



**MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE**

**UNIVERSITE MARIE ET LOUIS PASTEUR  
1, RUE CLAUDE GOUDIMEL  
25 030 BESANCON CEDEX**

**☎ : 03.81.66.60.97**  
[service.marches@univ-fcomte.fr](mailto:service.marches@univ-fcomte.fr)

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**CAHIER DES CLAUSES TECHNIQUES PARTICULIERES**

**TECHNICAL SPECIFICATIONS**

**PROCESSEUR DE TEMPS / TIME PROCESSOR**

## Contacts

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### **Responsable de l'institut FEMTO-ST**

Michael Gauthier  
[Michael.gauthier@femto-st.fr](mailto:Michael.gauthier@femto-st.fr)

### **Gestionnaire responsable du suivi administratif :**

Adrian Weirich  
Bureau 03.81.66.58.31  
[adrian.weirich@univ-fcomte.fr](mailto:adrian.weirich@univ-fcomte.fr)

### **Responsable technique :**

Enrico Rubiola  
Bureau 06.80.73.67.03  
[Enrico.rubiola@femto-st.fr](mailto:Enrico.rubiola@femto-st.fr)

# *Time Processor*

*(Multichannel phase-meter and three-cornered-hat time analyzer)*

## *Technical Specifications*

French administration uses the acronym CCTP for “Specifications”

### **1. Introduction**

The instrument is intended for the measurement of experimental and primary-metrology-grade frequency sources like active H masers, cryogenic sapphire oscillators, cold-ion/cold-atom clocks, and next-generation research oscillators. These sources are found in highly competitive metrology laboratory, and rarely in private Companies (commercial quantum standards only). The target measurements are

- Continuous monitoring of a few frequency standards simultaneously, with no data loss over years, at a rate of 1-10 samples/s.
- Simultaneous measurement of the phase time and frequency stability (ADEV, MDEV) of a few oscillators for  $\tau$  from 100 ms to  $10^8$  s.

At the state of the art, the masers can be measured with a single-channel instrument. Conversely, the CSOs require special dual-channel techniques, like the two-sample covariances, which mitigate the instrument background noise, at the cost of longer measurement time.

#### 1.1 Terminology

The terminology for frequency stability and phase noise used in this document is defined in the article E. Rubiola, F. Vernotte, [The Companion of Enrico's Chart for Phase Noise and Two-Sample Variances](#), *IEEE Trans. Microwave Theory Techniques* 71(7) pp. 2996-3025, July 2023, DOI 10.1109/TMTT.2023.3238267 (open access).

#### 1.2 What we expect, and what is not needed

The technical part of the manufacturer/seller response to this call for tender must be written in English. The instrument must be delivered within the deadline, with the companion software, and installed in our lab.

Once delivered and paid, the instrument (the physical object) is our full property. On the other hand, reasonable license terms can be accepted with the companion software. That said, open-source software is highly appreciated.

We do not need (we already have) the external computer which runs the companion software, RF cables and connectors, power cord and similar consumables.

### 1.3 If some specs cannot be met

We are aware that the object of this call is a special instrument, and we do not make a fuss for minor details. Some specs may be re-discussed and modified/relaxed after technical considerations (complexity, reliability, etc.). In this case, contact E. Rubiola ASAP.

## 2. Stability requirement

The stability requirement concerns the instrument itself, properly driven by at least one high-quality input signal (for example, H maser or sapphire oscillator). It is understood that the full stability is achieved with the instrument is installed in a proper metrology lab environment, and after a suitable warmup.

The required stability is  $3 \times 10^{-14}$  at  $\tau = 1$  s (ovl ADEV) in the following conditions

- 100 MHz input frequency
- Single-channel mode (correlation not used)
- +10 dBm input level
- 5 Hz measurement bandwidth ( $f_H$ )

The background noise must decrease with  $1/\tau$  law, or with a law reasonably close to  $1/\tau$ . Albeit the background noise cannot decrease infinitely, ADEV should get  $10^{-17}$  at  $\tau = 10^4$  s.

Higher instability can be tolerated at lower input frequency. It is reasonable to allow a factor of 2 at 10 MHz, and a factor of 4 at 5 MHz.

## 3. More detailed description and requirements

The instrument acquires the instantaneous time (or phase, or phase time) of  $n$  oscillators of arbitrary frequency in the specified range, with full freedom. For example, all frequencies may be different from one another and none at a round number; or all gathered in a narrow range at 10 or 100 MHz; or anything else.

### 3.1 Operating modes

- Single-channel mode. Each channel receives the signal from one oscillator. This is used for continuous time monitoring and for stability measurement (ADEV etc.).
- Two-channel mode. The signal of each oscillator is split into two inputs, thus the  $n$ -channel instrument can measure  $n/2$  oscillators. This is used for the stability measurement of the CSOs and similar oscillators, whose instability is smaller than the background noise of the instrument in single-channel mode. The mathematical tool will be the two-sample covariance (MVAR etc.).
- Mixed mode. A combination of the above, with  $n'$  channels in single-channel mode, and  $n''$  in two-channel mode ( $n''$  is even number). Accordingly, the total number of oscillators is  $m = n' + n''/2$ .

### 3.2 Hardware

<b>RF inputs</b>		
Number of RF inputs	16	Minimum 14
Input frequency range	5-400 MHz	Not less than 5-200
Input level	7-13 dBm	(not strict)
<b>Clock</b>		
External clock input	0.1/1 GHz (either), 50 Ohm nominal, 7-13 dBm	
Internal clock output	0.1/1 GHz (either), 50 Ohm nominal, 3-10 dBm	
<b>Synch</b>		
Input/output synch, intended to synchronize two machines		
<b>All inputs and output</b>		
Impedance, all RF I/O	50 Ohm nominal	
Connectors, all RF I/O	N-type F	
<b>Computer interface</b>		
Ethernet	Appropriate speed	RJ45 F connector

### 3.3 Data output and sampling rate

The phase-time is delivered at a user-programmable rate of 1-10 samples/s. This enables the measurement of the variances down to 100 ms or 1 s, at the user's choice.

Inside, the instrument should always operate at the highest sampling rate. The output data rate is available after decimation. The instrument implements a low-pass filter (the parameter  $f_H$  commonly found in the literature) whose bandwidth is suitable to the output rate chosen.

The output format is a data stream. The information at the output should include a time tag and the  $n$  values of phase-time  $x - x_{\text{ref}}$ , or equivalent.

We accept both continuous-mode or burst-mode data transfer. If the burst mode is proposed, the delay between bursts should be comfortable for the user, say, not less than two per minute.

Data will be available on Ethernet interface. This requirement is intended to guarantee compatibility with current and future standards.

### 3.4 Software

The software provided with the Time Processor must be installed on one of our computers. Thus, it must be compatible with Windows 10/11 and Linux (major distributions)

The purposes of the software are

- Program the instrument
- Import all data from the hardware module
- Record (local/external disk) the data stream for all the inputs
- Calculate the following quantities
  - Fractional frequency stability  $y_i - y_{\text{ref}}$  for all the inputs
  - Two-sample variances AVAR, MVAR (optional PVAR) for all the inputs
  - Two-sample covariances
- Display the following quantities
  - $(x_i - x_{\text{ref}})(t)$  and  $(y_i - y_{\text{ref}})(t)$
  - ADEV, MDEV, and PDEV as a function of  $\tau$
- Export the plots in PNG and PDF format

- Read-only access to partial data of a measurement in progress. The typical use is to detect oscillator misfunctions during selected time slots (heavy storms, air-conditioning maintenance, weekend vs working days, etc.) without stopping the continuous monitoring.

#### 4. General physical and electrical specs

The following specs are not all mandatory, please contact us if something does not fit.

- Size: Standard 19" rack mount, max 4 U
- Power
  - 220-240 V, max 80 W. Standard IEC 60320 C14 connector on the rear panel.
  - Additional 12-24 V input is appreciated.
- Temperature range
  - Full specs must be achieved at the temperature of 20 ... 25 °C, with slow fluctuations of  $\pm 1$  °C max once the instrument is set in its environment.
  - The instrument must work in the range of 10 ... 40 °C. In this condition, degraded stability is accepted.
  - Storage temperature: standard range for civil electronics
- The above specs indicate that safety is for sure not a critical issue. Common sense or the general rules for non-safety-critical instruments (say, digital oscilloscopes and RF spectrum analyzers), or even for consumer electronics, are good enough.

#### 5. Guarantee

At least two-year guarantee included, on site, parts and manpower.

#### 6. Installation and test

The following tasks are a **mandatory** complement to the product, at no additional cost.

A **first visit** to our lab estimated time is one full-time working week (minimum)

- Install the instrument and the companion software,
- Performance test
- Integration in our measurement system

A **second visit** to our lab is required (may be shorter than the first)

- Check on the installation and to refine the integration in our measurement system.
- The appropriate period is between 12 and 18 months after the initial delivery.

All this must be done by a senior scientist/engineer having deep knowledge of the instrument design at hardware/firmware/software level, and in tight collaboration with our engineers.

## Prestations de services demandées

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➤ **Installation et calibration :**

L'installation, la mise en service et la caractérisation des performances de l'appareil sont assurées par le titulaire.

➤ **Maintenance préventive :**

Une maintenance de 2 ans au minimum comprenant cellules et autres pièces de l'appareil est exigée.

Durant cette période, toutes les visites de maintenance (préventive et curative) ainsi que les pièces seront prises en charge par le titulaire.

➤ **Maintenance curative :**

Le coût de la main d'œuvre horaire et le coût des frais de déplacement sur site devront être précisés sur l'offre (Annexe B du dossier de consultation à compléter).

➤ **Garantie du matériel commandé :**

Une garantie de 24 mois minimum est exigée. Durant cette période, les délais d'intervention sur site et de réponse à la hotline devront être inférieurs respectivement à 72 h et à 24 h.

➤ **Livraison et Installation :**

La livraison et l'installation seront comprises dans l'offre.

- Impératif de livraison : **Le matériel devra être livré avant le 25/11/2025.** Un rendez-vous devra être pris avec le référent technique, Monsieur Enrico Rubiola, Professeur des Universités, pour convenir d'une date de livraison

- Lieu de livraison :

**UNIVERSITE MARIE ET LOUIS PASTEUR**

Institut FEMTO-ST

Département Temps-Fréquence

Supmicrotech/ENSMM

23 rue de l'Épitaphe

25 030 Besançon Cedex

**A** , **le**

**Cachet et signature de l'entreprise**