FF Physical Layer Components Best Practices

Binoy Kamath
AGM – Project Pursuit
Pepperl+Fuchs India Pvt. Ltd., Bangalore
Agenda

- Introduction to FF and FF Physical Layer
- FF Physical Layer Components
- FF Wiring Topologies
- FF Segment Design
- FF Monitoring and Diagnosis
- Summary and Conclusion
Preface

FOUNDATION™ Fieldbus
System Engineering Guidelines
(AG-181) Revision 3.1

This preface, as well as all footnotes and annexes, is included for informational 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 subject to periodic review. Toward this end, the foundation welcomes all comments and criticisms and asks that they be addressed to:

Fieldbus Foundation
9005 Mountain Ridge Drive
Bowie Building - Suite 200
Austin, Texas 78759-5316 USA

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What is 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.

How Do we build the network?
Physical Layer Components

- HOST
- FI POWER SUPPLY
- JUNCTION BOX
- Wiring Block
- Wiring Block
- FIELD BUS TERMINATOR
- Home Run
- Spurs
- SURGE PROTECTOR
- FIELD BUS DEVICES
- CONVENTIONAL FIELD DEVICES
- PROCESS INTERFACE

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Physical Layer and Its Components

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

- FF Power Supply
- FF Cables
- FF Wiring Blocks
- FF Surge Protector
- FF Terminators
FF Power Supply

- FOUNDATION Fieldbus Power Supplies (6.2.2 – AG 181 v3.1)

- FOUNDATION fieldbus power supplies are specialized power supplies that provide both the segment isolation from bulk power and the power conditioner in one unit.

- Power conditioning prevents the bulk power supply from shorting out the communications signal, preventing the segment from functioning.

- Isolation prevents ground loops and interference among segments.

- They shall have the appropriate approval: FF-831 “FOUNDATION Specification; Fieldbus Power Supply Test Specification” and associated check mark

- FOUNDATION fieldbus power supplies should be redundant, load sharing and output current limiting, and provide facilities for monitoring faults and failures.
FF Power Supply – General Purpose and With DCS System Connectors

APPROVED

FF831

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FF Power Supply – Recommendations

- Each Segment shall have a dedicated FFPS
- FFPS shall be modular and hot Swappable
- FFPS shall be Isolated, Redundant and Load Sharing
- FFPS shall provide facilities for monitoring faults and failures
- FFPS rating shall allow longer home run / Trunk length to benefit user
FF Wiring Blocks
FF Wiring Blocks

- FOUNDATION fieldbus Wiring block is located where the trunk (home run) is connected to the various device spurs.

Passed FF Device coupler Specification

FF-846-1.1
Only **registered** FOUNDATION fieldbus Wiring blocks shall be used.

The couplers shall have **built-in** spur short-circuit protection (to minimize the impact of a short at one device affecting the whole segment).

Spur short-circuit protection shall have **visual indication** (on a spur level) when short-circuit protection is active and the spur's maximum current shall be limited by area classification and the current available to the network.

The couplers should provide **visual indication of segment power** as a minimum.
FF Cables
The Physical Layer Specification of FOUNDATION Fieldbus defines four types of cables:

- Type A
- Type B
- Type C
- Type D

- The max. cable length per segment of 1900m (trunk + Spurs) could be reached with **cable type A only**!
- In the meantime there are cables available type A with **different cross sections**.
## Types of Cables

<table>
<thead>
<tr>
<th></th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable structure</strong></td>
<td>Twisted wire pair, shielded</td>
<td>One or more twisted wire pairs, complete shielding</td>
</tr>
<tr>
<td><strong>Conductor cross-section (nominal)</strong></td>
<td>0.8 mm² (AWG 18)</td>
<td>0.32 mm² (AWG 22)</td>
</tr>
<tr>
<td><strong>Loop resistor (direct current)</strong></td>
<td>44 Ω/km</td>
<td>112 Ω/km</td>
</tr>
<tr>
<td><strong>Wave resistance at 31.25 kHz</strong></td>
<td>100 Ω ± 20%</td>
<td>100 Ω ± 30%</td>
</tr>
<tr>
<td><strong>Wave attenuation at 39 kHz</strong></td>
<td>3 dB/km</td>
<td>5 dB/km</td>
</tr>
<tr>
<td><strong>Capacitive asymmetry</strong></td>
<td>2 nF/km</td>
<td>2 nF/km</td>
</tr>
<tr>
<td><strong>Group runtime distortion (7.9 ... 39) kHz</strong></td>
<td>1.7 μs</td>
<td>a</td>
</tr>
<tr>
<td><strong>Covering level of the shield</strong></td>
<td>90%</td>
<td>a</td>
</tr>
<tr>
<td><strong>Maximum extent of the network for non-intrinsically safe applications</strong></td>
<td>1900 m</td>
<td>1200 m</td>
</tr>
<tr>
<td><strong>Maximum extent of the network for intrinsically safe applications</strong></td>
<td>1000 m</td>
<td>a</td>
</tr>
</tbody>
</table>

*a = not specified*
Surge Protection (6.4 AG 181 V3.1)

Surge protection for FOUNDATION fieldbus devices may be required in areas where induced voltage is an issue.

This includes areas such as close wiring proximity where large inductive loads are started and stopped, or areas known for lightning incidence.

Surge suppression consists of a low-capacitance device installed at the device's electrical connection. It shall normally appear as an open circuit to the spur and segment to prevent any adverse effect on communications.
FF Surge Protectors
Surge suppression device **should not** measurably attenuate the fieldbus signal

Shall be installed at the Field Devices and host H1 Interface

Current-limiting couplers (Wiring Block spurs) **should not** be used in combination with surge protectors. The surge protectors will cause failure of the current limiting circuits when a lightning strike occurs.
FF Terminators

- FOUNDATION fieldbus segments require **EXACTLY two terminators**, one at each end of the trunk (home run) cable. The terminator is comprised of an RC network that provides 100 Ω impedance.

- The terminator allows the current-based FOUNDATION fieldbus communications signal to be viewed as a voltage while being offset on the DC segment voltage supply.

- Most fieldbus power supplies and/or wiring blocks have a built-in segment terminator. Some wiring components have switchable terminators. Terminators at a field device **shall not** be used (due to the impact on the whole segment should the device need replacement)
**Spur Topology (Bus with Spurs)**

This topology consists of fieldbus devices connected to a multi-drop bus segment through a length of cable called a spur. This technology is technically acceptable, but generally not a good economical choice when there is a high density of devices.

**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.
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. \textit{It should not be used, as it is unacceptable, for maintenance purposes.}
Accurate short circuit current limitation for each channel with LED indication

A fault at one instrument (e.g. short circuit) has no impact on the other outputs or on the segment

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Fieldbus in Hazardous Area

1980s Entity

1990s FISCO

2000s HPTC

2010s DART

The first step

Simplifying validation

MAX power + FISCO

Re-inventing Intrinsic Safety

Redundant FISCO

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Zone 2 Topology

Zone 2

Previous standards

- Ex nA (Non arcing) / Ex nL (energy Limiting) / Exic Intrinsically Safe
- FNICO (Non-Incendive)

Current standard – Exic

From 2007 onwards Ex nL and FNICO standards are omitted and replaced by Ex ic (similar to IS)
Zone 2 Hazardous Area Concept Ex nL / Ex ic

Accurate short circuit current limitation for each channel with LED indication

A fault at one instrument (e.g. short circuit) has no impact on the other outputs or on the segment

17 to 30V, 500mA

HOST DCS

Ex nA

16..32V

230VAC

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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:

- Field wiring is classified as EEx nL in accordance with IEC 60079-15, or North American non-incendive
- Maximum permissible value of $I_0$ is 570 mA
- Field devices may have a maximum of 20 μH internal capacitance, thereby permitting IS “Entity” certified field devices to be used in FNICO installations

7.6.4 High-power Trunk Installations

High-power trunks allow full utilization of maximum segment length and device capacity without limitations due to power restriction. These designs are generally more economical than FISCO, FNICO and Entity.

High-power trunks may be used in Zone 1 or 2 installations to:

- Supply power to non-incendive spurs in Zone 1 or 2 (requires current limiting couplers as shown in Figures 7.6, 7.7 and 7.9)
- Supply power to IS spurs in Zones 0, 1 or 2 (requires current-limiting couplers as shown in Figure 7.8)

7.6.5 High-power Trunk with Current Limiting Device Couplers (Non-Incendive)

If using non-incendive wiring practices with current limiting device couplers, all equipment should have appropriate zone ratings.

7.6.6 High-power Trunk with Isolating Device Couplers (Intrinsically Safe)

If using intrinsically safe wiring practices with isolating device couplers, all equipment should have appropriate zone ratings.
Zone1 Topology

- Non-IS(EEx d)
  - Trunk and spurs must be installed in increased safety EEx e

- IS (FISCO, HPT, DART)
  - A full intrinsically safe fieldbus segment (FISCO)
    - Intrinsic safe trunk and spur
    - Requires the use of IS Power Repeaters/Power Link module
  - A mixture of EEx e and EEx I (High Power Trunk)
    - Trunk has to be installed in increased safety
    - Spurs are intrinsically safe
    - Allows the use of Non IS Power Supplies/Power Repeaters/Power Links
  - High Power Intrinsically safe (DART)
Application Area - Zone 1 (EEx d)

R-SP-E12 is resin filled as per Exd installation requirements
Application Area - Zone1 IS - HPT

Exd Trunk live disconnect switch

Resin Filling for Zone 1 Installation

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Zone 1 IS Enclosure solutions

Fieldbus

Power

Ex e

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DART Fieldbus provides:

A completely intrinsically safe fieldbus segment in gas groups IIB and IIC with real power redundancy with load sharing and advanced diagnostics.

The Intrinsically Safe High-Power Trunk

DART Fieldbus is certified according to the international I.S. standard IEC 60079-11
DART: Intrinsically safe High-Power Trunk

Redundant, three-part isolated DART Power Supply

Intrinsically safe spurs
Ex ib IIC with S/c protection

General Purpose Area
Zone 2

Zone 1

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## Evolution of Various FF Hazardous Area Topologies

<table>
<thead>
<tr>
<th>Feature</th>
<th>Safe Area</th>
<th>FISCO / FNICO</th>
<th>FISCO Redundant</th>
<th>HPT Field Barrier</th>
<th>DART</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment Current</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Segment Voltage</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Redundancy</td>
<td>✔️</td>
<td>✖️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Load Sharing FFPS</td>
<td>✔️</td>
<td>✖️</td>
<td>✖️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Physical Layer Diagnostics</td>
<td>✔️</td>
<td>✖️</td>
<td>✖️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Segment Design Mix</td>
<td>✔️</td>
<td>✖️</td>
<td>✖️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Cabinet Space</td>
<td>✔️</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Initial Segment Cost (FFPS + Wiring Blocks)</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Live Trunk Working</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✖️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

**Symbols:**
- ✔️: Available
- ✖️: Not Available
- +: High
- -: Low

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FF Segment Design

- How to design Foundation Fieldbus segments?
Segment Design and Validation Tools

• Fieldbus allows to connect many devices on the same bus cable, but...
  
  • How many devices can I really connect?
  
  • What cable should I use, and what cable distances can I really achieve?
  
  • What happens in case of a short circuit in the field?
Segment Design and Validation Tools

- Graphical segment design tool example

- Download the NEW DesignMATE segment verification tool

- www.segmentchecker.com

- Various other tools are available with FF Vendors
Ethyllyn Cracker

Chemical compound extraction

**Project Parameters**

- **Segment Type**: Fieldbus Foundation: High Power Trunk for Zone 2/Div. 2
- **Cable Type**: A 0.8mm² (AWG 18)
- **Env. Temp.**: 45°C
- **Default Field Device Current**: 20mA
- **Default Spur Length**: 60m
- **Short Circuit Checking**: CN

**Checker Results**

<table>
<thead>
<tr>
<th>Checker Summary</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology Check</td>
<td>success</td>
</tr>
<tr>
<td>Power Distribution Check</td>
<td>success</td>
</tr>
<tr>
<td>Short Circuit Check</td>
<td>success</td>
</tr>
</tbody>
</table>

**Device Summary**

<table>
<thead>
<tr>
<th>Devices</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>240-Serie Intelligent Level Transmitter</td>
<td>1</td>
</tr>
<tr>
<td>ABB FXE4000</td>
<td>1</td>
</tr>
<tr>
<td>ABB TF12/02</td>
<td>1</td>
</tr>
<tr>
<td>BA414ND-F</td>
<td>1</td>
</tr>
<tr>
<td>DP-LBF-1.34</td>
<td>1</td>
</tr>
<tr>
<td>DTY(Flow) / F(KS25)</td>
<td>1</td>
</tr>
<tr>
<td>F2D0-TI-EX3.PF</td>
<td>1</td>
</tr>
<tr>
<td>FD0-VC-EX4.FF</td>
<td>1</td>
</tr>
<tr>
<td>Canaplot - M</td>
<td>1</td>
</tr>
<tr>
<td>Gen. Red. Host</td>
<td>1</td>
</tr>
<tr>
<td>HCD2-FBPS-1.300</td>
<td>1</td>
</tr>
<tr>
<td>IDP10 Differential Pressure Transmitter</td>
<td>1</td>
</tr>
</tbody>
</table>
6.8 On-line Diagnostic Tools

Several options exist for on-line diagnostic tools: permanently attached and portable devices.

The following measurements shall be included in FOUNDATION fieldbus diagnostic tools:

- Voltage per segment
- Segment noise
- Maximum fieldbus signal (communications) level
- Minimum fieldbus signal (communications) level
- Low resistance between shield and negative signal pole
- Low resistance between shield and positive signal pole

Optional measurements include:

- Fieldbus jitter on the segment

If the on-line diagnostic tool is permanently installed as part of the FOUNDATION fieldbus power supply, additional information may be available, such as:

- Minimum, maximum and real time bulk voltage supply to the FOUNDATION fieldbus power supply
- FOUNDATION fieldbus power supply operational status
- Minimum, maximum and real-time FOUNDATION fieldbus current

Benefits of permanently installed diagnostic tools may include the ability to historize the data, and provide real-time alarming and trending of the data. Portable diagnostic tools assist in troubleshooting specific problems and may present additional data not available with permanent diagnostic tools. Permanently installed diagnostic tools shall only be considered if they are well integrated with the Host system.
Fieldbus Diagnostic Capabilities Have Evolved – ARC Report

<table>
<thead>
<tr>
<th>Diagnostic Features</th>
<th>Advanced Online Diagnostics</th>
<th>Typical Online Diagnostics</th>
</tr>
</thead>
<tbody>
<tr>
<td>No need to track down terminals or interfere with cable</td>
<td>Yes</td>
<td>Limited</td>
</tr>
<tr>
<td>Trunk current measurement</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Jitter measurement</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Data signal amplitude</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Shield to pole AC and DC unbalance</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Direct pole to pole short circuit</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Full spectral frequency analysis</td>
<td>Yes</td>
<td>Some</td>
</tr>
<tr>
<td>High frequency noise measurement</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Digital storage oscilloscope</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Trunk voltage</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Advanced software analysis and hardcopy printout</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>‘Signal inverted’ warning</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Separate diagnostic information bus- operation not affected by any segment failure</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Draws zero current from the bus</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Trending and logging provide early warning</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Simultaneous monitoring of all segments</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Basic Physical Layer Diagnostic Coverage**

- DC Voltage
- DC Earth
- High frequency
- Data signal
- Full Spectral
- AC Jitter
- Inline DC current
- Data Polarity
- AC unbalance
- Storage oscilloscope

**Advanced Physical Layer Diagnostic Coverage for Analysis**

- New Advanced Online Fieldbus Diagnostic Information Provides a Complete View of the Entire Network
Typical problems – and how to solve them

- Tools to measure segment parameters (voltage, current)
- Tools to measure segment health (termination, noise)
- Tool to display EMC problems
- Tools to test communication
- Tool to measure cable degradation over time (trending)
- Tool to visualize signal quality of individual devices (noise, jitter, telegram level)
- Tool to allow remote access for expert
With Diagnostics of Physical Layer We Can....

- Commission Segments
- Monitor Segments Online
- Predictive Fault finding of Segments

SEE what's going on in your physical layer
KNOW when and how to act
ACT in your Asset Management tool

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Commissioning until now

- Always on the critical path
- Labor intensive
- Requires
  - Screw driver
  - Check sheet
  - Pencil
  - Multimeter
  - Oscilloscope
- Connect one device at a time
- Disconnect after testing
Simple Commissioning Steps with ADM

- Verify address setting
- Wire up devices in the right location
- Check shielding
- Activate communication
- Use automated work procedures
  - Testing
  - Documentation
- All devices at once
- Wiring remains undisturbed!
Commissioning Wizard

- With Expert System Support
  - Takes snapshot
  - Identifies wiring errors
  - Ensures compliance with **AG181 and IEC 61158-2**
  - Recommends limits for ADM messages
  - Stores limits in non-volatile memory

- Automatic Tag Readout

- Creates baseline report:
  - Snapshot of all measurements
  - Complete documentation

- Saves 80% of pre-commissioning time
Built-in fieldbus oscilloscope

- ADM provides expert tools for fast fault finding
  - For diagnosing complex scenarios
  - For the fieldbus expert
  - With fieldbus specific triggers
  - Captures up to 10 shots in a row
Online monitoring

- The Advanced Diagnostic Module:
  - Monitors physical layer health
  - Detects changing conditions
  - Sends messages with time stamps

- Expert System diagnoses faults:
  - Precisely diagnoses causes
  - Creates messages with clear text
  - Enables proactive plant up keep
  - Alerts before the segment fails
Online monitoring

Clean layout shows boundaries

- Displays measurement values
- Highlights violations with color coding:
- Issues diagnostic messages

- Good value
- Maintenance required
- Out of specification
Diagnostic Menu

Expert System delivers clear text information for fast fault finding:

1. Active messages
2. Actionable information with solution guidance based on expert system
3. History with timestamps

When the failure... occurred... disappeared

- Export function for external analysis and storage
The effect of Advanced Diagnostics

- Plan and purchase
  - Commission
  - Know before you act
  - Actionable information in clear text
  - Verify against original design
  - Automated checkout procedures
  - Segment Checker: design of the physical layer

- Install and commission
  - Know before you act
  - Actionable information in clear text
  - Automated checkout procedures

- Operate and maintain
  - Troubleshoot

ACT
Conclusion

Follow proper selection of components, design and installation guidelines

- System design guideline in AG 181 V3.1 will assist you to select right components for your Network
- Segment Design tools based on AG 181 V3.1 and IEC 61158-2 assist you to design your segments
- Always use Approved and registered products
- Right diagnostic tools helps to reduce installation and commissioning time
Thank You

Fieldbus Foundation
India Committee

21st September, 2011

www.fieldbus.org

FFIC : Automation 2011 - Mumbai

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