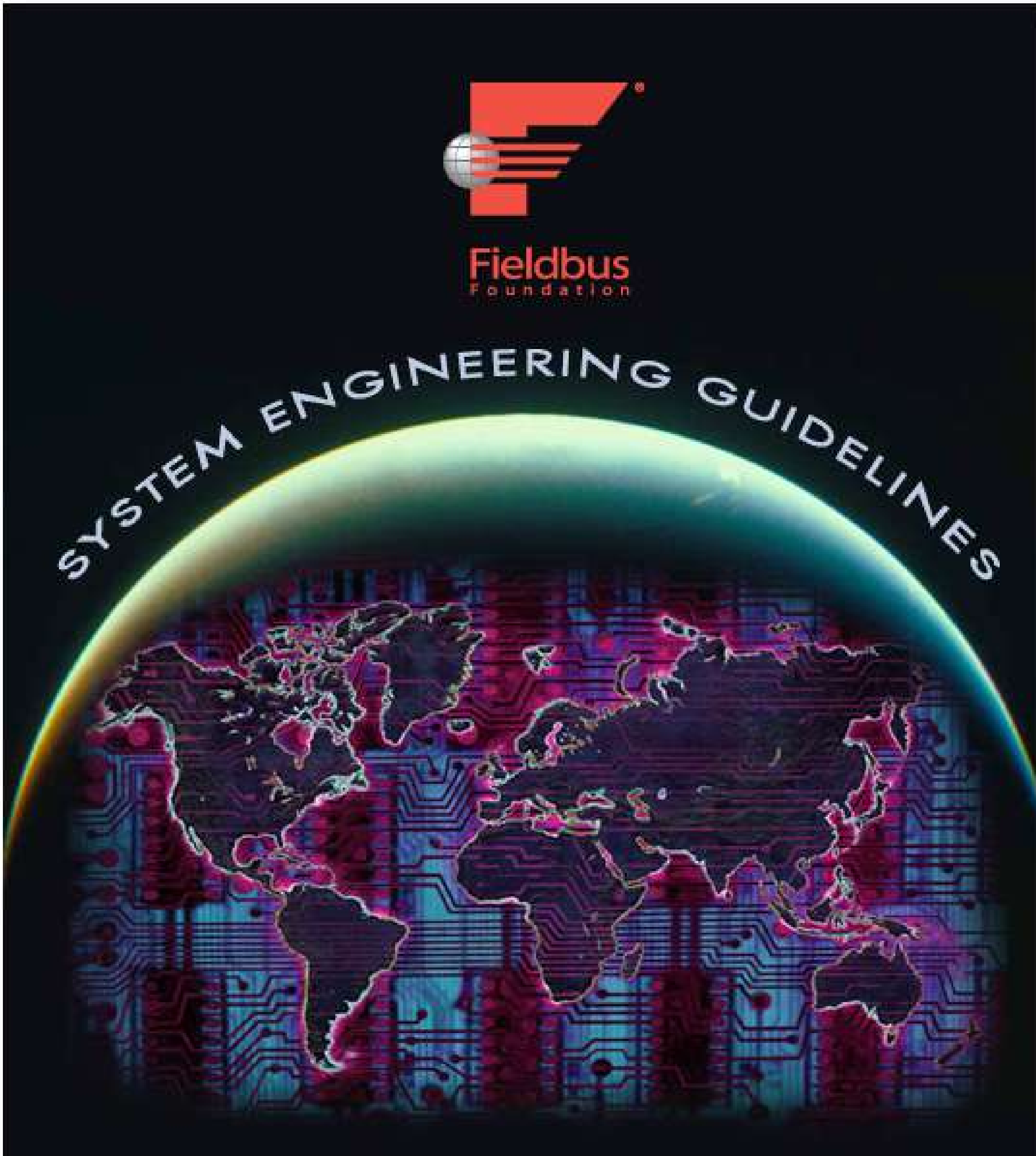

Compliments of:
The Fieldbus Foundation

Preface

FOUNDATION™ Fieldbus
System Engineering Guidelines

(AG-181) Revision 2.0

This preface, as well as all footnotes and annexes, is included for information purposes and is not part of AG-181.

This document has been prepared under the direction of the End User Advisory Council (EUAC) of the Fieldbus Foundation. To be of real value, it should not be static but should be subject to periodic review. Toward this end, the foundation welcomes all comments and criticisms and asks that they be addressed to:

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www.fieldbus.org

This document in its present revision and at time of publication recognizes that High Speed Ethernet (HSE) products are available from the Fieldbus Foundation and its members. The next revision of this document will incorporate guidelines for the installation and implementation of HSE.

The use of specific Vendor/Manufacturers in this document does not entail implicit endorsement of the product over other similar products by the authors or the Fieldbus Foundation. Individuals using this document are encouraged to seek out equivalent function equipment from other sources of which the authors may be unaware. To assist in our efforts to make this document as relevant as possible, should such equipment be known to a user of this document please forward that information to the address given above.

Preface

It is the policy of Fieldbus Foundation to encourage and welcome the participation of all concerned individuals and interests in the development of FOUNDATION™ fieldbus standards, recommended practices, and technical reports. Participation in the Fieldbus Foundation standards-making process by an individual in no way constitutes endorsement by the employer of that individual, of the Fieldbus Foundation, or of any of the standards, recommended practices, and technical reports that the Fieldbus Foundation develops.

The Fieldbus Foundation would like to thank the End User Advisory Council and the members of the End User Councils who have committed so much time and effort to the preparation of this guide.

In particular the Foundation wishes to acknowledge the following individuals without whose dedication this guide would not have been possible:

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Rev. No.	Date	Description	By
0	October 2003	Original Release	IV
1.0	December 2003	Editorial Revisions	IV
2.0	August 2004	Editorial Revisions	IV

Preface

Revision Memo

REVISION 1.0 – DECEMBER 2003

Addition of Saudi Aramco contributors to preface
Renumber 1.3.3 to 1.3.2
Renumber 4.4.3 to 4.4.2
Reference in Section 8.6.2 changed from 6.5.2 to 6.7.2

REVISION 2.0 – AUGUST 2004

Add abbreviation MOV – Motor Operated Valve to abbreviations list.
Section 2.2.9 Addition of reference to AG-163
Section 2.3.5 Correct IAONA URL from http://www.iaona-eu-com to www.iaona.org
Section 5.2.7 Statement of power conditioner isolation.
Section 6.3.5 Change to 8/20uS, not 8/20S
Section 6.5 & 6.6 Rewritten
Section 6.7 Addition of Section on FNICO. Renumber balance of Section 6.
Section 7.3.3 Correction SM Timer default settings were 2440000 (76.25 seconds) changed to 1440000 (45 seconds)
Table title changes “Network/Segment Checkout Form” and “Fieldbus Cable Checkout Form”
Update noise levels to <75 mV and lowest signal level to 150 mV in “Network/Segment Checkout Form”

Preface

Caution
The use of this guide may involve hazardous materials, operations or equipment. The guide cannot anticipate all possible applications or address all possible safety issues associated with use in hazardous conditions. The user of this guide must exercise sound professional judgment concerning its use and applicability under the user's particular circumstances and according to their established corporate policies and procedures. The user must also consider the applicability of any governmental regulatory limitations and established safety and health practices before implementing this standard.

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Preface

How To Use This Document

This document reflects standard industry practices for the application FOUNDATION fieldbus H1 projects at time of publication. As this is a “living document” it will be maintained and updated periodically to reflect changes in the technology including the adoption and application of High Speed Ethernet (HSE).

The authors recognize that each facility planning to or installing a FOUNDATION fieldbus project may not wish to adhere to all the recommendations as reflected in this guideline. Towards that end, the Council recommends that rather than change this document, which has several cross-references, that the user instead prepares a forward clearly identifying those sections to be modified or applied in a different way. An example of this follows:

“XYZ Company applies Section 6.3.3 to provide additional grounding protection for field devices."

Recommended changes additions or suggestions should be forwarded via email to: euac@fieldbus.org

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Introduction

1.1 CONTENTS

The FOUNDATION fieldbus Engineering Guideline is separated into sections. The following is an explanation of the intent of each chapter:

Section 01 – Introduction and Scope
The purpose and scope of the FOUNDATION fieldbus Engineering Guidelines.

Section 02 – References
References used to compile FOUNDATION fieldbus Engineering Guidelines.

Section 03 – Definitions
Terms used specifically with FOUNDATION fieldbus technology.

Section 04 – Field Device Requirements
Functional requirements of the field devices when used to implement FOUNDATION fieldbus technology.

Section 05 – Ancillary Device Requirements
Functional requirements of the ancillary components such as bulk power supplies and power conditioners for use with FOUNDATION fieldbus technology implementation.

Section 06 – Network/Segment Design Guidelines
Information, explanations & guidelines for use when designing FOUNDATION fieldbus networks/segments.

Section 07 – Host System Requirements
Functional requirements of the host system when used to implement FOUNDATION fieldbus technology.

Section 08 – Software Configuration Guidelines
Information, explanations and guidelines for use when configuring control system software for use in a strategy that incorporates FOUNDATION fieldbus. Items covered include control module configuration, function block implementation, condition-based monitoring software configuration, and alarm management and configuration.

Section 09 – Documentation Requirements
Required documentation for use when designing and maintaining FOUNDATION fieldbus technology. Documentation such as control philosophy, P&IDs & instrument location drawings is covered in this chapter.

Section 10 – Factory Acceptance Test (FAT) Requirements
Tasks and functions required to FAT a control system utilizing FOUNDATION fieldbus technology.

Section 11 – Site Installation Requirements
Information and procedures for use when installing fieldbus networks. This section also specifies the procedures required to check out a FOUNDATION fieldbus system, as well as identifying required tools for use in installing and maintaining FOUNDATION fieldbus equipment.

Introduction

1.2 PURPOSE

The FOUNDATION fieldbus System Engineering Guideline is intended to compliment the principal's existing series of instrument specifications. It details how fieldbus devices are specified, installed, configured, commissioned, and maintained differently than conventional analog or "smart" instruments.

Since this guideline covers several different "topics" it has been separated into a number of individual parts, one for each of the components of its "life cycle."

This Engineering Guideline addresses the implementation of FOUNDATION fieldbus only. Other fieldbus technologies exist that may be integrated to the basic process control system, if the engineering design requires. FOUNDATION fieldbus is primarily used to replace the traditional analog input/output signal types. FOUNDATION fieldbus technology is charted by the Fieldbus Foundation.

This guideline deliberately uses the terms fieldbus and Fieldbus. Lower case fieldbus refers to the generic use of the term and is applicable to all fieldbuses defined in the IEC documentation. Upper case Fieldbus refers specifically to FOUNDATION fieldbus.

1.3 SCOPE

Definition of the design, specification, installation, configuration, commissioning and maintenance for a FOUNDATION fieldbus-based control systems.

This guideline will only discuss the voltage mode (parallel coupling) medium attachment unit, as defined in ISA 50.02, operating at a signal speed of 31.25 kilobits per second (i.e., H1). This revision of the specification does not cover the High Speed Ethernet (HSE) version of FOUNDATION fieldbus.

FOUNDATION fieldbus systems include instruments and hosts that cover all applications and aspects of instrumentation and control. Therefore, it is intended that all FOUNDATION instrumentation and control system standards apply to FOUNDATION fieldbus systems, except as noted herein. Note, however, that only those standards called out by name within this document are specifically referenced.

Subject to the disclaimer at the front of this document, this Engineering Guideline is for use by users, contractors and control system vendors.

1.3.1 General

Fieldbus is an all digital, two-way multi-drop communications link among intelligent smart field devices and automation systems. FOUNDATION Fieldbus is the Local Area Network (LAN) for instruments used in process automation with built-in capability to distribute the control application across the network.

1.3.2 Project Consideration

As with any new project it is critical that the right skill sets be brought forth for the project. The same is true for a Fieldbus project. Experience has shown that training of all members of the project team, engineers, maintenance personnel, and operations staff is critical to the project success. This training should be provided at the 'front end' of the project to minimize rework as this information is gained through 'experience.'

Bringing in the right consultants at key junctures in the project to review and advise on the next steps is also often a prudent investment.

References

2.0 Other References

2.1 FOUNDATION Fieldbus Specifications

2.1.1 FF-569 Host Interoperability Support Test

2.2 Industry Codes and Standards

2.2.1 IEC 61158-1: Introductory Guide

2.2.2 IEC 61158-2: Physical Layer Specification and Service Definition

2.2.3 IEC 61158-3: Data Link Layer (DLL) Service Definition

2.2.4 IEC 61158-4: Data Link Layer (DLL) Protocol Specification

2.2.5 IEC 61158-5: Application Layer Service Specification

2.2.6 IEC 61158-6: Application Layer Protocol Specification

2.2.7 IEC 61158-7: System Management

2.2.8 IEC 61158-8: Conformance Testing

2.2.9 AG-163: Foundation Fieldbus Application Guide 31.25 kbit/s Intrinsically Safe Systems

Note that the parts dealing with the DDL and the Application Layer contain parallel sections for eight different protocols, including FOUNDATION fieldbus.

De facto standards are available from the Fieldbus Foundation that will comply with and be compatible with the IEC 61158 suite of standards.

2.3 Other References

2.3.1 Fieldbus Technical Overview Understanding Fieldbus Technology – Fisher Rosemount

2.3.2 Yokogawa TI 38K02A01-01E Fieldbus Book – A Tutorial

2.3.3 FOUNDATION Fieldbus Wiring Design & Installation Guidelines
Author – Relcom, Inc.
ISBN – Download @ http://www.relcominc.com/download/fbguide.pdf

2.3.4 Fieldbuses for Process Control: Engineering, Operation and Maintenance
Author – Jonas Berge
ISBN – 1-55617-760-7 (note – ISA publication) Also available in Chinese

2.3.5 Industrial Ethernet Planning and Installation Guide
Sponsoring Organization: IAONA e.V
Download @ http://www.iaona.org

2.3.6 FOUNDATION Fieldbus: A Pocket Guide
Authors – Ian Verhappen, Augusto Pereira
ISBN – 1-55617-775-5 (note – ISA publication) Also available in Portuguese

3.0 Definitions

3.1 General Definitions

The definitions below shall be included if the words defined are used in the Code of Practice.

The *Contractor* is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility.

The Principal may undertake all or part of the duties of the Contractor.

The *Manufacturer/Supplier* is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The *Principal* is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorized to act for, and on behalf of, the Principal.

The words *shall/must/will* indicate a mandatory requirement.

The word *should* indicates an acceptable course of action or feature based on past project implementations.

The words *may/can* indicate one acceptable course of action.

3.2 FOUNDATION fieldbus Definitions

The following represent definitions of terms commonly encountered in the use and application of Fieldbus technology. A comprehensive list of definitions related to FOUNDATION fieldbus can be found on the Fieldbus Foundation web site at http://www.fieldbus.org/.

A

Acyclic Period
That portion of the communication cycle time, during which information other than Publish/Subscribe data is transmitted. Typical information transmitted during this time includes Alarms/Events, Maintenance/ Diagnostic information, Program invocations, Permissives/Interlocks, Display information, Trend Information and Configuration.

Application Layer
A layer in the communication stack containing the object dictionary.

Automation System
A process automation, control, and diagnostic system that is composed of distinct modules. These modules may be physically and functionally distributed over the plant area. The automation system contains all the modules and associated software required to accomplish the regulatory control and monitoring of a process plant. This definition of automation system excludes field instruments, remote terminal units, auxiliary systems and management information systems.

Auto Sense
Capability by the system to automatically detect and recognize any hardware upon addition to or removal from the system without any user intervention.

Auxiliary System
A control and/or monitoring system that is stand-alone, performs a specialized task, and communicates with the automation system.

Definitions

B

Basic Device
A Basic Device is any device not having the capability to control communications on an H1 fieldbus segment.

Brick
Fully connectorised passive junction located on the bus.

Bus
A H1 fieldbus cable between a host and field devices connected to multiple segments, sometimes through the use of repeaters.

C

Capabilities File
A Capabilities File describes the communication objects in a fieldbus device. A configuration device can use Device Description (DD) Files and Capabilities Files to configure a fieldbus system without having the fieldbus devices online.

Common File Format File (CFF)
A software file used by the host to know the device detailed FF capabilities without requiring the actual device. This file format is used for Capabilities and Value files.

Communications Stack
Layered software supporting communication between devices. A Communications Stack is device communications software, which provides encoding and decoding of User Layer messages, deterministic control of message transmission, and message transfer.

Configurable
The capability to select and connect standard hardware modules to create a system; or the capability to change functionality or sizing of software functions by changing parameters without having to modify or regenerate software.

Configuration
The physical installation of hardware modules to satisfy system requirements; or the selection of software options to satisfy system requirements.

Connector
A Connector is a coupling device used to connect the wire medium to a fieldbus device or to another segment of wire.

Console
A collection of one or more workstations and associated equipment such as printers and communications devices used by an individual to interact with the automation system and perform other functions.

Control Loop
A Control Loop is a group of Function Blocks (FBs) that execute at a specified rate within a fieldbus device or distributed across the fieldbus network.

Coupler
A Coupler is a physical interface between a trunk and spur, or a trunk and a device.

Cycle
The scanning of inputs, execution of algorithms and transmission of output values to devices.

D

Data Link Layer (DLL)
The Data Link Layer (DLL) controls transmission of messages onto the fieldbus, and manages access to the fieldbus through the Link Active Scheduler (LAS). The DLL used by FOUNDATION fieldbus is defined in IEC 61158 and ISA 50. It includes Publisher/Subscriber, Client/Server and Source/Sink services.

Deterministic
Ability to measure the maximum worst-case delay in delivery of a message between any two nodes in a network. Any network protocol that depends on random delays to resolve mastership is nondeterministic.

Device Description (DD)
A Device Description (DD) provides an extended description of each object in the Virtual Field Device (VFD), and includes information needed for a control system or host to understand the meaning of data in the VFD.

Discrete Control
Control where inputs, algorithms, and, outputs are based on logical (yes or no) values. In the case of FF, discrete includes any integer operation between 0-255.

DI
Discrete Input – the signal is from the field device to the host system.

DO
Discrete Output – the signal is generated by the host system and transmitted to a field device.

E

EDDL
Enhanced Device Description Language

Ethernet
Physical and data link layer used by HSE Fieldbus

F

FF
FOUNDATION Fieldbus

Factory Acceptance Test (FAT)
The final test at the vendor's facility of the integrated system being purchased**.**

Fieldbus
A fieldbus is a digital, two-way, multi-drop communication link among intelligent measurement and control devices. It serves as a Local Area Network (LAN) for advanced process control, remote input/output and high speed factory automation applications.

Fieldbus Access Sublayer (FAS)
The Fieldbus Access Sublayer (FAS) maps the Fieldbus Message Specification (FMS) onto the Data Link Layer (DLL).

Fieldbus Messaging Specification (FMS)
The Fieldbus Messaging Specification (FMS) contains definitions of Application Layer services in FOUNDATION fieldbus. The FMS specifies services and message formats for accessing Function Block (FB) parameters, as well as Object Dictionary (OD) descriptions for those parameters defined in the Virtual Field Device (VFD).

Commentary:
Network Management (NM) permits FOUNDATION Network Manager (NMgr) entities to conduct management operations over the network using Network Management Agents (NMAs). Each NMA is responsible for managing the communications within a device. The NMgr and NMA communicate through use of the FMS and Virtual Communications Relationship (VCR).

FISCO
Fieldbus Intrinsic Safe COncept. Allows more power to an IS segment for approved FISCO devices, allowing for more devices per IS segment.

Commentary:
FISCO eliminates the requirement of calculating entity parameters of capacitance and inductance when designing networks.

Flexible Function Block (FFB)
A Flexible Function Block (FFB) is similar to a Standard FB, except that an application-specific algorithm created by a programming tool determines the function of the block, the order and definition of the block parameters, and the time required to execute the block. Flexible Function Blocks (FFBs) are typically used for control of discrete processes and for hybrid (batch) processes. A Programmable Logic Controller (PLC) can be modeled as a Flexible Function Block device.

FNICO
Fieldbus Non-Incendive COncept. Allows more power to a Fieldbus segment in a Zone 2 Area thus allowing for more devices per segment.

G

Gateway
Translates another protocol to Fieldbus, for example HART to Fieldbus or Modbus to Fieldbus.

H

H1
H1 is a term used to describe a fieldbus network operating at 31.25 kbit/second.

H1 Field Device
An H1 Field Device is a fieldbus device connected directly to an H1 fieldbus. Typical H1 Field Devices are valves and transmitters.

H1 Repeater
An H1 Repeater is an active, bus-powered or non-bus-powered device used to extend the range over which signals can be correctly transmitted and received for a given medium. A maximum of four Repeaters and/or active Couplers can be used between any two devices on an H1 fieldbus network. Repeaters connect segments together to form larger networks.

High Speed Ethernet (HSE)
High Speed Ethernet (HSE) is the Fieldbus Foundation's backbone network running Ethernet and IP.

HIST
Host Interoperability Support Test performed by the foundation to test host conformance to the FF specifications.

HSE Field Device
An HSE Field Device is a fieldbus device connected directly to a High Speed Ethernet (HSE) fieldbus. Typical HSE Field Devices are HSE Linking Devices, HSE

Field Devices running Function Blocks (FBs), and Host Computers.

HSE Linking Device
An HSE Linking Device is a device used to interconnect H1 fieldbus networks/ segments to High Speed Ethernet (HSE) to create a larger system.

HSE Switch
An HSE Switch is standard Ethernet equipment used to interconnect multiple High Speed Ethernet (HSE) devices such as HSE Linking Devices and HSE Field Devices to form a larger HSE network.

I

Input/Output (I/O) Subsystem Interface
An Input/Output (I/O) Subsystem Interface is a device used to connect other types of communications protocols to a fieldbus segment or segments. Refer also to Gateway.

Interchangeability
Interchangeability is the capability to substitute a device from one manufacturer with that of another manufacturer on a fieldbus network without loss of functionality or degree of integration.

Instantiable
The ability, for function block, to create multiple tagged function blocks of different types from a library as required by application. Quantity per device restricted by device memory and other resources

Interoperability
Interoperability is the capability for a device from one manufacturer to interact with that of another manufacturer on a fieldbus network without loss of functionality.

IS
Intrinsic Safety

ITK
Interoperability Test Kit used by the foundation to tick mark devices and confirms compliance with the relevant FOUNDATION fieldbus standards. This is a pass/fail test. Only devices passing the full suite of tests receive the FF "tick mark."

J

Junction Box / Quick Connection Station
A junction box station allows for quick installation of four to eight field instruments via Terminal connectors.

K

L

Link
A Link is the logical medium by which H1 Fieldbus devices are interconnected. It is composed of one or more physical segments interconnected by bus, Repeaters or Couplers. All of the devices on a link share a common schedule, which is administered by that link's current LAS. It is the data link layer name for a network.

Link Active Scheduler (LAS)
A Link Active Scheduler (LAS) is a deterministic, centralized bus scheduler that maintains a list of transmission times for all data buffers in all devices that need to be cyclically transmitted. Only one Link Master (LM) device on an H1 fieldbus Link can be functioning as that link's LAS.

Link Master (LM)
A Link Master (LM) is any device containing Link Active Scheduler (LAS) functionality that can control communications on an H1 fieldbus Link. There must be at least one LM on an H1 Link; one of those LM devices will be elected to serve as LAS.

Link Objects
A Link Object contains information to link Function Block (FB) Input/Output (I/O) parameters in the same device and between different devices. The Link Object links directly to a Virtual Communications Relationship (VCR).

M

MAC Address
A unique hardware address given to each Ethernet interface chip.

Methods
Methods are an optional (but highly desirable) addition to Device Descriptions (DDs). Methods are used to define/automate procedures (such as calibration) for operation of field devices.

Mode
Control block operational condition, such as manual, automatic, or cascade.

N

Network
A network as applied in this document, is the termination of one or more fieldbus segments into an interface card of the host system.

Commentary:
In this document, as has become industry practice, the term segment is used to represent a cable and devices installed between a pair of terminators.

Network Management (NM)
Network Management (NM) permits FOUNDATION fieldbus Network Manager (NMgr) entities to conduct management operations over the network by using Network Management Agents (NMAs). Each Network Management Agent (NMA) is responsible for managing the communications within a device. The NMgr and NMA communicate through use of the Fieldbus Messaging Specification (FMS) and Virtual Communications Relationship (VCR).

Noise AV
Average noise in the network during the silence period between frames.

O

Object Dictionary
An Object Dictionary (OD) contains all Function Block (FB), Resource Block (RB) and Transducer Block (TB) parameters used in a device. Through these parameters, the blocks may be accessed over the fieldbus network.

OPC (Object Linking and Embedding for Process Control)
Software application which allows bi-directional data flow between two separate applications. These applications may be running on the same or on separate servers.

Operator Console
A console used by an operator to perform the functions required to monitor and control his assigned units.

P

Physical Layer
The Physical Layer receives messages from the Communications Stack and converts the messages into physical signals on the fieldbus transmission medium, and vice-versa.

Q

Quiescent Current
The device power consumption, the current drawn while the device is not transmitting. Shall be as low as possible to enable many devices and long wires, particularly in intrinsic safety.

R

Redundant Configuration
A system/subsystem configuration that provides automatic switchover, in the event of a failure, without loss of a system function.

Regulatory Control
The functions of process measurement, control algorithm execution, and final control device manipulation that provide closed loop control of a plant process.

Resource Block (RB)
A Resource Block (RB) describes characteristics of the fieldbus device such as the device name, manufacturer and serial number. There is only one Resource Block (RB) in a device.

S

Schedules
Schedules define when Function Blocks (FBs) execute and when data and status is published on the bus.

Segment
A Segment is a section of an H1 fieldbus that is terminated in its characteristic impedance. Segments can be linked by Repeaters to form a longer H1 fieldbus. Each Segment can include up to 32 H1 devices.

Commentary:
In this document, as has become industry practice, the term segment is used to represent a cable and devices installed between a pair of terminators. The Fieldbus specifications use the term network to describe the system of devices though this document uses the terms interchangeably.

See ANSI/ISA–50.02, Part 2 (IEC 61158-2): SEGMENT = The section of a fieldbus that is terminated in its characteristic impedance. Segments are linked by repeaters to form a complete fieldbus. Several communication elements may be connected to the trunk at one point using a multi-port coupler. An active coupler may be used to extend a spur to a length that requires termination to avoid reflections and distortions. Active repeaters may be used to extend the length of the trunk beyond that of a single segment as permitted by the network configuration rules. A fully loaded (maximum number of connected devices) 31,25 kbit/s voltage-mode fieldbus segment shall have a total cable length, including spurs, between any two devices, of up to 1,900 m. There shall not be a nonredundant segment between two redundant segments.

Self-Diagnostic
The capability of an electronic device to monitor its own status and indicate faults that occur within the device.

Splice
A Splice is an H1 Spur measuring less than 1 m (3.28 ft.) in length.

Spur
A Spur is an H1 branch line connecting to the Trunk that is a final circuit. A Spur can vary in length from 1 m (3.28 ft.) to 120 m (394 ft.).

Standard Function Block (FB)
Standard Function Blocks (FBs) are built into fieldbus devices as needed to achieve the desired control functionality. Automation functions provided by Standard FBs include Analog Input (AI), Analog Output (AO) and Proportional/Integral/Derivative (PID) control. The Fieldbus Foundation has released specifications for 21 types of Standard FBs. There can be many types of FBs in a device. The order and definition of Standard FB parameters are fixed and defined by the specifications.

Rate/Stale Count
This is a number corresponding to the allowable missed communications before a device will shed mode. This is basically a Watchdog Timer.

System Management (SM)
System Management (SM) synchronizes execution of Function Blocks (FBs) and the communication of Function Block (FB) parameters on the fieldbus, and handles publication of the time of day to all devices, automatic assignment of device addresses, and searching for parameter names or "tags" on the fieldbus.

T

Tag
A collection of attributes that specify either a control loop or a process variable, or a measured input, or a calculated value, or some combination of these, and all associated control and output algorithms. Each tag is unique.

Tag Id
The unique alphanumeric code assigned to inputs, outputs, equipment items, and control blocks. The tag ID might include the plant area identifier.

Terminator
Impedance-matching module used at or near each end of a transmission line that has the same characteristic impedance of the line. Terminators are used to minimize signal distortion, which can cause data errors by converting between current variations and voltage variations. H1 terminators also have another even more important function. It converts the current signal transmitted by one device to a voltage signal that can be received by all devices on the network.

Topology
Shape and design of the fieldbus network (for example, tree branch, daisy chain, point-to-point, bus with spurs, etc.).

Transducer Block (TB)
A Transducer Block (TB) decouples Function Blocks (FBs) from the local Input/Output (I/O) functions required to read sensors and command output hardware. Transducer Blocks (TBs) contain information such as calibration date and sensor type. There is usually one TB channel for each input or output of a Function Block (FB).

Transmitter
A Transmitter is an active fieldbus device containing circuitry, which applies a digital signal on the bus.

Trunk
A Trunk is the main communication highway between devices on an H1 fieldbus network. The Trunk acts as a source of main supply to Spurs on the network.

U

User Application
The User Application is based on "blocks," including Resource Blocks (RBs), Function Blocks (FBs) and Transducer Blocks (TBs), which represent different types of application functions.

User Layer
The User Layer provides scheduling of Function Blocks (FBs), as well as Device Descriptions (DDs), which allow the host system to communicate with devices without the need for custom programming.

V

Virtual Communication Relationship (VCR)
Configured application layer channels that provide for the transfer of data between applications. FOUNDATION fieldbus describes three types of VCRs: Publisher/ Subscriber, client/Server, and Source/Sink.

Virtual Field Device (VFD)
A Virtual Field Device (VFD) is used to remotely view local device data described in the object dictionary. A typical device will have at least two Virtual Field Devices (VFDs).

W

Wizard
A Wizard is a means of automating procedures in Windows. Wizards can be used to implement methods.

Workstation
A set of electronic equipment including, at a minimum, one monitor, keyboard(s) and associated pointing device(s).

X

Y

Z

Abbreviations

Abbreviations	*Description*
AI	Analog Input
AO	Analog Output
BPS	Bulk Power Supply
CAPEX	Capital Expenditure
CCR	Central Control Room
C/S	Client/Server
CFF	Common File Format
DCS	Distributed Control System/Digital Control System
DI	Discrete Input
DD	Device Description
DLL	Data Link Layer
DO	Discrete Output
EDDL	Enhanced Device Description Language
ESD	Emergency Shut Down
FAR	Field Auxiliary Room
FAS	Fieldbus Access Sublayer
FB	Function Block
FF	FOUNDATION Fieldbus
FFB	Flexible Function Block
FFPS	FOUNDATION Fieldbus Power Supply
F&G	Fire and Gas
HIST	Host Interoperability Support Testing
HMI	Human Machine Interface
HSE	High Speed Ethernet
IEC	International Electro technical Commission
I/O	Input Output
IPF	Instrument Protective Function
IS	Intrinsic Safety
IT	Information Technology
ITC	Individual Twisted Cable

Abbreviations

Abbreviations	***Description***
ITK	Interoperability Test Kit
LAS	Link Active Schedule
LM	Link Master
MAI	Multi Analog Input
MAO	Multi Analog Output
ML	Manual Loader
MOV	Motor Operated Valve
MV	Manipulated Variable (controller output)
NM	Network Management
OD	Object Dictionary
OPEX	Operational Expenditure
PCS	Process Control System
PAS	Process Automation System
P/S	Publish/Subscribe
PD	Proportional/Derivative Control
P&ID	Process & Instrumentation Diagram
PID	Proportional/Integral/Derivative Control
PTB	Physikalisch-Technische Bundesanstalt
PV	Process Variable
PLC	Programmable Logic Controller
RA	Ratio
RB	Resource Block
SIL	Safety Integrity Level
SM	System Management
SP	Set Point
SS	Safety Systems
TB	Transducer Block
TCoO	Total Cost of Ownership
TPE	ThermoPlastic Elastomer
VCR	Virtual Communication Resource

4.1 Support for FOUNDATION fieldbus Functionality

All Fieldbus instruments should support Methods to allow automation of online procedures (such as calibration) from the Host.

4.1.1 Fieldbus Registration

All devices must, as a minimum, satisfy the requirements of the fieldbus registration laboratory. In the case of the Fieldbus Foundation, this is the FF "check mark" logo and listing on the approved devices list maintained on their web site (http://www.fieldbus.org/). This verifies interoperability of devices as indicated in the following example:

Example 4.1 FOUNDATION fieldbus Check Mark Logo

4.1.2 Fieldbus Function Blocks

The following function blocks are defined by the Fieldbus Foundation. Not all of these function blocks are available for use in all field devices, and some are not available and/or do not yet have interoperability tests.

Standard Function Blocks:

FF-891: Function Blocks – Part 2 defines these. The ten standard Function Blocks are as follows:

AI - Analog Input

AO - Analog Output

B - Bias

CS - Control Selector

DI - Discrete Input

DO - Discrete Output

ML - Manual Loader

PD - Proportional/Derivative Control

PID - Proportional/Integral/Derivative Control

RA - Ratio

Advanced Function Blocks:

Advanced Function Blocks are defined in FF-892: Function Blocks – Part 3 are as follows:

- Pulse Input
- Complex AO
- Complex DO
- Step Output PID
- Device Control
- Setpoint Ramp
- Splitter
- Input Selector
- Signal Characterizer
- Dead Time
- Calculate
- Lead/Lag
- Arithmetic
- Integrator
- Timer
- Analog Alarm
- Discrete Alarm
- Analog Human Interface
- Discrete Human Interface

Additional Function Blocks:

Function Blocks are defined in FF-892: Function Blocks – Part 4 are as follows:

- Multiple Analog Input
- Multiple Analog Output
- Multiple Digital Input
- Multiple Digital Output

Flexible Function Blocks are defined in FF-892: Function Blocks – Part 5 as follows:

- Flexible Function Block (IEC 1131 Logic)

Commentary:
It can be seen from the list that Function Block types are not suitable or available for all instruments. It is therefore essential to make a considered choice when specifying the Function Blocks to be included in various field device types. Although it is appropriate to host most of these blocks in controllers, field devices on H1 networks/ segments due to the availability of devices, may be limited to the following blocks: AI for transmitters, AO and PID for Valves, and DI/DO for discrete devices. See Section 8.3 and Section 8.6 for further guidance on use of field device function blocks. Further Function Blocks are likely to be added in the future, it is therefore wise to check Function Block availability with the instrument manufacturer at the time of purchase, thus ensuring that the features desired are available for use.

Function Block Testing:
The Fieldbus Foundation tests of Function Blocks only confirm that they are present and how their external interface behaves, not how well they work internally. Each manufacturer can configure the internal operations of Function Blocks as they wish and will in fact do so since this will provide them a competitive advantage. It is thus worthwhile to check which manufacturer gives the best result in regards to macrocycle efficiency and the needs of your process.

Example:
Each manufacturer can implement the PID algorithm with unique equations while still providing control in a PID block.

4.1.3 User Application Blocks

Function Blocks handle the control strategy. The Function Block diagram is a graphical programming language for building control strategies.

There are two kinds of blocks that are found in FOUNDATION fieldbus devices: Device application blocks, where the execution of these blocks uses predefined scheduling specified by the device manufacturers and are used to configure devices, these are the:

- Resource Block
- Transducer Block
- Function Blocks (FBs) whose schedule and usage is completely user-configurable.

4.1.4 Resource Block

The Resource Block (RB) describes characteristics of the fieldbus device such as the device name, manufacturer, and serial number. The following should be considered for design purposes:

- The user cannot make modifications.
- User can change parameters.
- There is only one RB in a device.
- The RB is the only obligatory block in FF devices.
- The RB contains ID information and general information related to the whole resource or state of the resource (no real details about device functionality).

- Consider this: contains overall health and operational status, contains write protection and enabling of simulation etc.

4.1.5 Transducer Blocks

The Transducer Block (TB) contains information such as calibration date and sensor type.

TBs decouple FBs from the local Input/ Output (I/O) functions required to read sensors and command output hardware. I.e. this is where parameterization, calibration and diagnostics for the device are done.

There is typically one TB channel for each input or output channel of a device (this may differ for some devices).

4.1.6 Function Blocks

Function Blocks (FBs) should be used in user-defined function block applications to provide various functions required in a control system (for example, input, output, signal selection, and other control actions). I.e. function blocks are the control strategy. The Fieldbus Foundation has defined several device profiles outlining the "root" requirement for several device types. This includes pressure, temperature, valves and some others. It is a good idea to use devices that conform to these specifications.

FBs are built into fieldbus devices, as needed, to achieve the desired control functionality. Section 4.1.2 provides a list of standard, advanced, and multiple I/O FBs.

Commentary:

The Fieldbus Foundation has defined dozens of standard function blocks. Additional function blocks may be defined and implemented by each manufacturer to accommodate individual control strategies and signal processing needs.

Each manufacturer configures the internal operations of FBs as they wish looking for competitive advantage. FF organization tests only confirm that FBs are present and how their external interface behaves, not how well they work internally. It may be a good idea to as far as possible only use standard blocks in the control strategy. Because enhanced blocks (standard blocks with additional parameters) have extensions that are unique to each manufacturer, it becomes much more difficult to replace a device that uses enhanced blocks. Devices with "instantiable" blocks have the advantage that they typically support both the standard block (e.g. PID) plus enhanced blocks (e.g. enhanced PID with some additional features). This way it becomes easy to chose standard blocks whenever sufficient, and enhanced blocks only when really required. Thus instantiable blocks make interchangeability much easier.

4.2 Device Diagnostics

The diagnostics shall be able to provide key information on the ability of the device to measure or control the process, including but not limited to basic device failure diagnostics and advanced diagnostics. The types of diagnostics required are explained in the following sections.

Basic Diagnostics:

Basic diagnostics are the device failure diagnostics that shall be viewable from any process control host. They help determine common problems with the device, communication path, and host. Diagnostics that indicate a device failure shall force the affected loop into MAN (Manual) for Transmitters and IMAN the PID block in the output device, typically a valve.

Advanced Diagnostics:
Advanced diagnostics include full device diagnostics so that the device health can be determined without removing it from the process. Advanced diagnostics come in two forms, online and off-line.

Online:
Online diagnostics perform their function while the device is performing its normal function, and provide the capability to alert operations in real time if a problem needs attention. This function provides one of the primary benefits of FOUNDATION fieldbus and should be supported by all field devices as rapidly as possible.

Offline:
Offline tests provide limited benefits and may not justify their cost.

FF devices should be capable of supporting incremental device description (DD) for extra functionality and/or software revisions in device memory.

Capabilities include the following diagnostics and should provide key information on the impact that an output device has on the process, including but not limited to:

- Position accuracy
- Operating resolution
- Total valve travel
- Packing friction and hysteresis
- Static and sliding friction
- Dead band

The following types of diagnostics should be provided:

Public Diagnostics:
Output device diagnostics that are viewable from any process control host. They help determine common problems with valve, actuator, and host.

Advanced Diagnostics:
Full output device diagnostics that determine output device health without removing it from the line. Advanced diagnostics come in two forms – dynamic scan and step scan. Dynamic scan (online or offline method): cycles output device, and in one test collects all parameters for drive signal, dynamic error band, output signal, and output device signature. Step scan (online or offline method): test moves output device in unique patterns, which help examine device's action in specific areas of travel. This action shall be password protected and require approval of a process operator before implementation.

Process Diagnostics:
Test that is run as the process is running. This test moves output device within a range until the process exceeds its configured maximum deviation. It allows maintenance personnel to compare host action, actuator action, output device action, and process action.

Process diagnostics helps determines the following:

- Is the output device sticking? How much? Where?
- Is the output device controlling the process for small variations?
- Is the output device properly sized?

4.3 Field Device Power
Fieldbus devices may be powered either from the segment (bus), or locally powered, depending on the device design. If at all possible field devices should be bus powered.

Commentary:
Bus-powered devices typically require 10-30 mA of current at between 9 and 32 volts.

Devices should strive for minimum power consumption, without negatively impacting desired functionality.

4.3.1 Polarity
Fieldbus device's communication signal shall be polarity insensitive.

Commentary:
Some older FF devices were polarity sensitive and if installed incorrectly could cause network problems.

4.3.2 2-Wire
Field devices shall be loop powered from the host control system. Fieldbus devices shall work with voltages of 9–32 VDC.

Commentary:
The 9 VDC specified is a minimum: it is highly desirable that a margin of at least 1 V (i.e. a minimum of 10 VDC) be maintained at the field end of the bus. Some devices do not conform to FF standards and require 11 volts to operate. Any segment designed to operate below 15 V normally should carry a warning about additional loads in the segment documentation. Minimum segment voltage should always be shown in the network/segment documentation.

4.3.3 4-Wire
Externally powered devices (e.g. 4-wire devices) with FOUNDATION fieldbus should have isolation between external power and Fieldbus signal inputs.

4.3.4 Short-circuit Protection
Devices should work with 60 mA current limiting short-circuit protection though a limit of 40 mA is preferred.

Commentary:
For practical purposes this means all devices shall draw no more than 50 mA since approximately 10 mA is needed to activate the short-circuit protection circuitry.

4.4 Service Conditions
Specific Fieldbus conditions should not relax any device requirements specified in other corporate specifications related to sensor or component selection.

4.4.1 General
The equipment shall be designed to withstand vibration forces of up to 1.0 g over the range of 5 to 100 Hz, and for a 5 msec duration a vibration force of 4.0 g over the same range. Networks, Data, I/O highways are required to have an approved type of electrical isolation at the point of connection to the Host System hardware, Fieldbus junction box, and the field instrument.

4.4.2 Electrical Certification (Hazardous Area Classification)
All devices shall be certified by a nationally-recognized testing laboratory, and labeled for Area classification (Zone or Division) where they will be installed.

4.5 Logical Field Devices
A Fieldbus device is divided into two or more Logical Field Devices, each of which is called a Virtual Field Device (VFD). These Logical Field Devices are:

- The Management VFD containing the device's physical and resource data. Resource data includes the Virtual Communication Resources (VCRs).
- One of more Function Block Application Processes (FBAP VFD).

Each device has a set number of VCRs as does each host system and each publish/

subscribe relationship link to another device or the host consumes one VCR. It is therefore important to be aware of the VCR availability in a device. Refer to Section 8.6.6 for more information on VCRs.

4.6 Factory Configuration

Internal software of fieldbus instruments should be configured by the manufacturer, including at least the following information:

- Serial number
- Tag name
- Process use description

Ancillary Device Requirements

5.1 Bulk Power Supplies

5.1.1 The 24 VDC bulk power supplies shall be redundant.

Commentary:
FFPS requires an input voltage of 20–35 VDC. Unless an appropriate DC bus exists in the plant, the BPS provides the power conversion from 240/120 VAC to 24 VDC.

Bus Power after conditioning is often approximately 19 VDC.

5.1.2 Two separate, independent, power circuits should source power the Bulk Supply. The Bulk Supply can be fed from UPS power or the bulk supply can include battery backup.

5.1.3 Overcurrent protection shall be provided for each feed supplying power to FF power conditioners.

5.1.4 The negative leg of the Bulk Supply shall be grounded.

5.1.5 The Bulk Supply may be either dedicated solely to the fieldbus network or shared between the fieldbus network and conventional I/O.

5.1.6 If the site has an existing power supply for conventional 4-20 mA instrumentation, this power supply may be used to supply the FFPSs. The available spare capacity of the power supplies shall be verified to meet the FFPS demands. The End User representative shall approve, in writing, the use of the existing power supply.

5.2 FOUNDATION fieldbus Power Supply/ Conditioner (FFPS)

5.2.1 One (1) Fieldbus Power Supply/Conditioner is required for each fieldbus network/segment.

Commentary:
If an ordinary power supply were to be used to power the Fieldbus, the power supply would absorb signals on the cable because it would try to maintain a constant voltage level. For this reason, an ordinary power supply has to be conditioned for Fieldbus. Putting an inductor between the power supply and the Fieldbus wiring is a way to isolate the Fieldbus signal from the low impedance of the bulk supply. The inductor lets the DC power on the wiring but prevents signals from going into the power supply.

In practice, a real inductor is not used. Inductors cause undesirable ringing on Fieldbus segments. The electronic circuit provides isolation of the Fieldbus circuits from ground, current limiting to the segment if the cable is shorted, and a high impedance for the Fieldbus signals.

5.2.2 Fieldbus Power Supplies/ Conditioners should be redundant, load sharing, and output current limited.

5.2.3 FF Power Conditioners should provide impedance matching required for FF signals.

5.2.4 Fieldbus Power Supplies/Conditioners should be powered from the primary and secondary (redundant) bulk power supplies. These may be linked primary-to-primary and secondary-to-secondary if desired.

5.2.5 FF Power Conditioners units may be connected together with common Bulk Power Supply feeds, and common alarms. No more than eight (8) FF Power conditioners units may be connected together. The primary and secondary Bulk Supply can feed both ends of the connected FF Power conditioners.

Commentary:
Some manufacturer's redundant power supplies (FFPS) can be ordered with pre-made wiring jumpers. The jumpers are used to efficiently distribute power and to series alarm to multiple (connected) FFPS units. In this way, a number of redundant FFPS may be fed from two primary and two secondary BPS feeds.

5.2.6 Failure or faults in any of the redundant FF Power conditioners shall be annunciated in the host system. A common alarm for all FF Power conditioners in a single cabinet may be used.

5.2.7 Power Conditioners should be isolated.

5.3 FOUNDATION fieldbus Terminators

5.3.1 Each fieldbus segment must have exactly two terminators. The wiring between the two terminators is defined as the *trunk.*

5.3.2 It is recommended that all terminators located in the field should be installed in a junction box; no terminators are to be installed in the FF devices.

Commentary:
When a signal travels on a cable and encounters a discontinuity, such as an open circuit or short, it produces a reflection. The portion of the signal that echoes from the discontinuity travels in the opposite direction. The reflection is a form of noise that distorts the signal. A terminator is used to prevent a reflection at the ends of a fieldbus cable. A fieldbus terminator consists of a 1µF capacitor in series with a 100 Ohm resistor. Some of the wiring components previously discussed may have terminators built into them, (e.g. FFPS). These terminators may be permanently installed, turned on or off using a dipswitch, or placed into use by a wiring jumper. The terminator on an H1 segment serves as a current shunt.

The following figure is for information only to show schematically the electrical equivalence of a terminator. Users should ***NOT*** *fabricate their own terminators as per this diagram.*

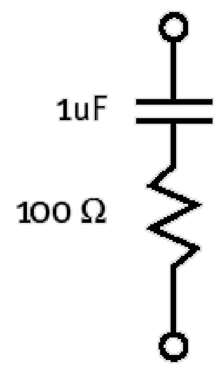


Figure 5.1 - Fieldbus Terminating Electrical Circuit

5.4 FOUNDATION fieldbus Repeaters

5.4.1 Repeaters replace one of the field devices in the network count, allowing the addition of the equivalent of an entire new segment by effectively splitting the network into a number of smaller segments.

5.4.2 By adding a repeater, a new segment can be connected and terminators are required on each end of this new segment.

5.4.3 Repeaters also provide the capability to increase the number of devices on a network to a maximum of 240 devices.

Commentary:

The host system and network schedule limit will likely be exceeded before the physical maximum number of devices is reached.

5.4.4 When Fieldbus Repeaters are used the Principal engineer is to be informed and it is to be clearly marked on the associated network drawing.

Typical uses:
If a segment (network) needs to extend further than the 1900 meter length constraint, then a repeater may be considered. The repeated segment design must be reviewed and approved in writing from the Principal.

The most common use of repeaters is not to get longer distance, but to join IS segments together. Because an entity barrier only supports 3-4 devices, many barriers are needed on a network to get loading of 16 devices per network.

Commentary:
In the cases where it is economically justified, a repeater may be considered to extend the total segment length. This would typically be in cases where the H1 interface card cannot be located relatively close to the process (e.g. flare systems).

Repeaters clean up the signal, by boosting it, re-timing it, and thereby improving the reliability of the communications. A repeater can be used in cases with wire less than 1900 m to improve network robustness.

5.5 FOUNDATION fieldbus Wire
FF wire is discussed in Section 6.2. Refer also to Section 6.3.7.

5.6 FOUNDATION fieldbus Junction Boxes
It is recommended that all trunk and spur connections in the field junction boxes, including pass-through trunk pairs without spurs, be terminated on 'wiring blocks' specifically made for FOUNDATION fieldbus networks. An alternate connection may be provided by weatherproof molded "bricks" that can be used without a junction box with factory molded plug connectors.

Commentary:
Fieldbus supports the use of traditional terminal blocks though the User must be aware that the wiring of all devices to the network is done via parallel connections.

The wiring block/Junction Box or Brick should meet the following requirements:

- Two (2) dedicated connections for the Fieldbus homerun/trunk cable.
- Integral short-circuit protector for spur connections, maximum current to spur is limited by the area classification and current available to the network. Spur circuits shall have a non-incendive rating.

Commentary:
The short-circuit protector can be connected to the terminating block at the homerun or main network cable.

- Pluggable (removable) 'trunk' and 'spur' connectors.
- An indicator for each spur connection indicating when a spur is shorted and is in overcurrent mode.
- Indication when bus power is available.
- Electrical regulatory (e.g. CSA or FM) approved for Ex n; Class I, Division 2, Groups B, C, D or Zone 2, IIA, IIB, IIC.
- Wire capacity: 12-24 AWG.
- Temperature range: -45° to +70° C.
- DIN rail mounting (terminal blocks).

- Available in four (4) spur, six (6) spur and eight (8) spur configurations.

Exception:
Inactive spare Fieldbus trunk pairs may be terminated on conventional terminal blocks, per End User standards.

Commentary:
Wiring Blocks with integral short-circuit protectors will prevent a fault (short-circuit) in the device or spur cable run from bringing the entire FF segment down. Typically an additional 10 mA load is added when this spur is short-circuited.

The system design should be well under-stood before the network and individual segment design is started. The P&ID's, Instrument Location drawings and Plot Plans are needed to effectively design fieldbus segments.

Commentary:
Prior to defining Fieldbus segments, the process control strategy should be complete, the P&IDs available, and instruments selected with locations determined. This is a necessary condition to allow for the design of control in the field, which requires all devices for the loop to be part of the same network/segment.

6.1 FOUNDATION fieldbus Network/Segment Topology

The fieldbus installation shall use the Tree, Spur or Combination topology. *Do not use the daisy chain topology.*

Commentary:
Components of fieldbus segments can be connected together in various topologies. The topology selected is usually, though not always[1] driven by the physical device location in order to reduce installation costs. Hence, control narratives and plot plans are used in addition to P&IDs and instrument indexes in the design of a fieldbus segment.

Spur connections shall be connected to current-limiting connections to the bus to provide short-circuit protection, and to provide the ability to work on field devices without a hot work permit. This current limiting connection should provide a non-incendive or intrinsically safe connection to the field device.

Commentary:
The drops and current limiting can be provided by terminal blocks in junction boxes or by bricks that are field-mounted.

The connection from the marshalling cabinet/host to the first junction box in the field for the topologies shown in 6.1.2, 6.1.3, and 6.1.4 are often provided by a multi-pair, individually shielded cable of the same type (ITC) and wire gauge used for the individual network and spur wires.

6.1.1 Point-to-Point Topology

This topology consists of a network having only two devices. The network could be entirely in the field (e.g. a transmitter and valve, with no connection beyond the two) or it could be a field device connected to a host system (doing control or monitoring). This topology is illustrated below and **should not be used**. It is not an economic design except as listed below.

Figure 6.1 Example of Point-to-Point Topology

Commentary:
Until such time as the FOUNDATION fieldbus for Safety specification is complete, this is the only way in which a user may wish to self-certify and apply Fieldbus technology in a safety application.

6.1.2 Tree Topology (Chicken Foot)

This topology consists of a single fieldbus segment connected to a common junction box to form a network. This topology can be used at the end of a home run cable. It is practical if the devices on the same segment are well separated but in the general area of the junction box. When using this topology, the maximum spur lengths must be considered. Maximum spur lengths are discussed in 6.2.4. This topology is illustrated below in figure 6.2.

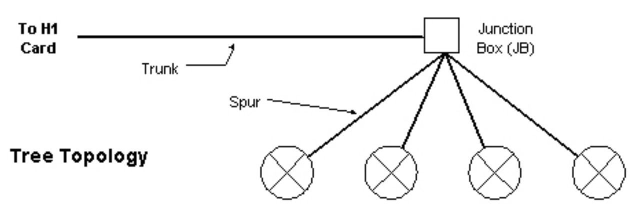


Figure 6.2 Example of Tree (Chickens Foot) Topology

[1] The desire to implement control in the field will drive the need to connect all the devices for the affected loop to reside on the same segment.

This is the preferred topology to be used for reuse of existing wiring, as it is most similar to the conventional installation and will therefore provide the optimal use of existing infrastructure.

Tree branch topology should be used for the following situations:

- Retrofit installations
- High density of fieldbus devices in a particular area
- High Speed Ethernet (HSE) is being used

This topology also allows maximum flexibility when configuring and assigning devices to networks/segments.

6.1.3 Spur Topology

This topology consists of fieldbus devices that are connected to a multi-drop bus segment through a length of cable called a spur. This technology is technically acceptable but not generally a good economic choice.

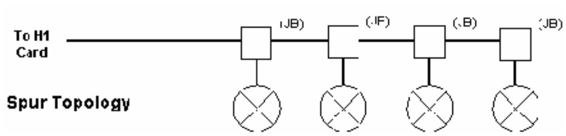


Figure 6.3 Example of Spur Topology

Bus with spur topology should be used in new installations that have a low density of devices in an area. Spurs shall be connected to current-limiting connections (30 mA, or as appropriate for the device on a particular spur) to the bus as this provides Short-circuit protection.

6.1.4 Combination Topology:

Combinations of the above topologies must follow all the rules for maximum fieldbus network/segment length, and include the length of spurs in the total length calculation. These types of topologies are preferred for designs using bricks with tray cable. Spurs are permitted to extend only from trunk lines and not from other spur lines.

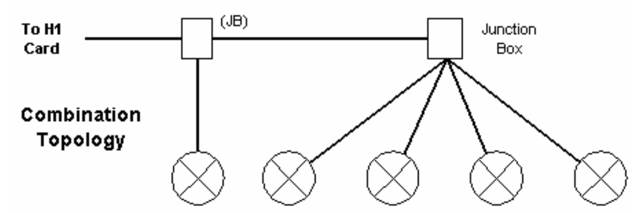


Figure 6.4 Example of Combination Topology

6.1.5 Daisy Chain Topology

This topology consists of a network/ segment that is routed from device to device, and is connected at the terminals of the fieldbus device. This topology is illustrated below in figure 6.5*. This topology should not be used*, *as it is unacceptable for maintenance purposes.*

Commentary:

The daisy chain topology is not used because devices cannot be added or removed from a network/segment during operation without disrupting service to other devices. Similarly, failure of one device will impact all other devices "downstream" of the failed field device.

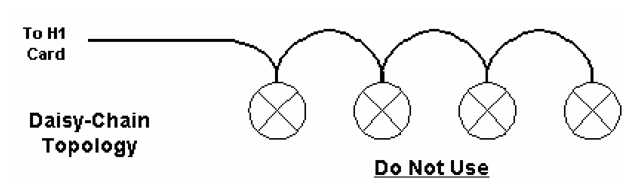


Figure 6.5 Example of Daisy Chain Topology

6.2 FOUNDATION fieldbus Wiring

6.2.1 Cable Types

For new installations or to get maximum performance for a FOUNDATION fieldbus Network, individually shielded twisted-pair overall screened cable designed especially for FOUNDATION fieldbus may be used. However, specially designed FF cable does not always provide significant benefits over standard tray cable that is available at a more attractive price.

Wire Size	18 GA (0.8 mm^2)
Shield	90% coverage
Attenuation	3 db/km at 39 kHz
Maximum Capacitance	150 pF/m
Characteristic Impedance	100 Ohms +/- 20% at 31.25 kHz

Table 6.1 Typical FF cable characteristics per IEC Physical Layer Standard

Commentary:

Twisted pair wire is used rather than a pair of parallel wires to reduce external noise from getting onto the wires. A shield over the twisted pairs further reduces noise susceptibility.

Type	Meters/Feet	Impedance Ohms	Resistivity	Attenuation (db/km)	Description
A	1900 / 6270	100	22	3	Individual shielded pairs
B	1200 / 3960	100	56	5	Multiple pairs with overall shield
C	400 /1320	Unknown	132	8	Multiple pairs with no shield
D	200 / 660	Unknown	20	8	Multiconductor, no pairing

Table 6.2 Fieldbus Cable Specifications

If the project is not using one of the cable types specified above, the cable should be tested before it is installed with induced Fieldbus signals at the anticipated maximum length plus 25%. Tests shall include signal captures at the Power Supply outlet, as well as at the remote end of the cable.

Cables for FF installations shall be labeled Type ITC (16 Gauge) and shall be installed in tray or conduit. All cables shall be single or multiple twisted pair with an individual shield for each pair. Multi-pair cables shall have an additional overall shield.

Fieldbus cable is to be unique in color and can be easily distinguished from conventional 4–20 mA cable.

Commentary:

Facilities will continue to have 4–20 mA signals for some time as fieldbus technology develops, hence the advantage of having the cable differentiated. This differentiation can be at the cable ends only through the use of lugs or colored heat shrink markers.

Fieldbus signals and 4-20 mA signals may be run together in multiconductor cables provided each wire pair is individually shielded. This may be convenient when it is necessary to install a conventional instrument in the field until such time as a Fieldbus version of the device becomes available. Once the Fieldbus device is available it is possible to swing the device over to the Fieldbus Network in the Field Junction box.

Cables shall have thermoplastic elastomer (TPE) flame-retardant insulation and comply with color conventions and polarities of existing facility. Cable should be as follows:

- Suitable for the electrical area classification
- Suitable for outdoor use in cable trays

Cable jacket shall be flame-retardant poly-vinyl chloride (PVC).

6.2.2 Distance Constraints

The maximum allowed length of a fieldbus segment is 1900 meters (6232 ft.) except where repeaters are installed. This total segment length is computed by adding the length of the main trunk line and all the spurs that extend from it.

Total Segment Length = Trunk + All Spurs

Commentary:

The maximum length given is specified in the ISA 50.02 Fieldbus standard. From field experience these lengths have been found to be conservative. As stated in this specification, the length of a segment is limited by voltage drop and signal quality (i.e. attenuation and distortion). As the End User gains field experience these length limits may be revised to reflect real world experience. See 6.7.4 for further information on signal attenuation limits to segment length.

6.2.3 Homerun Cable (Trunk)

Either prefabricated molded cables or industry standard 16 AWG multi-pair, individually shielded cable for analog signals shall be used for all trunk wiring. Cable routing should conform to site Engineering Specifications. Runs parallel to high power cables should be minimized, and adequate spacing and shielding should be employed.

Ten percent (10%) spare pairs should be provided for all muiltipair Fieldbus segment trunk cables, with a minimum of one spare pair. This requirement includes spares on trunk cable runs between marshalling racks and junction boxes, and between junction boxes.

Commentary:

The decision to use multi-pair or single pair trunk cabling depends on the number of networks/segments installed in the field area. Typically, the trunk cable will be a multi-pair cable if more than one network/segment is required in the area or the network/segment in the area would be loaded to maximum. Facilities may have their own rules relative to spare capacity requirements upon completion of a project. This is suggested as a guideline in cases where a standard has not been established.

6.2.3.1 When installing FOUNDATION fieldbus in a Brownfield Facility, the existing homerun cables shall be tested for suitability for reuse. This test can be done using the Relcom FBT-3 and FBT-5 cable testing tools.

Commentary:
At present these are the only known simple handheld test products available for this service.

6.2.4 Spurs

A spur can vary in length from 1 meter to 200 meters (656 ft.). A spur that is less than 1 meter is considered a splice.

Commentary:
A spur that is less than two hundred (200) meters is negligible as a transmission line and can accurately be modeled as an equivalent capacitor. Note: quarter-wavelength at H1 frequencies is in excess of 2 kilometers. The spur length allowances given in this document are considerably more generous than allowed by the FF wiring guide provided by Relcom; however, these allowances are based on transmission line theory, lab tests, and field installation experience. Strictly following the original ISA 50 wiring guide can place unnecessary and costly restrictions on FF field wiring.

Only one (1) FOUNDATION fieldbus device shall be connected to each spur.

Commentary:
Since a short-circuit protection wiring block is being used, the segment design is limited to one (1) device per spur.

The maximum spur length shall be 200 meters (656 ft.). The spur length is the length of the cable from the wiring block to the FF device.

Commentary:
A spur is a drop-off of the main trunk line. The trunk is considered to be the main cable run and will contain segment terminators at each end.

While un-terminated spur lengths up to 200 meters are allowed, any spur over 100 meters (328 ft.) requires Principal approval. The intent of the selected multi-drop bus wiring method is to eliminate the need for long spur lengths and to keep spurs under the recommended length of 30 meters (98 ft.) or less. Longer spurs may be needed to keep the bus out of high-risk areas.

6.3 FOUNDATION fieldbus Power, Grounding & Lightning Protection

6.3.1 Power

Fieldbus devices may be powered either from the segment (bus), or locally powered, depending on the device design.

Commentary:
Bus-powered devices typically require 10-30 mA of current at between 9 and 32 volts. Any network/segment designed to operate below 15V normally should carry a warning about additional loads in the network documentation. Minimum network/segment voltage should always be shown in the network documentation.

The total current draw from all devices on the network must not exceed the rating of the FOUNDATION fieldbus Power Supply. The network/segment design must take into account:

- Total device quiescent current draw
- One spur short-circuit fault (i.e. ~10 mA additional current draw)
- 25% additional current load above the two (2) previous requirements

The number of bus-powered (two-wire) devices on a segment is limited by the following factors:

- Output voltage of the FOUNDATION fieldbus Power Supply.
- Current consumption of each device.
- Location of device on the network/ segment, (i.e. voltage drop).
- Location of the FOUNDATION fieldbus Power Supply.
- Resistance of each section of cable, (i.e. cable type).
- Minimum operating voltage of each device.
- Additional current consumption due to one spur short-circuit fault, ~10 mA.

Commentary:
The length of a fieldbus wiring system and the number of devices on a network/ segment are limited by power distribution, attenuation and signal distortion. ISA 50.02 estimates how long a fieldbus cable can be and still have adequate signal quality, (i.e. acceptable attenuation and distortion Calculating power distribution for a network/segment is relatively simple and can be easily performed.

The number of devices on a network must also consider the Device Criticality to manage the risk associated with a potential single point failure. Refer to Section 6.4 below.

6.3.2 Polarity

Wiring polarity shall be maintained throughout the segment design and installation.

Commentary:
Wiring polarity is critical because some Fieldbus devices are polarity sensitive. Wired with the wrong polarity, a device may not operate.

6.3.3 Grounding

The instrument signal conductors must not be used as a ground. Instrument safety grounds must be made through a separate conductor outside of the signal cable. Fieldbus devices shall not connect either conductor of the twisted pair to ground at any point in the network. The Fieldbus signals are applied and preserved differentially throughout the network.
An alternate method of grounding that is applied in Europe is represented in the figure 6.6.

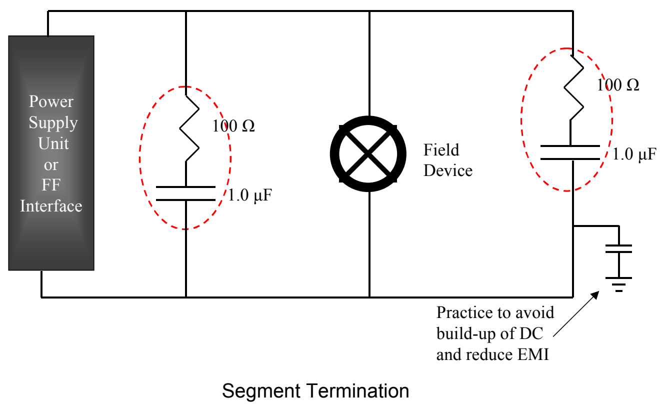


Figure 6.6 Alternate Segment Termination

Network cable shield shall be earthed/ grounded in one location only, at the field termination assembly (host) end. At a field instrument, cable shield shall not be connected to the instrument earth/ground or chassis.

Commentary
This is consistent with the practice employed for conventional instrumentation systems. Shielding over the twisted pair wires is to keep out noise that might interfere with the signals.

Instrument signal conductors shall not be used as an earth/ground. If an instrument safety earth/ground is required, it shall be made through a separate conductor. The conductor may be in the same cable as the instrument signal conductors and shield, but shall be located outside the shield within this cable.

Fieldbus devices should not connect either conductor of the twisted pair to earth/ ground at any point in the network.

Commentary:
The earthing/grounding of either fieldbus conductor would be expected to cause all devices on that bus network/segment to lose communications for the period that the conductor is earthed/grounded.

6.3.4 Shielding
The instrument shield shall be terminated at the host (power conditioner) end of the network in the marshalling cabinet and shall not be connected to ground at any other place. If a multiple home run cable goes to a field junction box, do not attach the cable shield wires from different networks together. This creates ground loops and noise onto the network.

6.3.5 Lightning/Surge Protection
Where surge protection is deemed necessary (e.g. areas of high lightning incidence, or where large inductive loads are started and stopped), surge protection should be provided. This surge suppression shall consist of low-capacitance silicon avalanche diodes or spark gaps, wired for both normal- and common-mode protection, connected to the electrical safety ground grid. Typical installations will be on field devices installed in tank farms or on top of distillation columns.

It is vitally important that the surge suppression device does not measurably attenuate the Fieldbus signal.

Commentary:
The expected surge values on signal conductors within shields, provided that the grounding practice for shields is followed, should be low. A surge rating of 1 kA for an 8/20 µS wave shape should be adequate.

Avalanche diodes generally fail to short-circuit. Where this is a concern, the surge suppression devices may be connected via a series fuse.

6.3.6 Terminators
All terminators located in the field shall be installed in a junction box. Terminators should not be installed in the Fieldbus devices.

Commentary:
A cable signal encountering a discontinuity, such as a wire open or short, produces a reflection. The reflection is a form of noise that distorts the original signal. A terminator, consisting of a capacitor in series with a resistor, is used at the ends of a Fieldbus cable, to prevent a reflection.

6.3.7 Repeaters

Commentary:
Repeaters replace one of the field devices in the physical device count, allowing the addition of the equivalent of an entire new segment. By adding a repeater, a new segment is created. Repeaters can be used to split a network into smaller segments.

If a repeater is added to the network, a new segment is connected, and the following should apply:

The newly created segment should have terminators at both ends. Repeaters should be considered as a field device in the physical device count. The number of devices on the network may be increased to the maximum determined by the field bus type.

Note: *The host system and network schedule limit will likely be exceeded long before the physical maximum number of devices is reached.*

Using barriers with built-in repeaters one gets four (4) devices per barrier and the repeater function permits four (4) hazardous area segments to be joined to form a network of sixteen (16) devices going to the host.

Actual number of devices may vary, depending on fieldbus type, type of power supply, and power consumption of the field device itself.

Power supplies shall comply with IEC 61158-2 criteria and performance requirements, with preferential consideration given to the low-power signaling option.

Power conditioners should be redundant units that provide flawless transfer from one unit to the other. Primary and secondary sources shall be physically separated, not sharing a common backplane or AC source. Power supply may be connected anywhere on a bus network/ segment.

In practice, power supply will probably be an integral element of the host control system's manufacturer.

6.4 FOUNDATION fieldbus Segment Risk Management

Each end user facility shall identify and document a risk assessment philosophy (method) by which Fieldbus devices are assigned to network/segments.

Existing plant risk area or card loading methods in place may be used. The philosophy shall consider network/segment segregation, multiple segments per H1 port, etc. The risk assessment ranking should be clearly shown on the network/segment drawings. Topology design should minimize single points of failure.

The following valve criticality rating and network/segment loading method should be used. The valve and associated measurement criticality shall be defined for prudent loading of Fieldbus segments. The following ratings should be assigned to each valve and segment.

Commentary:

The design restrictions are intended to minimize the effect of human error and interoperability problems from affecting plant reliability. The intent of Level 1 and 2 designs is to keep the number and variety of devices on a network small so that a minimum of interaction is required with the segment. Less is better; however, a unit with large numbers of dependent service valves may decide to increase the maximum number of valves to three (3) for Level 1 and 2.

Instruments that are part of a common reliability concept should not be on the same network (share the same host I/O controller) and if possible backplane to minimize the number of possible common mode failure points.

Risk Management Selections	
Redundant Controller	Required
Redundant H1 Interface	Required
Redundant Power Supplies	Required
DC Power Supply Battery Capacity	Required - 30 minutes minimum
Redundant Power Conditioners	Required
Field Backup LAS	Required
Control in Valve Positioner	Preferred for simple loops
Control in Transmitter	Only for Cascade Primary
Control in Host	Required for Complex Loops
Valve / Segment Criticality Ranking	Required
Maximum Devices per Segment	12 (default unless otherwise noted in section 6.4 or 6.7)
Maximum Valves per Segment	4 (default unless otherwise noted in section 6.4 or 6.7)
Repeaters	Requires Project Lead Engineer approval

Table 6.2 Network/Segment Risk Management Selections

6.4.1 Multi-variable Devices

Multi-input and multi-variable transmitters using FOUNDATION fieldbus Analog Input (AI) function block(s) may be used for control and monitoring. A multi-variable transmitter input should be used in one control loop only. All other variables from the transmitter can be used for monitor-only applications.

Multi-input transmitters using FOUNDATION fieldbus Multiple Analog Input (MAI) function block(s) shall be used for monitor only applications.

6.4.2 Discrete Devices

Discrete FF devices (using DI/DO function blocks) may be used on the same network/ segment as regulatory control and monitoring devices.

6.4.3 Level 1 Valves and Networks

Failure of a Level 1 valve will result in a total system trip, causing a shutdown of the entire unit, or other unavoidable losses in excess of $10M. Normal Valve failure mode is to be used for this classification.

Design Requirements:
Level 1 valves and their associated measurement device (transmitter) should reside on H1 networks that are only used for Level 1 control. The segment may have one (1) Level 1 Valve and associated Transmitter when services are independent, or two (2) Level 1 Valves and associated Transmitters when services are dependent. Dependent means that either of the two (2) valves will shut down the same piece of equipment (example pass flows on a fired heater).

To aid in assurance of interoperability, consideration may be given to having the Level 1 field devices in the loop supplied by a single vendor. Host interface cards and field devices for all Level 1 loops shall be independently tested for interoperability. The devices and interface cards shall be kept at compatible revision levels for the lifetime of the network. Upgrades should be done during plant turnarounds if necessary.

The network/segment drawing should show the criticality rating and shall prominently display that no additional devices shall be loaded on this network/segment.

6.4.4 Level 2 Valves and Networks
Failure of a level 2 valve will result in a total system trip, causing a shutdown of the entire unit, or other unavoidable losses in excess of $100K. However, the Level 2 valve's process dynamics allow time for quick recovery from the failure, either by quickly fixing a fault or by taking manual control. The material and energy capacity of associated vessels, geographic location, and elevation/accessibility of such valves should be considered. The difference in Level 1 and 2 valves are dependent on operations ability to respond to a single failure.

Commentary:
For example, a level control valve on a vessel with less than three minutes of holdup time, on the edge of the physical plant, might become a level 1 valve because of its limited accessibility, if loss of level or high-high level would result in a total unit shutdown.

Design Requirements:
Level 2 valves and their associated measurement device (transmitter) should reside on H1 networks/segments that are only used for control. The segment may have one Level 2 valve and associated transmitter when services are independent, or two Level 2 valves or a Level 2 and a Level 3 valve and associated transmitters when services are dependent. Dependent means that either of the two valves will shut down the same piece of equipment (example pass flows on a fired heater).

To aid in assurance of interoperability, consideration may be given to having the Level 2 field devices in the loop supplied by a single vendor. Host interface cards and field devices for all Level 2 loops shall be independently tested for interoperability. The devices and interface cards shall be kept at compatible revision levels for the lifetime of the network. Upgrades should be done during plant turnarounds if necessary.

The network/segment drawing should show the criticality rating and shall prominently display that no additional devices shall be loaded on this network/segment.

6.4.5 Level 3 Valves and Segments
Failure of this valve will not result in any short-term risk of total unit shutdown or major operating losses. Level 3 valves can go to their fail position without requiring immediate operator action.

Design Requirements:
Level 3 valves can reside on cards or networks/segments with up to three other level 3 valves, or on a segment with a level 2 valve (see Section 6.7.2 for other limitations on the number of valves on a segment). Networks containing Level 3 control contain products from multiple (approved) vendors including measurement only devices.

The devices and interface cards shall be kept at compatible revision levels for the lifetime of the network. Upgrades may be done online. The network/segment drawing shall show the criticality rating.

6.4.6 Level 4 Segments – No Control
Level 4 devices are measurement only devices that shall not be used for control and may be configured in a way that could interrupt control on a network/segment. This class includes MAI, MAO, MDI, and MDO block communication devices.

Design Restrictions:
Level 4 devices can reside on segments with up to the maximum number of devices based on network design bandwidth and physical limitations. The devices and interface cards shall be kept at compatible revision levels for the lifetime of the network. Upgrades may be done online. The network/ segment drawing should show the criticality rating.

6.4.7 Network/Segment Shorting
A shorted network/segment or power supply failure shall send valves to their designated failure position, regardless of the device hosting the PID algorithm.

6.4.8 Transmitter Assignment
Normal practice shall be to include the transmitter with the primary process variable on the same segment with its associated valve.

Commentary:
This is a necessary condition to allow for field-based control.

6.4.9 Multiple Process Variables
Multiple measurements used to provide a calculated differential shall be assigned to a common segment with the differential calculation performed in one of the transmitters as they typically have a lower 'load' than an output device.

Commentary:
This restriction does not apply for systems supporting bridge capability between H1 networks.

6.5 Intrinsically Safe (IS) Installations
In general the design of IS Fieldbus installations must follow the same guidelines as imposed by the technology for non-IS installations. The major differences are the power constraints imposed by the need to remain Intrinsically Safe and the requirement to use suitably certified power supplies, field instruments and wiring components.
For IS applications, cable should:

- Comply with IS inductance and capacitance limitations, as specified in the approvals documentation. For FISCO installations, additional requirements apply to the resistance characteristics of the cable.
- Be identified as carrying intrinsically safe circuits. This may be by means of marking or the use of a colored sheath.

Commentary:
Typically, IS wiring has a light blue insulation or shield.

6.6 Fieldbus Intrinsically Safe COncept (FISCO) Installations
The FISCO concept has been developed to provide a means of supplying additional power to the Fieldbus network/segment while still keeping the energy level below that which could cause an explosion.

Due to the limited DC power to be shared by a number of field devices, long cable runs and terminators storing capacitive energy, the traditional intrinsic safety installation and interconnection rules restrict the application of Intrinsically Safe (I.S.) systems.

The key advantages of FISCO, compared with systems installed according to the conventional FF-816 “Entity” concept, are:

- Higher bus current, allowing more field devices per segment
- Elimination of cable parameter calculations
- Simplification of the safety documentation – just a list of devices
- Addition of new devices without reviewing the safety case

Power supplies, terminators, cable and field instruments for use in FISCO systems must comply with the requirements of Table 6.1, as defined in IEC Technical specification IEC TS 60079-27. Where the individual components have been designed and certified according to these requirements, and carry FISCO marking where appropriate, they may be assembled without further approval of the overall combination. The criterion for such interconnection is that the voltage (U_i), the current (I_i) and the power (P_i) which the intrinsically safe apparatus can receive and still remain intrinsically safe, considering faults, must be equal or greater than the voltage (U_o), the current (I_o) and the power (P_o) which can be delivered by the associated apparatus (power supply unit). In addition, the maximum unprotected residual capacitance (C_i) and inductance (L_i) of each apparatus (other than the terminators) connected to the fieldbus must be less than or equal to 5nF and 10μH respectively.

In each IS fieldbus segment only one active device, normally the associated apparatus (power supply), is allowed to provide the necessary power for the fieldbus system. The allowed voltage Uo of the associated apparatus used to supply the bus is limited to the range of 14 VDC to 17.5 VDC. All other equipment connected to the bus cable has to be passive, meaning that except for a leakage current of 50 μA for each connected device, the apparatus is not allowed to provide energy to the system.

Table 6.1 FISCO Parameters

	EEx ia IIC (Groups A-D)	**EEx ib IIB (Groups C,D)**
POWER SUPPLY	Trapezoidal output characteristic	Rectangular output characteristic
Uo	14 - 17.5 V	
Io	In accordance with IEC 60079-11 but not exceeding 380 mA	
Po	In accordance with IEC 60079-11 but not exceeding 5.32 W	
CABLE		
Cable length, trunk	1000 m max.	5000 m max. Note 1
Cable length, spur	60 m max. Note 2	

Loop resistance R‘	15 - 150 Ω/km
Loop inductance L‘	0.4 - 1 mH/km
Capacitance C‘	45 - 200 nF/km Note 3
$C' = C'_{conductor/conductor} + 0.5\ C'_{conductor/screen}$ if the bus circuit is potential-free (balanced)	
$C' = C'_{conductor/conductor} + C'_{conductor/screen}$ if the screen is connected with one pole of the supply unit	
FIELD DEVICE	
Ui	17.5 V min.
Ii	380 mA min.
Pi	5.32 W min.
Classification	EEx ia IIC or Ex ib IIC (Groups A-D), T4
Maximum number of field devices	32
Internal capacitance	5 nF max.
Internal inductance	10 µH max.
TERMINATOR	90 – 102 Ω 0.8µF - 1.2µF (limited by FF specification)

Note 1. Limited to 1,900m by FOUNDATION Fieldbus

Note 2. IEC/TS 60079-27 has a limit of 30m; this has been increased to 60m in IEC draft 60079/27 Ed.1/CDV, and the 60m value is likely to be adopted in the final standard

Note 3. . IEC/TS 60079-27 has a lower limit of 80nF/km; this has been relaxed to 45nF/km in IEC draft 60079/27 Ed.1/CDV, and the 45nF value is likely to be adopted in the final standard

6.7 Fieldbus Non-Incendive COncept (FNICO) Installations

FNICO is a derivative of FISCO and is specifically intended for fieldbus installations in Zone 2 and Division 2 hazardous areas. It takes advantage of the relaxed design requirements for non-incendive (energy-limited) circuits compared with those for intrinsic safety. FNICO enjoys the same benefits as FISCO in terms of simple safety documentation and the elimination of cable parameter calculations, and retains the ability to connect and disconnect the field wiring in the hazardous area while under power and without 'gas clearance' procedures.

FNICO also has the following additional benefits compared with FISCO:

- Higher levels of bus current, allowing more devices to be connected to the hazardous area trunk.
- Easier selection of approved field devices. Suitable devices include EEx nL, non-incendive, IS (Entity) and IS (FISCO).
- Installation rules for non-incendive wiring are less onerous than those for intrinsic safety.

The requirements for FNICO systems are defined in IEC draft document 60079-27 Ed.1/CDV, and are expected to emerge in the final IEC 60079-27 standard, together with the requirements for FISCO.

The design requirements for FNICO power supplies, field devices, cable and terminators are essentially the same as those for FISCO, except in the following respects:

- The field wiring is classified as EEx nL in accordance with IEC 60079-15, or North American non-incendive.
- The maximum permissible value of I_o is 570mA.
- Field devices may have a maximum of 20 μH internal capacitance, thereby permitting IS "Entity" certified field devices to be used in FNICO installations

6.8 FOUNDATION fieldbus Loading and Calculations

Allowable network and segment loading is determined by the lower value of four parameters:

- Risk management criteria (Section 6.4).
- Spare Capacity required (Section 6.7.1).
- Free time in network macrocycle (Section 6.7.2).
- Voltage drop and current supply limitation (Section 6.7.3).

6.8.1 Spare Capacity

Networks/segments should be designed for 25% spare capacity to allow for future expansion. Networks/segments shall be designed with adequate spare capacity for the future addition of one (1) control loop (i.e. one (1) transmitter and one (1) final element). This requirement is consistent with maximum loadings with one (1) second loop execution. Requirements for fast execution that may conflict with this directive shall be approved by the end user engineering representative.

Commentary:

Spare capacity should consider the following network/segment constraints, power requirement (voltage at device, FFPS supply current), device number limits, and bandwidth constraints (function block capacity, number of VCRs, macrocycle times, etc.). The spare capacity require-

ment is not intended to restrict the designer to less than twelve (12) devices on a network/segment but to allow for future plant expansion.

Each host system has its own limitation on how many parameters can be passed during a given time. This must be included as a significant factor in the design of spare network/segment capacity.

6.8.2 Segment Execution Time

Use a default segment execution time of one (1) second unless otherwise approved by the principal. Further guidance on segment times is given in Section 8.6.2 and 8.6.3.

The suggested maximum numbers of devices per segment for the following listed execution times are as follows:

- For segments with monitor only measurements, limit segment to twelve (12) devices.
- For loops requiring 1-second execution time, limit segment to twelve (12) devices with 4 valves.
- For loops requiring 0.5-second execution time, limit segment to six (6) devices with 2 valves.
- For loops requiring 0.25-second execution time, limit segment to three (3) devices with 1 valve.

6.8.3 Voltage Drop Calculations

Circuit analysis shall be carried out for each fieldbus segment to determine the operating voltage at each device. The calculated voltage at the device shall exceed the devices minimum voltage rating by 4 volts, (e.g. minimum VDC required by device = 9 volts, therefore the calculated minimum voltage seen at the device shall be 13 VDC). The calculated voltage at each device shall be shown on the network/segment drawing.

Commentary:
The additional 4 volts at each device has been specified as a spare power margin for future device additions to the segment. The power used by fieldbus devices varies by device type and manufacturer. Specific minimum voltage and current requirements are contained in the product specifications for each device. The voltage and current requirement for each device shall be taken into consideration while conducting the circuit analysis of the network/segment. A Fieldbus Foundation registered device is required to be capable of operating between 9 and 32 VDC.

Commentary:
For estimating purposes, a series of simple rules can be used. For example assuming: no device used in the plant is allowed to consume more than 15 mA. No output device can consume more than 25 mA, No network can have more than 16 devices. No network can be more than 1000 m long. Using a worst case assumption of all 16 input devices clumped together at the far end of the bus. Total power consumption 16 x 15=240 mA. 1 km #18 loop with resistance of 44 ohm/km. The voltage drop is 44 x 0.24=10.6 V. The minimum required supply voltage will be 10.6+9=19.6 V.

6.8.4 Fieldbus Attenuation Calculation

The 1900 meters recommended by ISA 50 is a good practical limit for field installations. End user approval is required for longer runs.

As signals travel on a cable, they become attenuated, that is, get smaller. Attenuation is measured in units called dB or decibel. This calculates as follows:

$$dB = 20 \log \frac{\text{transmitted signal amplitude}}{\text{received signal amplitude}}$$

Commentary:
Cables have attenuation ratings for a given frequency. The frequency of interest for FOUNDATION fieldbus is 39 kHz. Standard FOUNDATION fieldbus cable has an attenuation of 3 dB/Km at 39 kHz or about 70% of the original signal after 1 Km. If a shorter cable is used, the attenuation would be less. For example, a 500 meter standard Fieldbus cable would have an attenuation of 1.5 dB.

A Fieldbus transmitter can have a signal as low as .75 volts peak-to-peak. A Fieldbus receiver must be able to detect a signal as low as .15 volts peak-to-peak. This means that the cable can attenuate the signal by 14 dB as indicated in the following expression:

$$20 \log \frac{0.75}{0.15} = 14 \text{ dB}$$

Since the standard Fieldbus cable has an attenuation of 3 dB/km, this indicates that the Fieldbus segment can be as long as 4.6 km as indicated in the following expression:

$$\frac{14 \text{ dB}}{3 \text{ dB/km}} = 4.6 \text{ km}$$

Commentary:
The distance may be theoretically possible, but there are other factors that have to be considered such as signals becoming distorted as they travel on the cable. While H1 signals have been transmitted over twisted pair well in excess of 2 km under ideal noise conditions, this is not a recommended practice. Normally, the power voltage drop due to the resistance in the wire will become a limitation before attenuation factors will become significant.

6.8.5 Virtual Communication Resources

Each device requires a minimum number of VCRs to communicate with each other and a host. Refer to Section 8.6.6 for information on how to calculate the required number of VCRs.

6.9 FOUNDATION fieldbus Network/Segment Naming Convention

A consistent method for identifying all signal wires is required in any control system; this is especially true for a FOUNDATION fieldbus system.

The following is a recommended network/ segment naming convention – ## NN MM P where:

- Indicates the plant/area number to which the segment is connected

NN - Indicates node number / controller name

MM = module number / card number

P = segment or port number

6.9.1 Loop and Instrument Naming Convention

Loop and Instrument tagging convention shall follow location / project guidelines.

6.9.2 Spur Naming Convention

All spurs shall be labeled with the instrument tag name.

7.0 FOUNDATION FIELDBUS HOST SYSTEM REQUIREMENTS

7.1 Use of Standard Products

The system shall be composed of manufacturer's standard hardware, systems software, and firmware that can be configured to meet the stated requirements. The vendor's standard system operating software shall not be modified to meet any of the user's requirements.

Application software shall be designed in a manner that requires no modification to the system operating software. Software design shall be such that future revisions or updates of the system operating software will not affect the successful operation of the system.

The information from the FF device shall not be mapped into the system as I/O channels. The function blocks resident in the device shall be directly employed in the control strategy.

7.2 Spare Capacity and Expansion

Each system should be supplied with minimum 10% spare capacity for all elements of the system configuration, including application software, graphics, history, reports, and trends. A spare capacity of 10% for each I/O type in the base system should be installed.

Commentary:

The base system is defined as the quantity of hardware and software needed to meet the project requirements.

The level of spare capacity is a sensitive issue. Recommendations on spares range from the minimum 10% given above to 50% capacity for backplanes and marshalling terminals as this is a relatively small investment up front but significant to add financially and from a logistics point of view for installation as expansion modules. Others recommend a minimum of 20-25% spare capacity for all elements of the system configuration including I/O cards, application software, graphics, history, reports, and trends.

Communication networks within the automation system should include ten percent (10%) unused node addresses. System expansion should be achievable without shutting down the regulatory controllers not directly involved with the expansion. The communication network shall utilize automatic network self-addressing technology (plug-and-play), which automatically assigns unique new controller addressing when a new device is connected to the control network. Each H1 module should be able to support a minimum of two segments. Each segment should support a minimum of 16 FOUNDATION Fieldbus devices.

7.3 Interoperability

7.3.1 All FF host systems shall have completed the Host Interoperability Support Test (HIST) as witnessed by Fieldbus Foundation staff and based on HIST Procedures Document FF-569.

7.3.2 A letter of conformance to the Host Interoperability System Test shall be provided to verify test completion and feature support.

Commentary:

All supported FF HIST features shall be integrated seamlessly into the existing control system's engineering, configuration, maintenance, and operations system.

7.3.3 The host shall use the registered device description as found on the Fieldbus Foundation web site and defined in Fieldbus Foundation Document FF-940.

The timing parameters (used to set the device address) shall include the following taken directly from FF-940:

	Default Value	Time (seconds)
T1	480 000	15
T2	2 880 000	90
T3	1 440 000	45

Time Sync Class = 1 millisecond
Slot Time = 8
Max. Response Delay = 10
InterPDU Gap = 16
Preamble Extension = 0 (zero)
PHL Post Transmission Gap Extension = 0 (zero)

Commentary:
All the parameters except for Preamble Extension and PHL Post Transmission gap are related to device timing. The product of Slot Time and Maximum Response Delay determines the bus speed.

The vendor shall clearly indicate if their default DLL parameter settings are different than those indicated above.

Commentary:
Having parameters that differ from these defined in FF-940 have caused difficulties with some installations. The issues appear 'sporadically' and can therefore be difficult to diagnose. It is for this reason these parameters are recommended for the initial configuration.

No Third party files should be required for device configuration.

Commentary:
Requiring third party files limits the freedom of choice in device selection to those devices for which the host has created the third party files.

7.4 Host Interoperability Support Test (HIST) Description

The Lead Project Engineer and Project Manager shall approve the use of an FF host system that does not support required HIST features in writing after a thorough review of the host limitations.

Commentary:
The HIST Procedures Document (FF-569) provides generic test procedures that would be performed or witnessed by qualified Fieldbus Foundation staff on FOUNDATION fieldbus (FF) systems as part of the Host Interoperability Support Test (HIST).

FF-569 does not intend to define the features and components of a FF host. Each host is defined by the manufacturer to provide specific functions within a fieldbus network. A host could be a configuration tool, a recording device, alarm display panel, human machine interface or a combination of functionality.

In order to implement a set of applicable test procedures, FF-569 defines a set of generic FF host features that may be implemented within the host. A host will conform to some, or perhaps all, features as defined by the host feature checklist. However, because hosts can have various definitions, not all features may be applicable to a host implementation. Therefore, it is not expected that every host should support each feature.

Each feature contains a set of test procedures that are to be run against the host or the fieldbus system using the host.

In order for a host to claim support of a feature, the host must be able to pass the test procedures defined by the feature. The features themselves are generic; therefore manufacturers will derive test cases, or actual implementation steps necessary to meet the requirements of the test procedure.

Many test procedures require features supported from both the device(s) as well as the host. Test administrators should refer to the HIST Device Data Sheet to determine if the test procedure is applicable to that specific device on the network/segment.

Though it is not yet fully supported by the FF specifications, online download of a software upgrade to a field device from a host will be supported. This highly desirable feature will be a testable host requirement in the near future.

Transducer Block support will also soon be part of the FOUNDATION fieldbus device test suite.

7.4.1 Additional Capabilities

New capabilities of FF hosts will be added to the list in Table 7.1 as they become available.

7.5 Support for FOUNDATION fieldbus Functionality

7.5.1 Host System DCS Fieldbus Functionality

The host system functionality should be designed to integrate the features of FOUNDATION fieldbus as follows:

- Automatic node addressing
- Interoperability
- Direct configuration of devices using standard DDL
- Direct integration of FF device operating, maintenance and diagnostic data.
- Tuning parameters, modes, alarms and quality of data.
- Field devices should be configurable while the host system is operating without shutting down the network.
- The host system should have the capability to add and fully configure new field devices to an existing network/segment (i.e. Device Tag/Placeholder) without commissioning and start-up delays.
- The host system should be provided with device capability files

Firmware revisions of Fieldbus devices should not impact upgrades to the host system software and vice-versa.

7.5.2 Data Transfer Capabilities

The host system shall be capable to integrate third party data base systems to Fieldbus devices.

Commentary:

This means that a third-party system should be able to read and write parameters to both the host and field devices (via the host).

If OPC (OLE for Process Control) is used, ensure that the OPC products used in the project have been “OPC Compliance Tested” to improve the operation of OPC based systems.

Commentary:

The above OPC test is done through a self-certification process. The test generates a compliance report listing all the functions that passed or failed the test. Be sure to review a copy of this report as part of your review process.

Table 7.1 HIST Feature Requirement Details	
Feature	A host that meets this feature must be able to:
Device Tag Assignment	1. Assign a PD-TAG 2. Clear a PD-TAG
Device Address Assignment	1. Assign a permanent device address 2. Clear a device address
Configuration of Link Master Devices	1. Support configuration of Link Master parameters including: • ConfiguredLinkSettings (Slot Time, Minimum Inter-PDU Delay, Max. Response Delay, etc.) • PrimaryLinkMasterFlag • LAS Scheduling
Block Tag Configuration	1. Set a function block tag
Block Instantiation	1. Instantiate a block 2. Delete an instantiated block
Standard Blocks	1. Read/Write all block parameters of FF standard blocks, and the standard portion of enhanced blocks. Currently 5 blocks are tested: AI, AO, DI, DO and PID. More blocks will be added in the future.
Enhanced Blocks	1. Read/Write all block parameters of FF enhanced blocks
Custom Blocks	1. Read/Write block parameters of FF custom blocks, including transducer blocks
Function Block Linkage Configuration	1. Link Function Blocks 2. Schedule Function Blocks
FF Alert Configuration	1. Configure device to source alert objects
FF Alert Handling	1. Receive FF Alerts 2. Confirm FF Alerts (via FMS Acknowledge Service)
FF Trend Configuration	1. Configure a block to trend an applicable parameter 2. Configure a device to source trend parameter
FF Trending Handling	1. Receive trend data received by sourced trend object
Device Description Services	1. Load a manufacturer's Device Description 2. Display labels, help, enumerations as appropriate. Full scope to be defined. 3. Display DD strings of user specified language, as supported by a DD. 4. Dynamically process conditional evaluations
DD Method Execution	*1. Full implementation of DD Bulletins (FD-112) and methods interpreter* 2. Execute a method: • Associated with a block • Associated with Pre/Post Edit/Read/Write attribute of variables • Associated with Pre/Post Edit attribute of Edit Displays (if supported)
DD Menu Handling	1. Display a Menu associated with a block
DD Edit Displays Handling	1. Display an Edit Display associated with a menu or block
Capability Files	1. Load a manufacturer's Capability File

7.6 Configuration Tool

A FF host should have a configuration tool capable of online and off-line configuration.

The configuration tool should have multi-user and multi-instance capability.

7.6.1 Integration

All host FF functions, including engineering, configuration, maintenance, and operational display functions, should be integrated into a single, seamless host system. Engineering, configuration, maintenance and operational features should apply consistently and seamlessly to conventional analog or discrete I/O, smart HART and proprietary I/O, bus-based I/O, and FF systems. Separate software tools, displays, or procedures — specific for FF and different from conventional — are not desirable.

7.6.2 Features

Host FF configuration should be consistent in method and 'look and feel' with conventional configuration.

Internal mirror or shadow function blocks used by control systems to map FF function blocks to internal proprietary function blocks should be completely transparent to the configuration engineer, maintenance technician, and operator. A single, unique and independent function block and parameter tag name should be used for both configuration and operation. Duplicate shadow blocks/parameters with parameter names different from FF block/parameters are not satisfactory.

The host FF configuration tool should seamlessly and transparently integrate with, and maintain, the master configuration database. Saves, restores and partial downloads of the master control system database should be seamlessly and transparently accomplished for both FF and conventional control strategies by the same configuration tool.

7.6.3 Capabilities

Offline FF configuration, e.g. to configure FF strategies without network/segment or FF devices connected. The host should be capable of configuring all FF function blocks and parameters and support of DD services and Common File Format (CFF) specification.

- Soft simulating and testing any and all FF control strategies.
- Importing non-native, bulk configuration data for developing configuration of larger project databases.
- Simple or complex online FF control strategy creation or modification.
- Transparently managing the macrocycle schedule including maintaining minimum unscheduled acyclic time (50%).
- Coordinating integration of custom FF function block execution times.
- Providing alerts and messages for FF configuration errors.

Commentary:

This represents the minimum acyclic time on a network. It is recommended that for a new installation, a minimum of 70% unscheduled acyclic time be available to allow for system expansion, addition of new devices, or modification to the configuration in the future.

- Partial or incremental downloads to target function blocks and link schedulers without interrupting the operating network/segment strategies.

Master database saves and restores of targeted strategies or FF networks/ segments.

7.6.4 Required Function Blocks

The host system shall support implementation of the following FF function blocks in field devices:

I/O Function Blocks:

- Analog Input Function Block (AI)
- Analog Output Function Block (AO)
- Discrete Input Function Block (DI)
- Discrete Output Function Block (DO)
- Multiplexed Analog Input Function Block (MAI)
- Multiplexed Discrete Input Function Block (MDI)
- Multiplexed Discrete Output Function Block (MDO)

Analog Control Function Blocks:

- Proportional Integral Derivative Function Block (PID)
- Input Selector Function Block

7.6.5 Additional Function Blocks

Additional (optional) function blocks listed below may be required or used to implement control schemes at the host and networks/segment level.

Additional Analog Control Function Blocks:

- Arithmetic /Logic/Flexible Function Block
- Signal Characterizer Function Block
- Integrator Function Block

Commentary:

Logical blocks should be used with caution in field devices at this time as they are not yet uniformly applied by all manufacturers.

7.7 Redundancy & Robustness

7.7.1 Redundancy

For applications that require high availability, the following redundant components shall be used:

- Redundant power feeds shall be provided.
- Redundant bulk power supplies with 20-minute battery backup.
- Redundant system controller power supplies.
- Redundant system controllers.
- Redundant FOUNDATION fieldbus H1 cards.
- Redundant FOUNDATION fieldbus power conditioners.
- Redundant controllers should not sit on the same backplane.
- Redundant H1 cards should not sit on the same backplane.
- Redundant power supplies should not share the same backplane.

See section 6 for more on segment design requirements.

7.7.2 Host Robustness

Due to processes that require high availability, the host system used shall be robust enough to handle bumpless switchovers of failed redundant components so as not to cause a process upset.

There should be a minimum of potential for single points of failure in the host system.

The host must provide for online software upgrades for all nodes where redundancy is specified.

A single failure anywhere in the system shall not result in the loss of regulatory control to more control loops than those associated with a single process input/output/H1 card. Failure of any single device shall not affect the ability of the system to communicate with other devices in the system. Switchover shall not disrupt any system functions.

Redundant equipment and software shall be continuously monitored for errors. All modules shall be diagnosed online. Errors shall be alarmed with an error message identifying the failed module.

I/O terminations shall be on "pluggable" connectors to facilitate the quick changeout of all parts of the network, including interface cards.

Commentary:
This same functionality can be obtained in the field through use of either the pluggable or quick connect terminations in the field junction boxes or at other terminations to the home run network/segment.

Indoor Installation:
Equipment installed in air-conditioned buildings shall be designed for:

Temperature range:	0° C to 60° C
Relative humidity:	5% to 95%

Outdoor Environment:
If required it shall be possible to install system controllers and I/O system in outdoor enclosures in Class 1 Div 2 (Zone 2) environments.

Storage Environment:
It shall be possible to store the equipment for up to six (6) months under the following conditions:

The equipment shall be packed in a moisture proof container in an air-conditioned building.

Temperature:	-40° C to 85° C
Relative humidity (outside the moisture proof container):	5% to 95%

7.8 Troubleshooting, Maintenance, and Diagnostics
The host should be capable of commissioning, setup, and maintaining all FF devices. This function should be integrated into the host and available from host workstations. The following functions should be supported:

- Report of load on all busses.
- Error counters for all busses.
- A schedule (time chart) report for H1 networks/segments.
- An online reconcile function to allow change management when replacing field devices.
- Ability to report, alarm, and acknowledge all device alarms.
- Add a new FF device to a network/ segment. Add a future FF device to a network/segment through use of placeholder templates.
- Move FF devices from/between offline, spare, standby, commissioned, and mismatch states and manage all address changes transparently. Manual address changes shall not be required.
- Simple and complex commissioning functions including transmitter range changes, zeroing, and control valve positioner setup.
- Support for DD methods and menus (wizards) for all maintenance functions

to walk technicians through the necessary maintenance procedures.

- Provide specific maintenance displays, organized in a logical manner, for all FF devices using specified language descriptors and definitions with access to all parameters.
- Ability to mirror existing FF device configuration (all FBs and parameters) onto a new FF device to allow quick device replacements.
- Display of commissioning and maintenance screens shall be possible from the operator/ engineering workstation.

7.9 Advanced Diagnostics and Computer Based Maintenance

The computer-based maintenance software solutions should have the capability to manage and protect industrial assets, by maximizing the effectiveness of plant operations (decrease downtime), equipment and human assets (reduced incidents) to help achieve superior business performance.

Computer-based maintenance systems separate from the host operator/ engineering workstations, may be used to manage and display real-time and historical diagnostic & maintenance information. However, it may not replace commissioning and maintenance function integrated into the host as described above.

Computer-based maintenance should include the measurement, management and regulation of the equipment running in the plant, not just the process.

Commentary:

One primary benefit to install a FOUNDATION fieldbus network is to get more information about the process and the device itself. The intelligent device can make available to the operator, technician, inspector and engineer or plant manager hundreds of different parameters about the process or instrument from a single smart device.

7.9.1 Minimum Diagnostic Requirements

As a minimum, diagnostic capabilities shall report critical failures of devices. Diagnostics shall be reported to the Host via FF Alarms and Alerts. Polling schemes for diagnostics are not acceptable. Diagnostics should be reflected in data quality to the operator and control loop, as well as through separate diagnostic alarms intended for maintenance.

7.9.2 Computer-based Maintenance/ Advanced Diagnostic Features

Computer-based maintenance should include but not be limited to the following features/benefits

- Remote diagnostics of FOUNDATION fieldbus devices from any operator workstation.
- Provide for a separate maintenance workstation to allow device diagnostics separate from operating functions.
- Streamline routine maintenance tasks such as loop checkout, configuration and calibration.
- Establish a predictive maintenance capability with reliable diagnostics, to allow maintenance before failure.
- Automatic documentation of diagnostics and maintenance activities.
- The H1 module should provide pass-through capability to transfer non-control data to field device asset management applications.

7.9.6 Maintenance Station

For security reasons, the maintenance station and functions shall be maintained on a separate server with access only from a controlled area. This will prevent changes from being made to the network, thus affecting the entire control system, without proper control and management of change procedures in place.

7.10 Evaluation Guidelines

NOTE: "Host" is essentially the work-stations and software. The true ISO term is "host computer". Therefore, "system host" is more appropriate than "host system". A linking device is considered a device rather than part of the host computer.

The following criteria should be used when evaluating an FF system host:

- Comparison of features supported by the host system with the feature requirement details specified by the Fieldbus Foundation's Host Interoperability Support Test (HIST) description.
- Function blocks limitation per network.
- Limitation on virtual communication relationship (VCR).

Commentary:

A VCR is a preconfigured application layer channel that provides for the transfer of data between applications. FF describes three types of VCRs: publisher/subscriber (P/S), client/server, and report and distribution.

- Schedule communication between the networks.
- Limitation on number of writes such as unscheduled communication. (For example, set point changes are writes.)

8.0 SOFTWARE CONFIGURATION GUIDELINES

8.1 Control System Graphics

All modifications to, or reconstruction of, control system graphics shall comply with existing end user standards for host system graphics detailing line colors, icon details, trend pages, alarm tracking, and historical data.

8.1.1 Additional FOUNDATION fieldbus Graphics

FOUNDATION fieldbus provides an abundance of additional information to the Host system. The end user will indicate to the control system integrator, which of the following parameters shall be included as part of the operator console and how they shall be represented on those graphics:

- Device Status Alarms
- FOUNDATION Fieldbus Trends
- Alerts

Though it is possible for the panel operator to acknowledge all device status alarms and inactivate them from the operating console this may not be desirable and should be evaluated on a site by site basis while being consistent with good alarm management practices. All such status alarms should also be transmitted to the computer-based maintenance system for repair by the maintenance personnel.

8.2 Node Addressing and Naming Conventions

8.2.1 Node Addressing

Each FOUNDATION fieldbus node must have a unique Node Address. The Node Address is the current address that the segment is using for the device.

Each fieldbus device shall have a unique physical device tag and corresponding network address.

Commentary:
A device tag is assigned to the device when it is commissioned and (for most device states) retains the tag in its memory when it is disconnected. The network address is the current address that the fieldbus is using for the device.

The Fieldbus Foundation uses node addresses in the range 0-255. Each vendor allocates the node numbers in a way that is somewhat unique. They all have reserved low numbers for overhead and host interfaces, and a group above that for live field devices, and some higher numbers for spares.

Addresses used by FF are in accordance with the following ranges:

- 0-15 are reserved.
- 16–247 are available for permanent devices. Some host systems may further subdivide this range. This range is typically shortened for efficiency.
- 248–251 are available for devices with no permanent address such as new devices or decommissioned devices.
- 252–255 are available for temporary devices, such as handhelds.

Third-party systems or configuration tools connected through a communications interface to an H1 network shall not be used to:

- Interrupt the operation of any device within the system.
- Change device address.
- Affect link schedule

Only client server communications should be used with a third-party tool. Communication interfaces shall have user-administered security to control read/write access and to select allowed functionality.

Commentary:
Default settings in <u>some</u> configuration tools can disrupt link operation without any overt action by the operator of the tool.

The field device management solution should be capable of completely configuring parameters associated with FF devices.

Standard Device Description Language (DDL) provided by FF shall be used throughout (i.e., the DD files called SYM and FFO). Also, the standard Capabilities Files (CFF) shall be used by the host. The host shall not require host proprietary files to achieve configuration, monitoring and diagnostics.

Host system shall be capable of completely configuring any fieldbus device for which a device description has been registered with FF.

The field device with the lowest commissioned device address is normally assigned the master stack and has the schedule loaded so that it can function as the backup LAS (BLAS).

Commentary:
All addresses stated previously are in decimal format. Typically, host systems automatically assign device addresses. For example, address 20 can be used for basic devices and devices with BLAS enabled.

8.2.2 Device Tag Naming Convention

Each FOUNDATION fieldbus device must have a unique physical device tag. The device tag is assigned to the device when it is commissioned and (for most device states), the device retains the tag in its memory when it is disconnected. The device tag is shown on the P&ID.

The device tag shall be used for the device diagnostic alarm faceplate.

Every FOUNDATION fieldbus has a 32-byte unique identifier, which is a hardware address very similar to MAC addressing and consists of the following:

- 6-byte manufacturer code
- 4-byte device type code
- 22-byte serial number

Commentary:
These identifiers uniquely distinguish the device from all others in the world. The manufacturer code is universally administered by the Fieldbus Foundation, which eliminates the potential for duplication. The device manufacturer assigns the device type code and sequential number. When devices are shipped or configured as spares, this is the default device tag.

FOUNDATION fieldbus device tag shall match the instrument tag Indicated on P&ID.

8.2.3 Control Strategy/Module Naming Convention

Each Fieldbus control strategy or module will be named as shown on the P&ID. The primary loop function block used for operator interface (AI or PID) will share the module name.

8.2.4 FOUNDATION fieldbus Block Naming Convention

Each Fieldbus device contains a number of blocks. These blocks are necessary to describe and contain the information for/from each device. Each block shall include as a suffix, information relative to the function or block type for which it is defined. The following table illustrates a list of typical suffixes:

FT5010_AI	Analog Input block for Flow Transmitter 5010
FT5010_B	Bias block for Flow Transmitter 5010
FT5010_CS	Control Selector block for Flow Transmitter 5010
FT5010_DI	Discrete Input block for Flow Transmitter 5010
FT5010_DO	Discrete Output block for Flow Transmitter 5010
FT5010_ML	Manual Loading block for Flow Transmitter 5010
FT5010_PD	Proportional Derivative block for Flow Transmitter 5010
FT5010_PID	PID block for Flow Transmitter 5010
FT5010_R	Ratio block for Flow Transmitter 5010
FT5010_RB	Resource block for Flow Transmitter 5010
FT5010_TX	Transducer block for Flow Transmitter 5010
FV5010_AO	Analog Output block for flow control valve 5010

Table 8.1 Typical Block Naming Suffixes

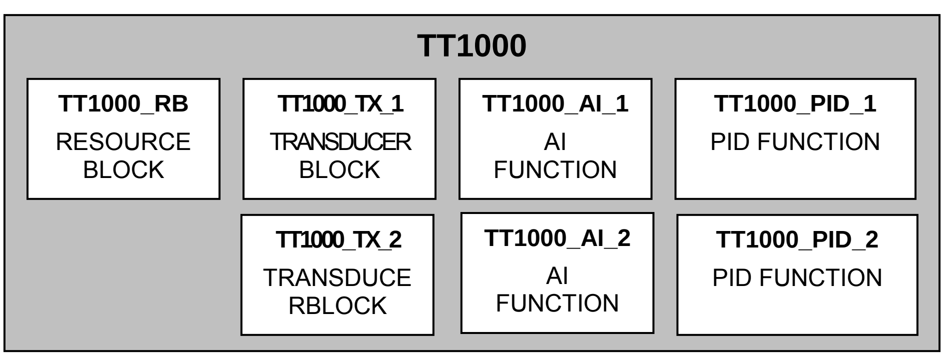


Figure 8.2 Fieldbus Device and Block Naming

Each block shall use the field device tag name for its main descriptive name. In the event a device has more than one identical block (for example, 2 analog input signals) they shall be uniquely identified as AI_1 and AI_2, etc. The following figure (8.3) illustrates the naming convention with an associated field device and its contained blocks.

8.3 Control Functionality Location

Control is contained in software entities called modules. The control blocks inside the module can be assigned to run in a field device or in the host controller. The module is named by the tag shown on the P&ID and is displayed by a faceplate with that same tag. An example is shown below:

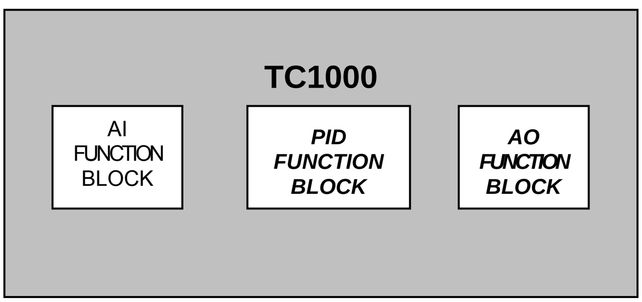


Figure 8.3 Module Naming

Configuration details (for example, analog input block parameter definitions of range, span, alarms, and liberalization) should be stored in the host Process Automation System (PAS) for download to field devices when they are connected.

Commentary:

The idea of a control module is based on ISA-88 and may not be supported by all FF hosts at this time, though the concept should be available from most suppliers.

8.3.1 Field-based Control

Field devices using a PID control algorithm shall be shown on the appropriate network/segment drawing with a bold letter P.

8.3.2 Single Loop PID Control In The Segment

For single PID control in the field device, all function blocks that make up that control loop must reside on the same segment.

When all function blocks of a single PID control loop cannot reside on the same segment, consider placing the PID control algorithm in the host system.

Commentary:

This restriction does not apply for systems supporting bridge capability between H1 networks.

When single loop PID control is implemented in the field device, the PID function block shall be located in the final control element.

Commentary:

Both the valve and transmitter typically have a PID block available, so locating the PID block in one device over another device is not a trivial issue. Issues such as execution speed, advanced diagnostics, failure mode, and operator access are generally considered when locating where the PID block resides. However, general consensus is that the PID block should be located in the control valve positioner. As with conventional control systems, loop and device failure modes need to be determined and the proper course of fail action identified for each control loop.

8.3.3 Cascade Control

The preferred cascade control configuration is to locate each of the cascade loop function blocks and devices on the same network/segment. The primary PID controller should reside in the primary measurement transmitter and secondary PID controllers should reside in the secondary final element.

If the primary and secondary loops have devices or function blocks on separate segments, the primary PID control should reside centralized controller/host. In this case, if all secondary loop function blocks and devices reside on the same segment, the secondary loop PID control may reside in the secondary final element.

8.4 Configuration Options and Defaults

8.4.1 Control Narrative

A control philosophy guideline document shall be created for all FF projects. The guideline shall define all typical control strategies, with control modules, function blocks and all parameter configurations defined. This guideline shall set function block and control module philosophy for this and future FF projects at the facility. The configuration guideline shall be reviewed and approved by the end user engineering representative.

As part of the guideline, a narrative shall be provided for each typical function block and control module, to describe in detail the parameter setting and subsequent blocks/module operation. Included shall be narrative discussion on parameter configuration and operation for signal "status," bad value determination, failure mode switching, initialization feature, anti-reset windup feature, etc. The guideline shall highlight any differences in configuration or operation between FF and non-FF control strategies.

Commentary:
This will form the basis for the configuration of the devices and control system behavior during "non-normal" conditions and is, therefore, critical to the safe and reliable operation of the facility.

The control system vendor shall produce configuration options and defaults for the specific host system-wide settings, configuration strategies, devices and asset management software. The principal shall approve all configuration options and defaults.

An example of some default settings for control loops include:

- Loop mode shall shed to manual for Bad PV, condition is alarmed and indicated by graphics and faceplate color change and blanked out data indication.
- Loop mode shall ignore Questionable PV, condition is not alarmed but is indicated by graphics and faceplate color change.

8.5 Alarms & Alerts

8.5.1 Alarms

Fieldbus contains fifteen (15) alarm priorities that must be mapped to the host system. These alarm priorities are shown in the following table along with how they map to the Distributed Control System (DCS).

Alarm	FF Alert Priority	Host Alarm Priority
15	Critical	Emergency
14	Critical	Emergency
13	Critical	Emergency
12	Critical	Emergency
11	Critical	High
10	Critical	High
9	Critical	High
8	Critical	High
7	Advisory	Low
6	Advisory	Low
5	Advisory	Low
4	Advisory	Journal
3	Advisory	Journal
2	Low – fixed	Journal
1	No notification	No Action

Alarm priorities and their mapping to the DCS.

Alarms must be managed as part of an overall system alarm management philosophy as used by the host control system.

The host shall support time synch and alarm time stamping in field devices. Support for FF alarms and alerts are required of hosts.

8.5.2 Alerts

Field devices generate alerts, due to miscommunication, misoperation (diagnostics) or failure.

Commentary:
"Alerts" is a collective term for "alarms" and "events." Alarms occur and eventually clear (disappear) (therefore two reports) whereas an event only occurs (one report). Failures are therefore reported as "alarms" just like process alarms. The reason is that both process alarms and faults both occur and then clear (repair). An example of "event" is the alert sent when a static parameter is changed. This is just one message.

Alerts are important for system integrity and are needed in order to take full advantage of new diagnostic capabilities in field devices.

Commentary:
Alerts are not the same as alarms but are rather used by the FF system to notify users of various status conditions of a device.

8.5.3 Trend Collection

FOUNDATION fieldbus can trend up to sixteen (16) of the most recent process values and status points, with time stamp for each network/segment. Trends could be supported in a variety of optional ways:

The preferred way to collect trends should be by using the FF trend object to gather high-speed data based on an event.

Commentary:
The FF trend object uses client/server services to read sixteen (16) trend variables with a single call. Note that it reads sixteen (16) consecutive samples of one (1) variable.

Trends can also be accomplished by using Publish/Subscribe (P/S) services from the field device to the host.

Commentary:
This method reduces loading on the bus and provides data with more exact timing, but at the expense of more slots in the LAS schedule. The result is increased loading on the bus. By publishing, one has a single

transaction every macrocycle (i.e., several transactions per second). A possible alternative is to use client/server to read the value once per second or once every few seconds (with relatively low loading). However, P/S definitely has the highest loading. The only exception is when trending a value linked from one device to another, in which case this value is already being published and no further publishing is required.

Hosts can read trend data from field devices by reading in single data values using client/server services.

Commentary:
Such a method places the highest traffic load on the bus, allowing the system to gather and store data in a long- and/or short-term history system. (Note: this is a better approach than publisher/subscriber since the read is only once per second or only once every few seconds as compared to several times per second for P/S.) This method in conjunction with MVC capability is very effective.

Trends can be supported in a variety of optional ways:

- The host can read trend data from field devices by reading in single data values using client server services. This method places the highest traffic load on the bus allowing the system to gather data and store it in a long and /or short-term history system.
- Trends can also be accomplished by using the publish/subscribe services from the field device to the host. This service reduces loading on the bus, and provides data with more exact timing but at the expense of more slots in the LASS schedule.

As described above, the Fieldbus trend object uses client/server services to read 16 trend variables with a single call. This object can also be used to gather high-speed data based on an event and is the preferred way to collect trends

8.6 Network Communications and Scheduling

8.6.1 Link Active Scheduler

Commentary:
A Link Active Scheduler (LAS) is a deterministic, centralized bus scheduler that maintains a list of transmission times for all data buffers in all devices that need to be cyclically transmitted. The LAS is responsible for coordinating all communication on the fieldbus (it is in charge of the token).

The Master and Primary Backup Link Active Scheduler (LAS) shall reside in the host control system in redundant H1 network interface cards.

An additional backup LM Link Master (B/U LAS Link Active Scheduler) shall be configured for all networks and shall reside in the network device with the lowest field node address. The Backup LAS should be placed in a separate device that does not have controlling functions.

Commentary:
Primary and secondary interfaces should sit in separate backplanes with separate CPUs, preferably in separate control panels. Similarly, the primary and secondary power supplies should not share the same backplane. Having redundant interface cards, CPUs, and power supplies in the same backplane is self-defeating since the backplane is a single point of failure.

Each network shall be configured for automatic fail-over to the Back-up LAS in the event of Master LAS failure.

Commentary:
By placing a LAS with each power supply, maximum protection is achieved without more LASs than are needed. The LAS is a function built into the linking device or the Fieldbus interface card. It is never found in a power supply.

There can be one or more backup LAS's on a fieldbus network, in addition to the main LAS. If the active LAS fails, one of the backup LAS's automatically takes charge of the bus. It is a well-ordered and reliable switch. Only one LAS is active on an H1 fieldbus network.

Failure modes should be considered for final placement of LAS and Back-up LAS.

8.6.2 Network/Segment Execution Time

See also section 6.7.2.

The network/segment macrocycles should match the module execution times. Each network/segment should operate with a single specified macrocycle execution time. Multiple macrocycles shall not be used on a single network/segment without the approval of the principal.

Commentary:
Do not mix devices with different macrocycle times (1 sec. vs. 0.25 sec) on the same network/segment. Mixing of macrocycle times can lead to schedules that may not be within the capability of some link masters.

Having different macrocycles on the same network are also likely to make it difficult to diagnose communications problem should they occur in the future, especially if they are sporadic in nature.

If a faster control loop is added to a network/segment containing slower loops, then the macrocycle times of all devices residing on that network/segment must be adjusted to accommodate the faster execution time.

Care should be taken to ensure that the network does not become overloaded.

8.6.3 Macrocycle

The macrocycle should have a minimum of 50% unscheduled (free asynchronous) time. The unscheduled time calculation shall allow for the spare capacity requirements. Therefore, a newly commissioned segment should have a minimum of 70% unscheduled time. Loops can be moved to another segment or macrocycles can be slowed if a segment has insufficient unscheduled time.

Commentary:
Function block execution frequencies must be compatible with both system loading and process control objectives. The execution frequency of all function blocks contained within a single fieldbus network/segment is defined by that network/segment's macrocycle time. This macrocycle time, which can typically range from 250ms to several seconds (depending on the nature of the device used), is configured for each fieldbus network/segment. The order of execution is automatically determined based on the connections between function blocks on the fieldbus network/segment.

Calculation of "free" asynchronous time should be based on the time required for the communications and the block execution time.

Note that the macrocycle contains unscheduled time required for non-deterministic bus communications, such as alarm transmission, setpoint changes, etc. While it is hoped that the vendor's configuration software will manage and maintain minimum (50%) unscheduled time, this is not necessarily true, and must be verified.

The macrocycle for the process must be sufficiently fast to obtain a representative sampling of the true process changes. Statistical behavior indicates that this should be at least six (6) times faster than the process time. For example, a process with a 60 second process "dead time" will require the macrocycle be less than ten (10) seconds. It will only be exceptional cases where this will have to be considered as the Fieldbus macrocycle can be resolved to millisecond resolution, typically a 100 millisecond minimum.

8.6.4 Network/Segment Scheduling

Scheduling is a constraint a person must design within when engineering Fieldbus networks/segments. Each host has a limit on how many parameters it can transmit during a single cycle. The following diagram shows the various components of a typical communication cycle for closed loop control with the PID algorithm in the Analog Output device.

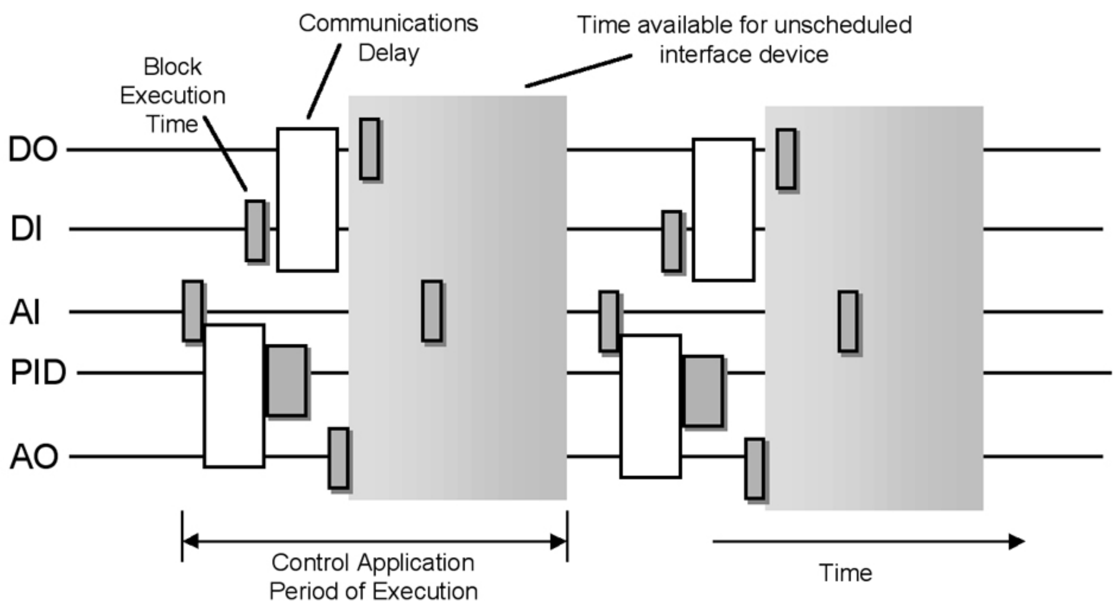


Figure 8.2 Typical communications cycle

The timing cycle map and associated calculations are to be retained as official design documents in electronic format. Scheduling of networks/segments and links must be done as each new point/block is added to a network/segment. Sufficient unscheduled time must remain in each cycle to transmit acyclic (maintenance and configuration) information.

8.6.5 Function Block Considerations

The stale rate on PID blocks must be set to a minimum of three (3). If left at the default state of one (1), the loop can periodically cycle between in and out of service should there be a sporadic communication issue on the segment, which causes the AI block to be missed. A side effect of cycling in and out of operation is inadvertent changing of setpoints when setpoint tracking is specified.

8.6.6 Virtual Communication Relationships (VCRs)

Designers of complex control strategies should be aware of the number of function blocks and VCRs that are supported by the field devices and host system.

Complex control strategies in field devices may require more function blocks and/or VCRs than are supported by a particular field device or host.

The following illustrates the complexity of keeping track of VCRs. This activity should be avoided by keeping complex control strategies in the host controller. Each device requires a minimum number of VCRs to communicate with each other and a host.

Each device requires:

One Client/Server for each MIB
One Client/Server for the Primary Host
One Client/Server for the Secondary host or maintenance tool
One Sink/Source for Alerts
One Sink/Source for Trends

Each function block requires:
One Publish/Subscriber for each I/O

Note: *If the Function Block is used internally it does not need a VCR*

An example for a device with 2 Analog Inputs, 1 PID, 1 Transducer Block, and 1 Resource Block:

2 AI blocks	2 Publisher/ Subscriber VCRs
2 PID blocks	5 Publisher/ Subscriber VCRs (In, Out, BckCal In, BckCal Out, Track)
Basic Device blocks	5 VCRs

Hence a single dual AI device for which the trends and alerts are being used could require:

5+2+1+5=13 VCRs

The following example illustrates a more typical scenario:

Assuming the two AI blocks and the PID block reside in the same device. Assuming that one of the AI blocks is associated with the PID function and the other one sends its data to some other device (see Diagram 1 below), the VCRs required are as follows:

AI_1_OUT	1 Publisher/ Subscriber VCR
AI_2_OUT	Internal communication
PID_IN	Internal communication
PID_OUT	1 Publisher/ Subscriber VCR
PID_BKCAL_IN	1 Publisher/ Subscriber VCR
Basic Device blocks	5 VCRs

BKCAL_OUT is only required for cascade PID control. TRK_VAL is used when output needs to track a certain signal, but this also requires a TRK_IN_D signal to turn tracking on and off. Therefore, the total number of VCRs needed is:

1 (AI_1) + 2 (PID) + 5 (Basic Device) = 8

Commentary:
Moving the PID block from the input device to the output device reduces the requirement by one (1) VCR.

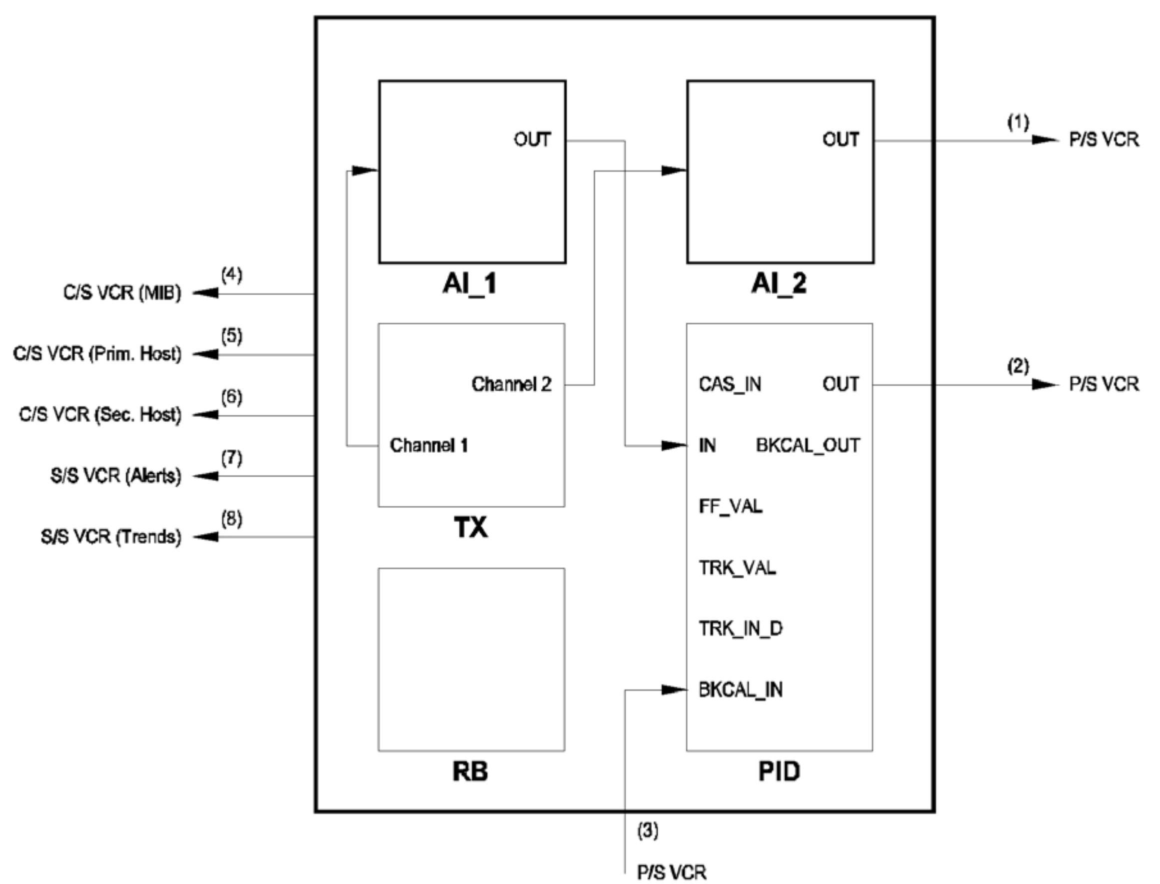


Figure 8.3 Example of VCRs between function blocks

8.7 Data Import and Export

The host configuration tool and database(s) should have import/export capability for data for all function blocks and modules. Formats for import/export may include: comma delimited, Microsoft Excel, text, Microsoft Access, SQL.

The host should be able to download all FF function blocks with imported data.

The host should be able to export updates and changes to an external database.

The host download function should include control functionality, scheduling, and initialization.

8.8 Operator Display

FOUNDATION fieldbus makes a tremendous amount of information available. Process, device and network information are all made visible and configurable from the engineering tool. However, in order for operations personnel to supervise the process, the operators only need to access some of this information. Too much information would only clutter operator displays and create confusion. In addition, too many pieces of information can also slow down the screen update rate.

8.8.1 Process Visualization Strategy

The process visualization shall be configured to show only the information that is relevant to the Process. When required such as in the case of a device failure, the operator shall be advised via an alarm. This alarm should trigger a more detailed analysis via engineering diagnostic tools.

Conventional and Fieldbus graphics shall be consistent by having the same look and feel. The process visualization software shall be configured in such a way that makes full use of fieldbus features. This will increase the operators' confidence level as well as the ease of use, availability and safety of the system.

8.8.2 Confidence Level

The operator workstation should display not only the process value, but also the quality (if not good) of the value and whether a limit is imposed on it. The status of the process value status quality should be configured in such a way as to bring attention to the operator if any abnormal condition exists. It is more important to show the operator what is abnormal versus what is normal. The abnormal information is more valuable.

8.8.3 Safety

One important safety aspect is that when communication fails, the values display as invalid to the operator. Numerical Values should not be the only means of displaying this state because the values alone may be mistaken for valid values.

Freezing a value that may be bad is dangerous and shall not be allowed without special approval of the principal.

8.8.4 Ease of Use

The Process Visualization shall be configured in such a way to provide an intuitive and easy convention to the operator.

8.8.5 Availability

Status displays shall be used to allow operators to spot problems faster and pinpoint them precisely.

8.8.6 Condition-based Maintenance Management

Information about calibration, identification, materials of construction and advanced diagnostics are all too numerous and complex to custom configure onto Process Screens. Condition-based Maintenance functions should be carried out from a dedicated tool or be integrated into the configuration tool. However, the operator shall have the ability to launch this tool directly from the process visualization software.

8.9 Software Revision

All software, exclusive of application software, shall be the most recent revision that is applicable to the system hardware at the time of the hardware freeze date as defined in the contract or purchase order.

The system shall allow for upgrading of system operating software on all redundant modules of the system without the necessity of shutting down the process, without losing the operator interface, and without the loss of access to any control function.

Application software shall not require modifications in order to be able to run under new releases of the system operating software. Any new release of system software shall be backward compatible with files created using the previous software releases.

8.10 System Management

System Management (SM) synchronizes execution of FBs to a common time clock shared by all devices. SM also handles the communication of FBs such as:

- Publication of the time of day to all devices, including automatic switchover to a redundant time publisher.
- Searching for parameter names, or tags, on the fieldbus.
- Automatic assignment of device addresses.

Commentary:

Fieldbus devices do not use jumpers or switches to configure addresses. Instead, device addresses are set by configuration tools using SM services.

8.11 Control and Data Handling

No proprietary programming languages should be used for regulatory control.

8.11.1 Fault Handling

Fault detection and processing shall conform to FOUNDATION fieldbus standards.

Invalid value status shall be generated for inputs and calculated variables.

A value shall be declared invalid if any of the following conditions are true:

- If a value is out of range
- If a value can not be measured or calculated
- If a value is declared invalid by an application program
- If a value is declared invalid by the source instrument

Invalid value status shall be propagated through control schemes. It shall be possible to inhibit the detection and propagation of an invalid value status. This selection shall be available on a per tag basis.

It shall be possible for an invalid value status to be used as a logical input to initiate control algorithm changes.

When a control algorithm's input is declared invalid, it shall be possible to configure the output to fail as follows:

- Hold last good value
- Zero output signal
- Full-scale output

In the event of communications subsystem failure, regulatory control algorithms at the users' discretion may continue operating with the last valid information.

All final control elements shall have a configured fail-state on loss of segment communication.

A control valve has two global classes of fail state depending on failure mode:

- Configured fail state
- Mechanical fail state

Configured fail state may be open, closed, hold last position or directed percentage open. The valve will go to its configured fail state on loss of communication or upon a selected event. A selected event may be:

- Loss of Input signal to the valve PID block
- Process event (emergency trip) or diagnostic event (valve fault)

The valve will go to its mechanical fail-state position (i.e. spring return position) on loss of power. Failure mode and handling shall be analyzed and assessed for impact and preventive mitigation measures.

Common mode faults shall be considered to ensure fieldbus design and system configuration handle faults properly and safely.

Final elements shall be configured to move to the desired safe position on the following circumstances:

- Total loss of power
- Loss of communication

Commentary:
A fault where the current is drained, such as in a partial short-circuit, and the bus voltage falls below the threshold may not have the same effect of moving a final element (actuator) to a fail safe position. This instance may leave the actuator in an indeterminate state. Hence, it is essential to follow this recommendation.

Network design shall be such that loss of a network does not affect more than one of the parallel (redundant/spare) process units or equipment items.

Installing redundant bus/host system interface cards avoids the possibility of a common mode failure that could fail several buses at the same time when multiple buses are installed on a single interface card. Primary and secondary interface cards shall not sit in the same backplane, and preferably not in the same panel.

Topology design shall minimize single points of failure.

Devices that operate together shall be on the same network to:

- Minimize communications between networks.
- Ensure control communications remain deterministic.

An example of this configuration is when using FF in a PID field configuration and/or cascade loops.

The system shall be configured to allow the operator to manipulate the valve manually and provide alarm of the condition when a transmitter is completely inoperative due to local failure (such as power loss, communication loss, or complete electronics failure).

8.11.2 Control Modes

Control modes shall conform to FOUNDATION fieldbus standards. It shall be possible to put any individual control loop in a manual mode; and it shall be possible for an operator to manipulate the output of a control loop in the manual mode.

For cascade control, it shall be possible to configure remote setpoints from other regulatory controllers or from other automation system modules.

All control blocks that can accept a setpoint shall be capable of being switched between local setpoint (operator entered) and remote setpoint.

All cascaded loops shall support bumpless transfer. Information shall be transferred between cascaded loops that are in the same controller module within a maximum of two (2) macrocycles.

Information shall be transferred between cascaded loops that are in separate devices within a maximum of eight (8) times the macrocycle time of the cascade loop within a controller.

Control blocks shall be able to perform automatic mode switching based on external or internal logic inputs.

Mode switching shall include the following:

- Auto/computer/manual switching
- Local/remote setpoint switching

8.11.3 Initialization

Initialization is the process by which initial values of the mode, setpoint and output of a control block are set. Initialization shall conform to FOUNDATION fieldbus standards. Initialization shall occur when any of the following conditions exist:

I. The control block is turned from off to on.
II. The control block mode is changed from manual to automatic, from manual to cascade or from automatic to cascade.
III. The control block output is cascaded to a control block which is being initialized.

Variables that are being initialized shall be subject to the following:

a) The system shall suppress nuisance alarms created by the initialization of the algorithm.
b) Calculations involving time-based data shall be reset.

Setpoint shall be initialized when the block is turned from off to on. It shall be possible to configure its initial value.

The control blocks shall offer the option of either initializing the setpoint to the input value or of maintaining the last valid setpoint upon algorithm initialization.

In a cascade loop an output tracking option shall be available. When configured for output tracking the primary controller output tracks the secondary controller setpoint when the secondary controller is either manual, automatic, or is itself output tracking.

When either setpoint tracking or output tracking is active, this state should be clearly visible to the operator in a standard faceplate display, and available as a parameter which can be accessed for either a graphic display or an application program.

8.11.4 Calculations

Algorithm calculations shall be performed in floating point engineering units or other such equivalent methods that do not require scaling.

8.11.5 Regulatory Control

Algorithms:

- Standard FOUNDATION fieldbus software algorithms shall be available to perform regulatory control functions. These process control functions shall be performed by predefined algorithms with configurable parameters.
- Standard FOUNDATION fieldbus control algorithms shall be identical regardless of whether they reside in system controllers or the H1 field devices.

Commentary:
To ensure this will occur seamlessly, the engineer must confirm the same algorithm is used within the PID or control function blocks being substituted for each other.

Setpoint Clamps:
Upper and lower clamps on all setpoints should be available.

Windup Protection:
Control functions that include integral action shall provide windup protection. Windup protection shall inhibit the integral action when the control block output is constrained by conditions such as:

- Output at high or low limits of span.
- Output at high or low clamps.
- Output is connected to the setpoint of a secondary controller which is clamped.
- Output is not connected to any valid device or algorithm.
- Output tracking is active.

Commentary:
The final requirement above does not apply if the primary controller is connected to a secondary controller which is not currently in cascade mode, or if a controller loses communication with the output module due to hardware failure.

When windup protection is active, this status should be clearly visible to the operator in a standard faceplate display, so the operator is aware of this condition and shall set a parameter that is accessible to graphic displays and application programs.

Control functions and computational functions should include the ability to propagate the windup parameter through multilevel control strategies.

8.11.6 Control and Execution Monitoring

The system should provide a mechanism to view control strategies as defined in the configuration while they execute in real-time as well as the real-time input and output values. When a tag is selected, the operator should be able to press a single button to view the control strategy. No additional configuration shall be necessary to provide this functionality.

8.11.7 Loop Performance Monitoring

The automation system should monitor all active control loops and set a flag upon detecting degradation in any loop performance or upon detecting an abnormal condition in a measurement, actuator, or control block. The following conditions should be flagged:

- Bad I/O (The block process variable is bad, uncertain, or limited.)
- Limited control action (A downstream condition exists that limits the control action taken by the block.)

- Mode not normal. (The actual mode of the block does not match the normal mode configured for the block.)

A variability index can be calculated for each loop. This index may be used to quantify the following and present the results graphically: loop utilization, bad, uncertain and limited measurement status; control action limitation; and process variability. Excessive variability should be automatically flagged.

This capability should be a standard feature of the system. No additional configuration should be required to add it. The system shall automatically detect when new control modules are added or deleted in the configuration and when used automatically activate loop performance monitoring.

8.12 System Configuration Tools

8.12.1 Configuration Tool

A configuration tool should be provided to generate or modify database and configuration data. The configuration tool should employ fill-in-the-blanks or graphical block connecting format. It should have step-by-step prompts to guide sequential actions followed by validation responses on completion of the actions. It shall request only applicable information based on previous responses.

A common configuration tool shall be used for traditional and FOUNDATION fieldbus-based control. It shall allow for selecting the location of control in the system controller or in the field device. Configuration of the control module shall be the same regardless of where the control is located.

The configuration tool should allow drag-and-drop functionality to move or copy configuration data from one location to another.

It should be possible to stop the execution of a configured module, execute a single block or step at a time, set a break point that stops execution at a particular point, or force specific values to override the actual signal — all without affecting other modules that may be running in the same controller.

The configuration tool shall include a help utility to provide configuration guidance.

8.12.2 Configuration Displays

Configuration displays shall be provided to aid in system configuration. All displays and tags should reside in one global database shared by the entire system. No data mapping between systems should be required. It should be possible to show:

- All tags in the system.
- All parameters for each tag, including (as applicable) tag ID, tag descriptor, the hardware address, tuning constants, mnemonics associated with the tag, algorithm relating to the tag, and input/output details.
- All configurable (or soft) keys and their function.
- All hardware modules in the system and the configuration parameters for each.

A facility such as copy/paste or a "template" should be provided to facilitate creating multiple tags that have common parameters (except for minor changes such as tag ID and I/O address). This template should be defined once and then used as the basis for each tag. It shall be possible to define and store multiple templates. An easy method of calling each template shall be available.

It should be possible to configure a series of keystrokes that can be initiated by a single operator action.

Configuration additions, changes, and deletions shall automatically update all modules and tags affected by the change. Configuration changes should follow a prompt-validation sequence requiring a final acknowledgment step before the change is downloaded to the online automation system.

When configuration data are downloaded to the automation system, invalid configuration entries shall be identified and the parameters affected shall be indicated.

It shall be possible to save all database and configuration data on both removable and non-removable media for back up purposes without taking the system off-line.

It shall be possible to provide redundant online storage media for configuration database.

It shall be possible to change, delete, and add any independent loop of a multiple loop process controller module without affecting the other loops.

The addition of new H1 field devices shall be auto sensing without manual intervention. New devices shall automatically report to the configuration database as unassigned devices. Device addresses shall be integer numbers. Hexadecimal code addresses shall not be used.

8.12.3 Tag Parameters

All tags shall be defined with at least the following parameters:

- Tag ID
- Tag descriptor
- Tag type
- Alarm requirements

Tag IDs shall be unique throughout the system; and access to all tag parameters for configuration shall be available directly by tag ID. The system shall provide the capability to define free-format alphanumeric descriptors for each state of a multistate device. Four (4) states should be allowed for each multistate device (for example: open, closed, in-between, and fault for an MOV (Motor Operated Valve)).

8.12.4 Engineering Units

Each analog input, output, and control block shall be assigned an engineering unit designation. It shall be possible to automatically display this designation with the value when the input, output, or algorithm is accessed.

8.12.5 Engineering Workstation

It shall be possible to install more than one engineering workstation in a system. Only one engineering workstation shall be necessary to perform all traditional and FOUNDATION fieldbus configuration, database generation, and editing. However, it should also be possible to use multiple engineering workstations simultaneously for configuration, database generation and editing. The automation system should use a single, global configuration database to be shared by all components of the system. User shall not be required to enter the same data or configuration more than once.

8.12.6 System Access

Access to automation system functions shall be restricted using passwords or other unique identifier such as biometric identification. It shall be possible to define single users with selectable access privileges. It shall also be possible to define groups of users. All users within each group shall have the same privileges. It shall also be possible to limit a user to particular areas of the plant.

At a minimum, the following access privileges shall be available:

- Operate
- Tune
- Download
- Plant area
- System administrator

It shall be possible for the automation system passwords to be global for the entire database.

8.13 Displays

8.13.1 Faceplates

Faceplates shall show dynamic process and status information about a single control loop and shall permit an operator to change control parameter values or mode for the loop.

The system should automatically provide default faceplates for each tag. User shall not be required to configure a faceplate detail display for each tag or control module.

Faceplates shall be defined to pop-up when the appropriate location on a process graphic is selected with the mouse.

Faceplates shall display the following information as applicable:

- Tag ID.
- Tag descriptor.
- Process input, setpoint, and output values displayed numerically with engineering units.
- Process input, setpoint, and output in bar graph representation.
- Auto/manual mode and remote/local setpoint status.
- Visual indication for alarm status.
- Symbolic and alphanumeric indication of discrete states both for two-state devices and multistate devices.
- Device Status (OOS, IMAN, MAN, AUTO)

It shall be possible to perform the following control actions from a faceplate:

- Change control block mode.
- Change setpoint and other operator settable parameters.
- Issue commands to multistate devices.
- Adjust outputs in manual mode.

Single faceplates shall be provided for control and indication of multistate devices. For example, a motor-operated valve shall indicate open, closed, intermediate position, and fault.

8.13.2 Communication System Status Displays

Standard displays should show the operational status of the communication system. The communication parameters of each module connected to the communication system (online, off-line, failed, primary failed, backup failed) shall be shown.

Online displays shall indicate the results of self-diagnostic tests. Failure diagnosis should be sufficiently specific to indicate which printed circuit boards, modules, or devices are at fault. The displays shall be designed to help maintenance and engineering personnel diagnose faults in the system and communications paths. Each category of diagnostic display shall be organized hierarchically.

Communications diagnostic displays should show errors for each of the redundant paths.

All events generated by the system shall be captured and electronically logged chronologically to the event database on a hard disk on one or more designated workstations. Events shall be time-stamped by the event generator. Events and their associated time stamp are passed to the event handler for capture.

It shall be possible to retrieve and sort events by time (ascending or descending order) or by type. The Operator should be able to filter the events on certain criteria such as time, tag name, area name, or any specific event. Events and the historical trend information for a control tag should be integrated into a single view.

All events shall be time stamped at the point of origin. Events generated in the controller shall be time-stamped in the controller. Those generated in the workstation shall be time stamped in the workstation.

Print on demand shall be included for all views possible with the event viewer application.

Documentation Requirements

9.0 FOUNDATION FIELDBUS DOCUMENTATION REQUIREMENTS

An integrated design and documentation system is recommended for initial design and for maintenance support of Fieldbus installations. The system should include a database with import and export provisions, design calculations for the project support, and a CAD system that can use data in the project database. Management of Change (MOC) tools and equipment history features are desirable after initial design.

FOUNDATION fieldbus system design requires the same documentation as conventional control system designs. However, some documents must be altered for FOUNDATION fieldbus architecture. Documentation alterations, additions and deletions required for FF use are defined below. The minimum document, data, and drawing requirements for FOUNDATION fieldbus installations shall include, but not be limited to, the following:

Document Requirements Table		
Document	**Required For Design**	**As Built for Permanent Records**
System Drawing	Yes	Yes
Network/Segment[2] Drawings	Yes	Yes
Location Drawings	Yes	No
Building Layouts	Yes	No
Installation Drawings	Yes	No
Process & Instrumentation Diagrams	Yes	Yes
Instrument Index / Database	Yes	Yes
Instrument Data Sheets	Yes	Yes
Material Requisitions	Yes	No
Manufacturer Documentation	Yes	Yes
Network/Segment Checkout Form	No	Yes
Valve Criticality List	Yes	No (captured elsewhere)
Logic Diagrams	Yes	Yes
Functional Description/Control Narratives	Yes	Yes

Table 9.1 Fieldbus Documentation Requirements Table

[2] Foundation Fieldbus projects replace the traditional Loop Diagram with a Network/Segment diagram as described in 9.1.2

Documentation Requirements

All documentation shall be transmitted in electronic format compatible with computer software products specified by the end user/purchaser. Exceptions to this shall be indicated in writing.

9.1 Drawings

9.1.1 System Drawing

The vendor shall supply a network topology diagram indicating how all the networks, controllers, communication highways, data historians and operator interfaces are interconnected.

This drawing is to be functional in its representation of how each system connects to the others and does not include devices on individual network/segments though it should indicate where or on what unit operation each of these segments is installed.

9.1.2 Segment Drawings – Network Drawings

When a loop is contained on a H1 segment, traditional loop drawings shall be replaced with network/segment drawings indicating all the devices on one wire pair on the same drawing.

When loops are on multiple segments or contain conventional I/O, a traditional loop drawing is required (in addition to network/segment drawings).

Commentary:

The instrument loop diagram is a hardware-wiring diagram intended to show the physical connections and layout of the network/segment.

Soft data including display, function block, and configuration data need not be shown.

In addition to standard loop drawing information, network/segment drawings shall include the following FF system details:

- The title block shall contain the "network name." The network name shall consist of the "Controller Name, Card Number and Port Number." For example, if the Controller name is "01," card number is "08" and we are using Port 1, the network/segment name will be ISD-010801.
- All network connections inclusive of the H1 interface card, bulk power supply, FOUNDATION fieldbus power supply, through the field devices, terminations, junction boxes, and terminators.
- All network/segment and field device tagging. All spur cables shall be labeled with the instrument tag number. All cable distances (with voltage drop calculation results if needed).
- The "risk assessment and network loading" philosophy chosen by the organization shall be clearly shown on the ISD.
- The Backup LAS device shall be identified.
- Terminator locations shall be clearly identified.

9.1.3 Location Drawings

To accurately determine the length of fieldbus spur and network/segment cables, drawings showing where the instrument is located in all three dimensions are required. This information must be available within a reasonable degree of accuracy as early in the project as possible since it is an input to design of the fieldbus system.

9.1.4 Building Layouts

Drawings to show where equipment is located within structures.

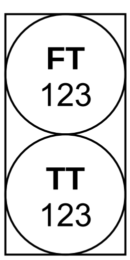
9.1.5 Installation Drawings

Details to show how equipment is to be mounted for a particular service. Often these can be a typical drawing shared for multiple similar device mounting conditions.

9.1.6 Process & Instrumentation Diagrams (P&ID's)

Process & Instrumentation Diagrams (P&IDs) are those drawings that represent the process flow as well as where the instrumentation is connected to the various pipes, vessels and equipment interact.

Where multivariable instruments are used, all functions within the field device shall be tagged with the same number, with individual function lettering for the function concerned. For example, a mass flow transmitter could incorporate FT123 and TT123. A control valve with PID control could incorporate FV-100 and FC-100. Alternately this valve could be tagged FCV-100. Multivariable transmitters shall be represented on P&ID's as shown below:



Multivariable Fieldbus transmitters (e.g. multiple process measurements from the same transmitter) shall be represented with connected instrument balloons.

Multivariable transmitters shall show the primary measurement both on top of the secondary measurements in the diagram and in **Bold** face.

Fieldbus instrumentation shall be shown on the P&ID per Company standards with the following exceptions:

- The line symbology for FF signal wiring shall be shown as a dash with a solid bubble " —•————•— ".
- The control or logic function balloons shall be shown independent of the hardware in which it is contained.

Commentary:
PID, selectors, or arithmetic function blocks shall be shown functionally on the P&ID, (i.e. not shown as a shared balloons with the device they reside in).

All functions within the same field device shall be tagged with the same number, with individual function lettering appropriate for the application.

Commentary:
For example using a multi-variable Coriolis meter, the instrument tagging would be FT-1010, DT-1010, and TT-1010 for flow, density and temperature, respectively.

The following figure is a representation of Fieldbus symbology on a P&ID.

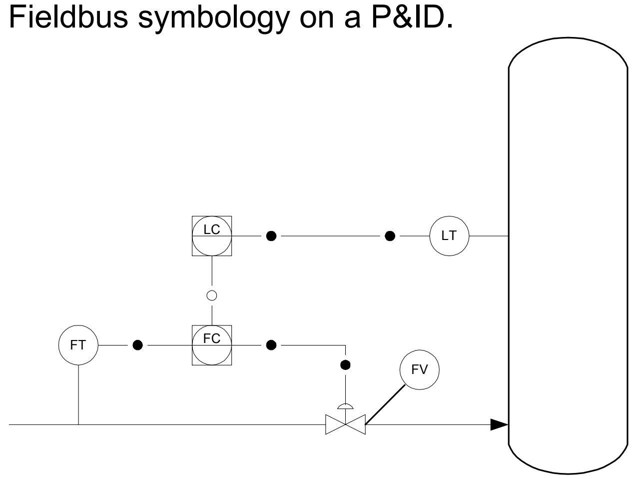


Figure 9.1 Fieldbus Representation on P&ID - Cascade Loop

The following figure (9.2) is a representation of Fieldbus symbology on a Shut Down system P&ID.

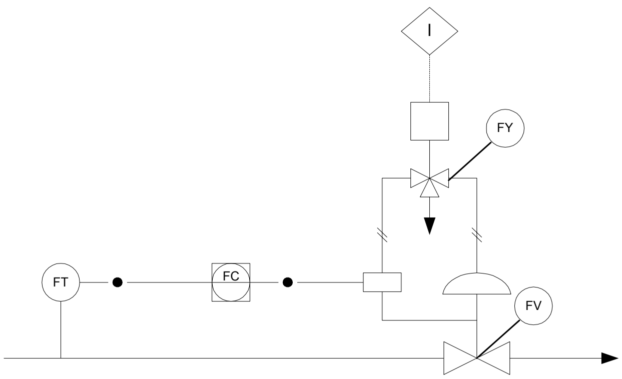


Figure 9.2 Fieldbus Representation on P&ID - S/D System

9.1.7 An instrument index should identify the following for each device:

- Whether the device is a fieldbus instrument
- Type of fieldbus
- Software revision
- Function blocks

9.2 Control Narrative

As part of the guideline, a narrative shall be provided for each typical function block and control module, to describe in detail the parameter setting and subsequent blocks/module operation. The narrative discussion shall include discussion on parameter configuration and operation for signal "status," bad value determination, failure mode switching, Initialization feature, anti-reset windup feature, etc.

9.3 Instrument Index/Database

A database to track all the instruments being used for a particular project or facility with as a minimum, information on how to locate a data sheet associated with the device tag. Many commercial products also include the device data sheet in the same data base product.

9.4 Instrument Datasheets

9.4.1 The Engineering Contractor is required to complete applicable data sheet(s) as per a conventional instrument and in addition they are to complete the supplementary Fieldbus data sheet.

9.4.2 FOUNDATION fieldbus Instruments shall be specified with standard instrument specification sheet with the following line item additions:

- LAS capable (yes/no)
- Minimum Operating Voltage (VDC)
- Quiescent Current Draw (mA)
- Polarity Sensitive Termination (yes/no)
- DEV revision
- DD revision level
- CF revision
- Channel number and Description, (e.g. Channel 1 - Sensor 1, Channel 2 - Body Temperature, Channel 3 - Sensor 2, etc.).
- Function Blocks Available, (e.g. AI_1, AI_2, PID_1, etc.)

9.5 Material Requisitions

All Bill of Materials and Material Requisitions are to be completed and issued to the purchasing department for procurement as per normal company procedures.

9.6 Manufacturer Documentation

9.6.1 The product manuals and specification requirements shall include, but not be limited to the following, delivered in electronic as well as paper form:

Installation Manuals:
Manufacturer-specific documentation with instructions on how to install, commission and maintain the device. These manuals should be available as early as possible in the design process and include dimensional drawings.

Product Specifications:
Information on the device parameters including but not limited to function blocks (including execution time), dimensional data, power consumption, and other data as per the data sheet as a minimum.

Training Manuals:
Documentation (electronic and paper) on how to properly install, commission and maintain the device.

Recommended Spare Parts:
Documentation (electronic and paper) on spare components required to support the Fieldbus-specific aspects of a device.

Commentary:
Distribution of this documentation in electronic format is preferred.

9.7 Maintenance Manuals

The contractor shall be responsible for supplying maintenance manuals as detailed below.

Copies of the plant maintenance manual for each piece of equipment which will include:

- Maintenance schedules
- Maintenance procedures
- A spare parts list including parts numbers, budget prices and delivery times from the original supplier.
- A schedule of references to detailed drawings, where the manufacturer will release them.

The vendor shall supply the end user with electronic documentation in addition to paper copies.

Fieldbus Data Sheet

Tag Number:

Basic Fieldbus Function Blocks	Segment Information
Analog Input (AI)__________Number ________Execution Time (msec)	Arithmetic (A) ___ Execution Time (msec) Digital Alarm (DA) _______ Execution Time (msec)
Discrete Input (DI)__________Number ________Execution Time (msec)	Calculate (C) ___ Execution Time (msec) Analog Alarm (AA) _______ Execution Time (msec)
Bias (B)__________Number ________Execution Time (msec)	Deadtime (D) ___ Execution Time (msec)
____Manual Loader (ML) ________Execution Time (msec)	____Complex Analog Output (CAO) ________Execution Time (msec)
____Proportional/Integral/Derivative (PID) ________Execution Time (msec)	Step Output PID (SOPID) ________Execution Time (msec)
Analog Output (AO)__________Number ________Execution Time (msec)	____Set Point Ramp Generator (SPG ________Execution Time (msec)
Discrete Output (DO) ________Execution Time (msec)	____Signal Characterizer (SC) ________Execution Time (msec)
____Control Selector (CS) ________Execution Time (msec)	____Digital Human Interface (DHI) ________Execution Time (msec)
____Proportional/Derivative (PD) ________Execution Time (msec)	____ ________________________ ________Execution Time (msec)
Ratio (RA)______ Execution Time (msec)	**Device:**
1.1.1.4 Advanced Function Blocks	**Segment #:**
Pulse Input (PI) _______ Execution Time (msec)	Link Master (LAS) Capable: YES NO
____Complex Discrete Output (CDO) ________Execution Time (msec)	Device current draw (mA): Device In-rush Current (mA): Device (Lift off) Minimum Voltage:
____Device Control (DC) ________Execution Time (msec)	Device capacitance: Polarity Sensitive: YES NO
____Integrator /Totalizer (IT) ________Execution Time (msec)	Segment terminator location: ITK Revision that Device was tested with:
____Analog Human Interface (AHI) ________Execution Time (msec)	**VCRs:** **DD Revision:**
1.1.1.1 Input Selector (IS) ________Execution Time (msec)	CFF Revision: **Notes**
____Lead Lag Controller (LL) ________Execution Time (msec)	Vendor to enter here all Non-Standard or Enhanced function block data: Vendor to enter here all unique Vendor Diagnostic/Advance Diagnostics capabilities: 1. All FOUNDATION Fieldbus devices will be Factory Configured with the Instrument Tag Number as the Device Tag.
____Output Splitter (OS) ________Execution Time (msec)	
Timer (TMR) __ Execution Time (msec)	

	FOUNDATION Fieldbus Data Sheet		**Project No.: 00000-000-00**			
PLANT :	REV					
LOCATION. .	DATE					
AREA :	BY		APROVED BY			
CONTRACT No.:	REQ. No.:					

FOUNDATION FIELDBUS
Intelligent Pressure Transmitter - Data Sheet

1	1.2 TAG		2 REQUIRED FUNCTION BLOCKS IN THE DEVICE
2	SERVICE		
3	LOCATION		_ Resource Block
4	DESCRIPTION		_ Transducer Block
5	HOUSING MATERIAL		_ Analog Input Block
6	ELECTRICAL CLASS		_ Display Block _ Input Selector Block
7	HOUSING COLOR		_ Diagnostics Transducer
8	MOUNTING		_ PID Block
9	LOCAL INDICATOR		_ Advanced PID Block
10	PROCESS VARIABLE RANGE		_ Integrator Block
11	PV ENGINEERING UNITS		_ Arithmetic Block
12	INDICATED VARIABLE (DISPLAY)		_ Signal Characterizer Block
13	TYPE OF INDICATOR		_ Analog Alarm
14	DISPLAY DIGITS		_ Timer Block
15	ZERO & SPAN ADJUSTMENT		_ Lead/Lag Block
16	SENSOR RANGE		_ Output Selector
17	MIN/NORM/MAX PROCESS TEMPERATURE		_ Constant Block
18	MIN/NORM/MAX OPERATION TEMPERATURE		
19	ELECTRICAL SUPPLY		
20	SENSOR ELEMENT		SPECIAL FUNCTION BLOCKS IN THE DEVICE
21	DIAPHRAGM MATERIAL		
22	SENSOR FILL FLUID		_ Density Block
23	SENSOR ACCURACY		_ Other
24	BODY MATERIAL		Specify________________
25	DRAIN VALVE POSITION		
26	O'RING MATERIAL		
27	BOLTS & NUTS MATERIAL		
28	BODY PRESSURE RATING		
29	PROCESS CONECTION		
30	ELECTRICAL CONECTION		
31	MANIFOLD/ TYPE		
32	CONFIGURATION METOD		
33	BAUD RATE		
34	COMMUNICATION PROTOCOL		
35	PHYSICAL COMMUNICATION MEDIA		
36	POLARITY PROTECTION		
37	FUNCTION BLOCK INSTANTIATION		
38	MINIMUN INSTANTIABLE FUNCTION BLOCKS		
39	REQUIRED DEVICE DESCRIPTORS	.sym, .ffo, .cff	
40	INTEROPERABLE		
41	CHANNEL & SEGMENT	Channel __ / Segment ___	
42	L.A.S. (Link Active Scheduler) FUNCTION		
43			
44			
45	MANUFACTURER		
46	MODEL		
47	ACCESORIES		

Notes.

1.- Is mandatory to provide the "Device Descriptors" files according with Fieldbus Foundation FF-524
2.- Is mandatory to provide the "Capability Format File" described in the Fieldbus Foundation FF-103 document
3.- All devices must be registered at the Fieldbus Foundation.

10.0 ACCEPTANCE TESTING REQUIREMENTS

10.1 Introduction

This document describes the factory tests of the Fieldbus portion of a system.

Factory Acceptance Tests (FATs) are traditionally done with systems and sub-systems, but not with field devices. It is not generally practical to test all field devices in a FAT, but a small but representative portion of field devices are needed for a Fieldbus FAT. This document will describe procedures to be used in these tests.

Factory Acceptance Tests are focused on verification of graphics, database, power, communications, and other system integration features and functions. The purpose of Fieldbus testing is to support these host system tests. Rigorous Fieldbus tests will be performed during Site Integration Tests.

The remainder of the field devices will be tested during Site Integration Tests. These tests are described in Section 11, which gives detailed procedures for site testing. The same procedures are used for factory testing of Fieldbus networks/segments.

10.2 Factory Staging

A factory staging test plan and design guidelines shall be written by system vendor and client and approved by all parties. It is recommended that at least one of each fieldbus device types be available at the staging facility. This is dependent on the functionality testing requirements in the specification. Some suggested test activities are as follows:

- Interoperability: the ability to test at least one (1) example of each configuration in the system.
- Control Strategy &/or Control Philosophy Configuration Verification
- Backup LAS Function
- Third-party systems communication (i.e., OPC communications)
- Moving devices from one network to another

10.3 Assumptions

The FAT procedure assumes that the following items are true:

- Any deficiencies observed in the pre-FAT are resolved.
- The manufacturer in accordance with their manufacturer standard procedures has performed pre-testing of all types of field devices with the host system. These procedures are executed at the manufacturer premises and are described in separate documents, which are available for reviewing during the FAT, and form a part of the overall set of FAT documents.
- The FAT will be performed at the manufacturer premises and is witnessed by the client. This will ensure that adequate FF expertise and professional knowledge is available to support the test and to implement corrective actions if required.
- The host configuration and graphics have been completed per customers' specification with the appropriate FF function blocks assigned to the appropriate FF devices.
- The FF device tags (including the FF addresses) corresponding to the host configuration above have been configured for each of the redundant

ports of each of the H1 interface cards.

- Sufficient devices are available to configure all typical networks. A selection of representative FF segments is available. Purchaser shall confirm the selected segments as being representative of the networks being installed.
- The selected FF networks/segments are prepared (but no FF devices connected) for the corresponding H1 cards and ports with the power and grounding checks successfully performed.
- The FF simulation of parameters will be enabled to simulate process conditions and to evaluate alarm settings.
- Sufficient external FF terminations are available.
- The final cabling and junctions boxes are not used. Representative connections will be made. The final infrastructure will be tested during the commissioning.

Commentary:

For especially long or complicated networks, the network should be simulated using reels of cable in the factory.

10.4 Factory Acceptance Test (FAT) Requirements

FAT is an essential quality assurance check to verify that all the components of the Host are working properly. A substantial part of the control strategy is executed in the field devices. Therefore, it is not possible to test the control strategy without connecting all the FF devices or a simulation application that can emulate FOUNDATION fieldbus function blocks. Fieldbus migrates much of the system functionality down to field level; a DCS factory test will typically only test the operator Interface, particularly if the field devices are supplied by a number of vendors.

The Fieldbus system vendor shall develop a separate written test plan and test procedure for the FOUNDATION fieldbus FAT.

Factory Acceptance Test shall be performed for the host system with the following additions for FOUNDATION fieldbus:

10.4.1 Functionality Test

A complete functional test shall be conducted for one of each FF device used on this project (i.e. third-party products). This test will include, but is not limited to, plug-and-play interconnectivity to host system, verify access to all function blocks, actual device operation, (e.g. stroke valves/MOVs, simulate process inputs for transmitters, etc.).

10.4.2 Calibration Test

The test shall include a calibration and setup for each type of FF device. Examples are as follows:

Temperature Transmitters:

- Changing RTD/thermocouple types and downloading transmitter span pressure transmitters

Pressure transmitters

- Zeroing pressure and DP transmitters
- Zeroing elevation on DP level transmitters

Valve Positioners:

- Setup & calibration of a new positioner on a control valve

Commentary:

The intent of this requirement is to verify the ease of access to calibration wizards and setup procedures via the host system.

The above tests shall be completed with the remainder of the devices remaining live on the system and in control if not part of the control loop proper.

10.4.3 Calibration and Setup Procedures

All calibration and setup procedures for each device shall be documented in detail by vendor and approved by end user lead project engineer in writing.

10.4.4 Redundancy Switch-over Test Procedure

The vendor shall develop a redundancy fail-over test procedure for the H1 interface cards and Fieldbus power conditioners. The test shall verify that automatic fail over shall not cause an upset, (i.e. signal bumps, loss of operator view, mode changes, etc.). All H1 interface cards and Fieldbus power conditioners shall be tested. This procedure shall be developed by the vendor and approved by End User lead project engineer.

All power supply and power conditioner failure alarms shall be tested and signed off.

10.4.5 Network Test Procedure

Each network (port), including spares shall be operationally tested by live connection of at least one Fieldbus device. The Fieldbus device shall be connected to the terminal block designated for the field wiring or system cable downstream of the Fieldbus power conditioner. This procedure shall be developed by the Vendor and approved by the end user.

10.5 FAT Procedure

The FAT procedure comprises three subsections: network/segment check, device check and data reconciliation (remark: the latter may be part of a different part of the FAT).

10.5.1 Network/Segment Check

The principal will select a representative number of segments during the FAT for testing.

For each selected FF network/segment to be tested, complete the following steps:

- Complete network/segment testing and commissioning per Section 11.
- Test/Confirm that the host and devices have the same firmware/software revisions.
- Test/Confirm that all H1 interface cards used in the host are the same firmware/software revision.
- Check that the relevant network/ segment communication parameters are correct and that the macrocycle duration has been set for each network.
- Check that the power conditioning module operates correctly and that a failure is communicated to the host system.
- Check that the network/segment recovers from a short-circuit.
- Measure the overall current consumption.
- Check that the FOUNDATION fieldbus host system interface module operates correctly and that a failure is identified by the host system.
- Check that the Back-up LAS is functioning and is executing the correct schedule.

- Obtain a National Instruments BusMonitor (or equivalent) to capture and check the communication load under stable (no download) condition. A load of less than 70% will be required. Record the overall result on FF FAT Checkout Form.
- Ensure that sufficient spare capacity is provided by connecting two extra FF devices and observe the bandwidth with National Instruments BusMonitor (or equivalent).
- Monitor stable operation for a minimum of 12 hours. Stable means no unexplained errors observed with the National Instruments BusMonitor (or equivalent).

10.5.2 Device Check

For each device to be tested as part of the network/segment under test as described in the previous section, complete the following steps:

- Check that the database for this device is correctly populated. It is assumed that the database is populated by an upload followed by modifying the relevant ranges, alarms, units, etc. The correct database population is checked by comparison with the relevant documents.
- Perform a download to the FF device and observe that both the FF Configurator and the National Instruments BusMonitor (or equivalent) will not raise unexplained errors.

10.5.3 Data Reconciliation

For each parameter which resides in the FF devices (e.g. in AI, PID or AO block) complete the following steps:

- Verify the appropriate scale and engineering units are configured as needed in both the AI (AO) function block and in the transducer block.
- Verify that the scale and engineering units are correct and consistent for the FF device and the associated faceplate, graphics and trends.
- Simulate a process variable equal to half the scale and verify.
- The process variable appears correctly within the PV parameter field of the AI (AO) block.
- The same value appears where the PV parameter is configured on a process graphic.
- The same value appears where the PV parameter is configured on a (historical) trend.

For the same device generate a process variable (variables if more than one is used in which case every parameter is checked separately) that exceeds the applied alarm limits and verify that the pre-configured alarms appear at the operator and/or maintenance workstation.

If the device is a valve positioner, complete the following steps:

- Verify that the AO block is in CAS mode.
- Verify that the PID block is in MAN mode.
- Manually enter the controller output on the controller faceplate.
- Verify the valve positioner maintains the same output.

11. SITE INSTALLATION GUIDELINES

11.1 Introduction
Fieldbus commissioning, being part of a computer network requires a high level of communications between the instrument/control engineers and the maintenance technicians.

Configuration of the field devices shall be carried out from the host system Fieldbus configuration software. This is in the interest of building the database as commissioning proceeds.

Procedures for commissioning of Fieldbus systems include:

- Cable, junction box, (and brick, if used) continuity, grounding, and insulation tests
- Field device connection and signal analysis
- Device download / Software checks
- Bus monitor capture, Scope waveform capture
- Process connection pressure testing and inspection
- Field device (physical installation)
- Valve calibration
- Loop tuning

11.2 Network Installation
The construction contractor should take care when installing the fieldbus wire networks. Listed below are the steps to be taken during the installation.

11.2.1 Initial Cable Checkout
It is not advisable to meter the reel of Fieldbus cable to verify the cable integrity before installation. Experience has shown that new cable irregularities are so infrequent that it is more efficient to check cable after installation.

11.2.2 Cable Installation
- Install the trunk cable (Longest cable of the fieldbus network).
- Install terminators at both ends of trunk cable. Terminators are not to be installed on a device but on a junction box or brick. Terminators are to be clearly marked.

Commentary:
If terminators are installed with or in a device they may be inadvertently removed when a technician is servicing a device and hence affect the entire network.

- Install any spur lines to the trunk cable.
- Perform cable resistance and grounding tests (Section 11.3)
- Connect power supply, power conditioner, grounds, and H1 interface to the trunk cable.
- Perform FOUNDATION Fieldbus Network/ Segment Test Procedure (Section 11.4)
- After testing the network wiring system, the devices can be connected and commissioning of the loops can proceed.

11.3 Cable Test Procedure

Commentary:
It is normally a good idea to install disconnect terminals in the Marshalling panel as a means to isolate a home run cable until it is ready to be tested/commissioned.

11.3.1 Scope
Use this procedure to check each network/segment for proper power, grounding, and isolation before you commission field devices on the network/ segment. Record the readings for steps 1-4 on the Fieldbus Network/Segment

Checkout Form. Make one copy of the form for each segment that is being checked.

11.3.2 Tools

The following tools will be needed to perform the network/segment checkout procedure:

- Digital Multi-meter with resistance, DC voltage, and capacitance measurement capability (Some capacitance meters measure components only and may not provide the expected results when measuring a complete segment.)
- Small screwdriver
- Fieldbus Network/Segment Checkout Form

11.3.3 Procedure

Before performing the checkout procedure:

- Ensure that the field wiring is completed and properly terminated and that all field spurs (but not devices) are attached.
- Remove the Fieldbus network cable (+, -, and shield) at power conditioner terminal block connector locations

Remove only the connector to the field wiring; it is not necessary to remove the connector to the H1 card. Removing the connector to the field wiring isolates the field wiring from the H1 card and power supply, isolates the shield from ground, and enables measurement of the resistance and capacitance measurements in the checkout procedure. If the field wiring connections differ from the connections described here, isolate the field wiring from both the H1 card and the power supply, and isolate the shield from ground.

Commentary:
Make sure that bare hands do not come in contact with meter leads or network/ segment wiring. The body acts as capacitor and body contact with leads or wiring could result in false readings.

Step 1: Resistance Check

Measure resistance on the H1 network/ segment conductors at the removed terminal block connector coming in from the field.

Measure resistance from the:	Expected Result:
+ signal conductor to - signal conductor	> 50 KΩ[1] (increasing)
+ signal conductor to drain/shield wire	open circuit >20 MΩ
- signal conductor to drain/shield wire	open circuit > 20 MΩ
+ signal conductor to instrument ground bar	open circuit > 20 MΩ
- signal conductor to instrument ground bar	open circuit > 20 MΩ
drain/shield wire to instrument ground bar	open circuit > 20 MΩ

Step 2: Capacitance Check

Measure capacitance on the H1 network/ segment conductors at the removed terminal block connector coming in from the field.

Measure capacitance from the:	Expected Result:
+ signal conductor to - signal conductor	1 μF (0.80 to 1.20 μF acceptable) [2]
+ signal conductor to drain/shield wire	< 300 nF
- signal conductor to drain/shield wire	< 300 nF
+ signal conductor to instrument ground bar	< 300 nF[3]
- signal conductor to instrument ground bar	< 300 nF[3]
drain/shield wire to instrument ground bar	< 300 nF[3]

Note[1]
This value will change due to the capacitor charging in the termination RC circuit and the capacitance in the fieldbus cables.

Note[2]
A reading of < .5 μF indicates no terminator on the segment. A reading of a nominal 2 μF indicates a second terminator on the segment. The acceptable values assume that the power supply terminator is used as the second terminator and only one additional terminator is connected in the field. Otherwise, the expected result would be 2 μF.

Note[3]
An actual reading that is much greater or varies in a capacitor-charging manner to a high capacitance value (>1 μF) indicates a poor quality noisy ground on the shield ground bar. Be sure to correct this ground problem to prevent communication errors on the fieldbus network/segment. A reading of 300 nF indicates noise on the ground system. Field data has shown that readings of up to 500 nF can be acceptable providing the fieldbus signal waveform and voltage compare to that shown in the Waveform with Two Terminators and 1000 ft Cable figure (11.1).

Step 3: DC Voltage Check
Reconnect the previously removed terminal block connectors to the power supply. Tug on the wire to verify that wiring at the connectors is secure. Measure the DC voltage at the terminal block connector going to the field.

11.4 Network/Segment Checkout Procedure

Clip-on tools shall not be allowed to do anything that affects the link schedule or control of the process.

Clip-on tools should not be used to perform extensive fieldbus functions beyond monitoring.

11.4.1 Scope

FOUNDATION Fieldbus wiring can be tested using a Fieldbus Wiring Monitor, which is used to test the voltage, signal levels and noise on the wiring.

11.4.2 Tools

The following tools are needed to perform the segment checkout procedure:

- Relcom, Inc. FBT-3 Fieldbus Monitor
- Small Screw Driver
- Fieldbus Cable Checkout Form (1 copy per segment)
- Oscilloscope

11.4.3 Procedure

Step 1: Connection
Connect the FBT-3 Fieldbus Monitor to the field terminals furthest from the power conditioner.

Commentary:
The red clips should connect to the positive Fieldbus wire and the black clip to the negative Fieldbus wire. If the wire are reversed, the FBT-3 Fieldbus Monitor will not turn on.

Fieldbus Cable Checkout Form

Company/Location ____________________ Unit/Description ___________________________

Controller No _________________________ Fieldbus Card No ________ Port No __________

Step 1: Resistance measurement at the H1 network/segment conductors coming in from the field

(+) to (-) signal	Expected = > 50 K ohm (increasing)	Actual = ____________________
(+) to shield	Expected = open circuit >20 MW	Actual = ____________________
(-) to shield	Expected = open circuit > 20 MW	Actual = ____________________
(+) to ground bar	Expected = open circuit > 20 MW	Actual = ____________________
(-) to ground bar	Expected = open circuit > 20 MW	Actual = ____________________
Shield to ground bar	Expected = open circuit > 20 MW	Actual = ____________________

Step 2: Capacitance measurement at the H1 network/segment conductors coming in from the field

(+) to (-) signal	Expected = 1 µF(+/- 20%)	Actual = ____________________
(+) to shield	Expected = < 300 nF	Actual = ____________________
(-) to shield	Expected = < 300 nF	Actual = ____________________
(+) to ground bar	Expected = < 300 nF	Actual = ____________________
(-) to ground bar	Expected = < 300 nF	Actual = ____________________
Shield to ground bar	Expected = < 300 nF	Actual = ____________________

Step 3: DC voltage measurement at Fieldbus power supply/conditioner

(+) to (-) signal	Expected = 18.6 -19.4 VDC	Actual = ____________________
(+) to (-) signal	Expected = 25 to 28 VDC	Actual = ____________________

Technician __________________________________ Pass ___________ Fail _____________

Date ____

- DC Voltage should match the result in Section 11.3.
- Push the FBT-3 Fieldbus Monitor's mode button once to read to the LAS function. The LAS signal level reading should indicate "OK" and show the signal level. The following table provides information on Signal Level and Wire Condition.

Signal Level	Wire Condition
800 mV or greater	Missing Terminator
350-700 mV	Good
150-350 mV	Marginal
150 or less	Will not work

Commentary:
LAS function: If there is any activity on the network, the Link Active Scheduler should be sending out Probe Node frames. The FBT-3 Fieldbus Monitor measures the signal level of the Probe Node frames. The signal level is in millivolts. Measurements over 150 mV are OK. If using FBT-3 Fieldbus Monitor in conjunction with the FBT-5 Fieldbus Wiring Validator, the FBT-5 will act as the LAS by injecting a Fieldbus Signal on the wire.

- Push the FBT-3 Fieldbus Monitor's mode button three times to get the NOISE Average function. The Reading should indicate "OK" and show a noise reading. The following table provides information on Noise Level and Wire Condition.

Noise Level	Wire Condition
25 mV or Less	Excellent
25-50 mV	Okay
50-100 mV	Marginal
100 mV or More	Poor

Commentary:
Noise Av function: The noise on the network is measured in the silence period between frames. The value is averaged over ten measurements. The Monitor will not display noise readings over 693 mV.

The FBT-3 should show 2 devices on line – each H1 interface card will register as a device with the FBT-3.

If the checks are okay in Step 1, proceed on to the remaining steps. If not, correct problems before proceeding.

Step 2: Connect Field devices
As each field device is connected and commissioned, FBT-3 readings should be taken at the field device to see that signals and noise are within tolerance.

Commentary:
Commissioning in this case refers to the initial download of a device to give it a Tag name, and a node number) on the network/segment. This commissioning does not include activities subsequent to this initial download and does not place the device in service.

Due to the rapidity with which Fieldbus loops can be commissioned, it is important that an applications engineer be available to work closely with each field crew as they connect each device to the network.

Step 3: Fill Out Form
The form should be filled out at the end of commissioning of all field devices. Readings should be taken with the FBT-3 at the marshalling cabinet and at the field device farthest from the marshaling cabinet.

Network/Segment Checkout Form

Company/Location ____________________ Unit/Description ________________________________

Controller No __________________________ Fieldbus Card No __________ Port No ___________

Cable No ____

Voltage at Marshaling Cabinet Measurement from FBT-3 Fieldbus Monitor

(+) to (-) signal	25 to 29 VDC	Actual = ______________________

Marshaling Cabinet Signal Level from FBT-3 Fieldbus Monitor

(+) to (-) signal	350 to 700 mV	Actual LAS= ______________________ Actual Min = ______________________

NOISE Average Function from FBT-3 Fieldbus Monitor

(+) to (-) signal	25 mV or Less (Excellent) 150 mV or More (Poor)	Actual = ______________________

Voltage at Field End Measurement from FBT-3 Fieldbus Monitor

(+) to (-) signal	25 to 29 VDC	Actual = ______________________

Field End Signal Level from FBT-3 Fieldbus Monitor

(+) to (-) signal	350 to 700 mV	Actual LAS= ______________________ Actual Min = ______________________

NOISE Average Function from FBT-3 Fieldbus Monitor

(+) to (-) signal	25 mV or Less (Excellent) 75 mV or More (Poor)	Actual = ______________________
Number of Devices	Field devices +2	Actual = ______________________

Technician ____________________________________ Pass ____________ Fail ______________

Date ____

Notes: ____

____

Early detection of unavoidable stress damage can be achieved by recording a “baseline” of dominant and recessive bit transitions and signal voltages at installation time and periodically checking these for deterioration. The following procedure identifies how to capture this data.

Step 4: Capture Scope Waveforms
Measure the AC waveform at the Marshaling cabinet terminal block field connector.

Procedure	Expected Result
Set the scope to AC, 200 mV/division, 10 micro seconds /division for best results and press HOLD to capture the waveform.	350 mV and 700 mV peak to peak

Verify the waveform against the expected waveform shown in the Waveform with Two Terminators and 1000 ft Cable figure (11.1). Note the differences in the signals with 1 terminator (Waveform with One Terminator and 1000 ft Cable) and with 3 terminators (Waveform with Three Terminators and 1000 ft Cable).

The following figure (11.1) shows a waveform with two terminators and 1000 feet of cable. This is the expected waveform.

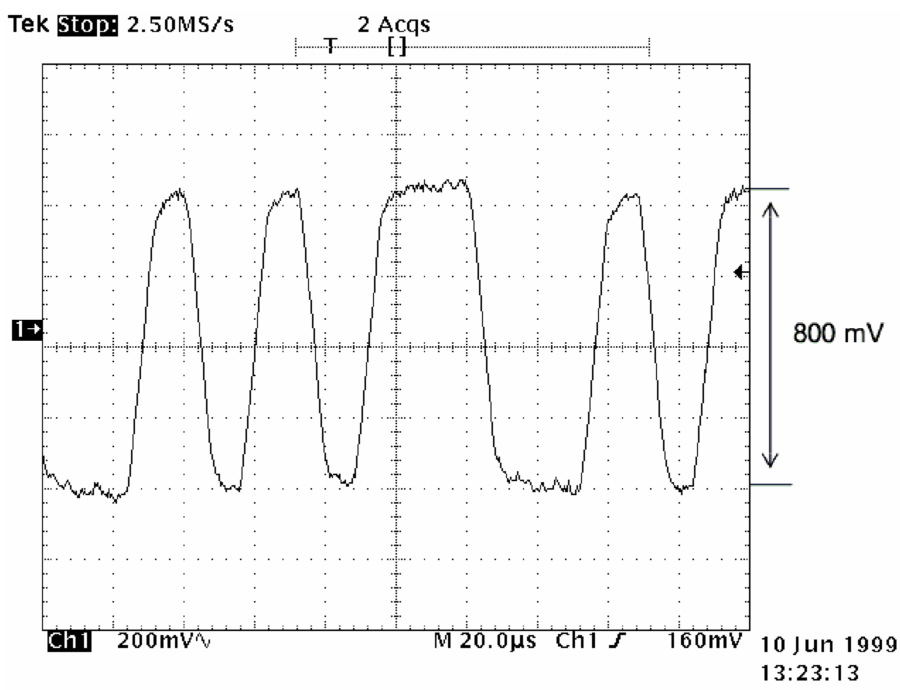


Figure 11.1 Waveform with Two Terminators and 1000 ft Cable

The following figure (11.2) shows a waveform with one terminator and 1000 feet of cable.

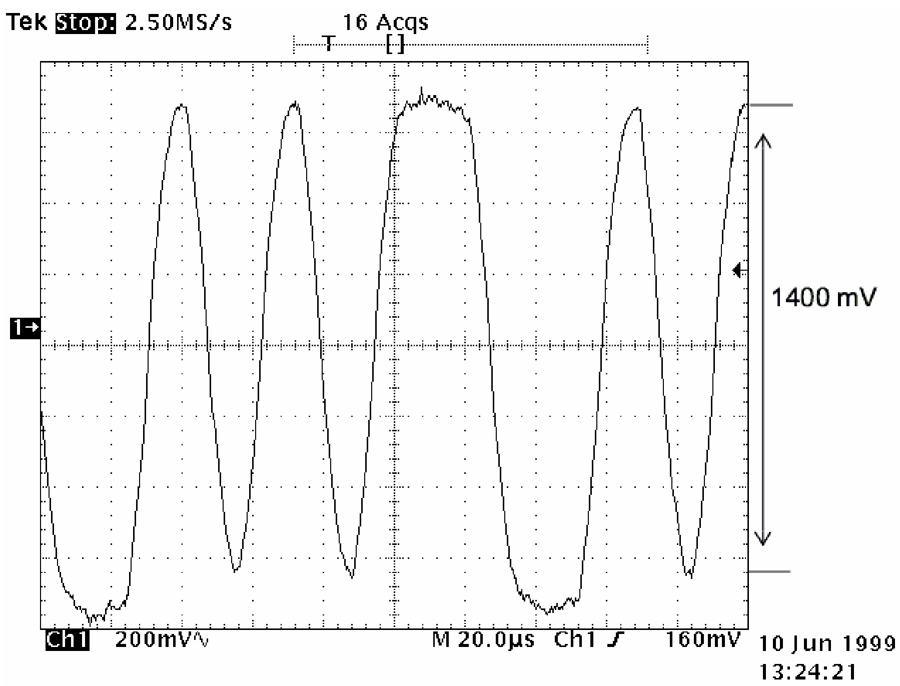


Figure 11.2 Waveform with one Terminator and 1000 ft Cable

The following figure (11.3) shows a waveform with three terminators and 1000 feet of cable.

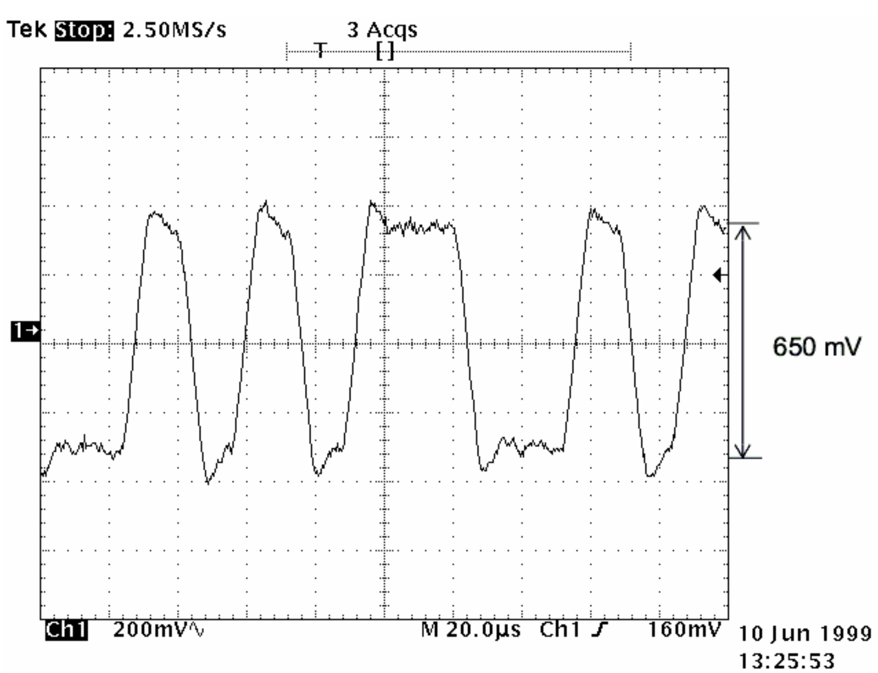


Figure 11.3 Waveform with Three Terminators and 1000 ft Cable

11.5 Loop Checkout/Site Integration Tests

At this point all devices on a segment have tags and are proven to work electrically, but may need additional configuration to operate in loops. Additionally, software checks are necessary to assure all graphics or other functions dependent on the field devices are properly configured.

All devices on a network must be fully functional and all software integration tests complete before any of the devices on a segment are placed in service (connected to the process). All transmitters are to be checked for:

- Correct range
- Alarms
- Failure mode

All control valves shall be checked for:

- Correct Operation
- Limits/Feedback
- Failure Mode

Site specific Field Installation, Testing, and Commissioning procedures should be followed for more detailed loop checkout and commissioning procedures. For the purposes of doing efficient testing and pre-commissioning work, a simple configuration guide is required. Such a document should contain simple procedures for the following types of typical operations:

- Adding a new instrument to the network
- Removing an instrument from the network
- Substituting instruments on the network
- Modifying instrument variables and parameters such as;
  - ➢ Changing tag names
  - ➢ Changing the measuring range
  - ➢ Changing the device descriptor
  - ➢ Changing Engineering units
  - ➢ Changing Instrument Display settings

At the end of all configuration and site commissioning activities but before hot cutover of segments begins, a capture of network/segment activities with a National Instruments Bus Monitor (or equivalent) should be completed. Generally, a capture should include adequate data to analyze for typical bus errors (at least a minute or more). Any abnormality in captured data should be addressed before cutover proceeds.

Commentary:

The National Instruments bus monitor is a safe and effective tool for analyzing bus problems. However, the Configuration mode of this tool can cause major problems with segment operation. Never use the National Instruments tool in configuration mode on a field segment when using it to monitor a system.

Be sure the National Instruments tool when used to monitor a network is always configured in the "slave" mode so that it will not conflict with the LAS in the host system.

11.6 Hot Cutover

Since most petrochemical plants are operated continuously, a complete shutdown of a process unit for the replacement of instrumentation and/or control system is not typically possible. Often critical loops are cutover during an outage or turnaround, with the balance completed while the unit is in operation. In some respects, online cutover of one loop at a time is more manageable than starting up a whole unit full of loops after a shutdown or turnaround conversion, since all loops then need to be tuned during the start-up. These hot cutovers are completed with significant planning between the project personnel and the plant operators. The result is maintained production throughout the hot cutover commissioning phase.

11.6.1 Execution and Approach

Hot Cutover typically means switching instrument indication and control loops from one automation platform (pneumatics, single-loop electronic) to another (DCS, fieldbus), while the loops are in operation. From an engineering & construction perspective, it is usually easier to cut over loops cold, while the plant is shutdown for maintenance. The potential for plant upsets is essentially eliminated during cold cutovers, and there is more flexibility in deploying project staff. However, plant economics may not allow for a shutdown. And from an operations perspective, hot cutovers make for an easier transition to the new automation platform. During startups after cold cutovers, there are often uncertainties whether bad data is due to instrument problems or process problems.

The decision to implement hot cutovers is made by the plant management, and it implies a transfer of some responsibilities to them. The major responsibility is that of planning. Loops to be cut over must be prioritized on the basis of operational needs instead of construction efficiency. Experience indicates the most success is achieved when a senior operator, with both excellent process knowledge and interpersonal skills, is identified early in the project and assigned to it full time as an engineering liaison. This operations representative provides input on criticality of loops during P&ID reviews, to give engineering time to plan cutover strategies.

During the cutover phase, the op rep takes the lead role to determine the loop cutover sequence, both long term and short term. The long-term plan is more general, on the sub-process level, such as a furnace, reactor, boiler, or column. The short-term plan, individual loops, can change daily or even hourly, depending on plant operating conditions.

11.6.2 Before Hot Cutover

Before cutovers, and preferably before construction, a detailed audit of the existing instrumentation is required. The type, condition, and disposition of every instrument must be determined. The status of auxiliaries, such as block valves, steam & electric heat tracing, insulation, and process purge systems must be determined as well, and appropriate courses of action determined. Leaking block valves can require a different course of action (installation of a P/I transducer on a transmitter instead of replacing it), or even preclude an instrument cutover entirely.

11.6.3 During Hot Cutover

During hot cutovers the plant will typically need to schedule one or more additional operators to assist the cutover crews. The additional operators are usually required outside to manually adjust the process with hand-wheel valves while loops are being cut over. Good two-way radios are a must for continual communication with the control room operators. To mitigate upsets, should they occur, upstream & downstream units should be notified during cutover of critical loops. Similarly, fire & emergency response crews may need to be notified. The cutover crews may require additional personal protective equipment, such as breathing air or H_2S & combustibles monitors.

11.6.4 Personnel
Having experienced foremen or inspectors in charge of the cutover crews is almost as essential as a good op rep. Good communications between the op rep & foremen will minimize the risk of upsets. Note that operations & construction are the key personnel during hot cutovers. Engineering ought to have been completed prior to cutovers; during cutovers engineering takes on a more or less interested observer role.

11.6.5 Work Schedule
Working 10 hour days during hot cutovers can be more efficient than 8 hour days, because the amount of time spent planning and staging the cutovers will be less a fraction of the total time. Most of the cutover time is due to mechanical, not electronic or programming, reasons. It takes time to rework piping and tubing, especially if it is old and corroded. If the op rep has put together a good cutover plan, the cutover crews have time to fabricate small pipe or tubing spools to ease transmitter replacement. The preferred approach is for the op rep to put together, at the end of the day, the next day's cutover plan. For contingency purposes, the list should contain "extra" loops, in case loops must be skipped due to changed process conditions or other operational change.

11.6.6 Starting Simple
Beginning the cutover process with "easy" loops, such as indication-only temperatures and off-sites will enable operators to adapt to and navigate about the new control system in a low-risk environment.

Commentary

If possible, convert these loops in advance of the plant outage during which the balance of the system will be commissioned, as it will give personnel an opportunity to gain experience with the technology.

11.6.7 Average Cutover Times
Experience has shown that an average of 8 hot loops (maybe ±2) can be cut over per day in a refinery. Many more simple, indicate only loops, such as thermocouples, can be cut over per day than complex control loops. Increasing the number of cutover crews will not typically increase the average, as the limiting factor is operations ability to handle the transition. For example, two hot control loops are not normally cut over simultaneously. FOUNDATION fieldbus cutovers can proceed more rapidly, due to less time required for the control room operator to become acclimated to cutover loops.

11.6.8 Control Room Issues
Cutover crew traffic in the control room is usually a nuisance and can undermine operator morale. Therefore locating a DCS workstation remote from the control room, but near the process, is almost a given. The cutover crews utilize this workstation to checkout instruments before their cutover begins to ensure that wiring and configuration are correct.

11.6.9 FOUNDATION fieldbus Hot Cutover Procedures
Hot cutover procedures for each FOUNDATION fieldbus device, shall be written by the Host System Vendor and approved by the Project Site Instrumentation Specialist.

- The follow procedures are required for typical Fieldbus Devices:
- Digital Control Valve Positioner Cutover Procedure
- Digital On/OFF Valve Cutover Procedure

- Pressure Transmitters used for Control
- Pressure Transmitters used for Monitoring only
- Temperature Transmitters used for Control
- Temperature Transmitters used for Monitoring only
- Flow Transmitters used for Control
- Flow Transmitters used for Monitoring only
- Analyzers used for Control
- Analyzers used for Monitoring only

11.7 Bench Simulation Testing

The Vendor shall allow for within his proposal for establishing a Bench Simulation Test Facility for the control system hardware and software. This facility will enable the testing of all the hardware, software, graphics and communications between the FOUNDATION fieldbus system, the DCS system and the Motor Control Center controllers.

This test facility shall be located at the End User production facility. The End User will establish a dedicated systems development room for the duration of this project.

This test facility shall be used to pre-commission all new items prior to installation.

The Vendor shall be responsible for the provision and set up of all test gear and software. All facilities shall be tested including indication, trend pages, alarm pages and all alarms and diagnostics.

If integrating with a brown field facility, the End User shall provide to the manufacturer one set of existing DCS racking and modules to the Vendor. The Vendor shall be responsible for the setup of all test gear and software. All facilities shall be tested including indication, trend pages, alarm pages and all alarms and diagnostics.

As part of the Bench Simulation Testing, the Vendor shall simulate field instrumentation and motor signals to test the operation of each component.

The Vendor is not expected to setup and test any Motor Control Centers as part of the bench testing. Testing of the MCCs will be the responsibility of the MCC supplier. However, Motor Control signals shall be simulated as part of the Vendor Bench Simulation Test.

11.8 System Development Room

Once the Control System and communication have been proved, the Vendor shall leave sufficient hardware and software within the development room to permit testing and field equipment set-up for the duration of the project.

This shall not compromise the availability of hardware and software at any stage of the project.

This development system will be the property of the Vendor and the Vendor shall be responsible for the removal of this system following the completion of the project, or at an agreed time with the Project Engineering sponsor.

11.9 MCC Testing

The Vendor shall be responsible for the coordination and organization of the MCC Factory Acceptance Test (FAT). The Vendor shall inform the End User or their representative when these checks are to take place. The End User shall reserve the right to witness these MCC FATs.

11.10 Provision of Spares

The Vendor shall be financially responsible for the provision of spares to cover commissioning and start-up for the project.

These spares shall cover all FOUNDATION fieldbus field instrumentation and associated host system.

The Vendor shall identify and supply to End User a list of recommended spares for all field equipment and the control system.

11.11 Removal of Redundant Equipment

The removal or disposal of equipment becoming redundant as a result of this project i.e., Field and panel mounted equipment, cabling, pneumatic instrument signal pipework etc. does NOT form part of this scope of works.

11.12 Maintenance Practices

Fieldbus device maintenance practices should consider the impact of device changes upon other devices and the host system.

Commentary

Because FF has changed the maintenance of devices from a single point-to-point system to that of a computer network, a change to one device affects at least the host system on that network, and quite likely other devices on the network.

- Field maintenance on fieldbus devices should be limited to:
- Inspection of cabling and enclosures to ensure they meet hazardous area requirements.
- Replacement of faulty items and equipment.
- Zeroing of instruments, as required, for calibration.
- Proof testing of safety devices.
- Mechanical associated work (for example, valve packing, tubing leaks, etc.).

A central maintenance tool should be provided to set up and manage change in the fieldbus devices. Any system offered should comply with the following:

It should be an integral part of the system.

For the purpose of troubleshooting intelligent field devices it should have the minimum following capability:

- Configuring
- Calibrating
- Monitoring
- Advanced diagnostics

The system should incorporate a targeted maintenance facility utilizing a single, common database with the following provisions:

- Configuration for field bus devices.
- Capturing of both current and historical device data.

Comparison and reconciliation between current and previous configurations.

- Audit trail capability.
- Device alert monitoring to facilitate early warning of developing problems.
- As found/as left device test capability.
- Device template creation.
- Device signal tag and device search capability.
- Online help.
- Database import/export capability.
- Diagnostic add-on capability.
- OPC and third party database.

A detailed maintenance method should be established, including at least the following:

Commentary

This is extremely important when different types of field device communication exist. An example is changing lockout practices depending on the design of the loops.

- Calibration procedures.
- Removal and replacement of a field device.
- Preventive maintenance activities.
- Testing for safety devices.
- Management of change procedures (for example, software revisions update).
- Software revisions should be well documented.
- A process should be in place for handling spares and software revision upgrades.