INSTITUTE OF ELECTRONICS AND COMPUTER SCIENCE

NATIONAL DEVELOPMENT PLAN 2020

EUROPEAN UNION
European Regional Development Fund

INVESTING IN YOUR FUTURE

Eiropas Reģionālās attīstības fonda līdzfinansēts projekts Nr.1.1.1.1/16/A/174
„Laika sinhronizācija ar augstu precizitāti
sadalītai zinātnisku mērījumu sistēmai (DaLaS)".
Projekta zinātniskais vadītājs Dr.comp. Ints Mednieks

Projekta ietvaros izstrādātā aparatūra, laboratorijas eksperimentu rezultāti

referents Jevgeņijs Buls

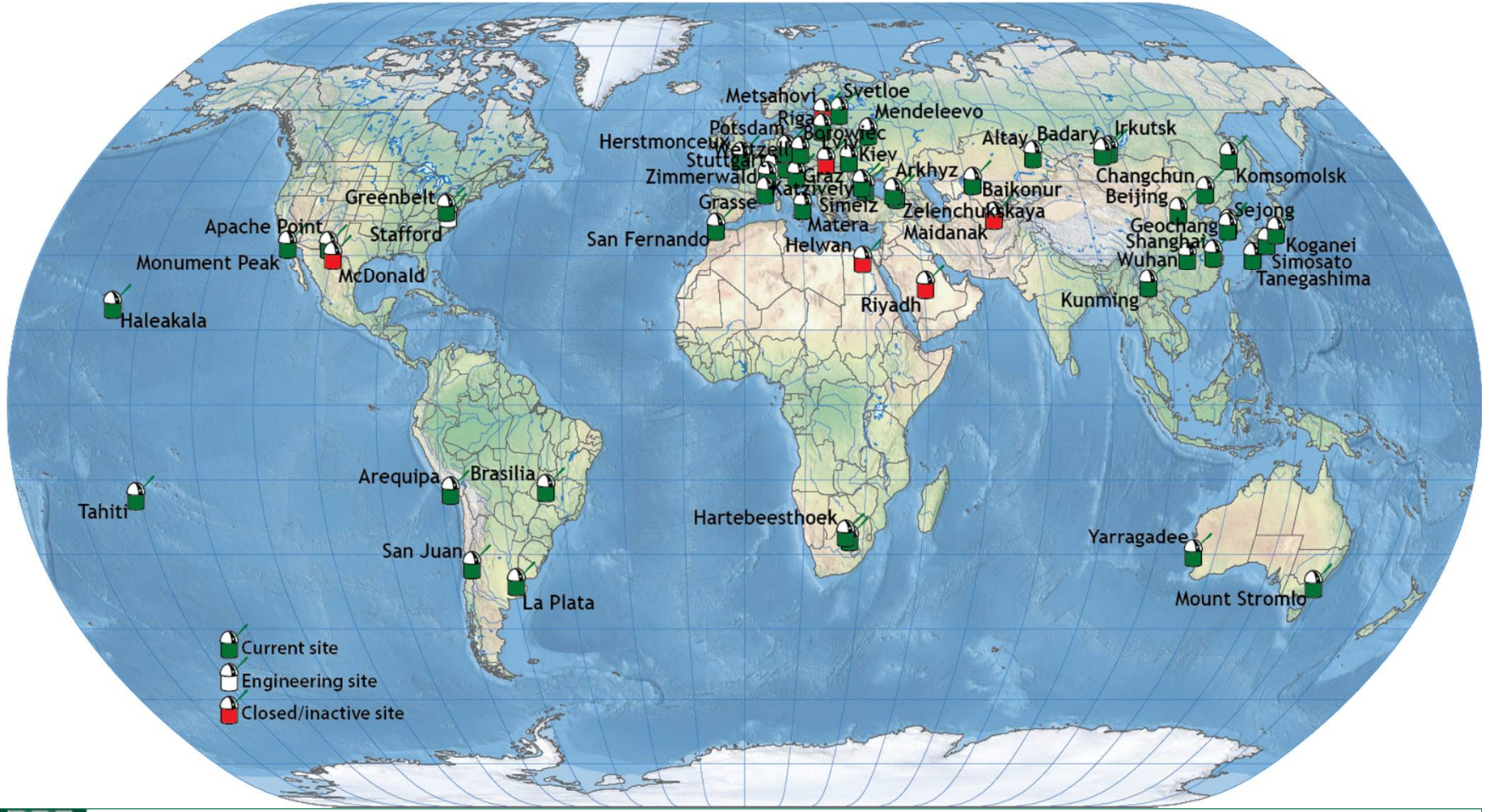
1. **Examples of spatially distributed timing systems**
2. **Two synchronization approaches**
3. **Event Timing Based Synchronization (ETBS)**
4. **Precise Event Timer A040-ET with synchronization functionality**
5. **Multifunctional True Event Timer for wide applications**
6. **True Event Timer not requiring the maintenance**
7. **Implementation and main components of the ETBS**
8. **Connection cable impact estimation**
9. **Estimation of Time and Frequency Standards**
10. **Estimation of the synchronization output of the A040-ET**
11. **Estimation of the accuracy and precision of the ETBS**

Examples of spatially distributed timing systems

- The Large Hadron Collider (LHC) is the world's largest and highest-energy particle collider and the largest machine in the world.
- Satellite Laser Ranging (SLR) stations around the world organized under International Laser Ranging Service (ILRS) and providing the precise data for geodetic and geophysical research activities by mean of satellite and Lunar ranging
- Satellite constellation is a group of artificial satellites working together as a system (navigation, communication, observation etc.)

Examples of spatially distributed timing systems

Satellite Laser Ranging stations around the world organized under International Laser Ranging Service providing the precise data for geodetic and geophysical research activities by mean of satellite and Lunar ranging



Two synchronization approaches

White Rabbit approach (CERN) – Special devices providing the precise time and frequency transfer via Ethernet

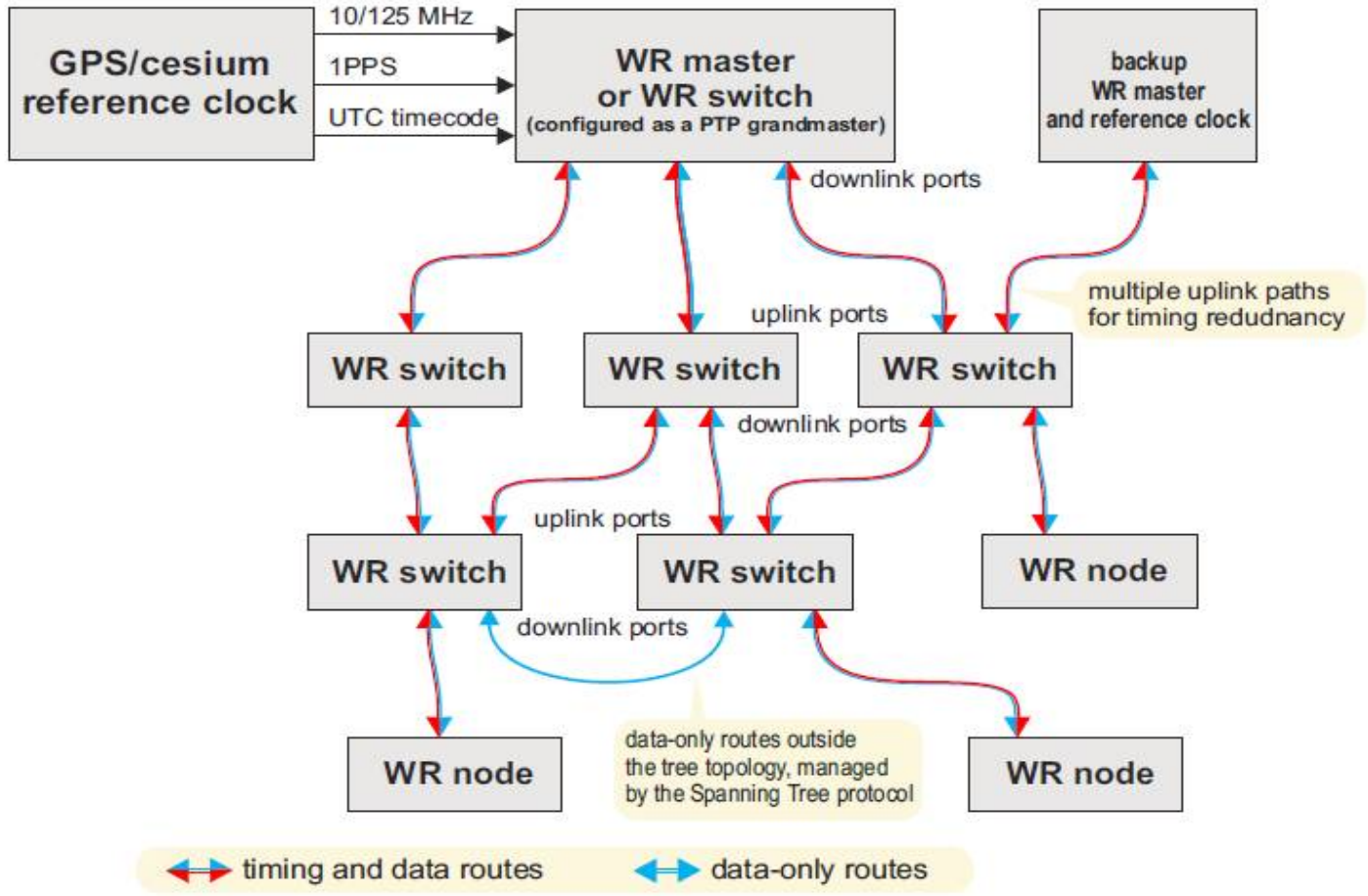
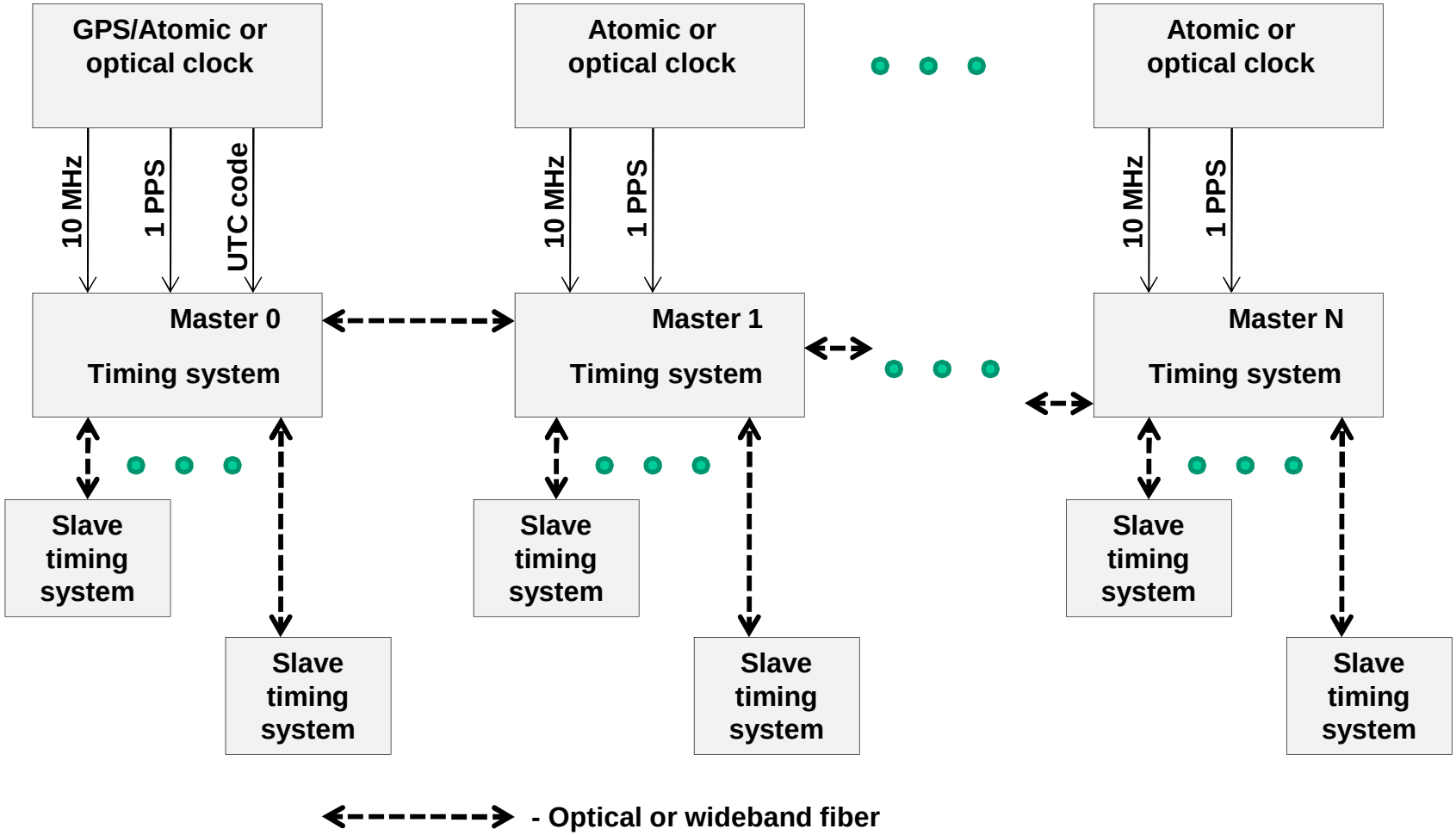


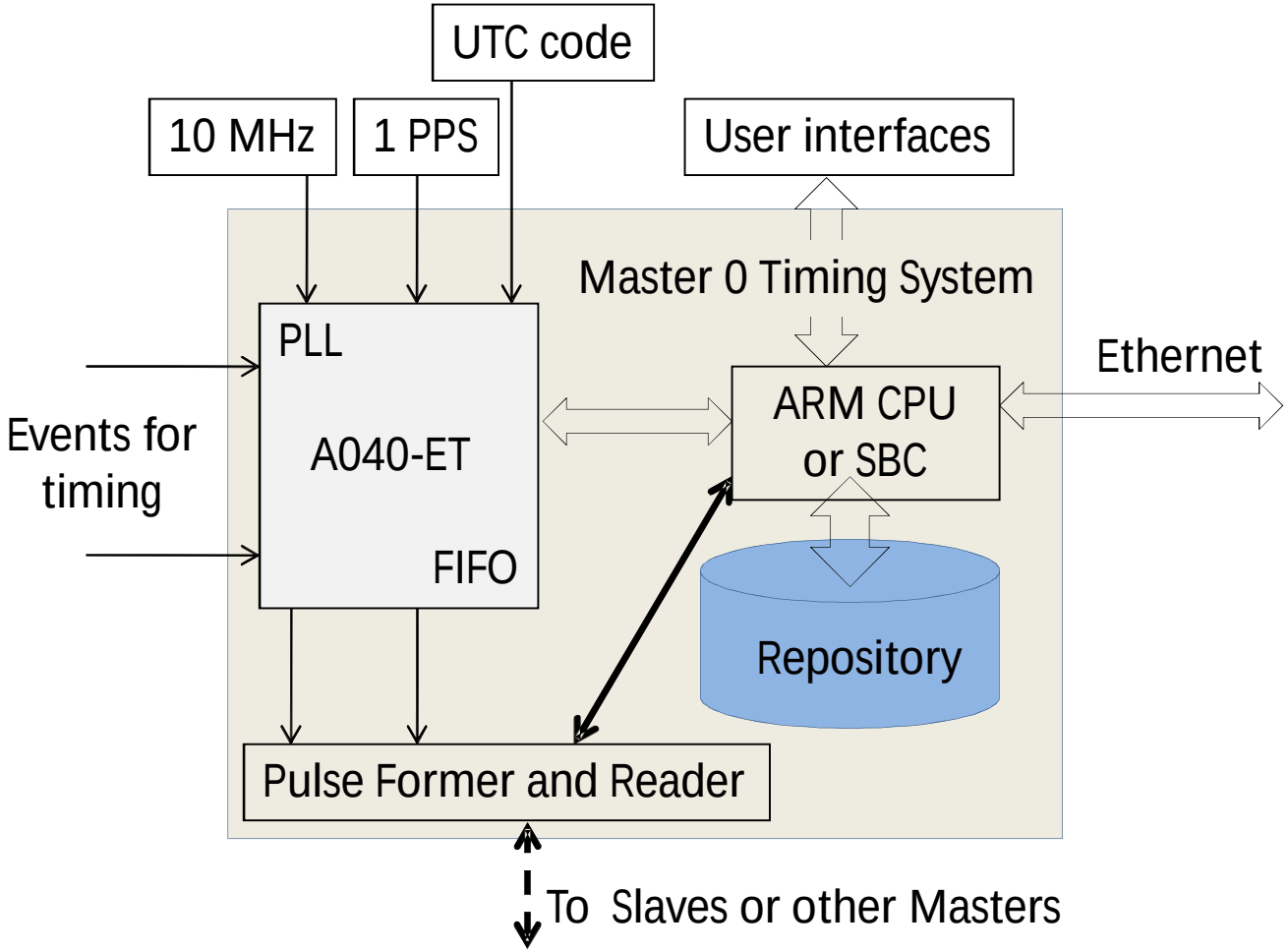
Figure from: Tomasz Włostowski. Precise time and frequency transfer in a White Rabbit network. Master of Science thesis. Warsaw University of Technology. 2011, 98 p

Two synchronization approaches

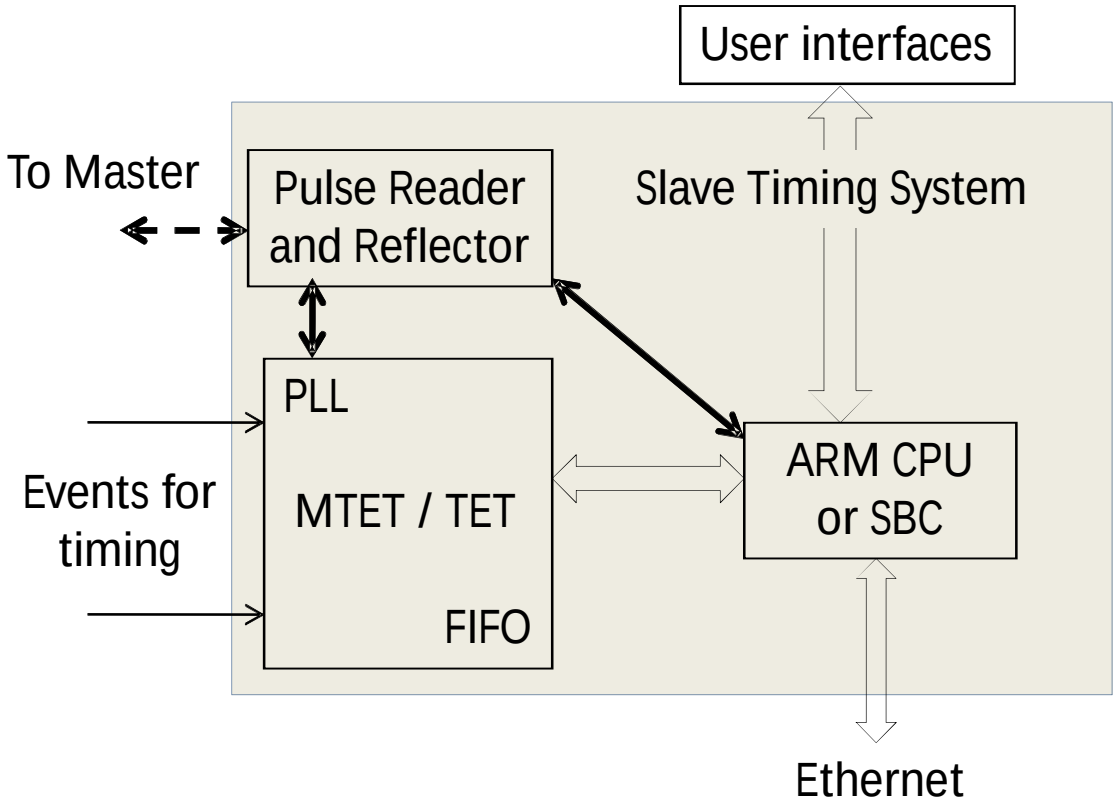
Event Timing based approach – synchronization of Networked Timing System using their own functionality



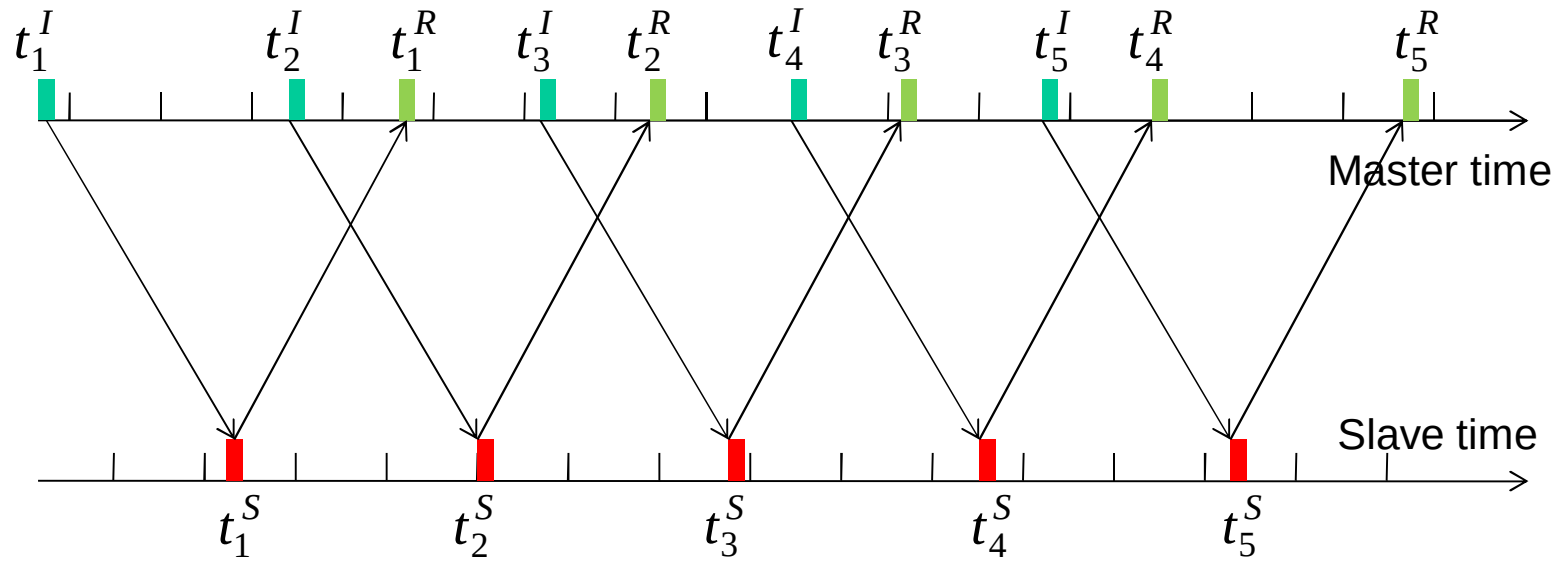
Master Timing System



Slave Timing system

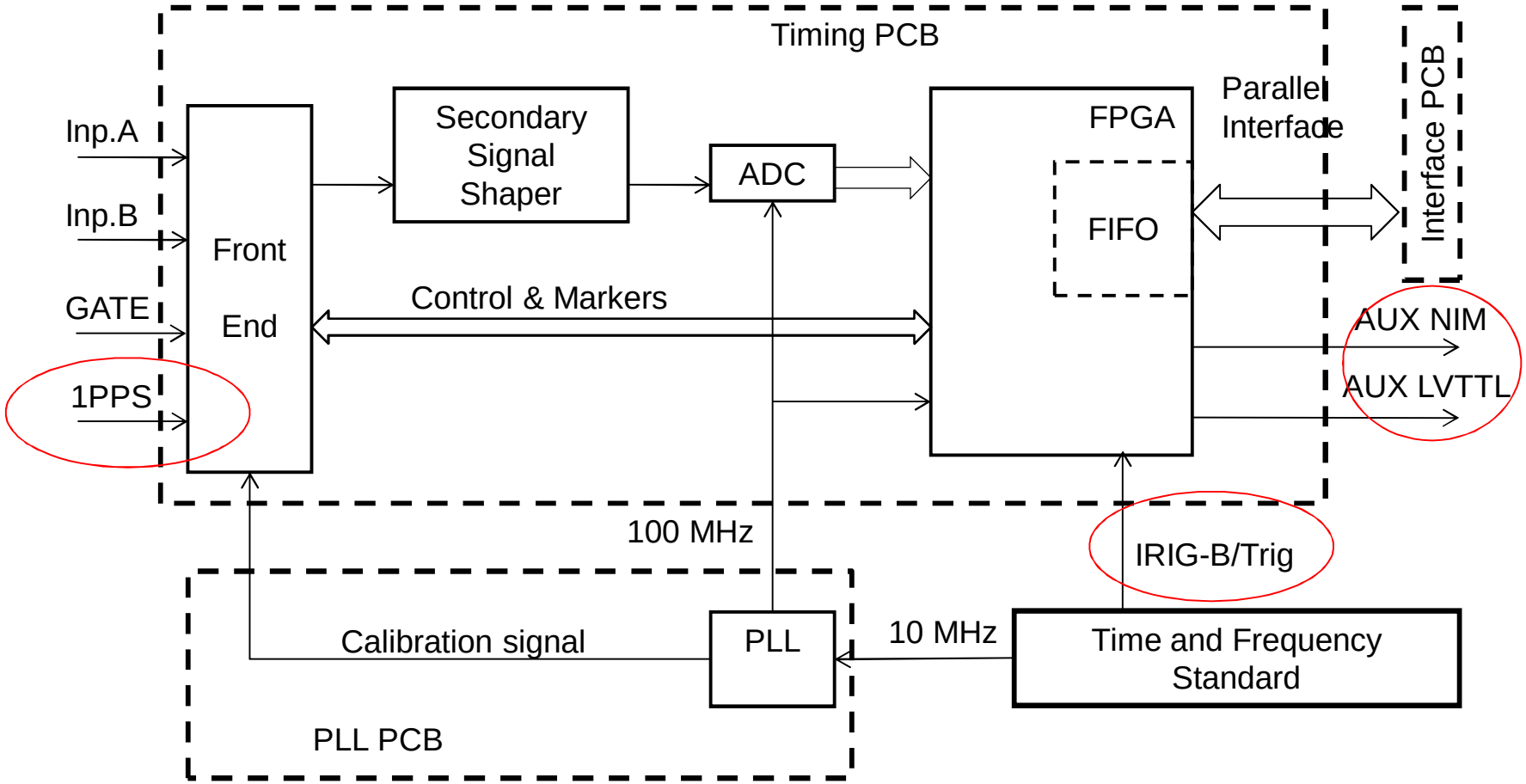


Time Offset calculation

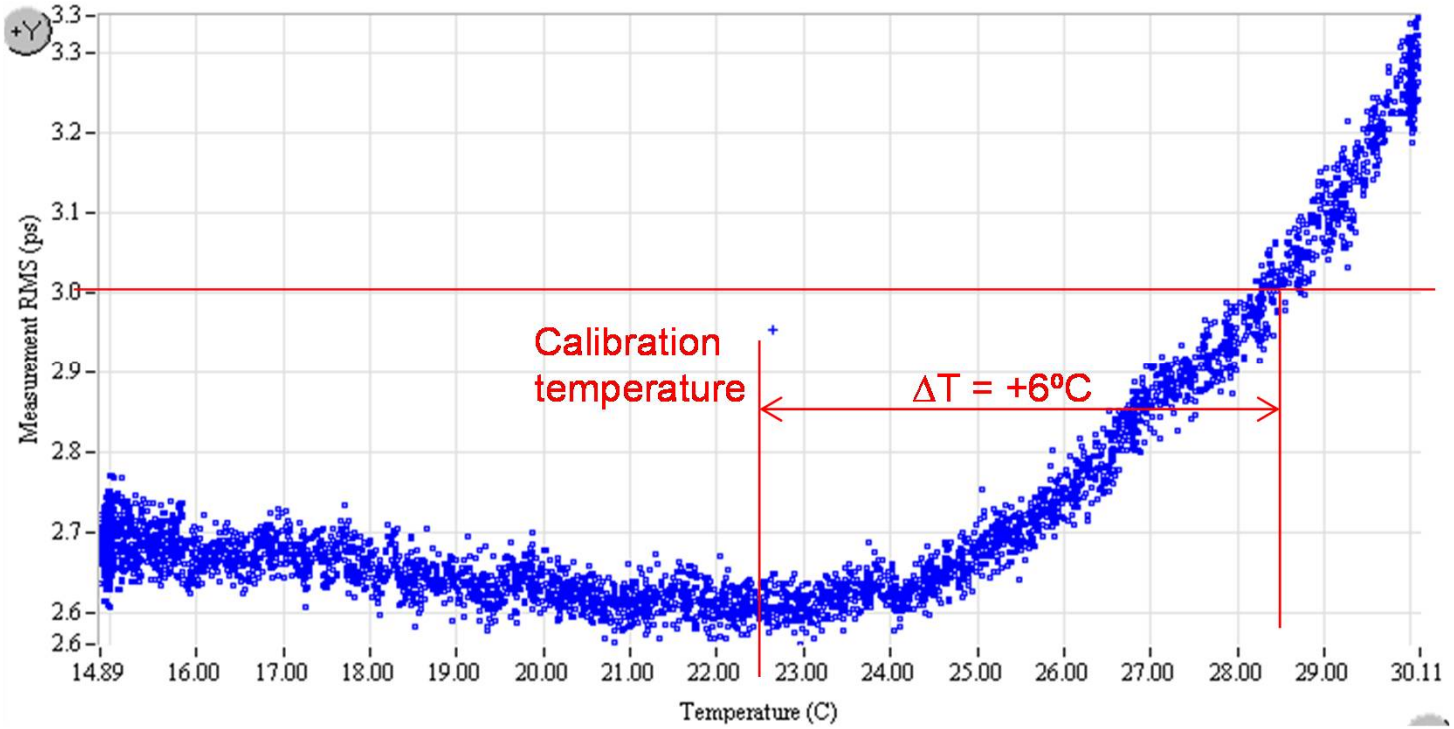


$$\delta_1 = \frac{t_1^I + t_1^R}{2} \qquad t_1^I + \Delta_1 + \delta_1 = t_1^S \qquad \Delta_1 = t_1^S - \frac{t_1^I + t_1^R}{2}$$

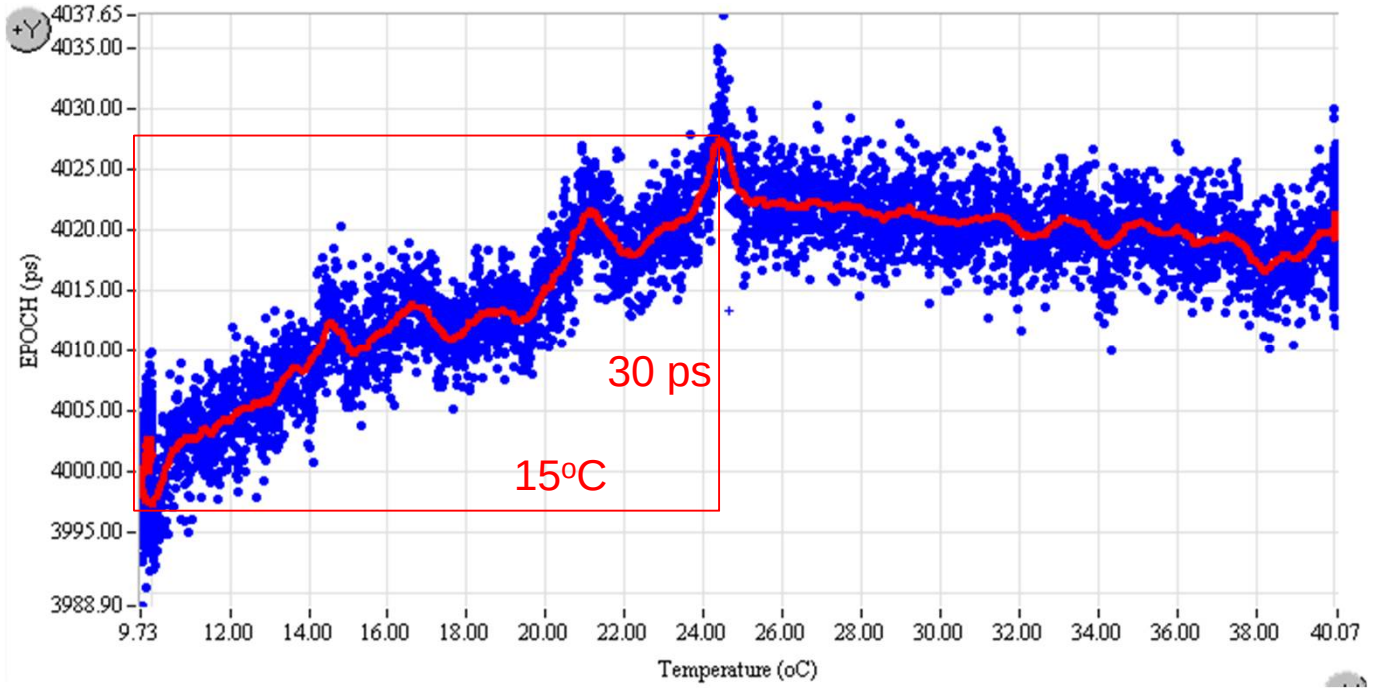
Block diagram of the A040-ET



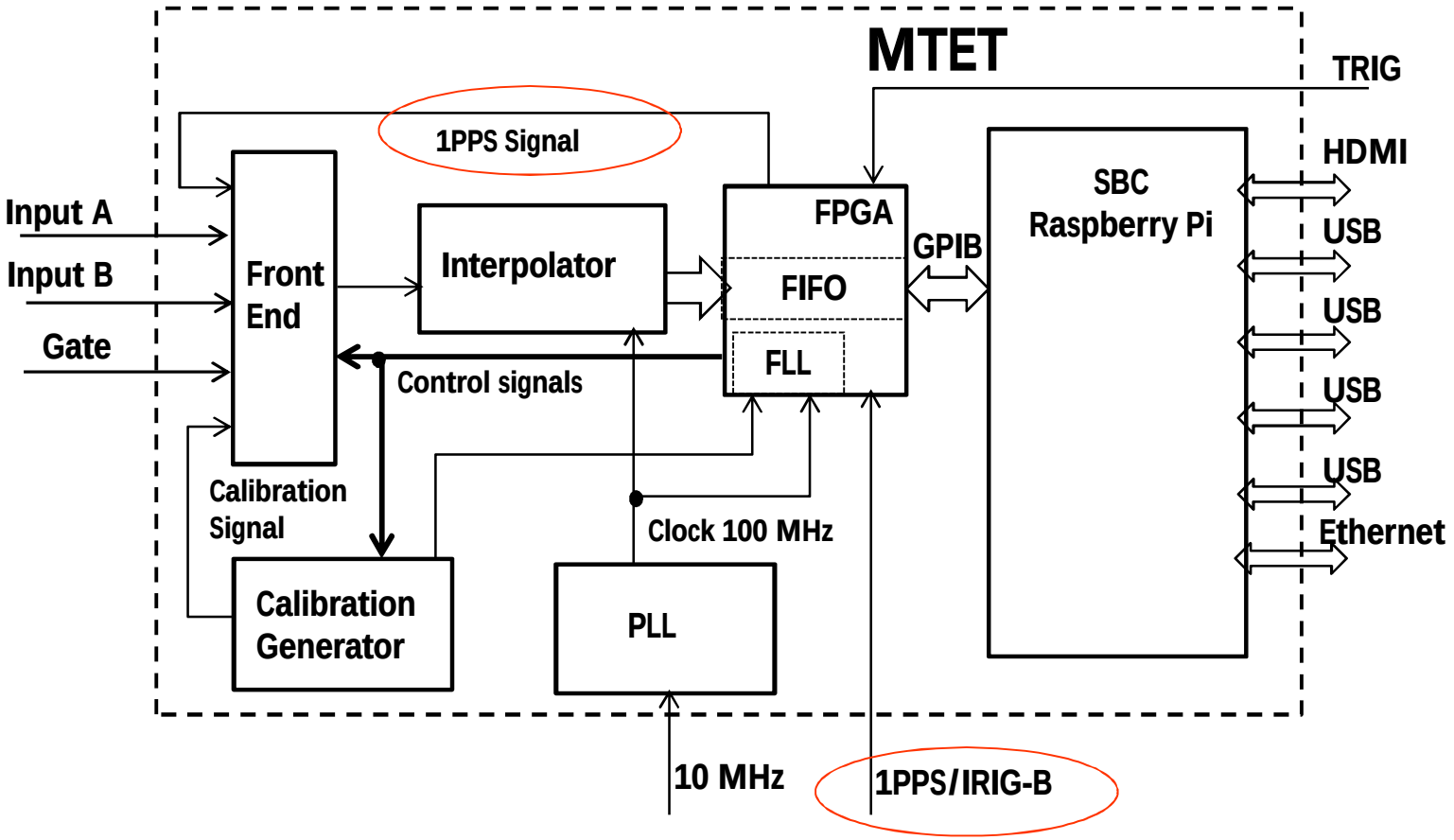
Precision in temperature



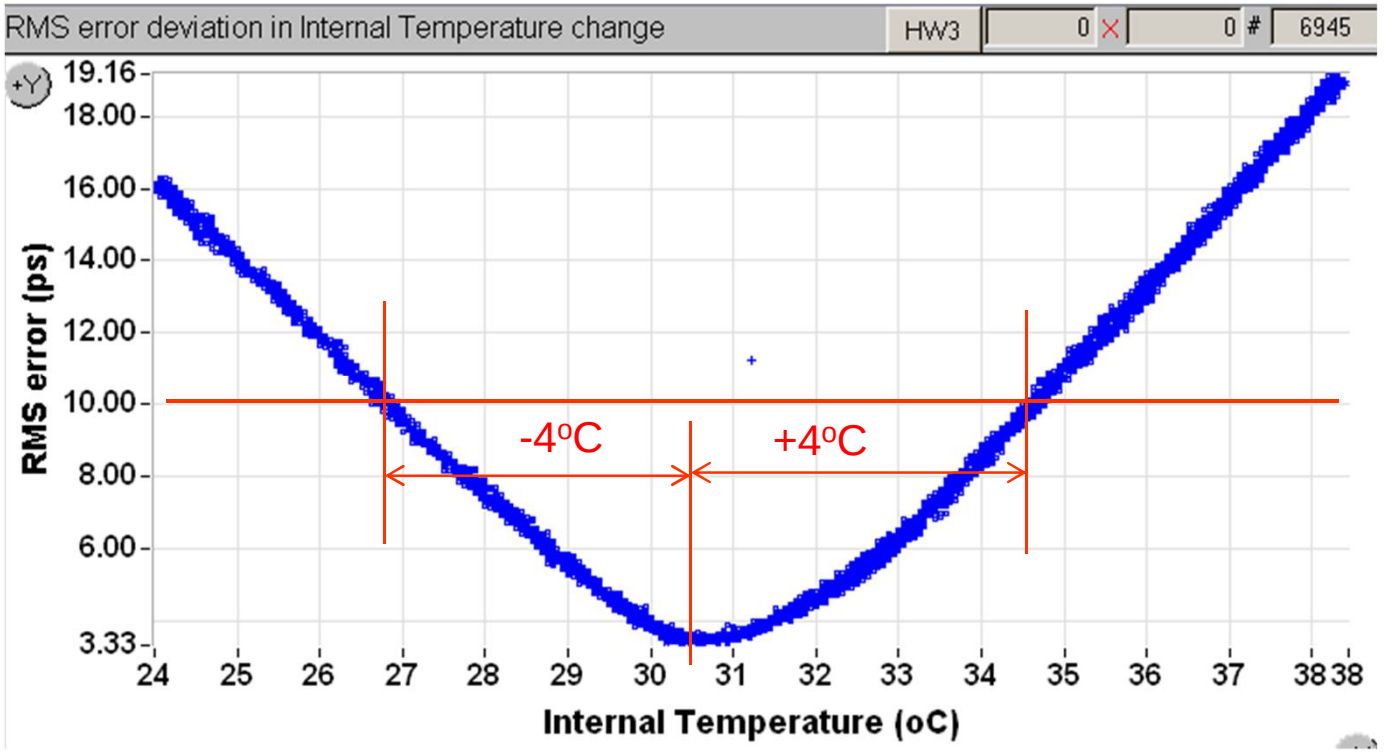
Time scale offset in temperature = 2 ps/^{o}C



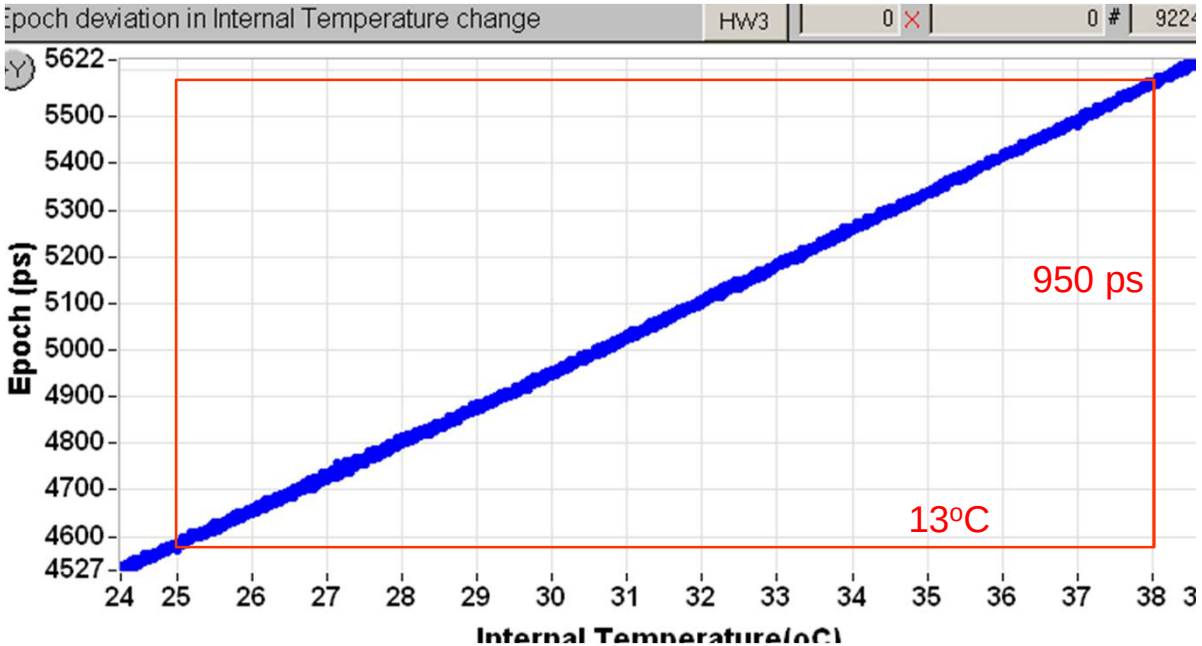
Block diagram of the MTET



Precision in temperature

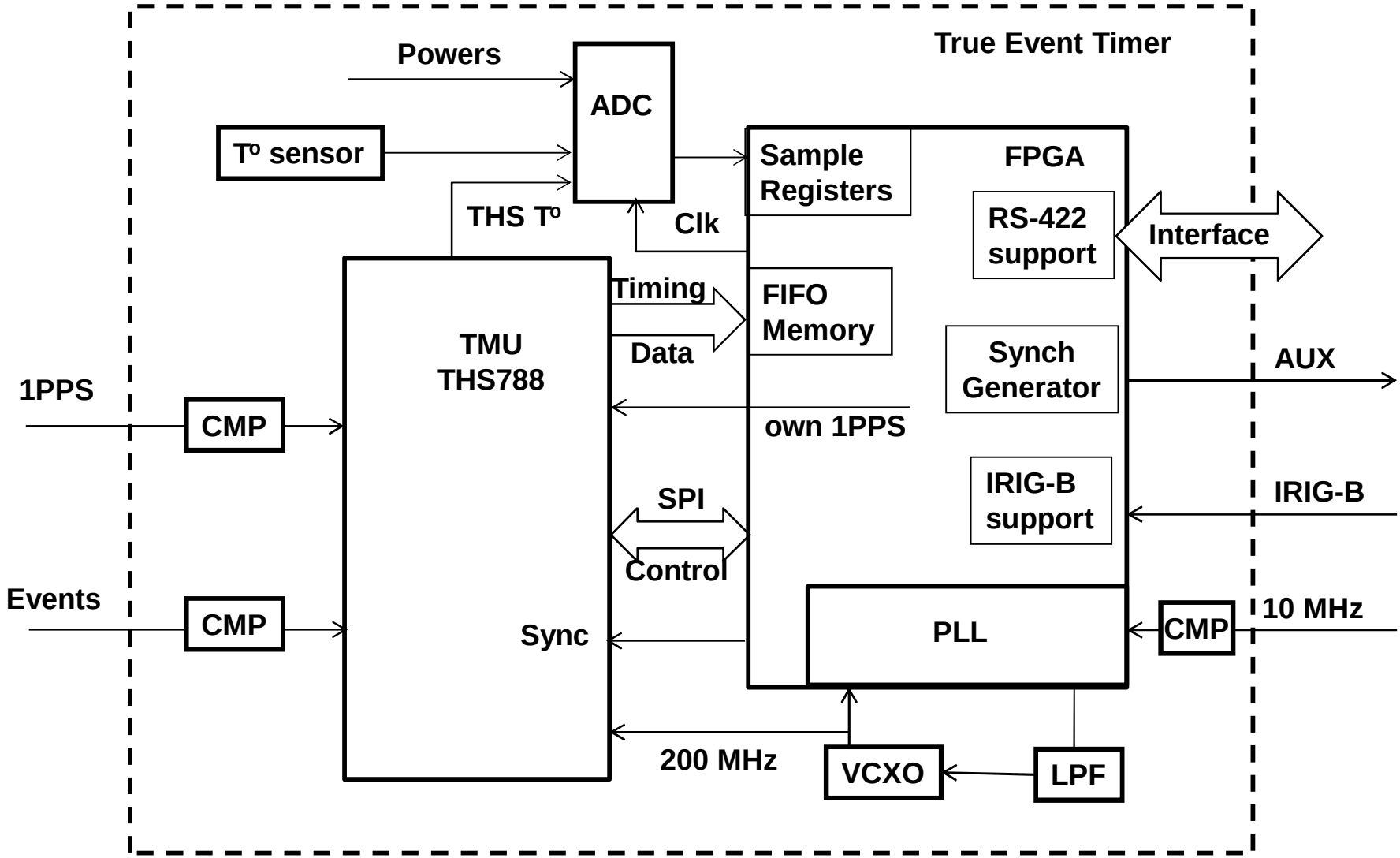


Time scale offset in temperature = 73 ps/^{o}C

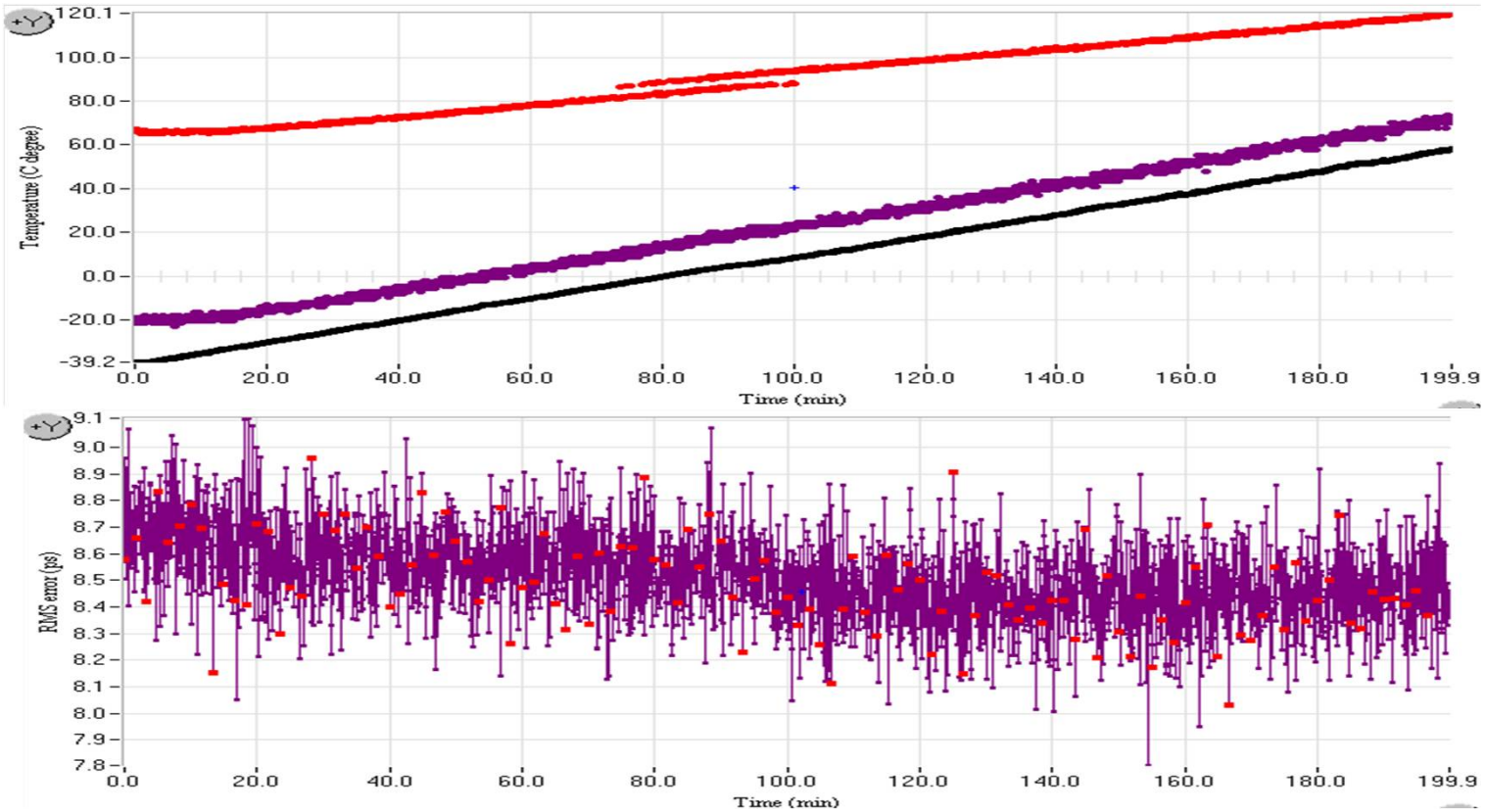


True Event Timer not requiring the maintenance

Block diagram of the TET

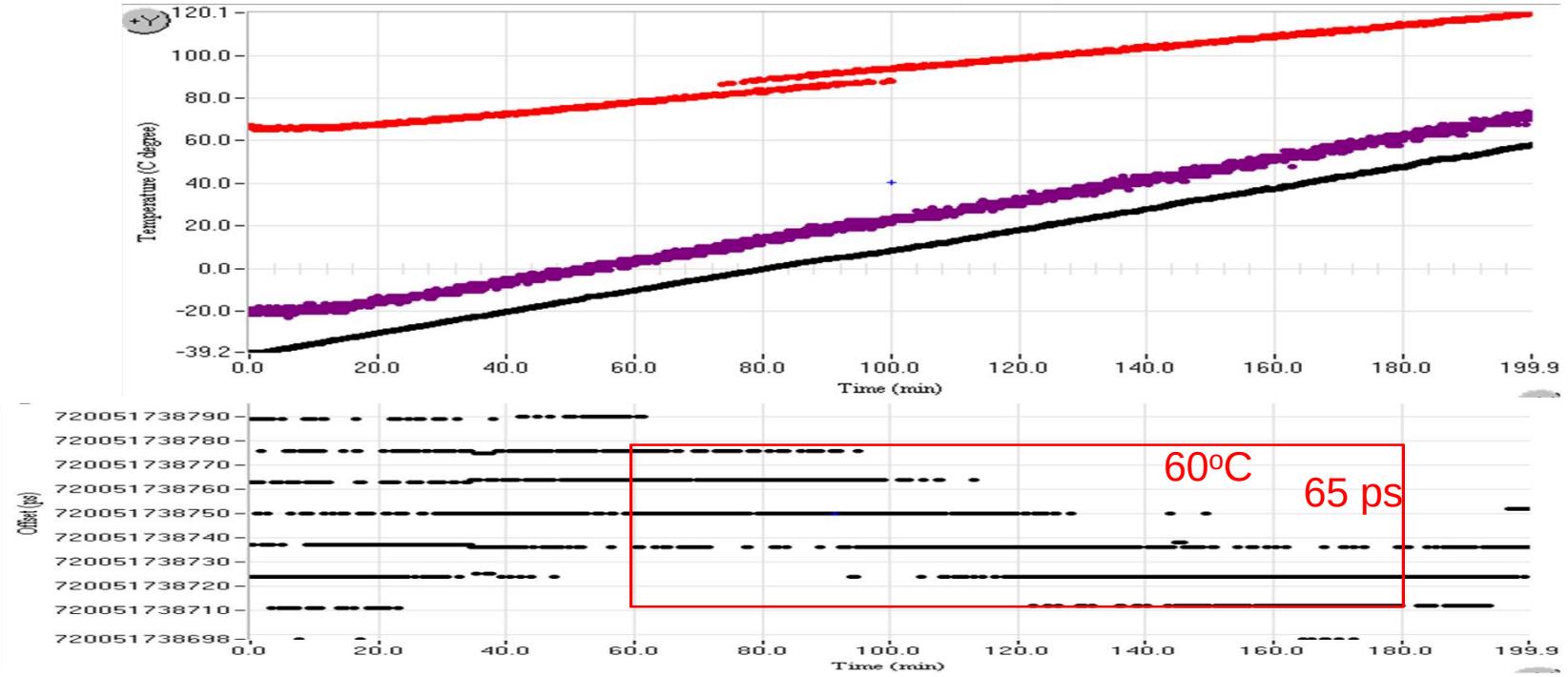


Precision in Temperature

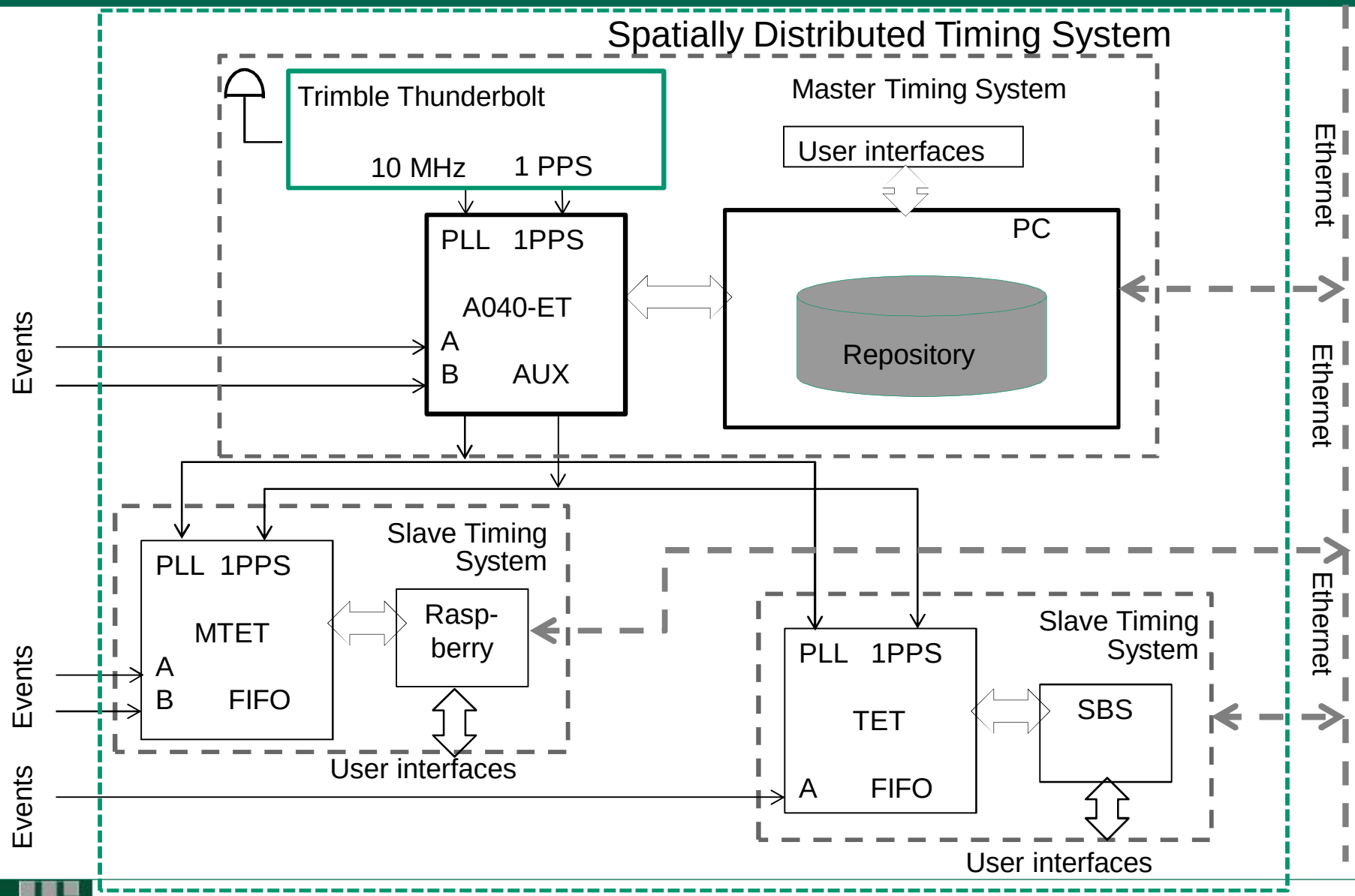


True Event Timer not requiring the maintenance

Time scale offset in temperature = 1.1 ps/^{o}C

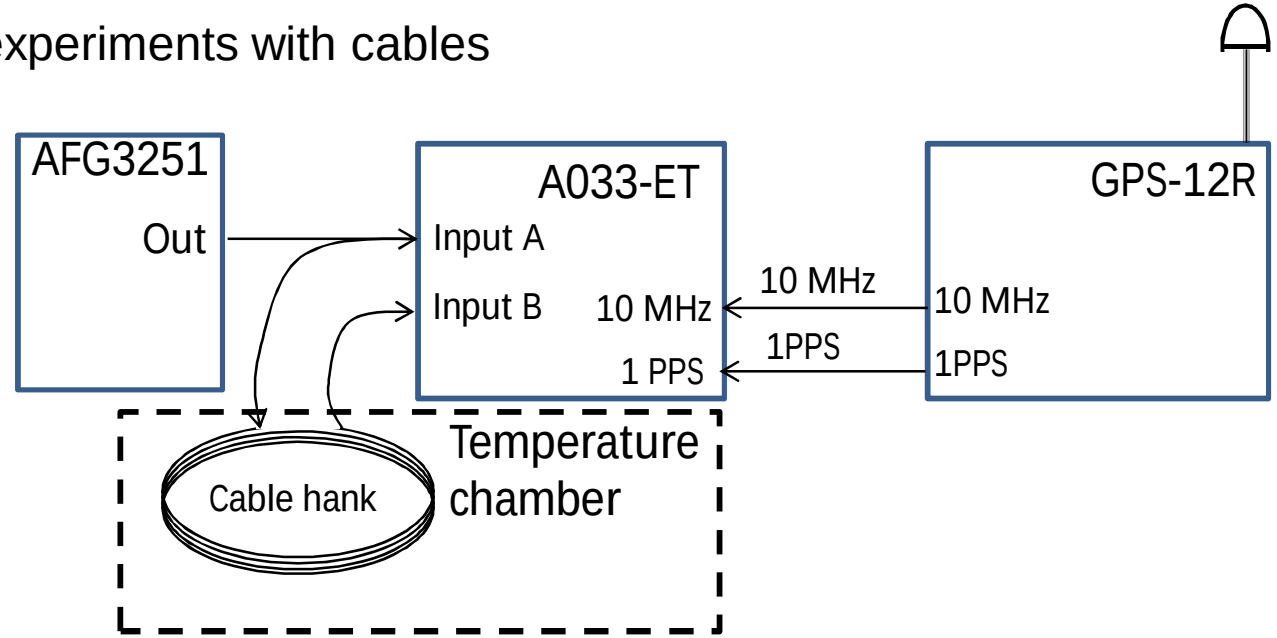


Implementation and main components of the ETBS



Connection cable impact estimation

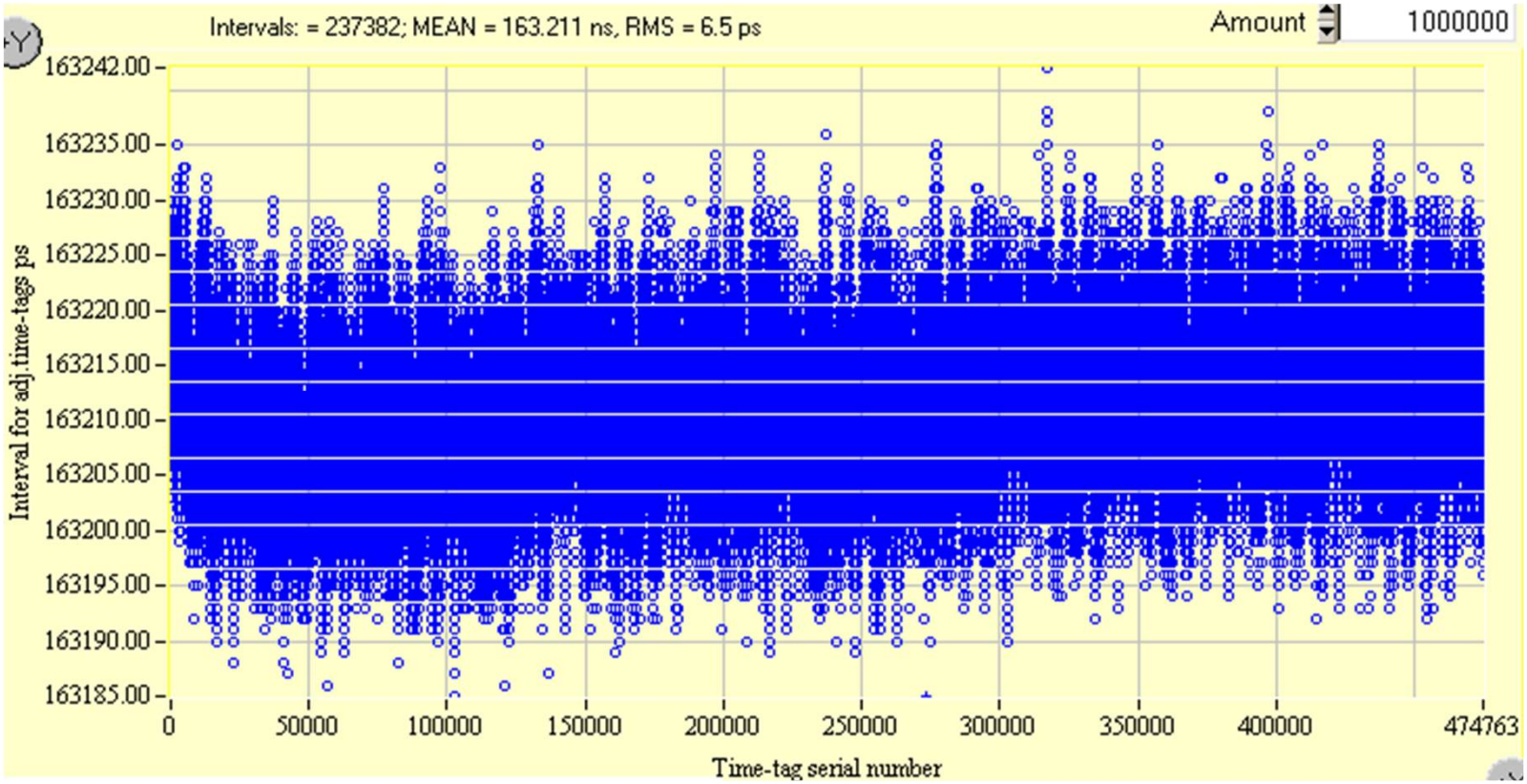
Laboratory experiments with cables



Cable	Length, m	Conductor (mm)	Diameter, mm	Atten., db/m	RMS, ps	Delay, ps	Temperature drift, ps/°C
RG58C-U	3	19x0.18	4.95	0.65	2.7	50715	4.5
РК50-2-16	10	7x0.24	3.2	0.8	18.7	193778	8.7
РК50-7-21	30	7x0.83	8.9	0.32	6.5	163221	0.4

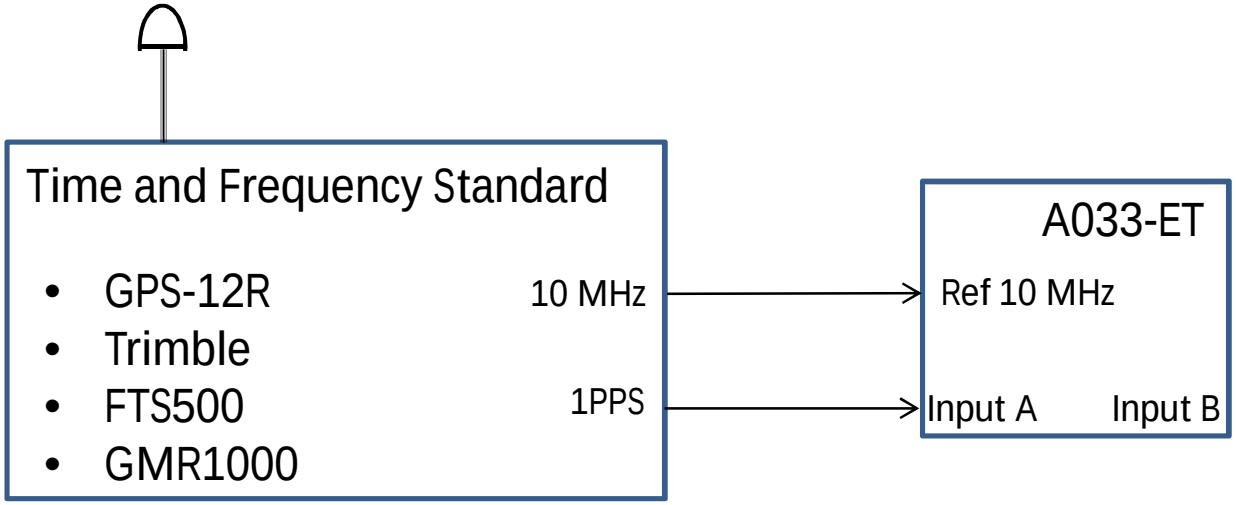
Connection cable impact estimation

Laboratory experiments with cables



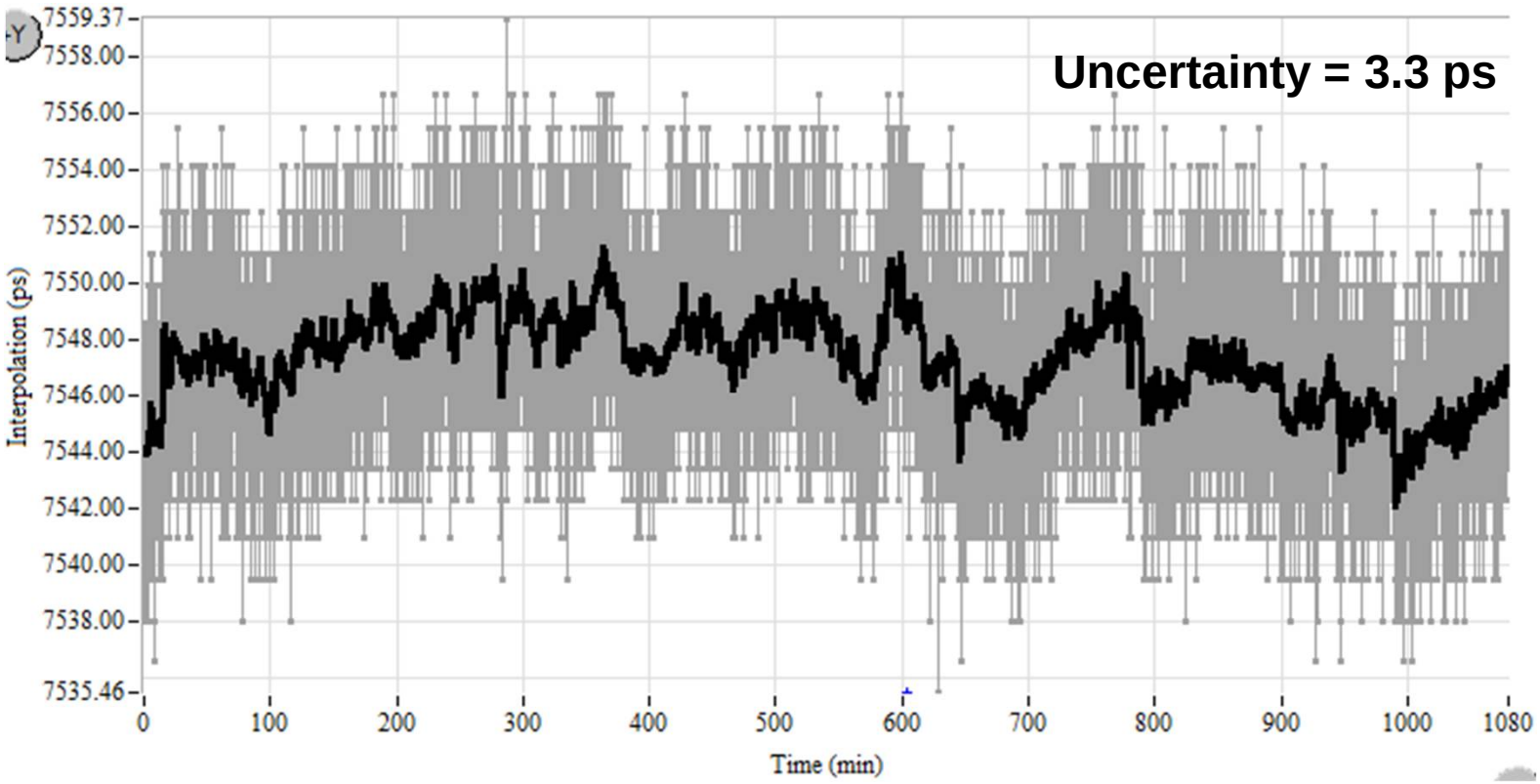
Estimation of cable delay and introduced uncertainty at constant temperature 40^{o}C

Laboratory experiments with Time and Frequency Standards



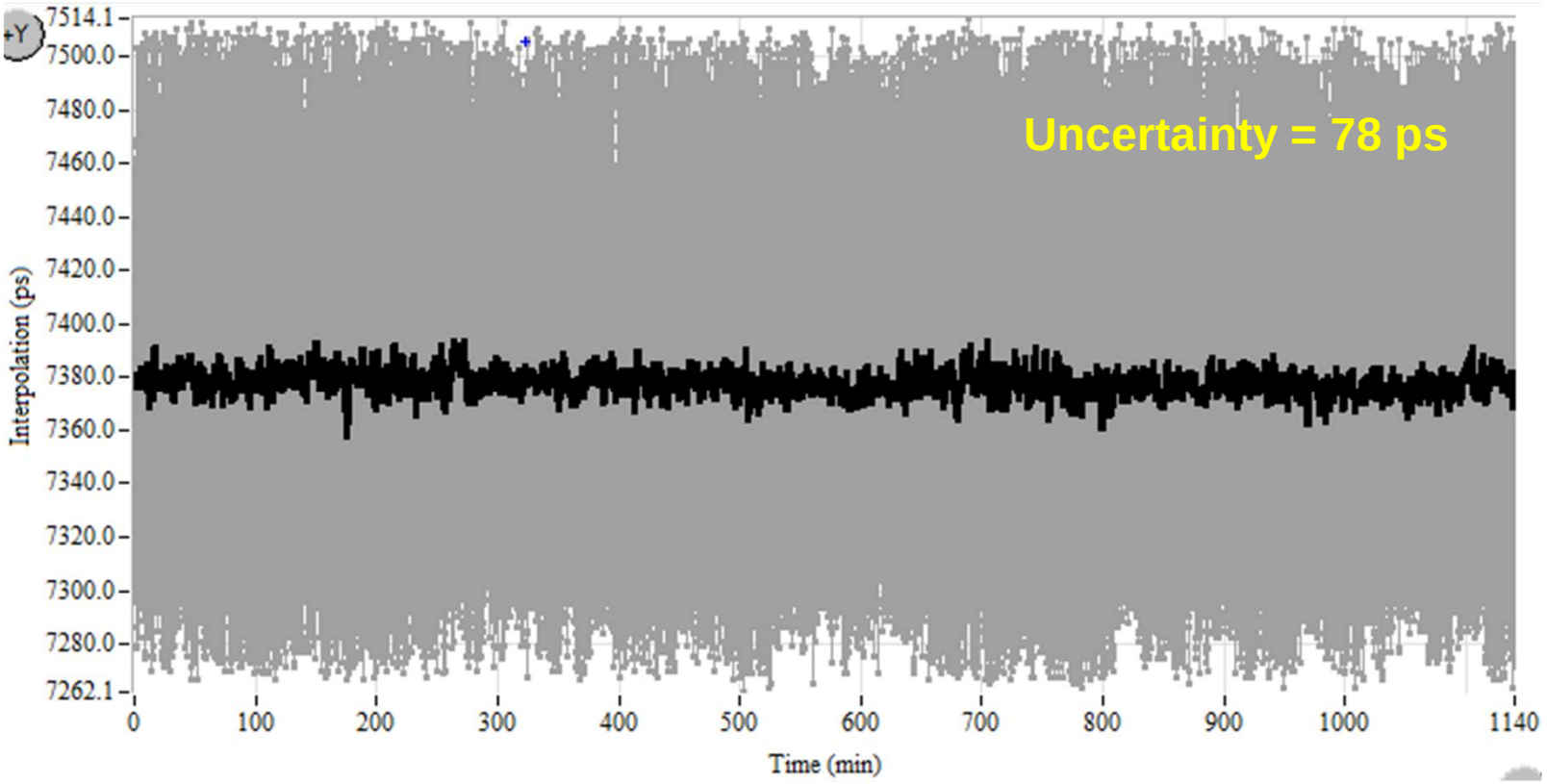
TFS	Own 1 PPS accuracy	1 PPS pulse period precision (RMS)
GPS-12R	26 ps	5.0 ps
Trimble	24 ps	3.3 ps
FTS500	22 ps	3.3 ps
GMR1000	252 ps	78 ps

Laboratory experiments with Time and Frequency Standards



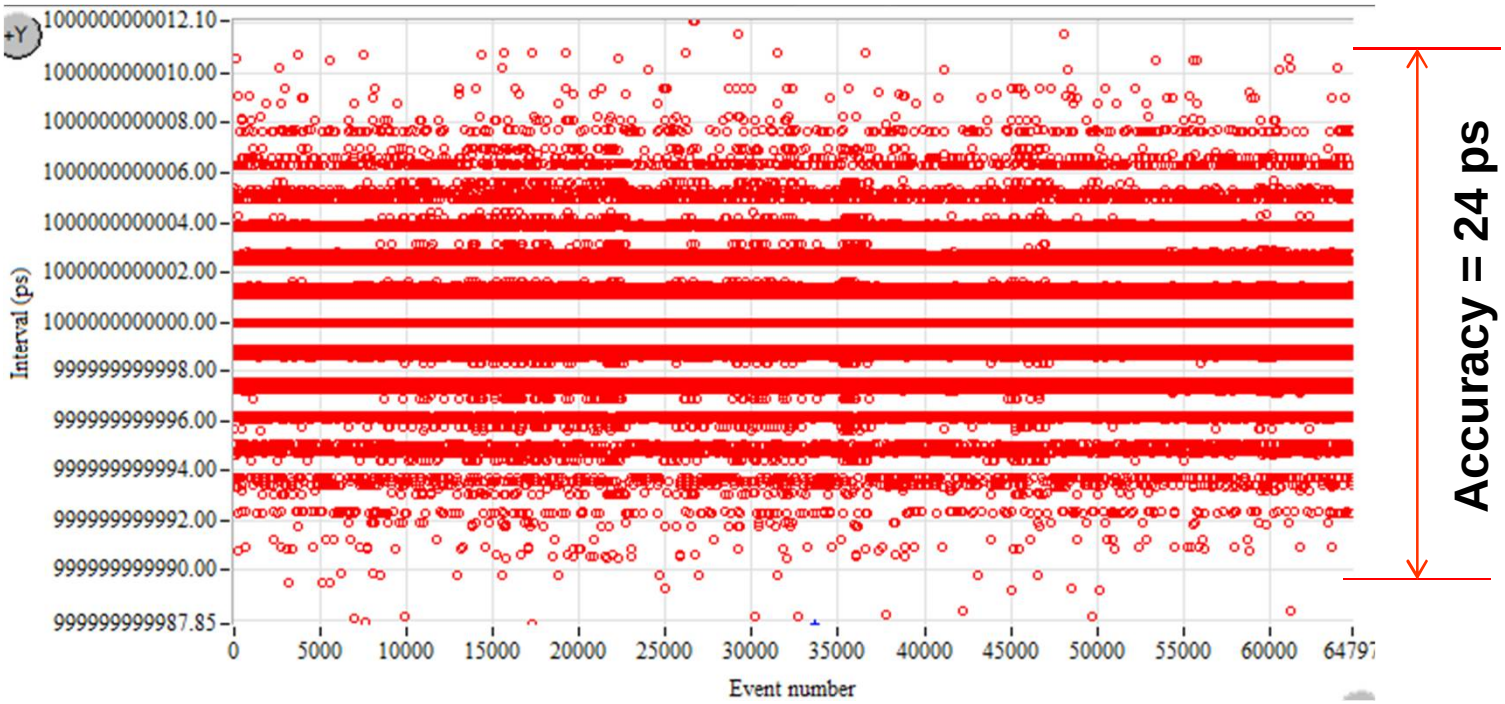
Trimble 1 PPS pulse position in the time scale of the ET

Laboratory experiments with Time and Frequency Standards



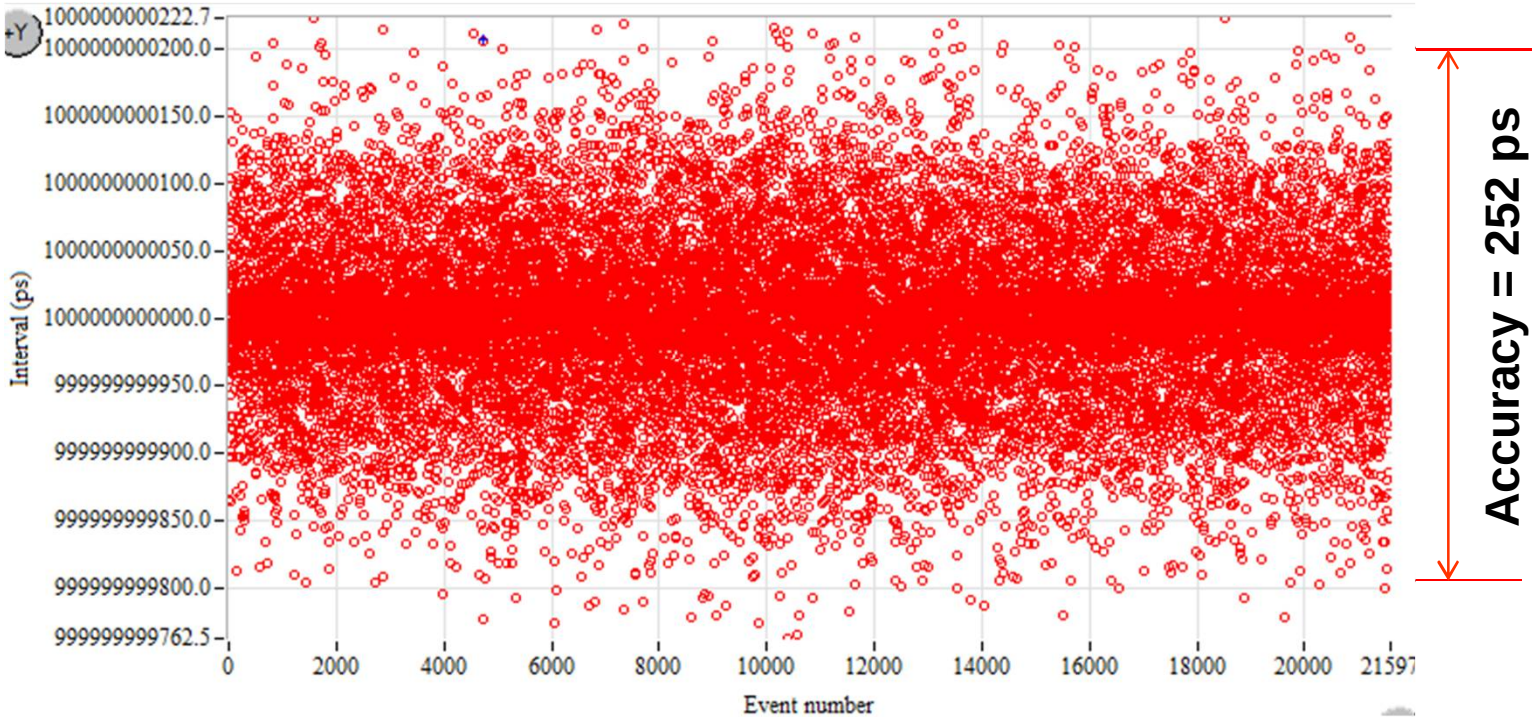
GMR1000 1 PPS pulse position in the time scale of the ET

Laboratory experiments with Time and Frequency Standards



Trimble 1 PPS pulse period estimations

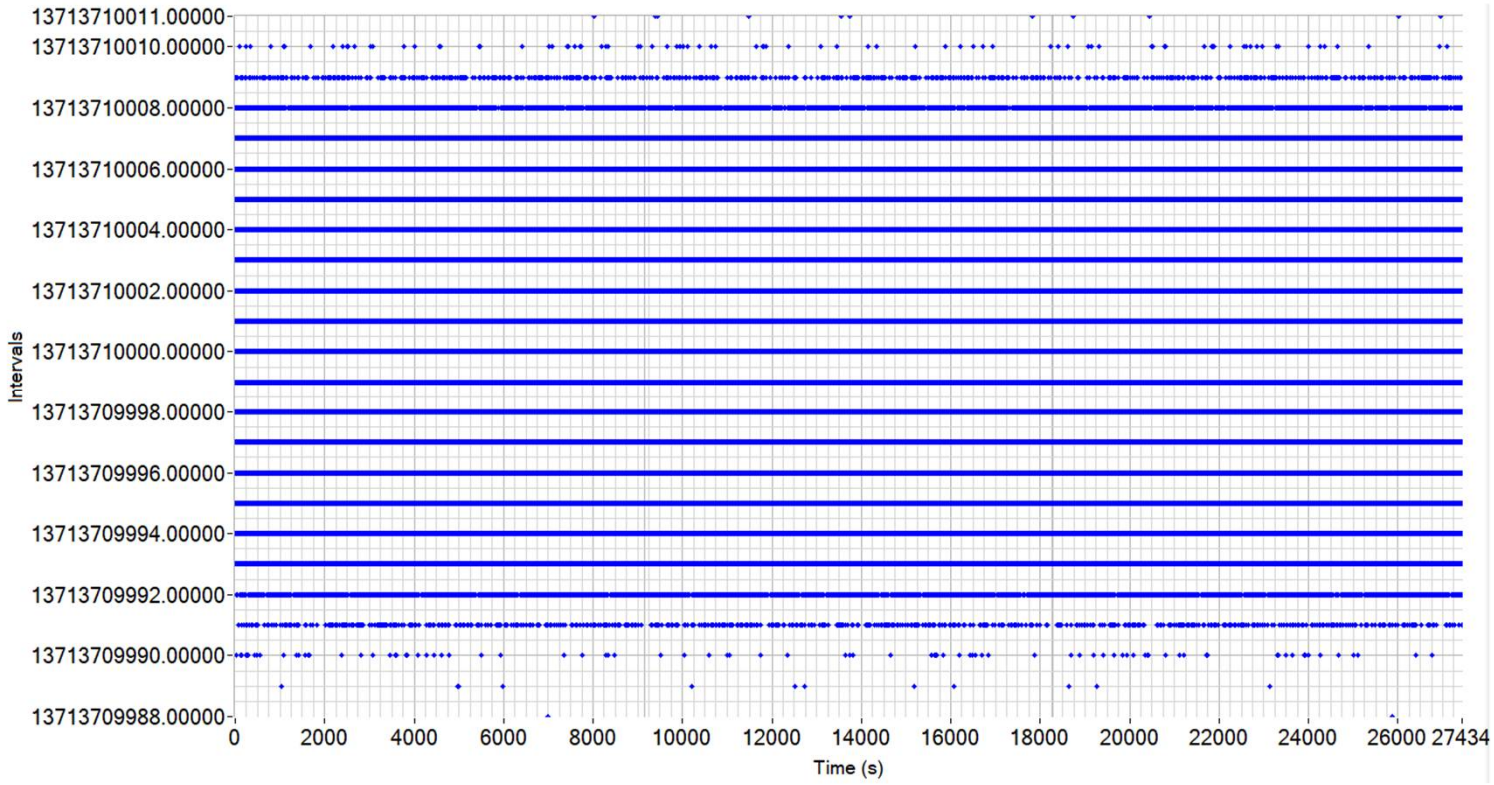
Laboratory experiments with Time and Frequency Standards



GMR1000 1 PPS pulse period estimations

Estimation of the synchronization output of the A040-ET

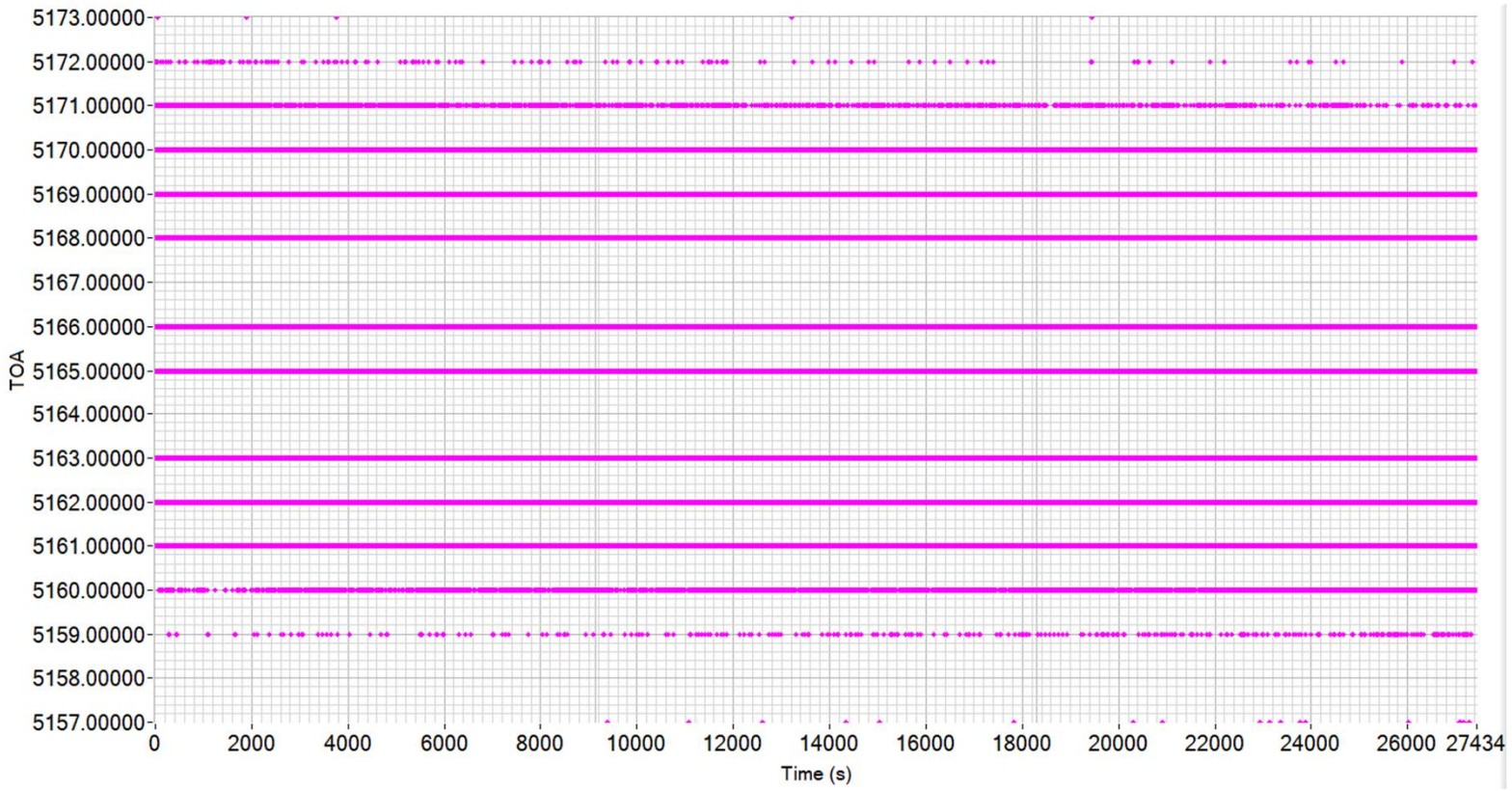
Using of A040-ET output AUX for time scales synchronization



Measurement results for AUX signal period during 7.4 hours

Estimation of the synchronization output of the A040-ET

Using of A040-ET output AUX for time scales synchronization



AUX signal position in the time scale of the ET

Estimation of the synchronization output of the A040-ET

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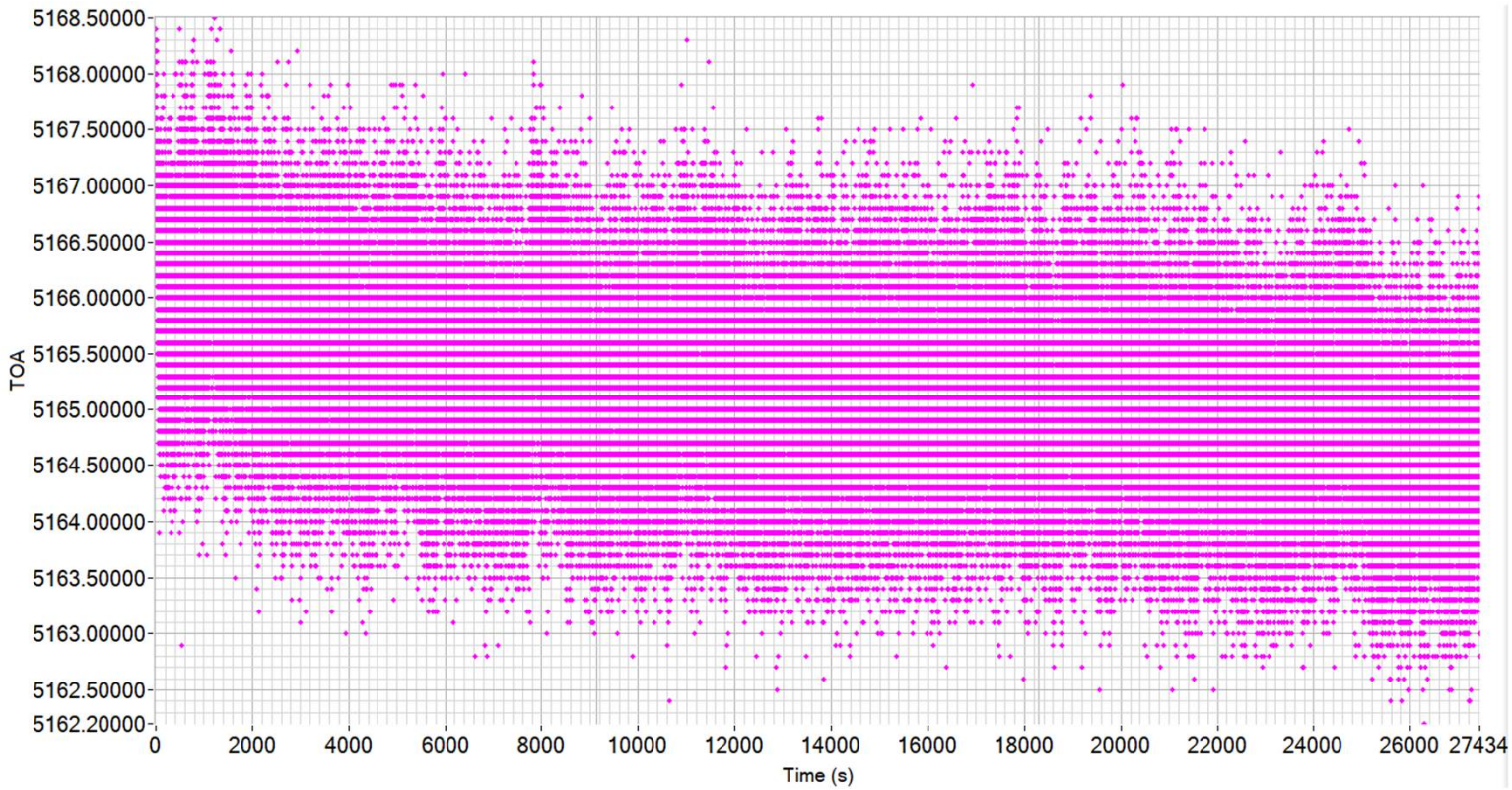
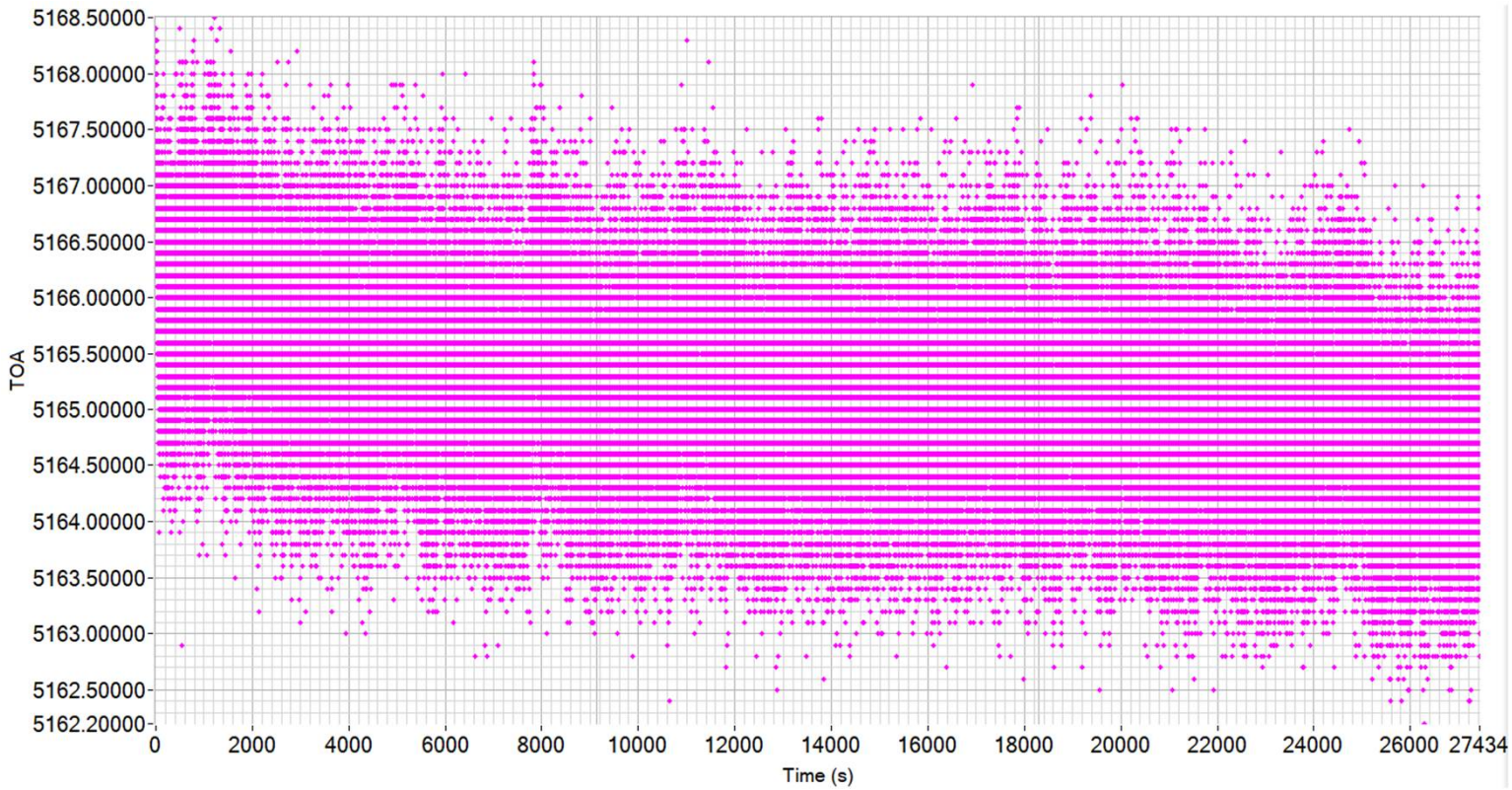


Averaging of the AUX signal position on 10 values

Estimation of the synchronization output of the A040-ET

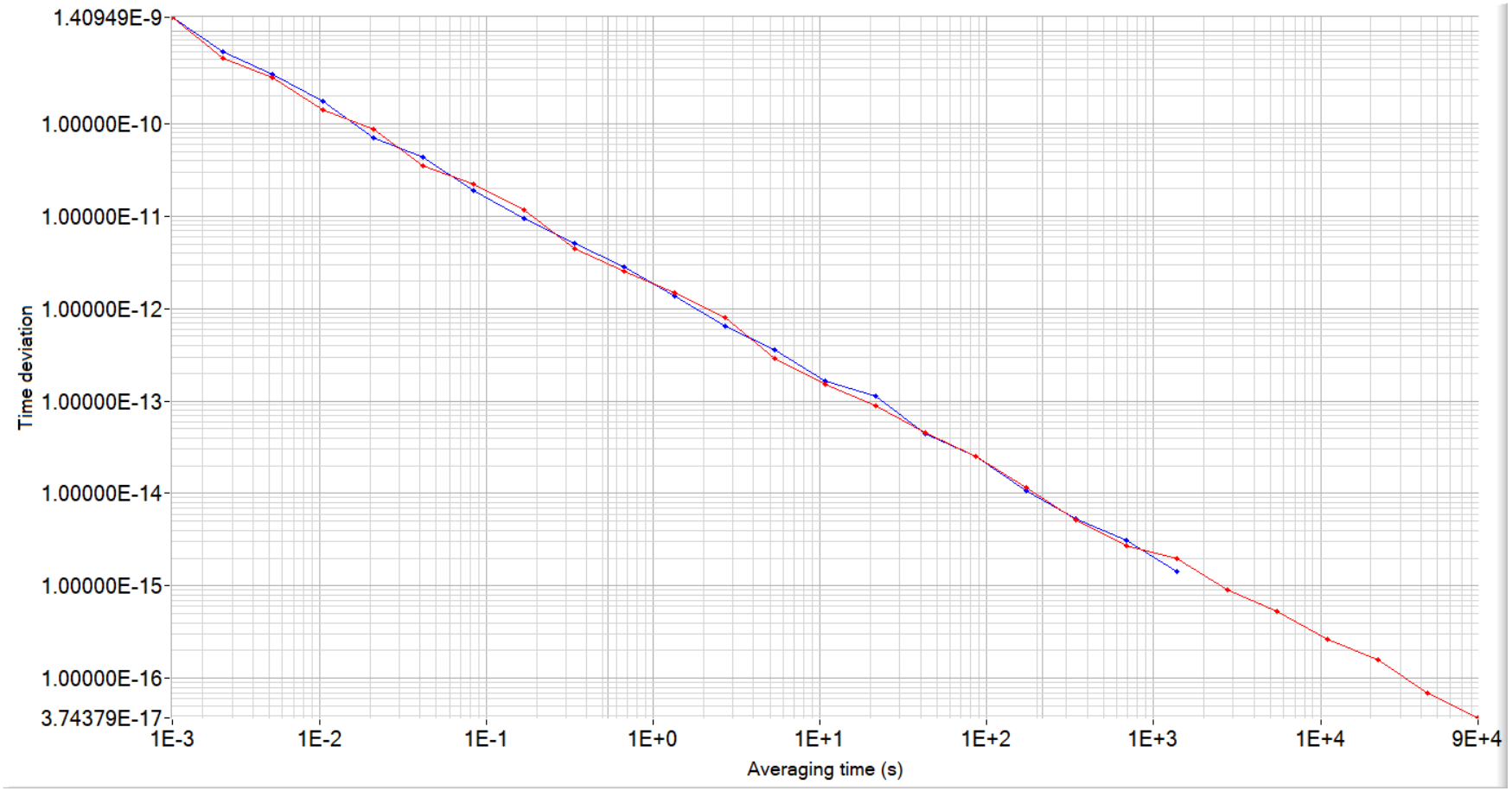
Using of A040-ET output AUX for time scales synchronization



Averaging of the AUX signal position on 10 values

Estimation of the synchronization output of the A040-ET

Stability of the A040-ET synchronization output AUX



Alan deviation (blue - classic; red – with overlapping) for signal with period = 1310610 ns)

Estimation of the accuracy and precision of the ETBS

Estimations of the accuracy and precision of the time-scale synchronization

Timing system synchronization based on:	Accuracy, ps	Precision, ps
A040-ET	28.6	6.2
TET	77.4	10.6
MTET	760	11.6
MTET with T-correction	≈100	≈6
WR network	495	36