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JTAG-based Remote Configuration of an FPGA Over Optical Fibers

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We present a remote FPGA-configuration method based on JTAG extension over optical fibers. The method takes advantage of commercial components and ready-to-use software such as iMPACT and does not require any hardware or software development. The method combines the advantages of the slow remote JTAG configuration and the fast local flash memory configuration. We have verified that we can successfully configure an FPGA 100-meter far away. The method will be used in the ATLAS liquid argon calorimeter upgrade Demonstrator. All components on the FPGA side are verified to meet the radiation tolerance requirements.

Summary

The ATLAS Liquid Argon Calorimeter (LAr) Phase-1 trigger upgrade has been proposed to enhance the physics reach of the ATLAS experiment. A LAr Trigger Digitizer Board (LTDB) is being developed to read out up to 320 detector channels and transmit all the data off the detector through 40 optical fibers. The LTDB, after installed, will operate in a harsh radiation environment and be implemented in radiation-tolerant components such as ASICs. The LTDB prototype, called the Demonstrator, based on gigabit-transceiver-embedded FPGAs is being developed to test and demonstrate the functions of the LTDB. The FPGAs need to be configured after each power cycle or after a single-event functional interrupts occurs during operation. The distance between the Demonstrator and the counting room is 70 meters. The commonly used FPGA configuration methods such as JTAG cannot support such a distance. It is critical to develop a remote FPGA configuration method.

We present a remote FPGA configuration method based on JTAG extension over optical fibers. The simplest way to extend JTAG signals is to use one fiber for each JTAG signal. Since the JTAG interface has at least four signals in two directions, we need four optical fibers. In order to reduce the fiber number, we multiplex all signals in one direction by using a serializer/deserializer and transmit through a single fiber so that we only need two fibers. As a backup solution, we put a flash memory with the SPI interface on the Demonstrator. The FPGA can be configured from the flash memory locally and quickly. The FPGA, however, may not start the local configuration if the FPGA is affected by single event effects. We use one extra parallel data signal of the serializer/deserializer, which has 16 input signals and 16 output signals, to initiate the local configuration. The flash memory can also be remotely configured via the FPGA. Therefore, our method combines the advantages of slow remote configuration and fast local configuration. The method takes advantage of commercial components and ready-to-use software such as iMPACT and does not require any hardware or software development.

The remote FPGA configuration method has been verified with two optical transceivers, two Serializers/deserializers, two 100-meter fibers, a Kintex-7 FPGA, a USB download cable, and the software iMPACT. Due to the latency of the long fibers, the clock frequency of the remote configuration needs to be smaller (750 kHz).

The Demonstrator will operate at low luminosity for one to three years (2014-2017), so the radiation level for the Demonstrator is lower than that for the LDTB. However, since the Demonstrator is based on COTS components, the radiation tolerance of all components has to be evaluated. The components on the FPGA side, including the optical transceiver, the serializer/deserializer, the flash memory, and the FPGA, were tested with a neutron or proton beam and with X-rays or gamma rays. The test results show that all components meet the radiation tolerance requirements for the Demonstrator.

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