SyncSystem 4380A Time Scale Edition

Clock Measurement and Ensemble Platform for Autonomous Time Scale Generation

Summary

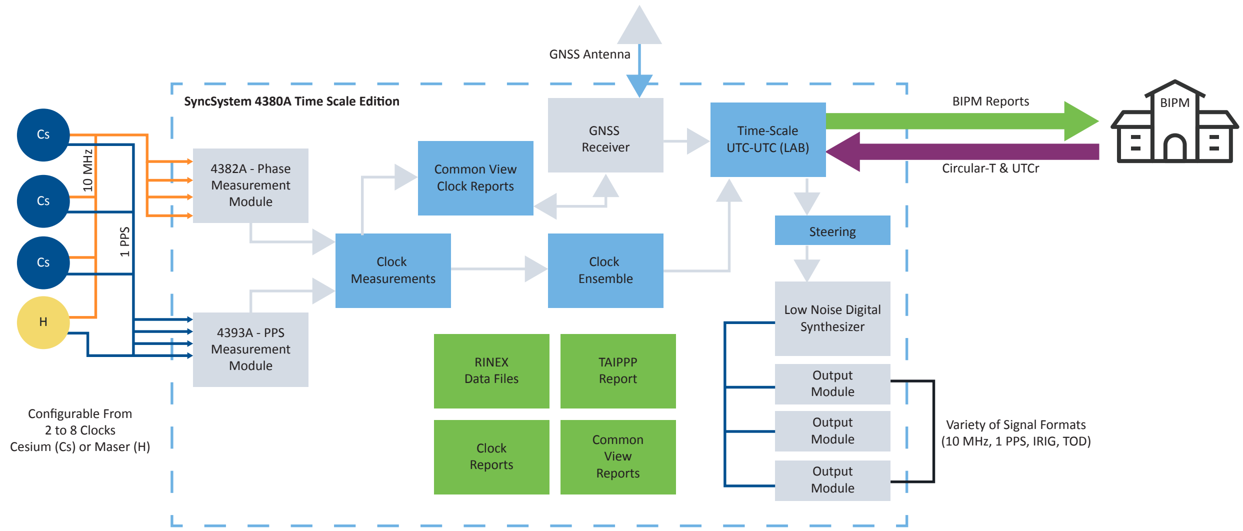
The SyncSystem 4380A Time Scale Edition generates an autonomous time scale derived from combining several highly accurate independent clocks. A multi-channel instrument for measuring high-performance cesium clocks or active hydrogen masers is built into the system. These frequency standards operate in a free-running mode and are continuously measured against each other to compute and generate the time scale frequency. The SyncSystem 4380A Time Scale Edition supports a variety of plug-in modules that enable the time scale output timing signals to be distributed in a wide range of formats. It also generates GNSS common view reports for comparison of the local clock's performance with remote clocks. This ultra-high-performance timing system is constructed in a robust 1U rack-mountable package with redundant and hot-swappable power supplies.

Key Features

- Multi-channel measurement system to measure member clocks
- Ensemble and time scale algorithms to combine clocks into one output
- Delivers local realization of UTC and contribution to worldwide UTC time scale calculated by the Bureau International des Poids et Mesures (BIPM)
- Built-in common view reporting enables multiple sites to be synchronized with high accuracy
- Provides BIPM reports including common view, clock reports and TAIPPP
- Distributes variety of clock signals: 1/5/10 MHz, PPS, DC-IRIG, AM-IRIG, Time-Of-Day (TOD) and more
- A member of our family of time scale products, including the Precise Time Scale System (PTSS)

SyncSystem 4380A Time Scale Edition Overview

The architecture of the SyncSystem 4380A Time Scale Edition is designed to function as the centerpiece of a time scale system, such as our Precise Time Scale System, or to be purchased individually and integrated into a previously established time scale environment. In cases where an environment already contains atomic clocks, the addition of the SyncSystem 4380A Time Scale Edition enables the system to accept inputs from the clocks to form the time scale and produce local UTC.



SyncSystem 4380A Time-Scale Edition

Clock Measurement

Our SyncSystem 4380A Time Scale Edition when equipped with the 4382A phase measurement and 4393A time interval counter modules delivers a flexible, multi-channel measurement system for quantifying clock performance. It can be used to measure the member clocks and generate the time scale frequency output. Both cards contain four input ports. The SyncSystem 4380A Time Scale Edition also has six module slots that can be used to install multiple cards.

The 4382A phase measurement module uses a highly precise heterodyne mixing technique to measure the phase of 5 MHz or 10 MHz signals to ascertain the phase difference of member clocks relative to the time scale frequency output. The heterodyning technique takes the 10 MHz (or 5 MHz) signal of each clock and mixes it with a reference signal offset by 10 Hz. The mixing produces a time expansion that achieves a heterodyne factor of 1,000,000 (when using 10 MHz as the input). This improves the intrinsic resolution of the resulting measurement to better than 100 femtoseconds. The phase measurements between clocks are then used to generate and steer the time scale frequency.

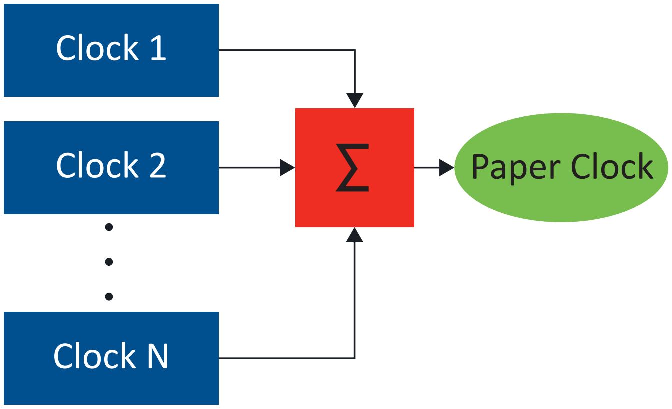
The 4393A card provides time interval measurements of 1 PPS signals. This module also has four input ports that can be used to measure the time interval between the internal time scale clock and up to four external sources. The averaging period for the measurements can be configured to 1, 10, 20, 60 or 300 seconds. The 4393A card measurements enable the system to quickly achieve time alignment with an external source, which may be beneficial in cases where the system is required to warm start following a system reconfiguration such as the addition and/or removal of clocks.

Clock Ensemble and Time Scale

The purpose of a time scale algorithm is to allow the use of an ensemble of clocks to generate a frequency reference superior in performance to any of the member clocks. Our SyncSystem 4380A Time Scale Edition uses the patented Kalman-Aided Sources version 2 (KAS-2) algorithm to accomplish this.

First, the SyncSystem 4380A Time Scale Edition approximates perfect time by blending the times of several highly accurate, independent free-running clocks. Based on the measurements provided by the 4382A and 4393A modules, the relative differences between independent clocks are used to create a clock ensemble.

Next, the time scale algorithm computes what is referred to as a paper clock using these independent clock measurements. The paper clock, which is superior to any of the component clocks in accuracy and stability, is used to generate the output time scale frequency.



Clock Ensemble and Construction of Paper Clock

Generating the time scale frequency reference is critical and poses a significant challenge since the only measurements available are the relative differences between independent clocks. Based on these measurements, our KAS-2 time scale algorithm offers unique and powerful advantages over other time scale algorithms in its use of two constraints (weights) per clock. One of these constraints is for phase and the other is for frequency. The use of constraint equations offers two key benefits:

- The phase and frequency noise, which are independent of each other, are properly apportioned between clocks based on the single set of time-difference measurements
- The short- and long-term stabilities of the time scale are optimized simultaneously

In addition to the use of constraints, the KAS-2 time scale algorithm also uses robust statistics to reject outlier events such as bad measurements or phase time steps. As a result, the KAS-2 time scale intelligently takes advantage of clock performance to achieve the best performance over short observation windows while simultaneously delivering excellent long-term stability.

Truth Source Steering and System Outputs

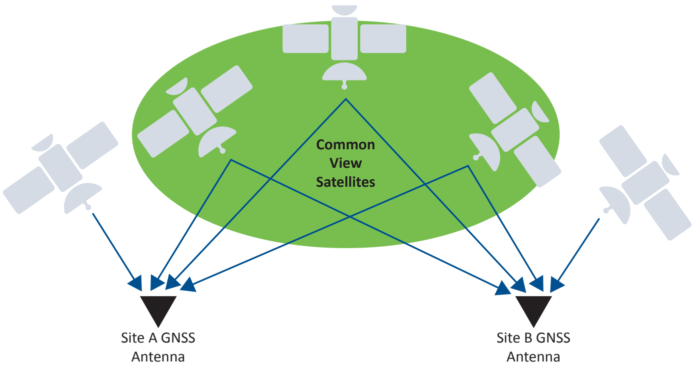
Steering of the time scale outputs is done in two steps. First, the user can select a truth source, which represents the source of time that the system is being aligned with. The truth source may be GNSS, a manually entered time/phase adjustment or UTC as provided by the BIPM (which is most often the case). The difference between UTC as computed by the BIPM and the time scale is described with the equation: [UTC – UTC(k)] where the letter “k” represents the contributing laboratory.

Values of [UTC – UTC(k)] are included in a monthly *Circular T* report provided by the BIPM. This report contains values of the differences [UTC – UTC(k)] every five days. Additionally, the BIPM also provides a *UTCr* report that contains values of the differences daily. Both *Circular T* and *UTCr* measurements can be entered into the SyncSystem 4380A Time Scale Edition. More details about *Circular T* and *UTCr* can be found at: http://bipm.org/time-metrology.

Using the selected truth source, the steering algorithm then drives a low-noise Direct Digital Synthesizer (DDS). The DDS is set to the correct phase and frequency (per the steering algorithm), and is used to drive the outputs, which prevents any discontinuities in the output signals.

Contributing to UTC Using GNSS Common View

GNSS common view is the most frequently used method of communicating clock measurements to the BIPM. It is used to achieve high-accuracy time transfer, which is extremely useful for synchronizing two or more geographically dispersed sites.



GNSS Common View Time Measurement

In GNSS common view (as an example, using GPS), two users with known positions simultaneously observe the same satellites and calculate their respective time offsets from the satellite clocks. The two simultaneous measurements are used in turn to compute the difference between the two users' clocks. Many of the GPS error sources cancel completely, including satellite clock error and radial ephemeris error. Others, such as ionospheric delay, are site dependent and must be accounted for as part of the common view calculation.

The SyncSystem 4380A Time Scale Edition's built-in GNSS receiver supports GNSS common view. The receiver measures all satellites in view and computes an estimate of the [UTC – UTC(k)] offset each second. Common view reports are available directly from the system per the format as defined by the GNSS time transfer working group.

Since the time scale system's member clocks (i.e., the frequency standards) are not steered, they can qualify as members of the international time scale, UTC. The SyncSystem 4380A Time Scale Edition also accumulates measurements of the individual clocks and provides these measurements as clock reports, which can be made available to the BIPM.

Additional Information

The SyncSystem 4380A Time Scale Edition is a part of our larger product family of time scale and site timing system products. Please refer to the following for more information:

Precise Time Scale System—This fully integrated timing system can provide timing accuracies comparable to the world's best national laboratories.

Time Scale Orchestrator Software—This software provides a web interface for clock configuration, clock management, viewing of time scale performance and BIPM report storage (including common view reports, clock reports, and TAIPPP reports).

SyncSystem 4380A With Multi-Channel Measurement—The SyncSystem 4380A, equipped with 4382A and 4393A cards, can be connected to the MeasDB software to provide a powerful and versatile database measurement platform.

SyncSystem 4380A Input/Output Modules—These Input/Output (I/O) modules can be installed easily to accommodate the end user's needs. The modules described in this document can be used in any combination, are hot-swappable and can be configured on the fly.

6300 Modular Distribution System—The 6300 system is a hot-swappable, modular distribution chassis that supports high-performance RF, 1 PPS and IRIG distribution. Designed for metrology applications, the 6300 Modular Distribution System delivers high-performance signal distribution without degradation.

TimeMonitor Software Suite—Performance metrics such as ADEV, TDEV, MTIE and many other calculations can be executed with a single push of a button and compared to a wide variety of industry performance masks.

Specifications

Number of Clocks

Up to eight clocks can be included in the time scale ensemble
Recommended clock types:

- Microchip 5071A Frequency Standard
- Microchip 5071A High Performance Frequency Standard
- Microchip MHM 2020 Active Hydrogen Maser

Accuracy

Typically, less than 10 ns (RMS) relative to truth source reference

- Truth source reference can be BIPM/UTC, GNSS or user-defined reference

Measurement Performance

4382A Phase Measurement Module

Performance

- Allan Deviation (using one 10 MHz port as reference)
  - 1 sec 2E-13
  - 10 sec 2E-14
  - 100 sec 2E-15
  - 1000 sec 4E-16
- Resolution: Less than 100 femtoseconds

4393A Time Interval Counter Module

Performance

- Accuracy: < ±500 ps to internal 1 PPS
- Resolution: < ±50 ps

Hot-Swappable Modules (Refer to Module's Data Sheet for More Details)

- Pulse Outputs
  - 4394A: PPS/DC IRIG output module
  - 4334A: Epoch pulse output module
  - 4391A: Code output module
  - 4331A: RS-422 Differential Code output module
  - 4376A: 4-port RS422 1 PPS output (DB-15)
  - 4335A: Pulse (DC-IRIG) output module
  - 4344A: Pulse (1PPS) output module
- Frequency
  - 4395B-1: 1 MHz output module
  - 4395B-5: 5 MHz output module
  - 4395B-10: 10 MHz output module
- AM IRIG
  - 4387A: AM IRIG module
  - 4337A: AM IRIG epoch module
  - 4338A: 4-epoch AM IRIG module
- Telecom
  - 4374A: 4-port T1/E1 module (RJ-45)
  - 4332A: 4-port TOD module (RJ-45)
- Input and Measurement
  - 4393A: 4-channel TIC measurement module
  - 4382A: 4-channel phase measurement module
  - 4383A: 4-port IRIG input module
- Optional Accessories
  - 90000-L1L2: Inline GNSS signal amplifier, L1/L2
  - 92003: GNSS antenna
  - 94000-115200: RS-232 console interface (115,200 bps) included
  - 94001-5071A: 5071A serial converter (9600 bps)

Standard Input/Output Signals

- GNSS input
  - Connector: TNC(F)
  - Antenna voltage: 0, 5 VDC or 12 VDC (selectable)
- Serial
  - Connector: DB9(M) (USB- to-serial adapter provided)
  - Format: RS-232
  - Baud: 115,200 (others available upon request)
- Network interface
  - Connector: RJ-45
  - Interface: 10/100/1000BASE-T
- Power supplies
- Hot swappable
- 4365A—AC power supply module
  - Connector: IEC 60320 C-14 inlet
  - Voltage: 100 VAC–240 VAC, 45 Hz–65 Hz
- 4366A—DC power supply module (optional, requires DC option in chassis)
  - Connector: 3-pin (mating connector: AMP #1-350346-0)
  - Voltage: 22 VDC–60 VDC

BIPM Reports

- GNSS common view reports
- Clock reports
- TAIPPP reports

Mechanical/Environmental

- Size: 1.75" (H) × 19.00" (W) × 19.00" (D)
- Weight: 20 lbs (9.1 kg)
- Operating temperature: 0˚C to 50˚C
- Humidity: 0% to 95% non-condensing
- Power: 55 Watts

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