Em# PROJECT. IMPROVEMENT OF LOW CURRENT MEASUREMENTS AT ALBA

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Abstract

After two years with 50 four-channels electrometer measurement units working successfully at Alba beamlines, new features implementation have forced a complete instrument architecture change. This new equipment is taking advantage of the targets achieved as the remarkable low noise in the current amplifier stage and implements new features currently not available in the market. First an embedded 18 bits SAR ADC able to work under up to 500V biasing has been implemented looking for the highest possible accuracy. The data stream is analysed by a flexible data processing based on a FPGA which is able to execute sample-by-sample real-time calculation aimed to be applied in experiments as the current normalization absorption between two channel acquisitions; being able to optimize the SNR of an absorption spectrum. The equipment is oriented from the design stage to be integrated in continuous scans setups, implementing low level timestamp compatible with multiple clock sources standards using an SFP port. This port could also be used in the future to integrate XBPM measures into the FOFB network for the accelerator beam position correction.

INTRODUCTION

ALBA is a 3GeV third generation synchrotron light source located in Cerdanyola del Vallès (Barcelona). Nowadays, the facility houses 7 commissioned beamlines and there is space for 24 beamlines more.

During the beamlines installation an in-house 4-channels electrometer (ALBA-Em) [1] was developed, which was thought to be mainly used for diagnostics applications (xBPMs, photo-diodes, slits). ALBA-Em achieved such nice performance that the current amplifier was chosen as the acquisition device of the spectroscopy beamline detector. Table 1 shows the specifications.

After the success and feedback from scientists it was clear that new features were needed. Some of these needs fit with the concept of an electrometer, such as, better resolution, higher sampling rate and acquisition with bias; other ones exceed the frame of a simple electrometer like the possibility to perform real-time signal processing, or the generation of feedback signals. Foreseeing the possibility of going beyond, a new approach to data-acquisition and electronics control has been created under the name of Harmony, which defines the communication protocol between the devices and their control system.

ELECTROMETER

The new electrometer (Alba-Em#), shown in Fig. 1, is thought to improve all features of the previous electrometer, from the current amplifier to its control system. This includes a rise in ADC accuracy and sampling rate up to 18 bits at 400kS/s. Another meaningful change is that the current input can be biased up to 500Vdc.

However, the biggest change is in the control of the Alba Em#, which will be done with an FPGA. The FPGA allows features that are not available or are very limited, when are implemented in a microprocessor. In this way, 1ns time resolution can be achieved and all measurements will include a timestamp. Moreover, the Alba Em# is being designed to be used in closed loop control systems and for this reason there will be several output channels like an analog output, 2 fast outputs to generate a frequency output or a PWM signal, and 4 general purpose outputs.

Table 1: Alba Em# Specifications

Feature	Target description
Current range	7 range available from 1mA to 100pA, or 5 ranges from 10nA to 1pA
Bias	Isolation Voltage of current amplifiers 500V
ADC	4 x monotonic 18bits bipolar SAR 400kS/s
Analog out	1x Monotonic low-glitch 16bits 200kS/s
Fast digital inputs	2 channels, for triggers inputs or to read frequency up to 100MHz
Fast digital outputs	2 channels, for triggers outputs or to generate frequencies up to 100MHz
GPIO	DE15M port for general purpose use
Control	Spartan 6 FPGA
Time Resolution	Timestamp in all the measurements with 1ns resolution
Latency	Maximum delay of 30µs.
External interface	RCM6700 in standalone Marvell 88E1111 in Harmony System

Current Amplifier

The actual current amplifier has a very good performance and for this reason is the less modified part. It is based on a transimpedance amplifier architecture with a gain up to 10GΩ and a second stage gain configurable up to 100. Also it has available two independent first order filters which can be adjusted from some kHz to some Hz bandwidth. The modification includes the implementation of over-current protections and a temperature sensor in order to correct gain drifts.

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The project includes a design of a new current amplifier using switching-capacitors to reduce noise as much that it was possible increase the gain and achieve resolutions in the sub-femto ampere range.

Analog to Digital Converter and Bias

The actual electrometer uses a 12bits ADC which resolution was mandatory to be increased, but also guaranteeing its monotonicity. AD7808 from Analog Devices was chosen because it matches with our initial requirements. The ADC works at 200kS/s, but two channels are used for each input to double the sampling rate.

Other important feature is being able to acquire measurement under bias voltage condition. This is used to increase the conductivity in the samples, to reduce the cross-talk in xBPM slits or when there are magnetic traps to break. In all this cases a bias of ±500V is enough. To allow bias voltage we decided to do a digital isolation after the ADC, which implies a radical redesign of the mechanics layout of all electrometer. For this reason and to keep current loses under control was mandatory to use triaxial cables where core are the signal to be measured, the inner shield is the guard at bias voltage and the outer shield is the ground.

Another decision was to place ADC and isolators in a different board of the Control Board to ease reparation and upgrades of the ADC.

Control Board

The major change of the control board refers to use of an FPGA, which not only brings to the new electrometer a huge flexibility, but also increase a lot the time resolution. This improved feature allows developing a new environment of device interconnection, named Harmony, with the following features: transfer rate higher than 500Mb/s, a time resolution of 1ns and a huge flexibility with the acquired data. The connection will be done using the 1000 base-T specification, allowing this speed using a Cat5e copper Ethernet cable.

The board includes an analog output that can be used in feedback control applications or as a diagnostic output. This output will be generated with a low glitch 16-bit monotonic DAC (DAC8560ID) with a sampling rate of 200kS/s and a range from 0 to 5V.

Alba Em# includes 2 fast digital inputs that will allow to be configured to be used as trigger input, measurement gate input or even reading encoder quadrature, or clock signals with a bandwidth of 100MHz. The output triggers are 2 fast digital outputs that also could be configured to generate pulses, frequency outputs or PWM signals up to 100MHz. The SDB15 includes serial communications and general purpose pins.

The unit will also include a generic microcontroller of the Rabbit Semiconductor family that will provide an external Ethernet connection for use the equipment without the need of implementing a Harmony platform or as diagnostic port of the device and for firmware upgrades.

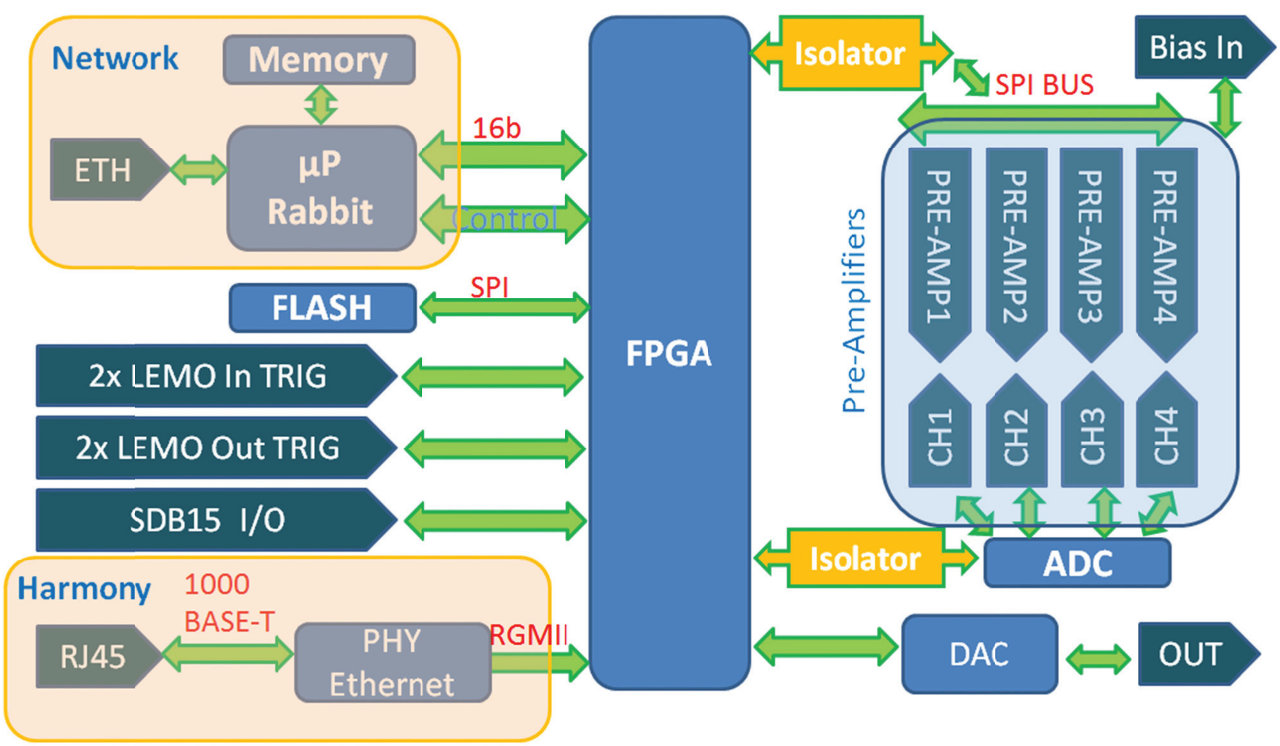

Figure 1: Schema of Alba Em# with the interconnection of the main elements.

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HARMONY

The conceptual necessity of an instrumentation system as Harmony emerged in the different meetings held in Alba while discussing the requirements of data synchronization, continuous scans [2] and for closed loop control systems. During them different conclusions were reached: first the need of implementing a generic timestamp framework below µs range accuracy, second the necessity of keeping the current high level software flexibility and third the convenience of implementing a synchronous acquisition scheme to ease generic closed loops implementation.

Harmony main objective is to implement a system, where synchronous timestamped data are shared between its elements, with a fully configurable bandwidth. To achieve it a star topology is proposed where a Device Manager will be responsible of external clock synchronization (using PTP, NTP or other generic synchronization standards depending on the application). Moreover, a synchronous communication to the different elements of the network will be executed with a characterized latency. Doing in this way the timestamp could be obtained directly close to the measurement point and therefore avoiding the transmission and processing jitter inherent in a standard high level language control system implementation.

For implementing this scheme in practice a reflective shared memory between the Harmony Master and the different elements will be implemented. Doing in this way the data collected by all the elements will be present in all the points with a known latency. Each field could be configured as send-on-request to avoid transfer of unneeded data. This new concept will allow making calculus with input data according to their timestamp (sample-by-sample). The resulting data could be selected to be sent to other device manager to implement a closed loop system. The chosen physical media for this link is a Category 5e Ethernet cable that allows high data rate at long distance at affordable cost.

The communication between the device Manager and the high level control system is planned to be optimized using a direct memory access using PCIe 4x to an external CPU with a TANGO server [3]. Doing in this way the strategy of keeping the flexibility in higher abstraction programming languages will be kept.

One of the main initial objectives of the system is being able to insert commercial hardware in Harmony. In a first step this will be done using a generic FMC (FPGA Mezzanine Card) slot in a Harmony compatible device. In it the data acquired with commercial hardware will be offered as an extra puzzle piece in the available shared memory.

Harmony platform implementation is a strategic mid-term objective for Alba that should help to solve different complex problems in the near future: continuous scans generic implementation, generic closed loops between different points of one system or completely configurable synchronization signals sharing.

NEXT STEPS

Em# project is currently inside a rush activity with the objective of having the first fully working unit on January 2014. Current amplifiers modules design are finished and being manufactured. The ADC and Control boards are facing the end of its schematic design and starting its PCB design.

The first objective is to implement Alba Em# as a fully standalone system on January 2014 and it is planned to finish its implementation in an Harmony synchronous platform for end of 2014.

CONCLUSION

After being used successfully in more than 100 measurement points for two years, Alba Em project is evolving towards a new concept to achieve the new functionalities needed for the future (so-called Alba Em#): increasing internal ADC resolution, acquiring current reading under voltage biasing, implementing analog voltage output, adding more synchronization signals and having a powerful internal digital processing capabilities.

As a middle term project Harmony is proposed as a way of implementing a multi-equipment synchronous acquisition platform, open for collaborations, that would allow generic timestamp and the inclusion of commercial hardware. This system will help solving complex mid-term projects as generic continuous scans, or complex synchronization schemes. Alba Em# is thought as the “first stone” toward this future system implementation.

The first fully functional unit of Alba Em# will be available in January 2014.

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REFERENCES

[1] J. Lidón-Simon *et al.*, “Low Current Measurements at ALBA”, WEPMS025, www.JACoW.org

[2] D. Fernandez *et al.*, “Synchronization of Motion and Detectors and Continuous Scans as the Standard Data Acquisition Technique,” WECOAAB03, ICALEPCS 2013, to be published, www.JACoW.org

[3] D. Fernandez *et al.*, “ALBA, a Tango Based Control System in Python,” THP016, ICALEPCS’09, www.JACoW.org

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