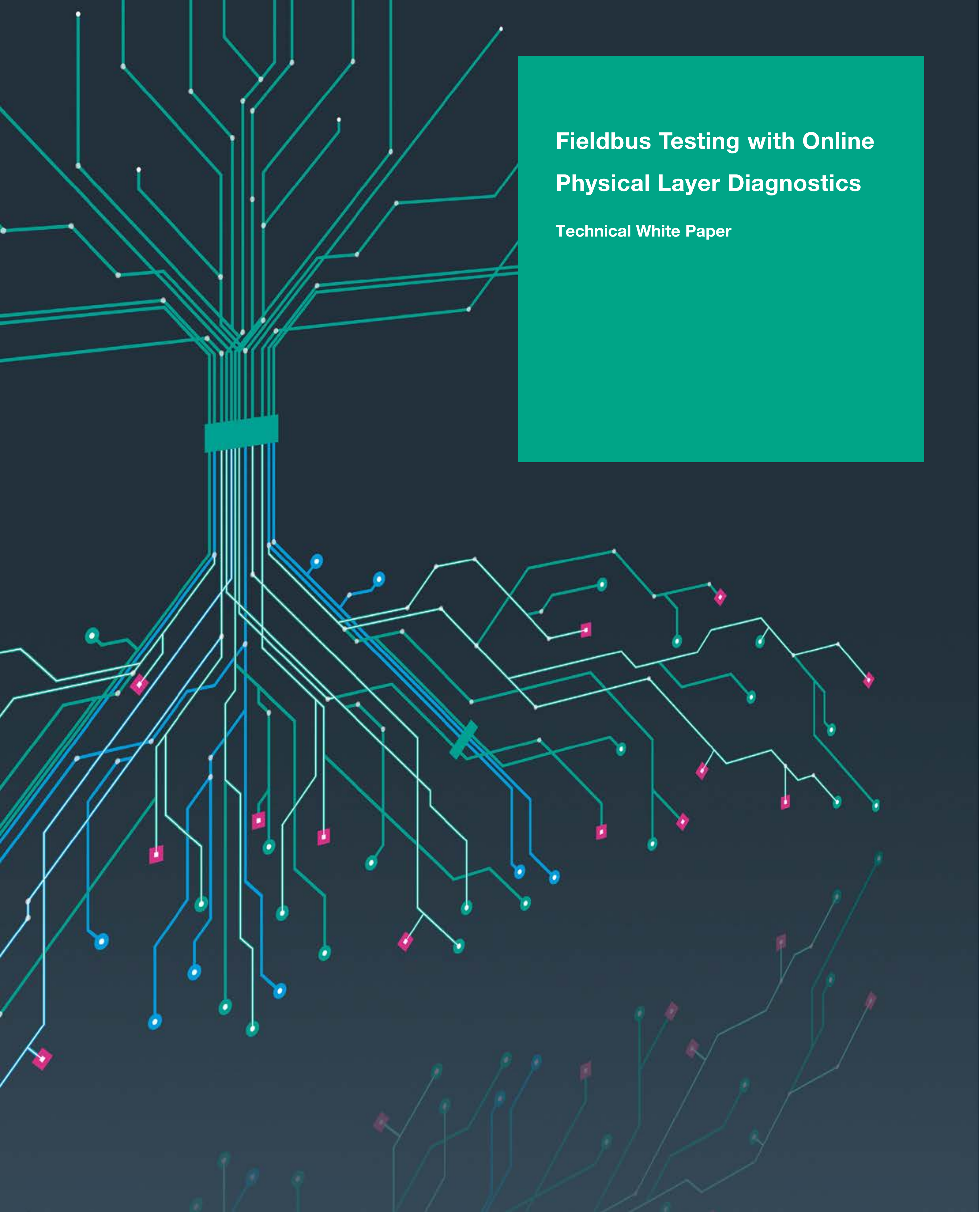

Fieldbus Testing with Online Physical Layer Diagnostics

Technical White Paper

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Abstract

Installation and wiring work for today's fieldbus installations in process automation, FOUNDATION Fieldbus H1 and PROFIBUS PA, currently requires tedious manual and typically incomplete methods for checkout and validation. New online advanced physical layer diagnostic systems automate construction and pre-commission test and report generation, up to the point of loop checkout. Fully automated fieldbus test methodology realizes better installation quality and time savings.

This paper describes a newly revised, significantly shortened and vastly simplified test procedure applicable to fieldbus systems. Additional guidelines for troubleshooting that is described herein will further enhance commissioning and testing work. A case study compares the new working procedure to existing technologies and procedures and shows the savings potential, which expresses itself in a reduction in commissioning time.

Prepared by:

Gunther Rogoll
Senior manager fieldbus technology

Ren Kitchener
Fieldbus specialist fieldbus technology

Andreas Hennecke
Product marketing manager fieldbus technology

Quality Information from a Quality Supplier

This technical white paper utilizes Pepperl+Fuchs' expertise and knowledge to provide a clear insight into the many new technological and application issues you may face with a fieldbus installation. It corresponds to our way of working and thinking: combining state-of-the-art technologies with years of research and innovation to simplify planning, installation and commissioning, operation, and plant up-keep.

If the content of this paper sparks comments or questions, we invite you to contact your Pepperl+Fuchs office or representative to get in touch with our experts. We are glad to share our expertise with you for your business success.

Our promise is to simplify your work processes with fieldbus: You can stay focused on your day-to-day business with a reliable Field-Connex® fieldbus infrastructure. It ensures the connection between DCS and instruments, fully digital with explosion protection for any hazardous area. We are driven to provide innovation with proven reliability for process automation practitioners:

- FieldConnex is robust, reliable, and the first choice of many well-known end users worldwide.
- Advanced physical layer diagnostics reach down to spurs, accessories, and instruments; interpret data, and provide detailed fault analysis. Water ingress and worn-out surge protectors are identified without manual inspection.
- The high-power trunk concept allows long cable runs and high device counts and is now an industry standard. DART Fieldbus makes the high-power trunk intrinsically safe.

Content

Table 1 lists abbreviations in this document.

Table 1: Abbreviations	
Abbreviation	**Definition**
ADM	Advanced diagnostic module
APLD	Advanced physical layer diagnostics
ATE	Automated test engine
CAPEX	Capital expenditure
DCS	Distributed control system
FDH-1	Fieldbus diagnostic handheld
OPEX	Operational expenditure
PAM	Plant asset management
RC	Resistance capacitance

1 Introduction

Many of the major projects are using digital fieldbus technology as the preferred platform for control and instrumentation. Most of the lessons learned from the early projects have been implemented successfully in technology, products and working procedures for the current projects. Testing the installation as described in working guidelines, published previously by the Fieldbus Foundation and PROFIBUS International [1], is manual, labor intensive and requires specialist knowledge.

With the introduction of online advanced physical layer diagnostic (APLD) equipment, fully automated network testing and reporting reduces the time and cost for commissioning and plant upkeep. This technology optimizes the test process and report generation. At the same time APLD helps establish the optimal fieldbus installation quality and thus a highly available automation system. The new APLD equipment needs a revised, yet vastly simplified construction and commissioning procedure, requiring minimal technical expertise.

Advanced physical layer diagnostics enable high-speed automated construction as well as commissioning testing with automated test report generation and documentation. APLD provide the ‘handover’ of a system that will have been fully checked to a highly detailed technical level. This is impossible to achieve with methods of manual inspection, thus assuring uncompromised segment quality and system availability for the end customer and plant operator.

This paper addresses two audiences: For practitioners, it provides insight into contemporary fieldbus commissioning and maintenance procedures (chapters 2 and 0). Step by step instructions assist in optimizing working procedures. Decision makers are presented with arguments and a case study (chapter 4) that show how CAPEX and OPEX savings that are realized with these procedures. Chapter 5 summarizes the facts.

2 Testing and commissioning procedures

This chapter describes testing procedures and related improvements that have been achieved over the past years. Testing installations with 4…20 mA interfacing is well-known in practice and thus not described in detail. Table 2 provides a comparison of basic testing attributes as they apply to testing the fieldbus installation. This chapter describes how automated testing utilizing APLD significantly reduces commissioning, testing and troubleshooting effort in comparison to manual inspection. Savings are even more dramatic in comparison to 4…20 mA infrastructures. At the same time the test quality is improved.

2.1 Manual inspection

AG-181 is the working guideline created by fieldbus users and issued by the Fieldbus Foundation [2]. The versions up to 3.0 (01/2009) detail manual procedures for installing and commissioning fieldbus segments. Manual inspection requires handling of diverse pieces of equipment such as:

1. Digital multi-meter for current, voltage and resistance
2. Advanced capacitance meter capable of independent RC measurement
3. Digital storage oscilloscope
4. Handheld fieldbus signal generator and data analyzer
5. Screwdriver for connect and disconnect of devices and wiring interfaces
6. Set of paper test sheets and pens for manual documentation

The manual inspection prescribes to first run a check on the segment cable and then connect each instrument in sequence and check as shown in Figure 1. Each instrument must be disconnected to repeat this procedure for the next instrument.

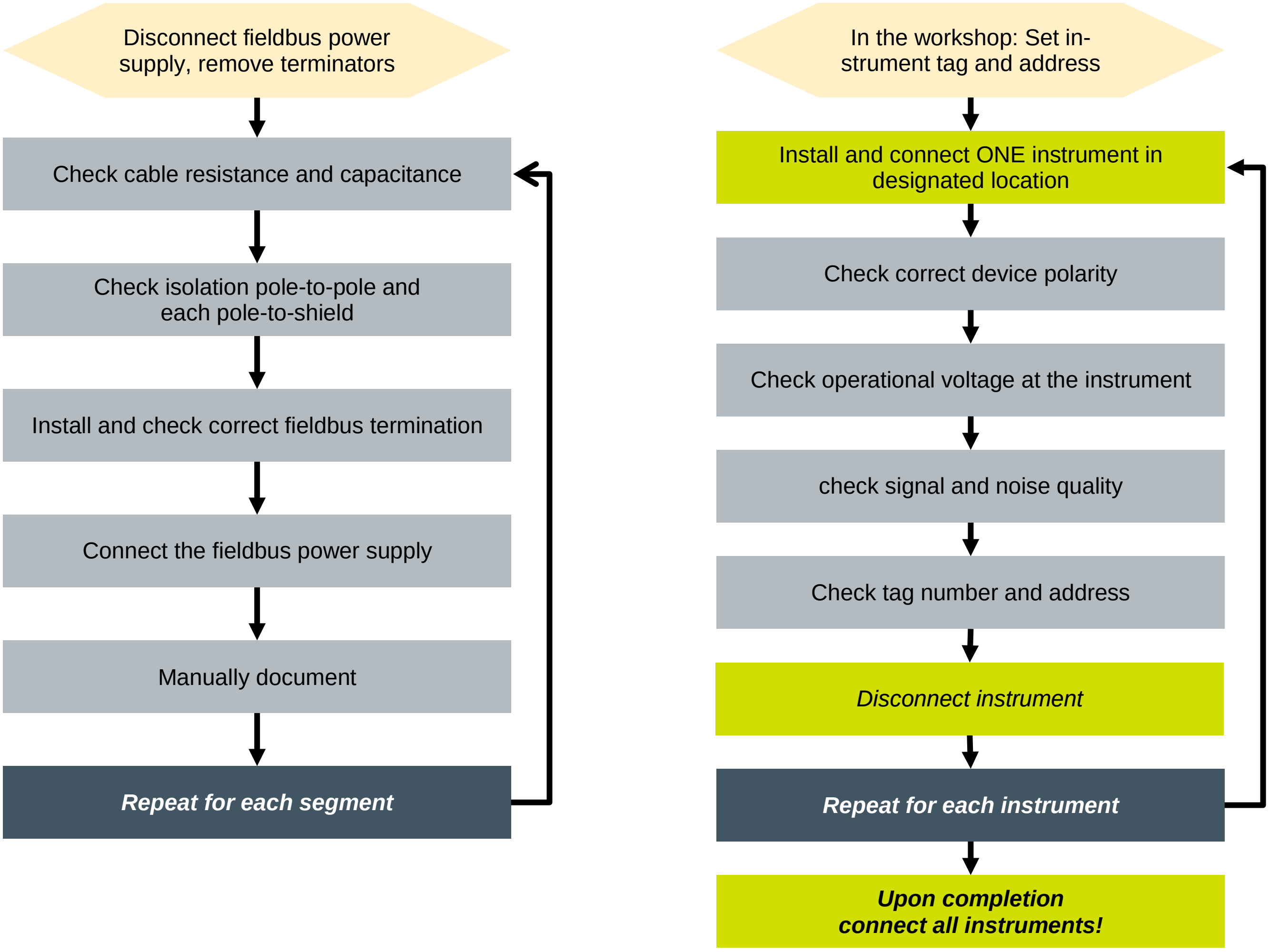

Figure 1: Manual constructional and electrical checks per segment and instrument

All documentation for constructional and instrument checks requires manual work. This procedure, though more efficient than classic cable checkout for 4…20 mA instrumentation, requires special preparations and has some disadvantages:

1. Special terminals or adaptors should be made available for connection of the various meter probes.
2. Many correctly installed terminals have no exposed conductors to clip test probes to. Therefore, 'eyelets' should be provided for testing, then removed after testing as they are exposed and not insulated. Alternatively, wires must be removed from the terminals and replaced after testing. This can give rise to potential failure issues if the terminals are not correctly reinstalled.
3. These tests demand far more expertise when compared to an equivalent 4...20 mA cable, and require a high level of measurement accuracy. Skilled engineers or technicians manually put together data from disparate devices to interpret the information. While oscilloscope data is extremely useful, to understand many of the potential faults that can occur or exist, it would require intricate specialist knowledge about signal analysis.
4. Certain failures remain unseen (see Table 2) and could create problems during loop checkout or further down the line during operation.
5. Hand-completed paper documents can be prone to errors, omissions or ultimately falsification. Signoffs and handovers may not be complete, particularly when performed under 'time penalty' pressures.

With the arrival and commoditization of physical layer diagnostic tools, AG-181 [2] was updated in 2012 to include and recommend automatic testing procedures. Planning, installation and wiring guidelines for PROFIBUS PA [3] include respective sections for automated electronic and software support. The following subchapter describes the implications with regards to commissioning and troubleshooting in detail.

2.2 Advanced physical layer diagnostics (APLD)

With online advanced physical layer diagnostics (APLD), it is now possible to test the entire network automatically at the 'touch of a button'. With very little knowledge required, APLD automatically tests many more physical layer attributes (see Table 2) and creates software-driven reporting. Simplified result summaries are easy to understand.

A major breakthrough is an automated test engine (ATE). With all devices connected at once, it automatically records many measurements from the physical layer. It can then interpret this data based on a rule-based expert system and provides messages in clear text with potential cause and suggested actions for remedy.

More so: During installation, wiring errors occur infrequently. A testing procedure should account for this by verifying the quality of the installation in very few steps. APLD offer tools for easy fault finding for rapid identification of those faults that do occur. The test procedure with APLD and troubleshooting procedures that are described in chapter 4 takes this into account.

Stationary APLD is integrated into the power supply as a plug-in module. It continuously monitors the physical layer and issues summary alarms to the operator workstation. Maintenance staff has access to detailed information via Ethernet or fieldbus communications and can thus intervene in a planned and proactive way.

Handheld APLD provides practically the same functionality due to the recent reduction in power consumption and increase in processor power. Measurements in the field are possible without a connection to a laptop, PC or plant asset management system (PAM). These handheld testers store results from measurements and allow for convenient data back-up that is tagged to the actual segment documentation. They are designed for the traveling fieldbus expert and for operators who deem continuous physical layer monitoring unnecessary to maintain the desired availability of process automation.

2.2.1 The optimized test procedure

The simplified testing procedure essentially tests the network "as built" eliminating the connect and disconnect operations required for individual instrument testing. Instead all instruments are connected to the segment at once and then automatically tested as shown in Figure 2. Each segment is tested for:

1. Compliance or conformance with respective fieldbus guidelines.
2. Compliance with IEC-61158-2 (fieldbus standard).
3. Compliance of power supply impedance and compatibility.
4. Operation, conformance and functionality of cable, devices, terminators, power supplies and protection electronics.

A major advancement is that the installation is tested as built and then left in place the way it was tested.

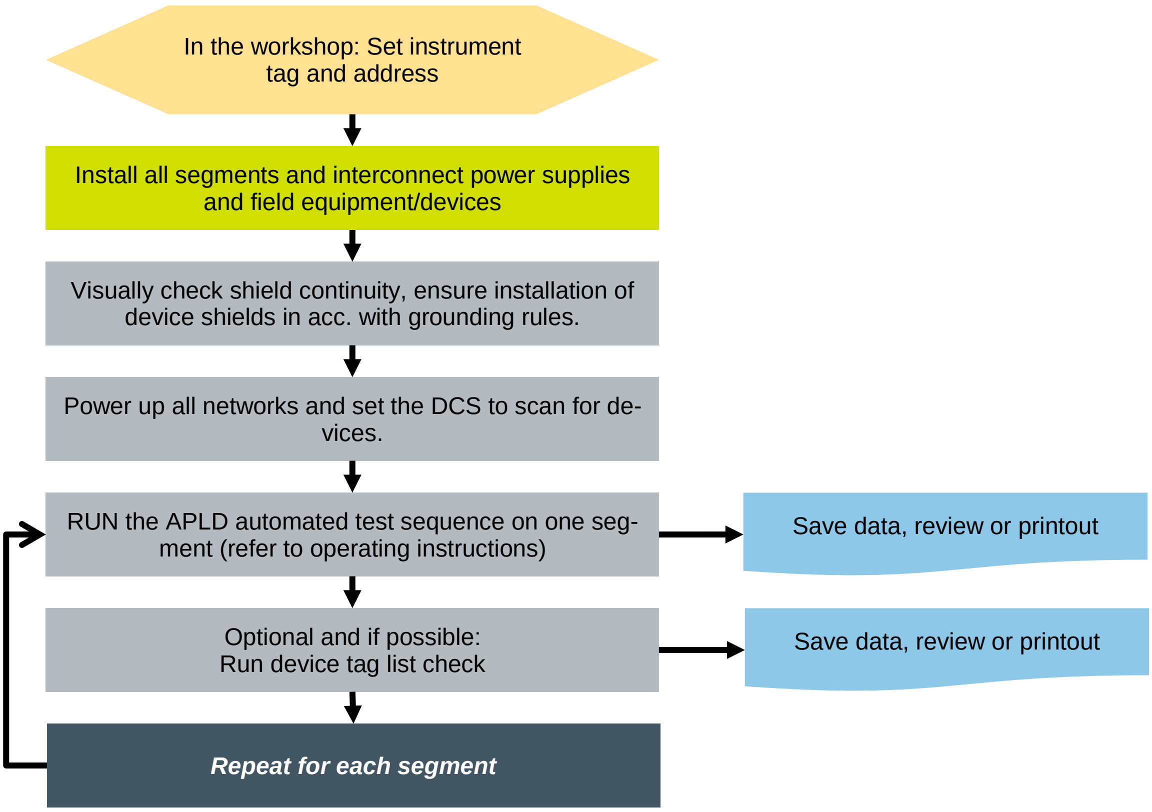

Figure 2: Revised test procedure utilizing APLD for optimized commissioning of fieldbus in process automation

Table 2: Comparison of test and report capabilities	Testing procedure		
Checks and issues	**Manual**	**Stationary ADM**	**Handheld Tester**
Cable checks			
Cable continuity, grounding and insulation test	✓	✓	✓
Shield to pole capacitive and resistive unbalance as a percentage for each pole.		✓	✓
General physical layer attributes and measurements			
Trunk voltage	✓	✓	✓
Load current	✓	✓	
Noise level analysis and limits	✓	✓	✓
Signal measurements			
Signal level analysis and limits	✓	✓	✓
Noise level analysis per device		✓	✓
Jitter measurement		✓	✓
‘Signal inverted’ warning		✓	✓
Oscilloscope signal capture	✓	✓	✓
Detailed waveform analysis with extended trigger functionality		✓	✓
Tests			
Automated commissioning procedure comparing planned to as built		✓	✓
Properties of existing installed cable to qualify for fieldbus operations			✓
Function check for device coupler short-circuit protection electronics			✓
Quick check mode for installation testing			✓
Fault resilience through failure margin test (amplitude, jitter and noise variation)			✓
General attributes			
Expert or technicians knowledge required for testing	✓		
Individual manual connect and disconnect of devices required	✓		
Automatic testing of all connected devices at once		✓	✓
Automatic documentation ready for signoff.		✓	✓
Support through off-site expert through data exchange		✓	✓

2.2.2 Hardware setup of stationary, integrated APLD

Stationary APLD is integrated within the power supply architecture. Wiring or electrically connecting test equipment into each segment is thus eliminated.

Figure 3 illustrates how the APLD module is integrated within a motherboard-based fieldbus power supply (Power Hub). Multiple APLD modules are daisy chained via a diagnostic bus, with a capability of monitoring and testing up to 124 segments for each diagnostic bus. The diagnostic bus uses simple RS485 hardware and can be connected to the control room via two ways:

1. **Ethernet interface:** This simple technology has the advantage of keeping response time fast on both the primary control system and the fieldbus diagnostic system. A separate path for communications to the APLD enables remote troubleshooting even when a detrimental fault hampers communication on the main line. Setup utility software systems automates the engineering process.
2. **FOUNDATION Fieldbus H1 node integration:** Up to 16 APLD modules can communicate to the distributed control system (DCS) albeit at a lower speed and utilizing bandwidth that is needed for process control and instrument diagnostics. Manual engineering is required for this method of integration.

The software on the maintenance station tests and reports on all segments reachable via the diagnostic bus. The interconnecting wiring for the test equipment is minimal. It remains permanently in place, without further connection or disconnection for online diagnostics during the operational lifetime of the plant.

After testing and commissioning, the APLD module continuously monitors the fieldbus physical layer for changes. In such a case, a summary alarm is issued to the operator workstation while the maintenance station provides all details to the case for analysis.

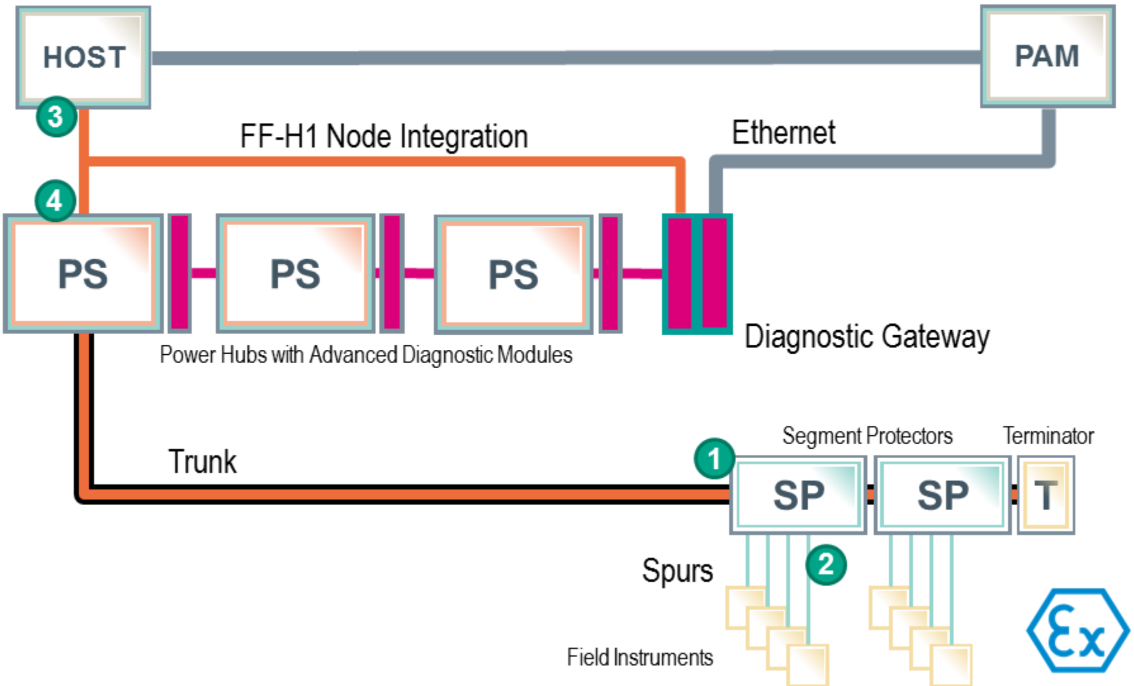

Figure 3: Connection diagram showing stationary APLD

2.2.3 Handheld APLD

Where the control system and/or supporting fieldbus power supplies are not on site or cannot be installed, handheld APLD equipment can be utilized. It provides the same level of automation and reporting albeit on a segment by segment test basis. Figure 4 illustrates that connection to any point of the segment is possible temporarily.

An important use case for handheld APLD is the checkout of partially constructed sites. Instrumentation and wiring work is complete but control room equipment is not yet available. Handheld APLD and a portable, battery-powered fieldbus power supply enable complete segment checkout. The ATE can interrogate devices independently including a comparison of design to as-built information.

This allows for compete field installation and validation before the DCS is available. This is efficient as installation and communications testing can occur while the installation teams are still on site at that time. Corrective action is taken immediately as necessary reducing testing time and effort.

Use cases for handheld APLD are:

- Checkout of partially constructed sites while installation teams are still available for corrective action.
- Detailed analysis for fieldbus experts as a service where APLD are not available.
- Quick check at anytime and anywhere.
- Verification of the installation quality after modifications or repair work is complete.

Optimized working procedures for validation of fieldbus installations and automatic documentation of the fully checked system provides assurance for all parties involved. The following chapter provides useful guidelines if faults are found and corrective action has to be taken.

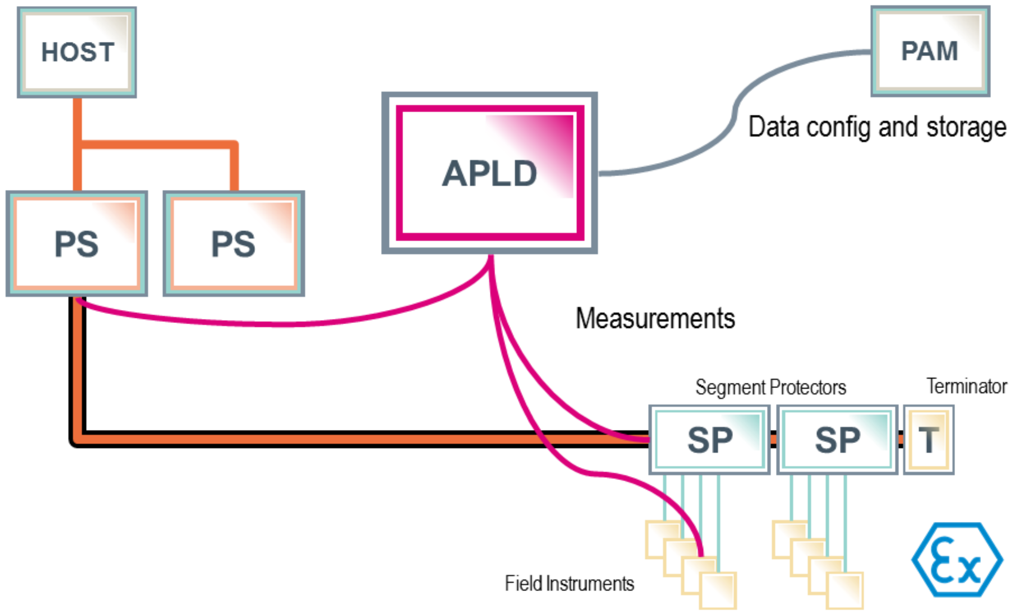

Figure 4: Connection diagram showing handheld diagnostics assisting in fieldbus analysis and validation

3 Fault Finding & Troubleshooting

In the best case, only few and simple wiring errors or installation faults will have been found and corrected with the help of the ATE. This chapter describes a working procedure for fault finding for more complicated and hard to track faults.

3.1 Elimination Method

As presented in the introduction of chapter 2.2, it would be anticipated that only a low percentage of segments display faults. First, primitive failures, such as power supply voltage loss or trunk short circuit need to be ruled out.

The automatic test engine (ATE) creates test reports with cause and action messages. Primitive faults can be easily found and fixed. If the software reports further failures, troubleshooting using a 'process of elimination' has to be performed.

If multiple faults exist in one segment, the information from the test report may on occasion not lead to a satisfactory repair of the fault. This can be the case in situations where the fault is hard to locate such as a ground fault. The flow chart (For connection points referenced in parentheses, refer to Figure 3.

Figure 5) describes how the process of elimination is undertaken. This is the quickest method to assess the probable type and position of the fault. Connection points referenced in parentheses refer to Figure 3.

1. Disconnect the trunk from the Segment Protector. (1)
2. Connect a discrete terminator to the open end of the trunk.
3. Run APLD test cycle to eliminate trunk, power supply or host failure. If this test passes then the failure resides with the segment protector or instruments. If the fault persists, go to step 9.
4. Remove the terminator and reconnect the trunk to the segment protector (1)
5. Sequentially disconnect each spur cable from the segment protector (2) and re-run test until the fault disappears. The fault then resides at the spur or instrument disconnected last.
6. If sequential disconnection of all spurs does not clear the fault, then the failure must reside with the device coupler and this can be replaced.
7. If the fault is discovered on one of the spur cables, then inspect spur installation and instrument for faults.
8. If the instrument is in question, then the instrument can be swapped out for an instrument emulator. if a further test cycle is re-run and the fault clears, the instrument is faulty and can be substituted.

COMMENTARY: To replace an instrument or device takes time if it is an inline item or attached to a manifold. To double-check that the device is indeed faulty before undertaking extensive work, a further autonomous test can be conducted with the instrument electrically isolated from the segment with a battery-powered fieldbus power supply and handheld APLD.

9. Disconnect the host spur cable (patch wire) at the host terminal bay (3) and re-run the test.
10. If this test cycle shows a clear segment, then the host system's I/O card may be faulty and should be replaced.
11. If the fault remains, disconnect the trunk cable from the fieldbus power supply (4), then the host spur cable should be checked. If a cable fault is not found, then replace the fieldbus power supplies.

Note: For the mobile diagnostic system, the above tasks would be applicable up to task 9.

For connection points referenced in parentheses, refer to Figure 3.

Figure 5: Method of elimination for fault finding in fieldbus networks.

3.2 Expert modes of APLD

3.2.1 The inline fieldbus oscilloscope

Where the procedure described in Figure 5 does not conclusively fix the fault, the use of the inline fieldbus oscilloscope can lead to more insight. Detailed oscilloscope data can be viewed for more advanced troubleshooting analysis (Figure 6). The fieldbus oscilloscope bridges the gap between automatic diagnostics and manual troubleshooting. A vast selection of trigger point options enables a competent engineer to further assess in-depth information. An oscilloscope with fieldbus-specific trigger options is by far the best tool for the fieldbus expert troubleshooting unusual or complex network faults. An integrated oscilloscope within the diagnostic module has many advantages which are similar to those already presented in 2.1 about manual inspection procedures.

- No need to read drawings to find the correct terminals
- No cable and junction box disturbance

Additionally the digital oscilloscope data can be recorded in a simple way at the maintenance terminal. This way the complete information: test report and oscilloscope traces can be sent to a remote expert for additional troubleshooting advice, saving travel cost and valuable time.

3.2.2 Failure margin checking for commissioning of installed components

The failure margin tests the segment as built for resilience against external disturbances. The ATE can distort the communication through modification of signal amplitude, jitter, and noise until communications fail. This test can be initiated for individual or all connected instruments at once.

This test is designed to determine in detail the stability of communication per device. NB: This test will disrupt communication and must not be run during production.

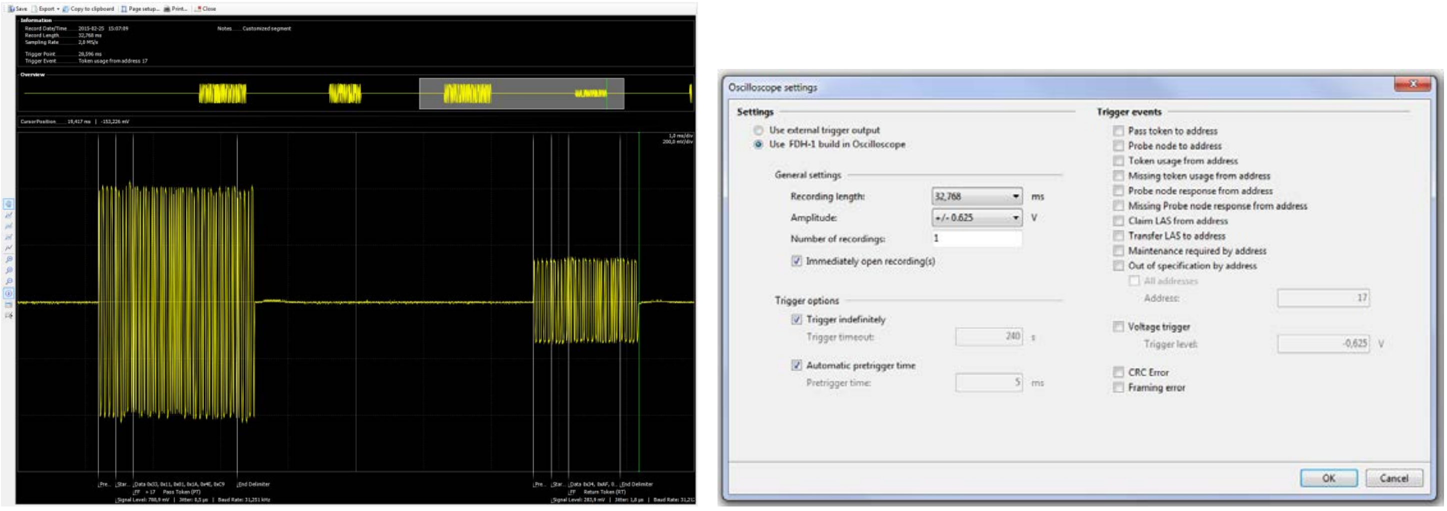

Figure 6: Oscilloscope example with zoom capability, a host of dedicated trigger point options and digital storage

3.3 More use cases for APLD tools

With exception of the failure margin check the methods shown can be applied at any time. This typically occurs during commissioning or during operations when a warning has been issued by APLD. With certification for hazardous area locations, mobile equipment can be connected anywhere on the segment.

3.3.1 During operation

In a very economical way, users are able to maintain the quality of the installation to the required standards and to ensure continued high availability of the process automation system. APLD can compare commissioning test records that are provided by the ATE to the current build of the segment. The resulting record highlights changes in the physical layer such as:

- Added, removed or changed instruments
- Communication quality in comparison to the commissioned, optimum or 'as-built' settings

The report enables users to identify and correct unwanted modifications or changes in physical layer quality. This is particularly useful to counteract aging and decay of equipment exchanging only components that require it. APLD can typically issue an early warning to allow timely intervention while the plant is still in production mode.

3.3.2 Cable check for plant upgrades and brown field sites

APLD can provide a suitability check for existing cable. A simple test determines the signal quality transmitted by the existing cable. This can lead to significant CAPEX savings in brown field site applications.

3.3.3 Device coupler short circuit test

Some fieldbus installations are in continuous operation, some of which may be older than 10 years. A feature that is never monitored is the device coupler's short circuit protection. Using modern-day APLD, the load current at a device coupler output can be automatically increased until it goes into a short-circuit condition. The peak current value is then determined. This value can be checked against the manufacturer's specifications to ensure the segment's continued integrity.

4 Case study

This case study provides an example of potential time savings when applying APLD. It compares APLD to an installation with 4…20 mA interfaces and a fieldbus installation using manual test procedures as described in chapter 2. The intention is to provide a means, idea and guideline that can be modified to fit actual project specifications. Though the estimates are general, this case study gives an idea about the vast savings potential.

Today's modern fieldbus installation technology with rigorous test requirements will exhibit a very low failure rate after installation. The cable installation generally reveals a failure, of one type or another, of much less than 2%. Based on this figure, only 2 segments per 100 would be expected not to function first time. Therefore, 98 segments would function first time without any failures. Where the majority of segments work first time, it would be pointless to approach testing with a view that the majority of instruments and cable runs may exhibit faults. This reinforces the option for complete installation and test at the same time.

The specifications that are considered in this case study are shown in Table 3. Results are summarized in Table 4. Factors influencing actual project specifications and parameters are:

- the process or the product to be manufactured,
- the geographic region and environment of the installation

Some contractors allow a team up to 30 minutes for construction testing, pre-commissioning checks and repair per instrument loop. The time seems to range depending on the project definition: 10 minutes per loop constitute just a check. Up to 2 hours per loop takes repair work into account. For a 4...20 mA system, 30 minutes per loop results in over 2¼ months' worth of qualified and experienced work, based on an 8 hour shift per day and a full working week. This case study considers a shorter time estimate of 5 minutes per instrument and cable loop.

Pre-commissioning is defined as work steps taken to install and validate the hardware configuration and the physical layer. It can be grouped with construction, but for simplicity, pre-commissioning is grouped with commissioning. For commissioning, the common aspect of control loop checking is ignored as this is the same independent of the hardware model.

NOTE: The APLD tests many more physical layer parameters in a shorter time.

In conclusion, the new strategy adopts a faster, more accurate method of testing by way of fully constructing each segment and testing it automatically in one single step. Thereafter, any failure can be dealt with in a sequential manner.

Table 3: Case Study – Base Specifications

Attribute	Value
Number of instruments	1,200
Number of segments	100
Instruments per segment	12
Man day	8 hours
Mean time to repair (MTTR) a fault	4 hours
Failure rate per total cable connections	1 %
Hardware failure rate	0.5 %
Installation faults estimated	2 %

Table 4: Case Study – Comparison

Task	Model	4...20 mA	Fieldbus without APLD	Fieldbus with APLD
Constructional checks: Each cable is checked for: continuity, pole to pole and each pole to shield isolation and a test sheet completed. Allowing for time to read the drawings and locate the terminals and connect the cable testers. **NOTE:** For fieldbus, additional cable resistance and capacitance checks are required. For fieldbus with diagnostics, the cable can be checked at the same time as pre-commissioning checks are performed.	Time/Unit	5 min	10 min	Not required
	Units	1200 loops	100 segments	Not required
	Total Time	6000 min = 12½ days	1000 min = 2 days	0
Construction failures: Anticipated percentage of cable failures and the time taken to repair the fault. **NOTE:** Fieldbus has the same number of spur cables as the 4...20 mA model, plus an additional trunk cable for 12 instruments.	Time/Unit	4 h MTTR	4 h MTTR	Not required
	Units	12 loops	1 trunk, 12 spurs	Not required
	Total Time	48 h = 6 days	52 h = 6 ½ days	0
Pre/commissioning instrument checks 4...20 mA Model: each instrument should be tested with a loop calibrator or handheld tester to ensure correct device polarity, operational voltage test and loop current check for both analog inputs and analog outputs with a test sheet completed. **Fieldbus:** each network is tested to ensure correct device communication, signal and noise quality, tag number and address validation, power supply voltage test with a test sheet completed.	Time/Unit	10 min	60 min	8 min
	Units	1200 loops	100 segments	100 segments
	Total Time	12,000 min = 25 days	6000 min = 12½ days	800 min = 1.6 days
Pre/commissioning failure: Anticipated failures and the time taken to repair the fault. **NOTE:** Fieldbus with advanced diagnostics includes the predicted cable failures as the new one-step-testing procedure will reveal such failures at this point.	Time/Unit	4h MTTR	4h MTTR	4h MTTR
	Units	0.5% = 6 loops	0.5% = 1 segment	1.5% = 2 segments
	Total Time	24 h = 3 days	4 h = ½ day	8 h = 1 day
Totals		46.5 days	21.5 days	2.6 days

5 Summary

Construction and pre-commissioning/commissioning time saving is a very important consideration for plant start-up. A high level of accuracy, quality and reliability of the work performed is critical to success.

Using advanced physical layer diagnostics during construction and pre-commissioning will:

- Increase the test performance
- Reduce time spent on site
- Accurately record and report findings
- No longer require high skill-sets
- Reduce staffing levels.

Depending on project size and scope, it is feasible to reduce the skill sets and staffing levels to only one on-site and/or off-site fieldbus specialist. This person can then focus only on the anticipated or more complex failures, if and when they occur. One might consider that the equipment supplier provides expert engineers to aid construction and commissioning during failure assessment when they are needed.

Non-intrusive automatic test equipment for construction or commissioning saves significant time, eliminates interference with properly installed cable and performs many more comprehensive test measurements. Automatic test and reporting is accurate and complete. It can accurately and reliably uncover faults that would have been overlooked otherwise, and uncover faults that could cause failure during operation.

Project managers can assess progress effectively. With APLD, they are able to assess repair time as a percentage of testing time and prepare for effortless and cost-effective transition into the operational phase. Finally, the handover to the customer follows a thorough and accurate test sequence at the appropriate time that guarantees quality, performance and reliability.

The stationary APLD system stays in place during operation. History trending and continuous monitoring with alarming integrated in the DCS enables operating and maintenance personnel to respond in a timely and educated manner. Expensive reactive repair work on the fieldbus is eliminated and plant operation is thus improved.

6 References / Bibliography

[1] The Fieldbus Foundation (www.fieldbus.org) and PROFIBUS International (www.profibus.com) are the non-profit organizations governing these technologies.

[2] Lancaster, David et al, 2012: *FOUNDATION Fieldbus System Engineering Guidelines (AG-181) Revision 3.2*. Free download at www.fieldbus.org.

[3] PROFIBUS International, 2014: *PROFIBUS Installation Guideline,* Free download at www.profibus.com

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7 FieldConnex® Components for Advanced Physical Layer Diagnostics

The following components comprise the offerings from Pepperl+Fuchs. The type codes provide an easy method for internet search or at www.pepperl-fuchs.com/fieldconnex.

Table 5: FieldConnex portfolio of components with advanced physical layer diagnostics

Type code	Short description
Physical layer diagnostic tools	
FDH-1	Fieldbus diagnostic handheld tester: Comprehensive diagnostics for the fieldbus physical layer, handheld with display and integrated expert system
HD2-DM-A	Advanced diagnostic module: Comprehensive diagnostics for fieldbus physical layer and power supply, Plug-in module for the FieldConnex Power Hub
KT-MB-GT*	Diagnostic gateway with Ethernet and FF-H1 interface: System integration kit for advanced diagnostics, DCS integration via diagnostic manager or device DTM, Simple automatic setup of advanced diagnostics
Diagnostic-enabled accessories	
ELS-1	Enclosure leakage sensor: Indication via LED and advanced diagnostics, intrinsically safe, FISCO or Entity, For instrument or device coupler, Fits inside terminal compartment,
TPH-SP*, TCP-SP*, SCP-SP-*	Fieldbus surge protector, field installation on spur: Pluggable, mounts between device coupler and spur cable, intrinsically safe (Ex ia), FISCO, Entity, DART Fieldbus, or general-purpose, Optional diagnostics for wear
FOUNDATION Fieldbus H1 Power supplies and PROFIBUS Segment Couplers	
MBHC-FB*	Compact Fieldbus Power Hub, motherboard: four or eight segments, individual modules per segment, interface to adaptable to PLC and DCS hosts, support ignition protection for any hazardous area. Redundancy of power supply modules selectable
HCD2-FBPS-1*	Compact power supply module with galvanic isolation, selectable output voltage
MB-FB-GT*	PROFIBUS Power Hub, gateway motherboard: For gateway modules in simplex or redundant configuration, Transparent connection to PROFIBUS DP.
HD2-GT-	PROFIBUS Power Hub, gateway module supporting PROFIBUS DP V1; for four PROFIBUS PA segments, connects PA transparently to PROFIBUS DP
Device couplers	
R4D0-FB-IA*	FieldBarrier: 8 ... 12 outputs Ex ia IIC, FISCO and Entity, Advanced fault isolation and diagnostics at the spur, FieldBarrier in Zone 1/Div. 2, Instruments in Zone 0...1/Div. 1
R2-SP-IC*	Segment Protector for Cabinet Installation: 4 ... 12 outputs Ex ic (FISCO or Entity) or non-incendive (Div. 2), Advanced fault isolation at the spur, Segment Protector in Zone 2/Div. 2, Instruments in Zone 2/Div. 2 or Zone 1/Div. 1. For plants without hazardous area classification

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