SPACEWIRE CABLE AND CONNECTOR VARIATIONS

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Introduction

SpaceWire spaceflight applications are growing steadily and the data protocol is well documented and standardized. Yet, unique requirements for various programs often make it necessary to deviate from the standard. The introduction of new technologies into the SpaceWire community can only serve to support increased technology growth.

The physical layer is often overlooked as a critical component of the SpaceWire link but experience will show that in certain situations a good physical layer design may be crucial to the success of the program. The SpaceWire cable assembly, consisting of the SpaceWire connector and cable, is one of the components that may offer design variations.

Background

The SpaceWire Standard (ECSS-E-50-12A) specifies the SpaceWire cable to be comprised of 8 American Wire Gauge (AWG) wires in accordance with ESCC 3902/003.

The SpaceWire connector is equally specified to be a 9-contact microminiature D-type (MDM) connector per ESCC 3401/071. The MDM connector offers good size and mass properties to the designer but also has a history of mechanical issues that make efficient handling procedures necessary. The number of contacts only allows for a single ground pin for the internal cable shields. The shield configuration also does not allow the inner shields to be carried through bulkhead interfaces. The connector is also not impedance matched to the cable or impedance traces creating an impedance mismatch and the possibility of reflections.

Connector Variations

W. L. Gore has designed matched-impedance twinax connectors that offer a 100 Ω impedance and the ability to carry all inner shields through bulkhead interfaces. W. L. Gore has also tested these connectors using the assembly shown in Figure 1according to the test sequence shown in Figure 2. The test results are summarized below.

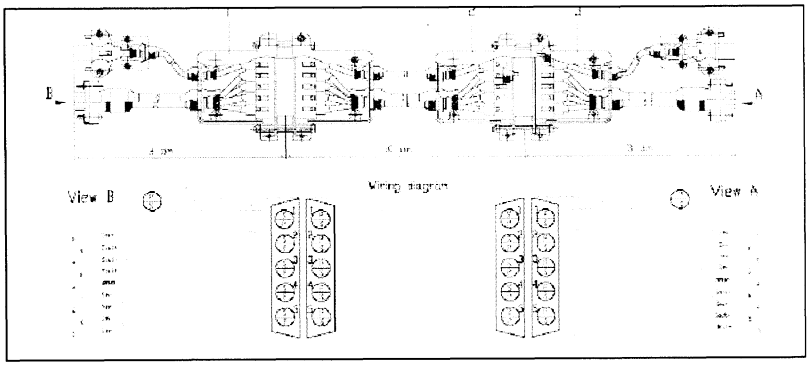

Figure 1. W. L. Gore Test Harness

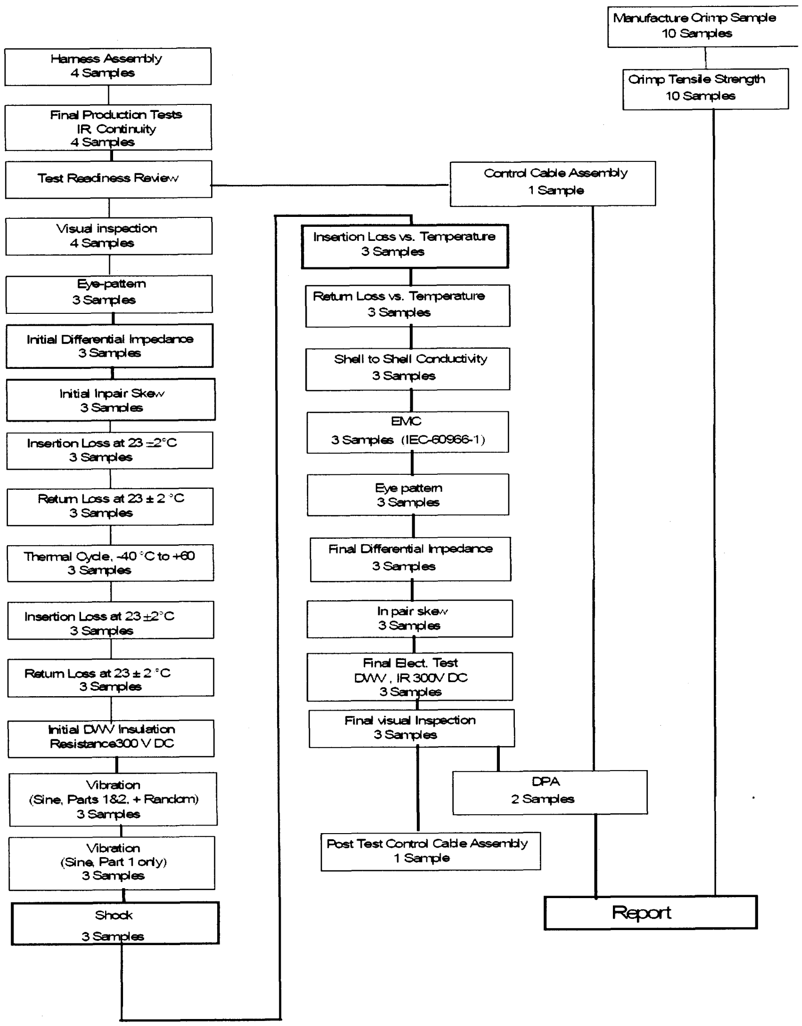

Figure 2. Test Sequence

Final Production Testing

Insulation resistance was tested between each insulated conductor. A test voltage of 300 Vdc was applied for a time period of 1 minute. It is required that the measured value shall be 100MΩ. Continuity was measured out according to a W. L. Gore procedure consistent with standard practices with a micro-ohm-meter. The test temperature was 22°C. The results are shown in Table 1.

Table 1. Final Production Tests Summary

Final Production Tests	SN01	SN02	SN03	SN04
Final Physical Inspection	Passed	Passed	Passed	Passed
Mass	Measured	Measured	Measured	Measured
Insulation	Passed	Passed	Passed	Passed
Continuity	Measured	Measured	Measured	Measured

Eye Pattern Measurements

Eye patterns were measured according to standard practices with an applied input voltage was 540mv peak to peak. The required eye height is 200mV. The jitter requirements are as follows:

peak to peak jitter = 0.2 * bit time

	65Mbit/s	100Mbit/s	200Mbit/s	400Mbit/s
Jitter pp	3086ps	2000ps	1000ps	500ps

The test results are given in Table 2.

Table 2. Eye Pattern Measurements

	Eye Height [mV]	Jitter pp [ps]	Eye Height [mV]	Jitter pp [ps]	Eye Height [mV]	Jitter pp [ps]	Eye Height [mV]	Jitter pp [ps]
SN Q001	65Mbit/s		100Mbit/s		200Mbit/s		400Mbit/s	
Pair 2	436	123	401	120	333	120	248	130
Pair 3	443	123	410	80	343	100	269	110
Pair 4	436	123	402	80	332	120	252	130
Pair 5	437	123	402	120	330	120	248	130
SN Q002	65Mbit/s		100Mbit/s		200Mbit/s		400Mbit/s	
Pair 2	445	123	412	80	344	100	268	120
Pair 3	435	123	401	120	331	140	245	160
Pair 4	436	123	402	120	330	120	251	160
Pair 5	435	123	401	120	331	120	250	140
SN Q003	65Mbit/s		100Mbit/s		200Mbit/s		400Mbit/s	
Pair 2	436	123	399	120	331	100	249	140
Pair 3	437	123	402	80	330	120	248	130
Pair 4	437	123	403	120	332	120	246	140
Pair 5	445	123	413	120	345	100	268	120

Initial Differential Impedance

Initial differential impedance was measured with a requirement of 100 ± 6 Ω. The test results are shown in Table 3.

Table 3. Differential Impedance Measurements

SN Q001	GSC-10-82789-003	GSC-10-82794-050	GSC-10-82787-003
Pair 2	99.2	102.2	101.8
Pair 3	99.2	101.9	102.2
Pair 4	101.4	105.4	100
Pair 5	102.7	102.7	98.65
SN Q002	GSC-10-82789-003	GSC-10-82794-050	GSC-10-82787-003
Pair 2	99.5	102.4	100.5
Pair 3	100	102.7	101.9
Pair 4	101.1	102.7	98.4
Pair 5	102.7	105.7	100
SN Q003	GS-1-8278-003	GSC-10-82794-050	GSC-10-82787-003
Pair 2	103.5	104.9	101.8
Pair 3	101.3	102.4	102.2
Pair 4	101.6	102.4	100
Pair 5	100.8	102.4	98.7

Initial In-Pair Skew

Testing was carried out differentially in S21configuration in accordance with the following parameters:

	CH 1	CH 2
Centre frequency:	70MHz	323MHz
Span frequency:	1MHz	156MHz
Number of points:	1601	1601
IF-BW:	100Hz	100Hz
Sweep time:	15.8s	15.8s
Marker:	70MHz	250MHz / 400MHz

The requirement for SpaceWire is 80ps/m. The results are given in Table 4 below.

Table 4. Initial In-Pair Skew Measurements

SN Q001	70MHz	250MHz	400MHz
Pair 1	0.7	3.6	3.5
Pair 2	1.7	6.6	6.8
Pair 3	1.5	0.4	2.4
Pair 4	14.3	6.3	5.2
Pair 5	19.8	15.1	12.7
SN Q002	**70MHz**	**250MHz**	**400MHz**
Pair 1	9.3	7.1	7.5
Pair 2	3.2	1.9	1.7
Pair 3	10.3	14.9	6.2
Pair 4	8.5	2.8	4.2
Pair 5	19.8	18.7	14.8
SN Q003	**70MHz**	**250MHz**	**400MHz**
Pair 1	6.9	5.6	4.8
Pair 2	0.5	3.6	0.5
Pair 3	3.4	12.5	8.7
Pair 4	5.7	10.5	5
Pair 5	2.8	4.1	2.5

1.0 INSERTION LOSS

Testing as carried out differentially in a frequency range from 1 MHz to 400 MHz at 23 °C with the following parameters:

Start frequency:	1MHz	Stop frequency:	400MHz
Number of points:	401	IF-BW:	100Hz
Measurement:	S21	Sweep time:	5s

The results are given in Table 5 below.

Table 5. Insertion Loss Measurements

SN Q001	33MHz	70MHz	100MHz	400MHz
Pair 1	-0.94	-1.37	-1.67	-3.41
Pair 2	-1.34	-2.02	-2.48	-5.58
Pair 3	-1.27	-1.9	-2.33	-5.19
Pair 4	-1.34	-2.02	-2.48	-5.66
Pair 5	-1.35	-2.03	-2.48	-5.7
SN Q002	**33MHz**	**70MHz**	**100MHz**	**400MHz**
Pair 1	-0.95	-1.4	-1.7	-3.5
Pair 2	-1.27	-1.89	-2.32	-5.13
Pair 3	-1.36	-2.05	-2.52	-5.68
Pair 4	-1.34	-2.01	-2.46	-5.56
Pair 5	-1.35	-2.03	-2.48	-5.62
SN Q003	**33MHz**	**70MHz**	**100MHz**	**400MHz**
Pair 1	-0.95	-1.39	-1.687	-3.44
Pair 2	-1.35	-2.03	-2.49	-5.63
Pair 3	-1.34	-2.02	-2.48	-5.7
Pair 4	-1.35	-2.03	-2.49	-5.63
Pair 5	-1.27	-1.9	-2.33	-5.16

2.0 RETURN LOSS MEASUREMENTS

Testing was carried out differentially in a frequency range from 1MHz to 400MHz. at 23 °C with the following parameters:

Start frequency:	1MHz	Stop frequency:	400MHz
Number of points:	401	IF-BW:	100Hz
Measurement:	S21	Sweep time:	5s

The results are given in Table 6 below.

Table 6. Return Loss Measurements

SN Q001	100MHz	200MHz	400MHz
Pair 1	-26.9	-26.6	-27.9
Pair 2	-21.3	-18	-12.8
Pair 3	-20.5	-21.9	-13.9
Pair 4	-21	-20.1	-12.5
Pair 5	-21.6	-18.7	-12.1
SN Q002	**100MHz**	**200MHz**	**400MHz**
Pair 1	-23.7	-25.4	-22.2
Pair 2	-20	-21.1	-15.3
Pair 3	-21	-21.4	-12.9
Pair 4	-22	-18.6	-12.5
Pair 5	-22.3	-18.3	-12.9
SN Q003	**100MHz**	**200MHz**	**400MHz**
Pair 1	-25	-27.7	-25.7
Pair 2	-20.4	-21.1	-13
Pair 3	-20.9	-20.8	-12.5
Pair 4	-22.5	-17.3	-12.3
Pair 5	-20.4	-20.3	-14.6

Physical/Mechanical Tests

Mechanical Testing was performed with the requirement that there be no electrical interruptions exceeding 1 microsecond and no disengagement of the mated connectors, evidence of cracking, breaking or loosening of parts. The test parameters are as follows:

- Resonance Search	20 - 2000 Hz	0 25 g	
	Sweep rate	4 0 oct/min	
- Sine Qualification	Frequency range:	5 - 100 Hz	
	Level:	5 - 21,3 Hz	±11 mm
		21,3 - 100 Hz	20 g
	Sweep rate:	2.0 oct/min	
	Duration:	1 sweep per axis	
- Random Qualification	Frequency range:	20 - 2000 Hz	
	Level:	20 Hz	0 026 g^2/Hz
		50 Hz	0 16 g^2/Hz
		800 Hz	0 16 g^2/Hz
		2000 Hz	0 026 g^2/Hz
	Total:	14.1 g_{RMS}	
	Duration:	180 sec per axis	
- Resonance Search	20 - 2000 Hz	0.25 g	
	Sweep rate:	4.0 oct/min	
- Shock:			
	Shape	Half-sine	
	Acceleration	500 g	
	Duration	1 ms	
	Number of shocks	1 per direction (2 per axis) total 6 shocks	

Shell-To-Shell Conductivity

Shell to shell conductivity was measured with an applied DC current of 1 ampere. Shell to shell conductivity was tested from backshell surface to backshell surface across the mated cascade assembly. The measurement is required not to exceed 65 mΩ. The backshells used for the 9-pin MDM Connector is 500T10M09H08 and the backshell for the twinax interconnect is DW 214-09-1-82822-6-0314. The results are shown in Table 7 below.

Table 7. Shell-to-Shell Conductivity Measurements

	500T10M09H08	DW 214-09-1-82822-6-0314
SN Q001	47.093	57.037
SN Q002	46.247	56.334
SN Q003	46.357	57.274

Electromagnetic Compatibility (Shielding Effectiveness)

Shielding effectiveness will be measured in accordance with IEC-60966-1, Appendix C: Shielding Effectiveness, Transfer Impedance line injection method. The requirement at 100 MHz is - 45 dB with respect to the signal.

Table 8. Shielding Effectiveness Measurements

	DC Resistance [mohms]		EMC at 100MHz	
	Test A	Test B	Test A	Test B
SN Q001	12.6	13	-101	-48
SN Q002	12.6	12.8	-105	-45
SN Q003	12.6	12.8	-103	-46

Testing Summary

The following table summarizes the testing done including testing during and after temperature cycling.

Table 9. Testing Summary

Visual Inspection	Passed	Passed	Passed
Eye Pattern Measurements	Passed	Passed	Passed
Initial Differential Impedance	Passed	Passed	Passed
Initial In-Pair Skew	Passed	Passed	Passed
Insertion Loss at 23 °C	Passed	Passed	Passed
Return Loss Measurements at 23 °C	Passed	Passed	Passed
Thermal Cycling	Performed	Performed	Performed
Insertion Loss at 23 °C after thermal cycling	Passed	Passed	Passed
Return Loss Measurements at 23 °C after thermal cycling	Passed	Passed	Passed
Initial DWV Insulation Resistance Test	Passed	Passed	Passed
Sinusoidal Vibration, Part 1: Low-Level Sweep	Passed	Passed	Passed
Sinusoidal Vibration, Part 2	Passed	Passed	Passed
Random Vibration	Passed	Passed	Passed
Shock	Passed	Passed	Passed
Insertion Loss versus Temperature	Passed	Passed	Passed
Return Loss versus Temperature	Passed	Passed	Passed
Shell To Shell Conductivity	Passed	Passed	Passed
Electromagnetic Compatibility (EMC)	Passed	Passed	Passed
Eye Pattern Measurements			
Final Differential Impedance	Passed	Passed	Passed
In-Pair Skew	Passed	Passed	Passed

Connector Comparison

The impedance of the MDM and twinax connectors were measured and is compared in Figure 3 below.

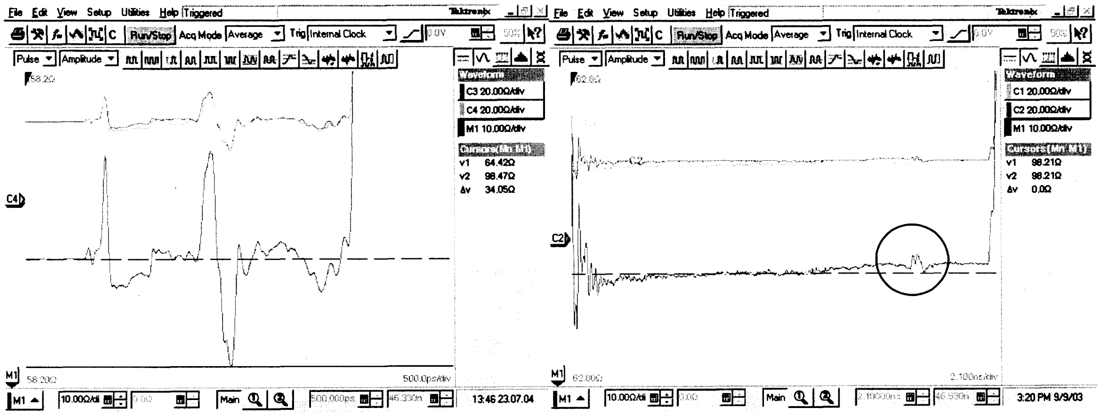

Figure 3. Comparison of MDM (left) and Twinax (right) connector impedances

Cable Comparison

The comparison between the AWG 28 and AWG 26 versions of the SpaceWire cable was tested using the configuration shown in Figure 5. The comparison of the eye patterns and return loss for the two cable configurations is shown in Figure 5 and Figure 6 and Table 10.

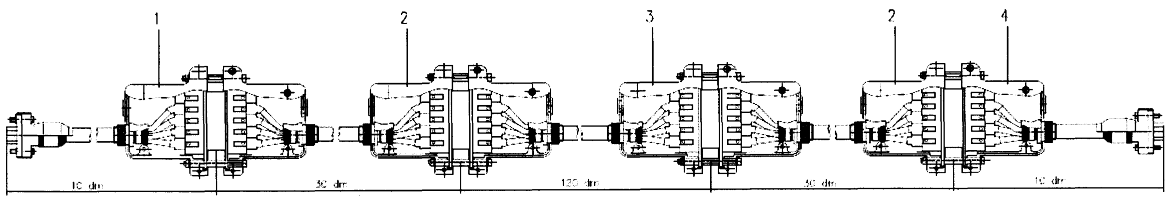

Figure 4. 20m cascade utilizing 5-way Twinax connector

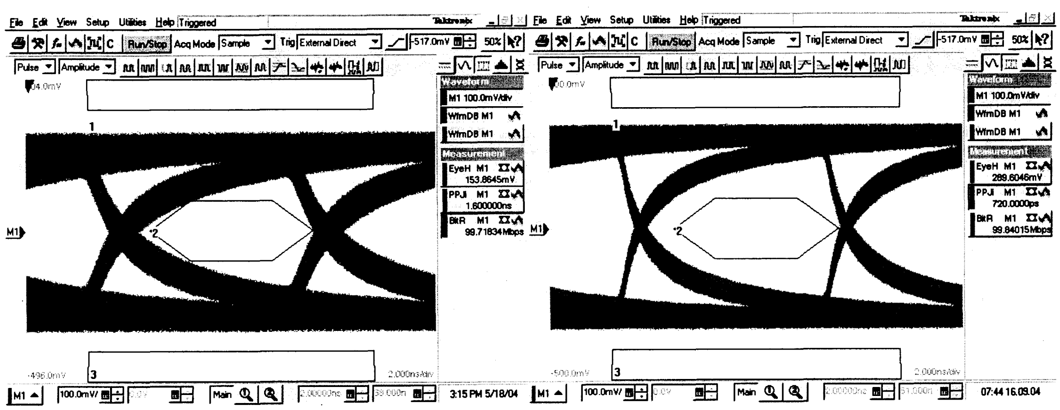

Figure 5. Eye Patterns of AWG 28 (left) and AWG 26 (right) SpaceWire Cables at 100 MHz

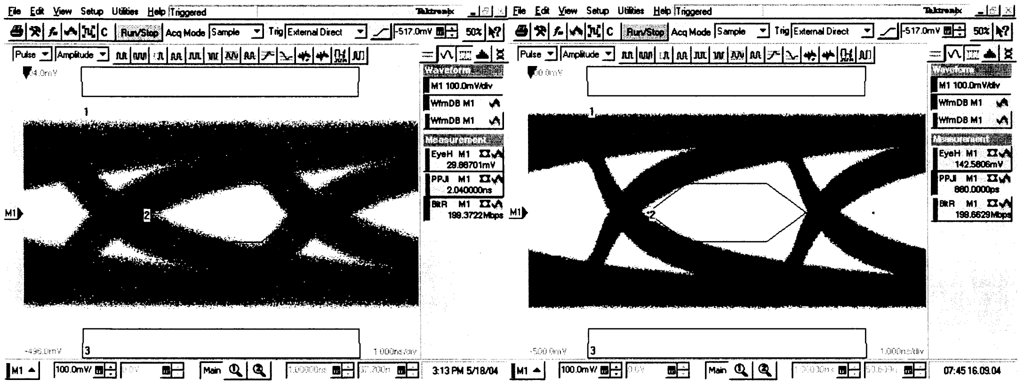

Figure 6. Eye Patterns of AWG 28 (left) and AWG 26 (right) SpaceWire Cables at 200 MHz

Table 10. Insertion loss of SpaceWire Cables

	Insertion Loss [dB/20m]		
f [MHz]	70	250	400
AWG 26	-4.96	-9.69	-12.71
AWG 28	-7.23	-14.46	-18.81

Conclusion

Testing has shown that the twinax connector is a suitable alternative to the 9-contact MDM in SpaceWire Applications. Additionally, an AWG 26 SpaceWire cable has improved technical performance and could be utilized in some applications. Size and mass properties should be weighed against the technical gains.