UTC to GPS Time Correction

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Note on GNSS time scales and conversions

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TAI (International Atomic Time)

International Atomic Time (TAI, from the French name Temps atomique international) is a high-precision atomic coordinate time standard based on the notional passage of proper time on Earth's geoid. It is the basis for Coordinated Universal Time (UTC), which is used for civil timekeeping all over the Earth's surface, and for Terrestrial Time, which is used for astronomical calculations. Since 30 June 2015 when the last leap second was added, TAI has been exactly 36 seconds ahead of UTC. The 36 seconds results from the initial difference of 10 seconds at the start of 1972, plus 26 leap seconds in UTC since 1972.

Time coordinates on the TAI scales are conventionally specified using traditional means of specifying days, carried over from non-uniform time standards based on the rotation of the Earth. Specifically, both Julian Dates and the Gregorian calendar are used. TAI in this form was synchronised with Universal Time at the beginning of 1958, and the two have drifted apart ever since, due to the changing motion of the Earth.

TAI as a time scale is a weighted average of the time kept by over 200 atomic clocks in over 50 national laboratories worldwide. The clocks are compared using GPS signals and two-way satellite time and frequency transfer. Due to the averaging it is far more stable than any clock would be alone (see signal averaging for a discussion). The majority of the clocks are caesium clocks; the definition of the SI second is written in terms of caesium.

Wikipedia - International Atomic Time

U.S. Naval Observatory - Systems of Time

UTC (Coordinated Universal Time)

Coordinated Universal Time (UTC) is the primary time standard by which the world regulates clocks and time. It is one of several closely related successors to Greenwich Mean Time (GMT). For most purposes, UTC is synonymous with GMT, but GMT is no longer precisely defined by the scientific community.

The UTC was officially formalized in 1963 by the International Radio Consultative Committee in Recommendation 374, having been initiated by several national time laboratories. The system was adjusted several times until leap seconds were adopted in 1972 to simplify future adjustments. A number of proposals have been made to replace UTC with a new system which would eliminate leap seconds but no consensus has yet been reached.

The current version of UTC is defined by International Telecommunications Union Recommendation (ITU-R TF.460-6), Standard-frequency and time-signal emissions. and is based on International Atomic Time (TAI) with leap seconds added at irregular intervals to compensate for the slowing of Earth's rotation. Leap seconds keep UTC within 0.9 seconds of UT1. In the 44 years up to and including 2015, a total of 26 leap seconds have been added; the most recent was added on 30 June 2015.

If high precision is not required, the general term Universal Time (UT) may be used. The term Greenwich Mean Time (GMT) does not have a precise definition at the sub-second level, but it is often considered equivalent to UTC or UT1. Saying "GMT" often implies either UTC or UT1 when used within informal or casual contexts. In technical contexts, usage of "GMT" is avoided; the unambiguous terminology "UTC" or "UT1" is preferred.

Wikipedia - Coordinated Universal Time

Leap Second and Announcement

A leap second is a one-second adjustment that is occasionally applied to Coordinated Universal Time (UTC) in order to keep its time of day close to the mean solar time. The most recent leap second was inserted on June 30, 2015 at 23:59:60 UTC.

The UTC time standard, which is widely used for international timekeeping and as the reference for civil time in most countries, uses the international system (SI) definition of the second, based on atomic clocks. Like most time standards, UTC defines a grouping of seconds into minutes, hours, days, months, and years. However, the duration of one mean solar day is slightly longer than 24 hours (86400 SI seconds). Therefore, if the UTC day were defined as precisely 86400 SI seconds, the UTC time-of-day would slowly drift apart from that of solar-based standards, such as Greenwich Mean Time (GMT) and its successor UT1. The purpose of a leap second is to compensate for this drift, by occasionally scheduling some UTC days with 86401 or 86399 SI seconds.

Specifically, a positive leap second is inserted between second 23:59:59 of a chosen UTC calendar date (the last day of a month, usually June 30 or December 31) and second 00:00:00 of the following date. This extra second is displayed on UTC clocks as 23:59:60. On clocks that display local time tied to UTC, the leap second may be inserted at the end of some other hour (or half-hour), depending on the local time zone.

A negative leap second would suppress second 23:59:59 of the last day of a chosen month, so that second 23:59:58 of that date would be followed immediately by second 00:00:00 of the following date. However, since the UTC standard was established, negative leap seconds have never been needed.

Because the Earth's rotation speed varies in response to climatic and geological events, UTC leap seconds are irregularly spaced and unpredictable. Insertion of each UTC leap second is usually decided about six months in advance by the International Earth Rotation and Reference Systems Service (IERS), when needed to ensure that the difference between the UTC and UT1 readings will never exceed 0.9 second. Between their adoption in 1972 and June 2015, 26 leap seconds have been scheduled, all positive.

Wikipedia - Leap second

U.S. Naval Observatory - Leap Seconds

The Future of Leap Seconds

Triggered by a questionnaire about Coordinated Universal Time (UTC) distributed by the IERS in 1999, scientists around the world began discussing the use of leap seconds. The argument revolves around the question: 'Should we adjust our clocks to the Earth's slowing rotation, or should atomic clocks be solely responsible for measuring time?'

The scientific community has so far failed to reach an agreement on this topic. The ITU World Radiocommunication Conference (WRC-15), in session in Geneva in November 2015, has decided that further studies are required on the impact and application of a future reference time-scale, including the modification of UTC and suppressing the so-called 'leap second'. A report will be considered by the World Radiocommunication Conference in 2023. Until then, UTC shall continue to be applied as described in Recommendation ITU -R TF.460 -6 and as maintained by the International Bureau of Weights and Measures (BIPM).

ITU WRC-15 - Press Release

Time and Date - The Future of Leap Seconds

GPS (Global Positioning System) Time

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver.

The GPS project was developed in 1973 to overcome the limitations of previous navigation systems, integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. GPS was created and realized by the U.S. Department of Defense (DoD) and was originally run with 24 satellites. It became fully operational in 1994. Bradford Parkinson, Roger L. Easton, and Ivan A. Getting are credited for inventing it.

Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS III satellites and Next Generation Operational Control System (OCX). Announcements from the Vice President and the White House in 1998 initiated these changes. In 2000, U.S. Congress authorized the modernization effort, GPS III.

In addition to GPS, other systems are in use or under development. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s. There are also the planned European Union Galileo positioning system, Chinese Compass navigation system, and Indian Regional Navigational Satellite System.

While most clocks derive their time from Coordinated Universal Time (UTC), the atomic clocks on the satellites are set to GPS time (GPST; see the page of United States Naval Observatory). The difference is that GPS time is not corrected to match the rotation of the Earth, so it does not contain leap seconds or other corrections that are periodically added to UTC. GPS time was set to match UTC in 1980, but has since diverged. The lack of corrections means that GPS time remains at a constant offset with International Atomic Time (TAI) (TAI – GPS = 19 seconds). Periodic corrections are performed to the on-board clocks to keep them synchronized with ground clocks.

The GPS navigation message includes the difference between GPS time and UTC. As of July 2015, GPS time is 17 seconds ahead of UTC because of the leap second added to UTC June 30, 2015. Receivers subtract this offset from GPS time to calculate UTC and specific timezone values. New GPS units may not show the correct UTC time until after receiving the UTC offset message. The GPS-UTC offset field can accommodate 255 leap seconds (eight bits).

GPS time is theoretically accurate to about 14 nanoseconds. However, most receivers lose accuracy in the interpretation of the signals and are only accurate to 100 nanoseconds.

As opposed to the year, month, and day format of the Gregorian calendar, the GPS date is expressed as a week number and a seconds-into-week number. The week number is transmitted as a ten-bit field in the C/A and P(Y) navigation messages, and so it becomes zero again every 1,024 weeks (19.6 years). GPS week zero started at 00:00:00 UTC (00:00:19 TAI) on January 6, 1980, and the week number became zero again for the first time at 23:59:47 UTC on August 21, 1999 (00:00:19 TAI on August 22, 1999). To determine the current Gregorian date, a GPS receiver must be provided with the approximate date (to within 3,584 days) to correctly translate the GPS date signal. To address this concern the modernized GPS navigation message uses a 13-bit field that only repeats every 8,192 weeks (157 years), thus lasting until the year 2137 (157 years after GPS week zero).

Wikipedia - GPS time

UTC to GPS Time Conversion Table

Limits of validity (at 0h UTC)	TAI - UTC (s)	GPS - UTC (s)
1972-01-01 - 1972-07-01	10	
1972-07-01 - 1973-01-01	11	
1973-01-01 - 1974-01-01	12	
1974-01-01 - 1975-01-01	13	
1975-01-01 - 1976-01-01	14	
1976-01-01 - 1977-01-01	15	
1977-01-01 - 1978-01-01	16	
1978-01-01 - 1979-01-01	17	
1979-01-01 - 1980-01-01	18	
1980-01-01 - 1981-07-01	19	0
1981-07-01 - 1982-07-01	20	1

Limits of validity (at 0h UTC)	TAI - UTC (s)	GPS - UTC (s)
1982-07-01 - 1983-07-01	21	2
1983-07-01 - 1985-07-01	22	3
1985-07-01 - 1988-01-01	23	4
1988-01-01 - 1990-01-01	24	5
1990-01-01 - 1991-01-01	25	6
1991-01-01 - 1992-07-01	26	7
1992-07-01 - 1993-07-01	27	8
1993-07-01 - 1994-07-01	28	9
1994-07-01 - 1996-01-01	29	10
1996-01-01 - 1997-07-01	30	11
1997-07-01 - 1999-01-01	31	12
1999-01-01 - 2006-01-01	32	13
2006-01-01 - 2009-01-01	33	14
2009-01-01 - 2012-07-01	34	15
2012-07-01 - 2015-07-01	35	16
2015-07-01 - ????-??-??	36	17

Latest IERS Bulletin C

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                              UTC TIME STEP
                        on the 1st of July 2015

A positive leap second will be introduced at the end of June 2015.
The sequence of dates of the UTC second markers will be:

                         2015 June 30,     23h 59m 59s
                         2015 June 30,     23h 59m 60s
                         2015 July  1,      0h  0m  0s

The difference between UTC and the International Atomic Time TAI is:

 from 2012 July 1,    0h UTC, to 2015 July 1  0h UTC  : UTC-TAI = - 35s
 from 2015 July 1,    0h UTC, until further notice    : UTC-TAI = - 36s
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Observatoire de Paris - Latest Bulletin C

IERS > Publications > IERS Bulletins

References

File	Modified
IERS_Leap_Seconds.pdf Brian Luzum, The Role of the IERS in the Leap Second, ITU News Magazine, 2013	2013-07-12 by Jos Verheijen [QPS]
UTC_to_retain_leap_second.pdf Coordinated Universal Time (UTC) to retain "leap second", ITU Press Release, 2015	2015-11-19 by Jos Verheijen [QPS]

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