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Elettra Sincrotrone Trieste

INSTRUMENTATION TECHNOLOGIES

Current Status of Elettra 2.0 eBPM system

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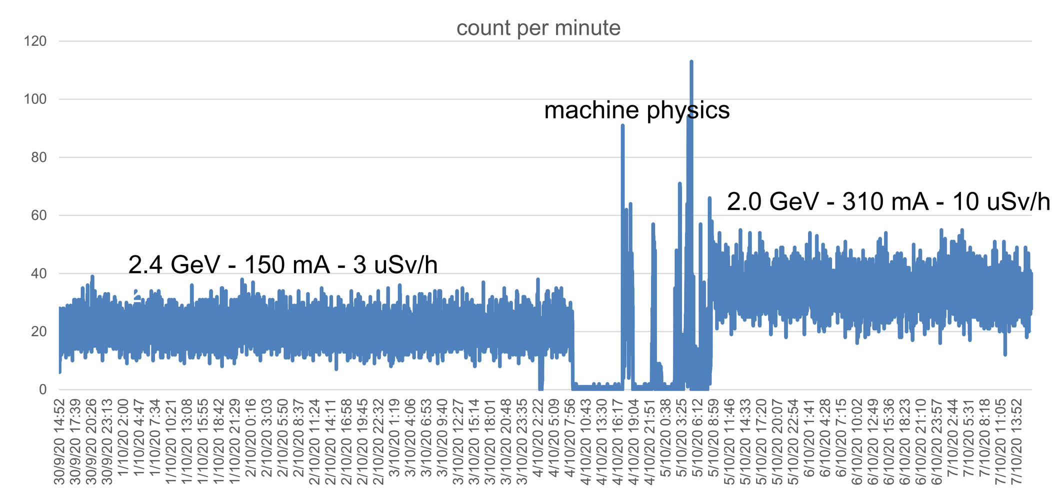
Introduction

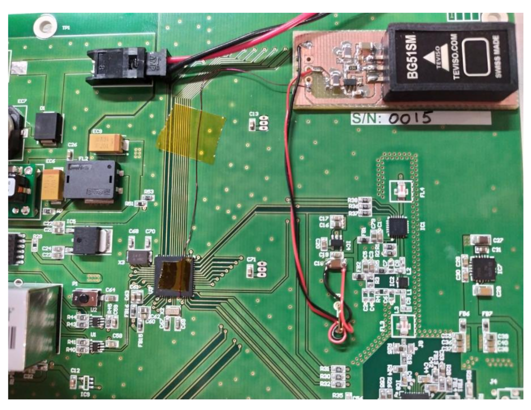
Elettra 2.0 will be the new diffraction limited storage ring that will start serving the users at the end of 2026, replacing the current machine (Elettra). Even if the lattice length will remain more or less the same, the number of beam position monitors (BPMs) will increase to 147. In order to reduce costs and optimize resources, the same electronics will be used in preinjector, transfer lines, booster and storage ring. Thus, different operation modes are required for a correct behaviour: single pass (first turn) mode, gated mode, close orbit mode. As a consequence of the excellent results obtained during the development of the overall prototype, the machine will be equipped with BPM controlled by electronics based on pilot tone. A modular approach was chosen, with analog front ends detached from the digital part. The front ends will be placed in machine tunnel, powered and controlled via Ethernet links, while the analog-to-digital conversion and processing unit will remain in accelerator service area (radiation safe), with sufficient computing power to manage two BPMs each. The required connections to machine infrastructure will be optical (e.g., 10 Gb Ethernet link for global orbit feedback data) or copper-based (interlock, synchronisation). The process of building such a system for a high number of units (about 200 for the analog front ends, 100 for the digital platform) is not straightforward. Many aspects have to be considered, especially whose related to manufacturing, maintenance and reliability. For this reason, a partnership was signed with Instrumentation Technologies after a tender procedure, in order to industrialize and produce all the components of the system. In this way, Instrumentation Technologies' long-term experience in manufacturing diagnostic tools for particle accelerators will be combined with Elettra's knowledge of the overall aspects of a light source. This collaboration is already making improvements over the original prototype, and these results will be discussed in the following sections.

Front end improvements

Radiation sensor

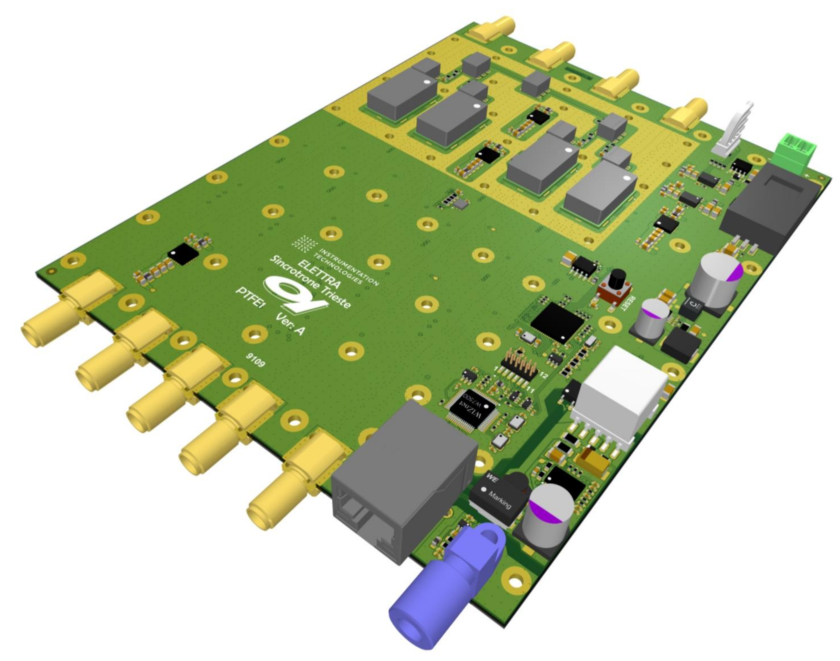
In order to compensate the overall signal path, the front end has to be installed in the machine tunnel, as near as possible to the pick-ups. This area presents unavoidable and unpredictable ionizing radiations due to multiple sources, that can damage the electronics and cause malfunctions. For this reason, a commercial radiation sensor has been integrated in the front end. Its output is directly connected to the internal microcontroller of the front end, that keeps track of the integrated dose over programmable time windows.



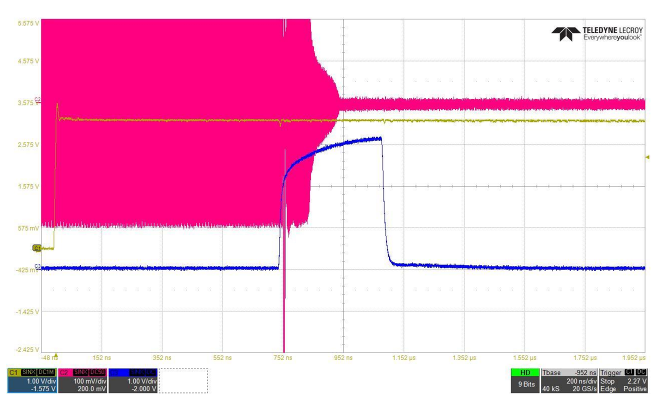


Industrialisation

The module's power supply has been changed from standard 12 V to Power-over-Ethernet (PoE) which reduces the number of cables and enables remote power cycle control. The prototype version was not optimized for special fill patterns, such as a "single bunch" fill pattern. The new module contains an additional RF path (selectable) with a SAW filter that stretches the short pulse to a usable filter ringing (200-250 ns) which is sufficient for a reliable position measurement. The original module was built from two PCBs connected over headers, while the new module is built from a single PCB which simplifies the mass production and eliminates failures associated with bad connection. From the installation point of view, the chassis and fittings were adapted to usually limited space in the tunnel and in order to facilitate the access for service. Nevertheless, it is possible to reprogram the firmware through the Ethernet connection.

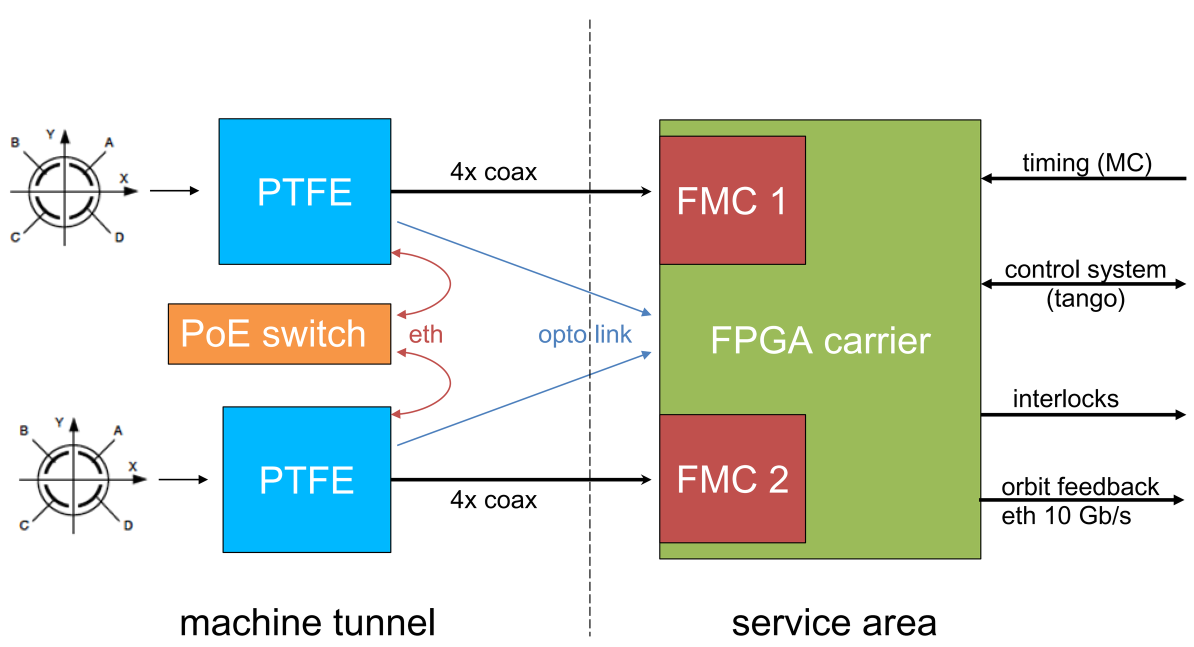


Glitch trigger



The procedure of changing the gain of the digital attenuators can require a significant amount of time, with a settling time of microseconds. During this time, glitches and spikes can occur on the output. These artefacts will reflect directly on the position calculated by the digital interface. Even if we proved that pilot tone compensation can greatly reduce them, a fiber optic phototransmitter (POF) has been added in order to communicate the gain switching event through a fiber optic link directly to the FPGA. The latter will tag the calculated positions during the switching phase, giving the user the possibility to decide whether to discard them or not.

Digital platform

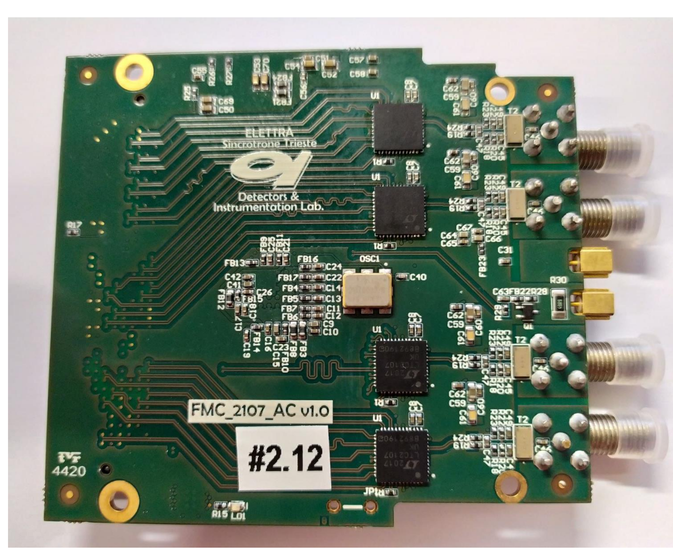


After the first experience with a FPGA-based evaluation board, we decide to move on the in-house developed board based on Intel Arria 10 GX FPGA. The whole double digital receiver and demodulator, written in Verilog HDL, has been successfully ported on the new platform, adding several features. Now the system is capable to send data over 10-Gb Ethernet, thanks to SFP+ interfaces. This will allow continuous streaming of turn-by-turn data to the global orbit feedback. Also, the possibility to choose the output data rate with a variable filter (from turn-by-turn to 10 kHz) has been added. However, we decided to go one step further: the final FPGA will be an Intel Arria 10 SX system-on-chip (SoC). The presence of an ARM hard processor assures more flexibility on higher level tasks, like system maintenance, configuration (remote firmware upgrade, diagnostic) and connection to the control system (Tango for Elettra). Furthermore, the higher pin number of the future FPGA will allow to host two HPC FMC connectors, that means two beam position monitors per digital unit. In this case, a beam angle calculation can be performed between two consecutive BPMs, enabling an efficient beam position interlock to protect the vacuum chamber.

4-channel, 16 bits A/D FMC

In order to use the new FPGA carrier board, we developed a 4-channel analog-to-digital conversion FMC card, based on Linear Technology LTC2107 ADCs, 16-bit, 210 MS/s. The input stage was carefully designed to handle 500 MHz signals, with a proper input impedance matching and an isolated balun for preventing ground loops.

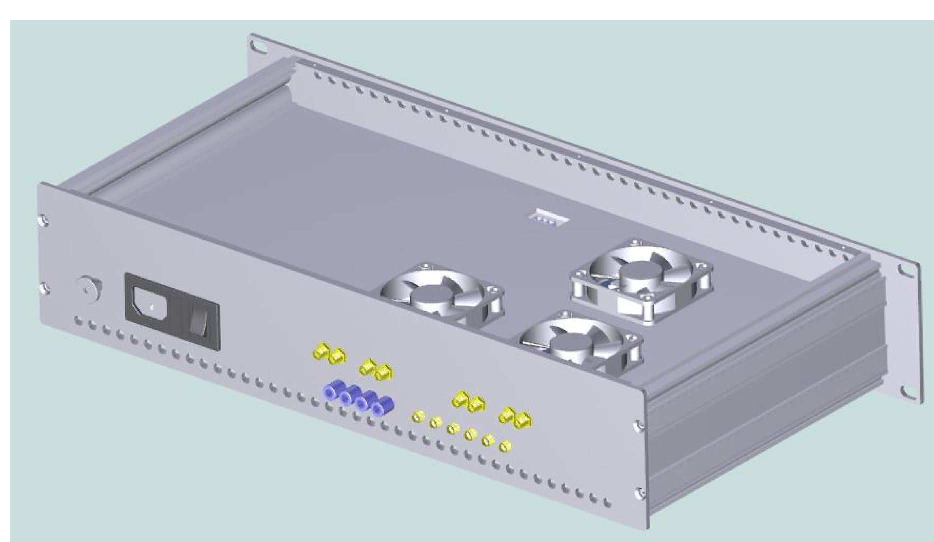
The clock tree relies on a Texas Instruments LMK04828 dual PLL, that generates and distributes to the four converters a clean sampling clock derived from machine revolution clock, with a fixed phase relationship.



Reliability and maintenance

The prototype of the digital acquisition unit was built from multiple boards connected with cables. After I-Tech's hardware review, the design was simplified and made ready for mass production. Due to more active and power-hungry components, the unit requires active cooling, provided by three fans. The cool air enters the chassis on the lower part of the front panel. The fans force the air through the PCBs to the upper part of the chassis. The warm air exits at the upper part of the back panel.

The 19" width chassis was designed to allow easy access to the fans on one side and to the PCB on the other side. Such design provides easy and quick service or maintenance.



REFERENCES

E. Karantzoulis et al., "Elettra and Elettra 2.0", IPAC 2021

G. Brajnik et al., "Integration of a Pilot-Tone Based BPM System Within the Global Orbit Feedback Environment of Elettra", IBIC 2018

G. Brajnik et al., "A Novel Electron-BPM Front End With Sub-Micron Resolution Based On Pilot Tone Compensation", IBIC 2016

G. Brajnik et al., "A Common Diagnostic Platform for Elettra 2.0 and FERMI", IBIC 2019

NEXT STEPS

- Review and optimization of the digital platform with hard processor
- Testing of pilot tone front end pre-series production
- Cope with worldwide delay of electronic components