White Rabbit based Picosecond Timing System for Scientific Facilities

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Abstract

The timing system is a critical element in scientific facilities such as particle accelerators and laser ignition installations. The various subsystems that comprise these facilities need a unified notion of time, which is provided by the timing system. This common time reference enables the machine to operate in a time-coherent manner and facilitates the accurate tracking of different events that occur during its operation. The timing system also supplies discrete triggering events and periodic signals required by the various subsystems. Additionally, it can be used for the distribution of radiofrequency signals throughout the facility.

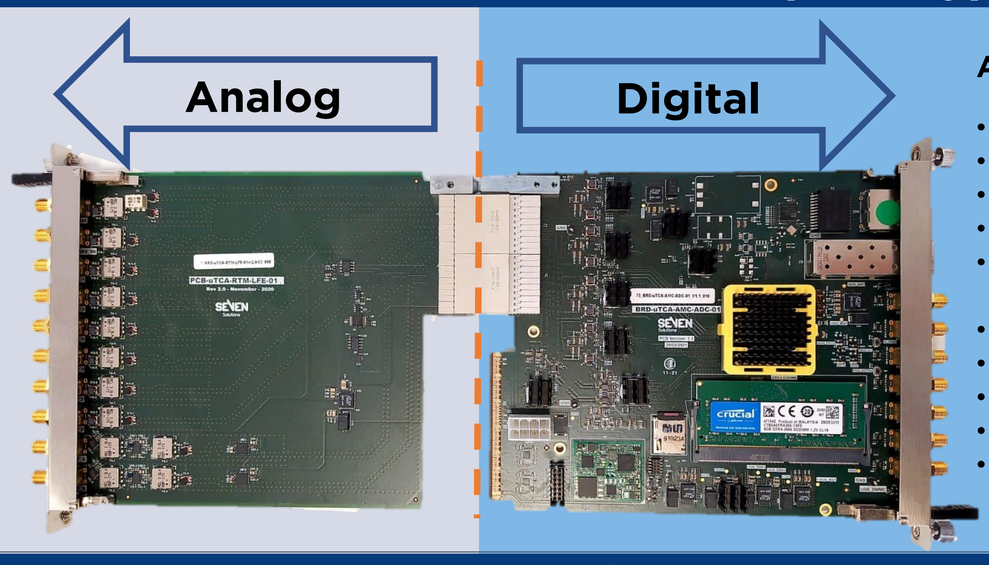
This work presents the timing system architecture based on White Rabbit technology, currently under development by Safran Electronic & Defense Spain SLU, for the distribution of synchronized triggers. The hardware, which is FPGA-based, will be detailed.

The timing system allows comprehensive configuration of triggering parameters, including direction, number of pulses, pulse rate, pulse period, and delay, offering a resolution on the order of 5 ps. White Rabbit technology provides sub-nanosecond accuracy and picosecond precision, along with important features such as automatic link calibration. The performance achieved will be demonstrated in this work.

Hardware architecture used for the prototype

Timing Analog board

- SMA connectors:
  - RF input for F_{ref}: this signal is used to get the reference of the installation, and it is used for synchronization with the installation itself.
  - Up to 7 additional RF inputs to monitor RF signals
  - Band pass filters in all the RF paths.
- Temperature sensor
- EEPROM memory
- Output amplifier in both channels



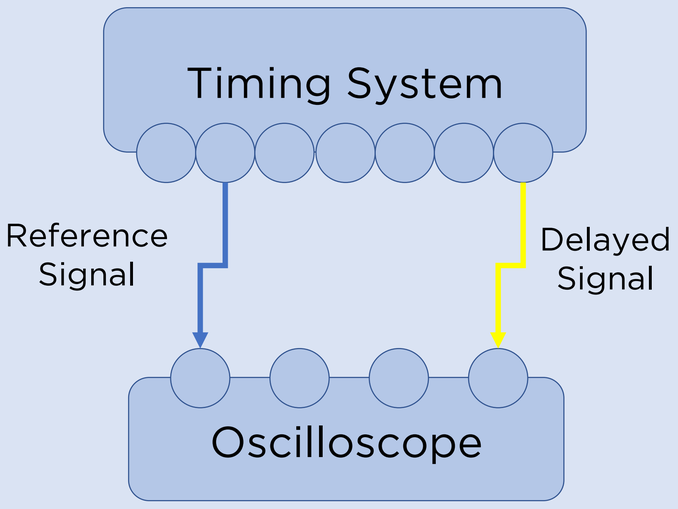
ADC board (AMC digitizer controller)

- 10 x Analog to digital converters (ADC)
- 2 x Digital to analog converters (DAC)
- Zynq UltraScale+ FPGA from Xilinx
- PLL to generate internal clock signals
- 8GB DDR4 memory for processor and data storage (postmortem analysis)
- uTCA MMC stamp
- Temperature sensor
- uSD socket, uUSB port
- ETH & SFP port (White Rabbit compatible)
- EPICS compatible (control system)

Performance test/results

Picoseconds accuracy

Set-up

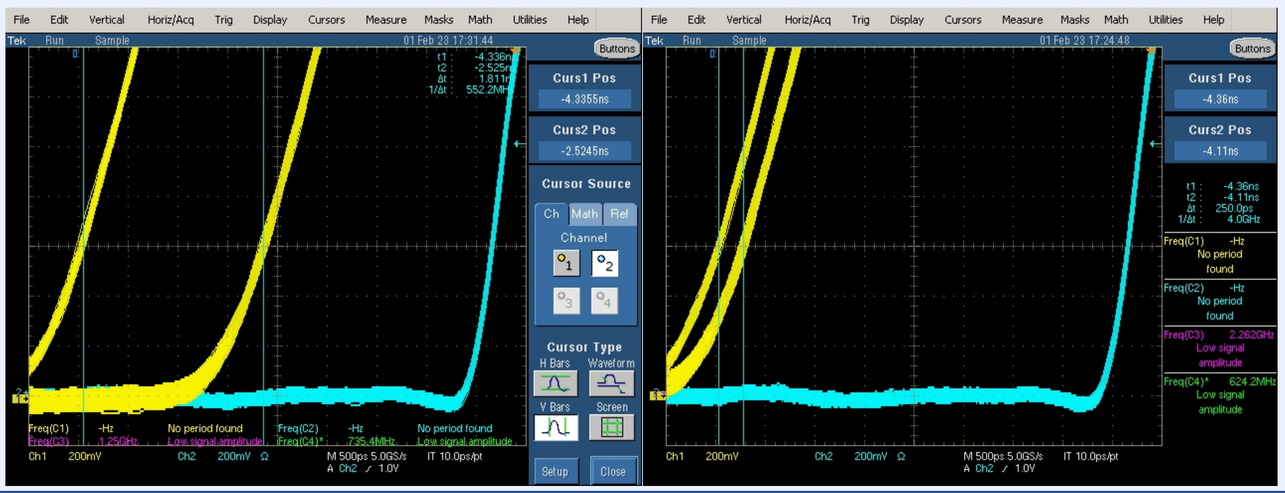


Results

Signal generation with an accuracy of a 3-15 picoseconds.
High accuracy signals can be generated with a delay of 3-15 picoseconds up to 1.8 nanoseconds compared to a reference PPS signal.

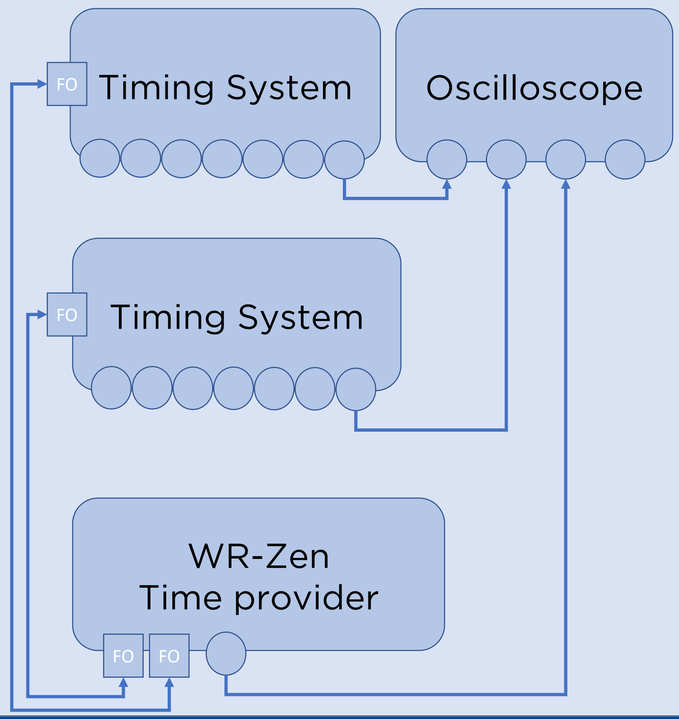
Images show a reference signal (blue) and another one delayed an amount of picoseconds (yellow).

- Signal delayed 1.81ns (image left)
- Signal delayed 250ps (image right)



Subnanosecond synchronization

Set-up

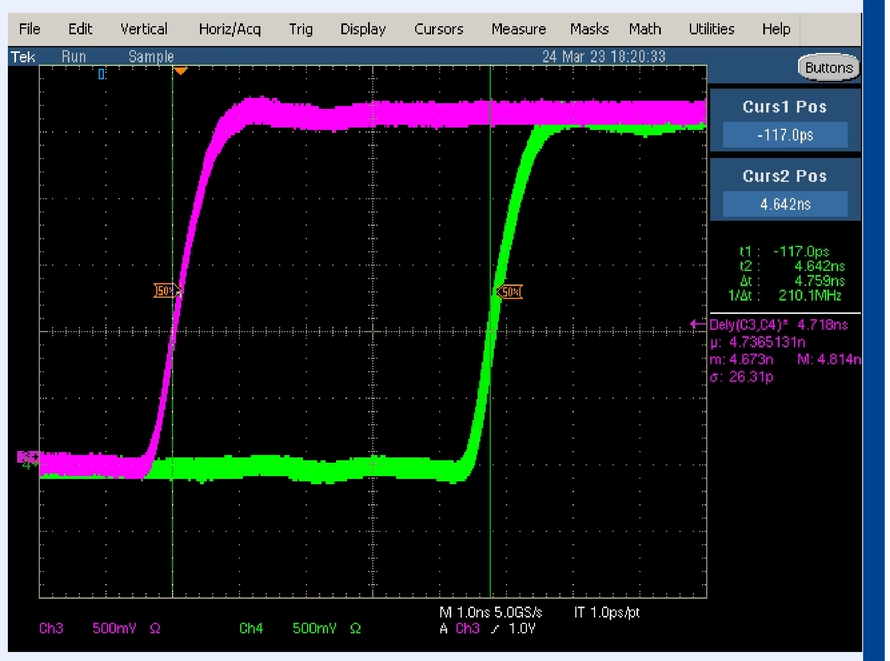


Results

The Timing System integrate our HATI IP core, allowing for sub-nanosecond synchronization between a master (WR-Zen) and several slave devices

The delay between PPS signals displayed in the image is maintained over time and can be calibrated to compensate cable delays.

The signal's capture persistence is set to infinite to ensure that any significant jitter in the signals is visible.



standard deviation between flanks= 26.31 picoseconds

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