PRAGMATIC MIL-AEROSPACE OPTICAL TRANSCEIVER QUALIFICATIONS

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Abstract

This invited paper presents a summary of qualification data and tests applied for harsh environment optical interconnect solutions and more especially optical transceivers.

Introduction

Thanks to the main advantages of optical communications regarding severe environments (EMI, weight, Losses), optical interconnects solutions are increasingly used in Military and Aerospace applications. The necessity to provide a common and recognized qualification plan and workflow is becoming more and more important. We present hereafter a pragmatic approach to qualify MIL-AERO grade optical transceivers. After summarizing some of the main optical transceiver characteristics or parameters that shall be tested in conjunction of the environmental stresses, we describe when and where qualification by similarity can be applied. The Qualification Tests are therefore listed per the operational environments.

Transceivers Characteristics

Among the various parameters and characteristics of the optical transceivers to monitor within the environments the transmission Link Budget (L_B) is definitively the one to carefully follow. The Link Budget – that represents the total losses margin available for the transmission – is a function of:

- The transmitter average optical power (P_{opt}),
- The transmitter Extinction Ratio (E_R) or the Optical Modulation Amplitude (OMA),
- And the receiver Sensitivity (S)

Modern receiver designs generally perform in such a way that a 1dB increase in the transmitter power directly add 1dB in the link budget (assuming that the ER is above a certain threshold typically ~6dB) whereas a 2dB increase in the E_R is needed for a 1dB increase of the L_B. In addition to these three parameters, the transmitter and receiver Jitters (random, deterministic, etc.) and Rise/Fall times shall be monitored demonstrate the compatibility of the components to operate within the environment and at the desired rate.

Table 1. Main optical Transceiver parameters monitored over Qual. Tests and typical values

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Emitter						
Optical output power (average)	P_{out}	-4	-	-0.7	dBm	1
Optical extinction ratio	E_R	7.5	9.0	-	dB	1
Total jitter	T_{JTx}	-	60	150	ps	1,2
Rise/Fall time	τ_R, τ_F	-	80	150	ps	1,3
Receiver						
Optical sensitivity	P_{in}	-	-19	-17	dBm	1,4
Total jitter	T_{JTx}	-	60	150	ps	1,2
Rise/Fall time	τ_R, τ_F	-	80	150	ps	1,3

Notes:

1. Over specified voltage supply and operating temperature range.
2. Measured at 20% / 80% levels.
3. Measured on a 2^7 PRBS pattern.
4. For BER=10^{-12} measured at 2.5 Gbps with a 2^7-1 PRBS signal

The previous table summarizes the main optical transceiver parameters and their typical values that shall be monitored over the qualification tests.

Qualification Plan

In order to keep a pragmatic approach regarding the number of tests and the costs of the qualification, we propose a qualification test plan divided in 5 main application fields: Civilian avionics, Ground and Avionics Military, Space Commercial and Military. The numbers of samples to test and the test to perform are optimized according to the fields. The following table tends to summarize the tests and their characteristics per field.

Table 2. Qualification Test Matrix

			Test type		Perfor. check Test		Application fields				
Type	**Test**	**Detail**	**Full**	**Bias**	**Live**	**After**	**Civ. Aero**	**Military**	**Mil. Aero**	**Mil. Space**	**Com. Space**
Electrical	**Performances**	See TRx	■		■	■	■	■	■	■	■
	EMI	Grade A: 500V/m	■		■	■	■	■	■	■	■
		Grade B: 800V/m	■		■	■	■	■	■		
	Radiation	See ESCC stand.	■	■		■				■	■
	ESD	1000V				■	■	■	■	■	■
	Operating Temp.	Grade A: [-40;+90°C]	■		■	■	■		■	■	■
		Grade B: [-55;+125°C]	■		■	■		■	■		
	Survival Temp.	[-55;+125°C]/1000h		■		■		■	■	■	■
	Temp Ageing	Grade A: 90°C/2000h	■		■	■	■		■		■
		Grade B: 125°C/2000h	■		■	■		■		■	
	Temp. Cycle	[-55;+125°C]/1000c		■		■	■	■	■	■	■
Mechanical	**Vibration**	20Grms 3 axis 1h	■		■	■	■	■		■	■
		50Grms 3 axis 1h	■		■	■			■		
	Shocks	1500G 0.5ms		■		■				■	■
	Pressure	15000FT/-1500FT	■		■	■	■		■	■	■
		Vaccum (10^-8 Atm)	■		■	■				■	■
Others	**Damp Heat**	RH 95% @60°C/48h	■		■	■		■	■		
		Cycles RH95%@60°C	■		■	■	■	■	■	■	■
	Hermeticity	leakage <10^-8				■					■
	Fiber Tensile	10N					■	■	■	■	■
	Reliability	MTBF >1.10^6hours					■	■	■	■	■

The presentation will discuss about the number of samples per tests to be performed, the tests standards to be used as references and the various results obtained with Radiall/D-Lightsys optical transceivers.

Qualification by Similarities

There are various tests that shall be performed to demonstrate the ability of the optical transceiver to withstand the operational environment. The qualification costs are high due to their number, the resource needed and the time needed for each steps. A pragmatic approach could be used in order to keep the balanced right between the necessity to qualify parts for operating in the targeted environment and the component cost. Qualification by similarity is an interesting way to proceed by extending existing qualification tests performed on a part or a component to similar part. The following table proposed the tests that could be extended from parts to parts according to the similarities in the three main parts that compose a transceiver. i.e: the Electronics, the optical engine (comprising the optoelectronic components) and the Mechanical or packaging aspects.

Table 3. Qualification by similarities cross matrix

		Similarities		
Domain	**Test**	**Electronics**	**Optical Engine**	**Mech/Package**
Electrical	Performances	■	■	
	EMI	■		■
	Radiation	■	■	■
	ESD	■		
	Temperature	■	■	■
Mechanical	Vibration		■	■
	Shocks		■	■
	Pressure		■	■
	Other		■	■
Others	Damp Heat		■	■
	Fiber Tensile		■	■
	BIST	■		
	Reliability	■	■	■

For example, the ESD qualification test should only be extended, from an already qualified transceiver to a new one, if similarities (same internal components or sub-assemblies) are at the electronic level. At the opposite the Radiation test could not be extended if similarities are not covering the three main parts

Conclusion

The numerous number of standard applying to optical transceivers is sometimes inappropriate or over specifying the real operational environment. The approach presented in this paper intends to be pragmatic in specifying, according to the operating environment, a qualification test plan optimizing the cost/performance ratio.