An I/O Controller for Real Time Distributed Tasks in Particle Accelerators

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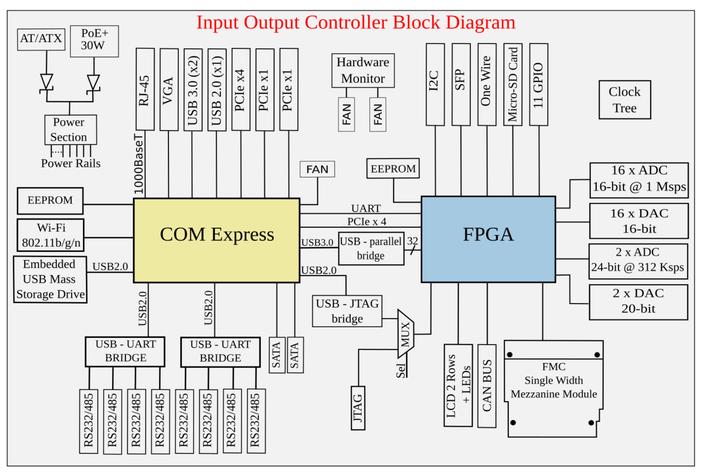
Introduction

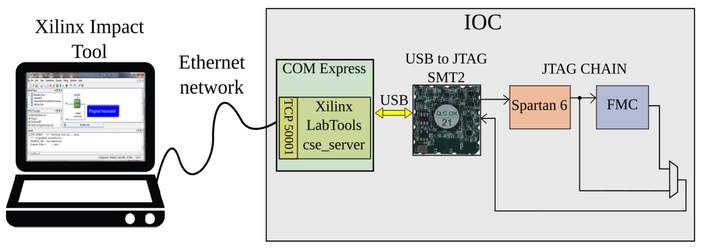
The research project focuses on the design of a custom Input Output Controller (IOC) which acts as a local intelligent node in the SPES distributed control network and it is generic enough to perform several different tasks spanning from security and surveillance operations, beam diagnostic, data acquisition, data logging and real-time processing. The result is a custom mother board equipped with general purpose PC features alongside more application specific functionalities. An hardware abstraction layer allows the development of soft and hard real-time applications leaving the final user with the possibility to deal with a general purpose PC or to exploit the FPGA in terms of fast peripherals control.

IOC General Overview and Status

The IOC aims to be an universal controller capable of extending the control reach to all the devices in the SPES facility. It will be embedded into physical equipment and will control or monitor their operation allowing the computational load to be spread among intelligent nodes in the control network. The IOC exploits the Computer On Module Express standard and a Xilinx Spartan-6 XC6SLX75T FPGA. The goal is to use in all our applications a standard Linux distribution since the most time-critical tasks will run in the FPGA avoiding the need of a real-time operating system. The resources linked to the FPGA become virtually part of the processor memory; the VHDL core that handles the communication with the COM Express, it allows a transparent map of the FPGA registers and I/O resources into the I/O space of the PC.

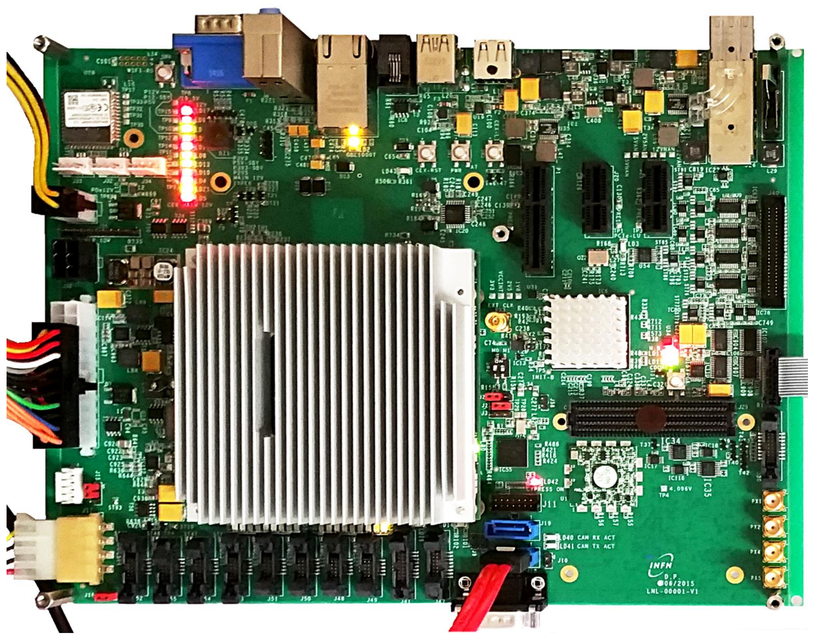


IOC Block Diagram.

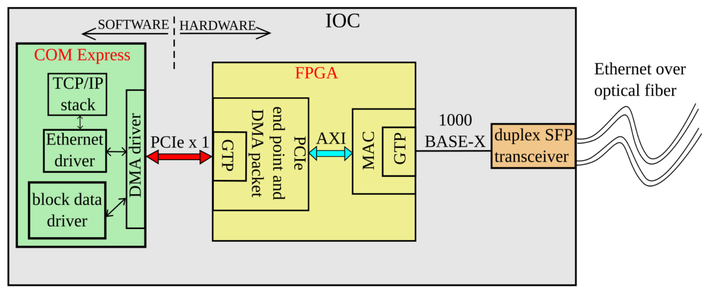


FPGA Remote Reconfiguration.

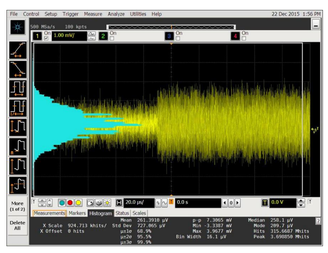
The COM Express used is the compact form factor cExpress-BT with the low power Intel Atom E3845 processor. The Intel x86_64 architecture makes software development straightforward, easing the portability.



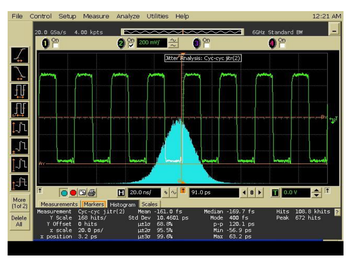
IOC Prototype Top View.



Optical Ethernet.

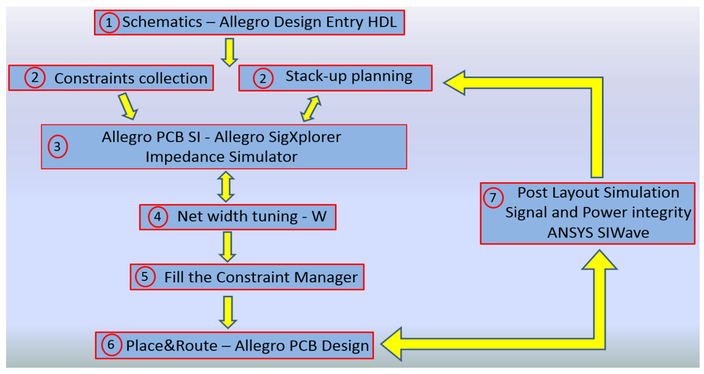


Ripple Measurements – FPGA Core Power Supply.

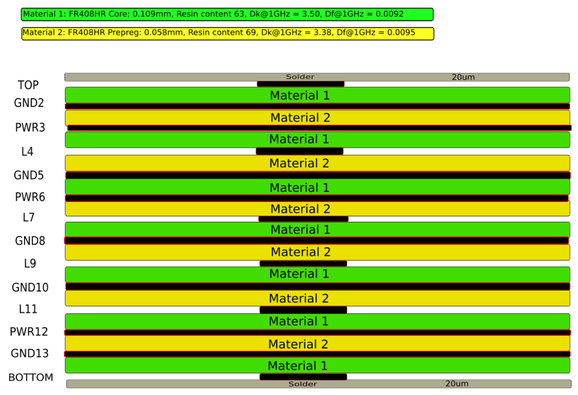


Cycle-to-Cycle Jitter Analysis.

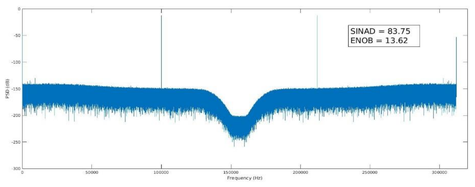
The grounding strategy has been analyzed carefully due to the presence of PoE+ powering together with high resolution analog converters.



PCB Design Flowchart.

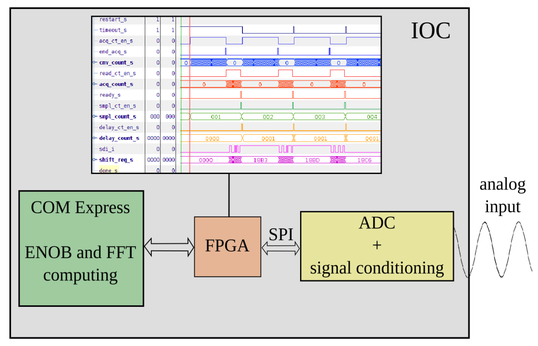


IOC Stackup.



Power Spectral Density ADC 24-bit.

$$ENOB = \frac{SINAD - 1.76 + 20\log(\frac{FullscaleAmplitude}{InputAmplitude})}{6.02}$$

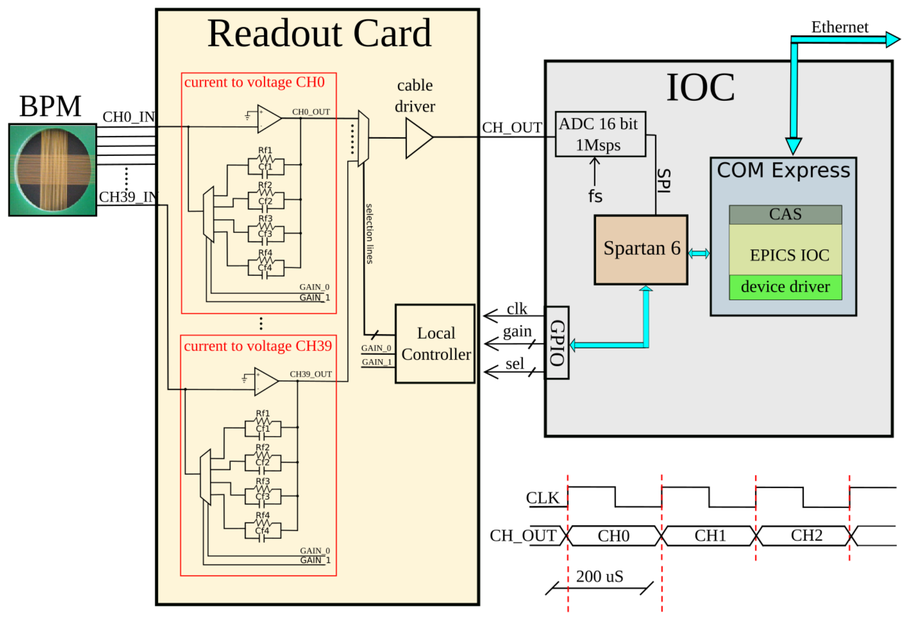


ADCs Test Setup.

Application of IOC in the Beam Diagnostic System

Beam Profiler Monitor (BPM)

BPM consists of a grid of twenty horizontal and twenty vertical thin gold plated tungsten wires. The ion beam crossing the grid deposits a charge on the wires. The beam profiler must be able to reconstruct the beam transverse profile by reading out the current from each wire. The existing acquisition system foresees the usage of VxWorks real-time operating system to run several parallel tasks. The new BPM data acquisition system architecture will be based on the IOC and the most time-critical tasks will be performed in the FPGA freeing the CPU from hard real-time operations. The 40 channels are multiplexed to a single voltage analog output. IOC controls the scanning of the forty channels via a clock signal which lasts 40 x 200 us period pulses. FPGA handles also the data digitization, data buffering and DMA data transfers to the processor. The COM Express, running a standard Linux distribution, it implements an EPICS Channel Access Server making BPM data available to remote EPICS clients for beam profile visualization. The refresh rate is set to about 20 frames per second. EPICS will also integrate in the control system the slow control for stepper motors.



BPM Data Acquisition Architecture.

Conclusion

The IOC designed addresses the needs of most control subsystems at LNL. It will be integrated in the distributed control system architecture foreseen by EPICS preserving the possibility to manage distribute hard real-time tasks. Beam diagnostic data acquisition, electrostatic beam focalization and extraction, electrostatic beam steerers are target applications and ideal test benches for the IOC.

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