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When every nanosecond counts

Software Defined Timing: The Synchronization Solution for Data Centers

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Summary

- Introduction
- White Rabbit technology integrated in third parties towards scalability.
- Software defined timing: High Accuracy Timing IP core (HATI)
  - HATI 1G
  - HATI 10G
  - HATI integration example

Introduction

INDUSTRIAL AUTOMATION

Alveo—An FPGA Board for the Cloud and Data Center

Xilinx's Alveo goes beyond machine-learning applications, bringing high-end FPGAs to the enterprise. The high-end U250 delivers 33.3 INT8 TOPS.

Facebook explores building its own ASICs and FPGAs

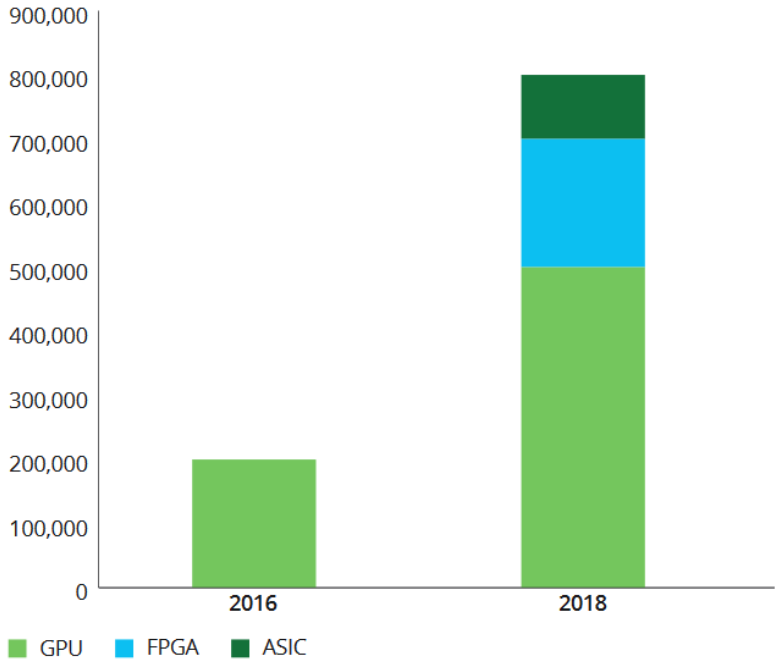
HOME > NEWS > SOUTH EAST ASIA

SK Telecom deploys Xilinx FPGAs in its data center

COMPANIES > MICROSOFT

Why Microsoft Has Bet on FPGAs to Infuse Its Cloud With AI

Figure 13. Annual minimum sales of ML chips in global data centers (units)



Source: Deloitte Global estimates, 2017, based on publicly available information. See endnotes for full methodology.

White Rabbit technology

White Rabbit (WR) is a technology born at CERN which achieves sub-nanosecond accuracy in Ethernet based networks. It allows easy deployments of scalable and reliable networks with high accuracy synchronization requirements.

White Rabbit technology

- +10 years of expertise synchronizing large scientific facilities:
  - CERN, GSI, Fermilab, …

- Validated by National Metrology Institutes: NIST, NPL, PTB, OP, VSL, ROA, VTT, RISE, …

- New PTP High Accuracy profile to be released is based on the pre-standard approach White Rabbit.

White Rabbit technology

Easy to integrate
within existing infrastructures (Ethernet, PTPv2).

Deterministic and highly accurate
This allows saving engineering and equipment costs to achieve a global target time budget.

Cost-effective
It compensates dynamically link asymmetries and temperature changes. Easy to deploy, pre-calibration.

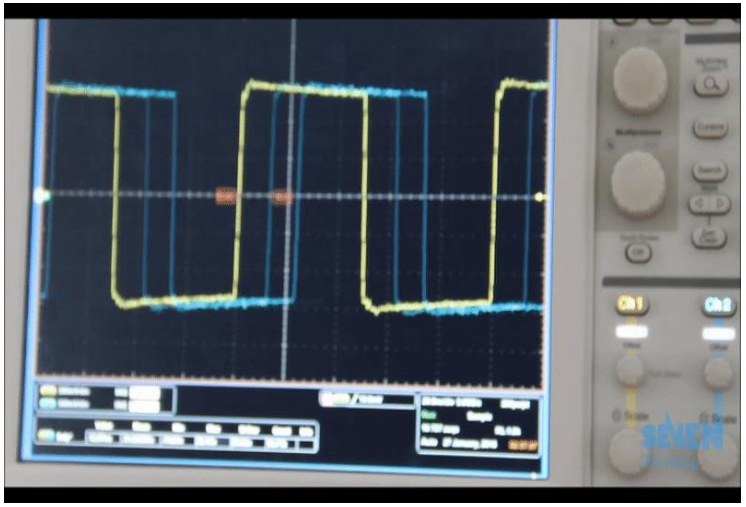
Scalable
to long distances & high number of nodes. It supports tree topologies and daisy-chain configurations

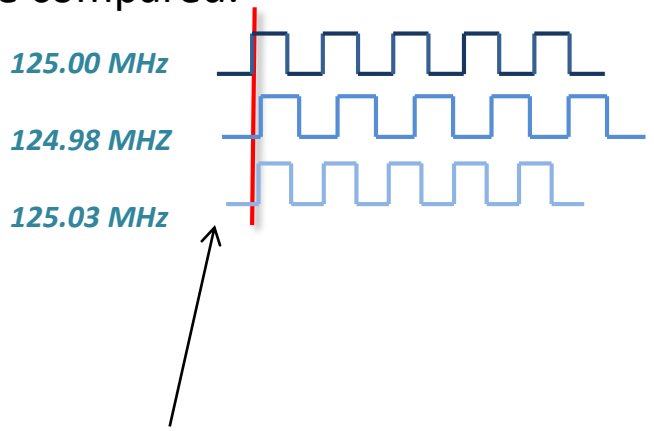
Dependable
It reduces vulnerabilities to spoofing or GPS jamming. Up to 100 km links without on site calibration.

Facilitates new services
Positioning, High Frequency Trading, Time as a Service

White Rabbit technology: Syntonization

- To reach subnanosecond synchronization, distributing the same clock through the network is needed.
- Syntonization: local clock tuning based on a measure of the error between two clocks. In White Rabbit, the external clock and the internal reference are compared.

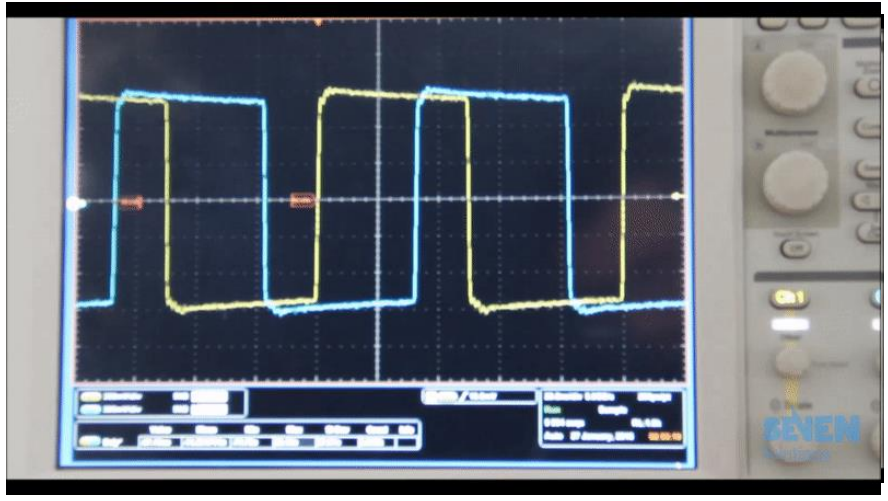


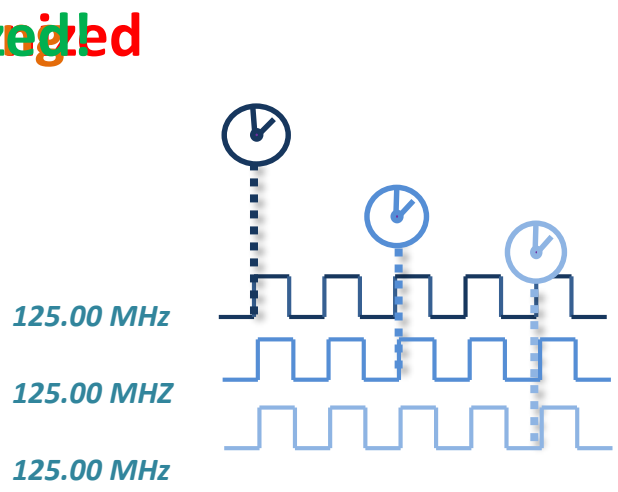


Free running clocks with the same nominal frequency are not accurate enough for accurate time transfer

White Rabbit technology: Syntonization

L1 syntonization is used as a customized version of **Sync-E** to transmit the clock over the optical links. It uses local VCXO to syntonize the local clock to the recovered clock from the link (Slave role).





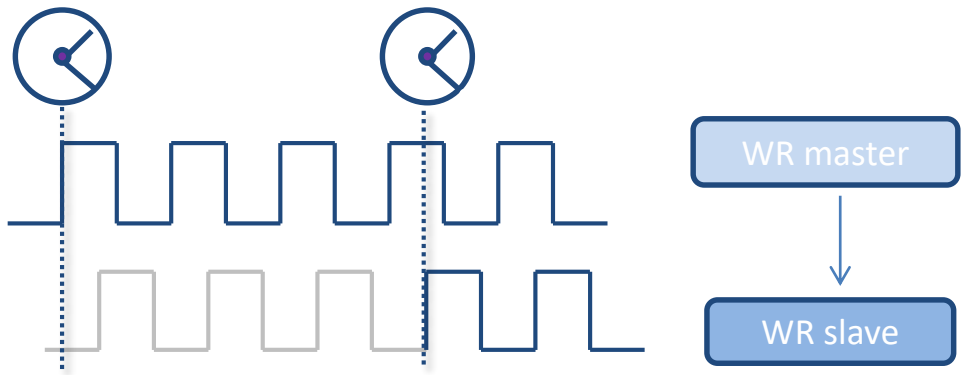
White Rabbit **requires specific clock circuitry** to perform the syntonization and ensure accurate time synchronization.

White Rabbit technology: Ultra-accurate timestamp

Synchronization: **L1 syntonization & PTP (IEEE-1588v2)**

White Rabbit measures the offset between devices, taking into account the link asymmetry and dynamic variations because of weather conditions using **picosecond level accurate timestamps**.

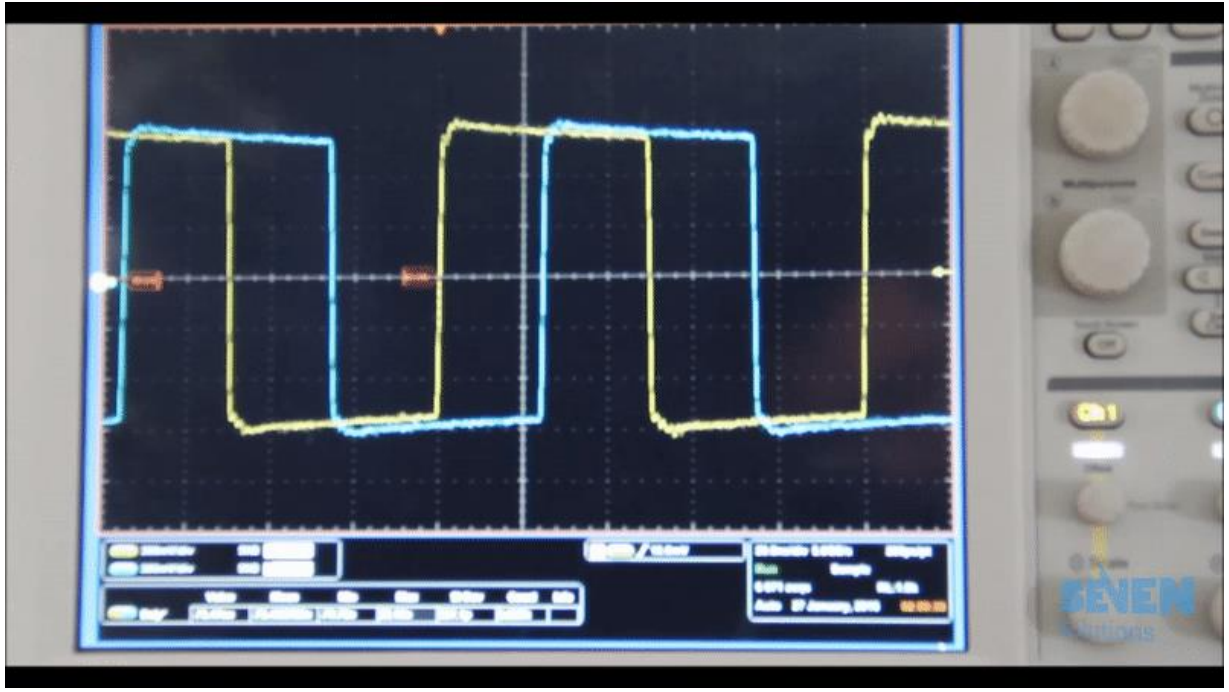
Timestamp generation based on frequency mixing techniques: Clock phase measurements



The timestamps are capable of measuring time differences between two digital clock signals with very fine resolution (picosecond) and they are used to adjust the received and generated clock offsets.

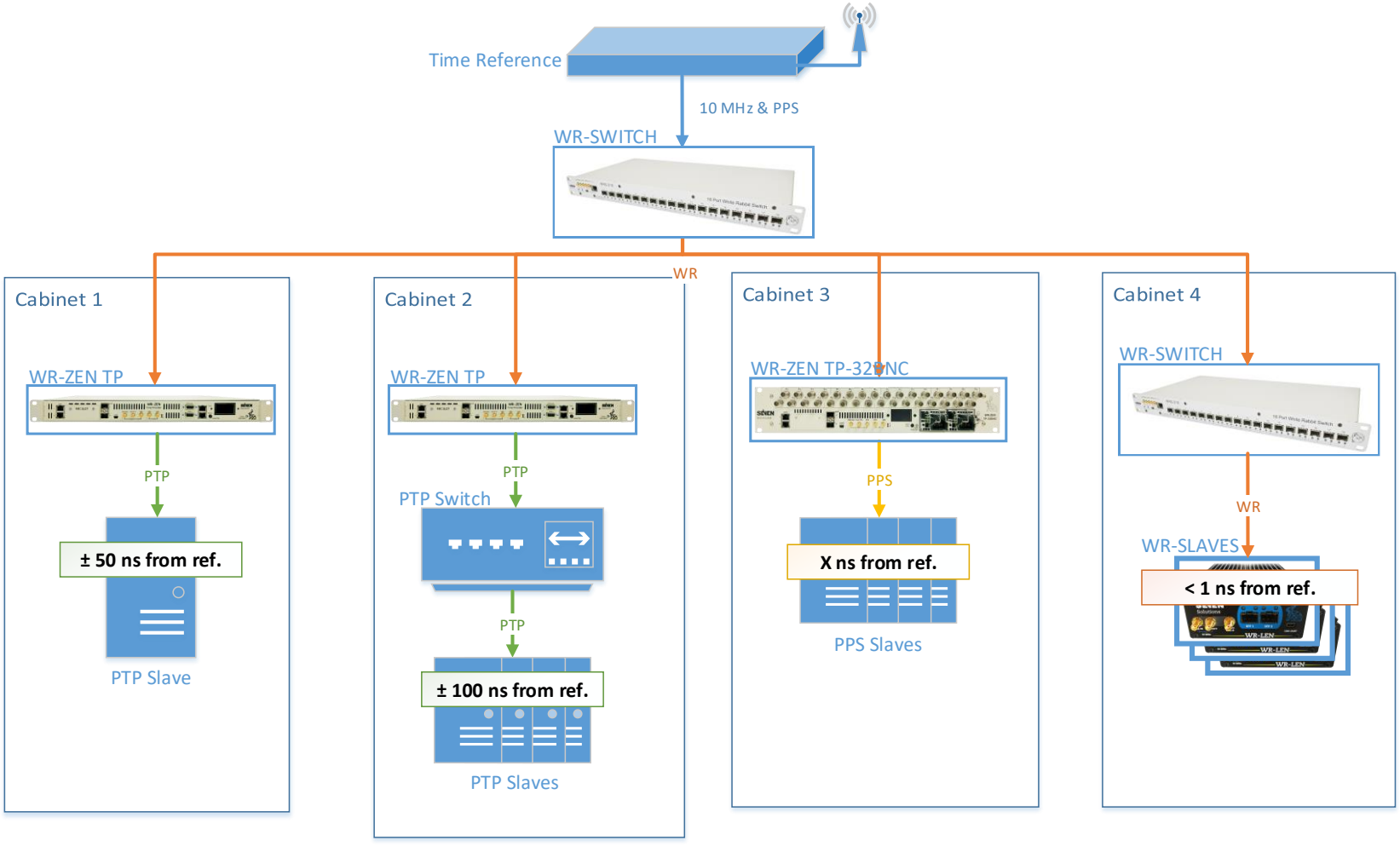
White Rabbit technology: Synchronization

White Rabbit uses the information collected by the exchange of timestamped packets for correcting the constant offset between nodes ($b_A \neq b_B$)



The information from the calibration is also important for compensating the static offset between nodes.

White Rabbit technology: Interoperability



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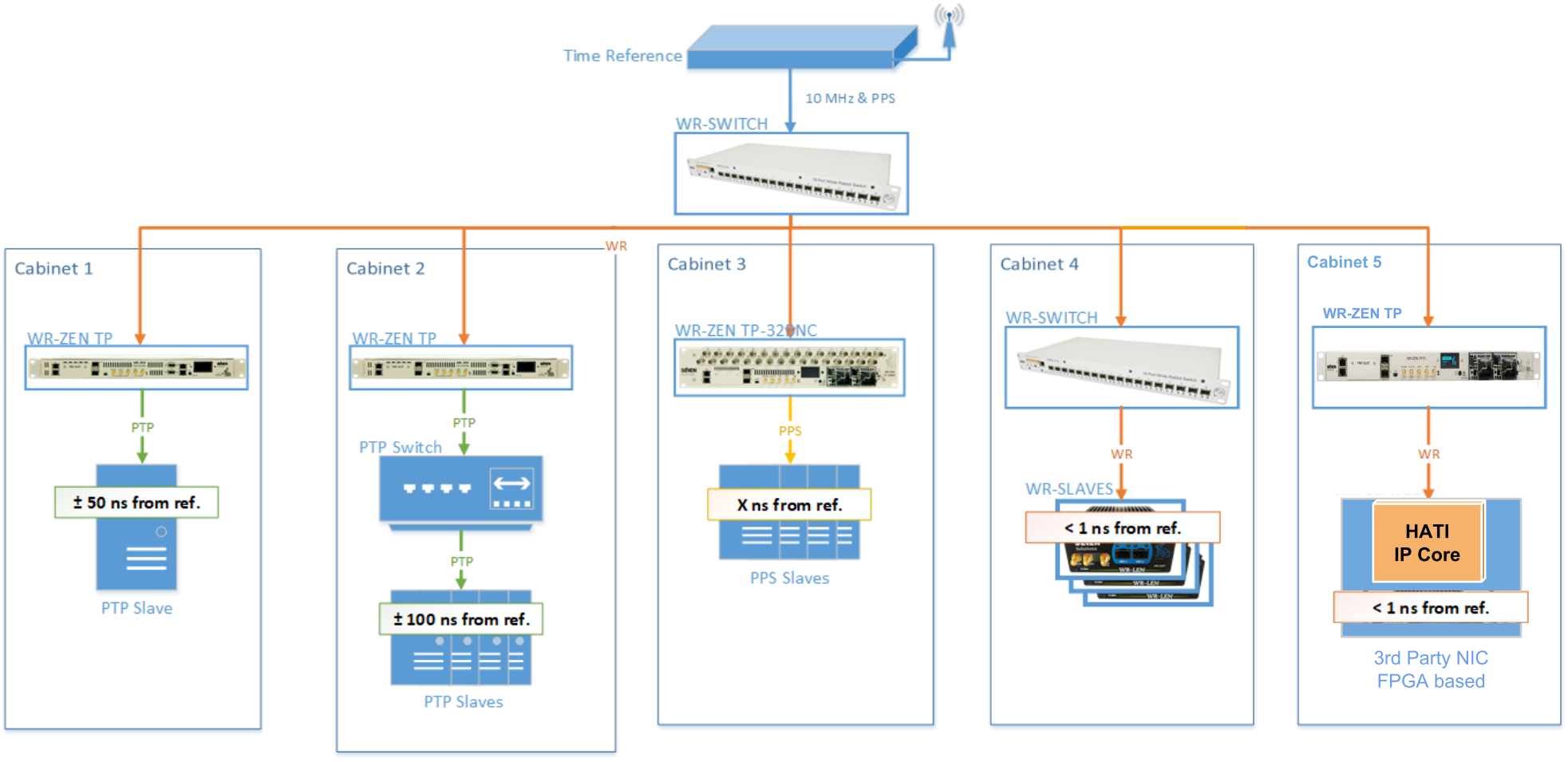
Software defined timing: High Accuracy Timing IP core



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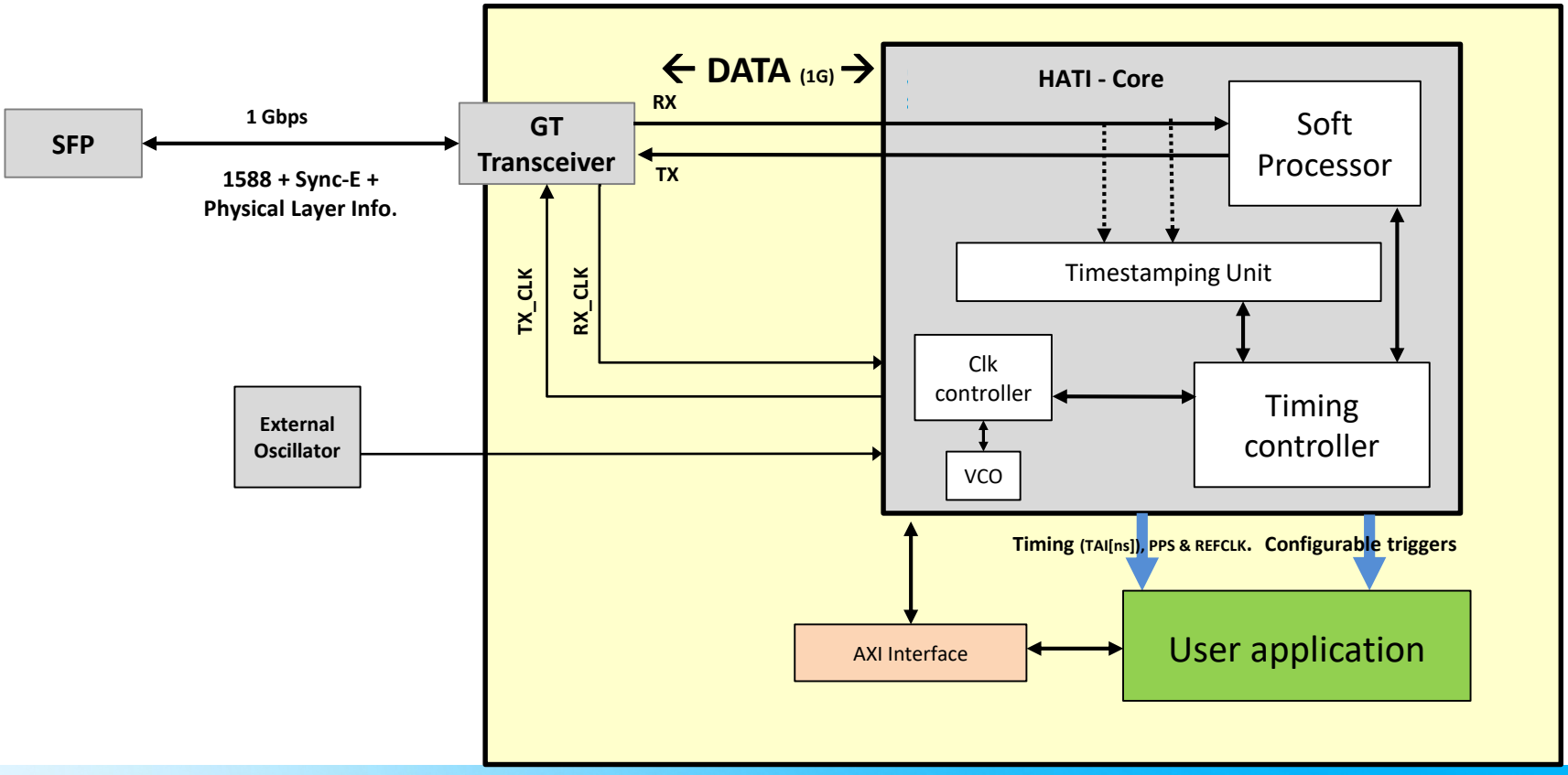
Software defined timing: High Accuracy Timing IP core

Software based solution:

- **Based on White Rabbit** technology (PTP v2.1 HA adaptable).
- **FPGA** IP core.
- **1G/10G** supported. 25G/40G in scope.
- **Several Xilinx FPGA** families supported.
- Specific **clock circuitry not required**.
- High resolution **timestamps**.
- **Sub-nanosecond** synchronization accuracy.
- Very precise **frequency distribution**.
- **Dynamic compensation** of asymmetries caused by **weather conditions**.
- **Minimal data bandwidth** consumption.
- Easily **integrable**.
- Distance range over **80 km without calibration** using precalibrated optics.
- **DWDM** compatible.

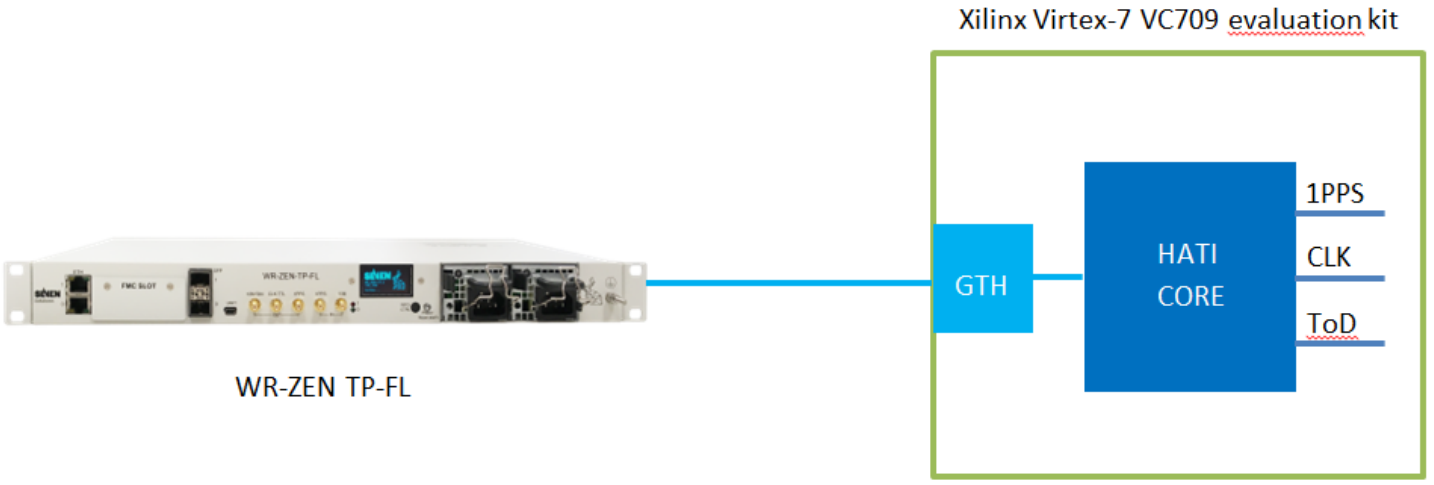
HATI 1G: Architecture

HATI template architecture: Xilinx FPGA (Family-7)



HATI 1G: Results

Example of HATI-1G performance: Test over 20 km of fiber during 84 hours.



HATI 1G: Results

Example of HATI-1G performance: Test over 20 km of fiber during 84 hours.

Max-Min (ps)	280,66
Mean (ps)	52,54
Std. Dev. (ps)	43,1595261

It ensures an error below 300ps

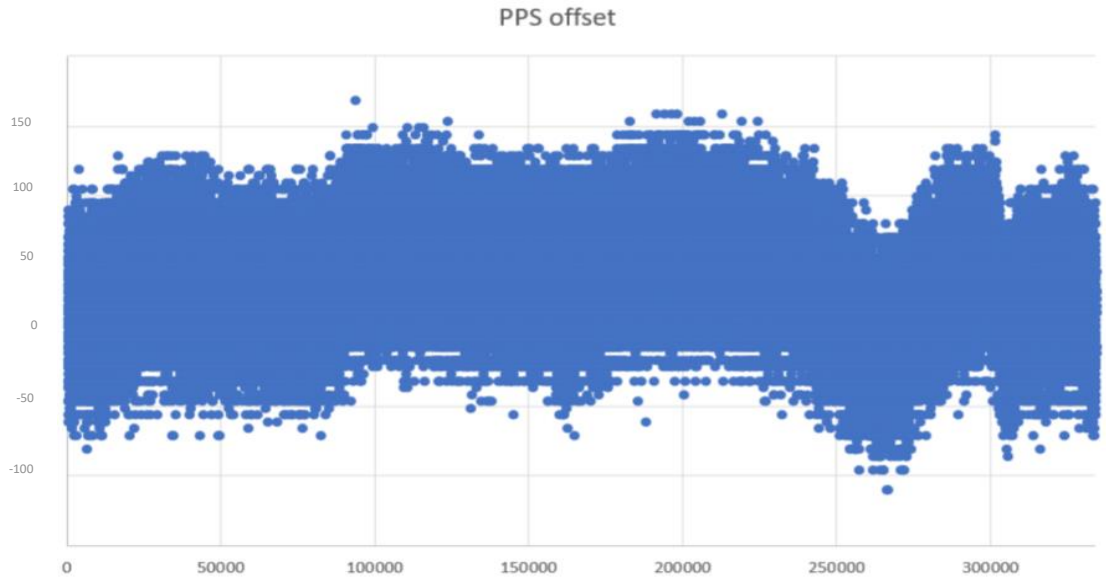
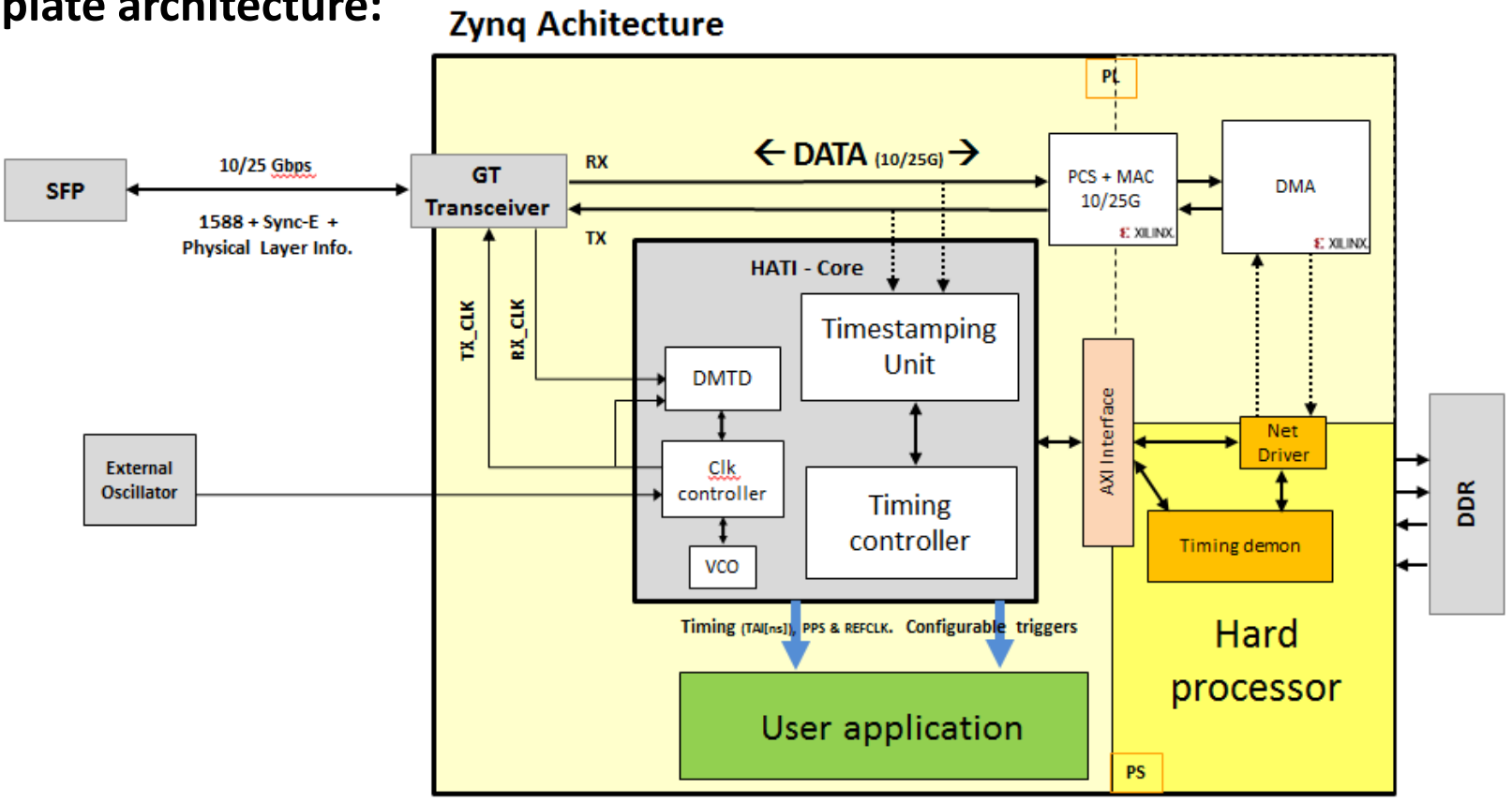


Figure 1: Long-term PPS offset measurement.

HATI 10G: Architecture

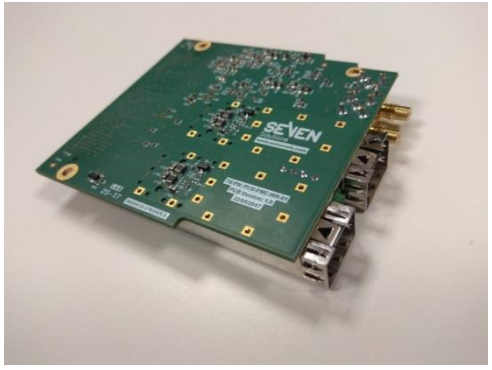
HATI template architecture:



HATI 10G: External clock cleaner

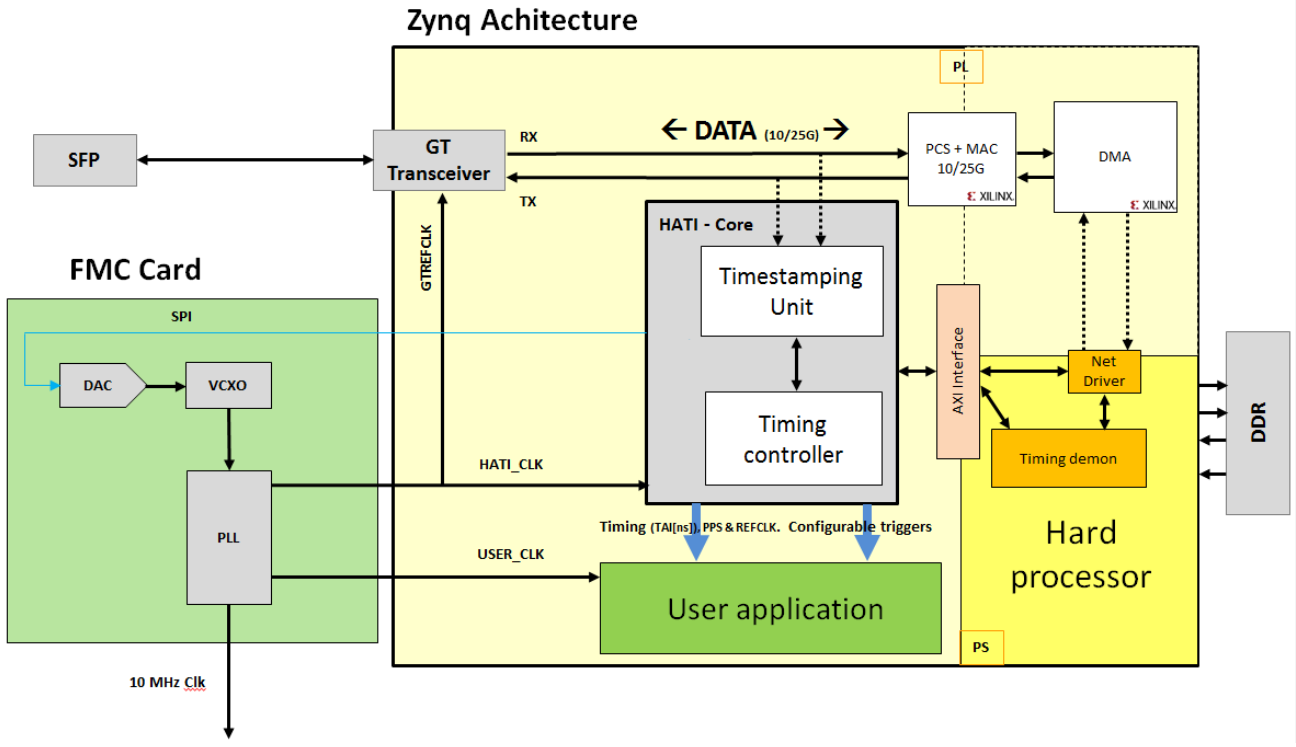
Optional: For frequency dissemination applications requiring low jitter, the HATI core can accept an external PLL to clean the clock signal from the FPGA.

Example of FMC cards with external clocking circuitry



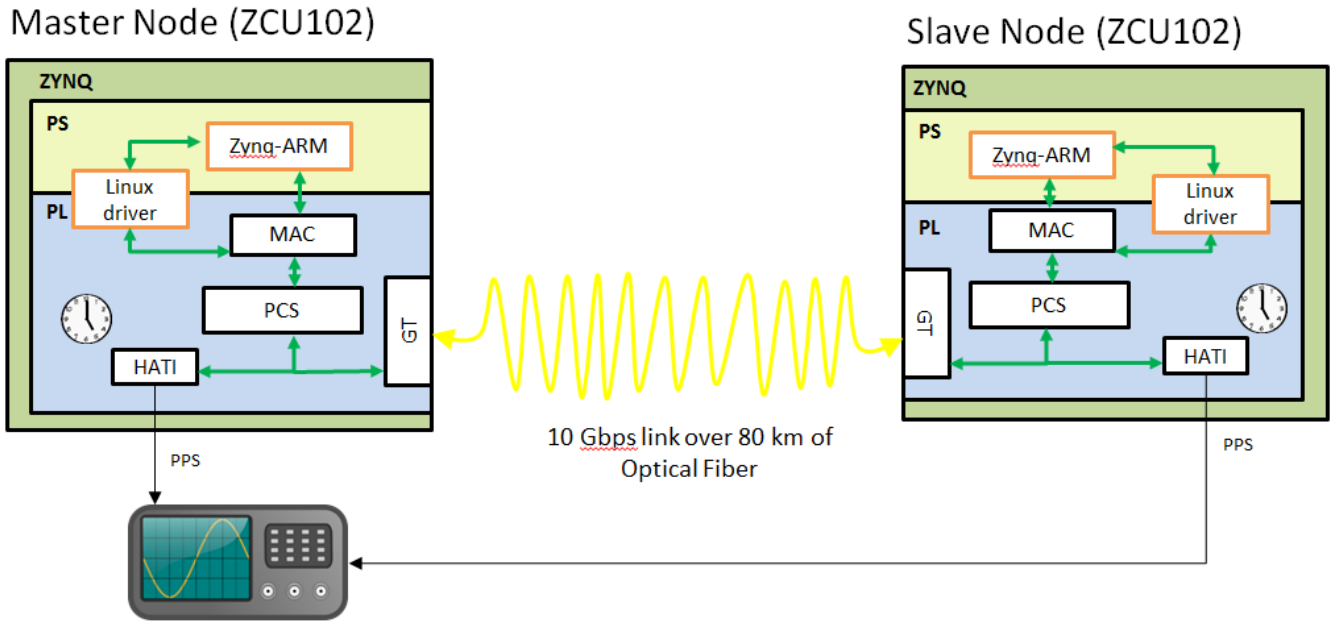
Stability with and without external hardware:

	Std. deviation	Peak to peak
External HW	8.03 ps	78.45 ps
Without Ext. HW	19.25 ps	137.12 ps



HATI 10G: Results

Example of HATI performance: Preliminary test over 80 km of fiber during 24 hours.

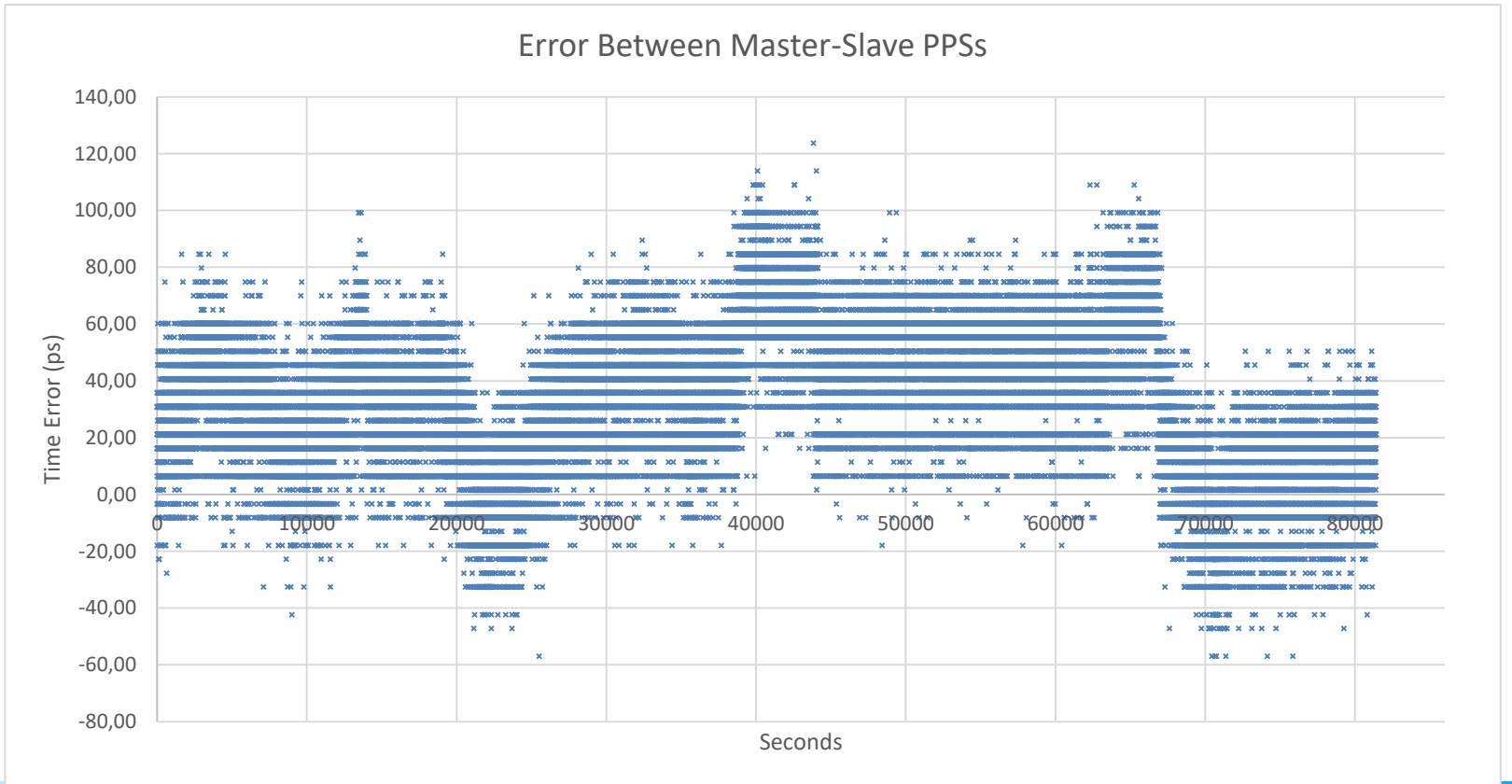


HATI 10G: Results.

HATI performance: Non-temperature controlled test over 80 km of fiber during 24 hours.

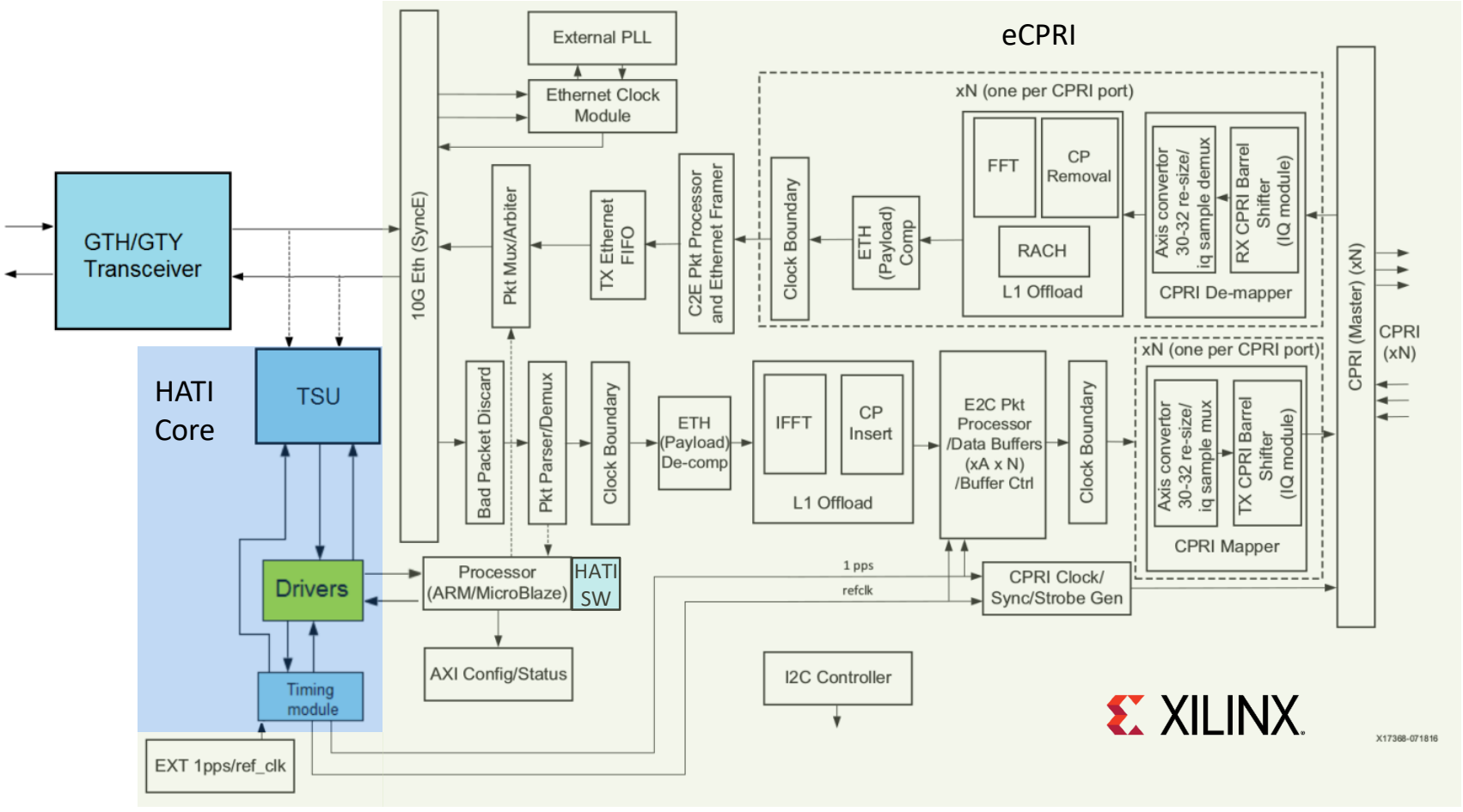
Max-Min (ps)	180,66
Mean (ps)	32,54
Std. Dev. (ps)	23,15952618

It ensures an error below 200ps!



HATI integration example: Xilinx eCPRI.

Example of HATI integration: **eCPRI Gateway design (Xilinx).**



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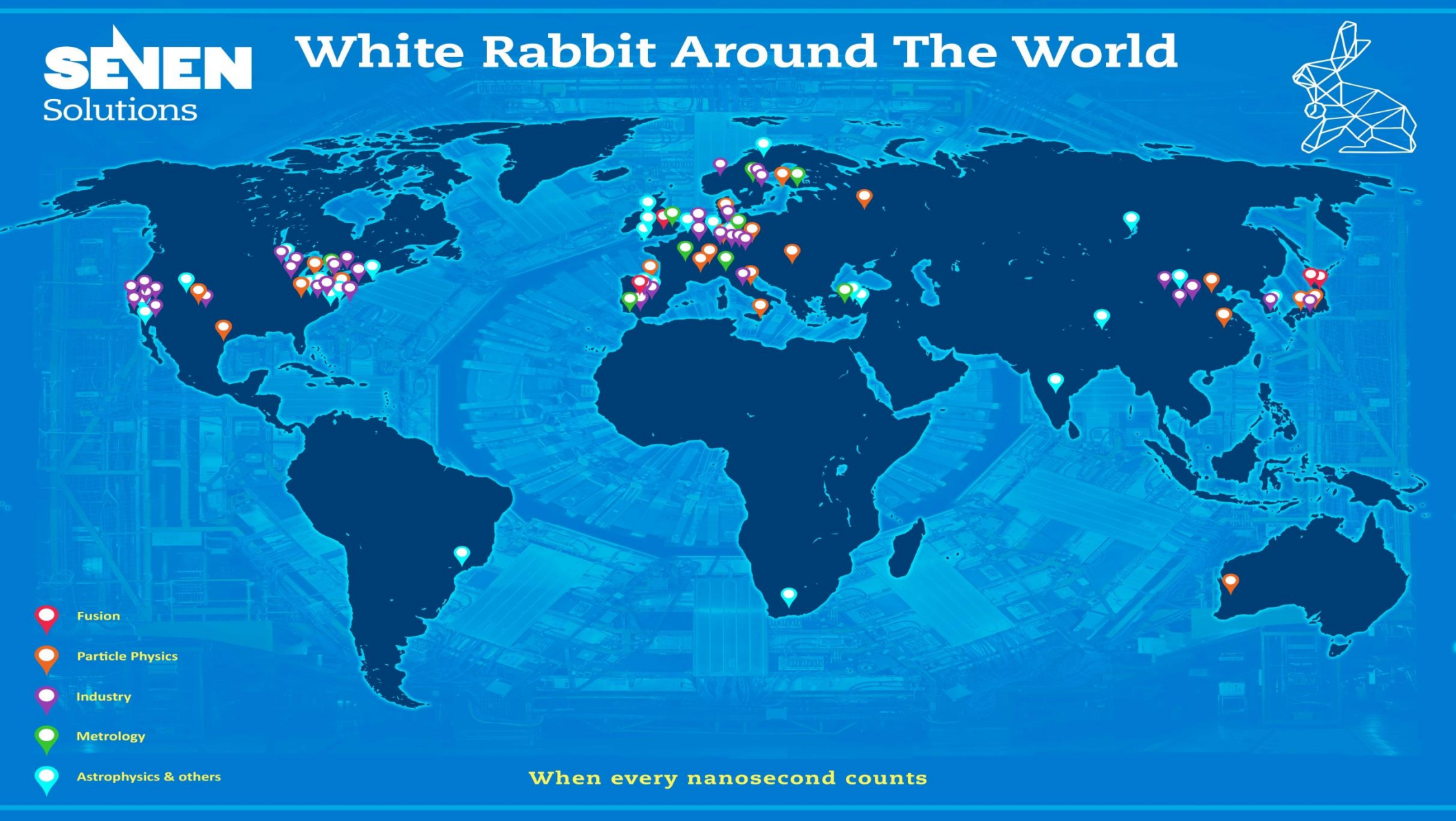
White Rabbit Around The World



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