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

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***Abstract*–The Center for Protontherapy at Paul Scherrer Institute is installing a new Gantry for cancer treatment. For its integration into the facility and especially to connect it to the existing controls and safety systems a generic FPGA based platform for distributed IO has been implemented.**

I. Gantry 3

PSI expands its PROSCAN protontherapy facility [1] [2], depicted in Fig. 1, by a further treatment room “Gantry 3”. The project is part of a research collaboration between PSI and Varian Medical Systems (VMS). The gantry installation follows a tight schedule in order to permit the start of the patient treatment in minimum time. The integration of two system environments with different design background constitutes a significant challenge.

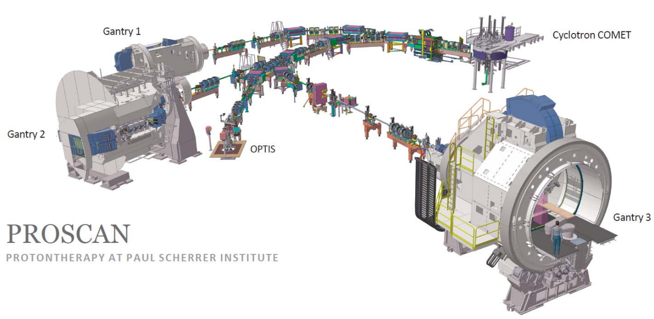

Figure 1: Layout of the PROSCAN facility beam lines including the new Gantry 3

The integration of the Gantry 3 safety system follows PSI’s concept with local (specific to one treatment room) and central (shared by the facility) components. The chosen architectural approach for the control system integration is the encapsulation of the two environments (PSI, Varian) and expose the necessary interfaces only at newly created adapters [3]. The PaSS (Patient Safety System) adapter constitutes the interface between the Varian and the existing PSI systems for beam control and patient safety.

II. PaSS adapter and Signal Converter Board

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.

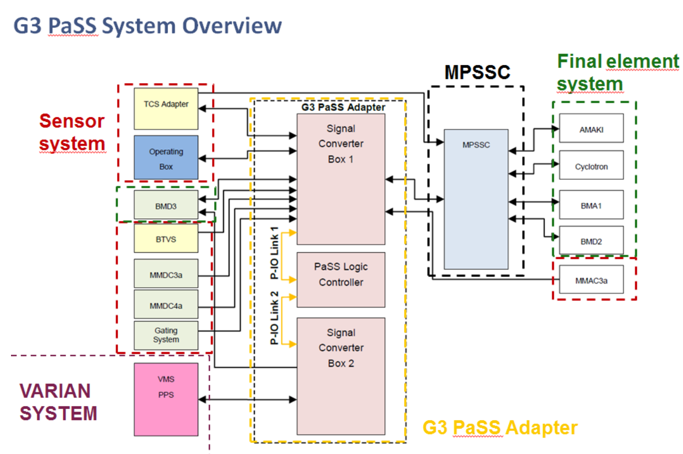

Figure 2: Gantry 3 Safety System overview

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

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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.

Figure 3: SCB mainboard

III. CURRENT STATUS

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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