Radiation qualification of Commercial-Off-The-Shelf LVDS and G-link serializers and deserializers for the ATLAS endcap muon level-1 trigger system

Abstract
The ATLAS endcap muon level-1 trigger system is divided into three parts: one off-detector part and two on-detector parts. Serialized data transfer with LVDS is used between two on-detector parts (15m apart) and serialized G-link transfer with optical transmission (90m) is used from one of the on-detector ones to the off detector part. Since the radiation damage of the components used in the on-detector parts is a matter of concern, we have investigated systematically the radiation susceptibility to both total ionizing dose and single event effects of COTS serializer/deserializer chipsets for LVDS (two candidates) and G-link (one) together. In this report we discuss in detail the characteristics of these LVDS chipsets and qualification of the G-link components for radiation.

Summary
ATLAS endcap muon level-1 trigger system will use about 1000 G-link lines and 10000 LVDS link lines. LVDS links are used to data transfer from front-end on-detector one to the second on-detector part over 15m with USTP (un-shielded twisted pair) category 5 cable. G-link optical transmission lines are used from the second on-detector one to the off-detector part over 90m distance. As both links are serial transmission, we need a serializer at the transmitter and a deserializer at the receiver side. We estimated the total dose of 24krad for ten years operation and a hadron fluence of $6 \times 10^{11}$ n/cm$^2$ at the on-detector parts including some safety factors.

For the LVDS, we have selected two Commercial-Off-The-Shelf serializer and deserializer chipsets (one from Texas Instruments (TI): SN65LV1023/1224 and one from National Semiconductor (NS): DS65LV1023/1224 as candidates for our system). Both chipsets have identical functionality and even the same pin allocation, though the frequency range is slightly different. For the G-link, we have uniquely selected one Agilent chipset (HDMP-1032A/1034A) and an optical transmitter by Infineon.

For TID evaluation, we have irradiated four samples from each LVDS chipset candidate with gamma-ray through 30krad. Source current (Icc) of all the samples were stable during irradiation, and kept pre-irradiation level up to 30krad. One sample among four from each candidate were exposed further to 160krad. Both serializer and deserializer of the TI candidate showed increase of current after 80krad till 100krad, and abrupt current drop immediately after 100krad. An LVDS link could no longer be established after the current drop while the chipset of NS candidate has no significant increase of the current even up to 160krad. All the samples from two candidates were found to survive till 80krad. Agilent G-link chipsets were also irradiated with gamma-ray up to 30krad. None has shown distinct current increase till 30krad dose.

For SEE test, we have made a special system for a pair of a serializer (Tx) and deserializer (Rx). A DUT board, which mounts both an Rx and a Tx is installed in 70MeV proton beam line. Two DUTs (Tx and Rx) was irradiated alternatively with the beam. Data generated outside of the beam area were sent to the DUT-Rx on the board through a Tx put in the outside, and 10bit deserialized data were transferred to a serializer on the board (DUT-Tx), then serialized data with this DUT-Tx were sent back to the outside, where the generated (transmitted) and received data were made
compared after deserialized with Rx. This feature of a test bench was common for both the LVDS and G-link test. We have tried to count SEU as well as link failure with operating the test bench during the proton irradiation. In the measurement of the LVDS chipsets, we have observed the characteristics of NS and TI candidates were different. All the samples of NS candidate showed always SEU and link failures uniformly over irradiation period while ones of TI showed seldom SEU and link failures. All TI deserializers showed, however, significant increase of the source current after the proton dose of 30krad up to 120krad where all the TI deserializers are broken. The increase of the source current has been observed already in the TID test for TI samples.

For the G-link chipset, we have also measured data transfer errors and link failures as the similar manner as in the LVDS test. But in this G-link test, we have made also qualification test of an optical transceiver for the proton irradiation beside Tx and Rx. We have delivered SEE cross sections for data transfer error and the link failure for the Tx, the Rx and the optical transceiver independently. The rate of data transfer error for TX is estimated as 2.2E-8/cm2 and one of the link error is as 3.3E-10/cm2. We have then estimated the G-link Tx error rate that would be happened actually in the overall ATLAS TGC system (1000 G-link lines) as 0.19/min. and 0.17/min for data transfer error and link failure respectively.

In summary, we have found very different characteristics of two type of LVDS chipsets (NS and TI) in the data analysis of the proton irradiation test. The NS one has many SEU or link failure but immune to TID while TI has relatively qualified for SEE if the proton dose is less than 120krad, but is fragile for the absorbed dose greater than 80krad, although both chipsets has no problem to be used anyway in the ATLAS muon endcap level-1 system because the total dose estimated with 10 years would be at most 30krad. The G-link chipset has shown also no problem for our usage.