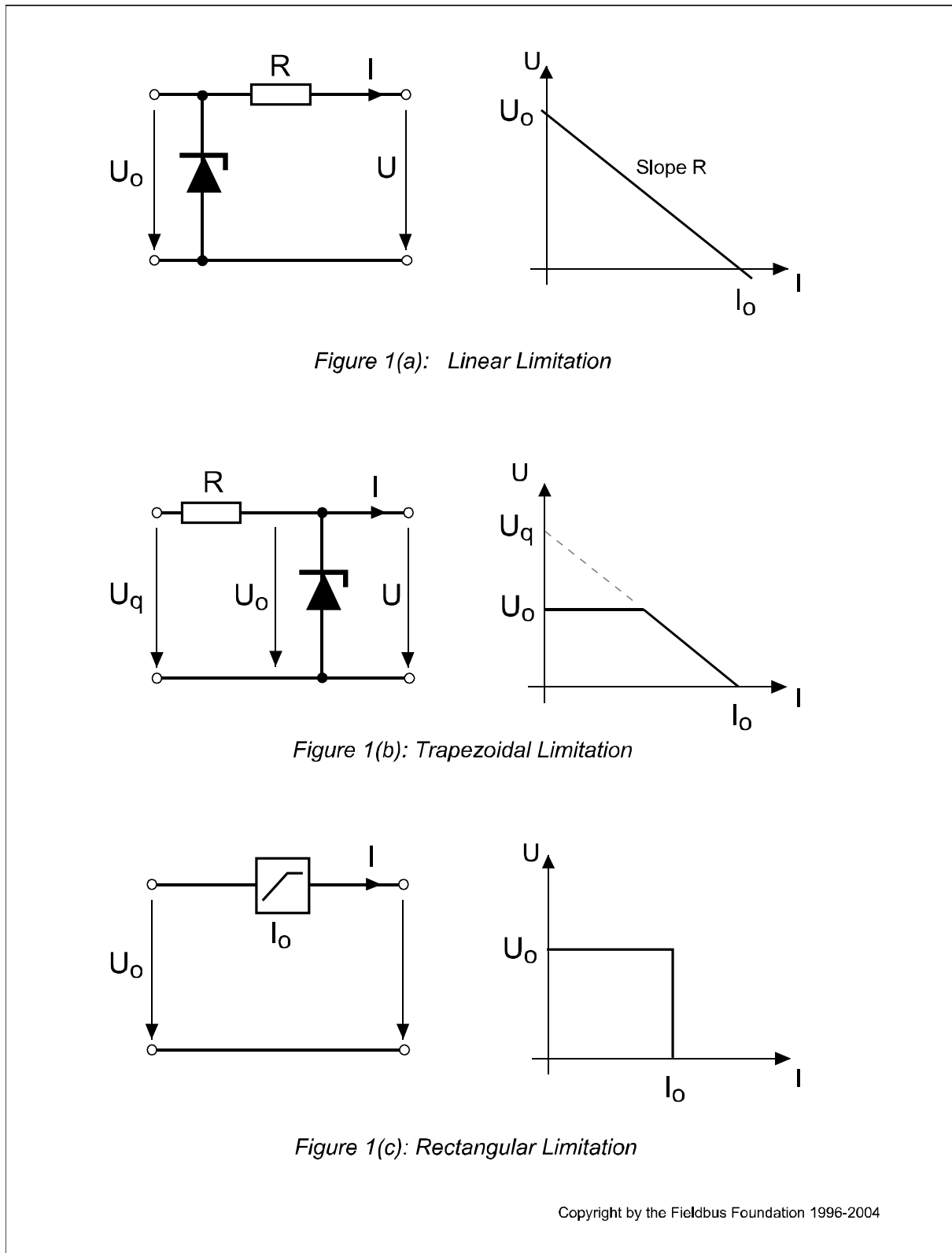


Figure 1. Intrinsic Safe Power Supply Output Characteristics.

Achieving redundant intrinsically safe fieldbus segments for FISCO and ENTITY devices.

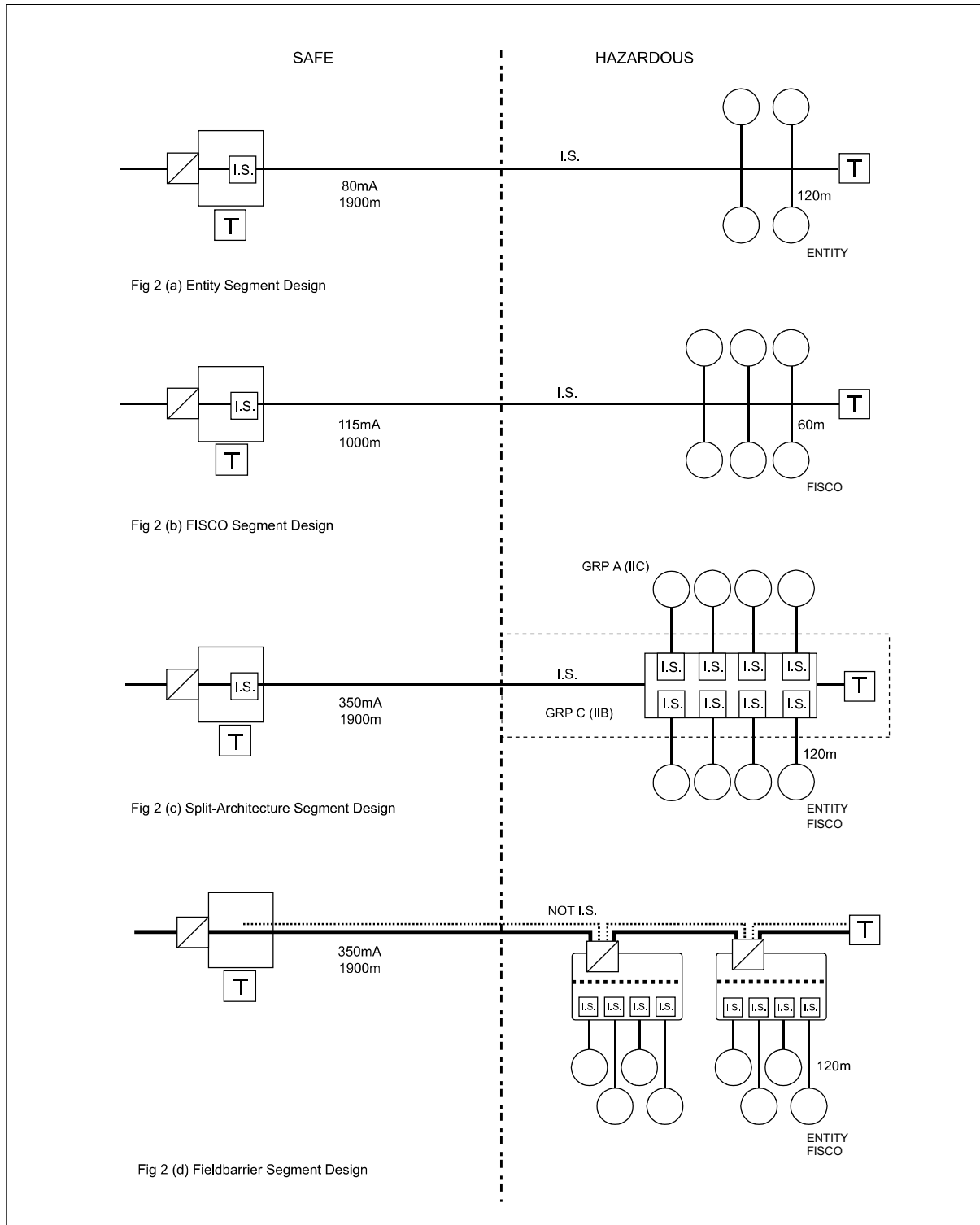


Figure 2. Intrinsically Safe Fieldbus system designs.

Achieving redundant intrinsically safe fieldbus segments for FISCO and ENTITY devices.

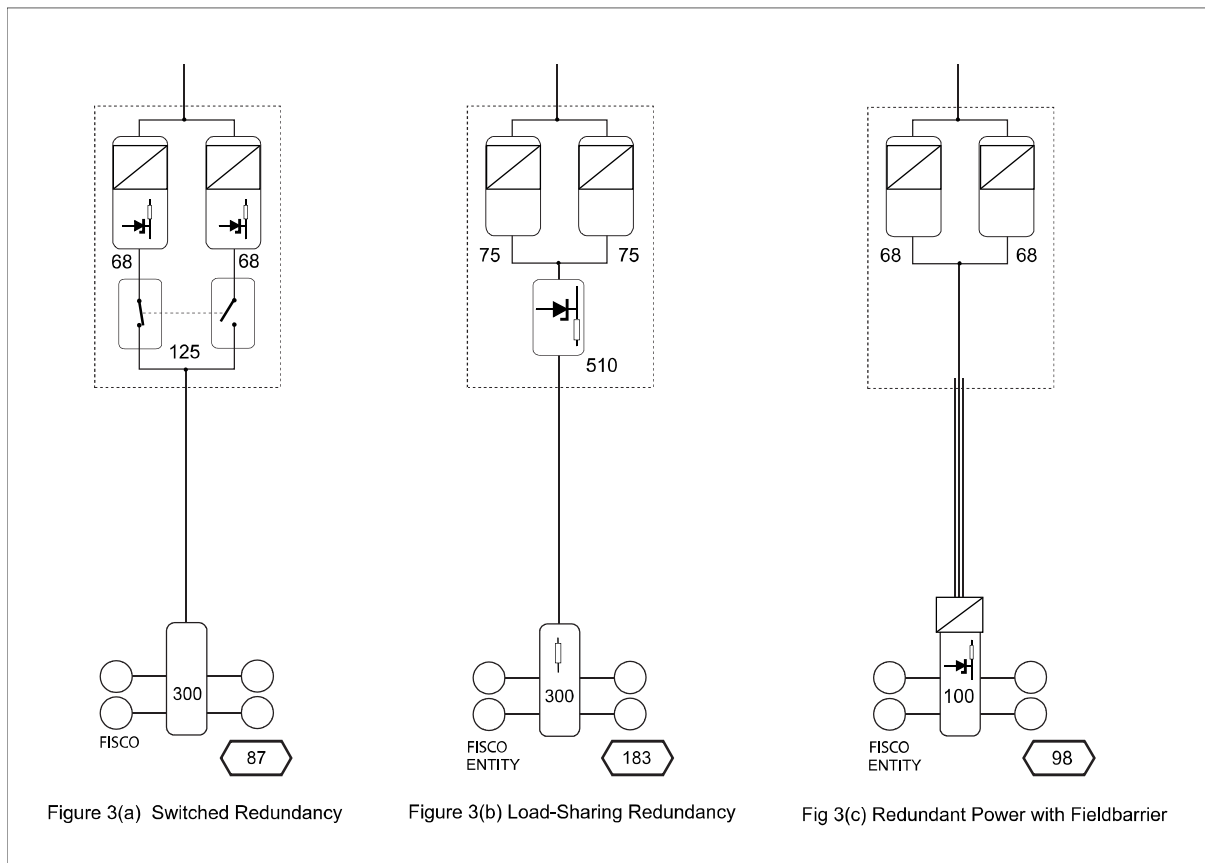


Figure 3. Redundant Intrinsically Safe Systems designs.
 (Figures refer to MTBF in years, estimated to MIL217K, comparative purposes only)

Achieving redundant intrinsically safe fieldbus segments for FISCO and ENTITY devices.

APPENDIX 1 GUIDENCE OF SEGEMENT CALCULATIONS

Every fieldbus segment design needs to be validated for performance. This is essentially an exercise in Ohms law, based on total segment load and total voltage drop. Vendor datasheets need to be consulted to get the base data for the calculation.

- Total segment load = (sum of all devices)
 - + (current taken by device coupler)
 - + (short-circuit load – it is normal practice to assume 1 fault)
- Total voltage drop = (source voltage)
 - (source voltage drop due to impedance at segment load current)
 - (spur voltage drop due to impedance & protection circuit)
 - (minimum device voltage)
- Cable capacity (Ω) = Total voltage drop / Total segment load
- Cable length (m) = Cable capacity / Cable resistance (Ω / km / loop)

Example:

Base data: Device load assumed 17mA
 Device minimum voltage 11V
 Cable 44 Ω /km/loop

	<u>FISCO (Redundant, IIB)</u>	<u>Split-Architecture (Redundant, IIB-IIC)</u>
Source voltage	12.9V	18.65V
Source impedance	not required	22 Ω
Device coupler load	3mA	25mA
Short-circuit load	42mA	0mA
Spur voltage drop	0.1V	1.0V

No. of devices	2	4	6	8	10	12	14	16
Redundant FISCO	660	426	315	249	206	176		
Split Architecture	1900	1125	690	439	275	160	75	9
Split Architecture (Dual Trunk)	1000	1000	1000	1000	874	690	550	439

Table 1. Segment Capacity (no. of devices vs segment length (m))