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A PCI Express Optical Link Based on Low-Cost Transceivers Qualified for Radiation Tolerance

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With this work we want to demonstrate that an optical physical medium is compatible with the second generation of PCI Express. The benefit introduced by the optical decoupling of a PCI Express endpoint is twofold: it allows for a geographical detachment of the device and it remains compliant with the usual PCI accesses to the legacy I/O and memory spaces. We propose two boards, that can bridge the PCI Express protocol over optical fiber, already working in the Drift Tube system of the CMS experiment. The positive outcome of a radiation test of the transceiver link is also reported.

Summary

Over the last decade, we have seen a definite stand out of PCI Express (PCIE) as a de-facto standard protocol for host to peripheral interfaces. It allows devices to achieve very high data transfer rate improving the bandwidth steadily every time a new generation appears on the market. However using copper cabling, the maximum reachable physical distance of a remote IO device decreases with the increase of the data rate. Thus industry leaders in PCIE solutions and in fiber optic products are moving towards a new off the record standard for the PCIE physical layer. We want to contribute to such research topic carrying on with our preliminary results accomplished in the context of the LINCO project. We developed a bus adapter that is able to bridge remote buses (>100m) to a single-host computer giving the legacy PCI compatibility to the endpoint device and without even the need of a specialized driver. In order to cope with the new generation of PCIE devices, we have developed two new models of LINCO boards: a one-lane PCIE optical translator and a general purpose one-to-four PCIE Gen2 optical switch that can be used as simple fan-out, generic data mover or for distributed computing aggregating a maximum bandwidth of 20Gbps. Such adapters were designed with the aim of exploiting the communication protocol nature of the PCIE bus even keeping the transparency of the link. Indeed the protocol provides for load-store operations between two nodes that are performed exchanging framed packets in accordance to a suite of stacked protocol layers taking care of the physical, link and transaction issues of the channel. Replacing the physical layer with an optical one we want to keep the model of field bus control in which software arranged packets are used to access memory and registers of the field bus for IO operation.

Since all the LINCO boards are used in the DCS and DAQ systems of the muon drift tube chambers employed in the trigger of the CMS experiment, a major consideration in the design of the link was the performance in presence of radiation. The remote part of the link resides in electronics crates which will be exposed in 10 years of LHC running to an integrated neutron fluence of 2.5x10^{10} n/cm^2. Even if the fluence is not high enough to generate a relevant bulk damage, the electronics could still be fooled or even damaged because of Single Event Effects. A detailed study of the transceivers performance in presence of proton radiation up to 5x10^{11} p/cm^2 is, therefore, subject of this work. The radiation tolerance of four kind of commercial low-cost Small Form Factor Pluggable transceivers has been compared. Transient errors, not critical for the protocol, have been observed during radiation exposure in the receiver channel. Finally an accurate jitter analysis to check the PCIE requirements validates the effectiveness of the optical link at the Bit Error Ratio level of 10^{-12}.

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