Practical Importance of the FOUNDATION™ Fieldbus Interoperability Test System

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Keywords

Fieldbus, Interoperability, Conformance, Testing, Function blocks

Abstract

FOUNDATION™ Fieldbus has moved much of the control functionality once found in the proprietary computer of a DCS into FF interoperable field devices, based on an open specification. End users need a way to recognize those devices that adhere to the FF specification so as to assure a functional fit into their control network.

The Interoperability Test System and FOUNDATION™ Fieldbus's compliance registration program thoroughly test intelligent field devices from the electrical circuit interface characteristics through the user layer function blocks. This testing allows users to apply "Best-in-Class" measurement and control technology with confidence that devices from various manufactures will work together.

Introduction

The Fieldbus Foundation's rigorous Interoperability Test and Registration Procedures thoroughly examine and verify all aspects of the intelligent field device. The registration process is not a simple exercise in paperwork, but a detailed and methodical set of procedures that test all specified functions of the device. In order to fulfill the registration process, manufacturers must submit their devices to independent lab verification performed by the Fieldbus Foundation or a qualified third party testing agency.

The actual testing of the field device cannot begin until the manufacturer has completed both the communication stack and the physical layer conformance certifications. The physical layer conformance test verifies the electrical characteristics of the device, while the stack conformance test validates the messaging component of the device software. Only when a device has met both requirements will it qualify for interoperability testing. Manufacturers may then submit their device to the Fieldbus Foundation, where the device undergoes a suite of test procedures aimed at verifying the functionality of the device's user layer, which is the function block application. Finally, manufacturers have the opportunity to submit their device for testing in the Host Test Bed. Using a suite of automatic and manual test procedures, interoperability is verified between known registered devices and qualified host systems operating in the market today. The results: Manufacturers and users have complete confidence that devices certified with the FF Registration Mark have undergone a rigorous testing by independent third parties. Control system designers can have confidence that FF registered devices will truly interoperate in a plant environment.

Physical Layer Testing

The Physical Layer refers to the electrical characteristics of the field device. Manufacturers or manufacturer chosen third party testing facilities perform physical layer testing. The Physical Layer Conformance Test Specification details cookbook style procedures that must be executed to verify that the field device conforms electrically to the FOUNDATION™ Fieldbus (FF) specifications. Manufactures are required to document all applicable test cases for their field devices and submit a report to the Fieldbus Foundation with proof of conformance.

Physical Layer Conformance Testing

- Transmission Levels & Timing
- Receiver Noise Rejection
- Ripple Sensitivity
- Operating Voltage
- Input Impedance
- Withstand Voltage

The Physical Layer Conformance Test Specification covers all aspects of specified physical layer requirements. First, manufacturers must document the profile class to which the field device conforms. These profile classes characterize the device as either bus or self-powered, standard or low power signaling, and intrinsically safe (IS) or non-IS. End users utilize this information for choosing proper devices based on installation requirements.

Many of the test procedures require detailed analysis of the transmission and reception characteristics of the device under test (DUT). Such test cases include verification of the proper transmission level and timings over a full range of bus supply voltages. (See figure 1) In addition, bus powered devices must undergo specific operating voltage tests to verify the DUT will function within the specified voltage range. Other test procedures validate that the actual current draw matches that specified for the device, and that the maximum change in quiescent current, over time, is within specification. These test procedures guarantee that a device can be attached to a live fieldbus without affecting communication of an existing operational segment.

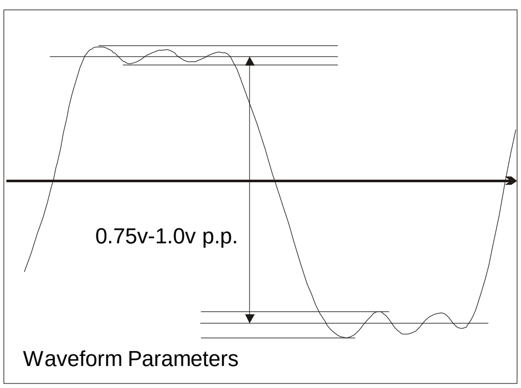

***Figure 1** -- Physical Layer Conformance validates the fieldbus waveform.*

A lab is a relatively noise free environment, but actual installations experience a wide range of electric noise from other devices in the plant environment. As a result, the specifications have been robustly designed to reject such noises that can interfere with normal fieldbus communications. Specific tests for ripple sensitivity and common mode broadband interference susceptibility guarantee the field device will be capable of operating in the real world's noisy environment found in today's plant-floor environments.

The FF specification dictates specific network rules that end users can follow to build a successful FF network. But, these rules depend on specified operational characteristics. By verifying all aspects of the physical layer of the field device, engineers can design fieldbus systems using a known set of rules that will support any field device configuration.

Conformance Testing

In addition to physical layer testing, the registered field device must contain a registered communication stack. The fieldbus communication stack is the messaging component of the field device. Specifically, the stack is composed of the data link layer, the fieldbus access sub-layer, the fieldbus message specification, system management and network management agents.

Many third party stack vendors have implemented fieldbus communication stacks over a variety of processor platforms. In order to receive registration, the stack vendor must submit the stack software for testing. Some field device manufacturers have chosen to design and implement their own fieldbus communication stack while others choose to obtain a stack from a stack vendor. Policies dictate that manufacturers who obtain a registered stack from a third party vendor and use the stack without modifications are not required to re-register the stack. Manufacturers, who do obtain a stack from third party vendors and modify the stack, including service additions or processor ports will require a re-registration of the communications stack. All stack conformance testing is performed by the Fraunhofer Institute, a non-profit testing agency located in Karlsruhe, Germany.

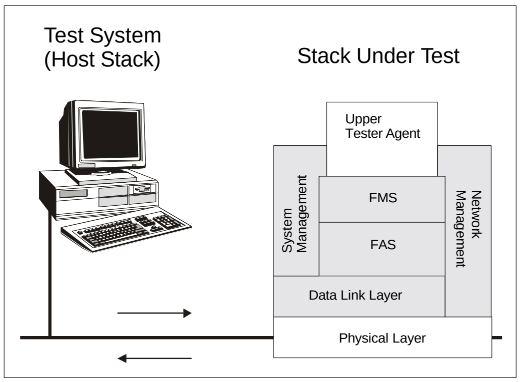

Figure 2 *– The Conformance Test System (CTS) communicates with the Upper Tester Agent*

The stack conformance test consists of a suite of both automated and manual test procedures. Before the developer submits the stack software for registration, the developer ports an application, the Upper Test Agent (UTA), to the stack under test (SUT). (See Figure 2) The test system, utilizing a tested, or "golden" stack, can communicate to the remote stack via the UTA. The UTA is responsible for collecting the remote indications from the SUT, which can later be verified by the test system after execution of a specific test procedure. In addition, the test system can remotely instruct the UTA to trigger responses from the SUT which are recorded and evaluated by the test system. Hence, the test system can confirm all communication paths between the UTA and the SUT.

Conformance Test System

- Fieldbus Message Specification Messaging
- System Management Messaging
- Object Dictionary Conformance
- Data Link Timing
- Link Active Scheduler

The automated test procedures validate both Fieldbus Message Specification (FMS) and System Management (SM) messaging. The test system validates that the messages for the different services are both formed and decoded correctly by the SUT. Other test procedures validate the data structures present in the device's object dictionary (OD) are conformant to the current FF specifications. The OD contains the list of data that is accessible in the device via the fieldbus. Host systems use the FMS messaging to read and write to the objects located in the OD. As a result, end users have the assurance that FF devices with conformant stacks "speak a common language."

FF field device communication is enabled via a centralized token passing mechanism controlled by the Link Active Scheduler (LAS). Any Link Master (LM) class device is capable of becoming a LAS for the given network segment. In a typical installation, the FF interface to the host system executes the LAS function, however the specification has been designed to allow any other LM class device to assume the role of LAS in the event of a failure by a primary LAS. The basic function of the LAS is to manage bus communications by maintaining the specific message timing for the devices. This timing structure controls both the cyclic and acyclic messaging on the fieldbus and must be observed by all field devices on the segment. Failure to observe this critical timing information can result in poor performance and potential loss of communication. Manual test procedures validate that field devices observe these timing elements which are crucial for proper fieldbus operation.

Additional test procedures examine the distribution and synchronization of the application time clock. All FF field devices are synchronized to a known sense of time that is specifically used to timestamp critical events such as alarm detection. The specifications dictate that one device on the segment is assigned the role of primary time publisher, and all other devices capable of publishing the application time become backup time publishers. Procedures verify that those devices with backup application clock abilities can continue to publish the application time in the event of failure by the primary time master. This guarantees that all devices will have a common sense of time required in both alert and trend reporting.

Finally, those stacks that are classified as Link Master undergo special test procedures to validate LAS functionality, especially noting the abilities for a backup Link Master to seamlessly assume the LAS function in the event of failure by the primary LAS. As a result, end users can have confidence that the process control functions distributed in the field will continue to run unaffected in event of failure of the primary LAS.

Interoperability Testing

Once manufacturers have completed both physical layer and stack conformance testing, the device will qualify for interoperability testing. The primary goal of interoperability testing is to validate the user layer, or the function block application of the FF field device. Interoperability Testing consists of two separate test systems: the Interoperability Test System (ITS) and Device Description Verification.

Interoperability Test System

The interoperability test system is designed to verify the manufacture implementation is consistent with the Function block specifications. The current version of the ITS contains over 280 individual test cases to validate all aspects of the user layer specifications. Test cases are grouped into test classes based on the device functionality they test. A special certification schedule, which executes all test cases for the device class, is used during the actual interoperability testing. Devices must pass all applicable test cases in order to qualify for device registration.

The first test section of the ITS verifies proper System Management behavior. This behavior consists of configuration of both the Physical Device Tag (PD-TAG) and node address. Specific test cases verify both valid and invalid behavior. An example of an invalid behavior might be attempting to change the PD-TAG of the device by specifying the wrong Device ID (unique serial number for the device).

Additional test cases verify object dictionary (OD) conformance. The OD is a table in the device that details all the device parameters that are accessible over the fieldbus. The Function Block specification mandates a specific structure for the OD that allows configuration tools to access and locate all information available in the device. For example, a specific test case verifies that an Analog Input (AI) block has the specified minimum 36 typed parameters as defined by the Function Block specification.

Perhaps the most important test cases that verify true device-to-device interoperability relate to mode and status. FF enables control functions to be distributed across multiple field devices and host systems. The only mechanism for these function blocks to exchange data is via communication links between the function blocks. During each cycle of the function block schedules, a block will publish a value and a status related to that value. Each transmitted data value has attached status information revealing the quality of the data value: Good, Bad or Uncertain. In addition to the overall quality, each status item contains specific sub-status detail as well as information describing the limit status of the value.

Interoperability Test System

- Initial Connections
- Mode and Status
- Function Block Linkage
- Alarms and Events
- Trending
- Fault State
- Power Failure Recovery
- Simulation
- Device Description Verification

As in today's traditional control systems, FF function blocks contain an operation mode. Blocks, such as PID, will support such modes including AUTO, MANUAL and CASCADE. System operators control the operation of the function blocks by configuring a desired mode for the block. This is referred to as the **Target Mode**.

During the cyclic execution of the function blocks, each block must determine an **Actual Mode** that the block may execute. Many events can affect the **Actual Mode** of a block, including the data status from connected blocks.

For example, consider the common configuration where a transmitter is configured to publish its process variable (PV) to a PID control block. The system operator has configured the **Target Mode** of the PID block to run in the AUTO mode. Under normal conditions the transmitter might publish a value of 25°C with a status of GOOD. Because the PID control block receives a status of GOOD, the PID block will use the data to compute an output value in the AUTO mode.

Now, assume the transmitter has detected a sensor problem. The transmitter can publish a value with a status of BAD (and perhaps a sub-status of Sensor Failure). The BAD status indication informs the PID block that the data received from the transmitter block is not reliable. In a PID control block, an automatic mode is not an acceptable **Actual Mode** when the input PV has a BAD status. The **Actual Mode** will default down to the MANUAL mode, trigger a block alarm, and inform operator to take control of the process in order to perform the necessary steps to alleviate the problem.

The ITS is designed to simulate real world situations as just described. In order to properly synchronize field devices and simulate real world behavior, the ITS utilizes a separate device call a Test Function Block (TFB). The TFB can be thought of as a function block simulator. (See figure 3) The TFB contains a custom function block with a set of input and output parameters tied to internal parameter value queues. During the execution of a test case, the ITS will link the manufacturer's device under test (DUT) to the TFB's input and output parameters. Next, the test system will download specific information to the TFB's output parameter queues that would stimulate expected behavior in the DUT. After execution, the ITS will upload the input parameter queues from the TFB and compare those against expected values. The ITS uses the above procedures to validate advanced behaviors including specific mode and status handling, cascade initialization handshaking and mode shedding operations.

Because of the extensive testing performed on mode and status, end users can be assured that the different manufacturers devices registered against a common test system will fully interoperate.

During operation in a plant, unforeseen circumstances might lead to unexpected power failure on the fieldbus segment. The fieldbus specification is designed to allow full, automatic recovery of device configuration after power restoration. In order to meet these specifications, field devices are required to store specific objects in a non-volatile memory. In order to validate this behavior, certain test cases require that the test administrator physically disconnect and reconnect the device from the power source to verify that the device does indeed recover from these power failures as specified.

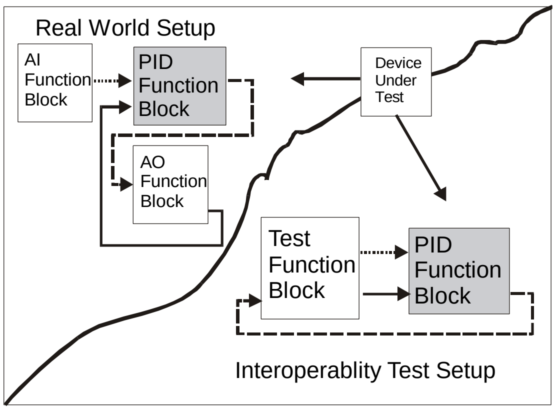

Figure 3 *– The Test Function Block (TFB) simulates real world devices.*

The above highlights only a small percentage of the total coverage of the ITS. In addition, the ITS includes test cases to verify such mandatory characteristics as alarm and event handling, trending, write lock handling (the ability to write protect the device's configuration), device fault states, simulation, output tracking and mandatory write checks.

Finally, it is important to note that the ITS is written to validate the behavior of standard, defined FF function blocks. Each function block contained in a field device can be classified as standard, enhanced or custom. A standard function block fully conforms to the specification of the block as required by the FF Function Block Specifications. These blocks contain no custom features. An enhanced block will contain the minimum functionality as specified by the Function Block Specification and include additional manufacturer added functionality. Enhanced function blocks will contain additional parameters, which are located immediately after the standard parameters. Standard function blocks and the "standard" portion of the enhanced function blocks are fully covered by the ITS. The final classification, custom, defines a block, which does not meet the other two criteria. Custom function blocks are blocks that do not correspond to any standard specified block. Although custom function blocks can be designed to be interoperable with other field devices, the ITS has no knowledge of the specific behavior of these custom blocks and therefore cannot test custom function blocks.

All interoperability testing is performed at the Fieldbus Foundation lab located in Austin, Texas. As of this writing, additional test sites are in the planning stages.

Device Description Verification

The second key process during interoperability testing is the device description verification. A device description (DD) file is a binary file that contains descriptive information about the field device. If manufacturers implement additional functionality above and beyond that specified in the Function Block Specifications, a manufacturer must supply a Device Description file.

At a minimum, a device description will contain a descriptive reference to every block and block parameter implemented in the device. Each description will contain such features as a label, help text information, unit codes, display formats, and specific class and handling information. A device description may contain a valid range for a set of parameters, informing the operator what values he may enter for a specific parameter. The device description may contain sets of enumerations that would allow an operator to choose a specific value from a list of choices.

In addition to the standard features of a device description, manufacturers may implement advanced features such as menus and method procedures. Such method procedures might instruct the operator on the calibration procedure for the device or how to enable special features.

The Device Description Verification validates that a host using the Device Description Services (DDS) can access all descriptions for all the parameter in the device, including both standard and manufacturer specific. Although the ITS cannot verify the functionality of custom function blocks, the Device Description Verification validates that all blocks, including those classified as custom, contain a complete device description reference. Additional verification is made on the standard parameters to validate that the standard set of FF function block parameters conform to the specifications.

The completion of the device description verification assures the user that a tool utilizing the FF Device Description Services will be able to access all parameters in the device. This enables tools to configure both the standard, enhanced and custom set of parameters found in today's field devices.

Interoperability Test Bed

As a final part of device registration, manufacturers have the opportunity to submit their device for testing on the Interoperability Test Bed (ITB). The ITB consists contains a set of fully functional FF host systems from a wide range of systems manufacturers. As a minimum requirement, host systems are required to contain registered FF stack software and implement the Device Description Services (DDS). Attached to each host system is a set of registered FF devices. The selection of devices is such that each host system will contain a mixture of devices from various manufacturers. Special considerations are made to represent a variety of function blocks and communication stack implementations. The resulting configurations represent real world examples of actual fieldbus host systems operating in a true mixture of multi-vendor configurations.

Host Systems Testing

- Device management
- Device parameter access
- Host configuration
- Multi device configurations
- Redundant Link Master functionality

As the device under test is attached to each host segment, a suite of manual test procedures is performed on the device. The initial set of test procedures will validate that the host systems can access the parameters in the field device. Additional test procedures will confirm that host systems can properly configure and download simple and complex function block schedules between various devices on the segment. If the host system supports standard FF function blocks, those function blocks are also used in the configurations.

As described earlier, the LAS is an integral part of the fieldbus. Test procedures will verify that host systems can properly configure the LAS functionality in the remote devices. Other test procedures will confirm that field devices supporting the LAS function will seamlessly acquire the communication management of a fieldbus segment during simulated failure of the host system interface.

As a result of the extensive testing in the Interoperability Test Bed, end users will have the ultimate assurance that plants implementing FOUNDATION™ fieldbus using registered field devices from multiple manufacturers will interoperate within the plant's control systems.

Summary

The Fieldbus Foundation's rigorous Interoperability Test and Registration procedures thoroughly examine and verify all aspects of the intelligent field device. The test procedures begin with Physical Layer testing, which validate the electrical characteristics of the field device. Because of the rigorous physical layer requirement, end users can rely on the specified network when designing FF segments. In addition to the thorough physical layer testing, FF field devices must contain registered stack software. Registered stack software guarantees all field devices communicate in a known, common, specified manner and adhere to the critical timing requirements of the fieldbus protocol. Only after the device has met both physical layer and stack conformance criteria can the device apply for interoperability testing. The goal of interoperability testing is to validate the implementation of the device user layer, or function block application. All aspects of the function block application are meticulously examined, including mode and status behavior, parameter conformance, alert handling, trending, simulation and power failure recovery. End users have the assurance that different devices from different manufacturers, possibly using different physical layers or different stack configurations, will interoperate fully on a given FF segment. Finally, the Interoperability Test Bed completes the thorough test by verifying devices can truly interoperate with other registered field devices using a set of qualified FF host systems. End users can have the utmost confidence that the FF field devices of today and tomorrow will fully interoperate in a control system environment.

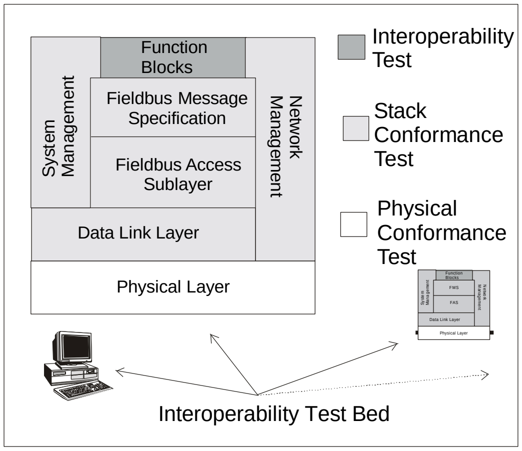

***Figure 4** -- Interoperability Testing covers all aspect of the FF field device.*

The Interoperability Test System is continually evolving. As the Fieldbus Foundation specifies new function blocks, the test system will be enhanced to include specific test cases to verify the standard behavior of those new function blocks.

It should also be noted that each of the four test systems is implicitly cumulative. For example, the conformance test system requires a conformant physical layer. The Interoperability Test System requires a conformant stack and physical layer. The Host Systems Test requires a conformant physical layer, a conformant stack and interoperable function blocks. (See figure 4)

Manufacturers have complete confidence that devices marked with the FF Registration Mark have undergone rigorous testing by independent third parties. Manufacturers can have confidence that FF registered devices will truly interoperate in a plant environment.

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