Timing the Industry

Introduction

Nowadays, the number of applications with very demanding time synchronization requirements are increasing in markets such as science, defence, finance, telecom (5G), smart grid, broadcast, etc. To meet such demanding specifications, protocols such as **White Rabbit** (capable of distributing time with sub-nanosecond accuracy and picosecond precision) were developed. However, as accuracy and precision improve, the measuring instruments used to monitor and ensure such performance must improve with them.

The objective of this document is to study whether an advanced measurement system as the **Time Tagger Ultra** by Swabian Instruments can be applied to White Rabbit time distribution local networks with the advantages that this would entail for the previously mentioned sectors and applications.

Set-up

Figure 1 shows the setup used for testing the capabilities of the **Time Tagger Ultra** from **Swabian Instruments** to measure the time accuracy in a **White Rabbit** (WR) network based on **Seven Solutions** product ecosystem.

The equipment used for this setup is listed below:

Swabian Instruments

- Time Tagger Ultra Performance.

Seven Solutions

- WR Z16.
- WR ZEN TP FL.
- WR ZEN TP 32 BNC.
- DOWR.

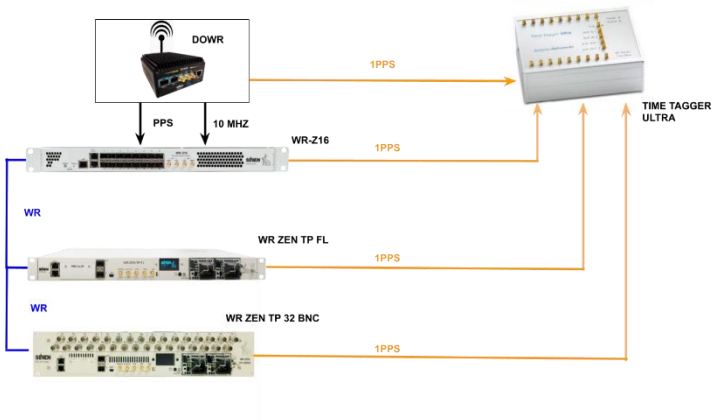

Figure 1: Test setup

In this setup, a GPS signal is used as an external time reference of the WR network. The **DOWR**, which integrates a GPS receiver, is used to provide this GPS reference to the WR-Z16 via 1PPS (Pulse Per Second) and 10 MHz signals.

The **WR-Z16** acts as a **WR Grandmaster**, locked to the external reference, and as a **WR time distribution device** for the different time nodes of the network.

Two **WR ZEN TP family** devices are used as WR end nodes of the network. They are synchronized to the time reference provided by the WR-Z16 via WR over **optical fibre links**.

To measure the **time accuracy** of the synchronization on each level of the network architecture, the **1PPS** outputs signals are being used on each WR node to be provided to the **Time Tagger Ultra**, which timestamps these pulses and compares them with respect to a given reference.

Results

Figure 2 and **Figure 3** show the **results obtained** by measuring the 1PPS signals during a 24h duration test. The samples provided by the Time Tagger represent the **time error** obtained by comparing the timestamp of the DOWR to the timestamps of the other nodes.

Figure 2 is directly provided by the **Time Tagger graphical interface tool** on real time, so no data processing was applied in these results. A reduced span of hundreds of samples is shown in the plots with the purpose of facilitate the visualization.

Two different **tests** were performed over the same setup:

- **Test 1: Synchronization with respect to the GPS reference**

For this test, the 1PPS signal defined as reference was the one provided by the GPS receiver integrated in the DOWR.

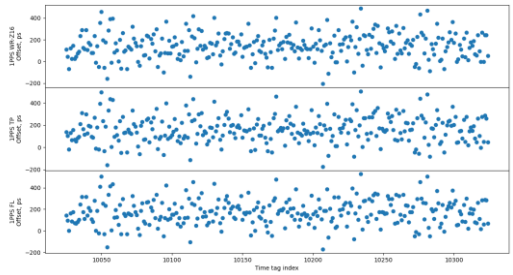

Figure 2: Time accuracy with respect to GPS time reference

The **results** which can be seen in the plot correspond to the time error of each node in comparison with the GPS reference. The first subplot corresponds to the WR-Z16, the second one to the WR ZEN TP 32 BNC and the third one to the WR ZEN TP FL.

These results allow to confirm that the **sub nanosecond time error** with respect to the GPS reference is preserved on each node of the network.

For a better understanding of the results, a histogram of the time error is included below, as well as the most relevant statistical parameters obtained from the measurements.

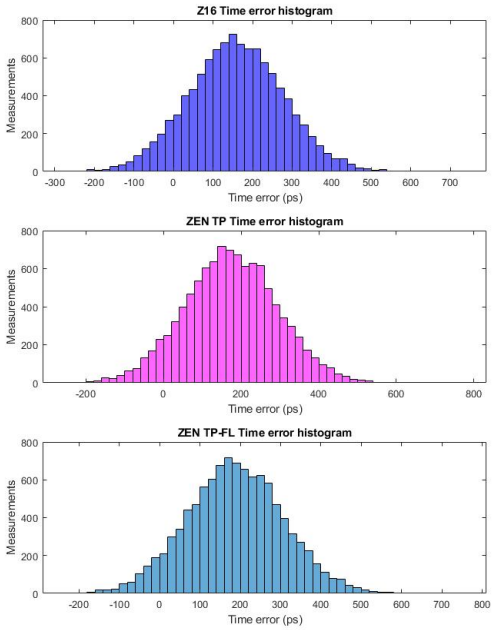

Figure 3: Time error histogram with respect to GPS time reference

Node	Accuracy (ps)	Jitter (ps)	Peak2Peak (ps)
Z16	158	119	1001
TP32	174	120	1010
TPFL	187	119	994

Table 1: Relevant statistics of test with GPS reference

- **Test 2: Synchronization with respect to the WR Grandmaster**

In this second test, the 1PPS output from the WR-Z16 was defined as a reference.

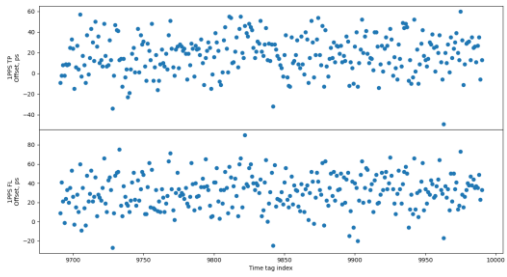

Figure 4: Time accuracy with respect to WR time reference

In this case, the **results** correspond to the time error with respect to the WR time reference, so they are referred to the real time transfer capabilities and stability of the WR technology, as we are looking only at the 1PPS signals provided by WR, and the typical instability of the GPS signal is not involved.

The first subplot corresponds to the WR-ZEN TP 32 BNC and the second to the WR ZEN TP FL.

The histogram of the time error and the table of statistical parameters are included below:

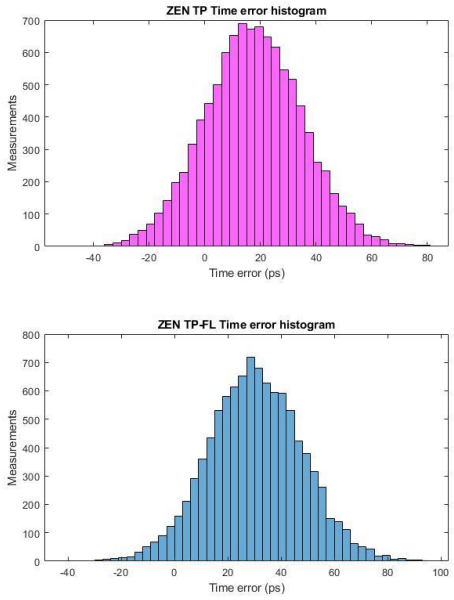

Figure 5: Time error histogram with respect to WR time reference

Node	Accuracy (ps)	Jitter (ps)	Peak2Peak (ps)
TP32	17	17	129
TPFL	30	17	135

Table 2: Relevant statistics of test with WR reference

Conclusions

The results obtained in this experiment allowed us not only to demonstrate, using a high-performance measuring device, the well-known time accuracy and precision of the synchronization that **White Rabbit** provides, but also evaluate the multiple advantages that the Time Tagger Ultra can offer in applications with high requirements in terms of synchronization and monitoring capabilities, which are typically demanded in diverse sectors within critical infrastructure.

The **Time Tagger Ultra** provides a very high time resolution for measuring the 1PPS signals and offers a comprehensive and user-friendly graphical interface which allows to control and monitor the system remotely, providing telemetry capability.

The high flexibility of the software tools and libraries allows to configure and adapt the measuring functions to the specific test and signals which are involved in a specific application.

The possibility using multiple channels simultaneously (up to 18) is especially interesting for the applications involving multiple network layers and multiple devices which must be monitored in relation to the same time reference.

About Swabian Instruments

Swabian Instruments is a test and measurement company headquartered in Stuttgart, Germany. They develop and sell digital data acquisition and signal generation systems that are easy to use, performant, and packed with useful features. Their instruments empower scientists around the globe to perform ground-breaking research. With their Time Tagger Series, they are emerging as the technology leader in time-correlated single photon counting instrumentation. www.swabianinstruments.com

About Seven Solutions

Seven Solutions S.L. is a privately held company with high expertise in embedded systems and leading accurate sub-nanosecond time transfer and frequency distribution for reliable aerospace and defense, industrial and scientific applications. With more than ten years of expertise in embedded systems design (electronics, firmware, embedded software), we offer the best-in class full turn-key solutions as well as customized solutions for timing applications. We are leaders in time and frequency distribution solutions based on White-Rabbit technology and derived standards (IEEE-1588-2019-HA). www.sevensols.com