Finding your way in the maze of industrial Ethernet standards

Making industrial Ethernet standards work for you

If you are an industrial automation control engineer or technician embarking upon the design and installation of an industrial network, you will quickly confront a bewildering array of standards written by a host of international, regional, national and trade organizations. This article will give you some historical perspective on what has caused such a proliferation of standards. Then we'll overview the primary standards organizations you should be familiar with and how they relate to one another (if at all). We'll look at the key standards these organizations write, the current status of those standards, and what the future may hold. This article will guide you as you ferret out the particular sections in the standards that apply to your Ethernet network, and where you can turn for help as you plan, install and maintain it.

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Why worry about standards anyway?

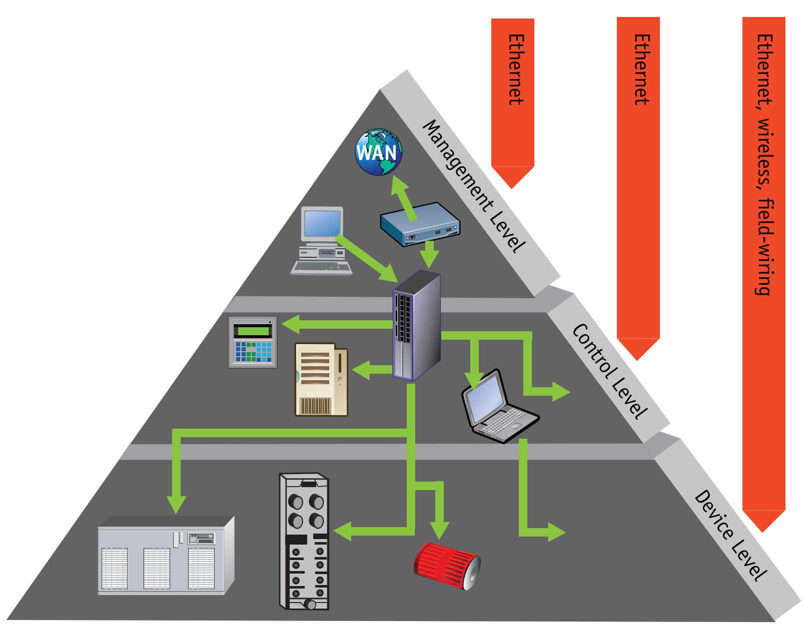
Building your network to national or international standards ensures interoperability and cross-vendor support, including building in support for future applications. When installing your network, you don't have to re-invent the wheel. You can design and specify to proven component and equipment compliance requirements. You can take advantage of proven installation, verification, and maintenance methods. This helps ensure the quality and reliability of your network, extends the lifetime of your investment, and improves maintainability.

Operational requirements of industrial cabling

Cables and connectors destined for a climate-controlled data center or a relatively benign office environment are not always suitable for the demands of industrial automation and control environments. First, the mission-critical control-based applications traffic carried on an industrial network demands high reliability with deterministic timing, constraints on bit-error rates and limited or no re-transmissions because excess latency can cause equipment control failures. Downtime in manufacturing processes is extremely costly, making high uptime mandatory. Then there are the stresses of harsh environments such as vibration, electrical noise, equipment in motion, impact dangers, and all manner of sunlight, water, contaminants, and solvents that need to be guarded against. In these industrial environments, the cabling may need to be flexible and/or mechanically hardened. In some environments, intrinsic safety is required to allow electronic equipment to allow operation in a hazardous or flammable environment without danger of accidentally igniting a spark.

Why the focus on industrial Ethernet?

The use of Ethernet for industrial automation and its associated standardization work has grown dramatically. Industrial Ethernet is expected to continue to displace traditional Fieldbuses, homogenizing industrial networks with the office environment. Legacy implementations that used Ethernet-only for management, combined with non-Ethernet Fieldbuses at the controller level, and low-level Fieldbuses and field-wiring at the device/sensor/actuator level will transition to implementations that use industrial Ethernet at all levels of the automation network. This transition will accelerate as standards support is bolstered by the availability of cost-effective, highly integrated, Ethernet embedded solutions.



There are two key challenges for industrial Ethernet:

1. Industrial Ethernet must support real-time functionality that is not well supported by the Ethernet-layered protocol used in TCP/IP-based office applications.
2. Industrial Ethernet must be compatible with legacy Fieldbus implementations to protect a considerable existing infrastructure investment.

Driven by the need for application backward-compatibility and competing commercial interests, several standardized versions of industrial Ethernet have been designed to interoperate with specific existing non-Ethernet Fieldbuses. In addition to offering applications compatibility to legacy Fieldbus, different implementations have different performance characteristics targeted to specific application in the automation network such as motion control, communication between systems, process automation, distributed I/O, and distributed control.

A brief history of industrial Ethernet cabling standards and the people who write them

For those designing cabling components or networks for commercial and industrial Ethernet, standards ISO/IEC 11801, the ANSI/TIA 568 series, ISO/IEC 24702, IEC 61158-1, -2, IEC 61784-1, -2, and ANSI/TIA 1005 apply. These standards specify the physical design and performance requirements for connectors and cabling, and installed configurations.

If you are involved in planning and installation of the physical infrastructure for your industrial Ethernet automation network, understanding and applying ISO/IEC 14763-2, IEC 61918, and 61784-5 will ensure robustness, compatibly, and maintainability.

Why so many different standards? And which one(s) apply to you?

An understanding of the history and focus of the standards development organizations that support Industrial Ethernet infrastructure will help you to select and apply these standards. There are three technical committees in three major organizations that develop and maintain standards pertinent to Industrial Ethernet cabling.

International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) Working Group JTC1/SC25/WG3

WG3 is a joint ISO/IEC Working Group and a world leader in the development of standards for generic structured cabling. There are two pertinent Task Groups of WG3 that were formed to focus on specific areas:

1. IPTG (Inter-Premises Task Group) supports standards for Ethernet cabling in industrial environments
2. CITG (Commissioning and Installation Task Group) supports installation practice standards for cabling. CITG is now also working to add support for industrial applications.

TIA, Telecommunications Industry Association, Engineering Committee TR-42

In addition to ISO/IEC JTC1/SC25/WG3, the TIA, an ANSI standards organization in the United States, is also a world leader in standardizing structured cabling. Although this is a US national standards body, TIA cabling standards are also used in Canada and Mexico. Due to the need for suppliers to be able to produce standards- compliant connectivity solutions both domestically and internationally, there is strong international participation in this Engineering Committee. Both the ISO/IEC WG3 and the TIA TR-42 Subcommittees (sub-levels of the TR-42 Engineering Committee) share many of the same active participants. TIA Engineering Committee TR-42, responsible for premises telecommunications infrastructure, develops and maintains these standards.

International Electrotechnical Commission (IEC) Subcommittee SC65C.

All Fieldbus standardization work at the international level takes place within IEC Subcommittee SC65C. A joint WG (JWG) between the ISO and the IEC, SC65C/JWG-10 was specifically formed to define wiring and cabling of Ethernet in an industrial environment and is responsible for developing and maintaining the Fieldbus installation specifications within the Fieldbus framework of standards. SC65C/JWG-10 was formed to coordinate overlapping domains of premise structured cabling and Ethernet Fieldbus cabling.

Org.	Technical Committee	Standards Focus	Applicable Standards
ISO	JTC1/SC25/WG3	Premise cabling	ISO/IEC 11801
TIA	TR-42	Premise cabling	ANSI/TIA 568 Series
ISO	JTC1/SC25/WG3/IPTG	Cabling in industrial premises	ISO/IEC 24702
TIA	TR-42.9	Cabling in industrial premises	ANSI/TIA 1005
ISO	JTC1/SC25/WG3/CITG	Installation	ISO/IEC 14763-2
IEC	SC56C	Fieldbus	IEC 61158 IEC 61184-1, -2
IEC	SC56C/JWG-10	Fieldbus installation	IEC 61918 IEC 61784-5

Table 1: *Technical committees applicable to industrial Ethernet cabling.*

Other Regional and National Standards Organizations

In addition to ISO, IEC, and TIA, there are other regional cabling standards groups such as CENELEC (European Committee for Electrotechnical Standardization), JSA/JSI (Japanese Standards Association), CSA (Canadian Standards Association) that develop specifications for their geographic area or country. These regional standards groups contribute actively to ISO technical advisory committees and the contents of their standards are usually very much in harmony with ISO, IEC, and TIA requirements. In addition to cabling standards, CENELEC, also has equivalent Fieldbus standards that are well harmonized with the IEC version.

The cabling standards you need to know about

Now that you know which committees are at work, let's look at how the specific standards they develop relate to your network. Figure 1 maps out the key ISO, IEC and joint ISO/IEC standards you need to be concerned with, first in the design, and then in the planning, installation, verification, and testing of industrial Ethernet. The upper tier is application agnostic and applies to generic cabling in office premises. Moving down on the vertical axis of the figure, the lower tier applies to Fieldbus, industrial premises, and automation environments. Let's take it from the top.

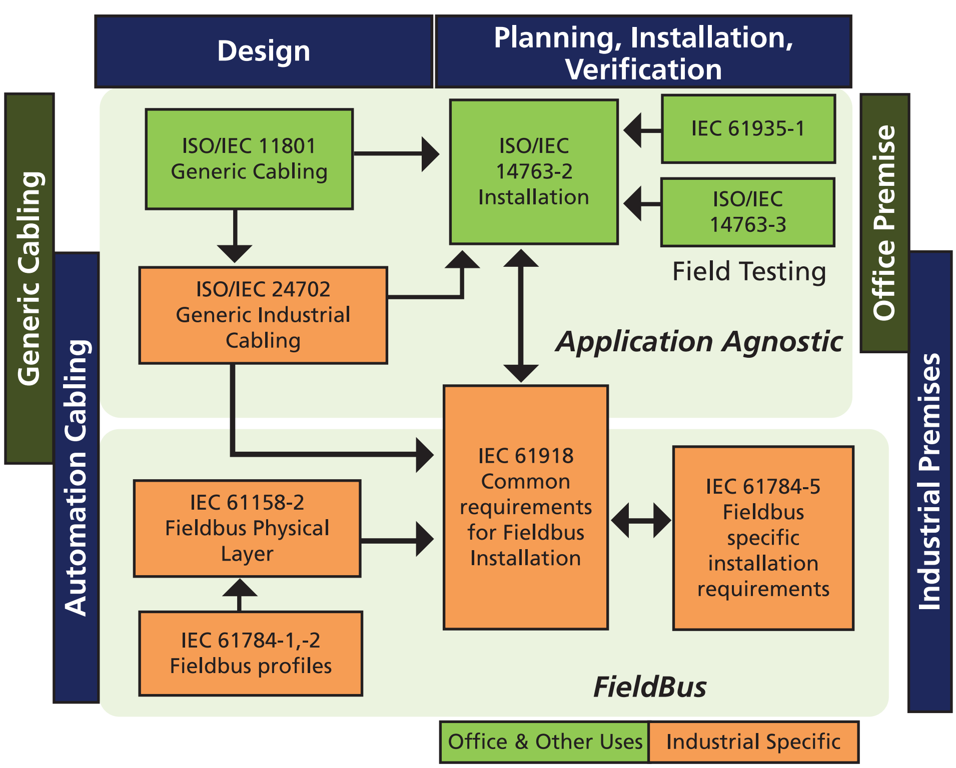


Figure 1: Key ISO and IEC cabling standards.

ISO/IEC 11801 is the base standard covering generic structured cabling.

It covers cabling systems that are typically used for premise local area networks including both 4-pair balanced twisted-pair copper and fiber optic cabling. It specifies end-to-end physical media and transmission performance. These performance levels can be mapped to support different Ethernet speeds. For example, an ISO/IEC 11801 cable system that meets Class D performance can support up to 1000BASE-T up to lengths of 100 meter, where a Class EA performance level is required for 10GBASE-T.

ISO/IEC 14763-2 specifies planning, installation, and operation of infrastructures in support of generic cabling.

It includes implementation of cabling, pathways, spaces, grounding and bonding.
Aspects covered are:

- Work specifications depending on the application, electromagnetic environment, building infrastructure, facilities, etc.
- Quality assurance
- Installation planning (including pathways and spaces) depending on the application, electromagnetic environment, building infrastructure, facilities, etc.
- Installation practice (including pathways and spaces)
- Documentation and administration
- Testing
- Inspection
- Operation
- Repair, maintenance and maintainability

The present version ISO/IEC/TR 14763-2 Ed. 1.0 was released in 2000 as a technical report. The next version will be converted to standard ISO/IEC 14763-2 and will add support for the industrial premise in accordance with ISO/IEC 24702 (the industrial cabling specification) and is expected to be available in late 2009.

Two specifications cover field testing based on the ISO/IEC 11801 standard

Testing copper cabling: IEC 61935-1 – "Specification for the testing of balanced communication cabling in accordance with ISO/IEC 11801- Part 1: Installed cabling" specifies comprehensive testing for installed cabling in order to ensure that the cabling will support telecommunications applications that are designed to operate on the generic cabling system.

Testing optical fiber cabling: ISO/IEC 14763-3 – This standard outlines test procedures to be used to ensure that optical fiber cabling, designed in accordance with ISO/IEC 11801 and installed according to the recommendations of ISO/IEC 14763-2, is capable of delivering the level of transmission performance specified in ISO/IEC 11801.

An industrialized design standard: ISO/IEC 24702

Building upon the office premise generic cabling standard ISO/IEC 11801, IEC 24702 was released in 2006 to modify the requirements for industrial premises. Key modifications support harsh industrial environments based upon the MICE (Mechanical, Ingress, Climatic, and Electromagnetic) classifications commonly used across industrial cabling standards. Here's what each of the categories includes:

- **Mechanical:** shock, impact vibration, bending and flexing and crush
- **Ingress:** particulate size and immersion
- **Climatic/Chemical:** temperature, thermal shock, humidity, UV (solar radiation) and chemical pollution
- **Electromagnetic:** ESD, RF, EFT, transient ground potential, magnetic field

The MICE classifications segment industrial environments into three levels, based upon their degree of severity:

- **MICE 1:** Commercial office environment
- **MICE 2:** Light industrial, such as assembly, food processing, health care, or wash-down areas
- **MICE 3:** Heavy industrial such as petrochemical, foundry, automotive manufacturing or machining.

Modification to the physical, electrical component and channel requirements such as improved balance requirements in balanced twisted-pair cabling, and the topology for industrial cabling systems are specified in ISO/IEC 24702 to meet these requirements.

Fieldbus cabling standards

Now we enter the lower tier on the standards chart above: the realm of Fieldbus. Unlike the WG3 standards that are application agnostic, the cabling design and process requirements that are controlled by the IEC's Subcommittee 65C (SC65C) are specified within the framework of specific Fieldbus profiles.

The original fifteen-year effort to standardize a Fieldbus began in 1985 and culminated in a grand compromise that standardized eight distinct implementations of Fieldbuses in year 1999. The international standardization vacuum over that period was addressed by CENELEC, the European regional standardization organization, and in the United States by a trade organization, Foundation Fieldbus. First, in 1996, CENELEC published specifications for P-Net, Profibus, and WorldFIP published in 1996. These specifications along with some subsequent work were incorporated into a first release of the compromised international specification IEC 61158 in 2000. Rather than appending each individual Fieldbus specification, each was published in separate sections of IEC 61158 organized by physical layer, data link layer, application layer, etc. Because of this peculiar convention, a separate profiles document, IEC 61784-1, is required. The profiles document calls out the appropriate IEC 61158 sections for each commercially implemented Fieldbus. In 2007, a second profiles document, IEC 61784-2, was introduced to add seven new Real-time Ethernet (RTE) specific profiles.

CPF*	IEC 61784 Volume	Fieldbus commercial Name
1	1	Foundation Fieldbus HSE
2	1,2	Ethernet/IP
3	1,2	PROFInet
4	1,2	P-NET
10	2	VNET/IP
11	2	TCnet
12	2	EtherCAT
13	2	Ethernet Powerlink
14	2	EPA
15	2	Modbus-RTPS
16	2	Sercos III

*CPF (Communication Profile Family)

Table 2: *Fieldbus industrial Ethernet supported profiles.*

You will notice that missing from **Table 2** above are Fieldbus communication profile families 5, 6, 7, 8, 9, which represent WorldFIP, Swiftnet, Interbus, CC-Link, and Hart respectively. These are all IEC 61158 standardized Fieldbuses but do not have Ethernet profiles. Swiftnet, a standard proposed by Boeing, was removed from the standard altogether.

Finding your way to your own Fieldbus design specs

The IEC 61158 Fieldbus specification is arranged in six parts. Part 1 is the introduction. The remaining parts are arranged by physical layer, data link layer, application layer protocols, and services. The pertinent section to the infrastructure engineer or technician is IEC 61158-2: Fieldbus for use in industrial control systems – Part 2: Physical Layer specification" that covers non-Ethernet Fieldbus cabling. Use this document in conjunction with the Fieldbus profiles documents IEC 61784-1 and IEC 61784-2 to specify the cabling requirements for your individual non-Ethernet Fieldbus implementation. Ethernet Fieldbus performance requirements are covered by ISO/IEC 24702.

Fieldbus installation standards

IEC 61918 standardizes common elements across all the Fieldbuses, and IEC 61784-5 provides profile-specific installations requirements. Use these two documents as a set to specify installation requirements. IEC 61784-5 is divided into subparts by communication profile family (CPF). For example, IEC 61784-5-2 applies to the CPF 2 CIP™ Fieldbuses and IEC 61784-5-3 apples to CPF 3 Fieldbuses PROFIBUS & PROFINET. The first 2007 edition of IEC 61784-5 has specific support for CIP™ (Part 5-2), PROFIBUS & PROFINET (Part 5-3), INTERBUS® (Part 5-6), Vnet/IP (Part 5-10), and TCnet (Part 5-11). Work on a second edition, planned for release in early 2010, adds support for

P-Net, EthernCAT, EPA, and Modbus. This edition combined with a new release of IEC 61918 will also be better harmonized with Industrial Ethernet generic cabling specification ISO/IEC 24702 though continued coordination with the ISO/IEC JTC1/SC25/WG3.

These documents are large and rather expensive. The IEC does, however, package and sell groups of IEC 61158, IEC 61918, and 61784 documents pertinent to the Fieldbus that you are using. For example, if all you care about is a Foundation Fieldbus, IEC offers a pre-packed set of documents that covers this application*. Furthermore, if you were strictly concerned with Foundation Fieldbus cabling, only IEC 61158-1, 61158-2, 61784-1, and 61918 Fieldbus specifications apply, and those can be obtained individually.

*The full set of documents in this case are 61158-1, 61158-2, 61158-3-1, 61158-4-1, 61158-5-5, 61158-5-9, 61158-6-5, 61158-6-9, 61784-1, 61784-3-1, and 61918.

Relationships between the ISO and IEC standards

In Figure 1 you can see the relationship and overlaps between the standards we discussed. The function is mapped on the horizontal axis and the premises and cable type on the vertical axis. Note that ISO/IEC 24702, the generic cabling standard for industrial premises, overlaps both on office and industrial premises, and generic and automation cabling. IEC 61918, the installation specification for Fieldbus, covers generic cabling. There is room for further harmonization for ISO/IEC 24702, ISO/IEC 14763-2, and the Fieldbus documents, which the joint working groups are actively addressing. ISO/IEC 24702 takes precedence for cabling between the office environments up to what is called the telecommunication outlet (TO). This is denoted as the automation outlet (AO) in the Fieldbus installation specification. This AO/TO is the connection to what is called an Automation Island. In addition, the next version of ISO/IEC 14763-2, which will add industrial installation requirements, is being coordinated with SC65C/JWG10, the committee that maintains IEC 61918 and IEC 61784-5.

How the TIA specifications fit in

The TIA generic cabling standard series, ANSI/TIA-568, is fairly well aligned with the ISO/IEC generic cabling standard 11801 with some terminology differences. For example, the ANSI/TIA-568 Series standards specify performance-grade, balanced, twisted-pair cabling in both component and installed configurations in terms of categories, such as “category 5e”. The ISO/IEC 11801 standard uses category classifications for individual components and a letter classification to denote end-to-end transmission performance of an installed multi-segmented point-to-point connection. A few examples are:

- An ISO equivalent of a TIA category 5e installed cable system is ISO Class D
- An ISO equivalent to a TIA category 6 installed cable system is Class E.

ISO/IEC 11801 references a separate IEC specification that covers component performance such as individual connectors. These IEC component specifications use the same category 5e/6/6A performance classifications as TIA.

TIA-1005 “Telecommunications Infrastructure Standards for Industrial Premises” is the TIA equivalent of ISO/IEC 24702. TIA-1005 references the TIA-568 Series with added topology, environmental, and electrical transmission requirements for industrial premises. ANSI/TIA-1005 was approved for publication in October 2008. ANSI/TIA-1005 references the MICE environmental classification, which was added to the ANSI/TIA-568-C.0 standard. (The MICE environmental classification was moved to ANSI/TIA-568-C.0 because it was considered universally applicable to all installed environments.) At the time of this writing, TIA 568-C.0 (generic cabling), 568-C.1 (commercial cabling), and 568-C.3 (optical fiber components) have been released for publication. The remaining section–the copper specification 568-C.2– is expected in 2009.

Trade organizations can help you with Fieldbus standards

If you are new to these standards, the application guides provided by Fieldbus trade organizations are a great place to begin understanding these specifications. They offer an excellent source of standards-compliant application guides. Some of these organizations also produce their own standards that later get incorporated into international standards. **Table 3** lists trade organizations by applicable Fieldbus.

CPF	Technology Name (Ethernet Fieldbus Name)	Developer	Other Manufacturers	Trade Organizations
1.	**FOUNDATION Fieldbus™** (Foundation Fieldbus HSE)	Fieldbus Foundation	ABB, Emerson, Honeywell, Yokogawa, BEKA, Endress+Hauser, Smar, Krohne, Invensys, Topworx, Vega	Fieldbus Foundation **www.fieldbus.org** Fieldbus Incorporated **www.fieldbusinc.com**
2.	**CIP™** (Ethernet/IP)	Rockwell Automation	Schneider Electric, Cisco, N-Tron, Comtrol Woodhead Industries,Phoenix Contact, Harting, Real Time Automation, Hilscher, NMS	ODVA **www.odva.org**
3.	**PROFIBUS** (PROFInet)	Siemens	Beckhoff, Bosch Rexroth, Danfoss, GE Fanuc, Harting, Hilscher, Kuka, Phoenix Contact, Saia, SEW, Sick	PTO (Profibus Trade Organization) **www.us.profibus.com**
10.	**Vnet/IP**	Yokogawa, Japan		**www.yokogawa.com**
11.	**TCnet**	Toshiba, Japan	Toshiba	
12.	**EtherCAT**	Beckoff	AAB, Baldor, Baumuller, Kuka, Philips	EtherCAT Technology Group **www.EtherCAT.org**
13.	**Ethernet Powerlink**	Firma B&R, Austria	AAB, Baldor, Danaher Motion, Baumuller, Harting, Hirschmann, Kuka, Lenze, Lust	Ethernet Powerlink Standardization Group **www.ethernet-powerlink.org**
14.	**EPA**	Supcon, China		Curently not used outside China: Information only available in Chinese
15.	**MODBUS®-TCP**	Modicon (Schneider Electric), France	Schneider Electric, Jetter, Lenze, Phoenix Contact, GE Fanuc, Mitsubbishi	Modbus-IDA **www.modbus.org**
16.	**SERCOS** **(Sercos III)**	Bosch Rexroth	Rockwell	Interest Group SERCOS Interface (IGS) **www.sercos.de**

Table 3: *Fieldbus Trade Organizations.*

Other useful resources

Here are some other organizations that can provide valuable support, training, references and resources.

- BICSI provides training and certification, applications guides, and standards for structured cabling. **www.bicsi.org**
- IAONA provides manuals, guides and standards for industrial Ethernet. **www.iaona.org**
- IEAG (Industrial Ethernet Advisory Group) provides a forum for technical support and queries – news & events, articles and product information for industrial Ethernet. **www.industrial-ethernet.org**
- ISA focuses on industrial automation. ISA develops standards, certifies industry professions, and publishes book and technical articles. **www.isa.org**

Where do you go from here?

Now that you have some historical perspective and an overview of the industrial Ethernet standards environment, we hope it seems less confusing and more manageable. At least you know where to start. You now know which standards documents you need to get your hands on, and which organizations and committees to keep an eye on in the future. Although the ideal of one global standard is still a distant dream, we do see continuing efforts to harmonize, coordinate, and streamline specifications as industrial applications move towards an increasingly integrated, standardized environment based on Ethernet.

Contact Fluke Networks: Phone **800-283-5853** (US/Canada) or **425-446-4519** (other locations). **Email: info@flukenetworks.com**.

NETWORKSUPERVISION

Fluke Networks
P.O. Box 777, Everett, WA USA 98206-0777

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Printed in U.S.A. 12/2008 3433787 WB-ENG-N Rev A