White Paper

How to Test to TIA/EIA-568-B.2-10

What every installer needs to know about the new standard for augmented category 6 cabling

The Telecommunications Industry Association approved a new cabling standard published as Amendment 10 of the TIA/EIA-568-B.2 document. This is an important new standard because it documents and specifies an increase in transmission capability for 100 Ohm 4-pair cabling to support high-speed applications including 10 Gbps Ethernet over channels up to 100 Meters long. This white paper includes everything you need to know to certify cabling to meet this new standard that defines cabling transmission performance to 500 MHz and testing for Alien Crosstalk.

Table of contents

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Introduction

The Telecommunications Industry Association (TIA) technical committee TR-42 approved the standard for augmented category 6 cabling (Cat 6A) at the February 2008 meeting in Tampa, FL. to be published as Amendment 10 to the ANSI/TIA/EIA-568-B.2 document (abbreviated as TIA/EIA-568-B.2-10).

The development of a new standard requires more than the definition of the transmission performance (and test limits) for installed Permanent Links or channels. Standards also define the performance of components such as the cable, the connecting hardware components and patch cords. This paper explains the best method to certify installed cabling links to obtain the assurance that they meet the established performance level and that 8-pin modular jacks meet the specifications of the standard. Compliance of these jacks with the standards promotes the long-term viability of the installation. Compliance also offers interoperability and an open architecture.

Revision B of the TIA/EIA-568 standard defines two link models: the permanent link and channel. Field certification using the permanent link model with high performance test adapters is crucial because it assures that the installed cabling meets the performance specified in the standard.

Overview of the new standard – purpose and scope

The development of this standard was a response to new high-speed network applications such as 10GBASE-T (10 Gbps Ethernet) over a full 100-meter channel of twisted-pair cabling. This standard specifies the requirements and recommendations for 100 Ω 4-pair augmented category 6 (Cat 6A) cabling links, cables, cords, and connecting hardware. It extends the frequency range to 500 MHz and adds Alien Crosstalk to the performance parameters specified in the ANSI/TIA/EIA-568-B.2 standard.

The test parameters for the performance of each installed cabling link remain the same as those for Cat 5e and Cat 6, but some have been renamed. Table 1 shows these parameters with their old and new names, as well as their abbreviations. We refer to them as in-channel performance parameters. A certification tester for Cat 6A must be able to measure performance parameters over the frequency range of 1 MHz through 500 MHz.

Test Parameter – 'Old' Name	Test Parameter – 'New' Name
Insertion Loss (IL)	Insertion Loss (IL)
Near End Crosstalk (NEXT)	Near End Crosstalk (NEXT)
Power Sum Near End Crosstalk (PSNEXT)	Power Sum Near End Crosstalk (PSNEXT)
Attenuation to Crosstalk Ratio (ACR)	Attenuation to Crosstalk Ratio – Near End (ACRN)
Power Sum Attenuation to Crosstalk Ratio (PSACR)	Power Sum Attenuation to Crosstalk Ratio – Near End (PSACR-N)
Far End Crosstalk (FEXT)	Far End Crosstalk (FEXT)
Equal Level Far End Crosstalk (ELFEXT)	Attenuation to Crosstalk Ratio – Far end (ACRF)
Power Sum Equal Level Far End Crosstalk (PSELFEXT)	Power Sum Attenuation to Crosstalk Ratio – Far End (PSACRF)
Return Loss (RL)	Return Loss (RL)
Wire Map	Wire Map
Propagation Delay	Propagation Delay
Delay Skew	Delay Skew
Length	Length

Table 1. In-Channel test parameters for Cat 6A are the same as those for Cat 5e and Cat 6. A few parameters have been renamed.

In addition to the in-channel performance parameters, high-speed applications such as 10GBASE-T demands that the signal coupling be controlled between adjacent cables and within patch panels. There are two new test parameters to characterize "Alien Crosstalk:" Power Sum Alien NEXT (PSANEXT) and Power Sum Alien Attenuation to Crosstalk Ratio from the Far-end (PSAACRF).

Proper field certification must include a test of in-channel parameters for every installed link plus a test for Alien Crosstalk (AXTalk) in a sampling of links.

In-Channel Performance depends on every cabling component

Experiments that highlight the challenges

Have you ever tested a channel, then flipped a patch cord over and measured the same channel again? Did the change in the measurement data surprise you? You may have observed that the link delivered marginal test results or even a failure and that after flipping the patch cord the link passed with a respectable margin of two or more dB. Or, have you observed that many short Cat 6A links fail or show marginal pass results while longer links built with components from the same vendor show passing results? These behaviors are the result of component performance and the variability in performance of components.

Link performance depends on the transmission performance of the cable and the connections – the mated electrical performance of each plug and jack. For example, installing a Cat 5 jack in a Cat 6A link creates a problem because the Cat 5 jack will not deliver the desired mated performance over the frequency range of 1 MHz through 500 MHz. It is very important to realize that the mated performance of an 8-pin modular jack and plug can significantly vary with variations in the performance of either component. Variations in the mated connections of plugs and jacks produce variations of the link test results. Modular jacks are not created equal since no commercial manufacturing process can deliver absolutely identical items. Plugs also vary, so the ends of one patch cord do not deliver identical mated performance with a jack. While component specifications in the standard establish acceptable ranges of performance, only proper testing will show that each component in the link meets its specifications.

An analysis of the NEXT measurement

To appreciate exactly how the performance of components affects the performance of a link, let us examine Near End Crosstalk (NEXT) in more depth.

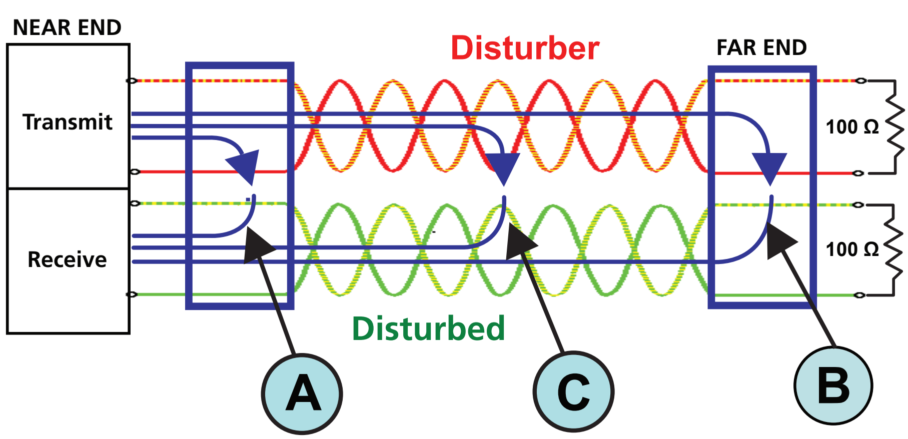

*Figure 1. **NEXT Proximity Rule:** the signal coupled closer to the near end contributes significantly more to the observed NEXT due to the signal loss (attenuation) in the link transmission.*

Figure 1 depicts the NEXT coupling between two wire pairs: the disturber pair and the disturbed pair. The NEXT measurement captures the summation of all the energy coupled into the disturbed wire pair that travels back to the end from which the stimulus signal is transmitted (the "near end").

The signal coupled into the disturbed wire pair at a greater distance from the end must travel a longer distance and its contribution to the measured NEXT value is smaller due to the attenuation that occurs in the transmission. Consider the difference in distance traveled between the three paths identified in Figure 1:

1. path A: crosstalk coupling through the jack at the near end,
2. path B: crosstalk coupling through the jack at the remote end (far end), and
3. path C: crosstalk coupling through a point in the middle of the link.

The length of path A is very short and hence the energy that couples through this path contributes nearly 100% of the coupled signal (after very little attenuation) to the NEXT disturbance. The length of path B is the longest possible path for NEXT. The coupled signal will have traveled the length of the link and back – twice its length. It will have been subject to a significant amount of loss or attenuation and depending on the length of the link, it will contribute a small amount to the measured value of NEXT. If the link is longer than 40 m (130 feet) the amount of NEXT disturbance from the far end becomes negligible. The NEXT disturbance contributed by the cable is an accumulation of many small contributions that happen every inch along the way like paths C in Figure 1. A key point is that a NEXT disturbance at a distance closer to the end from which we are measuring contributes far more to the link result than the same level of disturbance at a greater distance removed form the end.

The physics of the NEXT measurement also apply to the Return Loss (RL) measurement.

These physical characteristics lead us to a number of rules:

1. Cabling certification requires that parameters like NEXT and Return Loss be measured from both ends of the link. Today's testers like the Fluke Networks DTX Series execute these tests automatically from both ends. The Main and Smart Remote unit handshake with each other to perform the tests and all results are automatically transmitted to the Main unit for analysis, display and storage.

2. The quality and performance of patch cords have a tremendous impact on the performance of a cabling channel. The patch cords are after all the first component in the channel in either direction. The key parameters are Return Loss of the patch cord cable and the mated NEXT and Return Loss performance between patch cord plug and the jack at the end of the permanent link. The FEXT parameter remains very important as well but most cabling systems have no trouble meeting the FEXT performance. The proximity rule that relates the magnitude of the disturbance to the distance form the end of the link does not apply to FEXT coupling.

3. The quality of connecting hardware has a significant influence on the performance of link or channel. Shorter channels may fail NEXT and RL more often than longer channels. When a channel is short, the NEXT and/or the RL disturbance from the mated connection at the far end of the link makes a greater contribution to the link results than the same level disturbance that is positioned at a greater distance (longer cabling link). If the components are marginal in meeting the standard specification or the workmanship of installation is poor, shorter channels fail NEXT and/or RL more often than longer links. We stated earlier that in links longer than 40 m the NEXT and RL disturbances form the far end may become negligible.

The standard for augmented category 6 does significantly raise the performance bar for all test parameters up to much higher frequencies than previous standards have demanded. The difference between the performance of a typical component and the standard minimum is in most cases small. Another way of saying the same thing, component designs offer little margin and the workmanship of installation is critical to obtain links that pass the link tests. Not all the new designs come to market and deliver equal performance. Some components may meet the specifications with better margins. Other may meet the specs with smaller but more consistent margins. The latter would create less variability and maybe more passing link test results overall. How can you measure the link and the performance level of the installed components? We will discuss how the permanent link test model provides the answer.

Component Specifications

The standards define the electrical performance of each of the connecting components such as 8-pin modular plugs, 8-pin modular jacks as well as their mated electrical performance. Each component must fall within the defined range of performance. The variability of each component must be controlled to achieve a minimum passing level of performance for all combinations of compliant plugs and compliant jacks. This is also a prerequisite if the standards are going to deliver interoperability.

Defining a measurement method to assess the electrical performance of each part of a mated connection has always been a challenge. Earlier standards defined a statistical de-embedding method to select reference devices with which to test components. The repeatability of this methodology from laboratory to laboratory was limited. Fluke Networks proposed a direct probing technique during the development of the Cat 6 standard that was further refined during Cat 6A development.

As a result of this work, Amendment 10 references an 8-pin modular plug that employs printed circuit board wiring as an example of a test reference plug for testing of NEXT, FEXT and Return Loss of 8-pin modular jacks. Fluke Networks developed this example reference plug depicted in the standards document [Section G.3.9.2 Test plug construction for return loss testing – Fig G.11 Example of a test plug using PCB substrate]. This same plug is incorporated in the new Fluke Networks Permanent Link adapter – the DTX-PLA002 – that was released several months ago to support field certification of augmented category 6 installations.

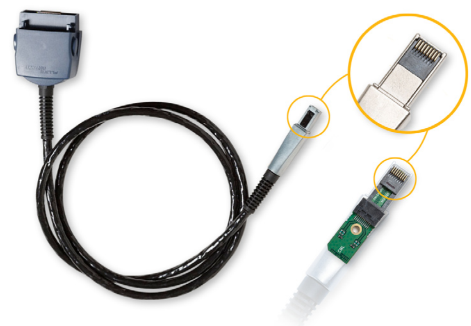

Figure 2. Fluke Networks Permanent Link Adapter DTX-PLA002 for Cat 6A testing. The adapter plug is implemented on a circuit board, which delivers extremely repeatable plug performance in the center of the range of the Cat 6A plug specifications.

The Permanent Link Test Model

Figure 3 depicts the permanent link model as defined in the standard. The test parameter values must be reported at the endpoints shown in the figure. In other words, the contribution of the test adapters between the tester units and the link must be totally transparent with the exception of the interaction between the plug at the end of the test adapter and the jack at the end of the link-under-test. We must include this interaction in order to establish that the 8-pin modular jack at the end of the link will deliver sufficient performance. Note that the mated performance of plug and jack are the very first element in the permanent link and that the plug at the end of the adapter must be a test reference plug to assess the performance of Cat 6A 8-pin modular jacks.

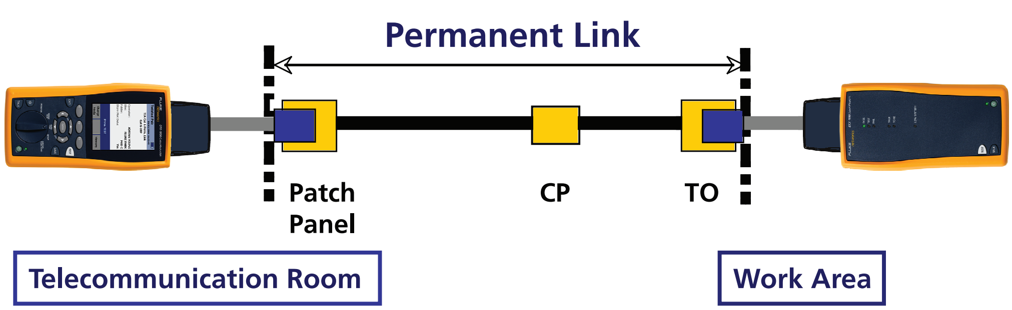

Figure 3. The permanent link model ends with the inclusion of mated plug-jack at the patch panel and at the Telecommunication Outlet (TO). Permanent link may contain an optional connection called the "Consolidation Point". The interface cable or test adapter from the plug to the tester must be totally transparent to the measurements.

Based on the earlier discussion of the proximity rule for NEXT and Return Loss, the contribution of the plug-jack mated performance to the permanent link test results is very high.

The Fluke Networks permanent link adapters with these Cat 6A test reference plugs offer several advantages:

1. The variability between different permanent link adapters is very small. All the plugs fall within a narrow range of performance in the center of the allowable range. This means that the test results obtained for a link when changing link adapters only vary with a small amount.

2. If the jacks installed in the link comply with the standard and the workmanship (wire pair termination) is of high quality, the mated NEXT and RL with a test reference plug will deliver the best values (and margins) that can be achieved.

3. Passing permanent link test results assure that the permanently installed cabling meets the expected link level performance and that the end jacks and wiring terminations comply with the performance specifications. This assurance delivers benefits over the entire life of the cabling system. A cabling installation contractor typically does not install the patch cords that complete the cabling link between the network devices. Furthermore, patch cords may be changed a number of times during the life of the cabling system while most Permanent Links will remain static, except for a few major moves, adds and change projects. Since Permanent Link certification provides the assurance that the jacks terminating the Permanent Link pass or exceed the component specifications, the channels will also pass the test limit specification if you use compliant patch cords.

4. The new standard safeguards backward compatibility, which assures that testing with the centered Cat 6A test plug also assures Cat 6 and Cat 5e component performance. The opposite is not true, of course. If you are certifying Cat 6A links, you should use the Cat 6A Permanent Link adapter and not a Cat 6 Permanent Link adapter.

If the permanent link test executed with reference test plugs passes and you add compliant patch cords to a permanent link, you have the assurance of a passing channel – the end-to-end link – over which the network devices communicate. This lifetime benefit of this test will save you time, money and trouble.

The benefits of the Permanent Link hinge on two critically important conditions: (1) the Permanent Link Adapters must use a test reference plug and (2) the adapter cordage must exhibit very good return los characteristics over time.

The test reference plug. Obtaining this reference performance with an 8-pin modular wired plug is extremely difficult. Therefore, we can safely state that Permanent Link Adapters made with commercial grade cable and plugs cannot claim that a passing Permanent Link test guarantees component compliance.

You can run a few simple experiments to observe the variability of test results when using commercial patch cords. The DTX CableAnalyzer™ Series testers allow you to run a permanent link test with channel adapters and regular commercially available patch cords. This is by no means an endorsement of this setup for certifying a cabling system. But if you did use this setup and you measured a permanent link several times with several random patch cords, you would see widely varying test results for the link NEXT and RL.

Testing the Permanent Link with random commercial patch cords also jeopardizes the benefit that exchanging patch cords guarantees channel performance. It is worthwhile at this point to emphasize that in order to obtain the benefits highlighted in Figure 4 all patch cords used must be truly compliant with the standard. Do not trust the printing on the patch cord packaging. Purchase cords from a known and established premise wiring system manufacturer or make sure that you certify patch cords. The DTX Series CableAnalyzer has the capability to certify patch cords with the appropriate patch cord test adapters.

Compliant Permanent Link
+ Compliant Path Cords

= Compliant Channel

Figure 4. The installer certifies the permanent link using an adapter that ends in a centered test plug. A passing certification result allows the user to connect known good (tested) patch cords and have the assurance that the channel – the entire end-to-end link – is compliant.

The test adapter cordage. A second very important characteristic of the permanent link test adapter is the return loss property of the cord of this adapter. The RL contribution of the cord must be transparent to the link measurements as discussed earlier. The RL of twisted pair cabling deteriorates after the cabling is coiled and uncoiled several times. Laboratory test procedures have shown that the RL value of commercial patch cords will drop by 10 dB or more after coiling and uncoiling the cords 150 to 200 times. Tester adapter cords are regularly and often subject to this coiling action since they are to be packed between jobs or job sites. You do not expect cords in normal use to be affected by this action. Even the very high-performance proprietary cords used in the Fluke Networks Permanent Link Adapters will undergo some changes after several months of usage. Therefore, Fluke Networks offers a simple adapter calibration procedure that can be executed in the office with the DTX-PLCAL module under control of a software utility in the LinkWare software. For test equipment in heavy usage, this procedure is recommend every six months.

What about certification of the Channel?

A channel includes the patch cords that support the operating network. If you certify a channel and it passes, that channel will support the transmission requirements of all applications corresponding to the level of the certification (i.e. Cat 5e, Cat 6 or Cat 6A) as well as the applications supported by lower rated categories.

If after certifying the channel you replace or exchange a patch cord, all bets are off. You cannot guarantee that the replacement patch cord delivers the same mated performance as the original cord. Proper execution of the Permanent Link certification is a different matter. The plug used to test the link is the reference plug for the category. It assures that the channel passes if good patch cords are added.

Network Application	Data Rate	Minimum Channel Category
10GBASE-T	10 Gigabit/sec	Cat 6 (limited distance) Cat 6A (up to 100 m)
1000BASE-T	1 Gigabit/sec	Cat 5e
100BASE-Tx	100 Megabit/sec (2-wire)	Cat 5
ATM-155	155 Megabit/sec	Cat 5
Token Ring	16 Megabit/sec	Cat 5
Token Ring	4 Megabit/sec	Cat 3
100BASE-T4	100 Megabit/sec (4-wire)	Cat 3
10BASE-T	10 Megabit/sec	Cat 3

Table 2. Network applications, their typical data rate and the corresponding minimum cabling category for the channel.

The channel test model is valuable if you can guarantee that the patch cords used during the test will remain in-place for the network operation. Unfortunately, this is rarely the case for the initial certification of cabling links. The channel model can be very useful for troubleshooting links.

Lastly, most cabling manufacturers guarantee their cabling system. You should inquire with the manufacturer regarding the detailed terms of this warranty. While some warranties only cover the channel performance, you should inquire that the permanent link test certification qualifies for the warranty coverage of the cabling system.

Alien Crosstalk Test

As mentioned earlier, the cabling performance requirements to support high data rates like 10 Gigabit per second (10 Gbps) include specifications for the signal coupling that occurs between wire pairs in adjacent links. This signal coupling from link to link, called Alien Crosstalk, increases at the higher frequencies required to successfully transmit and receive network data. The electronics in high-speed transmissions like 1000BASE-T and 10GBASE T use Digital Signal Processing (DSP) techniques to enhance in-channel performance of the cabling for NEXT and Return Loss. However, a transmitter has no knowledge of the signaling outside the four wire pairs in a link and therefore has no means to perform mitigation, crosstalk cancellation or improve performance against an Alien Crosstalk noise source. The cabling system must – and only the cabling system can – provide the Alien Crosstalk performance required to obtain a reliable and error free transmission when deploying these very high data rate network applications.

A statement by some cabling manufacturers about Alien Crosstalk testing is, "You do not have to spend any time on this test since we exhaustively test the worst case conditions in our laboratories." It is important that manufacturers of premise wiring hardware thoroughly evaluate the performance of their products in the laboratory. However, laboratory tests ignore the workmanship of the installation. This is critically important for shielded cabling systems. The RF effectiveness of the shielded installation can only be assessed in the field by executing the Alien Crosstalk tests. Shield tests executed during the in-channel test phase only test DC continuity of the shield. This is no indication of their effectiveness at high frequencies.

Since network operation ultimately relies on the cabling system's ability to meet Alien Crosstalk performance standards, testing should be performed to guarantee that the real world installation meets these requirements. We will discuss a sampling technique to save test time but obtain a high level of confidence that the installed cabling system meets the Alien Crosstalk performance.

Another reason to perform Alien Crosstalk testing before the network is installed is the fact that testing after the network has been turned up may be prohibitively expensive and cumbersome.

The two phases of cabling certification

Certification of a new installation should include a complete test of every Permanent Link (or channel) by itself. We have referred to these tests as the in-channel performance tests. Table 1 provides a list of the in-channel test parameters. The second phase of the field certification of an augmented category 6 (Cat 6A) cabling installation involves Alien Crosstalk testing.

Testing the interaction between all cabling links for Alien Crosstalk is not practical. It requires an excessive amount of time and it is not necessary. Field and laboratory experiments have shown that cabling links in separate bundles do not interact with each other. Even when these bundles are no more than an inch apart, Alien Crosstalk tests will not show any measureable coupling. Alien Crosstalk therefore, is to be analyzed on a bundle-by-bundle basis. The proposed sampling technique allows you to select the links most prone to Alien Crosstalk disturbance for a complete and standards-compliant evaluation.

The test methodology and the sampling technique to evaluate the alien crosstalk of an installed cabling system are described in a separate Fluke Networks white paper. Please refer to, "How to Certify or Re-certify Twisted-Pair Cabling for 10 Gb/s Ethernet", which can be found at **www.flukenetworks.com/10gigpaper**.

Conclusion

One of the important benefits of the Permanent Link certification test is that it determines (1) that the link delivers the transmission performance prescribed by the category and (2) that the components in the link meet the commensurate component specifications. The latter affords the assurance that when you exchange patch cords at any time with tested patch cords, the newly created channel continues to meet the category performance. This may be more important for augmented category 6 since the transmission requirements of the high-speed networks applications it is designed to support demand the last bit of performance the cabling provides. The Fluke Networks Permanent Link adapter for Cat 6A (DTX-PLA002) fully delivers on the Permanent Link test benefit. The plug at the end of this adapter is what the standard defines as a centered Cat 6A reference plug.

The Permanent Link test is the recommended test for all Cat 6A installations. Only when troubleshooting a specific channel would it make sense to select the channel test.

In addition, it seems very prudent to obtain as part of the cabling certification a true indication of the performance of the installed links with regard to Alien Crosstalk performance. Performance that can only be provided by the installed cabling. The sophisticated DSP techniques in the transceiver electronics cannot mitigate an Alien Crosstalk shortcoming in the cabling. Fluke Networks proposes a very effective method to sample links for Alien Crosstalk analysis. Perform the analysis of these links in full compliance with the standard by including all the disturbers for each disturbed link. These test recommendations apply to unshielded as well as to shielded cabling solutions. The RF effectiveness of the shielded installation is only tested by executing the Alien Crosstalk tests. Shield tests executed during the in-channel test phase only test DC continuity of the shield. Continuity does not provide an indication of effectiveness at high frequencies.

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