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#03-242 In-situ gamma irradiation testing of radiation hardened chips till 1MGy

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Most of today's commercial off-the-shelf (COTS) electronics are not specified to meet the demanding requirements of advanced nuclear applications requiring MGy-level TID tolerance. Examples are maintenance and diagnostics tasks in future burning plasma fusion reactors, for example the ITER. Applications such as interventions during nuclear accidents, dismantling of old nuclear power plants and disposal of radioactive waste also call for rad-hard electronics. Therefore, first, the development and, secondly, the testing of custom tailored MGy hardened integrated solutions become necessary for use in these environments. It will not only reduce the shielding but will make it possible to place electronics closer to front-end sensor transducers and actuators in a radiation environment.
To address this need, Magics Instruments has developed a set of 5 chips which are highly resistant to ionizing radiation of over 1 MGy. The pioneering technology of Magics Instruments offers unprecedented opportunities for the use of electronics. Furthermore, Magics Instruments developed a modular test system to assess the radiation hardness of these chips even during irradiation (in-situ). Due to the modularity, this test setup can be customized for any other chip.
The set of these 5 chips developed by Magics Instruments on behalf of F4E deploys an RS485 communication network for reading out sensors and driving actuators. The performances of 3 of these chips were tested on a set of samples during an irradiation assessment. In total 30 samples at once were measured, from which 24 in-situ. The first chip is a BiSS (RS485) interface communication Application Specific Integrated Circuit (ASIC) used for building up a sensor/actuator network. Another chip is a resistive bridge sensor signal conditioner ASIC capable of reading out resistive based sensors like temperature sensor, strain gauges, potentiometers and so on. The last chip tested is a resolver or Linear Variable Differential Transformer (LVDT)-to-digital converter that can be used to read out these sensors typically used in closed-loop motor control applications. The remaining 2 chips out of the set of 5 were tested during a previous irradiation assessment. One chip is a 10-channel relay driver chip and the second one a 10-channel limit switch sensing ASIC.
The irradiation assessment was performed in the Co60 gamma underwater test facility at SCK CEN (called RITA) in Mol. The 30 chips were loaded in a closed container that was lowered down in a pool of water with the Co60 radioactive sources at the bottom. Prior to the actual irradiation assessment of these chips a reference dosimetry was performed to determine the dose rate distribution inside the irradiation volume. Axial variations of the dose rate along the chip-support were ~20%. On average, the exposure dose rate was 484 kGy/h. The chips themselves were connected to a Data-Acquisition system, using cables pulled through 4 tubes of 10 meters length what made it possible to perform a challenging task of the in-situ measurements.
To achieve in-situ measurements, Magics developed a modular test rack computer making it possible to measure the chips fully autonomous in a remotely controlled setup with only limited lab equipment. Data was locally stored in a database on a hard drive and replicated continuously to a database in a cloud storage server for reasons of redundancy. A test setup failure warning mechanism was built in the test setup to lower the risk of data loss. When the test software would crash or power to the setup was interrupted, a warning email and text message was sent to undertake fully remotely necessary actions. An uninterruptable power supply was included to overcome short power interruptions. Even a self-restoring functionality, restarting measurements after failure, was built in.
Multiple tests were continuously performed in a loop on all samples for 97 days to reach at a total ionizing dose of at least 1 MGy for each sample in the test. The higher located samples received even 1.2 MGy. The irradiation itself was interrupted twice to investigate the dynamic balance between defect generation due to irradiation and recovery. These interruptions were performed for 1 hour when average TID of 10 kGy and

100 kGy were reached. After the end of the irradiation, all samples were measured in-situ for 2 more weeks to investigate the recovery during the annealing phase. First, 1 week of annealing at room temperature was performed followed by another week of high temperature annealing at 100 ℃. These tests were performed in a climate chamber. The full assessment was performed in-line with the ESCC 22900 standard: Total dose irradiation test standard . Furthermore, the ITER EEE Nuclear Radiation Compatibility Handbook was used as the reference throughout the full project, from design in the very beginning till the final post-processing of the data.

The collected data was processed into readable plots showing the performance of the chips along the TID they received and their recovery. Almost 9000 plots were generated. Some of these data plots show a drift in the measured data, but all of these were acceptable. Therefore, it can be concluded that performance was proven over the full TID range. The data obtained during this irradiation assessment complete the data yet obtained for the 2 other chips, out of the set of 5, tested in a previous irradiation assessment. The performance of these chips was also proven over the full TID range. This means that the radiation hardness of the RS485 communication network to read out sensor and drive actuators, build up by the chips of Magics Instruments is proven.

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