International Conference on Space Optics—ICSO 2012

Ajaccio, Corse

9–12 October 2012

Edited by Bruno Cugny, Errico Armandillo, and Nikos Karafolas

Development and ESCC evaluation of an European optocoupler for space applications

Matteo Bregoli

Cristina Ress

Amos Collini

Francesco Ficorella

et al.

esa icso proceedings cnes

International Conference on Space Optics — ICSO 2012, edited by Bruno Cugny, Errico Armandillo, Nikos Karafolas
Proc. of SPIE Vol. 10564, 1056432 · © 2012 ESA and CNES · CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2309108

Development and ESCC evaluation of an European Optocoupler for Space Applications

Matteo Bregoli, Cristina Ress
Optoelettronica Italia Srl
Trento, Italy
research@optoi.com

Amos Collini, Francesco Ficorella, Gabriele Giacomini, Francesca Mattedi
Fondazione Bruno Kessler
Trento, Italy

Alessandra Costantino, Stephan Hernandez
Mustapha Zahir
European Space Agency
Noordwijk, The Netherlands

***Abstract* — This paper presents Optoi's Optocouplers, being developed in the frame of ESA's European Component Initiative (Phase 2). Their design and main test results are reported, together with the plan of future activities, including the Evaluation Test Plan and radiation tests.**

Keywords: optocouplers, opto-isolators, radiation hardness, Evaluation Test Plan

I. INTRODUCTION

Optoelettronica Italia Srl, better known as Optoi, is a young Italian Company which has been dealing with optoelectronics and microelectronics in the past 15 years. Recently, a new development centred on a radiation tolerant Optocoupler has started, among the rapidly growing activities involving the Company's aerospace activity line [1][2]. This project has been funded by the European Space Agency, in the frame of the European Component Initiative (Phase 2). The ECI programme [3] comes from an Electrical-Electronic-Electromechanical (EEE) Parts European Action Plan, formulated by ESA and supported by several National Space Agencies, which aims at the development of components in Europe that are currently only available from the US and may fall under export restrictions. So, Optoi's project is focused on the development and European-Space-Component-Coordination (ESCC) evaluation of an European Optocoupler for space applications, keeping the performances of the non-European counterparts as reference.

This paper reports the main aspects of design and manufacture of the component, and presents the most representative electro-optical results obtained on different device architectures, as well as preliminary radiation tests performed on different device layouts, from preliminary manufactured samples. A section of this paper is dedicated to the organization of the Evaluation Test Plan according to ESCC requirements, including reliability, environmental, mechanical and radiation testing. Besides, some considerations about visual inspection and quality assessment are provided, based on the reference ESCC and MIL standards.

II. DESIGN AND MANUFACTURE

The Optocoupler is manufactured using Optoi's internal facilities; the project consortium includes a close collaboration with FBK for the microelectronic front-end and the French Company AdvEOTec for the support on evaluation and reliability tests.

The device design inherits solutions implemented by Optoi during previous developments for CNES, centred on optoelectronic receivers for angular optical encoders to be used in control moment gyros [1][2]. However, application-related requirements have been taken into account, leading to a dedicated development featuring its own design and technology.

Pictures of the TO-5 and LCC6 package typologies hosting the first manufactured prototypes are shown in Figure 1. The optoelectronic devices composing the Optocouplers are assembled and connected by means of die bonding and ball bond processes; their optical coupling is enhanced by means of a transparent light pipe positioned between the optical source, i.e. a LED, and the receiver, i.e. a phototransistor.

Optoi organized its assembly line in order to manufacture these components using fully automated tools and machinery, in each assembly step. The resulting Optocouplers need to be compliant with MIL-STD-883, MIL-STD-750 and ESCC Basic Spec. No. 2049000.

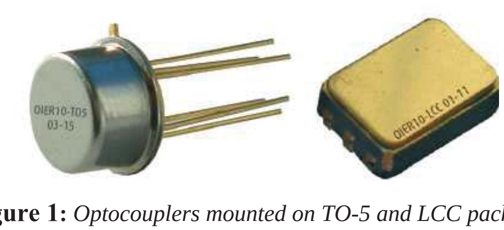


Figure 1: *Optocouplers mounted on TO-5 and LCC package*

III. FUNCTIONALITY AND RELIABILITY TESTS

The first batch of Optocouplers has been characterized through dedicated test campaigns, carried out by FBK's MT-Lab and Optoi between mid 2011 and the first months of 2012. AdvEOTec supported part of these activities.

Tests have been conducted both at wafer level and on packaged devices, following a well-established set of measurements and leading to the analysis of the main electro-optical parameters, including dark current, spectral response, output photocurrent (providing the CTR), dynamics etc. [Figure 2].

The electro-optical parameters on packaged devices have been measured considering alternative gain values in the output stage of the Optocoupler, i.e. the phototransistor. In general, several assembly options led to the comparison of a variety of design alternatives, throughout this first year of development.

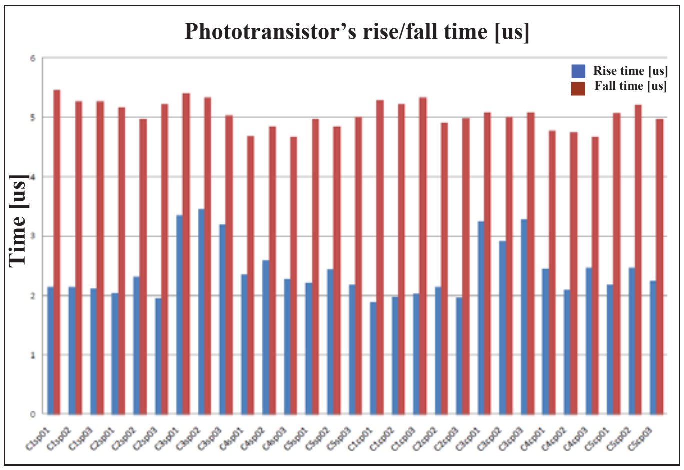


Figure 2: *rise and fall times measured on the output stage of the Optocoupler*

Both TO-5 and LCC Optocoupler configurations have been characterized, leading to CTR peak values in the range between 7 and 14 [Figure 3], depending on device type and assembly options.

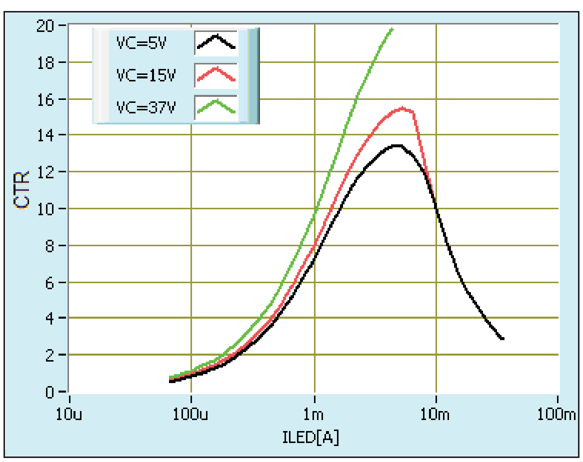


Figure 3: *example of CTR values for an Optocoupler assembled in a TO-5 package, with different voltage levels applied on the output phototransistor*

The whole basic set of technical specifications has been successfully fulfilled by the first manufacture run, the devices being in compliance with the reference electrical and physical requirements. The Optocoupler has also satisfied the specifications concerning leakage resistance ($R_{coupling}$ higher than 500Gohm) and coupling capacitance ($C_{coupling}$ lower than 5pF). The photoconductive bandwidth extrapolated at -3dB is equal to 15kHz at low injections currents and around 25kHz at high injections currents.

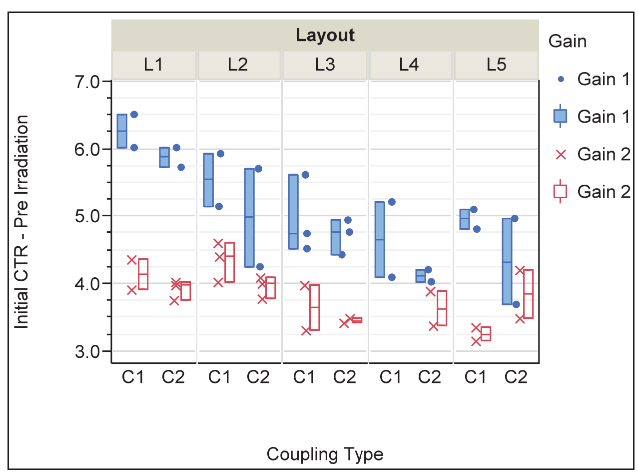
In general, the obtained electro-optical parameters are satisfactory, although some improvements in the electrical robustness (HTRB) is required, in order to reduce the dark current under combined thermal-voltage stress. This improvement is expected in the second manufacture run, which will be available by September 2012.

IV. RADIATION TESTS

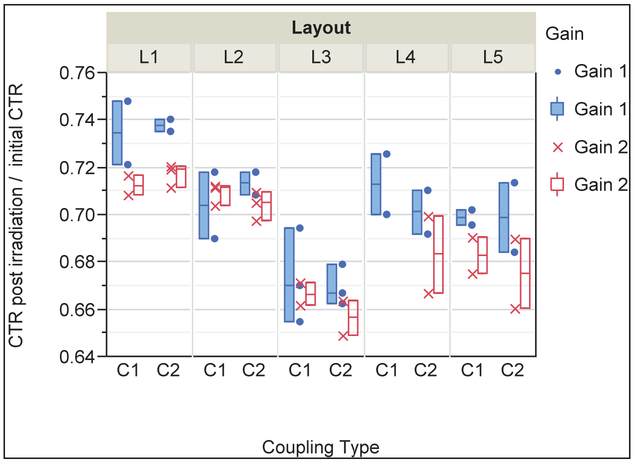
Preliminary radiation tests have been performed on different device layouts from preliminary manufactured samples, in this first phase of the development; this activity was supported and supervised by ESA.

A batch of 58 samples has been submitted to displacement damage dose (DDD) with the following conditions: energy of 60 MeV, fluence equal to 7E10 p/cm^2, flux equal to 3E8 p/cm^2/s. The devices have been fully tested before and after irradiation; in-situ intermediate measurements were also possible, leading to a responsive outcome of the ongoing tests during the campaign.

The extrapolated results are shown below [Figure 4]. Five different Optocoupler layouts have been compared, varying different aspects such as the reciprocal position of the emitter and receiver, the gain value in the output stage, i.e. the phototransistor, and the package type: Optocouplers in TO-5 package have been tested together with some ones assembled in ceramic LCC6 packages.



a)



b)

Figure 4: *comparison of Current Transfer Ratio measurements on preliminary samples with different design solutions (electrical layout, gain and coupling type): (a)Initial CTR characterization (@Vce=5V, If=1mA) (b)preliminary assessment of radiation degradation. CTR after irradiation with a fluence of 7E+10 p/cm*^{2}*of 60 MeV proton, normalized to initial CTR*

The obtained results have been elaborated, leading to the selection of the most robust layout solution, i.e. layout *L1*. The high gain option proved slightly more tolerant against proton radiation. The comparison between the package types didn't show relevant variations, in terms of radiation hardness.

The overall range of final results in terms of CTR degradation normalized to its initial value spans from 65% to 75%, which is encouraging.

In the second phase of the project, a more extended campaign of radiation tests will be preformed. It will include displacement damage dose tests at three energy levels spanning from about 20MeV to 200MeV, and total ionizing dose tests reaching 150krad at two comparative doses of 36rad/h and 360rad/h. These radiation tests will be performed on both biased and unbiased devices. The accomplishment of these tests will be supported and supervised by ESA.

V. EVALUATION TEST PLAN

In the next project phase the most promising Optocoupler typology will be submitted to a full ESCC Evaluation Test Plan, under the supervision of ESA and with the support of AdvEOTec. The evaluation plan follows the methodology described in ESCC 2265000 with four group of tests: destructive tests, endurance tests, control devices and spare parts [Figure 5]. Each test sequence is concluded by Destructive Physical Analyses. In total, a hundred components will be involved, including those for spare and control; they will be assembled both in TO-5 and LCC package type.

The start of this activity is scheduled in the beginning of 2013; its accomplishment (accompanied by the elaboration of the obtained results) is expected in the second half of the same year. In case of successful results, the devices will be subject to an ESCC Space Qualification, leading this technology to be proposed for introduction in the European Preferred Part List and European Qualified Part List.

VI. VISUAL INSPECTION AND QUALITY ASSESSMENT

Optoi's Optocouplers have been subject to visual inspections and quality evaluations, to assess space-related standards in terms of Residual Gas Analyses (RGA), quality in the sealing and bonding procedures, as well as the validation of the front-end technologies for both the LED and the phototransistor devices. The analyses revealed that various assembly aspects have been mastered, for example an adequate sealing process for the TO-5 package has been implemented; however, some other aspects are currently being optimized in order to accomplish the evaluation criteria of MIL-STD-883, by improving the RGA, reducing the humidity level and optimizing the resin polymerization together with the wire bond connections.

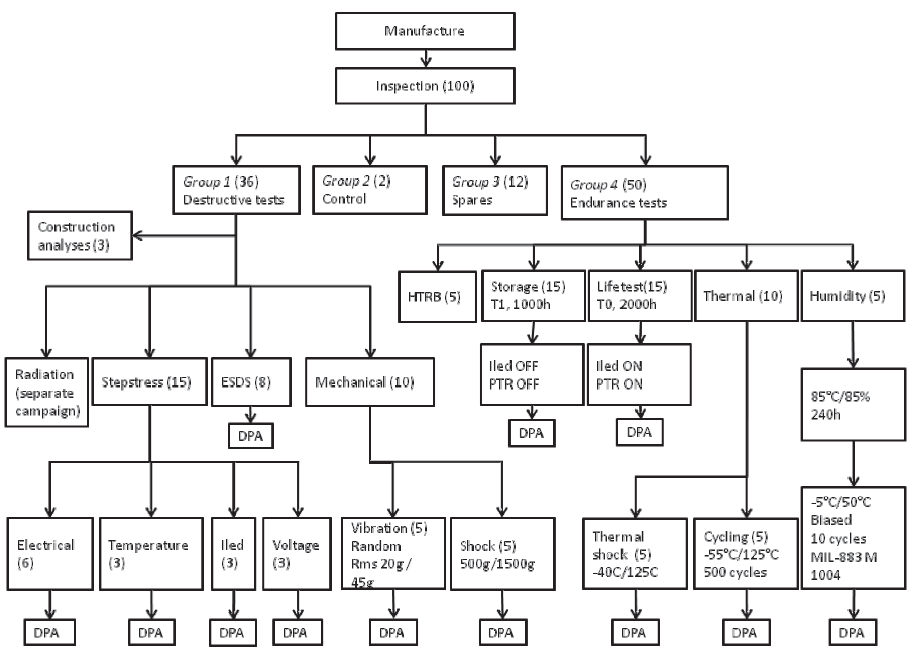


Figure 5: *ESCC Eval Test Plan*

Concerning the front-end technologies, visual inspections showed some cosmetic issues induced by laser cutting on a specific type of optical emitter [Figure 6]. In particular, such mechanical defects (chip-outs or cracks) may become relevant if they reach the active structure and create dislocations in the semiconductor, under environmental stress. An apparent damage to the passivation layer was also observed, specifically in the region between the dicing line and the edge of the active area of the die [Figure 6 (b)].

Alternative front-end technologies and dicing procedures are currently being taken into consideration, in order to comply with ESA/SCC 2045000 Basic Specification. Work is currently in progress and comparative analyses are being performed.

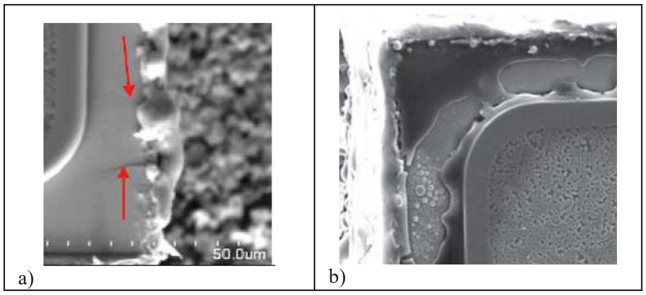


Figure 6: *a) cracks induced by laser cutting (red arrows); b) apparent damage to the passivation layer*

CONCLUSION AND FUTURE PLANS

This paper reviews the development and the most representative characterizations of an Optocoupler designed and manufactured by Optoi, for space applications. The device proved compliant with the main electro-optical specifications and it showed a promising behavior under proton radiation. After achieving these encouraging results, the consortium is now focusing on the improvement of the performance under stress tests (HTRB), as well as the optimization of the quality related to visual aspects, together with the improvement of the assembly procedures for the microelectronic back-end process.

The conclusion of this project phase should lead to the start of the ESCC Evaluation Test Plan accompanied by dedicated radiation tests. The collection of the whole set of results is expected in the second half of 2013. In case of successful results, the devices will be subject to an ESCC Space Qualification, leading this technology to be proposed for introduction in the EPPL and EQPL.

ACKNOWLEDGMENT

The reported activities have been conducted within a development program funded by ESA, in the frame of the European Component Initiative (Phase 2).

The entire work of design, simulation, manufacturing, testing and data elaboration has been conducted by Optoi's and MT-Lab's staff, with the support of AdvEOTec and supervision of ESA. The Evaluation Test Plan has been defined by AdvEOTec and approved by ESA.

Some design solutions and test procedures have been inherited from previous developments for CNES.

REFERENCES

[1] M. Bregoli et al., "Customized and highly reliable 8-channel phototransistor array for aerospace optical encoders" presented at ISROS, in Cagliari, in May 2009

[2] M. Bregoli, P. Bouvier, A. Maglione, "Microelectronic packaging assembly and qualification process flows of a customized phototransistor array for aerospace optical encoders", presented at ISROS, in Cagliari, in April 2010

[3] https://spacecomponents.org/webdocument/showArticle?id=899 &groupid=7