EVALUATING CONNECTORS FOR GIGABIT AND 10-GIGABIT ETHERNET IN MILITARY AND AEROSPACE APPLICATIONS

by: Robert Moore, Senior Principal Engineer at TE Connectivity

ABSTRACT

As military and aerospace application move toward Gigabit and 10G networks, standard military connector technology has not kept pace. To evaluate the suitability of various connectors, we tested differential near-end crosstalk in links containing a traditional MIL-DTL-38999 connector and two connectors from TE Connectivity (TE) designed specifically for gigabit and 10G applications.

Testing for both gigabit (Cat 5e) and 10-gigabit (Cat 6a) data rates included links with 1, 2, 3, 4, and 5 connectors in the path. The results showed that the 38999 connectors passed Cat 5e tests for one connector, but was unsuited to other configurations. The TE connectors passed all tests—indicating the need for controlled-impedance connectors designed for high data rates.

INTRODUCTION

The MIL-DTL-38999 I/O interface was designed decades ago, when the primary concerns were ruggedness and field reparability. This connection had to be rugged to survive the harsh environmental conditions to which they would typically be exposed. These conditions included high vibration and mechanical shock levels, temperature extremes, hundreds of mating cycles and sealing of the contact interface against corrosive fluids and chemicals.

Easy field reparability is also key as these systems are often deployed in remote locations where repair facilities are scarce and critical missions can be compromised with a system failure. The ability to remove and replace a damaged contact interface with readily available hand tools to restore system operation was a key part of the design criteria. Data transmission rates, however, were not a key consideration in the initial connector design.

As a high-speed interconnect solution for military and aerospace applications, Gigabit Ethernet is widely deployed today with 10G Ethernet coming on strong. The ubiquitous 38999 connector is good enough for Gigabit Ethernet, but not necessarily the most space efficient. Thus there is interest in the military and aerospace community for connectors capable of 10G Ethernet.

This paper reports on evaluations of the electrical performance of 38999 connectors and two recently introduced connector families: TE Connectivity's CeeLok FAS-T and CeeLok FAS-X connectors. Testing involved two application scenarios for evaluating Gigabit and 10G Ethernet performance. The first was a simple link with one mated pair in the path. The second series of tests reflects better real-world application with multiple interconnections for such needs as production breaks. These tests used 2, 3, 4, and 5 mated pairs in the path.

Figure 1 shows the arrangements and relative sizes of the connectors tested.

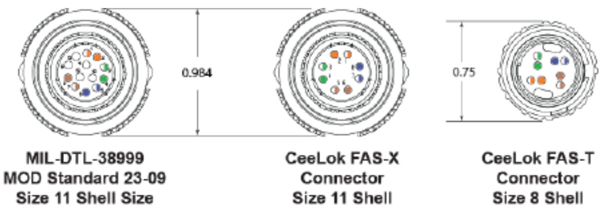

Figure 1. Connector Contact Arrangement and Relative Size (Source: TE Connectivity)

CONNECTOR

MIL-DTL-38999 Connectors

These connectors are among the most familiar and widely used mil-spec connectors. They exist in a rich ecosystem of backshells, accessories, and non-mil-spec versions for special needs. For Gigabit Ethernet applications, the connectors usually follow the size and pinout arrangement defined in the U.K.'s Ministry of Defence Standard 23-09. This standard provides a single Ethernet channel in a size 11 shell with an 11-35 insert.

There are other pinouts used for Gigabit Ethernet. We chose the 23-09 standard because its shell size makes it the smallest (and hence lightest) of the various options—an important consideration in many applications.

CeeLok FAS-T Connectors

CeeLok FAS-T connectors were specifically designed as controlled-impedance devices for 10G applications in harsh environments. To minimize the effects of crosstalk within the interface, an asymmetrical cancellation approach was taken. By arranging the interface with an asymmetrical contact pair pattern, the full effects of cancellation can be realized, reducing the amount of required pair separation. This has the added advantage of allowing for higher contact density. A "T" pattern was selected as the best way to achieve crosstalk cancellation. This pattern was selected based on an existing TE Connectivity commercial connector interface that had met 10G Ethernet data transmission through Signal Integrity 3D modeling software analysis and physical testing.

The connector uses a size 8 shell, making it the smallest and lightest of the connectors being considered here. Note that the connector does not use a 38999 shell. To also reduce size and weight, it uses an integral backshell that can be used for cable shield termination. Band straps and heat-shrink molded boots provide shield termination and strain relief.

CeeLok FAS-X Connectors

Also designed for 10G applications, CeeLok FAS-X connectors use a standard 38999 shell and AS39029 size 22D contacts. The connector is designed to maintain the shielding of each pair through the connector and thereby electrically isolate them from one another. Such isolation allows more consistent impedance and lower crosstalk. The connectors are available to carry one Ethernet (or 10G Ethernet) channel in a size 11 shell—the same as the 38999 23-09—or four Ethernet (or 10G Ethernet) channels in a size 25 shell. The one-channel version was used in this test.

Due to its robust design and the high amount of component re-use from the standard MIL-DTL-38999 connectors, NAVAIR has selected the CeeLok FAS-X connector as the basis for establishing a Military Standard. To that end, MIL-DTL-32546 has been released. TE will soon be qualified to this standard, providing a ruggedized mil-spec connector that is capable of 10 Gigabit Ethernet speeds.

Testing for Near-End Crosstalk

We chose to test Near-End Crosstalk (NEXT), since it is arguably the best single indication of performance. Testing conformed to the requirements of TIA-568-C.2. To pass, all pairs must be below the frequency thresholds defined in TIA-568 for 1 Gb/s and 10 Gb/s applications: 100 MHz (Cat 5e) for Gigabit Ethernet and 500 MHz for 10G Ethernet. Since Cat 6a cables were used on all samples, performance differences between gigabit and 10G is not cable related.

Single-Connector Link Testing

Figure 2 shows the test setup schematically: a single mated pair with 1 meter of cable at each end.

Figure 2. Single-Connector Test Setup (Source: TE Connectivity)

Results: Standard 23-09 Pinout – MIL-DTL-38999 Connector

Figure 3 shows test results for the 38999 at both gigabit and 10G speeds. The connector meets gigabit requirements with adequate margin, but does not pass 10G requirements.

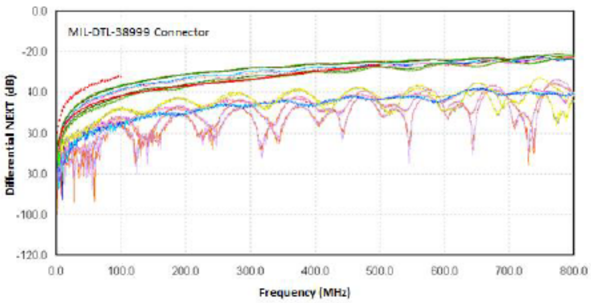

Figure 3. Differential NEXT for 38999 Connector in a Single-Connector Link (Source: TE Connectivity)

Results: CeeLok FAS-T Connector

Figure 4 shows the results for CeeLok FAS-T performance. The connectors pass both gigabit and 10G requirements. Of significance is the much higher margin of the CeeLok FAS-T connector over the 38999 connector for Cat 5e performance. The CeeLok FAS-T connector also has plenty of margin in Cat 6a testing.

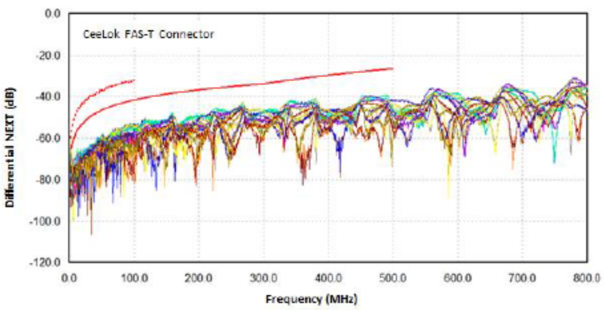

Figure 4. Differential NEXT for CeeLok FAS-T Connector: Single-Connector Link (Source: TE Connectivity)

Results: CeeLok FAS-X Connector

As shown in Figure 5, the CeeLok FAS-X connectors also passed both gigabit and 10G requirements with plenty of headroom.

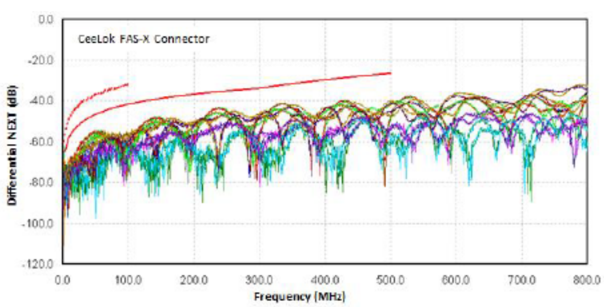

Figure 5. Differential NEXT for CeeLok FAS-X Connector: Single-Connector Link (Source: TE Connectivity)

The results show that the MIL-DTL-38999 connector is capable of supporting Gigabit Ethernet, but not 10G Ethernet, even when using a pinout configured for high speeds. This is due, at least in part, to the connector's legacy: 10G speeds were not even on the far horizon.

CeeLok FAS-T and CeeLok FAS-X not only meet Cat 5e and Cat 6a requirements, they do so with a nice margin. They demonstrate the inherent advantages of a purpose-build design.

Multiconnector Link Testing

Multiconnector link testing was similar to the testing just discussed. The difference is that multiple connectors were placed in the link to simulate the real world better. See Figure 6. Many applications have bulkheads or other production breaks in the transmission path.

Figure 6. Multiconnector Test Setup (Source: TE Connectivity)

Results: Standard 23-09 Pinout – MIL-DTL-38999 Connector

With multiple connectors, the strain on the 38999 connectors becomes apparent. As shown in Figure 7, it barely squeaks through the Cat 5e requirements and fails for Cat 6a with only two connectors. For high connector counts, the connectors fails both Cat 5e and Cat 6a. The takeaway is that with multiconnector links, the 38999 connector is not recommended for Gigabit Ethernet or 10G Ethernet. Since the connector failed at both speeds for three mated pairs, we will not show the results for four and five pairs. Suffice to say, the situation did not improve.

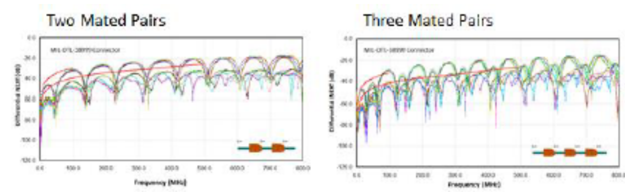

Figure 7. Differential NEXT for 38999 Connectors in a Multiconnector Link (Source: TE Connectivity)

Results: CeeLok FAS-T Connector

Unlike the M38999 results, the CeeLok FAS-T connector successfully passed the NEXT requirement for Gigabit and 10G Ethernet through 2, 3, 4 and then 5 disconnects. Note that the five-disconnect results seem to be approaching the channel limit line for 10G Ethernet at approximately 100 MHz. However, the noise cancelling technology deployed in this connector was good enough to achieve 10G Ethernet NEXT performance through 5 disconnects.

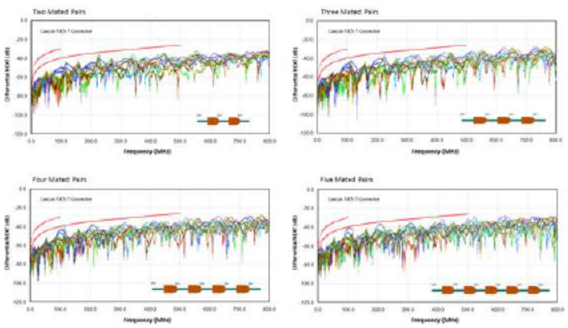

Figure 8. Differential NEXT for CeeLok FAS-T Connectors in a Multiconnector Link (Source: TE Connectivity)

Results: CeeLok FAS-X Connector

The CeeLok FAS-X connector achieve 10G Ethernet NEXT performance through 5 disconnects with substantial headroom. This connector's noise isolation technology yielded outstanding NEXT results in this multi-disconnect study.

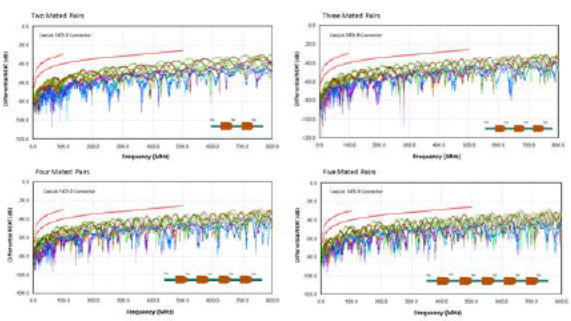

Figure 9. Differential NEXT for CeeLok FAS-X Connectors in a Multiconnector Link (Source: TE Connectivity)

CONCLUSION

Figure 10 summarizes the results. All the connectors supported Gigabit Ethernet, although headroom increases as we move from 38999 to CeeLok FAS-T to CeeLok FAS-X connectors.

Disconnects	MIL-DTL-38999 Connector Pinout: MOD Std. 23-09		CeeLok FAS-T Connector Pinout: As Designed		CeeLok FAS-X Connector Pinout: As Designed	
	1 Gb/s	10 Gb/s	1 Gb/s	10 Gb/s	1 Gb/s	10 Gb/s
1	Pass	Fail	Pass	Pass	Pass	Pass
2	Pass*	Fail	Pass	Pass	Pass	Pass
3	Fail	Fail	Pass	Pass	Pass	Pass
4	Fail	Fail	Pass	Pass	Pass	Pass
5	Fail	Fail	Pass	Pass*	Pass	Pass

*Connectors pass, but without headroom

Figure 10. Summary of Differential NEXT Results per TIA-568-C.2 (Source: TE Connectivity)

The MIL-DTL-38999 connector with the MOD Standard 23-09 pinout fails all 10G Ethernet tests. Both the CeeLok FAS-T and CeeLok FAS-X connectors are suited to 10G speeds, even with five connectors in the path. The CeeLok FAS-X provides more headroom than the CeeLok FAS-T.

The 38999-style connector will remain popular for a vast range of military and aerospace applications. It has the advantages of being a rich ecosystem, with tried-and-true technology, an ever-growing array of options and accessories, and familiarity. It is, however, not well suited to high-speed Ethernet, having only successfully passed Gigabit Ethernet for the limited case of one disconnect in the path.

The CeeLok FAS-T connector passed all tests. It offers the benefit of being smaller and lighter than the other two connector styles tested. One possible drawback is that it does not have a 38999-style pedigree.

The CeeLok FAS-X connector performed best in all tests in terms of headroom. Excellent performance was especially apparent with five disconnects.

As applications move to high-speed Gigabit and 10G Ethernet, designers need to carefully evaluate the link. How far, how fast, and how many disconnects in the link? What is the possibility of a disconnect being added, either late in the design cycle or in an upgrade?

As next generations of high-speed networks show, legacy I/O connectors are not suited to new applications. Purpose-built connectors have a strong tradition of filling special needs, even if the special need is as commonplace as high-speed Ethernet. In many cases, purpose-built connectors like the CeeLok FAS-T are a combination of successful commercial technologies and rugged packaging. It is not a case of reinventing the wheel as much as it is a case of ruggedizing the wheel for harsh technologies.

ABOUT THE AUTHOR

Robert has more than 30 years' experience designing, developing, specifying, and evaluating RF and data communication products for aerospace, marine and ground systems. Robert holds a BS and a BA from the University of California, Berkeley and a Master's in RF and Microwave Components from Santa Clara University. He is currently a member of the National Electrical Manufacturers Association (NEMA) Shipboard Cable, the NEMA Aerospace Cable committees and member of Society of Automotive Engineers SAE AE8D.

te.com

WHITE PAPER

Aerospace, Defense & Marine

www.te.com/aerospace
www.te.com/ground-defense
www.te.com/offshore
.