

INDUSTRIAL FIELDBUS TECHNOLOGY AND FIELDBUS CABLE OVERVIEW - CABLE STANDARDS AND ELECTRICAL QUALIFICATIONS

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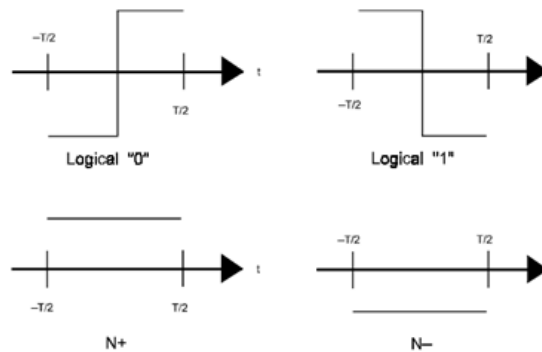
Abstract - The purpose of this paper is to educate operators, facility and design engineers about Fieldbus technology and Fieldbus communication in industrial and Petro-Chemical facilities. Fieldbus technology is a rapid growing infrastructure for automation and field control in North America and around the world. The technology is governed by standards that allow the freedom to choose and power to integrate field devices, cables, host systems. Fieldbus Foundation, a not-for-profit organization created standards that improve safety, operability and reduce cost when adopting Fieldbus technology. Fieldbus Foundation tests and registers Fieldbus devices to ensure that they meet Fieldbus Foundation specifications and marked with \sqrt{FF} for interoperability assurance.

In addition to Fieldbus technology and the function of Fieldbus Foundation, the paper will explain and educate about Fieldbus cables technology and cable construction. The paper will review the governing cable standards in Europe and US (IEC, Fieldbus Foundation, ISA), cable electrical specifications and the types of Fieldbus cables that are available for locations such as Class I DIV 1 and off shore platforms.

Index Terms – FF, Fieldbus Foundation, Foundation Fieldbus, H1, HSE, EDDL, ISA 50.02, IEC 61158, FF-844, Fieldbus cable, Characteristic Impedance, Attenuation, Capacitance Unbalance, MC -HL, TC, Type P, Fire resistant, ITC, PLTC, -ER

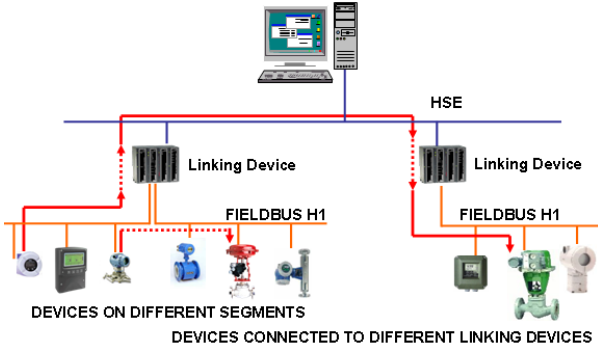
I. INTRODUCTION

Fieldbus technology incorporates a complete solution for the implementation of field automation and field control. Fieldbus is a Digital, Serial, Multidrop, data bus for communication with low level industrial control and instrumentation devices such as transducers, actuators, and local controllers.



Two of the benchmarks that drive Foundation infrastructure application are the **Freedom to Choose** and the **Power to integrate** when implementing Fieldbus installation. The choice and power are not left totally open to anyone's interpretation. The Fieldbus infrastructure brings a common frame of reference to the technology; choices are guided by specifications and registration and application.

Scalable Environment One Technology At Two Speeds

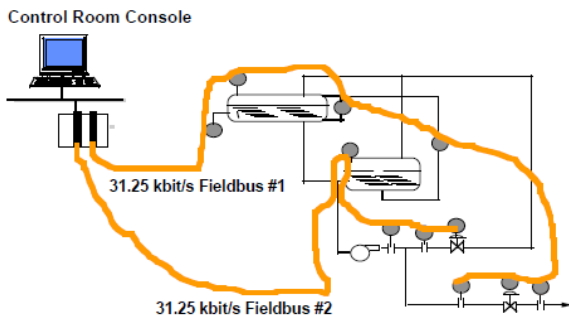


II. THE FIELDBUS NETWORK

Fieldbus network vs. Ethernet communication

	Fieldbus communication	High speed internet
Speed	31.25 kbits/s	100 Mbits/s
Distance (per segment)	1900M / 6300 ft	100M / 330 ft
Two – wire	Yes	No
Multidrop	Yes	No
Bus power	Yes	No
Intrinsically safe	Yes	No

Fieldbus Network VS 4-20mA network



4-20 mA requires wire to each device from the host. Fieldbus requires one wire between all devices because each device has its own address on the network.

Fieldbus technology allows many smart devices to share one communication network. The digital communication signal is superimposed onto a DC carrier. This reduces the amount of terminations to connect all the field

devices to a host system and allows greater flexibility for future additions of I/O points.

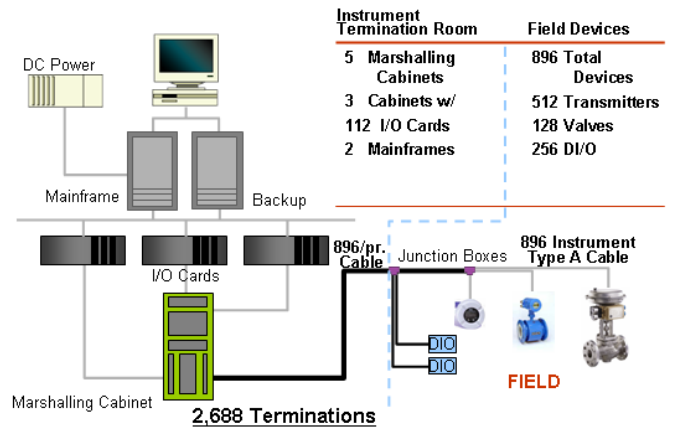
4 -20 mA and Fieldbus Wiring Similarities

- Uses existing industry standard terminal blocks
- Uses similar industry standard wiring practices
- Provides for intrinsic safety requirements
- Provides for redundant power supplies

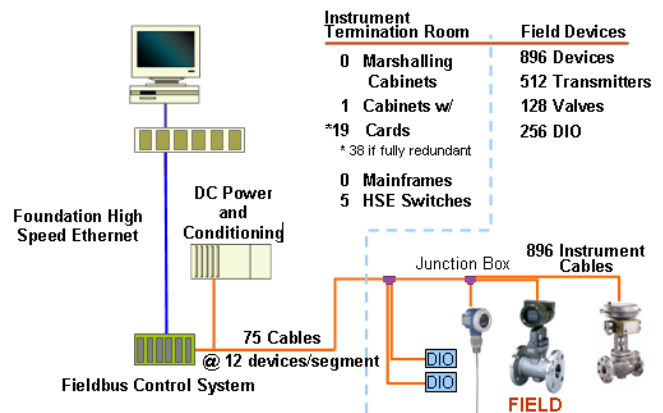
4 - 20 mA Wiring Differences to Fieldbus

- Fieldbus supports up to 32 parallel field devices
- It is a balanced transmission line
- Requires an impedance matched power supply
- Requires a terminator at each end
- Prevents reflections and noise

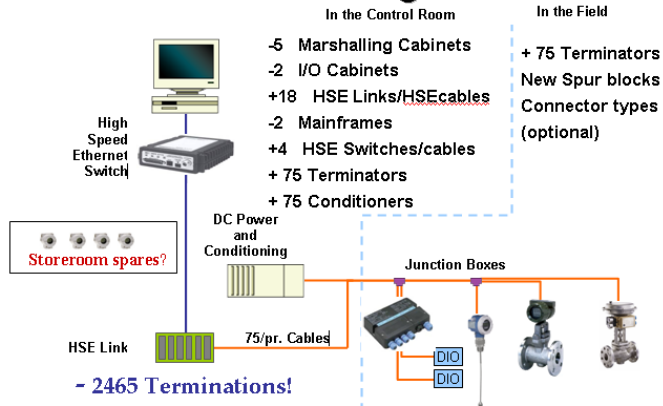
Traditional System



...Fieldbus Changes The Landscape



What Changed?



Fieldbus Project Costs

Estimated Project Savings

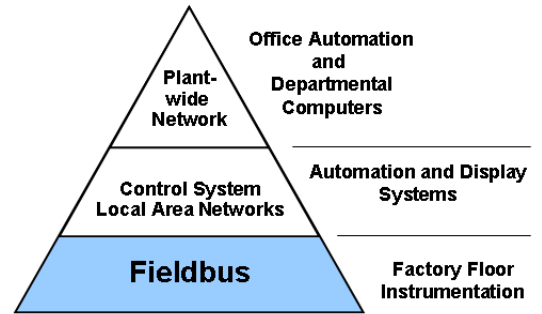
- Materials/Field Devices: Increased by 15%
- Installation Labor: Reduced by 50%
- Commissioning: Reduced by 75%
- Engineering: Reduced by 50%
- Overall Capital Savings of 25 – 30%

Advantage of Fieldbus Network

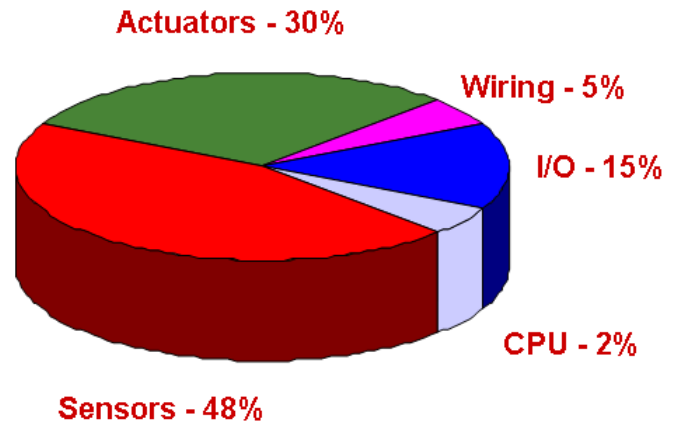
- A configurable control system
- Decentralized control
- Factory floor H1 segments are bridged with existing High Speed Ethernet networks
- Status information relating to the health and quality of the data in addition to the measurement
- Status information includes quality, sub-status, and limit information
- Measurement validations in real time
- Field diagnostics provide the right information to the right person at the right time
- Fault tolerance without need for redundancy
- Dynamic and static operational parameters can be viewed
- Improved control with 100% deterministic single loop integrity in the field
- Supports Safety Instrumented Functions

Plant Network Hierarchy

Fieldbus is a key part of the plant data network



Areas of Failures



65% of work orders generated for transmitters are unnecessary – either no problem or problem with other equipment

75% of control valves removed from process lines did not require removal

50% of instrument tech's time is spent on paperwork

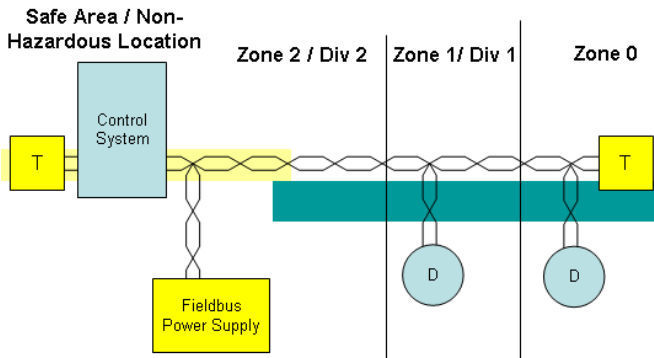
Industry Served

Chemical
Oil & Gas
Manufacturing
Food and Beverage
Water & Waste Water
Power Industry
Pharmaceuticals
Metals & Mining

Reason for adoption

Real time diagnostics
Control in the Field
Single loop integrity
Higher availability
Avoiding shutdowns
Tighter control

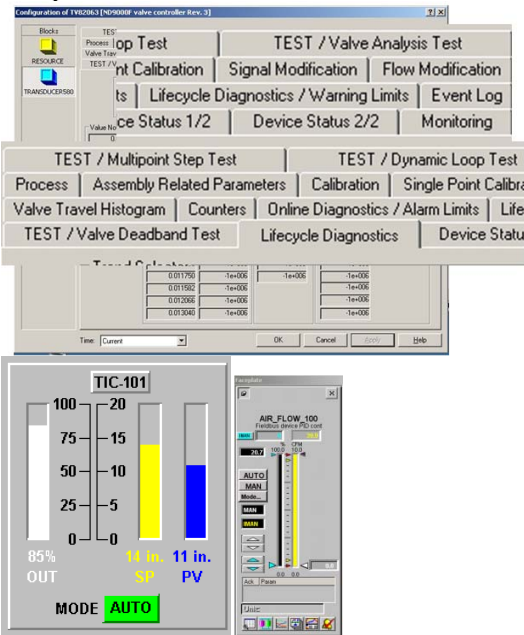
Fieldbus in hazardous areas



Fieldbus offers all hazardous area option from intrinsically safe to explosion proof.

Fieldbus Software

The Fieldbus software is platform independent. Most host system software is Windows based and it allows extensive diagnostics of the network and the devices. The software carries the device history in case of repair or replacement.



III. Fieldbus Foundation

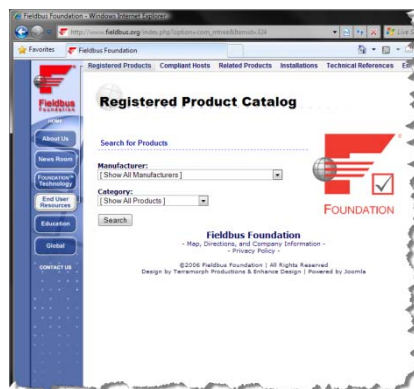
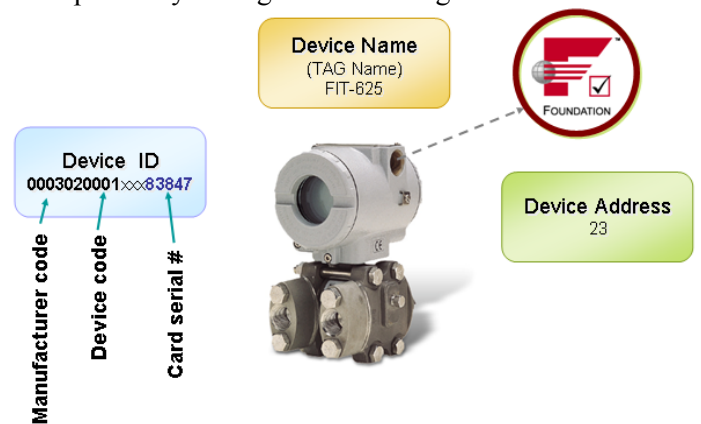
What is Fieldbus Foundation?

Not for profit organization that organizes development programs, conducts field trials, and establishes the industry program for testing and registration of Fieldbus devices.



Device marking and registration

Foundation Fieldbus standards bring a common look and feel to system information, Interoperability of Foundation Fieldbus devices is assured by the Fieldbus Foundation's program for conformance and interoperability testing and device registration.



Foundation Fieldbus registered 400 Devices up to date. More than 1.2 Millions Foundation compliant Devices were sold and 15,000 systems were Installed!

A Foundation Fieldbus device is addressable and can store and transmit data. The devices can store values, track changes and use pre-set alarms to trigger. Based on pre-defined tag names host systems can read transmitter

values such as temperature and pressure to set values of a valve actuator.

IV. COMPONENTS OF Fieldbus Foundation

Foundation H1

Foundation H1 is intended primarily for process control, field-level interface and device integration. Running at 31.25 kbit/s, the technology interconnects devices such as transmitters and actuators on a field network. H1 is designed to operate on existing twisted pair instrument cabling with power and signal on the same wire. Fiber optic media is optional. It also supports Intrinsic Safety (IS) applications.

Foundation H1 devices comprise a function block application, act as a publisher and subscriber of process variables, transmit alarms and trends, and provide server functionality for host access and management functions. Devices can act as a scheduler and time master for regulating communication on a Fieldbus segment. They are also used for bus interfaces in process control systems or in linking devices. Capable of controlling bus communications and many connections to multiple devices, they support both client and server applications.

H1 technology enables field instruments and other devices to execute control functions reducing the load on plant computers and workstations. Since the H1 network is digital, I/O conversion subsystems are eliminated. The Fieldbus Foundation tests and registers the devices to ensure interoperability of registered instruments from multiple vendors. This enables the end user to select the best instruments for the application regardless of the host system supplier.

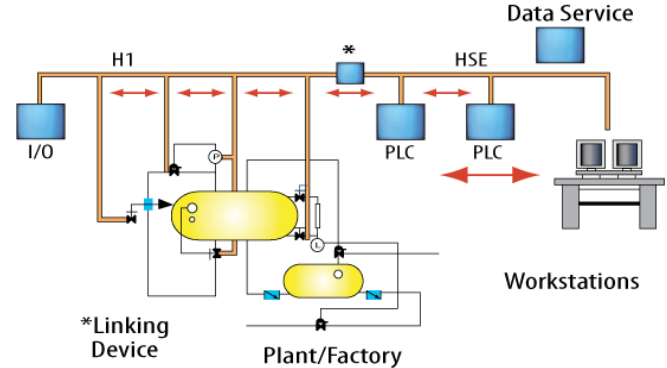
Reports from leading adopters of the Foundation protocol demonstrate the advantages of control in the field with the H1 solution. For example, end users in the petrochemical industry have realized up to a 30 percent reduction in operating costs due to advanced diagnostics. Users have also seen that the all-digital H1 communications network is far less susceptible to electrical noise than traditional 4-20 mA analog systems.

H1 technology enjoys widespread acceptance throughout the process industries, and is included in the international IEC standard (IEC 61158).

Foundation HSE

High Speed Ethernet (HSE) is ideally suited for use as a control backbone. Running at 100 Mbit/s, the technology is designed for device, subsystem and enterprise integration. It supports the entire range of Fieldbus capabilities, including standard function blocks and

Device Descriptions (DDs), as well as application-specific Flexible Function Blocks (FFBs) for advanced process and discrete/hybrid/batch applications.



HSE supports complex logic functions, such as those performed by Programmable Logic Controllers (PLCs), or data-intensive process devices, such as analyzers and gateways to other networks. HSE enhances access to H1 Fieldbus technology via linking devices, while providing expanded capabilities for high-speed automation devices and hybrid/batch applications.

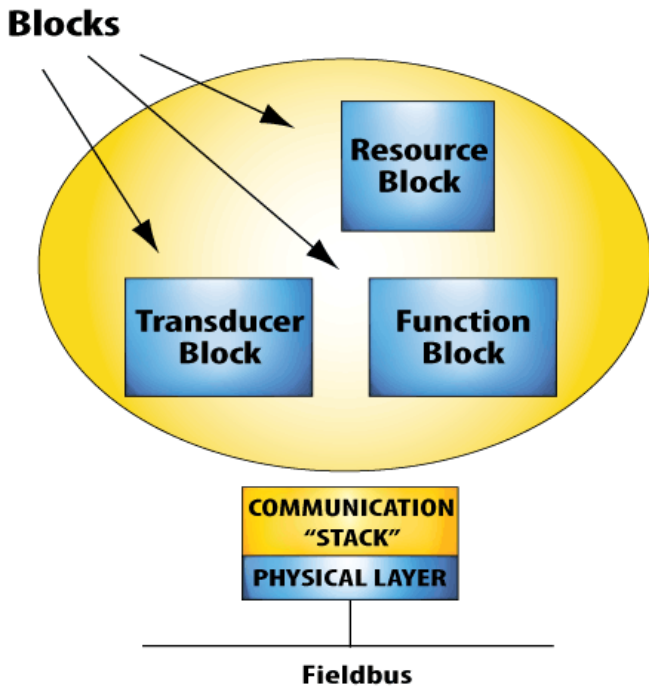
HSE enables tight integration and a free exchange of information needed for the plant enterprise. HSE is a superior solution to proprietary, Ethernet-based technologies since it provides end users with interoperable devices from multiple suppliers. And like H1, HSE is an international standard (IEC 51158).

HSE provides the same benefits as H1, but at the subsystem integration level instead of the field device level. It supports interoperability between disparate controllers and gateways in the same way that H1 supports interoperability between transmitters and actuators from different suppliers. FFBs in HSE devices can be set up using programming languages such as those found in the international standard IEC 61131-3.

HSE technology was designed from the ground-up to support fault-tolerant networks and devices used in mission-critical monitoring and control applications. All or part of the HSE network and devices can be made redundant to achieve the level of fault tolerance required for a particular application. Best of all, redundancy is supported using standard Ethernet equipment, thus eliminating the cost of special network equipment. HSE also supports standard Ethernet wiring, including a fiber optic media option to provide cost-effective electrical isolation between plant areas or immunity from distortion through noisy environments.

Function Block Model

A unique characteristic of the Foundation architecture ensuring device interoperability is its use of a fully specified, standard User Layer based on "Blocks" and Device Descriptions (DDs). The User Layer defines a Function Block Application Process (FBAP) using Resource Blocks, Function Blocks, Transducer Blocks, System Management, Network Management and DD technology.



Resource Blocks define parameters that pertain to the entire application process (e.g., manufacturing ID, device type, etc.). Function Blocks encapsulate control functions (e.g., PID controller, analog input, etc.) and Transducer Blocks offer an interface to sensors such as Temperature, pressure and flow, and actuators for valves.

Blocks are incorporated into Fieldbus devices to achieve the desired device functionality, as well as to define a wide range of features and behaviors that must work in a standard way for devices to interoperate. For example, a simple temperature transmitter may contain an Analog Input (AI) function block. A control valve might contain a Proportional/Integral/Derivative (PID) function block as well as the expected Analog Output (AO) block. Thus, a complete control loop can be built using only a simple transmitter and a control valve. Each block's parameters are represented by object descriptions that define how the parameters are communicated on the Fieldbus network. The FBAP

represents a very comprehensive application model that, in conjunction with the protocol, provides the technology that allows devices from different manufacturers to interoperate.

As specified by the FBAP, a Fieldbus device must have a Resource Block and at least one Function Block with input and/or output parameters that link to other function blocks, either in the same device or in separate devices by means of the bus. The "link object" defines the connection. Each input/output parameter passed will have a value and a status. The status portion of each parameter carries information on the quality of each value, of good, uncertain or bad.

In addition, the FBAP specifies the handling of control modes, alarms, events, trend reports and views. All of these features must comply with the Foundation specification in order for a device to be considered interoperable at the User Layer.

Distribution of control to the field device is made possible by synchronization of function block execution and communication of function block parameters on the Fieldbus. This function, along with publication of the time of day to all devices, automatic switch over to a redundant time publisher, assignment of device addresses, and searching for parameter names or "tags" on the Fieldbus, are handled by System Management (SM) and Network Management (NM).

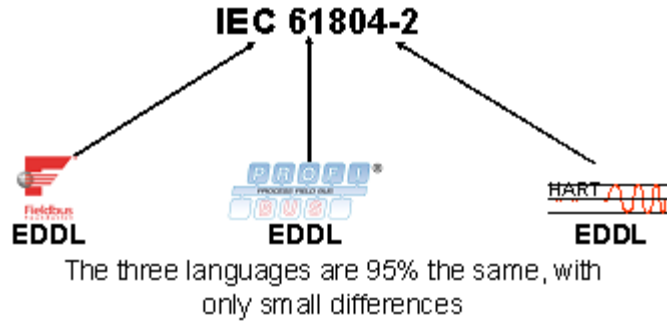
A Flexible Function Block (FFB) is a user-defined block. The FFB allows a manufacturer or user to define block parameters and algorithms to suit an application that interoperates with standard function blocks and host systems.

The use of FFBs enhances the ability to move control functionality to the field—a unique and important characteristic of Foundation technology. This strategy eliminates the need for proprietary unit controllers in many applications, and in doing so, decreases equipment costs and space requirements. Distributing control to the field also minimizes the effects of any loss or failure of supervisory control.

EDDL

Electronic Device Description Language (EDDL) is a programming language used to create Device Descriptions (DDs) to describe the attributes of field devices in an Operating System (OS) and Human Machine Interface (HMI)-neutral environment. EDDL is used to create DDs for functions such as generic digital and analog input/output modules, HMI displays and

transmitters, on-off and regulating valves, and closed-loop controller diagnostics.



EDDL is a universal, proven and state-of-the-art method of accessing diagnostic, real-time and asset management information contained in more than 20 million compliant field instruments from a host of manufacturers, and to provide optimum data and device interoperability.

EDDL is a text-based description of the variables contained in field devices, such as flow, pressure, drive speed, ambient temperature, high and low limits, calibration settings, and so on. The description defines each variable, and describes the way to access it.

With EDDL technology, a user can calibrate instruments, diagnose problems, provide data for user interface displays, identify process alarms and obtain information needed for high-level software, such as MES, UI/SCADA, plant historians, asset management and ERP.

EDDL is supported by virtually every vendor of process control systems worldwide, and the information it describes is available in any Fieldbus Foundation, HART Communication Foundation or Profibus User Organization based field device. As such, end users can easily profit from all device data provided by the EDD.

Safety Instrumented Functions

With the TÜV Protocol Type Approval, Foundation technology has been extended to provide a comprehensive solution for safety-instrumented functions in a wide range of industrial plant applications. The specifications enable manufacturers to build Foundation registered devices in compliance with IEC 61508. Third-party test agencies such as TÜV will certify that these devices are suitable for use in safety-instrumented functions. End-users will be able to choose devices meeting the requirements of IEC 61511 (functional safety: safety instrumented functions for the process industry sector) from multiple suppliers, instead of being restricted to devices designed specifically for a proprietary safety system platform. IEC 61511 is also available as an

ANSI/ISA Standard: ANSI/ISA-84.00.01-2004.

Extensive laboratory testing and application analysis has verified that the Foundation's safety instrumented systems technology meets the needs of industrial end-users, who regard these systems as critical to their overall plant operating strategy.

TÜV Type Approval will help meet the growing worldwide demand for commercial, standards-based, safety instrumented system products incorporating Foundation technology. End-users can now adopt the powerful Foundation diagnostics, and at the same time, maintain the protection in up to a SIL3 environment. No changes were required to the existing H1 protocol to add the safety instrumented systems protocol extensions, clearly indicating the value of the comprehensive, forward-thinking design of Foundation technology.

Standards

The Foundation protocol is designed to be compatible with the officially sanctioned SP50 standards project of the ISA, as well as and the specifications of the International Electrotechnical Committee (IEC). Since its founding, the Fieldbus Foundation has made compliance with the ISA/IEC standards a priority. The IEC voted to include the Foundation HI and HSE specifications in the IEC 61158 international standard. The CENELEC

The Foundation specifications are also compliant with IEC 61804 (Function Blocks for Process Control and Electronic Device Description Language) and IEC 61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems).

Approval and support by key international industry bodies gave users the confidence that their investments in Foundation-registered solutions were based on recognized global standards and sound best practices from industry groups.

The Foundation Technical specifications are based on the ISO/OSI layered communications model, and consists of three major functional components: the Physical Layer, the communication "stack," and the User Layer.

The Physical Layer corresponds to OSI Layer 1, which receives encoded messages from the upper layers and converts the messages to physical signals on the Fieldbus transmission medium and vice-versa.

V. FIELDBUS CABLE OVERVIEW

Cable Standards- Physical Layer

Fieldbus cables are defined by several standards. The Physical Layer, the cable, was initially defined by ISA Standard SP 50-02 “**Fieldbus standards for use in industrial control systems**”. This standard was modified and published by the Fieldbus Foundation in standard FF-844 “**Foundation Fieldbus specifications for Type A H1 Fieldbus cable**”. The IEC (International Electrotechnical Committee) has their own standard IEC- 61158-2 “**Digital data communications for measurement and control -Fieldbus for use in industrial control systems -Part 2: Physical layer specification and service definition.**”

These standards are similar in the general electrical requirements for the cables. However, the FF-844 is universally specified and accepted for the design and performance of Fieldbus cables in North America.

Agency Approvals

Industrial cables used in the United States are primarily listed and approved by Underwriters Laboratories. The UL Listing insures that the cables meet design requirements. In addition, UL regularly selects samples for testing to insure continued compliance with the standards.

Although Fieldbus cable signals are low voltage, cables can be listed for PLTC (NEC article 725) and ITC (NEC article 727). These are power limited 300 V rated applications. Cables can also be UL listed for TC (Tray Cable) and MC (Metal Clad) that are 600 V rated constructions.

Options performance ratings for these cables can include (ER) exposed raceway, armored Type of MC -HL and ITC -HL for Class I div 1 and Class I Zone 1 applications, direct burial, oil resistant, marine shipboard approved, abrasion resistant, weld flash resistant, and cutting fluid resistant. Fieldbus cable can also be listed in Canada to CSA standards Control and Instrumentation cable (CIC) or Armored control and instrumentation cable (ACIC) per CSA C22.2 No. 239.

Internationally, cable can comply to Instrumentation and control cable to European standard EN 50288-7; 300 V

Cable Construction and Electrical Characteristics

The FF-844 standard specifies the following construction for trunk wire Fieldbus.

Wire

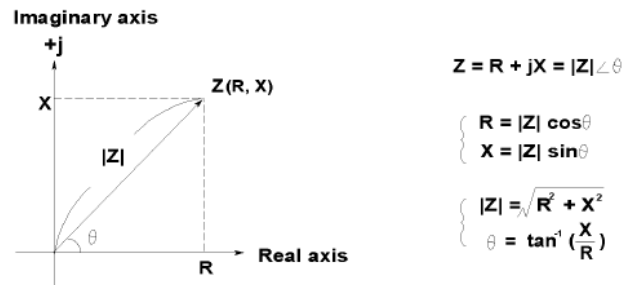
18 AWG tinned copper conductor.
(Foundation Fieldbus registered 16 AWG as well) with DCR - 23.5 Ohms/km at 20 °C

Shielded pair

Each twisted pair shall be individually shielded with metalized polyester, 90% Coverage Drain wire DCR less than 51 Ohms/km, Multi pairs cable should be SP-OS. The shielded pair is to be twisted to a lay length of 10-22 twists/meter. (that is a lay length of 1.8-3.9 inches)
Note: twisted pair lay length is a factor in magnetic noise rejection.

Characteristic Impedance, Z₀

100 +/- 20 Ohms at 31.25 KHz



The impedance shall be determined by any one of the methods described in ASTM D4566-05 “Electrical performance properties of insulations and jackets for Telecommunications wire and cable”.

Impedance – test method I

Characteristic Impedance from the Propagation Constant and Capacitance

$$Z_0 = \sqrt{L/C}$$

L = the inductance of the pair length, Henry

C = the capacitance of the pair length, Farad

Impedance – test method II

Open and Short Circuit Measurements

$$Z_0 = \sqrt{Z_{oc} * Z_{sc}}$$

Z_{oc} = the complex open circuit impedance

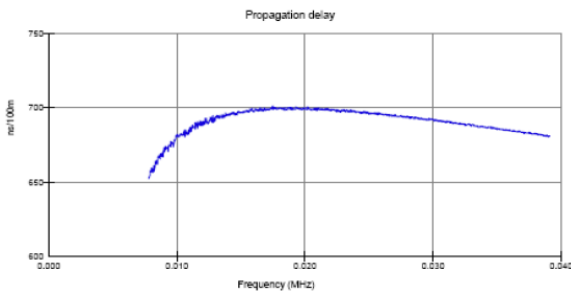
Z_{sc} = the complex short circuit impedance

Propagation Delay

Specified by ISA 50.02 but not by Foundation Fieldbus FF-844

Max Propagation Delay change

$$7.8125 \text{ KHz to } 39.0625 \text{ KHz} = 1.7 \mu\text{S/KM}$$



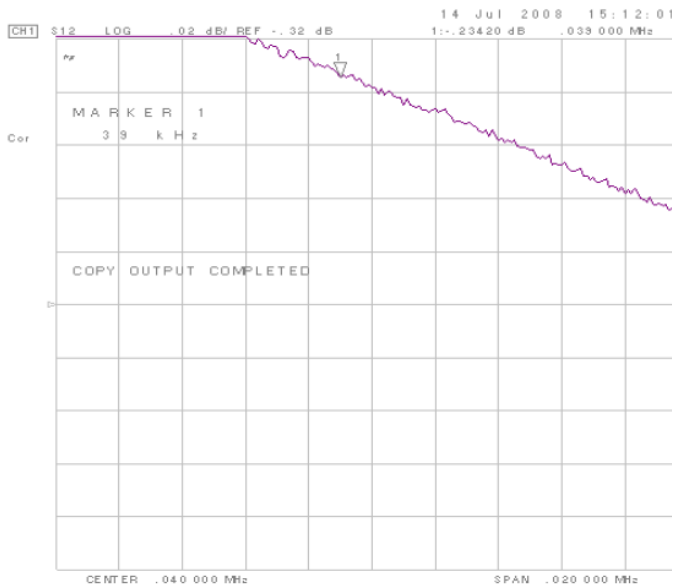
Attenuation

Attenuation is a measure of the loss in signal strength over a length of wire or cable and is affected by the materials and geometry of the insulated conductors, the surrounding jacket material and Shield

$$\text{Attenuation} = - 20 * \text{Log} (V_{out} / V_{in})$$

The test length for attenuation is 328 ft of Fieldbus cable, attenuation specifications is 3 dB/km at 39 KHz or lower.

**Data Sheet
Fieldbus Cable**



Wire-to-Shield Capacitance Unbalance

The difference in capacitance between one wire (+) and the shield and the other wire (-) and the shield
 FF-844 - No more than 4pF/meter
 ISA 50.02 - No more than 2pF/meter
 Sample length = 30 meter of cable

Jacket Resistance

1 MOhm/330 meters – tested in water.500V for 1 min

Cable Markings

In Addition to all NRTL listings, cable that is registered with Fieldbus Foundation shall be marked with **“TYPE A FIELDBUS CABLE FF-844 H1”**

Types of Fieldbus Cables for different applications

- Power Limited tray cable PLTC, PLTC -ER
- Instrumentation Tray Cable ITC, ITC -ER
- Tray Cable TC, TC -ER
- Armored type MC, MC -HL, ITC -HL
- Marine shipboard type P Fieldbus cable
- Fire rated Fieldbus cable type TC
- Interlocked or SWA armored Fieldbus cable
- Nuclear class 1E Fieldbus cable

VI. CONCLUSION

Fieldbus technology incorporates a complete solution for the implementation of field automation and field control. The Fieldbus infrastructure brings a common frame of reference to the technology; choices are guided by specifications, registration and application.

The advantage of the Fieldbus Network is the distance that can be achieved with low frequency communication and easy integration in the field. The freedom to choose and power to integrate design allows devices and software from different manufactures to work under one protocol with the same common communication and language. Fieldbus Foundation is a not for profit organization that organizes development programs, conducts field trials, and establishes the industry program for testing and registration of Fieldbus devices. Fieldbus Foundation developed the industry standards for the physical layer such as H1, HSE and the software protocol Electronic Device Description Language (EDDL) that is the programming language used to create device descriptions. The Fieldbus network uses less cable when compared to point to point network such as 4-20 mA. Each device has its own IP address and devices from different manufacturers can communicate to the server and the Fieldbus software.

Part of the physical layer infrastructure is the Fieldbus cable that is specifies in FF-844 “Foundation Fieldbus specifications for Type A H1 Fieldbus cable”. The cable is a shielded pair 18 AWG that is designed to meet certain electrical characteristics such as impedance and capacitance. Different cable insulation and jacket materials are used in Fieldbus cables, the materials are selected for the applicable industry such as mud resistance or arctic characteristics. Fieldbus cable can be registered with Fieldbus Foundation and posted in the “End User Resources” section of the Fieldbus Foundation web site.

VII. REFERENCES

- ISA 50.02 Fieldbus standards for use in industrial control systems
- Fieldbus Foundation FF-844 “Foundation Fieldbus specifications for Type A H1 Fieldbus cable”
- IEC- 61158-2 “Digital data communications for measurement and control -Fieldbus for use in industrial control systems -Part 2: Physical layer specification and service definition
- Foundation Fieldbus – “System Engineering Guidelines”
- ASTM D4566-05: Standard Test Methods for Electrical Performance Properties of Insulation and Jackets for telecommunications Wire and Cable, Mar. 1, 2005
- IEC 61158-2: 2003 (ed.3.0), Fieldbus standard for use in industrial control systems – Part 2: Physical Layer specification and service definition

VIII. VITAE



Gil Shoshani received his Bachelor’s of Science degree in Electrical Engineering from the University of New Haven in Connecticut in 1992. He is with Rockbestos-Surprenant Cable Corp. (RSCC) as a Fire and Safety Sales Engineer. He has worked with Times Microwave Systems, Circuit Wise, Tyco Engineered Systems and Orbotech Inc.



Stan Stephan received his Bachelor’s of Science degree in Electrical Engineering from Ohio Northern University in 1972. He is a registered Professional Engineer in Ohio and a member of the IEEE and ISA. He has worked at Dekoron Wire and Cable for 36 years. Responsibilities have included Product Development with emphasis on polymer materials and Agency Listings.



Stephen Mitschke is Product Manager - Fieldbus Products at the Fieldbus Foundation based in Austin, Texas USA. He is responsible for the Foundation’s products and services including specifications, product development tools, conformance and interoperability test tools, product registration services, certified training and consulting. Stephen is a Senior Member of the International Society of Automation (ISA) and participates as an official liaison to International Electrotechnical Commission (IEC) standards working groups and maintenance teams. Stephen holds a Bachelors of Science in Electrical Engineering from the University of Texas at Austin.