CERTIFICATE OF CALIBRATION

Applicant	Tweede golf Castellastraat 26 6512 EX NIJMEGEN
Submitted	Two PTP software implementations PTP software implementation 1 Type : Linux PTP Version number : 3.1.1 Software source : https://sourceforge.net/projects/linuxptp/ PTP software implementation 2 Type : Statime PTP Version number : 2.0 Software source : https://github.com/pendulum-project/statime
Calibration method	The relative timescale deviation and the stability of the two PTP software implementations have been investigated by measuring the phase difference between a PPS signal deduced from a PTP server and a PPS signal deduced from a PTP client which was implemented by the PTP software package under test. During the measurements, the PTP server was synchronized to the VSL time standard UTC(VSL), and the PTP client was synchronized with the PTP server. The phase difference measurements were performed by a Time Interval Counter (TIC) SR620. The trigger level on two measurement channels was both set to be 0.5 V, and the input impedance on two measurement channels was both set to be 50 Ohm. The measurement duration for each PTP software implementation was 1 hour, with 3600 samples collected. The measurements have been carried out at an ambient temperature of (23.1 ± 0.5) °C and a relative air humidity of (45 ± 2) %.
Date of calibration	04-04-2024
Result	The results of the calibration are shown on page 2 and page 3 of this certificate. The reported uncertainty of measurement is based on the standard uncertainty multiplied by a coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95 %. The standard uncertainty has been determined in accordance with the GUM 'Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement'.
Traceability	The results of the calibration services are traceable to primary and/or (inter)nationally accepted measurement standards.

Delft, 31 May 2024

On behalf of VSL,
The Certificate Committee

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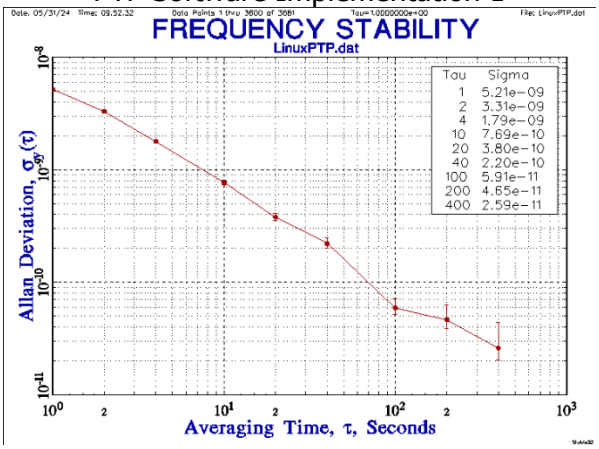
Relative Timescale Deviation
The average deviation ΔT of the relative timescale deviation between the PTP software implementation 1 and the PTP software implementation 2 was: (0 ± 12) ns.

A positive value of ΔT means that the timescale of the PTP software implementation 1 is ahead of the PTP software implementation 2; a negative value means that the PTP software implementation 1 is lagging with respect to the PTP software implementation 2.

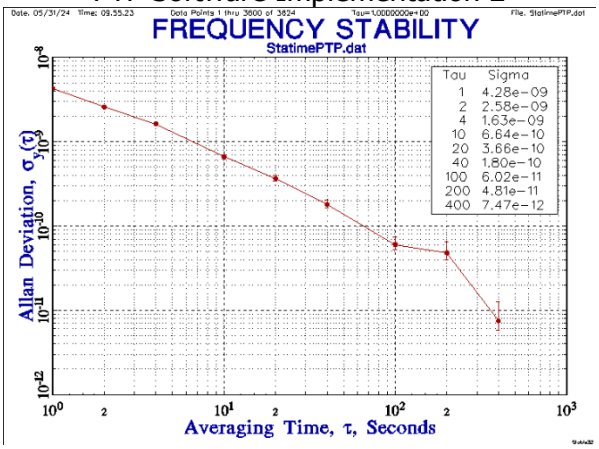
Stability
The frequency stability of the two PTP software implementations in the form of Allan Deviation were:

Measurement Time Interval τ Unit: second	Allan Deviation of PTP Software Implementation 1 $\sigma_y(\tau)$ Unit: Hz/Hz	Allan Deviation of PTP Software Implementation 2 $\sigma_y(\tau)$ Unit: Hz/Hz
1	5.21×10^{-09}	4.28×10^{-09}
2	3.31×10^{-09}	2.58×10^{-09}
4	1.79×10^{-09}	1.63×10^{-09}
10	7.69×10^{-10}	6.64×10^{-10}
20	3.80×10^{-10}	3.66×10^{-10}
40	2.20×10^{-10}	1.80×10^{-10}
100	5.91×10^{-11}	6.02×10^{-11}
200	4.65×10^{-11}	4.81×10^{-11}
400	2.59×10^{-11}	7.47×10^{-12}

Allan Deviation Plot of
PTP Software Implementation 1



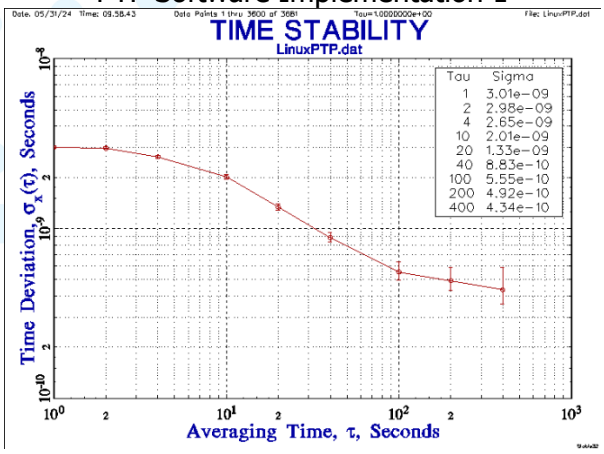
Allan Deviation Plot of
PTP Software Implementation 2



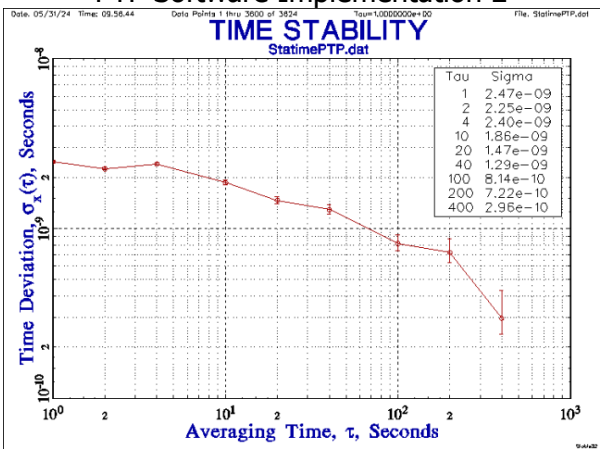
The time stability of the two PTP software implementations in the form of Time Deviation were:

Measurement Time Interval τ Unit: second	Time Deviation of PTP Software Implementation 1 $\sigma_x(\tau)$ Unit: second	Time Deviation of PTP Software Implementation 2 $\sigma_x(\tau)$ Unit: second
1	3.01×10^{-09}	2.47×10^{-09}
2	2.98×10^{-09}	2.25×10^{-09}
4	2.65×10^{-09}	2.40×10^{-09}
10	2.01×10^{-09}	1.86×10^{-09}
20	1.33×10^{-09}	1.47×10^{-09}
40	8.83×10^{-10}	1.29×10^{-09}
100	5.55×10^{-10}	8.14×10^{-10}
200	4.92×10^{-10}	7.22×10^{-10}
400	4.34×10^{-10}	2.96×10^{-10}

Time Deviation Plot of
PTP Software Implementation 1



Time Deviation Plot of
PTP Software Implementation 2



The reported results are consistent with the national designation of VSL, its international acceptance under the CIPM MRA and international accreditation (ILAC/RvA) as mentioned on this page. If identified, only the noted designation or accreditation is valid.

[1] The reported content in this certificate is traceable to the National (Primary) Standards of The Netherlands, which realize units of measurement according to the International System of Units (SI). Measurement traceability is realized according to ILAC policy on Metrological Traceability of Measurement results (ILAC-P10:07/2020) and Acceptable Traceability (RvA-T018-NL/UK, article 3.1).

Van Swinden Laboratorium (VSL) is designated by law as the National Metrology Institute (NMI) of the Netherlands. As such, it provides direct traceability of measurement results to internationally accepted measurement standards. VSL is a signatory member of the Mutual Recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM). The existence of mutual confidence in product specifications and product control is of fundamental importance in order to fulfill international, harmonized legislation on trade, quality, health, safety, and the environment. In this respect, standardized and equivalent measurement units and traceability to internationally accepted standards are essential. More information can be found at https://www.vsl.nl/ .

[2] The reported content in this certificate is consistent with the Calibration and Measurement Capability represented in the Key Comparison Database (KCDB) as part of the Mutual Recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM).

This certificate is consistent with the calibration and measurement capabilities (CMCs) that are included in Appendix C of the Mutual Recognition Arrangement (CIPM MRA) drawn up by the International Committee for Weights and Measures (CIPM). Under the CIPM MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in the KCDB (for details https://www.bipm.org/kcdb/).

[3] The reported content in this certificate is consistent with the RvA scope of accreditation of VSL with identification K999 for calibrations against the requirements as laid down in ISO/IEC 17025:2017.

The scope can be verified on https://www.rva.nl/. RvA is signatory of the EA MLA and ILAC MRA.