SPI BOARDS PACKAGE, A NEW SET OF ELECTRONIC BOARDS AT SYNCHROTRON SOLEIL

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Abstract

SOLEIL is a third generation Synchrotron radiation source located in France near Paris. The Storage Ring currently delivers photon beam to 23 beamlines.

As the machine and beamlines improve their performance over time, new requirements are identified. On the machine side, new implementation for feedforward of electromagnetic undulators is required to improve beam stability [1]. On the beamlines side, a solution is required to synchronize data acquisition with motor position during continuous scan.

In order to provide a simple and modular solution for these applications requiring synchronization, the electronics group has developed a set of electronic boards known as the "SPI board package".

This paper describes the development conducted and the results obtained with this solution.

REQUIREMENTS

Since accelerators and beamlines work and received users, operational feedback has enabled us to identify requirements to improve systems. The two main requirements are the improvement of beam stability during undulator movement and the enhancement of the beamlines scan. The translation of these two requirements in terms of control is as follows:

- Upgrading control of Electromagnetic undulators to improve the feedforward
- Developing an optimized control for EMPHU (rapid undulator combining coils and permanent magnets).
- Processing encoder signals:
  - Interfacing incremental encoder signals with our standard counter board
  - Protocol Conversion
    - incremental encoder signals into « PULSE » and « DIR »
    - single turn absolute encoder to multiturn absolute encoder…
    - generating trigger or synchronization from encoder signals
    - calculation on multiple encoders
    - duplication of encoder signals

Moreover our strategy for these developments not only considers technical aspects but also budget and working load. The R&D activity of the ECA (Electronic Control and Acquisition) group is shared with accelerators and beamline operation. Considering these aspects, it is crucial for a small team with a small budget like ours to coordinate developments well and choose a technical solution that is easy to implement and maintain.

In order to offer a solution to these requirements, the ECA group has implemented the following architecture.

ARCHITECTURE

In the SPI board package architecture (Figure 1), the boards can be connected together in a daisy chain and communicate with the controller via a SPI (Serial Peripheral Interface) Bus. Communication with the control system is done via Ethernet.

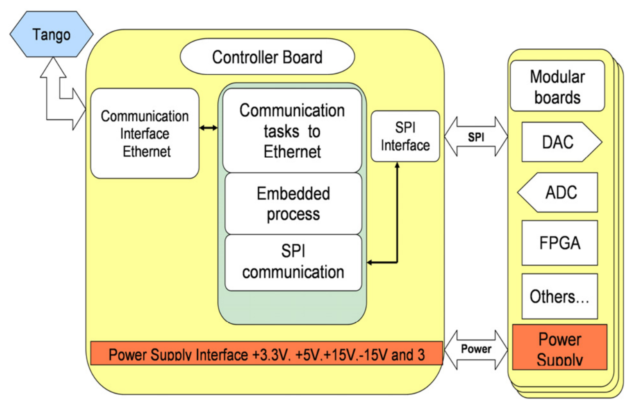

Figure 1: Functional diagram of the SPI BOARD PACKAGE.

The goal of this architecture is to give us a platform on which we can develop specific solutions with simple, reliable and durable tools. The platform is suitable in particular for applications with synchronization requirements, which are managed by implementing the process at low level.

Furthermore, this platform is modular. Each board can be connected with others as needed. And it enables us to deliver solutions for applications with an analog interface or motion interface (encoder side). Finally it's easy to connect it to the Soleil control network.

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TECHNICAL CHOICES FOR PROGRAMMABLE COMPONENTS

In order to give a solution for the requirements identified in 2007, initial versions of boards were developed with basic components which allowed us to start quickly and validate the architecture. The first version of the controller board is built around an 8051 microcontroller communicating via Profibus to the supervision. For the board processing encoder signals, we use a basic SPARTRAN III FPGA Xilinx [2].

Microcontroller

Thanks to this experience with the first boards, an upgrade of the controller board called SPICONTROLLER has been approved for a more powerful microcontroller with an Ethernet interface. After analysing the market states for microcontrollers and microprocessors, ARM cortex M3 technology was selected.

The choice of this device takes into account the state of the technology, the price and the investment required for the development tools and test bench.

The device selected for the development is the Texas Instruments [3] LM3S9B96 for the following characteristics: Multipurpose microcontroller used in industry and medical applications: Integrated Ethernet controller, Ethernet 10/100 MAC&PHY, On-chip Memory: 256KB Flash, 96KB SRAM, 80MHz Cortex Processor Core, 2 SPI interfaces.

For the embedded software of the SPICONTROLLER, after evaluating different operating systems and TCP/IP stacks, we selected RTX and TCPnet.

The choice to use this OS and TCP/IP stack is motivated, after evaluation of other OSs and stacks, by the full set of configurations and the ease of configuration via a wizard in the Keil [1] framework.

FPGA (Field Programmable Gate Array)

The FPGA selected for the SPIETBOX was chosen because it had sufficient capacity in terms of pins, cells etc., to implement the first requirement of protocol conversion for encoders (figure 2).

Furthermore this FPGA was already used by the team on the TIMBEL cPCI board [4]. The experience with this component allowed us to quickly design the SPIETBOX. This board is now also used to implement more complex applications such as “Synchronization of Goniometer and Pilatus detector for continuous scan” This application is presented below in the results section.

For that reason, we are envisaging, for future requirements, improving the performances of the FPGA and the input and output of the board.

But before considering an upgrade of the SPIETBOX, a review of the first experience and an analysis of the new requirements must be carried out.

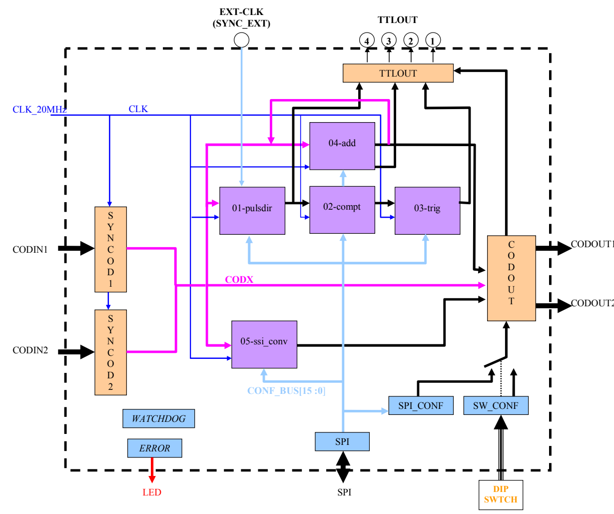

Figure 2: FPGA architecture of protocol conversion for encoders.

BOARDS

To date, the ECA group has developed the following set of boards:

- SPICONTROLLER: controller board with Cortex M3 microcontroller.
- SPIDAC: DAC 4 channels board, 16 bits, ±10V range
- SPIADC: ADC 4 channels board, 16 bits, ±10V range
- SPIETBOX: Processing encoder signal board based on Xilinx FPGA SPARTAN III, 4 Encoder inputs/outputs, 4 TTL Outputs, 1 SPI interface (Works in standalone or connected to SPICONTROLLER

This set of boards is integrated in a low cost standard 3U, 19” crate as shown on Figure 3.

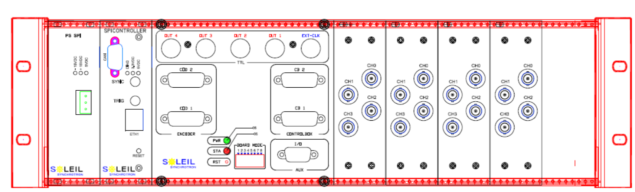

Figure 3: SPI Boards integration.

SOFTWARE STANDARDIZATION

To ease the integration of the SPICONTROLLER in the control systems, a generic memory structure has been specified. The memory is organized in 32 bits data block Registers with the following organization: State, Status, Error, Command, RW and Read Attributes.

You can have as many blocks as you have identified objects or functions.

This organization of the memory fits with the requirements of the generic Tango [5] device server known as SPIdataviewer. This server is designed to be easily configured to access the memory of the SPICONTROLLER.

RESULTS

In this part, we describe two applications of the SPI board Package already in production.

Upgrade of the Control of HU256 Electromagnetic Undulator

Each HU256 undulator[6] is driven by a total of fifteen power supplies including three main power supplies, four correction power supplies and eight so-called modulation power supplies. Whereas the main power supplies generate the 256 mm period, 3 m long periodic magnetic field, which makes the electron beam radiate, the correction power supplies create short extremity magnetic fields in order to cancel the residual closed orbit distortion caused by the undulator magnetic defects. Finally the modulation power supplies modulate some field peaks, allowing the so-called quasi-periodic mode, in order to decrease the intensity of the radiation higher harmonics.

Since they were installed, the three HU256 undulators used to be driven using the Profibus interface, but many transitory variations could be observed on the electron beam orbit, perturbing the radiation stability for all the beamlines as shown on Figure 3. An analysis determined that these effects were caused by non-synchronization between the different power supplies.

The upgrade of the system entails generating synchronized analog signals with the SPICONTROLLER in order to drive the power supplies. This evolution allowed improved synchronization of the power supplies, leading to a decreasing of the orbit transitory perturbation and thus as shown on Figure 4, reduced use of the SOLEIL storage ring fast orbit feedback.

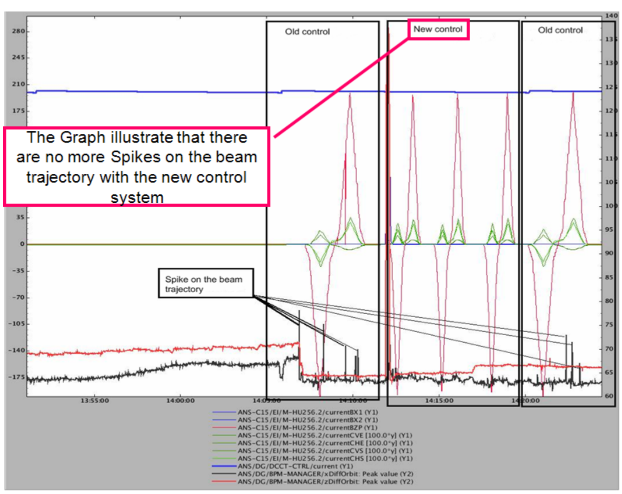

Figure 4: Acquisition showing the difference between old and new control system of HU256 undulators.

Synchronization of Goniometer and Pilatus Detector for Continuous Scan

On PX1 beamline [7], when a continuous scan is done acquiring Frames on Pilatus detector during goniometer movement, the following architecture (Figure 5) has been implemented to:

- Synchronize goniometer position, Shutter aperture and Pilatus acquisition
- Check that acquisition is well done.

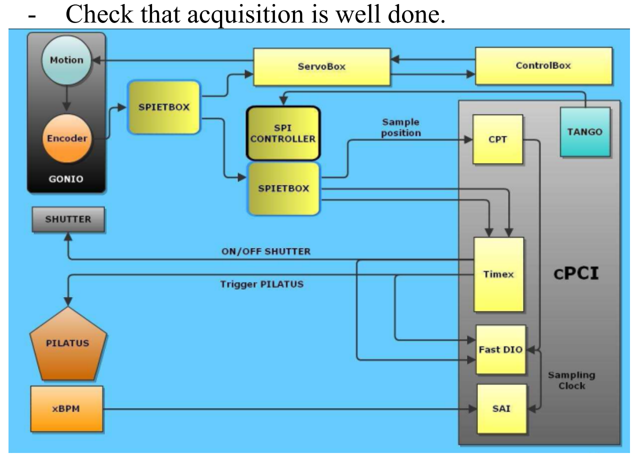

Figure 5: Architecture for PX1acquisition with Pilatus.

The Pilatus detector allows four acquisition modes that are four different ways to synchronize acquisition. In this architecture these synchronizations are implemented in the SPIETBOX managing the following signals: encoder position, trigger to and from the Pilatus, shutter trigger.

The SPICONTROLLER is used to configure the different modes and to transfer some information along the process. The information coming from the SPIETBOX and beam intensity from XBPM are logged for diagnosis along the process.

At the moment in the most used acquisition mode with Pilatus internal clock (Figure 6), the SPIETBOX sends a trigger to start the detector which uses its own internal clock to take the images.

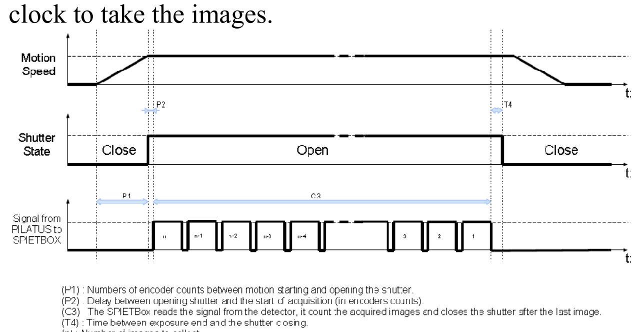

Figure 6: Timing of the most use triggering mode.

The advantages of this architecture using the SPIETBOX are to have good correlation between data acquisition and motor movement thanks to hardware synchronization. It enables the scientists to have a quick validation of the acquisition, thanks to the logging of all experimental conditions. Lastly, it simplifies control of the Pilatus detector's modes.

CONCLUSION

This platform allows us to embed process close to the hardware with open tools. Thanks to this solution we improve the performances of applications requiring beam stability or synchronization of multiple detectors acquisition.

The next step to increase calculation possibilities with this platform is to upgrade the SPIETBOX but we are also considering developing a co-processing board for SPICONTROLLER based on DSP or FPGA.

Future applications using this solution will include:

- Upgrade of HU640 Undulators to improve switching performance.
- Control of Emphu Undulators.

Finally all these boards are interesting for other synchrotron facilities that have the same requirements. In order to collaborate with them, the ECA group shares a part of these developments through the "Open Hardware Repository (OHR) [8]" platform.

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