PARALIGHT* Active Cable Assembly, 4 Lane PN 2123287

1. INTRODUCTION

1.1. Purpose

Tests were performed on, QSFP 10 Gbs, 4 lane Active Cable assembly part number 2123287-X to determine conformance to the manufacturing processes and control procedures specified in assembly drawing 2123287-X and their conformance to the requirements of Product Specification 108-2397, Revision B. These tests were limited to the Active Cable assemblies produced by Tyco Electronics, Harrisburg, PA.

1.2. Scope

This report covers the electrical, mechanical, and environmental performance of the PARALIGHT* Active Cable QSFP 4x10, manufactured by Tyco Electronics, Harrisburg, PA. Testing was performed between November 2010 and January 2011. The test file numbers for this testing are B126326-004.

1.3. Conclusion

Fiber Optic PARALIGHT Active Cable Assembly, QSFP 10Gbs,4 Lanes, listed in paragraph 1.5, with the exception of test group 3, meets the environmental, electrical and mechanical performance requirements of Product Specification 108-2397, Revision B. After subjecting to each environmental test, mechanical, or parametric test, evidence of damage or failure to meet the specification or failure to meet the 20% Lot Tolerance Percent Defective (LTPD) Acceptance Criteria in paragraph 1.5 are noted and explained in this report.

1.4. Product Description

Tyco Electronics' PARALIGHT active optical cable assemblies use state-of-the- art technology to provide cost effective high data throughput interconnects. The cables incorporate E/O and O/E conversion built into the connector shell to yield a dramatic improvement in PCB real estate utilization. Using 850 nm VCSEL technology, the 10 Gbs active cable assemblies will operate over a data rate of 2.5 to 10 Gbs per lane with an aggregate data rate of 40 Gbs in each direction.

1.5. Test Specimens

Specimens were manufactured using normal production means and selected at random from current production. Where noted, some specimens were used for more than one test group.

Test Group	1	2	3	4	5	6	7	8
Cable Assembly Part Number	2123287-2 QSFP 10Gbs							
Test Specimen Quantity/Failures Allowed	18/1	18/1	18/1	32/3	18/1	11/0	5/0	1/0
Control Cable Required	Yes	Yes	Yes	Yes	Yes	Yes	No	No

1.6. Product Test Groups and Sequences

Test or Examination	Test Group (a)							
	1	2	3	4	5	6	7	8
	Test Sequence (b)							
Examination of product	1	1	1	1	1	1	1	1
RX output eye width	2,6,8,10	2,6,10,12	2,6	2,6	2,6,8,11	2,7,9,11	2,6	2
RX output eye height	3	3,7,13	3,7	3,7	3,9,12	3	3	3
Supply current per cable end	4	4,8,14	4,8	4,8	4	4	4	4
ESD, human body							5	
EMI test								5
Vibration, variable frequency	5							
Mechanical shock	7							
Durability					5			
Flex					7			
Twist					10			
Insertion force						5		
Withdrawal force						6		
Retention force						8		
Off-axis load capability						10		
Thermal shock	9							
Thermal operation (4 corners test)		5						
Temperature cycling, non-operating		9						
Moisture resistance		11						
Humidity (life test)			5					
Accelerated aging (life test)				5				

NOTE

(a) See paragraph 1.5.
(b) Numbers indicate sequence in which tests are performed.

2. SUMMARY OF TESTING

2.1. Examination of Product

All specimens submitted for testing were manufactured by Tyco Electronics using normal production processes, and were inspected and accepted by the Product Assurance Department.

2.2. Initial Performance - All Test Groups

All electrical measurements from a quantity of 125 QSFP 10Gbs samples met the specification requirements for new product.

Table 1, New Product Performance, QSFP 10 Gbs

Performance Criteria	Requirements	Actual
Eye Width (picoseconds)	65 minimum (see Note)	65.28 minimum 74.71 median
Eye Height (millivolts)	200 minimum 1000 maximum	305 minimum 334 median 359 maximum
Supply Current (milliamperes)	600 maximum	256 maximum 245 median

NOTE *65 picoseconds eye width corresponds to 0.65 U.I.*

2.3. Test Results

Test results are summarized in Tables 2, 3 and 4 below.

Table 2, Parametric Test Results During and After Test, QSFP 10 Gbs

Test Group	Condition	Requirements		Actual	
		During	After	During	After
1	Vibration	NA	58 (W_{min}) <15% (W_{Δ})	NA	63 (W_{min}) see Note 74 (W_{med}) 11.9% (W_{Δ})
1	Mechanical shock	NA	58 (W_{min}) <15% (W_{Δ})	NA	66 (W_{min}) 76(W_{med}) 10.5% (W_{Δ})
1	Thermal shock	NA	58 (W_{min}) <15% (W_{Δ})	NA	66 (W_{min}) 76 (W_{med}) 11.6% (W_{Δ})
2	Thermal operation and 4 corners test	See Table 3			
2	Temperature cycling	NA	58 (W_{min})	NA	70 (W_{min}) 76 (W_{med})
2	Moisture resistance	NA	58 (W_{min})	NA	63 (W_{min}) 74.1 (W_{med})
3	Humidity	NA	1000 hours: 200 (H_{min}) 1000 (H_{max}) 58 (W_{min}) 600 (C_{max})	482 hours: 61 (W_{min}) 255 (C_{max})	292 (H_{min}) 352 (H_{max}) 64 (W_{min}) see Note 254 (C_{max})

Table 2 (continued)

Test Group	Condition	Requirements		Actual	
		During	After	During	After
4	Accelerated aging	NA	1000 hours: 200 (H_{min}) 1000 (H_{max}) 58 (W_{min}) 600 (C_{max})	569 hours: 64(W_{min}) 255 (C_{max})	297 (H_{min}) 351 (H_{max}) 63 (W_{min}) 258(C_{max})
	Durability		58 (W_{min}) <15% (W_{Δ})		66 (W_{min}) 76 (W_{med}) 4.2% (W_{Δ})
5	Flex	NA	200 (H_{min}) 1000 (H_{max}) 58 (W_{min}) <15% (W_{Δ})	NA	306 (H_{min}) 334 (H_{med}) 360 (H_{max}) 67 (W_{min}) 77 (W_{med}) 7.4% (W_{Δ})
	Twist		200(H_{min}) 1000 (H_{max}) 58 (W_{min}) <15% (W_{Δ})		297 (H_{min}) 330 (H_{med}) 360 (H_{max}) 66 (W_{min}) 76 (W_{med}) 9.7% (W_{Δ})
	Insertion force	No parametric requirements		Results given in Table 4	
	Withdrawal force				
6	Retention force	200 (H_{min}) 1000 (H_{max}) 15% (W_{Δ})	58 (W_{min}) <15% (W_{Δ})	295 (H_{min}) 334 (H_{med}) 358 (H_{max}) 9.2 % (W_{Δ})	69 (W_{min}) 76 (W_{med}) 7.7% (W_{Δ})
	Off-axis load capability	200 (H_{min}) 1000 (H_{max}) 15% (W_{Δ})	58 (W_{min}) <15% (W_{Δ})	221 (H_{min}) 337 (H_{med}) 356 (H_{max}) 10.0% (W_{Δ})	70 (W_{min}) 76 (W_{med}) 5.0% (W_{Δ})
7	ESD	NA	58 (W_{min}) <15% (W_{Δ})	NA	71 (W_{min}) 2.9% (W_{Δ})
8	EMI	No parametric requirements			Passed

NOTE *See paragraph 4. for failure details.*

KEY:
(W_{min}) - Minimum Eye Width in picoseconds;
(W_{med}) - Median Eye Width in picoseconds;
(W_{Δ}) - Maximum Percent Decrease in Eye Width;
(H_{min}) - Minimum Eye Height in millivolts;
(H_{med}) - Median Eye Height in millivolts;
(H_{max}) - Maximum Eye Height in millivolts;
(C_{max}) - Maximum Supply Current per cable end in milliamperes.

Table 2 (end)

Table 3, Thermal Operation/4 Corners Test, QSFP 10 Gbs

<table>
<tr><th rowspan="2">Test Condition</th><th colspan="2">Requirements</th><th colspan="2">Actual</th></tr>
<tr><th>During</th><th>After</th><th>During</th><th>After</th></tr>
<tr><td>25°C + Trise, 3.3 volts</td><td>58 (W_{min})
200 (H_{min})
1000 (H_{max})
600 (C_{max})</td><td rowspan="5">58 (W_{min})</td><td>67 (W_{min})
74 (W_{med})
249 (H_{min})
292 (H_{max})
256 (C_{max})</td><td rowspan="5">67 (W_{min})
75 (W_{med})</td></tr>
<tr><td>0°C, 3.13 volts</td><td rowspan="4">58 (W_{min})
200 (H_{min})
1000 (H_{max})
600 (C_{max})</td><td>59 (W_{min})
70 (W_{med})
227 (H_{min})
287 (H_{max})
246 (C_{max})</td></tr>
<tr><td>0°C, 3.47 volts</td><td>62 (W_{min})
70 (W_{med})
210 (H_{min})
295 (H_{max})
247 (C_{max})</td></tr>
<tr><td>70°C, 3.13 volts</td><td>62 (W_{min}) see Note
73 (W_{med})
225 (H_{min})
286 (H_{max})
260 (C_{max})</td></tr>
<tr><td>70°C, 3.47 volts</td><td>63 (W_{min})
78 (W_{med})
246 (H_{min})
295 (H_{max})
268 (C_{max})</td></tr>
</table>

NOTE *See paragraph 4. for failure details.*

KEY: (W_{min}) - Minimum Eye Width in picoseconds; 65 ps corresponds to 0.65 U.I. and 58 ps corresponds to 0.58 U.I.;
(W_{med}) - Median Eye Width in picoseconds;
(H_{min}) - Minimum Eye Height in millivolts;
(H_{med}) - Median Eye Height in millivolts;
(H_{max}) - Maximum Eye Height in millivolts;
(C_{max}) - Maximum Supply Current per cable end in milliamperes.

Table 4, Insertion and Withdrawal Forces, QSFP 10 Gbs

Test Condition	Requirement (N [lbf])	Actual (N [lbf])
Insertion force	40.0 [9.0] maximum	34.8 [7.8] maximum
Withdrawal force	30.0 [6.7] maximum	28.1 [6.3] maximum

3. TEST METHODS

Initial electrical performance was recorded by verifying eye width, eye height, and supply current, then the sequential testing was performed.

Eye width is measured with a Centellax TGB1A BERT. A bathtub curve is generated by sampling points between a BER of 1e-4 and 1e-10 on each side of the eye and then extrapolating in order to compute the eye width at a BER of 1e-12.

Eye height is measured using an Agilent 86100A DCA. The measurement is made halfway between the two crossing points and extrapolates the vertical eye opening by fitting a Gaussian probability density curve to the upper and lower rails and extrapolating inward to 3 standard deviations. This measurement is part of the DCAs built in functionality.

Supply current is measured once at the start of a test using a calibrated programmable power supply (HP 6624A) with all 8 VCSELS being modulated.

3.1. Visual and Mechanical Inspection (TIA/EIA-455-13A)

Product drawings and inspection plans were used to examine the specimens. They were examined visually and functionally.

3.2. Vibration

Specimens were secured to the vibration platform and subjected to 4 sweeps of simple harmonic motion with a 1.5 mm [.06 in] peak-to-peak displacement (10%) below the crossover frequency and 20 G (+20/-0%) acceleration above the crossover frequency in each of 3 mutually perpendicular axes. Each sweep consisted of logarithmically varying the frequency from 20 to 2000 and back to 20 Hz during a 4 minute period. Exposure time in each axis was 16 minutes. Total exposure time was 48 minutes. Performance data of the specimens was recorded before and after the exposure.

3.3. Mechanical Shock

Specimens were secured to the mechanical shock platform and subjected to 500 G (distortion ≤ 20%), 1 millisecond (tolerances of the greater, 0.1 ms or 30%) half-sine shock pulses. Five shock pulses were applied in 6 mutually perpendicular axes. The total number of shock pulses was 30. Performance data of the specimens was recorded before and after the exposure.

3.4. Thermal Shock

Specimens were exposed to 15 thermal shock cycles. Each cycle consisted of a 30 minute dwell at 100 +10/-2°C followed by a 30 minute dwell at 0 +2/-10°C. Maximum transfer time between the temperature extremes was 10 seconds. Performance data of the specimens was recorded before and after the exposure.

3.5. Thermal Operation and 4 Corners Test

Specimens were exposed at operating (case) temperature extremes (0 and 70°C) at minimum and maximum power supply voltage. In addition, test at nominal voltage and room ambient plus Trise temperature, for a total of 5 sets of data. TX differential input voltage level was set to minimum value. Record RX output eye width, RX output eye height, and supply current for each combination of temperature and voltage conditions.

3.6. Temperature Cycling, Non Operating

Specimens were exposed to 100 temperature cycles between -40 +0/-10°C and 85 +10/-0°C. The dwell time at each temperature extreme was 30 minutes. The ramp time was 12 minutes for a ramp rate $\geq$ 10°C per minute. Performance data of the specimens was recorded before and after the exposure.

3.7. Moisture Resistance

Specimens were exposed without any prior conditioning to 20 cycles between 25 +10/-2°C and 65 ± 2°C with humidity between 90 and 100% RH during the ramp to and dwell at 65°C. During the ramp to and dwell at 25°C, the humidity was between 80 and 100% RH. Starting with the 2nd cycle and repeating every other cycle, a cold temperature sub-cycle at -10 +2/-5°C and uncontrolled humidity was performed. The specimens were powered except during the cold temperature sub-cycles. Performance data of the specimens was recorded before the exposure. Final performance data was recorded within 48 hours after the specimens returned to ambient conditions.

3.8. Humidity

Specimens were preconditioned in a dry oven at 40 ± 5°C for 24 hours. Initial performance data was recorded after preconditioning. Specimens were powered and exposed to 85 ± 2°C and 85 ± 2% RH for a 1000 hour period. Interim performance data was recorded after 168 hours and 500 hours. Interim and final performance data was recorded as soon as possible after the samples were at room ambient for 1 hour In order to shorten the time of test to accurately determine Failure In Time (FIT) and Mean Time To Failure (MTTF), Tyco Electronics elected to perform certain of our qualification tests at stress levels in excess of design margin of some PARALIGHT components. While this accelerates the time to achieve FIT and MTTF data, it increases the probability of stress-related failures. In the limited cases where such overstress failures occur, they were discounted and were not included in qualification or reliability calculations.

3.9. Accelerated Aging (Life Test)

Specimens were powered and exposed to 85 ± 2°C, low humidity for a 1000 hour period. Interim performance data was recorded after 500 hours. Interim and final performance data was recorded as soon as possible after the samples were at room ambient for 1 hour. In order to shorten the time of test to accurately determine FIT and MTTF, Tyco Electronics elected to perform certain of our qualification tests at stress levels in excess of design margin of some PARALIGHT components. While this accelerates the time to achieve FIT and MTTF data, it increases the probability of stress-related failures. In the limited cases where such overstress failures occur, they were discounted and were not included in qualification or reliability calculations.

3.10. Durability (EIA-364-09C)

One connector end of each specimen was manually mated to and unmated from a corresponding socket, which was mounted to a PCB. A total of 250 durability cycles were performed at a maximum rate of 500 cycles per hour. Performance data of the specimens was recorded before and after the test.

3.11. Flex (TIA/EIA-455-1B)

Using automated equipment, 1 connector end of each specimen was subjected to 200 flexing cycles; 100 cycles with the connector mounted in a 0 degree orientation (cable flexing toward the top and bottom of the connector) and 100 cycles with the connector mounted in a 90 degree orientation (cable flexing toward the sides of the connector). Specimens were tested at a rate of approximately 30 cycles per minute. A 7.62 cm [3 in] mandrel was used to apply a tensile load of 4.9 N [1.1 lbf] to the specimen cable at a point 30.5 cm [12 in] from the strain relief boot of the connector under test. The flex arc was ± 90 degrees from a vertical position. Performance data of the specimens was recorded before and after the test.

3.12. Twist (TIA-455-36A)

Using automated equipment, 1 connector end of each specimen was subjected to 500 twist cycles. The specimen cables were twisted at a rate of approximately 30 cycles per minute. A 7.62 cm [3 in] mandrel was used to apply a tensile load of 14.7 N [3.3 lbf] to the specimen cable at a point 25.4 cm [10 in] from the strain relief boot of the connector under test. The twist arc was ± 90 degrees from a vertical (normally untwisted) position. Performance data of the specimens was recorded before and after the test.

3.13. Insertion Force and Withdrawal force (EIA/ECA-364-13D)

Using automated equipment, the force necessary to mate each specimen to a corresponding socket at a maximum rate of 12.7 mm [0.5 in] per minute was measured. The force necessary to unmate each specimen from the corresponding socket at a maximum rate of 12.7 mm [0.5 in] per minute was measured. One connector end of each specimen was tested. Performance data was recorded before and after the test.

3.14. Retention Force (EIA-364-38B)

One connector end of each specimen was mated to the corresponding socket of a test board and subjected to a sustained axial load of 89 N [20 lbf]. Using a 7.62 cm [3 in] mandrel, the load was manually applied to the cable at a point 30.5 cm [1 ft] from the strain relief boot of the connector under test. Performance data was recorded before applying the load, at least 1 minute after applying the load, and after removing the load.

3.15. Off-axis Load Capability

One connector end of each specimen was mated to the corresponding socket of a test board and subjected to a sustained load of 22.2 N [5 lbf]. Using a 7.62 cm [3 in] mandrel, the load was manually applied to the cable at a point 30.5 cm [1 ft] from the strain relief boot of the connector under test and at a 90 degree angle to the axis orientation of the connector. A 50 mm [3 in] diameter "half moon" mandrel was positioned at the end of the crimp body to ensure that the strain relief and cable exiting the connector did not exceed the minimum radius of 25 mm [1 in]. Performance data was recorded before applying the load and at least 1 minute after applying the load. The load was manually removed, the orientation of the connector rotated 90 degrees and the test repeated. The test was performed in a total of 4 directions (with load applied parallel and perpendicular to the I/O plate). Performance data was recorded after completing the test.

3.16. Electrostatic Discharge (ESD)

Testing was performed in accordance with JEDEC JESD22-A114D. Class 1B,human body model. ESD shall be tested on each I/O pin relative to power and ground.

3.17. Electromagnetic Interference (EMI)

EMI Testing was performed with the device under test (DUT) connected to a Mellanox Host Card Adapter installed in a PC. The DUT and the PC was placed in a semi-anechoic chamber on a turntable allowing the test platform to be rotated 360 degrees. A log-periodic antenna measured emissions from 30 MHZ to 1 GHz 3 meters away from the test system. A horn antenna measured emissions from 1 to 7 GHz 1 meter away from the test system. Both antennas were positioned horizontally and vertically at 1 meter heights measured from the chamber floor.

4. FAILURE ANALYSIS

4.1 Vibration

Eighteen cable assemblies were exposed to vibration testing. One cable assembly failed for the post end-of-life measurement requirement for eye width of 58 picoseconds, measuring -999 picoseconds. Development engineering performed a thorough analysis on the failed engine to identify the root cause of the failure. Failure analysis indicated that a fiber had broken during the vibration test. The cause for the failure was a design in the upper housing that included a protrusion for the heat sink that was required in a previous design. This protrusion was indenting the fibers exiting the lens, placing unnecessary pressure/bending stress on the fibers. The corrective action taken was to remove the center protrusion which is no longer needed in this new design to allow more clearance for the fibers exiting the lens. The LTPD sampling requirement was met in this test-allowing for one failure in a sample size of 18.

4.2. 4-Corners

Eighteen cable assemblies were exposed to 4 corner testing. One cable assembly failed the eye width requirement for 70° at 3.13 volts with a reading of 51 picoseconds for Lane A0. Development engineering performed a thorough analysis on the failed engine to identify the root cause of the failure. Failure analysis indicated that during the burn-in screen, the software program routine had an error in which it did not record the pre- and post- burn-in optical power for VCSEL lanes A0 and B0. This part would have been rejected at post burn-in had the software worked properly and would not have been submitted for testing. The corrective action was to correct the burn in screen software routine so that it records and evaluates the optical power of all 4 lanes. The LTPD sampling requirement was met in this test-allowing for one failure in a sample size of 18.

4.3. Humidity

Eighteen cable assemblies were exposed to 1,000 hour humidity soak. Two units exhibited degraded performance on one of the four lanes for the post end of life requirement for eye width of 58 picoseconds. One sample was measured as failing at 168 hours (SN 123). The second sample was measured as failing at 1000 hours (SN 109). Development engineering performed a thorough analysis on the failed engines to identify the root cause of each failure. SN 123 was found to have epoxy penetration between the lens block and the surface of the PCB. This penetration was predominant at the end of the lens at lanes 0 and 1. Failure to properly seat the lens block when bonding it to the PCB allowed a gap into which the Epotek 353 attaching epoxy wicked by capillary action. For corrective action, an auto-alignment process will be implemented for attaching the lens to the pyrex surface which will greatly reduce or eliminate the variability of what is currently a manual alignment process. The auto-aligner will precisely dispense a set volume of epoxy to the lens and will improve the repeatability in the location of applied epoxy and the force on the lens as it is held to the pyrex surface. This tool provides continuous positive force to ensure full surface contact of the lens block to the PCB during the application and tack curing of the epoxy.

SN 109 was found to have contamination in the lens bore of lane 6, between the end face of the fiber and the rear face of the lens bore. This condition cannot be "seen" with the fiber and lens installed. Installation of the cleaved fibers into the lens block bores is a blind insertion. At the point of insertion, the lens block has been bonded in place on the PCB, and neither the lens nor turning mirror is directly observable. Corrective action to screen material in the optical path will be added to the assembly process which will measure the optical power to the RX. By reducing the voltage to the RX end of the cable assembly and enabling each VCSEL on the TX end of each lane individually, the optical power of each lane can be measured as it is proportional to the current draw of the RX module.

Both failures in humidity testing were conclusively shown to be the result of human process interaction in the mechanical assembly of the optical components of the unit. Neither involved the active elements of the cable assembly. In both cases, the active engines, and supporting electronics, met specification and continued to perform within design parameters following the biased damp heat test. Definitive causes were identified for each physical anomaly. Regardless of low frequency of these mechanical workmanship deviations, positive corrective actions were identified and implemented for each that prevent recurrence. We believe that the focus of the biased damp heat testing, as detailed in paragraph 3.3.3.3 of Telcordia GR-468, is to apply cumulative combined environmental stress on the "…devices", specifically the VCSEL's, PINs, and associated silicon IC drive devices. Indeed, the title of section 3.3.3.3 is "Damp Heat (Powered Tests for non-hermetic devices)". The PARALIGHT QSFP "devices" performed flawlessly in this test, and in the associated High Temp Operating Life (HTOL) test. We therefore find the subject Active Optical Cable to have fully demonstrated function, robustness, and durability to warrant full Commercial Release.