Delta-evaluation of a European optocoupler for space applications

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Abstract

Optoi's optocouplers previously developed in the framework of a ECI-2 project with ESA, have been recently subjected to a delta-evaluation for their reinforcement, thanks to a GSTP funding scheme. The results presented in this paper demonstrate how the developed technology has upgraded from TRL 4 to 5, with the current intention to promote the latest achievements and start an interaction with the end-users.

Notes: ECI stands for European Component Initiative; references to TRL are made in relation to ECSS-E-HB-11A specification

I. INTRODUCTION

Optoi's R&D has been involved in the development of high-rel optoelectronic components specifically focusing on space applications for over a decade [1]. Between 2011 and 2015, Optoi has run a ECI-2 project for the development and ESCC evaluation of a first generation of optocouplers in TO-5, LCC4 and LCC6 package formats, radiation included [2, 3]. The obtained results were encouraging, especially the behaviour under radiation [4, 5] and allowed to determine the functional boundaries of the component under development, leading to the first release of component's Detailed Specifications as well as PID and preliminary Screening and Lot Validation Test Plans as per ESCC Generic Specification No. 5000. This work was accompanied by a first ESCC evaluation audit exercise involving Optoi and its key partners in 2014. Back then, the achieved TRL was equal to 4.

The developed technology needed a further reinforcement which was implemented on a GSTP project between 2017 and 2019 as presented in this paper. The reactivation of this development was possible also by statements of support by various end-users in Europe, expressing their need for a European ESCC-compliant component.

II. PURPOSE OF THE ACTIVITY

The previous activity allowed the identification of the main aspects requiring reinforcement, namely the method for sealing the lid (package closure), as well as the resistance to soldering heat, temperature cycles and humidity test sequence. In addition, the following aspects were incorporated in this new project, in order to further satisfy the reference requirements: functional monitoring during temperature cycles, measurement of the electrical capacitance following the typical requirements specified by the end-users, thorough characterization of the electrical isolation properties, introduction of the hot solder dipping operation in order to obtain pre-tinned parts, and X-ray validation.

Optoi has developed four device variants as shown in TABLE I and Figure 1. The "space approach" has been based on design options and raw materials well know in the space sector, i.e. with space heritage, while the "industrial approach" has been based on design choices and materials derived from Optoi's traditional division dealing with industrial applications [6], in order to develop a variant where the manufacture is more compatible with demands for higher volumes and lower costs, motivated by recent trends often referred to as the "New Space" paradigm.

TABLE I. DEVELOPED DEVICE VARIANTS

Split no.	Package	Build
1	LCC4	Space approach
2	LCC6	
3	LCC4	Industrial approach
4	LCC6	

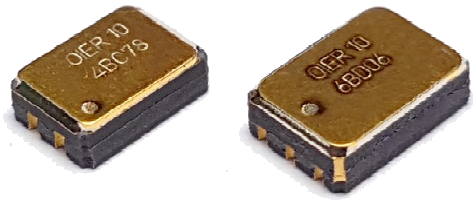

Figure 1 : *picture of the developed components in ceramic LCC4 and LCC6 package formats*

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III. DEVICE MANUFACTURING

The manufacturing of parts followed well established procedures and protocols developed in the framework of the previous ECI-2 project, duly adapted and further optimized in this activity. Phototransistors fabricated by Optoi's close partner FBK were used, and the assembly was carried out in Optoi's internal assembly line facilities, with a collaboration with FBK.

Dedicated Lot Travellers have been adopted, with in-process destructive controls as well as intermediate visual inspections, in order to check the requirements of ESCC Basic Specification No. 2045000 Iss.2 and MIL-STD-883K TM 2010.14 and 2017.13. Traceability was possible through laser-engraved marks present both on the device's package (back-side) and on the lids (front-side).

ESCC Basic Specification No. 21100 has been taken into account for seal test, by using the requirements as per discrete semiconductor components (more severe conditions if compared to integrated circuit components).

ECSS-Q-ST-70-08 has been adopted for the hot solder dipping operations, where the components have undergone the de-golding / pre-tinning solder baths by using Sn63Pb37 solder alloy as often requested by the end-users.

ESCC Basic Specifications No. 20900, 2095000 and 2055000 have been followed for the validation of X-ray inspections, mainly focused on the evaluation of the quality of the sealing fillet.

IV. TEST RESULTS

After defining the device's functional boundaries (which were found not so distant from the previous performance in the past ECI-2 activity), reliability tests took place.

For all the implemented stresses, the focus was addressed to the drift in the CTR and in the phototransistor's dark current. Drifts in the CTR have been considered tolerable as long as within the +/-20% range, with respect to the value before stress.

Firstly, resistance to soldering heat was investigated, following ESCC 2265000 and considering both manual soldering i.e. by means of soldering iron, and automated soldering i.e. through vapour phase oven. The obtained results allowed the definition of the soldering conditions for the component's Detailed Specifications.

Each of the two types of test presented hereafter has been conducted on separate groups composed by 16 devices, where the four variants indicated on TABLE I were used, with two identical devices under test and with the pre-tinning operation as an option, thus leading to 4·2·2=16 components per test.

Temperature cycling was conducted by following MIL-STD-750 TM1051, and implementing 500 cycles between -55°C and 125°C, with ramp rates of 15degC/min and dwell time of 10 minutes. Devices have been kept unbiased during stress, but intermediate functional verifications were implemented by means of a dedicated, purposely developed monitoring of functionality as shown in Figure 2 and Figure 3.

Results after stress, seal test included, demonstrated that three device variants passed the test, specifically splits no.2, 3 and 4 as per TABLE I.

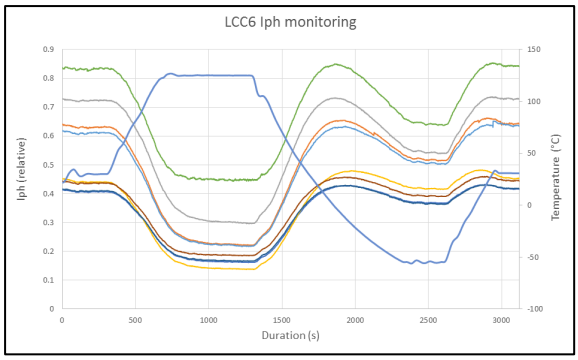

Figure 2 : *example of real-time monitoring during temperature cycling (phototransistor's I_{ph} output monitoring)*

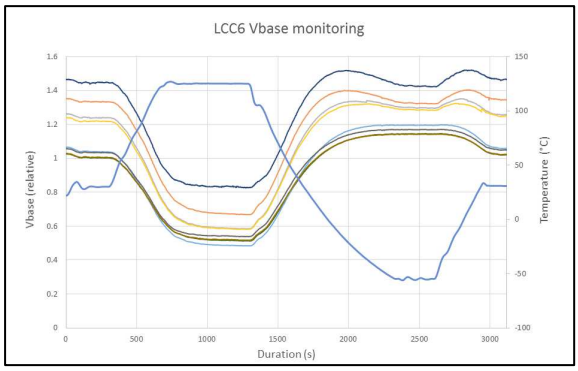

Figure 3 : *example of real-time monitoring during temperature cycling (monitoring of the phototransistor's base contact on the LCC6 device variants)*

The humidity test sequence was implemented following MIL-STD-750 TM1021, with a first stage of 85degC/85%RH/240h (unbiased) followed by cycles in the final phase, with biasing as indicated by the TM. When applicable, the biasing was equal to I_{led}=2mA, V_{ce}=5V. The obtained results were in agreement with temperature cycles, i.e. three device families passed the test, again specifically splits no.2, 3 and 4 demonstrating how split no.1 was affected by an intrinsic weakness.

The activity was complemented by Construction Analyses supported by ESTEC's lab, which gave further indications on how to improve the manufacturing process, especially focusing on visual aspects and repeatability of specific manufacturing operations.

V. ELABORATION

In the final phase of the project, Optoi interacted with ESA in order to identify the root cause for the weakness of split no.1. The main cause of such limitation has been clearly identified.

Optoi amended the previously issued quality documentation, including the component PID, the Detailed Specifications (which are now available upon request) and the Screening and Lot Validation Test Plans as per ESCC Generic Specification No. 5000 for potential future procurements.

VI. CONLUSION

Optoi's optocouplers have been subjected to a delta-evaluation, intended as complementary study with respect to a previous, more complete ESCC evaluation. The conducted activity demonstrated how three device variants have now upgraded from TRL 4 to 5, with some necessary reinforcement on the remaining one although the root cause has been identified, combined with its solution.

Optoi is now promoting its technology and especially its rad-hard, internally designed, developed and manufactured optocouplers in order to satisfy the requirements of the end-users, specifically addressing the European market.

ACKNOWLEDGMENTS

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The reliability tests have been mainly delegated to the French test house AdvEOTec.

Optoi's work was possible through a well-established collaboration with FBK.

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