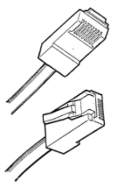
Raising the Bar on Patch Cord Performance in the Real World

Randy Ivans
UL LLC
Melville, New York
+1-631-546-2269 · randy.ivans@ul.com

Abstract
This paper examines patch cord field performance problems relating to the 8-pin modular connector and cable assembly construction in general. Applicable standards such as ANSI/TIA-1096, IEC 60603-7 and IEC 60512-99-001 are reviewed. Compliance and verification issues and how they relate to patch cord performance are discussed. This paper also looks at the darker side of patch cords in the marketplace; how false claims, inferior products and counterfeiting have the potential to slow down or disrupt network communications with potentially disastrous results. Possible solutions are examined.



Keywords: Wire; cable; symposium; patch cord, patch cord performance, TIA-1096, IEC 60603-7, IEC 60512-99, RJ-45, modular plugs.

1. Introduction
A chain is only as strong as its weakest link. Likewise, a network is only as fast as its slowest connection and is only as reliable as its most unreliable component. While great care is taken in the design and installation of the structured cabling backbone, patch cord selection is often less rigorous resulting in these cable assemblies often being the network's weakest link. Yes, they are usually the cheapest part of a cabling system and easy to replace but a patch cord of questionable quality will, without a doubt, seriously affect network performance.

A patch cord is an electrical cable with connectors on both ends. They are used to connect two pieces of equipment together or a piece of equipment to a network for data sharing. In the computing and communications world, the most common type of patch cord consists of a 4-pair balanced twisted pair cable and 8-pin modular "RJ45" style plugs. To maintain flexibility and for ease of installation, patch cords are usually constructed with stranded wire rather than the solid copper conductors commonly used for structured cabling.

2. Background
Since patch cords are easily replaceable, there is frequently no requirement that patch cords be verified as meeting performance requirements. As far as installers are concerned, if it works, they use it and, if it doesn't, they replace it. However, often there is little consideration given to the fact that non-compliant patch cords might still work but severely degrade the performance of the network. Poor quality plugs can cause intermittent failures due to loose mating of the connectors. Corrosion over time can cause failures that would not be apparent when a patch cord is first installed.

A study in 2003 by Quabbin Wire & Cable Co. tested ninety-six Category 5e and fifty-three Category 6 rated patch cords for compliance with TIA/EIA-568-B. [1] The cords were purchased from 34 different vendors throughout North America. The test results showed that 70% of Cat 5e and 83% of Cat 6 cords failed.

In 2010, the Communications Cable and Connectivity Association (CCCA) completed a study on Category 6 copper patch cords that found 322 of 379 patch cords produced offshore by little known companies failed to meet minimum industry electrical performance requirements as specified in TIA 568-C.2. That's an 85% failure rate. [2]

Some industry experts say that the number of products in the US market that do not meet industry safety and/or performance requirements can be as high as 94.5%! Of 71,826 part numbers/ spec sheets reviewed, only 4,076 met the prescribed requirements in ANSI/TIA-1096-A [3] (formerly FCC Part 68).

3. Problems and Possible Solutions

3.1 Failures due to improper assembly
Patch cords are notoriously difficult to manufacture consistently. Small differences in conductor position within the plug can cause large differences in crosstalk performance. Assembling a modular patch cord requires skill and patience. Cable assemblers must be capable of ensuring proper cable preparation (maintaining the integrity of the pair twists), precise alignment of conductors, and correct plug terminations. Maintaining the integrity of the pair twists and minimizing pair disturbance at the connector is critical for good cable performance.

To overcome these manufacturing challenges, proper training of assembly technicians is mandatory. This can take a substantial amount of time. Even with skilled operators, many manufacturers implement at least some production line testing of their assembled cords. This can range from batch testing to complete 100% transmission testing to ensure proper assembly. Finally, quality control (QC) inspections of the processes, manufacturing equipment and products are desirable.

3.2 Failures due to "sloppy" (loose) connections
Loose connections can cause intermittent or permanent electrical signal failures. Mechanical stresses caused by the installation and routing of the patch cord can shift and twist the plug to the point that the connection at one or more of the contacts is lost. Vibration from local traffic or machinery can also cause a sloppy connection to fail.

Loose connections are the result of a dimensional mismatch between the plug and jack. This can be caused by a number of factors.

3.2.1 Specification not sufficient with respect to dimensions and/or tolerances

If dimensions and tolerances are not controlled tight enough, a loose fit can result. Since plugs and jacks are not usually installed as a matched pair from the same manufacturer, you also have to consider the situation where the plug meets the minimum tolerance and the jack meets the maximum tolerance.

The best way overcome this shortcoming is to make sure that the appropriate specifications are referenced and that the specifications contain the dimensions and tolerances necessary for a proper fit. For example, ANSI/TIA-1096-A [3] and EN60603-7 [4] both contain dimensional information for plugs and jacks with tolerances. See Figure 1. However, some say that the tolerances for the jacks are not sufficient for today's gigabit speed applications and need to be tightened.

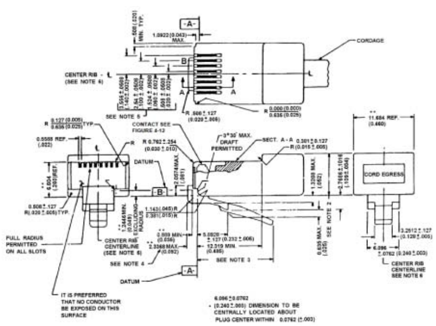


Figure 1. Example of a Mechanical Specification for an 8-Pin Modular Plug from ANSI/TIA 1096-A [3]

3.2.2 Not manufacturing to specified tolerances

Not much can be said about this except that sometimes manufacturers cut corners and don't manufacture the connectors in compliance with the specifications. This can result in poor connections in the field.

The best solution for this is to make sure suppliers employ a quality system in compliance with ISO 9001that includes manufacturing to specified dimensions and tolerances. Certification by an independent 3rd party that includes testing, inspections and market surveillance adds another level of assurance that the parts are manufactured correctly.

3.2.3 Poor manufacturing quality control

This can include things like using molds beyond their recommended life and poor machinery maintenance resulting in dimensional drift away from the original specifications. Also, inferior assembly practices would also fall under this category.

The solutions for this item would be the same as 3.2.2 above.

3.3 Failures due to contact material/plating/ contact design

When all is said and done, it is the electrical contacts that allow the transmission of the signals through the plug/jack interface. The quality of the interface is dependent on maintaining good physical contact between the contacts of the plug and jack and keeping the contact surfaces free from corrosion.

Electrical and mechanical performance testing can go a long way to making sure good physical contact is maintained. For example, determining if a part can still meet transmission requirements after 750 insertions/withdrawals can show that the design and materials are suitable for the task. In addition, defining the "wipe" and contact areas can ensure good electrical contact.

Most people agree that there is nothing like gold plating to fight corrosion. However, gold plating is expensive and difficult to implement and control. A number of years ago the Administrative Council for Terminal Attachments (ACTA) made the following statement regarding Gold: "Cost pressures have increased on all components, especially those with gold and precious metals involved. Many of these products are subject to offshore outsourcing and subcontractor manufacturing in the supply chain to meet these cost pressures. Unfortunately, quality standards are being compromised. As a result, there is a TICKING TIME BOMB WITH POROSITY, OXIDATION, CONDUCTIVITY, CONTACT RESISTANCE AND CORROSION that may cause complete signal transmission loss or intermittent contact (that alternates rapidly between a high and low resistance), which is the worst nightmare for anyone who has to troubleshoot network equipment."

To address this issue, the first step is to require gold plating. ANSI/TIA-1096-A contains detailed specifications relating to gold plating. This includes gold purity (99%), thickness (min. 50 µin), hardness and porosity. It also requires a nickel barrier layer between the gold layer and the base material to prevent material migration. In order to be effective, the integrity of the plated surface must be maintained.

Quality control is of the utmost importance when it comes to gold plating. Most of the parameters cannot be checked at the place of connector manufacturing so a system must be in place to do periodic checks of the vendors related to the plating process. This might involve requiring periodic tests of the material with test reports, attestations, certificates of conformity and the like. Similar to other manufacturing related issues, employing a quality system in compliance with ISO 9001 and certification by an independent 3rd party can help ensure the quality of the plating.

3.4 Failures due to cable terminations and internal connections

The RJ-45 style plugs are normally made for either solid conductors or stranded conductors. It is very important to be sure that the plug's internal connections are designed for both the type and gauge of conductor being used. Specifications must be carefully reviewed since it is very difficult, if not impossible, to determine this by looking at them. In addition, the overall cable diameter also needs to be considered and a plug with the correct dimensions selected.

Testing of the connections and preventing stress being transmitted to the connections during installation and handling will go a long way to minimizing connection failures. Conductor connections can be evaluated in accordance with standards such as IEC 60352-4 [6]. Cable strain relief and resistance to flexing stresses should also be evaluated using a standard such as EN 61935-2 [7].

3.5 Failures due to non-compliant cable

Although the plug and its assembly provide the greatest opportunities for problems, it is the cable that transports the signal from one end of the cable to the other. Hence, a bad cable means a bad patch cord.

To give you the best chance of success, cables should be tested for compliance with TIA-568-C.2-1 [8]. However, often claims of compliance are unfounded and there is a large industry associated with making and selling inferior cables. Cables constructed with copper clad aluminum conductors (not permitted by TIA-568) or questionable insulating materials and jackets (both a performance and fire safety issue) are not easily identifiable. Neither is a poorly performing cable that is still marked with a "Category" type designation. Yet, these are easily obtained on-line or from dubious distributers.

The best defense against this is to obtain the cables from reputable sources and make sure they are verified for performance and certified for safety by a well-known third party certification laboratory. As an extra measure of confidence, cables can be tested as part of a patch cord manufacturer's quality control process.

3.6 Materials

The material that a connector is constructed of forms the basis of the mechanical structure of the device and provides insulation between the electrical contacts. Inferior materials or poor manufacturing controls can affect the material's short and long term properties leading to mechanical failure and inadequate electrical performance. In addition, flammable materials can pose a risk of fire.

Certified materials have been evaluated for their ability to maintain physical and electrical properties over time, are suitably rated for expected temperatures and will have an appropriate flammability rating to reduce the risk of fire. Likewise, certified connectors are evaluated and inspected to make sure appropriate materials are used in their construction and suitable manufacturing processes are in place.

3.7 Powering over LAN cabling

With the fast growth of powering over LAN cable technologies, new performance and safety issues arise. Arcing of the contacts when connectors are dis-connected under load can damage the contacts and affect performance. Connectors carrying current can overheat, soften and distort resulting in premature failures. Cables carrying current can get hot enough to exceed the temperature rating of the cable resulting in damage and long-term material degradation. Performance is affected by increased insertion loss due to the heated copper conductors.

To address the arcing concern, connectors should be evaluated in accordance with IEC 60512-99-001 [9]. Designs that separate the connect/disconnect point of the contacts (where the arc occurs) from the mated interface point of the contacts (where the signals are carried) will also minimize this problem.

Connectors should be rated and certified to handle the anticipated current. Cables should be constructed with conductors sized according to table 725.144 of the National Electrical Code ® [10] or be provided with an "-LP" rating indicating that the cable has been specifically evaluated for powering over LAN cable applications.

3.8 Counterfeiting

Even with the best of intentions and careful due diligence, at some point counterfeit products will creep into the supply chain of manufacturers, assemblers, vendors, distributers and users. The first defense against this to use reputable sources and specify that parts and materials need to be 3rd party certified. This ensures that there are routine inspections keeping an eye on things. Select certification programs that include market surveillance testing and certification organizations that are fanatical about protecting their mark and going after counterfeiters.

Supplier / customer / distributor education can go a long way in identifying "real" products and controlling the spread of counterfeit ones. For example, everyone should know what certification marks to look for and how to tell a legitimate certification mark from a fake one. Figure 2 shows an example of authenticating a certification mark. Note how the symbol is blanked out until viewed in the window of the authenticator.

Figure 2. Authenticating a Certification Mark

4. Conclusions

Although patch cords are a critical part of the network, they are often overlooked. There is a misconception that since patch cords are easily replaceable, they do not need the scrutiny that is usually applied to the structured cable plant. However, a trial and error approach to performance can be time consuming and expensive and system failures down the road caused by inferior patch cords can be devastating.

In the connected world of the internet of things (IoT) every segment of the network is critical. For patch cords, this means that appropriate specifications need to be developed, followed, verified and specified to ensure that expected performance is achieved at the time of installation and for years to come.

5. References

[1] Quabbin Wire & Cable Co., Inc., Technology Brief, "*Most Patch Cords Fail Testing*"

http://www.quabbin.com/tech-briefs/most-patch-cords-fail-testing

[2] Communications Cable and Connectivity Association (CCCA), "Testing *by CCCA Finds High Failure Rate in Electrical Performance of Imported Category 6 Copper Patch Cords*", December 6, 2010

http://cccassoc.org/news/press-releases/testing-ccca-finds-high-failure-rate-electrical-performance-imported-category-6-copper-patch-cords/

[3] ANSI/TIA-1096-A, "*Telecommunications Telephone Terminal Equipment Connector Requirements for Connection of Terminal Equipment to the Telephone Network*", March 17, 2008

[4] EN60603-7, "Connectors for electronic equipment - Part 7: Detail specification for 8-way, unshielded, free and fixed connectors", November 1, 2010

[5] ISO 9001:2015, "*Quality management systems – Requirements*", 2015

[6] IEC 60352-4, "*Solderless connections - Part 4: Solderless non-accessible insulation displacement connections - General requirements, test methods and practical guidance*"

[7] EN 61935-2, "*Generic cabling systems – Specification for the testing of balanced communication cabling in accordance with EN 50173 Part 2: Patch cords and work area cords*", September 2003

[8] TIA-568-C.2-1, "*Balanced Twisted-Pair Telecommunications Cabling and Components Standard*", July 2016

[9] IEC 60512-99-001, “*Connectors for electronic equipment – Tests and measurements – Part 99-001: Test schedule for engaging and separating connectors under electrical load – Test 99a: Connectors used in twisted pair communication cabling with remote power*”

[10] National Fire Protection Association, NFPA 70 ®, “*National Electrical Code ® (NEC)*”, 2017 Edition, Section 725.144.

6. Author

Randy Ivans
UL LLC
1285 Walt Whitman Road
Melville, NY 11747

Randy Ivans is a program / project manager in the wire and cable division of UL LLC. He has been with UL for 40 years and is currently part of a team responsible for the development, implementation and maintenance of various UL programs in the wire & cable area.

Randy served as chairman of the Telecommunications Industry Association (TIA) committee TR41.7, “Environmental and Safety Issues” and subcommittee TR41.7.1, “Harmonization of International Safety Standards”. He was also a contributing member of TR-41.9, “Technical and Administrative Regulatory Considerations”, that is responsible for the development and maintenance of ANSI/TIA 1096-A.

He was the project leader for a Fact Finding investigation on Power over Local Area Network Type Cables (4-Pair Data / Communications Cables) and authored the Fact Finding Report on that investigation.