

Hewlett-Packard offers frequency standards and clocks that provide accurate frequency, time-interval, and timekeeping capabilities. HP standards provide means for comparing these quantities against national standards such as those of the U.S. National Institute of Standards and Technology (NIST) and the U.S. Naval Observatory (USNO).

A range of HP source products and systems components can be integrated into high-quality frequency and time applications. A choice of standards technologies can match desired accuracy and capabilities to varying tasks.

Frequency sources and systems manufactured by HP are used for control and calibration at observatories, national centers for measurement standards, physical research laboratories, missile and satellite tracking stations, communications systems, radio navigation systems, manufacturing plants, radio-monitoring and transmitting stations, and telecommunications.

Types of Frequency Standards

Hewlett-Packard currently offers frequency-standard products based on two types of technology. These are:

- The cesium atomic-beam-controlled oscillator
- The quartz crystal oscillator

Of these standards, the first is a primary frequency standard and the latter is a secondary frequency standard. A primary standard does not require any other reference for calibration; a secondary standard requires calibrations both during manufacturing and at intervals during use, depending on the accuracy desired.

Cesium-Beam Frequency Standard

Cesium-beam standards are in use whenever the goal is a very high accuracy primary frequency standard. In fact, the NIST frequency standard itself is of the cesium-beam type. The cesium-beam standard is an atomic resonance device that provides access to one of nature's invariant frequencies.

Quartz-Crystal Oscillators

Quartz oscillators are used in virtually every frequency-control application, including atomic standards. The excellent short-term stability and spectral purity of the quartz oscillators used in HP atomic standards contribute to the high quality of the output signal of these standards. For less demanding applications where some long-term drift can be tolerated, quartz oscillators are used as independent frequency sources.

Frequency Standards and Clocks

Frequency standards and clocks have no fundamental differences—they are based upon dual aspects of the same phenomenon. The basic unit of time, the second, is defined as the duration of 9,192,631,770 periods of transition within the cesium atom. Frequency is determined by counting the number of cycles over the period of a second.

Time Scale and Standards

The time interval of the atomic time scale is the International Second, defined in October 1967 by the Thirteenth General Conference of Weights and Measures. Since January 1972, the frequency offset between universal time coordinated (UTC) and atomic time has been zero and the UTC time scale is kept in synchronism with the rotation of the earth to within ± 0.9 s by step-time adjustments of exactly 1 s, when needed (see HP Application Note 52-2).

The NIST provides the official basis for standard time for the United States. The UTC signal is broadcast from the NIST stations WWV and WWVB and by several other stations throughout the world. (See "HP Applications Note 52-1, Fundamentals of Time and Frequency Standards," for a list of stations broadcasting time signals.)

The master clock at the USNO, one of the world's most accurate clocks, is made of an ensemble of more than a dozen HP cesium-beam frequency standards. HP portable cesium standards, "flying clocks," are used periodically to check the synchronization between these stations and the master clock.

Hewlett-Packard House Standard

The Hewlett-Packard House Standard at the Santa Clara Division consists of an ensemble of five high-performance HP cesium-beam standards.

Time is maintained relative to the USNO and NIST master clocks to an accuracy of better than $\pm 1.0 \mu\text{s}$. This accuracy is verified using Loran C and GPS time-transfer techniques between HP Santa Clara Division, HP Geneva Calibration Lab, and the U.S. Naval Observatory. Both HP locations have been designated USNO time reference stations.

System Components

HP standby power supplies ensure continued operation despite line interruptions, and operate over a range of ac line voltage to supply regulated dc to operate frequency standards and frequency dividers and clocks. The batteries in the supplies assume the full load immediately when ac power fails.

High isolation and versatile configurations of the HP distribution amplifiers allow the outputs of high-quality frequency standards to be delivered to multiple channels. Modular construction tailors this component for a variety of system requirements.

Comparison of Frequency Standards

Standard	Principal construction feature	Principal advantages
Oscillator controlled with cesium atomic-beam resonator	Beam of free cesium atoms, spatially state-selected, is subjected to a microwave signal at resonance frequency.	<ul style="list-style-type: none"> • High intrinsic reproducibility and long-term stability • Primary standard for definition of time interval
Quartz crystal oscillator	Piezoelectrically active quartz crystal with electronic stabilization	<ul style="list-style-type: none"> • Very compact, light • Rugged • Inexpensive • Low phase noise