Presented to the 1993 Aerospace Avionic Systems Division Conference April 22, 1993.
Paper # 931594

Experiences In Validating MIL-STD-1553 Remote Terminals

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ABSTRACT

Although MIL-STD-1553 has been around for almost 20 years and is well supported today, our experience in testing over the last five and a half years confirms the need for validation testing. Validation testing verifies the compliance of a terminal's interface with MIL-STD-1553. Testing is often avoided because of limited experience, increased costs and, most importantly, misconceptions about 1553. The misconceptions tend to be a mixture of hopeful expectations about compliance and misunderstandings about the performance of parts claiming to be "certified", board designs that have been validated only in specific LRUs, and operational but untested LRUs.

The complexity of MIL-STD-1553 provides many pitfalls for the unwary. Failures can result from marginal components, improper selection of components, incorrect usage of components, poor part layout and deficient software. A "certified" 1553 interface board from one LRU may fail the test plan when tested in a different LRU. LRUs may appear to operate correctly under normal conditions yet fail the test plan because they do not have the required margins. Without validation testing, the performance of a 1553 interface cannot be properly determined.

INTRODUCTION

MIL-STD-1553 has been around since 1973. It's flexible, dependable, inexpensive to implement and has off-the-shelf support. It's also taken for granted. 1553 has been around so long that many engineers seem to think that you can just buy all of the parts, "glue" them together, and "presto" it works.

Unfortunately, a 1553 interface is not quite as easy as many people would like to think. Care must be taken to use parts correctly and the choice of parts is critical since many of the available 1553 parts fail some part of the 1553 test plans. In over five and a half years of performing validation testing, we have not had a 1553 interface pass the test plan the first time through. We will look at what validation testing involves, misconceptions people have about it, some examples of remote terminal (RT) failures we have found in testing and finally, what options are available for validation testing.

PURPOSE OF VALIDATION TESTING

The purpose of MIL-STD-1553 validation testing is to verify compliance of a terminal's data bus interface with MIL-STD-1553. Published test plans for MIL-STD-1553 terminals are currently the best "tools" for verifying compliance, characterizing a terminal and defining its margins and limitations. The information gained from validation testing is essential for minimizing incompatibilities in system integration. Since validation testing does not test the operation or functional aspects of the subsystem, it can be performed as soon as the remote terminal hardware is available. Subcontractors who believe that validation testing is too costly and unnecessary are finding out how costly it can be to delay or avoid testing.

Providing a validation testing service for MIL-STD-1553 remote terminals for several years has given us interesting glimpses of the priority companies put on testing. We have seen companies that have taken time to train their personnel and acquire appropriate test equipment. We have also seen companies that have tried to ad-lib their way through the testing process. Most companies fall somewhere in the middle. They generally have test equipment with partial capability but lack the necessary understanding and experience in testing 1553 for maximum effectiveness. This results in insufficient testing and the capabilities and margins of the terminal's design are not verified. Any improper or marginal operation not found prior to a production run or system integration will be much more costly to track down and correct in the long run.

REASONS FOR LIMITED TESTING

In addition to inexperienced personnel and inadequate test equipment, there are two other factors that are responsible for the limited testing being performed. The obvious one is that testing is frequently cut back when costs increase and time runs short. The second reason is that there are some widely-held misconceptions regarding the necessity for thorough testing. We will look at the three most common misconceptions and address the problems with each.

MISCONCEPTION 1 - The first misconception is *Validation testing is not necessary if validated components are used to build the RT.* This is the most widely-held misconception we have come across. At present, there are several chipsets and other components which have undergone at least partial validation testing by the former Systems Engineering Avionics Facility (SEAFAC) at Wright Patterson Air Force Base. Manufacturers whose components have passed testing at SEAFAC claim their parts are "validated" or "SEAFAC certified."

While using "validated" or "SEAFAC certified" parts in an RT does minimize potential problems, it does not eliminate the need for thorough testing. Some of these parts have problems and do not pass the test plan. For example, some chipsets fail the test plan for sync errors because they do not recognize illegal sync waveforms. It is also important that the validated component be used correctly. The company which brought us a unit with an 8-layer board for testing after its first production run found out how costly it was to have connected the wrong taps on the transformers. In addition, the correct validated components be used together. This is quite obvious, yet we have tested RTs that had, for instance, the wrong transformers (incorrect turns ratio) or wrong transceivers (quiescent state).

There can still be problems even if the right parts are used correctly. Consideration must be given to the physical location of the parts and the user software in the RT. The proximity of components to one another in the PWB layout can affect performance. User software may improperly handle the initialization of parts on power up and reset and incorrectly process mode commands and normal data transfer commands.

MISCONCEPTION 2 - The second misconception is *Validation testing is not necessary because the interface board was validated in another LRU.* Remote terminals using an interface board that has passed validation testing in another LRU should still be tested with at least the electrical and noise rejection tests of the RT Validation Test Plan. The placement of the interface board in an LRU with different internal bus cable lengths, the proximity of the board to other cards or devices, and differences between power supplies can all noticeably affect the performance of the board. Although these physical variations will mainly affect the electrical and noise rejection characteristics, it should not be taken for granted that the protocol tests will produce identical results if the board uses different software or firmware.

MISCONCEPTION 3 - The last misconception to discuss is *Validation testing is not necessary because the LRU is already operating in the system.* The fact that an RT is already operating in an application (i.e. it's flying) does not mean that it satisfies the requirements of MIL-STD-1553. We once tested an RT that had already been flying without any noticeable problems and found a broken address line, initialization problems in the software, and the wrong transformer specified in the design. The use of the wrong transformer caused a reduced output signal and increased input threshold. The 1553 standard has built-in margin and the Test Plan tests for this margin. The margin in the standard was not put there to tolerate sloppy designs. Using an RT without the required margins in a system will reduce the operating margins for the entire system. Margins are not checked in normal system operation or operational testing. In addition, normal system operation or operational testing is not able to verify either proper handling of detected errors or proper noise rejection. Consequently, testing an RT under actual flight conditions to verify that the unit has the required margins will never be as thorough as validation testing.

COMMON FAILURES

In performing RT validation testing, we find that many RTs fail the same tests. Table I lists common failures we have seen. The four most common failures are in the Input Zero Crossing Distortion, Noise Rejection, Power On Response, and Reset Remote Terminal tests. The Zero Crossing Distortion (ZCD) test fails an RT for detecting an error in a word with a ZCD of 150 ns or less. Having inadequate test equipment on hand is the major culprit here. Not all test equipment is created equal and measurement resolution to 2 ns or less is not a standard feature. This is a good example of where accuracy is necessary for proper characterization of an RT's margins. Noise rejection problems were found in more than four out of every ten remote terminals we tested. The problem is often chipset dependent. Some chipsets inherently fail the noise rejection test. An RT will also fail the noise rejection test when a late response occurs or a status bit like terminal flag gets set. Critical tests like noise rejection and zero crossing distortion provide a figure of merit for the RT and require appropriate test equipment.

TABLE I. Common Failures In 1553 Testing

FAILURE	FAILURE RATE
Noise Rejection	42%
Power On Response	40%
Reset Remote Terminal	35%
Zero Crossing Distortion	29%
Setting the Subsystem Flag bit	20%
Using the Message Error bit	18%
Common Mode Rejection	17%
Bus Switching	15%
Input Impedance	15%

Forty percent of the remote terminals failed the Power On Response test. One example of a failure we have seen was a unit that responded with the busy bit set, then with a clear status, then stopped responding and finally started responding again. Over one third of the RTs failed the Reset Remote Terminal test. In some RTs, the reset function took longer than the 5 ms allowed by Notice 2 of the standard. Other RTs truncated part of a message following the reset command. Some RTs also incorrectly set a status bit like Subsystem Flag.

Some failures are not test specific. We have seen many RTs exceed the allowable response time of 12.0 us, causing a late response. We have also seen several RTs respond incorrectly in many of the protocol tests by setting status bits inappropriately, especially the Subsystem Flag, Terminal Flag and Message Error bits. In fact, some of the common failures are actually inherent problems in the "validated" or "SEAFAC certified" parts that SEAFAC missed in their testing!

Of course, each RT has its own problem areas. Take for instance, the output amplitude of one RT that started transmitting at 21.0 V but had decreased to 18.5 V by the end of the 32 data word message. Another design had zero crossing distortion ability that was sensitive to input signal amplitude. While these are not failures, they do indicate very marginal operation or a potential problem. Other problems are more blatant. One RT transmitted data in response to a receive command! Another RT responded to a command to one address with a status response that had a different terminal address. We have seen remote terminals lock up, process data from broadcast commands defined as illegal, execute a mode command defined as illegal, and abort responses. Not all problems are this exotic; improper operation can also be due to a misunderstanding of the standard or the data sheet of the parts used in the design. Table II provides a list of common problem areas associated with components and hardware and software design techniques.

TABLE II. Common 1553 RT Problem Areas

COMPONENT PROBLEM AREAS

- Noise Rejection
- Threshold Levels
- Input ZCD Tolerance
- Late Responses
- Setting of Terminal Flag Bit
- Mode Command Implementation
- Detection of Sync Error

HARDWARE DESIGN PROBLEM AREAS

- Input Impedance
- Crosstalk (Output Isolation)
- Output Noise
- Output Amplitude
- Ground Plane
- Wrong Transceiver Chosen
- Wrong Transformer Chosen

SOFTWARE DESIGN PROBLEM AREAS

- Initialization of Protocol Chip
- Use of Status Bits
- Reset Remote Terminal Command
- Bus Switching
- Initiate Self-Test Command

OPTIONS FOR TESTING

Verifying that the RT design meets MIL-STD-1553 specifications and that all implemented options are performing correctly is an enormous task. To obtain acceptable results in validation testing, it is necessary to have appropriate test equipment and personnel experienced in MIL-STD-1553 testing. Two alternatives are available. One option is to acquire test equipment and train personnel who can be committed to validation testing so that measurements and results are repeatable. If several MIL-STD-1553 projects are in the works, it may be feasible to set up a test facility. The other alternative is to bring in a specialist in MIL-STD-1553 validation testing who can complete testing in a day or two. A specialist can provide a wealth of experience and a knowledgeable interpretation of the standard to assist in solving problems on the spot. His experience will aid in determining if problems are inherent in the parts used or if the problems are the results of how the parts are used in the design. His knowledge of the standard will be helpful in assessing the system impact of problems. As a third party, the specialist may also give more credibility to the test results.

Our experience in testing has shown that neglecting validation testing for an interface as complex as MIL-STD-1553 can be a costly mistake. The more testing we do, the more we see the need for validation testing. Even when validation testing is not contractually required, the supplier is generally required to satisfy the requirements of MIL-STD-1553. The RT Validation Test Plan is the best "tool" we have today for determining a remote terminal's compliance with the standard. We recommend that complete testing to the RT Validation Test Plan be performed on all MIL-STD-1553 remote terminals prior to system integration.