LIBERA ELECTRON BEAM POSITION PROCESSOR

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Abstract

Libera is a product family delivering unprecedented possibilities for either building powerful single station solutions or architecting complex feedback systems in the field of accelerator instrumentation and controls. This paper presents functionality and field performance of its first member, the electron beam position processor. It offers superior performance with multiple measurement channels delivering simultaneously position measurements in digital format with MHz kHz and Hz bandwidths. This all-in-one product, facilitating pulsed and CW measurements, is much more than simply a high performance beam position measuring device delivering micrometer level reproducibility with sub-micrometer resolution. Rich connectivity options and innate processing power make it a powerful feedback building block. By interconnecting multiple Libera electron beam position processors one can build a low-latency high throughput orbit feedback system without adding additional hardware. Libera electron beam position processor is ideally suited for the Third and the Fourth generation light sources.

INTRODUCTION

The experience, gained through first two generations of DBPM (Digital Beam Position Monitor), inspired our team to develop entirely new generation of the EBPP (Electron Beam Position Processor) – the Libera.

Figure 1: Libera.

Libera is an all-in-one solution that enables accurate beam position monitoring, trouble-free commissioning, and local and global feedback building. Customization is a capability that allows adaptation of functionality of the device to specific requirements without changing hardware. Fast serial interconnect technologies provide a brand new perspective on the process of developing high availability and next-generation accelerator control and feedback systems.

DATA FLOW

Three branches of data flow are running in parallel, giving the user the possibility to perform more different measurements at the same time.

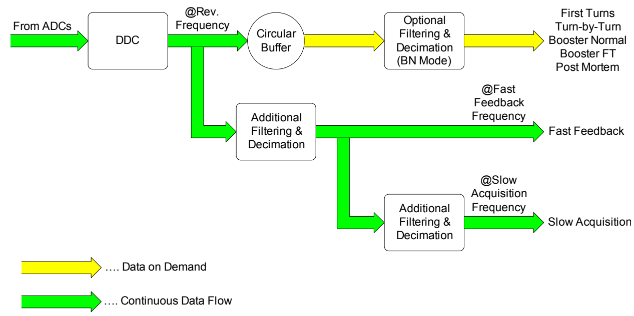

Figure 2: Simplified Data Flow.

Coming from analog module, the signal is digitized and processed inside FPGA on DDC (Digital Down Converter).

The data (four pairs of I and Q components) on first branch is stored in the circular buffer with a depth of 32MB. From there it is acquired on demand, either on trigger or on direct request from control system.

The data on second and third branch is additionally filtered and decimated down to fast feedback rate and then to closed orbit rate.

HARDWARE

A 1U 19” enclosure with a power supply accommodates analog module, digital module and SBC (Single Board Computer), which are supported by software that is easily adjustable to customer needs.

Analog Module

The analog module (Figure 3) consists of a quasi-crossbar switch, four identical RF channels, four analog-to-digital converters, and an interface to the digital board.

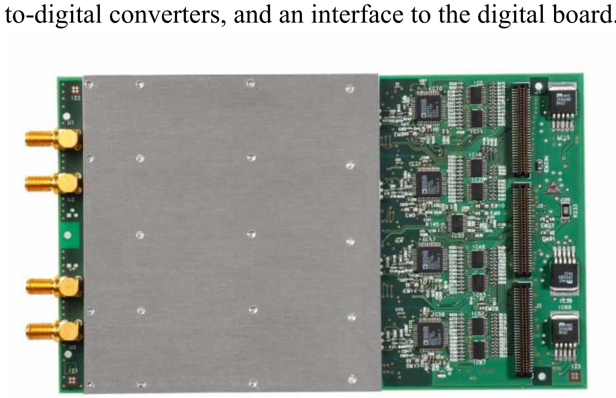

Figure 3: Analog Module.

The innovative patent-pending quasi-crossbar switch matrix unites the benefits of both the multi-channel and the multiplexed system, and at the same time compensates for the disadvantages of the two.

We achieve reproducibility and good "beam vs. current" dependence, which are multiplexed system characteristics and – using a multi-channel approach – we ensure much broader band of operation facilitating position measurements on a turn-by-turn basis. The details are available in [2].

Digital Module

The Virtex II Pro FPGA with two embedded IBM PowerPC™ 405 processors from Xilinx is the core of the digital module (Figure 4). It is a system-on-chip (SoC) solution, which facilitates the following functionalities: digital signal processing, communication, formatting, timing, and housekeeping. This architecture allows replacement of some hard-wired DSP functionality with more flexible procedural description of algorithms.

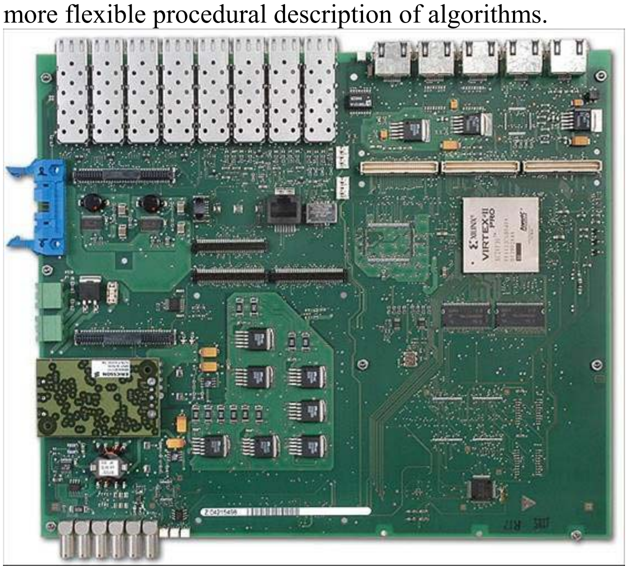

Figure 4: Digital Module.

Another powerful feature of the Virtex-II Pro FPGA are integrated Rocket IO transceivers with up to 3.125 Gbps.

High capacity memory enables the storage of a large amount of data. The basic Libera Electron Beam Position Processor allows storing of 32 Mbytes of data or approx. 1 million turn-by-turn samples.

SBC

The SBC built around a StrongArm based Intel Xscale PXA255A processor, is a mezzanine board. It provides application software, bootstrap for the configurable FPGA logic, configuration, diagnostics and maintenance of Libera. It has 64MB of RAM and 32MB of flash. Fast Ethernet is a native networking solution.

Interfaces

With its numerous hardware interfaces, Libera offers rich connectivity options. Most of interfaces are connected directly to the FPGA, allowing total flexibility in purpose and use.

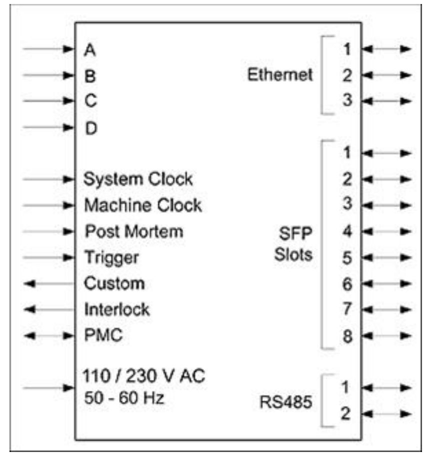

Figure 5: Hardware Interfaces.

The SFP (Small Form Pluggable) widely supported open standard enables hot swap of various types of fiber optic and copper-based transceivers into host equipment. This provides a user with the flexibility to choose between different protocols. Applications include: Gigabit Ethernet, Fibre Channel, and Infiniband.

SOFTWARE

The software is composed of system software and application software. The application software is limited to the SBC, while the system software spans FPGA with embedded PowerPC processors, in addition to the SBC.

System Software

The System Software can be roughly divided into the operating system component, covering GNU/Linux and the embedded, digital signal processing (DSP) component on the FPGA. The key elements of the latter are various filtering and decimation algorithms The GNU/Linux operating system on the SBC provides a flexible and capable platform for such tasks as networking, maintenance and customization.

Application Software

The Application Software enables seamless integration of Libera into various accelerator control systems. It allows users to interface Libera across a network, deploy custom applications on Libera and use Libera in fields or for tasks previously not envisioned, yet in a way that is consistent and well defined. This software can be divided into core and extensions.

Core is a set of components common to all members of the Libera family and required to access Libera. Its most exposed component, the Control System Programming Interface (CSPI), is a high-level programming interface that allows separating control system-dependent knowledge from logic and details related to Libera. The CSPI is effectively shielding applications from intricacies and changes in the underlying system software and hardware. Implemented as a library, the CSPI facilitates accessing full Libera functionality in a consistent and documented way.

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Extensions, on the other hand, address customer-specific needs such as integration into accelerator's control system (i.e., EPICS IOC, Tango Device,..)

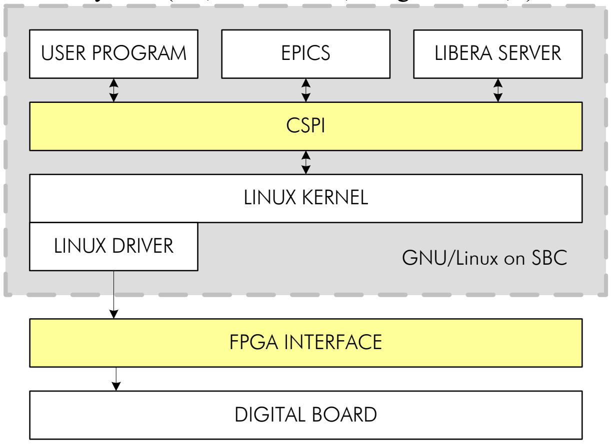

Figure 6: Software Architecture.

SOME PRELIMINARY RESULTS

The presented results are preliminary and done without signal conditioning.

Measurements in Laboratory

The measurement below (Figure 7) was done in laboratory on DLS (Diamond Light Source) Libera from series.

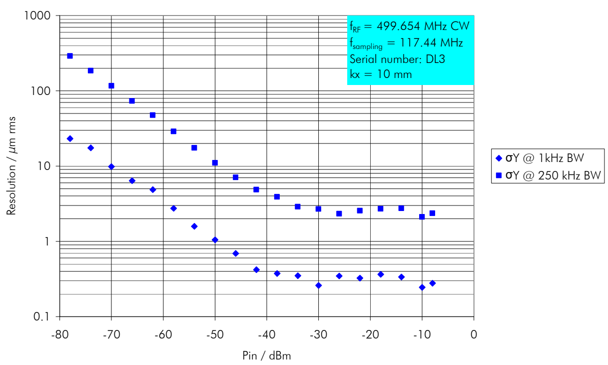

Figure 7: Resolution at two different bandwidths.

As it can be seen from the graphs of resolution over huge dynamic range, both curves follow theoretic model. RMS is getting smaller from -80dBm to -40dBm of P_{in}. Prevailing influence on the curve in that section is coming from thermal noise.

From around -35dBm to 0dBm the resolution is constant due to prevailing influence of phase noise.

Measurements on Beam

First measurements on the beam with Soleil Libera were performed on ESRF booster in April 2005. On the graph below (Figure 8), there is a kick in vertical plane. The kick happened 15ms after injection in the booster. The amplitude of the kick is relatively high because the energy of the beam immediately after injection is low.

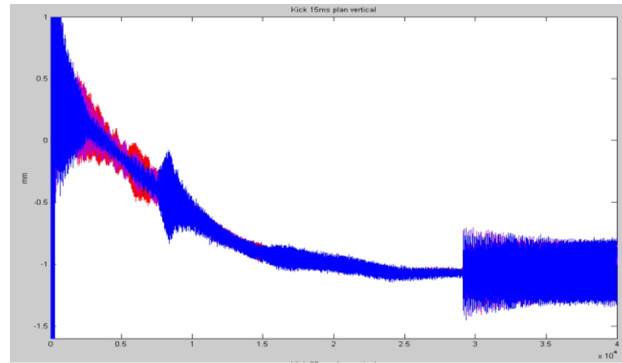

Figure 8: The Kick in vertical plane.

Another measurement with DLS Libera was performed on SRS storage ring. The decay of the signal from one injection to the other was observed. Note that the horizontal scale is in hours. The movement that can be seen at the measured beam was confirmed as actual move of the beam during decay.

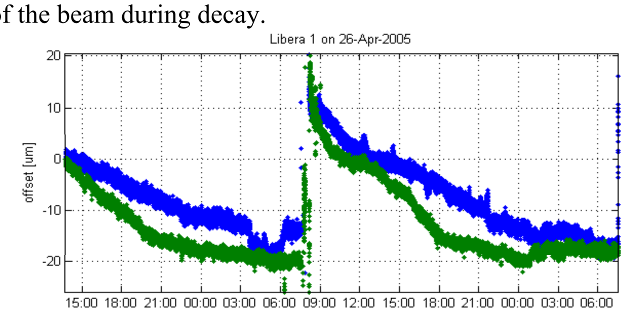

Figure 9: The Decay of the beam between two injections.

CONCLUSION

Libera is a product family, which open architecture provides solid foundation for building different family members, each optimized to satisfy specific beam instrumentation needs. In this article we have explained the advantages of Libera family and demonstrated excellent performance of its first member.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Jean-Claude Denard and the Soleil team, Guenther Rehm from DLS and Rob Smith from SRS for giving thesupporting beam measurements. I would also like to thank the Instrumentation Technologies colleagues, who designed and developed Libera.

REFERENCES

[1] R. Ursic and B. Solar "FEL and Libera Both Push Performance into New Frontiers" Free Electron Laser Conference 2004, Trieste, Italy.
[2] U. Mavric "Innovative RF Design Unites Benefits of Multiplexed and Multi-channel System", 11th Beam Instrumentation Workshop 2004, Knoxville, USA.
[3] R. Ursic "Libera Electron Beam Position Processor", 3rd International Workshop on Beam Orbit Stabilization – IWBS 2004, Switzerland.