UNH-IOL
FIBRE CHANNEL CONSORTIUM

FC-1 Conformance Test Suite
Version 4.3

Technical Document

Last Updated: February 23, 2008

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David Woolf: Updated procedures and appendix.

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Daniel Reynolds: Updated procedures, test patterns and appendix.

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Michael Davidson: Removed references to Research Computing Center

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Mikkel Hagen: Added Group 1 and modified the test vectors format.

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Mikkel Hagen: Made changes provided by MikeD and DanR during their review.

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Daniel Reynolds: Changed all test vectors for test #2.3. Also fixed Test #2.2 point-to-point C. In 2.1 changed the wording "Data Word" to "Valid Transmission Word" in order to clarify there is a K character.

February 23, 2008 (Version 4.3) FINAL
Daniel Reynolds: Changed test #2.2 Observable Results to include that the DUT must gain synchronization and also changed the possible problems. Changed test #2.3 to send less than 3 ordered sets at all times to ensure the DUT does not gain synchronization, removed possible problems and added an observable result that the DUT must not gain synchronization. Also updated to rev 1.9 of the FC-FS standard.

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Daniel Reynolds	UNH InterOperability Laboratory
Mikkel Hagen	UNH InterOperability Laboratory
David Woolf	UNH InterOperability Laboratory
Michael Davidson	UNH InterOperability Laboratory

INTRODUCTION

Overview

The University of New Hampshire's InterOperability Laboratory (IOL) is an institution designed to improve the interoperability of standards based products by providing an environment where a product can be tested against other implementations of a standard. This particular suite of tests has been developed to help implementers evaluate the functionality of their Fibre Channel (FC) products.

These tests are designed to determine if a FC product conforms to specifications defined in Clause 6 of ***Fibre Channel Framing and Signaling (FC-FS) Rev 1.9 standard NCITS/Project 1331-D*** (hereafter referred to as "FC-FS"), and in Clause 8.3.1.2 of ***Fibre Channel Arbitrated Loop (FC-AL-2) Rev 7.0 Amendment standard T11/Project 1133D*** (hereafter referred to as "FC-AL-2"). Successful completion of all tests contained in this suite does not guarantee that the tested device will successfully operate with other FC products. However, when combined with satisfactory operation in the IOL's interoperability test bed, these tests provide a reasonable level of confidence that the Device Under Test (DUT) will function properly in many FC environments.

The tests contained in this document are organized in order to simplify the identification of information related to a test, and to facilitate in the actual testing process. Tests are separated into groups, primarily in order to reduce setup time in the lab environment, however the different groups typically also tend to focus on specific aspects of device functionality.

The test definitions themselves are intended to provide a high-level description of the motivation, resources, procedures, and methodologies specific to each test. Formally, each test description contains the following sections:

Purpose

The purpose is a brief statement outlining what the test attempts to achieve. The test is written at the functional level.

References

This section specifies all reference material *external* to the test suite, including the specific sub clauses references for the test in question, and any other references that might be helpful in understanding the test methodology and/or test results.

Resource Requirements

The requirements section specifies the test hardware and/or software needed to perform the test. This is generally expressed in terms of minimum requirements, however in some cases specific equipment manufacturer/model information may be provided.

Last Modification

This specifies the date of the last modification to this test.

Discussion

The discussion covers the assumptions made in the design or implementation of the test, as well as known limitations. Other items specific to the test are covered here as well.

Test Setup

The setup section describes the initial configuration of the test environment. Small changes in the configuration should not be included here, and are generally covered in the test procedure section (next).

Procedure

The procedure section of the test description contains the systematic instructions for carrying out the test. It provides a cookbook approach to testing, and may be interspersed with observable results.

Observable Results

This section lists the specific observables that can be examined by the tester in order to verify that the DUT is operating properly. When multiple values for an observable are possible, this section provides a short discussion on how to interpret them. The determination of a pass or fail outcome for a particular test is generally based on the successful (or unsuccessful) detection of a specific observable.

Possible Problems

This section contains a description of known issues with the test procedure, which may affect test results in certain situations. It may also refer the reader to test suite appendices and/or other external sources that may provide more detail regarding these issues.

Group 1: CHARACTER ENCODE AND DECODE

Overview:

This group of tests verifies the 8b/10b encoding of a device as defined by the FC-FS standard. Comments and questions regarding the implementation and specification of these tests are welcome, and may be forwarded to the Fibre Channel Consortium at the UNH InterOperability Lab (fcclab@iol.unh.edu).

Test #1.1: All possible 8b/10b Codes in a frame

Purpose: To determine that the DUT can correctly encode and decode all possible 8b/10b codes.

References: FC-AL-2, FC-FS

Resource Requirements:

- A testing station capable of transmitting arbitrary sequences of 8 bit Transmission Characters.
- Device capable of supporting loop topology.

Date of Revision: September 18, 2006

Discussion: Fibre Channel uses 8b/10b encoding on its characters for higher transition density and better error detection. The mapping from 8b to 10b characters is shown in the FC-FS standard.

Test Setup: A connection is established between the DUT and the testing station such that the DUT enters the MONITORING (Loop) state.

Procedure:

1. Transmit LPByx, where y=the AL_PA of the DUT until the DUT retransmits the received LPB.
2. Transmit a frame to the DUT with a data body consisting of every possible 8b/10b code, the DUT is expected to retransmit the frame.

Observable Results:

Verify that the frame the DUT transmits does not have any errors contained within it and the CRC is identical to the CRC transmitted from the Testing Station.

Possible Problems: None.

GROUP 2: SYNCHRONIZATION TESTS

Overview:

The following tests cover the synchronization of a device as defined by the FC-FS standard. These tests are designed to verify the various transitions and actions required of all Fibre Channel devices to achieve synchronization. Comments and questions regarding the implementation and specification of these tests are welcome, and may be forwarded to the Fibre Channel Consortium at the UNH InterOperability Lab (fcclab@iol.unh.edu).

Test #2.1: Enter Loss of Synchronization State

Purpose: To verify that the device under test (DUT) loses synchronization upon the reception of four invalid transmission words without sufficient intervening valid transmission words.

References: FC-FS

Resource Requirements: A Testing Station capable of generating arbitrary sequences of 10 bit Transmission Characters. An analyzer capable of decoding a Fibre Channel bit stream, and displaying FC characters at the binary level.

Date of Revision: October 23, 2006

Discussion: A DUT in the Synchronization Acquired state will transition to the LOS state if it receives a sequence containing enough invalid transmission words (a transmission word being a four byte ordered set) within a string of code groups, which does not contain two consecutive valid transmission words. This test is to verify that the DUT does this correctly according to the synchronization state machine defined in FC-FS. The operation of this state machine can be illustrated with a ladder that has 5 rungs. The top of the ladder being the "Synchronization Acquired - no invalid transmission words seen" state, and the bottom of the ladder being the "Loss of Synchronization - 4 or more invalid transmission words seen" state. Every time the DUT receives an invalid transmission word, it moves down one rung on the ladder. The DUT cannot descend further than the "Loss of Synchronization state", which is the bottom rung. In order to move up one rung on the ladder, the DUT needs to receive 2 consecutive valid transmission words. The DUT cannot ascend higher than the "no invalid transmission words seen state", which is the top rung.

An invalid transmission word can be a word that contains any invalid 10-bit character; any word that contains a special character in the second, third or fourth positions of a transmission word; and any word with an invalid running disparity.

This test attempts to discern if the DUT can correctly identify invalid transmission words, and whether it can move around within the Loss of Synchronization state machine.

Test Setup: A link is established between the DUT and the testing station. The connection is either point-to-point or a loop, such that the DUT enters either the ACTIVE (Point-to-Point) or MONITORING (Loop) states.

Procedure: Instruct the Testing Station to send the following patterns:

A. IDLE – RD Error Word – IDLE – RD Error Word – IDLE – RD Error Word – IDLE – RD Error Word – Continuous DATA Words
B. IDLE – 4 Extra K Character Words – Continuous DATA Words
C. IDLE – 2 Invalid Character Words – 2 IDLE – 3 Invalid Character Words – Continuous Data Words
D. IDLE – 3 Invalid K Character Words – 2 IDLE – 2 Invalid K Character Words – Continuous DATA Words
E. IDLE – 4 RD Error Words – Continuous DATA Words
F. IDLE – Invalid Character Word – Valid Transmission Word – Invalid Character Word – DATA Word – Invalid Character Word – Valid Transmission Word – Invalid Character Word – Continuous DATA Words
G. IDLE – Extra K Character Word – 2 Valid Transmission Words – 4 Extra K Character Words – Continuous DATA Words
H. IDLE – Invalid K Character Word – RD Error Word – IDLE – Neutral DATA Word – 4 RD Error Words – Continuous DATA Words
I. IDLE – Neutral DATA Word – 3 Invalid K Character Words – Neutral DATA Word – Invalid K Character Word – Continuous DATA Words
J. IDLE – 2 Extra K Character Words – IDLE – 2 Extra K Character Words – Continuous DATA Words

Observable Results: After reception of each test pattern, which follows the format outlined above, the DUT is expected to transition to the Loss of Synchronization State, wait R_T_TOV (100 msec) and transmit LIP(F8,AL_PA) if the DUT is a loop device or NOS if the DUT is a point to point device.

Possible Problems: Some devices that are acting as a transmission media will not source Fibre Channel primitives and will need to have modified triggers used. Some substandard devices may lose synchronization when receiving continuous valid data characters. In this case, the following patterns are to be used:

Loop:
A. 5 RD Error Words – ARB (AL_PS, AL_PS) – Continuous IDLE
B. 4 Extra K Character Words – ARB (AL_PS, AL_PS) – Continuous IDLE
C. 4 Invalid Character Words – ARB (AL_PS, AL_PS) – Continuous IDLE
D. 4 Invalid K Character Words – ARB (AL_PS, AL_PS) – Continuous IDLE

Observable Results: The DUT should not respond to the received ARB (AL_PS, AL_PS).

Point-to-Point:
A. 5 RD Error Words – 3 NOS – Continuous IDLE
B. 4 Extra K Character Words – 3 NOS – Continuous IDLE
C. 4 Invalid Character Words – 3 NOS – Continuous IDLE
D. 4 Invalid K Character Words – 3 NOS – Continuous IDLE

Observable Results: The DUT should not respond to the received NOS.

Test #2.2: Acquire Synchronization

Purpose: To verify that device under test (DUT) in the Loss of Synchronization state, acquires synchronization upon the reception of three consecutive ordered sets each starting with a code group containing /-K28.5/.

References: FC-FS

Resource Requirements: A testing station capable of receiving arbitrary sequences of 10 bit Transmission Characters and either retransmitting those characters, or transmitting an arbitrary sequence of characters.

Date of Revision: February 23, 2008

Discussion: A device in the Loss of Synchronization state must first acquire bit synchronization, then Transmission Word synchronization. Transmission word synchronization is acquired when at least three ordered sets containing commas in their leftmost bit positions are detected without any intervening invalid Transmission Words. The DUT is expected to act on the third of those received valid transmission words, if that word requires a response, such as a LIP would. It is important to consider the definition of an ordered set. An Ordered Set is defined in FC-FS as a Transmission Word, which has a special character in its leftmost position and data characters in its remaining positions. It is now important to consider the definition of a Transmission Word. FC-FS defines a Transmission Word as " A string of four contiguous Transmission Characters occurring on boundaries that are zero modulo 4 from a previously received or transmitted Special Character. Based on these two definitions and the requirements for gaining synchronization defined in FC-FS, the sequences in the following procedure should enable the DUT to acquire synchronization.

Procedure: A link is established between the DUT and the testing station. The connections are either point-to-point or a loop, such that the DUT enters either the ACTIVE (Point-to-Point) or MONITORING (Loop) states. The DUT is then transmitted a continuous stream of invalid transmission words. The Testing Station will continue to transmit invalid transmission words until the DUT transmits either NOS or LIP(F8). The Testing Station will then send one of the following patterns depending on whether the DUT is a loop or point-to-point device:

Arbitrated Loop:

A. 5 LIP(F7,51) – Continuous DATA Words
B. LIP(F7,51) – IDLE – LIP(F7,51) – IDLE – 3 LIP(F7,51) – Continuous DATA Words
C. 2 LIP(F7,51) – RD Error Word – 5 LIP(F7,51) – Continuous DATA Words
D. 2 LIP(F7,51) – 3 IDLE – 3 LIP(F7,51) – Continuous DATA Words
E. 2 LIP(F7,51) – RD Error Word – 5 LIP(F7,51) – Continuous DATA Words
F. LIP(F7,51) – RD Error Word – LIP(F7,51) – RD Error Word – 5 LIP(F7,51) – Continuous DATA Words
G. 2 LIP(F7,51) – IDLE – 3 LIP(F7,51) – Continuous DATA Words
H. LIP(F7,51) – RD Error Word – LIP(F7,51) – RD Error Word – 2 LIP(F7,51) – 2 IDLE – 3 LIP(F7,51) – Continuous DATA Words
I. 4 LIP(F7,51) – Extra K Character Word – 3 LIP(F7,51) – Continuous DATA Words
J. 3 LIP(F7,51) – 2 IDLE – 3 LIP(F7,51) – Continuous DATA Words

Point to Point:

A. 5 NOS – Continuous DATA Words
B. NOS – IDLE – NOS – IDLE – 3 NOS – Continuous DATA Words
C. 2 NOS – RD Error Word – 5 NOS – Continuous DATA Words
D. 2 NOS – 3 IDLE – 3 NOS – Continuous DATA Words
E. 2 NOS – RD Error Word – 5 NOS – Continuous DATA Words
F. NOS – RD Error Word – NOS – RD Error Word – 5 NOS – Continuous DATA Words
G. 2 NOS – IDLE – 3 NOS – Continuous DATA Words

H. NOS – RD Error Word – NOS – RD Error Word – 2 NOS – 2 IDLE – 3 NOS – Continuous DATA Words
I. 4 NOS – Extra K Character Word – 3 NOS – Continuous DATA Words
J. 3 NOS – 2 IDLE – 3 NOS – Continuous DATA Words

Observable Results: Verify that the DUT gains synchronization and responds to the received LIP or NOS primitive sequences.

Possible Problems: Some devices may not respond to the reception of three LIP or NOS primitives. Upon this occurrence the test procedure will be the same as in Test #1.2 with an additional amount of primitives added after the sequence and before the continuous data words.

Test #2.3: Fail to Acquire Synchronization

Purpose: To verify that a station in the Loss of Synchronization state will not acquire synchronization if it does not receive three consecutive valid transmission words.

References: FC-FS

Resource Requirements: A testing station capable of receiving arbitrary sequences of 10 bit Transmission Characters and either retransmitting those characters, or transmitting an arbitrary sequence of characters.

Date of Revision: February 23, 2008

Discussion: While in the Loss of Synchronization state, an L_Port shall regain synchronization state only after receiving 3 consecutive Ordered Sets, without any intervening invalid transmission words. Word alignment of a received bit stream shall be achieved via the detection of a Comma or a K28.5 Transmission Character. Some devices operating in the continuously enabled mode may choose to align to the full K28.5 Ordered Set, rather than the comma alone. This test verifies that the DUT does not gain synchronization from invalid transmission words, even if those words contain a -K28.5 character in the leftmost position.

Procedure: A link is established between the DUT and the testing station. The connection is either point-to-point or a loop, such that the DUT enters either the ACTIVE (Point-to-Point) or MONITORING (Loop) states. The DUT is then transmitted a continuous stream of invalid transmission words. The Testing Station will continue to transmit invalid transmission words until the DUT transmits either NOS or LIP(F8). The Testing Station will then send one of the following patterns depending on whether the DUT is a loop or point-to-point device:

Loop:
A. 2 LIP – 2 DATA Words – 2 LIP – Continuous DATA Words
B. 1 LIP – 2 DATA Words – 2 LIP – Continuous DATA Words
C. 1 LIP – DATA Word – 1 LIP – DATA Word – 2 LIP – Continuous DATA Words
D. 1 LIP – Invalid K Character Word – 2 LIP – RD Error Word – 1 LIP – Continuous DATA Words
E. 2 LIP – DATA Word – 2 LIP – RD Error Word – 2 LIP – Continuous DATA Words
F. 1 LIP – DATA Word – 1 LIP – DATA Word – 1 LIP – Extra K Character Word – Continuous DATA Words
G. 2 LIP – RD Error Word – 2 LIP – Data Word – 2 LIP – Continuous DATA Words
H. 2 LIP – DATA Word – 2 LIP – Continuous DATA Words
I. 2 LIP – DATA Word – 1 LIP – Continuous DATA Words
J. 1 LIP – DATA Word – 2 LIP – DATA Word – 1 LIP – Continuous DATA Words

Point-to-Point:
A. 2 NOS – 2 DATA Words – 2NOS – Continuous DATA Words
B. 1 NOS – 2 DATA Words – 2 NOS – Continuous DATA Words
C. 1 NOS – DATA Word – 1 NOS – DATA Word – 2 NOS – Continuous DATA Words
D. 1 NOS – Invalid K Character Word – 2 NOS – RD Error Word – 1 NOS – Continuous DATA Words
E. 2 NOS – DATA Word – 2 NOS – RD Error Word – 2 NOS – Continuous DATA Words
F. 1 NOS – DATA Word – 1 NOS – DATA Word – 1 NOS – Extra K Character Word – Continuous DATA Words
G. 2 NOS – RD Error Word – 2 NOS – Data Word – 2 NOS – Continuous DATA Words
H. 2 NOS – DATA Word – 2 NOS – Continuous DATA Words
I. 2 NOS – DATA Word – 1 NOS – Continuous DATA Words
A. 1 NOS – DATA Word – 2 NOS – DATA Word – 1 NOS – Continuous DATA Words

Observable Results: Verify that the DUT does not gain synchronization and does not respond to the received LIP or NOS primitive sequences.

Possible Problems: None

Test #2.4: Maintain Synchronization

Purpose: To verify that the device under test (DUT) is able to maintain synchronization while receiving invalid transmission words.

References: FC-FS

Resource Requirements: A testing station capable of receiving arbitrary sequences of 10 bit Transmission Characters and either retransmitting those characters, or transmitting an arbitrary sequence of characters.

Date of Revision: October 23, 2006

Discussion: A DUT in the Synchronization Acquired state will remain in that state while receiving invalid transmission words if it does not receive four or more consecutive invalid transmission words within a string of code groups, which contains two consecutive valid transmission words. This state machine is shown in Appendix A. This test attempts to discern if the DUT can correctly identify invalid transmission words, and maintain synchronization when receiving them.

Procedure: A link is established between the DUT and the testing station. The connections are either point-to-point or a loop link. Linked such that the DUT enters either the ACTIVE (Point-to-Point) or MONITORING (Loop) states. The DUT is then transmitted one of the following patterns:

A. 3 RD Error Words – Continuous DATA Words
B. RD Error Word – IDLE – RD Error Word – IDLE – RD Error Word – Continuous DATA Words
C. IDLE – RD Error Word – 2 IDLE – Continuous DATA Words
D. 3 Invalid Character Words – 2 IDLE – Invalid Character Word – Continuous DATA Words
E. 2 Invalid Character Words – 4 IDLE – Continuous DATA Words
F. Invalid Character Word – 2 IDLE – 3 Invalid Character Words – Continuous DATA Words
G. IDLE – RD Error Word – 2 IDLE – RD Error Word – Continuous DATA Words
H. RD Error Word – 2 IDLE – Continuous DATA Words
I. 3 RD Error Words – 4 IDLE – 2 RD Error Words – Continuous DATA Words
J. 3 RD Error Words – 2 IDLE – RD Error Word – 2 IDLE – Continuous DATA Words

Observable Results: Once the sequences are received by the DUT, verify that the DUT does not go to the Loss of Synchronization state.

Possible Problems: None.

Test #2.5: Receive Invalid Transmission Character

Purpose: To verify that the DUT correctly substitutes for invalid Transmission Characters while in the MONITORING state.

References: FC-AL-2, FC-FS

Resource Requirements:
- A testing station capable of receiving arbitrary sequences of 10 bit Transmission Characters and either retransmitting those characters, or transmitting an arbitrary sequence of characters.
- Device capable of supporting loop topology.

Date of Revision: September 20, 2006

Discussion: If an L_Port is in the MONITORING state, it shall make substitutions for received invalid Transmission Words as follows:
- If an invalid Transmission Word is detected, the L_Port shall substitute the CFW for that Transmission Word.
- If an invalid Beginning Running Disparity condition is detected on an Ordered Set, the L_Port shall substitute the current Fill Word

Procedure: A connection is established between the DUT and the testing station such that the DUT enters the MONITORING (Loop) state. The DUT is then transmitted the following pattern:
1. IDLE with an Invalid Transmission Character
2. 10 IDLE
3. IDLE with a Misplaced K Character
4. 10 IDLE
5. IDLE with an RD Error
6. 10 IDLE
7. IDLE with an Invalid K Character
8. 10 IDLE
9. ARB with an Invalid Transmission Character
10. 10 IDLE
11. ARB with a Misplaced K Character
12. 10 IDLE
13. ARB with an RD Error
14. 10 IDLE
15. ARB with an Invalid K Character

Observable Results:
- Verify that the DUT transmitted any valid transmission character in place of the error in the invalid word.
- Verify that the DUT transmitted Idle upon receiving the corrupted ARBx.

Possible Problems: None.

Appendix A: FC Synchronization State Machine

Purpose: To describe the interpretation of the FC-1 Synchronization state machine as applied in the FC-1 test suite.

References:
- FC-FS

Last Modification: June 9, 2005

A.1 Discussion:

A.2 Notational Conventions:

Character	Meaning
*	Boolean AND
+	Boolean OR
mod	Modulus operation
=	Test of equality
!=	Test of inequality
$\Leftarrow$	Assignment operator
$\in$	Indicates set membership
$\notin$	Indicates set nonmembership

Table A-1: State Machine Operators

A.3 Important Definitions of Terms

Transmission Character: Any encoded character (valid or invalid) transmitted across a physical interface specified by FC-0. Valid Transmission Characters are specified by the Transmission Code and include Data and Special Characters.

Transmission Word: A string of four continuous Transmission Characters occurring on boundaries that are zero modulo 4 from a previously received or transmitted Special Character.

Ordered set: A Transmission Word composed of a Special Character in its first (leftmost) position and Data Characters in its remaining positions. An Ordered Set is represented by the combination of Special Codes and data bytes which, when encoded, result in the generation of the Transmission Characters specified for the Ordered set.

Comma: The seven-bit sequence 0011111 or 1100000 in an encoded stream.

Comma character: A Special Character containing a comma.

State Constants:

/COMMA/

The special character K28.5. While special characters K28.1 and K28.7 also contain commas, *sub clause 12.1.2.2 Note 1* allows implementers to choose to restrict the comma detection to only those patterns which are K28.5.
Note, that the standard does not specify which running disparity of the K28.5 is permissible, thus, technically a +K28.5 (1100000101) should be considered a comma character. However, currently defined Ordered Sets all begin with a negative running disparity (with the exception of EOF), thus realistically a device would not need to be able to obtain synchronization off a +K28.5.

/Data/

The set of valid data characters listed in *sub clause 11.2, Table 22* and meeting the validity requirements of 11.2.2.

/INVALID/

The set of characters (data or special) that do not meet the validity requirements of 11.2.2.

/SPECIAL CHAR/

The set of valid special characters listed in *sub clause 11.2, Table 23* and meeting the validity requirements of 11.2.2.

State Variables

indicate_Trans_Word

Pass the currently received transmission word up to the FC-2 layer.

power_on

Values: TRUE; The device has not been completely powered and is Not Operational.
FALSE; The receiver has been powered on and is Operational.

reset

Determines whether the receiver should enter the Reset State and become Not Operational.

Values: TRUE; The Reset State should be entered
FALSE; No reset desired.

rx(/ X /)

The currently received 10-bit Transmission Character

rx_transmission_word

Checks the validity of the last received Transmission Word according to the requirements in *12.1.3.1 Invalid Transmission Word rules*.

Values: VALID; The Transmission Word passes all requirements.
INVALID; The Transmission Word fails at least one requirement.

signal_detect

An indication passed from the FC-0 layer that a signal is present at the input to the receiver.
Values: TRUE; A signal is present on the link.
FALSE; A signal is not present on the link.

word_align_cnt

Counts the number of Transmission Characters received since the last /COMMA/ during Transmission-Word synchronization. Used to determine if any Transmission Character in the set of /SPECIAL CHAR/ falls on the proper zero modulo four boundary, thereby ensuring that the Special Character appears in the leftmost position of the Transmission Word.

Receiver State Diagram:

Figure 9: FC-FS Rev. 1.9

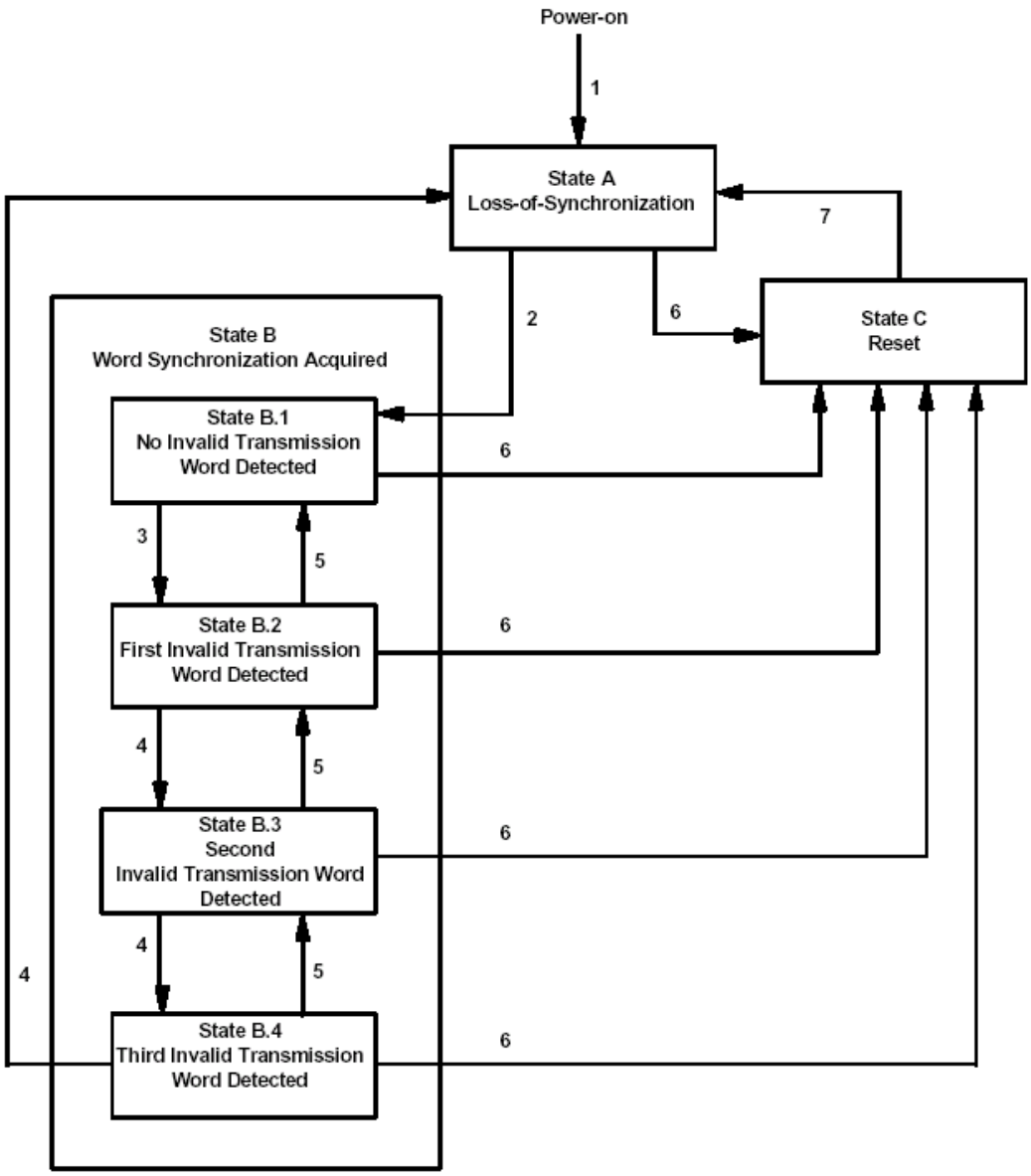

Figure 9 - Receiver State Diagram