TWEPP-08 Topical Workshop on Electronics for Particle Physics

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Single-Event Upsets in Photodiodes for Multi-Gb/s Data Transmission

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A Single-Event Upset study has been carried out on PIN photodiodes from a range of manufacturers. A total of 22 devices of eleven types from six vendors were exposed to a beam of 63MeV protons. The angle of incidence of the proton beam was varied between normal and grazing incidence for three data-rates (1.5, 2.0 and 2.5Gb/s).

We report on the cross-sections measured as well as on the detailed statistics of the interactions measured using novel functionalities in a custom-designed Bit Error Rate Tester. Upsets lasting for multiple bit periods have been observed and the fraction of errors when a logical zero is transmitted has been measured to be less than one over a large range of input optical power.

Summary

Single Event effects have been widely documented to occur in the photodiodes typically used in modern high-speed serial communications. At CERN, we are currently designing the next generation of optical data transmission link operating at multi-Gb/s rates for reading-out and controlling particle physics detectors to be operated at CERN's upgraded Super Large Hadron Collider (SLHC). The innermost regions of the detectors will encounter a radiation environment with particle fluxes of 10ˆ6 –10ˆ8 particles/cmˆ2/s. The control information flowing into the detectors from shielded control rooms is crucial for maintaining the synchronization of the data-taking system. It is therefore of critical importance that this control information be transmitted error-free and, with the knowledge that Single Event Upsets (SEUs) will occur within a photodiode placed in such an environment, the use of Forward Error Correction (FEC) coding will be mandatory. Validation of any choice of FEC code depends upon a detailed knowledge of the statistics of the expected errors and the test reported in this paper aims to gather that knowledge.

We have performed a small survey of the radiation-response of several different devices. InGaAs PIN photodiodes operating at 1310nm, GaAs PIN photodiodes operating at 850nm were combined in this test with Receiver Optical Sub-Assemblies (ROSA) where the Transimpedance Amplifier (TIA) is mounted in the same TO-can as the photodiode. Again, both 1310nm InGaAs and 850nm GaAs ROSAs were included.

The irradiation was carried out at the PIF-NEB facility at the Paul Scherer Institut, Villigen, Switzerland using a 63MeV proton beam. Ten photodiodes were arranged on a rotating axle to be tested simultaneously. Data were taken at 0°, 10°, 80° and 90° angles of incidence with a flux of approx. 8×10ˆ8 p/cmˆ2/s.

A custom BERT was implemented in a Stratix II GX FPGA with embedded high-speed transceivers. The primary testing goal of measuring error statistics was achieved through the use of an error log memory that could hold up to 8K 20bit words containing the XOR of transmitted and received data in the case an error was detected anywhere in that word along with a timestamp corresponding to each error word. Firmware was developed that would allow operation at the three data rates used in the test (1.5, 2.0 and 2.5Gb/s) by simply supplying a different frequency base clock to the FPGA.

Measurements of the detailed statistics of error events due to proton strikes in PIN photodiodes will be presented. These show that multiple bit-errors do occur and will have to be mitigated using FEC coding in data-links for future particle physics detectors operating at CERN's SLHC.

Bursts of errors lasting for multiple bit periods have been observed. The long length of bursts observed ROSAs could be due to upsets taking place in the TIA. A particle strikes in a bias circuit of the TIA could dramatically reduce its gain, leaving the output in an fixed state and causing the receiver of the FPGA detect only noise at its input. In contrast, short bursts lasting for up to 20 consecutive bit periods seem to be related to upsets in the photodiodes, since we observe a dependence on the received power level. To the best of our knowledge this kind of behaviour, where an SEU upsets several successive bits, has not been previously reported in SEU tests performed with photodiodes at other data rates.

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