

Glossary of Time & Frequency Terms

Accuracy

The degree of conformity of a measured or calculated value to its definition or with respect to a standard reference (see uncertainty).

Aging

The systematic change in frequency over time because of internal changes in the oscillator. For example, a 100 kHz quartz oscillator may age until its frequency becomes 100.01 kHz (see drift). Aging is the frequency change with time when factors external to the oscillator such as environment and power supply are kept constant.

Allan Variance or Allan Deviation

The standard method of characterizing the frequency stability of oscillators in the time domain, both short and long term.

Ambiguity

The properties of something that allows it to have more than one possible meaning. In the case of a clock, if it displays 3 hours and 5 minutes, it could be morning or night. The clock is then said to be ambiguous to the hour.

Atomic Time Scale (TA)

A time scale based on atomic or molecular resonance phenomena. Elapsed time is measured by counting cycles of a frequency locked to an atomic or molecular transition. Earlier time scales were based on the rotational rate of the earth.

Calibration

The process of identifying and measuring time or frequency errors, offsets, or deviations of a clock/oscillator relative to an established standard, such as UTC(NIST).

Clock

A device for maintaining and displaying time.

Coordinated Universal Time (UTC)

A coordinated time scale, maintained by the Bureau International des Poids et Mesures (BIPM), which forms the basis of a coordinated dissemination of standard frequencies and time signals. A UTC clock has the same rate as a Temps Atomique International (TAI) clock or international atomic time clock but differs by an integral number of seconds called leap seconds. The UTC scale is adjusted by the insertion or deletion of leap seconds to ensure approximate agreement with UT1.

Date

A unique instant defined in a specified time scale. NOTE: The date can be conventionally expressed in years, months, days, hours, minutes, seconds, and fractions. Also, Julian Date (JD) and Modified Julian Date (MJD) are useful dating measures (see Julian Date and Modified Julian Date).

Disciplined Oscillator (DO)

An oscillator with a servo loop that has its phase and frequency locked to an external reference signal.

Drift (frequency)

The linear (first-order) component of a systematic change in frequency of an oscillator over time. Drift is due to aging plus changes in the environment and other factors external to the oscillator (see aging).

DUT1

The approximate time difference between UT1 and UTC, expressed to the nearest 0.1 s. $DUT1 = UT1 + \text{or} - UTC$. DUT1 may be regarded as a correction to be added to UTC to obtain a better approximation to UT1. The values of DUT1 are given by the International Earth Rotation Service (IERS) in integral multiples of 0.1 s.

Ephemeris Time (ET)

An astronomical time scale based on the orbital motion of the earth around the sun (see Terrestrial Time).

Epoch

The beginning of an era (or event) or the reference date for a system of measurements.

Frequency

The rate at which a periodic phenomenon occurs over time.

Frequency drift

See drift and aging.

Frequency offset

The frequency difference between the measured value and the defined value.

Frequency shift

Change in frequency from a standard reference.

Frequency stability

Statistical estimate of the frequency fluctuations of a signal over a given time interval.

- *Long term stability* usually involves measurement averages beyond 100s.
- *Short term stability* usually involves measurement averages from a few tenths of a second to 100s.

Generally, there is a distinction between systematic effects such as frequency drift and stochastic frequency fluctuations. Special variances have been developed for the characterization of these fluctuations. Systematic instabilities may be caused by radiation, pressure, temperature, and humidity. Random or stochastic instabilities are typically characterized in the time domain or frequency domain. They are typically dependent on the measurement system bandwidth or on the sample time or integration time.

Frequency standard

An oscillator such as a rubidium, cesium, or hydrogen maser whose output is used as a frequency.

Global Positioning System (GPS)

A highly accurate, global satellite navigation system based on a constellation of at 24 satellites orbiting the earth at a very high altitude. In addition to navigation, the system also provides very precise time.

- **GPS signals** {broadcast signals of GPS and their functions are as follows}:
 - L1 - 1575.42 MHz
 - - primary navigation signal
 - - C/A and P codes and navigation data
 - L2 - 1227.6 MHz
 - - second frequency provides higher accuracy ionospheric delay calibration
 - - P code and navigation data
 - L3 - 1381.05 MHz
 - - global burst detector
 - - SBand command channel
- **GPS C/A code:** The standard GPS code known as the coarse/acquisition code or "civilian code." The code is a series of 1023 pseudorandom binary byphase modulations on the carrier and has a chip rate (bit transition time) of 1.023 MHz (often called "Standard Positioning Service").
- **GPS Pcode:** This is called the precise code or "protected code" and is a series of pseudorandom, binary byphase modulations on the carrier and has a chip rate of 10.23 MHz. The P code repeats about every 267 days. Each 1 week segment of the code is unique to a particular GPS satellite and is reset each week.

Greenwich Mean Time (GMT)

A 24 Hour system based on mean solar time plus 12 hours at Greenwich, England. Greenwich Mean Time can be considered approximately equivalent to Coordinated Universal Time (UTC), which is broadcast from all standard time and frequency radio stations. However, GMT is now obsolete and has been replaced by UTC.

International Atomic Time (TAI)

An atomic time scale based on data from a worldwide set of atomic clocks. It is the internationally agreed upon time reference conforming to the definition of the second, the fundamental unit of atomic time in the International System of Units (SI). It is defined as the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium - 133 atom. The TAI is maintained by the Bureau International des Poids et Mesures (BIPM) in France. Although TAI was officially introduced in January 1972, it has been available since July 1955. Its epoch was set so that TAI was in approximate agreement with UT1 on 1 January 1958 (see second).

Julian Day

Obtained by counting days from the starting point of noon on 1 January 4713 B.C. (Julian Day zero). One way of telling what day it is with the least possible ambiguity.

- **Julian Date (JD):** The Julian Day number followed by the fraction of the day elapsed since the preceding noon (1200 UT). {*Example:* The date 1900 January (1) 0.5 day UT corresponds to JD = 2 415 020}.
- **Julian Day Number (JDN):** The number of a specific day from a continuous day count having an initial origin of 1200 UT on 1 January 4713 BC, the start of Julian day zero. {*Example:* The day extending from 1900 January (1) 0.5 day UT to 1900 January 1.5 days UT has the number 2 415 020}.
- **Modified Julian Day (MJD):** Equal to the Julian day. Shifted so its origin occurs at midnight on 17 November 1858. The MJD differs from the Julian date by exactly 2 400 000.5 days.

Leap second

An intentional time step of one second used to adjust UTC to ensure approximate agreement with UT1. An inserted second is called a positive leap second, and an omitted second is called a negative leap second. A positive leap second is presently needed slightly more often than once per year.

Nominal value

The defined value of a quantity, or an ideal value whose uncertainty is 0. Frequency offset can be estimated by using the measured frequency (f1) minus the nominal frequency (f2) over the nominal frequency.

On Time Marker (OTM)

The part of a time code that is synchronized to the UTC second.

Phase

A measure of a fraction of the period of a repetitive phenomenon, measured with respect to some distinguishable feature of the phenomenon itself. In the standard frequency and time signal service, phase time differences such as time differences between two identified phases of the same phenomenon or of two different phenomena are mainly considered.

- **Phase jump:** A sudden phase change in a signal.
- **Phase shift:** An intentional change in phase from a reference.
- **Phase deviation:** The difference of the phase from a reference.
- **Phase signature:** A deliberate phase offset for the purpose of signal identification. For example, NIST's radio station WWVB broadcast is deliberately phase shifted at 10 minutes after the hour, so a person knows that WWVB is being tracked and not some other signal.

Precision

The degree of mutual agreement among a series of individual measurements. Precision is often, but not necessarily, expressed by the standard deviation of the measurements.

Reproducibility

With respect to a set of independent devices of the same design, it is the ability of these devices to produce the same value. With respect to a single device, it is the ability to produce the same value and to put it into operation repeatedly without adjustments.

Resolution

The degree to which a measurement can be determined is called the resolution of the measurement.

The smallest significant difference that can be measured with a given instrument. For example, a measurement made with a time interval counter might have a resolution of 10 ns.

Second

The basic unit of time or time interval in the International System of Units (SI) which is equal to 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of cesium-133.

Sidereal time

The measure of time defined by the apparent diurnal motion of the vernal equinox; hence, a measure of the rotation of the Earth with respect to the reference frame that is related to the stars rather than the sun. Two types of sidereal time are used in astronomy: mean sidereal time and apparent sidereal time. One sidereal day is equal to about 23 hours, 56 minutes, and 4.090 seconds of mean solar time. Also, 366.2422 mean sidereal days equal 365.2422 mean solar days.

Synchronization

The process of measuring the difference in time of two time scales such as the output signals generated by two clocks. In the context of timing, synchronization means to bring two clocks or data streams into phase so that their difference is 0 (see time scales in synchronism).

Syntonzation

Relative adjustment of two frequency sources with the purpose of canceling their frequency difference but not necessarily their phase difference.

Stratum clocks

Accuracy requirements placed on clocks in four strata. Accuracy of stratum clocks refers to clock performance when the clock receives no input reference.

Terrestrial Time (TT)

The new 1991 International Astronomical Union replacement for what was once called Ephemeris Time. On 1 January 1997, $TT = TAI + 32.184$ seconds, and the length of the second is chosen so that it agrees with the International Second (SI) on the geoid. The TT scale differs from the old Ephemeris Time in its conceptual definition. Practically, however, it is realized by means of International Atomic Time (TAI).

Time code

A system of symbols (digital or analog) used for identifying specific instants of time. An information format used to convey time information.

Time interval

The duration between two instants read on the same time scale.

Time scale

A system of unambiguous ordering of events. A time scale is meant to be stable and homogeneous.

Time standard

A continuously operated device used for the realization of a time scale in accordance with the definition of the second and with an appropriately chosen origin.

Time step

A discontinuity in a time scale at some instant. A step is positive (+) if the time scale reading is increased and negative (-) if the reading is decreased at that instant.

Uncertainty

The limits of the confidence interval of a measured or calculated quantity. NOTE: The probability of the confidence limits should be specified, preferably as two standard deviations.

Universal Time (UT) Family

Universal Time (UT) is the general designation of time scales based on the rotation of the Earth. In applications in which a precision of a few tenths of a second cannot be tolerated, it is necessary to specify the form of UT such as UT1 which is directly related to polar motion and is proportional to the rotation of the Earth in space. The UT1 is further corrected empirically for annual and semiannual variations in the rotation rate of the earth to obtain UT2.

- Universal Time is the mean solar time of the prime meridian plus 12 hours, determined by measuring the angular position of the Earth about its axis. The UT is sometimes designated GMT, but this designation should be avoided.
- Mean Solar Time is simply apparent solar time corrected for the effects of orbital eccentricity and the tilt of the Earth's axis relative to the ecliptic plane; that is, corrected by the equation of time which is defined as the hour angle of the true Sun minus the hour angle of the mean Sun.