# ISOLATED PAIR QUADRAX FOR RUGGED D-SUBMINIATURE AND MIL-DTL-38999 CONNECTORS

**Richard A. Johannes**

*Smiths Interconnection*
*1550 Scenic Ave., Suite 150*
*Costa Mesa, CA 92626*
*USA*
*richard.johannes@smithsinterconnect.com*

## INTRODUCTION

The standard quadrax contact carried in a ruggedized D-Subminiature or MIL-DTL-38999 connector housing has been the work-horse for point to point space architecture. The contact system comfortably supports digital signals related to Fibre Channel and other space protocols. As signal speeds exceed the 3.125 Gbps level to drive new applications in satellite design, the current four wire quadrax cable and interconnects begin to fall short due to attenuation, cross talk and signal to noise ratio.

The next generation of cable connection requires the ability to reliably transmit 6.25 Gbps and beyond per pair, with a stable characteristic impedance of 100Ω. Twinax interconnects have been demonstrated to support data rates above 10 Gbps, but this performance improvement is typically achieved at the cost of signal density in the architecture. The ideal solution is to isolate the individual pairs within the quadrax format through the cable and contact systems, while maintaining the use of space proven connectors and inner contact designs. The resulting isolated pair contact system must also be cavity compatible with qualified ruggedized D-Subminiature and MIL-DTL-38999 connectors to ensure drop-in packaging compatibility. This "best of both worlds" solution provides a robust connection system vetted in extreme mechanical shock, thermal shock and vibration testing and a contact system heritage with demonstrated signal integrity performance before, after and during the extreme events.

## DESIGN REQUIREMENTS FOR THE NEXT GENERATION QUADRAX

The next generation quadrax contact system must support all mechanical and environmental performance parameters, but with significantly enhanced electrical signal integrity. The current contact system has been proven to meet test requirements as shown in Table 1.

Table 1 – Mechanical and Environmental Performance

| | |
|---|---|
| Temperature Rating | -65°C To +165°C |
| Corrosion | MIL-STD-202 Method 101 for 48 Hours |
| Mechanical Shock | Half Sine Pulse > 1,500g's |
| Vibration | Random Vibration > 60g's rms |
| Thermal Shock | EIA-364-32 for 10 Cycles |
| Durability | 500 Mating Cycles |

The enhanced electrical performance requirements are defined in Table 2.

Table 2 – Enhanced Electrical Performance

| | |
|---|---|
| Dielectric Withstanding Voltage | 250 V DC Maximum |
| Insulation Resistance | >5,000 MΩ at 200 VDC |
| Contact Current Rating | 3.0 Amps DC Minimum |
| Insertion Loss (SDD12) | ≤ - 2 dB at 1.5625 GHz (Frequency Range up to 5.5 GHz) |
| Return Loss ($-20\log_{10}\|SDD11\|$) | < - 10 dB |
| Characteristic Impedance | 100 Ω ± 10 Ω |
| Near & Far End Cross Talk | 4% cross talk maximum (< -28 dB) |

## DESIGN CONSIDERATIONS

The next generation split or isolated pair quadrax contact incorporates a number of features to increase its robustness. These include the following:

1. Reverse Gender Contacts
2. Hermaphroditic Inner Contact Layout
3. Molded Internal Insulators for Enhanced Dimensional Stability and Impedance Control

The reverse gender configuration of the inner contacts is a design feature that protects the fragile pin contact from probe damage and scooping from the mating connector half. As shown in Fig. 1, an unprotected pin can be easily damaged and represents one of the major failure modes in quadrax contacts today.

Bent or Broken Pins due to scooping or stubbing

Fig. 1 – Standard Gender (Pin Exposed) Pin Damage

In Fig. 2 & Fig. 3, the increased protection for the 0.38 mm (0.015") diameter pin contact is evident. The small diameters of the pin and socket contacts are necessary to maintain the characteristic impedance of the contact system and support the signal integrity to the transmission line through the connector.

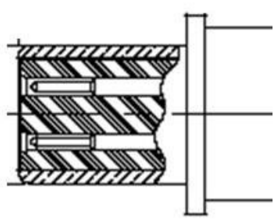


Fig. 2 – Reverse Gender Pin Side

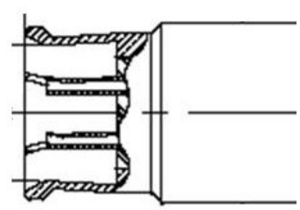
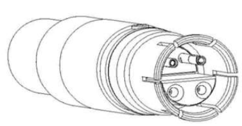
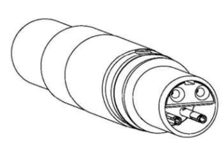


Fig. 3 – Reverse Gender Socket Side

The hermaphroditic design of the mating insulators serves a dual function. It enhances the scoop proof nature of the design (the mating plug cannot contact and potentially bend the opposing contacts unless correctly oriented), but also acts to support the inner ground shield used to provide isolation between the two differential pairs through the connector (Fig. 4 & 5).





Hermaphroditic Inner Contacts with Sockets Exposed and Pins Buried

Fig. 4 – Socket Contact

Fig. 5 – Pin Contact

In using a molded high flow polymer in the insulator with a dielectric constant at 3.1, the result is a high degree of stability in both impedance and dimension. It is also possible to decrease the impedance by adding void cores to provide air gaps in key locations.

The design features described above, work together in ensuring an extremely robust design that is cavity compatible with the quadrax contacts used today. With the addition of the internal ground shield plate, that engages across the mated connector interface, this drop-in contact can now support data rates in the 10 Gbps range and still meet necessary cross talk limits (Fig. 6 & 7).

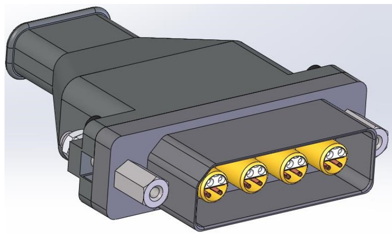


Fig. 6 – Receptacle Connector

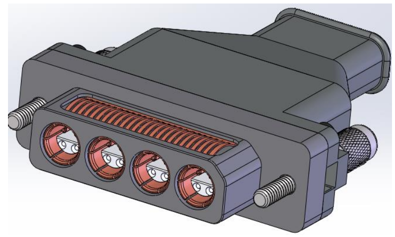


Fig. 7 – Plug Connector

## ELECTRICAL PERFORMANCE

The electrical performance and characteristic impedance has been tested both before and after the 500 cycles of durability and demonstrated to be well within the design requirements. The characteristic impedance can be seen in the TDR trace of Fig.8 and Fig. 9, to meet the 100 Ω ± 10 Ω target.

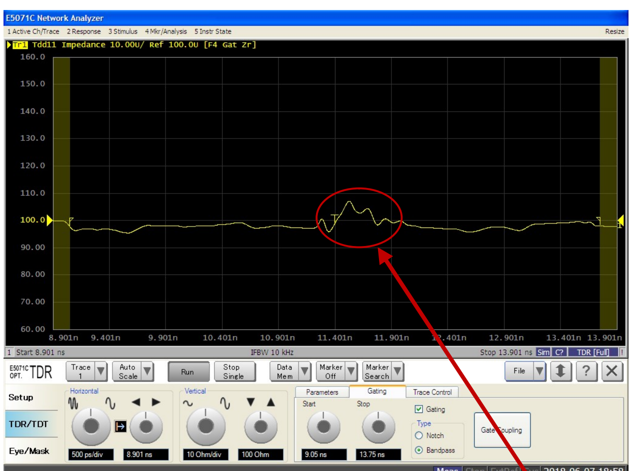



Fig. 8 – Pair #1 & 2

Connector Interface

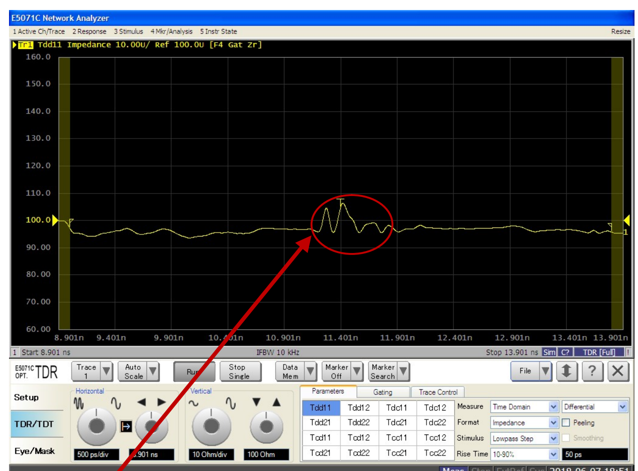



Fig. 9 – Pair #3 & 4

The signal integrity measurements and the corresponding eye patterns also clearly show the strong performance of the system (Fig. 10 & Fig. 11). The measured characteristic impedance through the connector pairs is approximately 101 Ω ± 6 Ω. The eye patterns shown in Fig. 10 & Fig. 11, display relatively low jitter and wide eye opening. These eye patterns were generated on an Agilent E5071C Vector Network Analyzer and are based on data rates of 6.25 Gbps and 10 Gbps. The resulting far end cross talk was measured below the 4% or -28 dB requirement. With improvement of the electrical test set-up in the transition from the 100 Ω quadrax cable to the necessary 50 Ω coaxial cable to facilitate the connection to the VNA, even better measurement results are expected.

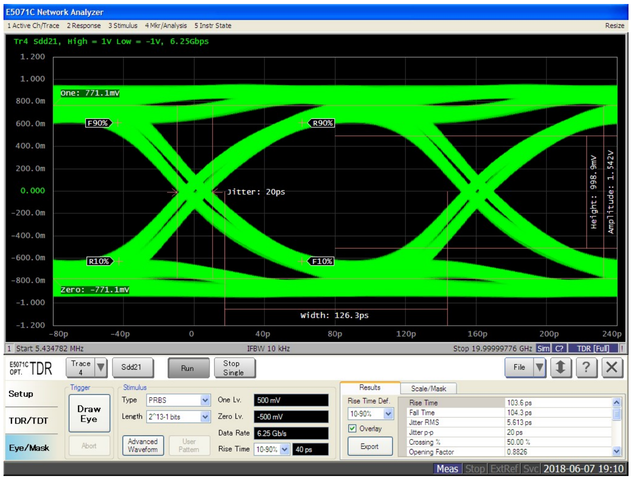



Fig. 10 – Eye Pattern for 6.25 Gbps Data Rate

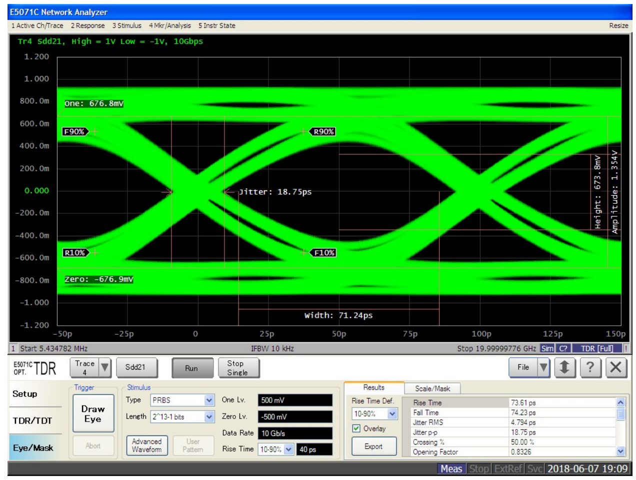



Fig. 11 – Eye Pattern for 10 Gbps Data Rate

## CONCLUSIONS

The next generation isolated pair quadrax contact system is a successful blend of the best features from the existing quadrax contact and the supporting ruggedized D-Subminiature and MIL-DTL-38999 circular connectors, with the new shielding and hermaphroditic interface to further increase the robustness. The mechanical and environmental performance of the contact and connector system will be in-line with the extremely rugged, proven systems in use today. The electrical performance ensures system signal integrity "head room" for the data rate increases demanded by new satellites, space hardware and architectures. This next generation interconnect system provides electrical performance of a twinax with the higher density expected from a quadrax (Fig. 12).


Fig. 12 – Ruggedized D-Subminiature with cavity compatible Isolated Pair Quadrax

## REFERENCES


[1] M. Carlson, "White Paper – Rugged D-Sub Connector Series", Smiths Connectors, 2014.

[2] J. Kutnink, Qualification Test Plan – Qualification of Connectors - Rugged D-Sub 4-Way Plug with Quadrax Pins and Rugged D-Sub 4-Way Receptacle with Quadrax Sockets - QTP # 2018-04-021