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Application of flash-based field-programmable gate arrays in high energy experiments

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Field-programmable gate arrays (FPGAs) based on flash memories provide a high radiation tolerance. We discuss potential application of the Microsemi IGLOO2 FPGAs in high energy experiments. We implement a 24 channel time-to-digital converter with a time binning of 0.78 ns and evaluate the performance. The time resolution is obtained to be 0.25 ns. The radiation tolerance against total ionizing dose is studied by irradiating gamma ray up to 10 kGy using Cobalt-60 source. The degradation of the performance on the ring oscillator, the phase-locked loop, and the high-speed transceiver is evaluated.

Summary

Field-programmable gate arrays (FPGAs) are widely used in the experiments of high energy physics. FPGAs based on flash memories have relatively high radiation tolerance with respect to the FPGAs based on static random access memories. It extends the potential application of the FPGAs. In this study, the flash-based IGLOO2 FPGA produced by Microsemi is focused on. A time-to-digital converter (TDC) with time binning of 0.78 ns is implemented and tested. The radiation tolerance against total irradiation dose is evaluated using gamma ray up to 10 kGy.

An example of the application of the TDCs is the drift time measurement for the monitored drift tube chambers at the ATLAS experiment. The TDCs are implemented in application-specific integrated circuits, which have 24 channels per chip and time binning of 0.78 nsec. In this study, we implement a 24 channel TDC with a time binning of 0.78 nsec in the IGLOO2 FPGA. The time measurement is provided by the counters running with a frequency of 1.28 GHz. The counters are based on a multisampling scheme with quad phase clocks, each of which has a frequency of one fourth of the one for the counters. The quad phase clocks are produced from an external 40 MHz reference clock using highly reliable phase-locked loop circuit implemented in the FPGA.

As a performance evaluation of the implemented TDC, the differential nonlinearity is measured to be less than 0.5 of the time binning for all the least significant bits of the 24 channels. The integral non-linearity is consistent with zero up to time window of 100 us. The time resolution is obtained to be about 0.25 ns.

The radiation tolerance against total ionizing dose is studied with a dedicated test board which includes an IGLOO2 FPGA. Gamma ray is irradiated up to 10 kGy at the Cobalt 60 irradiation facility of Nagoya University in Japan. The degradation of the performance on the ring oscillator, the phase-locked loop, and the high-speed transceiver is measured. For the ring oscillator and the phase-locked loop, the frequency and the power consumption are measured. For the high-speed transceiver, the bit error rate and the eye diagram for several transfer speeds are extracted. The functionality of the firmware configuration is also tested.

In summary, we examine the performance of the flash-based Microsemi IGLOO2 FPGA. We implement a 24 channel time-to-digital converter with a time binning of 0.78 ns. The differential non-linearity is measured to be far below the time binning. The time resolution is obtained to be about 0.25 ns. The radiation tolerance against total ionizing dose is studied by irradiating 10 kGy of gamma ray using Cobalt-60 source. The degradation of the performance on ring oscillator, phase-locked loop, and high-speed transceiver is measured. Microsemi IGLOO2 FPGA extends the potential application of the FPGAs in high energy experiments.

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