



IPC-D-640

# **Design and Critical Process Requirements for Optical Fiber, Optical Cable and Hybrid Wiring Harness Assemblies**

Developed by the Fiber Optic Cable Acceptability Task Group (7-31m)  
of the Acceptability Subcommittee (7-31) of IPC

Users of this publication are encouraged to participate in the  
development of future revisions.

Contact:

IPC

# Table of Contents

<b>1 SCOPE</b> .....	1	2.2 Military Handbooks .....	7
1.1 Purpose .....	1	2.2.1 U.S. Department of Defense (DoD) .....	7
1.2 Performance/Product Classification .....	1	2.3 Military Specifications .....	7
1.3 Definition of Requirements .....	2	2.3.1 Department of Defense (DoD) .....	7
1.3.1 Design Requirement Format (A/N) .....	2	2.3.2 U.S. Naval Research Laboratory (NRL) .....	7
1.3.2 Requirements Flowdown .....	2	2.4 Reference Documents .....	7
1.3.3 Notes/Italicized Text .....	2	2.4.1 IPC .....	8
1.3.4 Commercial Off-the-Shelf (COTS) .....	2	2.4.2 Department of Defense (DoD) .....	8
1.3.5 Existing or Previously Approved Designs .....	2	2.4.3 Aeronautical Radio, Incorporated (ARINC)/SAE Industry Technologies Consortia (ITC) .....	8
1.3.6 Line Drawings and Illustrations .....	3	2.4.4 Electronic Components Industry Association (ECIA) .....	8
1.4 Measurement Units and Applications .....	3	2.4.5 IEEE .....	8
1.5 Definition of Terms .....	3	2.4.6 National Aeronautics and Space Administration (NASA) .....	9
1.6 Engineering Documentation .....	3	2.4.7 International Organization for Standardization (ISO) .....	9
1.7 Order of Precedence .....	3	2.4.8 Laser Institute of America (LIA) .....	9
1.7.1 Conflict .....	3	2.4.9 National Electrical Manufacturers Association (NEMA) .....	9
1.7.2 Clause References .....	3	2.4.10 SAE International .....	9
1.8 Appendices A – C .....	3	2.4.11 Telecommunications Industry Association (TIA) .....	9
1.9 Approval of Departures From Standards and Requirements .....	3	<b>3 DESIGN PHILOSOPHY</b> .....	10
1.10 Foreign Object Debris (FOD) Control Plan .....	4	3.1 General Design Requirements .....	10
1.11 Safety .....	4	3.2 System Requirements Specification (SyRS) .....	11
1.11.1 Chemicals .....	4	3.2.1 Interface Control Document (ICD) .....	11
1.11.2 Eye Safety – Energized Source Concern .....	5	3.2.2 System Power Budget (Link Loss Budget + Unallocated Margin) .....	17
<b>2 APPLICABLE DOCUMENTS</b> .....	5	3.2.3 Performance and Reliability .....	19
2.1 Commercial .....	5	3.2.4 Environmental Requirements .....	20
2.1.1 IPC .....	5	3.2.5 Packaging, Handling, Shipping and Transportation (PHS&T) .....	20
2.1.2 American Society of Mechanical Engineers (ASME) .....	5	3.2.6 Documentation Requirements .....	20
2.1.3 American Society for Testing and Materials (ASTM) .....	6	3.2.7 Intellectual Property (IP) Control Requirements .....	20
2.1.4 Institute of Electrical and Electronics Engineers (IEEE) .....	6	3.2.8 Physical Security .....	20
2.1.5 International Electrotechnical Commission (IEC) .....	6	<b>4 SELECTION OF PARTS, MATERIALS AND PROCESSES</b> .....	22
2.1.6 International Organization for Standardization (ISO) .....	6	4.1 Commonality .....	22
2.1.7 International Telecommunications Union (ITU) .....	6	4.2 Flammability .....	22
2.1.8 Laser Institute of America (LIA) .....	6	4.3 Outgassing .....	22
2.1.9 National Fire Protection Association (NFPA) .....	7	4.4 Materials Requiring Cure .....	22
2.1.10 SAE International .....	7	4.5 Dissimilar Metals .....	22
2.1.11 Telecommunications Industry Association (TIA) .....	7		
2.1.12 UL .....	7		

4.6	Optical Fiber and Cable .....	22	6.1.3	Bend Radii .....	39
4.6.1	Strength Member .....	23	6.1.4	Axial Alignment .....	39
4.6.2	External Jacket(s) .....	23	6.1.5	Tensile Load .....	39
4.6.3	Cable Types .....	23	6.1.6	Mating .....	40
4.7	Connectors .....	27	6.1.7	Torquing .....	40
4.7.1	Mating Provisions .....	27	6.1.8	Coefficient of Thermal Expansion (CTE) Issues .....	40
4.8	Attenuators, Couplers, Splices, and Other Interconnecting Components .....	29	6.2	Routing .....	40
4.8.1	Attenuators .....	29	6.3	Protection and Support .....	40
4.8.2	Couplers .....	29	<b>7</b>	<b>CLEANING</b> .....	41
4.8.3	Isolators .....	30	7.1	General Requirements .....	41
4.8.4	Pigtailed Component .....	30	7.1.1	Solvents .....	41
4.8.5	Splices .....	30	7.1.2	Wipes/Swabs .....	41
4.8.6	Identification and Marking .....	31	7.1.3	Drying .....	41
4.9	Prohibited/Restricted Usage Parts, Materials, Processes (PMP) .....	33	<b>8</b>	<b>DOCUMENTATION</b> .....	42
4.9.1	Acetic Acid-Cure Room-Temperature Vulcanizing (RTV) Silicone Sealants, Adhesives and Coatings .....	33	8.1	General .....	42
4.9.2	Beeswax/Wax (All Types) Lacing Tape .....	34	8.2	Data .....	42
4.9.3	Beryllium (Be) .....	34	8.3	Connector Orientation (Clocking) .....	42
4.9.4	Cadmium (Cd) .....	34	8.4	Connector Pin-Out .....	42
4.9.5	Cuprous Oxide Corrosion (Red Plague) .....	34	8.5	Dimensioning and Tolerance .....	43
4.9.6	Fluorine Attack (White Plague) .....	35	8.6	Documentation for Maintenance/ Emergency Restoration .....	43
4.9.7	FN/HN-Grade Polyimide (Kapton®) .....	35	<b>9</b>	<b>TAILORING</b> .....	44
4.9.8	Glass/Glass-Like Materials .....	36	9.1	Alternate Technological Applications – Fiber Optic Sensor (FOS) .....	44
4.9.9	Use of Lead-Free Tin (Sn) Materials and/or Processes .....	36	<b>10</b>	<b>DEFINITIONS AND ACRONYMS</b> .....	45
4.9.10	Lock Washers (Star/Tooth Type) .....	36	<b>11</b>	<b>TABLES</b> .....	58
4.9.11	Magnesium .....	37	<b>APPENDICES</b>	<b>HOW TO USE THE APPENDICES</b> ....	63
4.9.12	Mercury .....	37	<b>APPENDIX A</b>	<b>Military/Space Applications Requirements</b> .....	64
4.9.13	Micro-D Connectors .....	37	<b>APPENDIX B</b>	<b>Test Methods for the Verification of Optical Fiber Fabrication Processes</b> .....	66
4.9.14	Natural Rubber Materials .....	38	<b>APPENDIX C</b>	<b>Verification and Validation Matrix</b> ....	68
4.9.15	Polyvinyl Chloride (PVC/Vinyl) .....	38		<b>Figures</b>	
4.9.16	Silver .....	38	Figure 1-1	Optical Fiber Assemblies, Cables and Wiring Harnesses Connector, Splice and Transmitter.....	1
4.9.17	Splices .....	38	Figure 3-1	Basic Types of Optical Cables.....	10
4.9.18	Zinc .....	38	Figure 3-2	Physical Contact (PC) Connector (Cross-Section).....	13
4.10	Time-Critical or Limited-Life .....	38	Figure 3-3	Common Commercial Single-Channel PC Connectors .....	13
4.11	Moisture Protection .....	38	Figure 3-4	Optical Fiber Contact (M29504/4 & M29504/5).....	14
<b>5</b>	<b>ASSEMBLY</b> .....	39			
5.1	Optical Fiber End Preparation .....	39			
5.2	Optical Fiber – Connector Termination .....	39			
<b>6</b>	<b>INSTALLATION</b> .....	39			
6.1	General Installation Requirements .....	39			
6.1.1	Bundling (Fiber in the Wiring Harness) .....	39			
6.1.2	Conduits .....	39			

Figure 3-5	Multichannel Optical Connector (ARINC 801) .....	14	Figure 4-17	White Plague (Fluorine Attack) .....	35
Figure 3-6	Expanded Beam (EB) Connector (Cross-Section) .....	14	Figure 4-18	FN/HN Grade Polyimide (Kapton®) .....	35
Figure 3-7	EB Multichannel Contact .....	15	Figure 4-19	Glass/Glass-Like Materials (e.g., Fuses) .....	36
Figure 3-8	EB Multichannel Connector .....	15	Figure 4-20	Tin Whiskers on Cardguide .....	36
Figure 3-9	Design Process Flowchart .....	21	Figure 4-21	Lock Washer (Internal/Split/External Tooth) ....	37
Figure 4-1	Simplex/Duplex Detail (Interconnect Cable – Tight Buffer) .....	23	Figure 4-22	Serrated-Face/Wedge-Lock Washer (Paired Set) .....	37
Figure 4-2	Distribution Cable Detail (Tight Buffer) .....	23	Figure 4-23	Micro-D Connector (Fiber/Copper Combination) .....	37
Figure 4-3	Breakout Cable Detail (Tight Buffer) .....	24	Figure 6-1	Improper Axial Alignment .....	39
Figure 4-4	Loose Tube Cable Detail (Indoor/Outdoor Riser) .....	24	Figure 8-1	Connector Orientation (Clocking) and Mating Face View (Inset) .....	43
Figure 4-5	Ribbon Cable Detail (Riser/Plenum Rated) .....	24	<b>Tables</b>		
Figure 4-6	Armored Cable Detail (Tight Buffer) .....	25	Table 11-1	Bend Radius .....	59
Figure 4-7	Aerial Armored Cable Detail .....	25	Table 11-2	Optical Fiber/Cable Length Measurement Tolerance .....	59
Figure 4-8	Blown Optical Fiber Tube (BOFT) .....	26	Table 11-3	Optical Power (Absolute Power and Power Loss) .....	60
Figure 4-9	Crashed Endface .....	27	Table 11-4	Typical Transmitter Specifications .....	60
Figure 4-10	Attenuator .....	29	Table 11-5	Comparison of LED and LD Transmitter Parameters .....	60
Figure 4-11	T-Coupler/Splitter .....	29	Table 11-6	Comparison of Optical Cable Types .....	61
Figure 4-12	Isolator .....	30	Table 11-7	Typical Optical Fiber Specifications .....	62
Figure 4-13	Pigttailed Component (Cover Removed) .....	30	Table A1	Military/Space Applications Requirements .....	65
Figure 4-14	Mechanical Splice .....	30	Table B-1	Test Methods for the Verification of Optical Fiber Fabrication Processes .....	67
Figure 4-15	Waxed Lacing Tape .....	34			
Figure 4-16	Red Plague (Cuprous Oxide Corrosion) .....	35			

# Design and Critical Process Requirements for Optical Fiber, Optical Cable and Hybrid Wiring Harness Assemblies

## 1 SCOPE

This document provides design and critical process requirements and technical insight for cable and wire harness assemblies incorporating optical fiber, optical cable and hybrid wiring technology. Reference materials listed in this text are among those considered as required reading. The User is encouraged to obtain all relevant referenced materials, as this document cannot (nor can any single document) cover every material, process, environment, performance or safety aspect that affect a given design.

**1.1 Purpose** This standard is intended to provide information on the general design requirements for optical fiber, optical cable, hybrid wiring harness assemblies and fiber optic communications systems (FOCS) to the extent that they can be applied to the broad spectrum of optical cable and wiring harness design (see Figure 1-1).

This document is intended for use by the design engineer, manufacturing engineer, quality engineer or other individual responsible for the tailoring of specific requirements of this document to the applicable performance class.

It is not the intent of this document to exclude any alternate or contractor-proprietary documents or processes that meet or exceed the baseline requirements established by this document. Use of alternate or contractor-proprietary documents or processes **shall [A1A2A3]** require review and prior approval of the User.

For purposes of this document:

- a) The Designer is the design agent for the User.
- b) The User is the individual, organization, company, contractually designated authority or agency responsible for the procurement or design of electrical/electronic/electromechanical (EEE) hardware, and having the authority to define the class of equipment and any variation or restrictions to the requirements of this document (i.e., the originator/custodian of the contract detailing these requirements). The User is considered the Design Authority.
- c) The Supplier is considered the individual, organization or company which provides the Manufacturer (assembler) with components (e.g., electrical, electronic, electromechanical, mechanical, printed boards, etc.) and/or materials (e.g., solder, flux, cleaning agents, etc.).
- d) The Manufacturer is considered the entity that provides a service or product to the User.

**1.2 Performance/Product Classification** This document recognizes that optical wiring harnesses and cable assemblies are subject to performance/product classifications by intended end-item use. Three general end-product classes have been established to reflect differences in producibility, complexity, functional performance requirements and verification (inspection/test) frequency. It should be recognized that there may be requirement overlaps between classes.

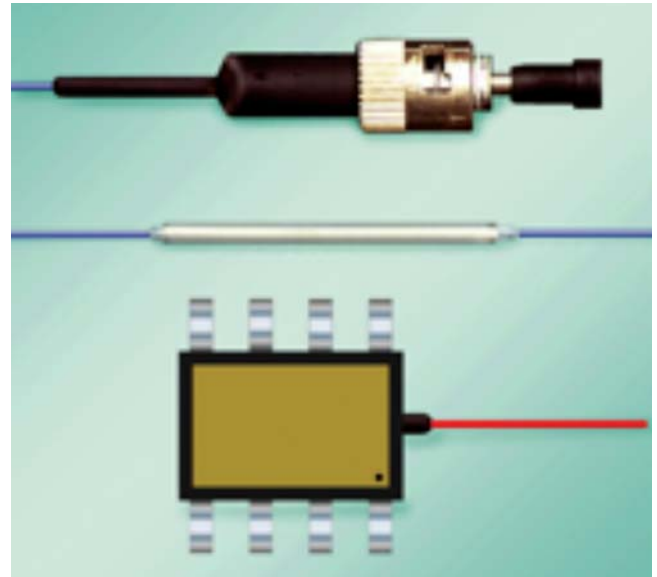
The User is responsible for defining the product class. The contract **shall [A1A2A3]** specify the performance class required, whether compliance to any of the Appendices is required and indicate any exceptions to specific parameters where appropriate.

### CLASS 1 – General Electronic Products

Includes products suitable for applications where the major requirement is function of the completed assembly.

### CLASS 2 – Dedicated Service Electronic Products

Includes products where continued performance and extended life are required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.



**Figure 1-1 Optical Fiber Assemblies, Cables and Wiring Harnesses Connector, Splice and Transmitter**