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Generic FPGA based platform for distributed IO in a Proton Therapy Patient Safety Interlock System

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A new gantry for cancer treatment has been installed at the Center for Proton Therapy in the Paul Scherrer Institute (PSI), Switzerland, where already two in house developed ones operate since 1996 and 2013. The new gantry is a commercial device and had to be integrated into the existing control system of PSI. For this purpose it was necessary to develop a customized adapter, which supports an interface between the PSI systems and the vendor's gantry safety system. The adapter is divided into two main components one is a VME-bus based logic controller containing all patient safety related functionality implemented on one Virtex 6 FPGA. The other is a generic IO platform to support the interconnection of signals from and to all subsystems, called the Signal Converter Board (SCB). The SCB is a generic platform based on a XILINX ARTIX-7 FPGA and 10 modular IO ports, each with up to 34 user configurable IO signals. All IO ports share a standard connector, and application specific modules can be connected as mezzanine plugins. For this project dedicated hardware interfaces were developed supporting different interface standards like 24V digital IO, optical IO and additional proprietary wiring standards. In case of power failure all output signals are set to a safe state.

To communicate with the main logic controller the SCB supports up to 6 low latency optical high speed links. The communication link layer is based on the XILINX AURORA standard. On top of this, a new protocol called PaSS-IO (P-IO) link was developed. The P-IO link uses a deterministic streaming mechanism where the logic controller sends periodically the status of the output signals to the SCB and the SCB itself transmits the status of the input signals to the logic controller. To detect communication errors several supervision functions like frame CRC and link alive checks are implemented. The P-IO protocol and its supervision functions are implemented in a VHDL module supporting a simple interface to the XILINX AURORA core interface on one side and a user friendly interface to the user application on the other side. Only a few user specific configurations in a package file are required to integrate the design of P-IO link VHDL module into any FPGA application with AURORA communication links. For our safety system we use a serial link communication settings of 2 GBit/s and a frame cycle time of 1µs with a link load of 15% between the systems. With these communication parameters we achieve a reaction latency of less than 4µs from an input signal change to an appropriate reaction at an output signal. The separation of the system into a central VME based logic controller and a distributed IO platform allows optimizing the cabling installation of the whole system.

The system has been successfully installed at PSI's new treatment room, commissioning is ongoing and beam at isocenter was achieved in January 2016. Patient treatments are scheduled to start end of 2016.

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