Leap second

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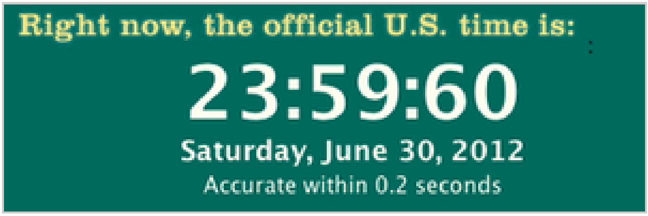
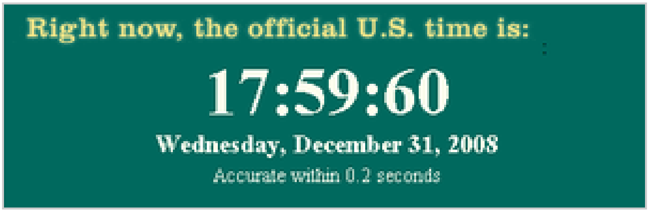
A **leap second** is a one-second adjustment that is occasionally applied to Coordinated Universal Time (UTC) in order to keep its time of day close to the mean solar time. The most recent leap second was inserted on June 30, 2012 at 23:59:60 UTC.[1]



Screencapture of the UTC clock from time.gov (http://time.gov) during the UTC leap second, on June 30, 2012, 23:59:60.

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.



Screencapture of the UTC-derived Central Standard Time clock from time.gov (http://time.gov) during the UTC leap second December 31, 2008, 23:59:60.

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 2012, 25 leap seconds have been scheduled, all positive.

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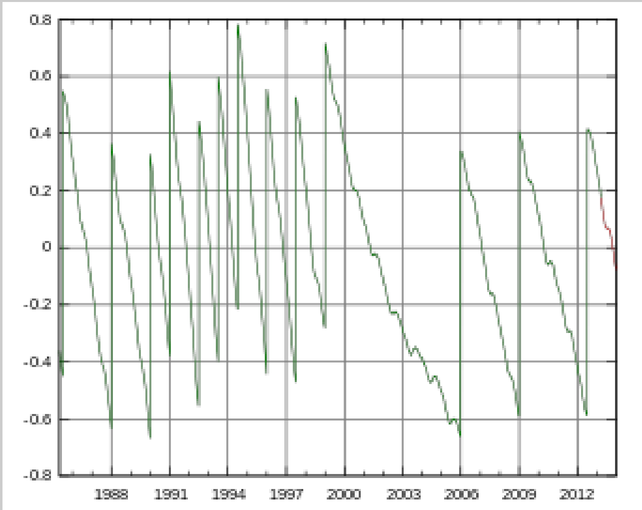


Graph showing the difference between UT1 and UTC. Vertical segments correspond to leap seconds.

About 140 AD Ptolemy sexagesimally subdivided both the mean solar day and the true solar day to at least six places after the sexagesimal point, and he used simple fractions of both the equinoctial hour and the seasonal hour, none of which resemble the modern second.[2] Muslim scholars, including al-Biruni in 1000, subdivided the mean solar day into 24 equinoctial hours, each of which was subdivided sexagesimally, that is into the units of minute, second, third, fourth and fifth, creating the modern second as $^1⁄_{60}$ of $^1⁄_{60}$ of $^1⁄_{24}$ = $^1⁄_{86400}$ of the mean solar day in the process.[3] With this definition, the second was proposed in 1874 as the base unit of time in the CGS system of units.[4] Soon afterwards Simon Newcomb and others discovered that Earth's rotation period varied irregularly,[5] so in 1952 the International Astronomical Union (IAU) defined the second as a fraction of the sidereal year. Because the tropical year was considered more fundamental than the sidereal year, in 1955 the IAU redefined the second as the fraction $^1⁄_{31,556,925.9747}$ of the 1900.0 mean tropical year, which was adopted in 1956 by the International Committee for Weights and Measures and in 1960 by the General Conference on Weights and Measures, becoming a part of the International System of Units (SI).[6]

Eventually this definition too was found to be inadequate for precise time measurements, so in 1967 the SI second was again redefined as 9,192,631,770 periods of the radiation emitted by a caesium-133 atom in the transition between the two hyperfine levels of its ground state.[7] That value agreed to 1 part in 10^{10} with the astronomical (ephemeris) second then in use.[8] It was also close to $^1⁄_{86400}$ of the mean solar day as averaged between 1750 and 1892.

However, for the past several centuries the length of the mean solar day has been increasing by about 1.7 ms per century, on the average.[9] By 1961 the mean solar day was already a millisecond or two longer than 86400 SI seconds.[10] Therefore, time standards that change the date after precisely 86400 SI seconds, such the International Atomic Time (TAI), will get increasingly ahead of time standards tied to the mean solar day, such as Greenwich Mean Time (GMT).

When the Coordinated Universal Time standard was instituted in 1961, based on atomic clocks, it was felt necessary to maintain agreement with the GMT time of day, which until then had been the reference for broadcast time services. Thus, from 1961 to 1971, the rate of (some) atomic clocks was constantly slowed to remain synchronised with GMT. During that period, therefore, the "seconds" of broadcast services were actually slightly longer than the SI second and closer to the GMT seconds.

In 1972 the leap-second system was introduced so that the broadcast UTC seconds could be made exactly equal to the standard SI second, while still maintaining the UTC time of day and changes of UTC date synchronized with those of UT1 (the solar time standard that superseded GMT).[7] By then the UTC clock was already 10 seconds behind TAI, which had been synchronized with UT1 in 1958 but had been counting true SI seconds since then. After 1972, both clocks have been ticking in SI seconds, so the difference between their readouts at any time is 10 seconds plus the total number of leap seconds that have been applied to UTC (35 seconds in July 2012).

Insertion of leap seconds

The scheduling of leap seconds was initially delegated to the Bureau International de l'Heure (BIH), but passed to the International Earth Rotation and Reference Systems Service (IERS) on January 1, 1988. IERS usually decides to apply a leap second whenever the difference between UTC and UT1 approaches 0.6 s, in order to keep the difference between UTC and UT1 from exceeding 0.9 s.

The UTC standard allows leap seconds to be applied at the end of any UTC month, but as of July 2012 all of them have been inserted either at the end of June 30 or December 31. IERS publishes announcements every six months, whether leap seconds are to occur or not, in its "Bulletin C" (ftp://hpiers.obspm.fr/iers/bul/bulc/bulletinc.dat). Such announcements are typically published well in advance of each possible leap second date — usually in early January for June 30 and in early July for December 31. [11][12] Some time signal broadcasts give voice announcements of an impending leap second.

Between 1972 and 2012 a leap second has been inserted about every 18 months, on the average. However, the spacing is quite irregular: there were no leap seconds in the seven-year interval between January 1, 1999 and December 31, 2005, but there were 9 leap seconds in the 8 years 1972–1979.

Unlike leap days, UTC leap seconds occur simultaneously worldwide; for example, the leap second on December 31, 2005 23:59:60 UTC was December 31, 2005 18:59:60 (6:59:60 p.m.) in U.S. Eastern Standard Time and January 1, 2006 08:59:60 (a.m.) in Japan Standard Time.

Announced leap seconds to date

Year	Jun 30	Dec 31
1972	+1	+1
1973	0	+1
1974	0	+1
1975	0	+1
1976	0	+1
1977	0	+1
1978	0	+1
1979	0	+1
1980	0	0
1981	+1	0
1982	+1	0
1983	+1	0
1984	0	0
1985	+1	0
1986	0	0
1987	0	+1
1988	0	0
1989	0	+1
1990	0	+1
1991	0	0
1992	+1	0

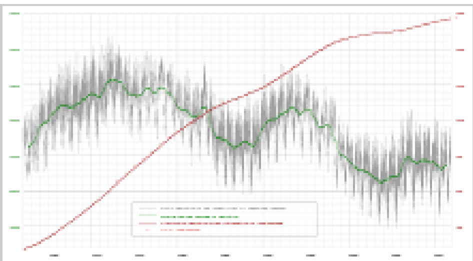
Slowing down of the Earth

Main article: ΔT

Leap seconds are irregularly spaced because the Earth's rotation speed changes irregularly. Indeed the Earth's rotation is quite unpredictable in the long term, which explains why leap seconds are announced only six months in advance.

1993	+1	0
1994	+1	0
1995	0	+1
1996	0	0
1997	+1	0
1998	0	+1
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	0	+1
2006	0	0
2007	0	0
2008	0	+1
2009	0	0
2010	0	0
2011	0	0
2012	+1	0
2013	0	
Year	**Jun 30**	**Dec 31**
Total	10	15
	25	
Current TAI − UTC		
35		

A mathematical model of the variations in the length of the solar day was developed by F. R. Stephenson and L. V. Morrison,[9] based on records of eclipses for the period 700 BC to 1623 AD, telescopic observations of occultations for the period 1623 until 1967 and atomic clocks thereafter. The model shows a steady increase of the mean solar day by 1.70 ms (± 0.05 ms) per century, plus a periodic shift of about 4 ms amplitude and period of about 1500 yr.[9] Over the last few centuries, the periodic component reduced the rate of lengthening of the mean solar day to about 1.4 ms per century.[13]



Deviation of day length from SI based day, 1962–2010

The main reason for the slowing down of the Earth's rotation is tidal friction, which alone would lengthen the day by 2.3 ms/century.[9] Other contributing factors are the movement of the Earth's crust relative to its core, changes in mantle convection, and any other events or processes that cause a significant redistribution of mass. These processes change the Earth's moment of inertia, affecting the rate of rotation due to conservation of angular momentum, sometimes increasing earth's rotational speed (decreasing the solar day and opposing tidal friction). For example, glacial rebound shortens the solar day by 0.6 ms/century and the 2004 Indian Ocean earthquake is thought to have shortened it by 2.68 microseconds.[14]

Proposal to abolish leap seconds

The irregularity and unpredictability of UTC leap seconds is problematic for several areas, especially computing. For example, to compute the elapsed time in seconds between two given UTC past dates requires consulting a table of leap seconds, which needs to be updated whenever a new leap second is announced. Moreover, it is not possible to compute accurate time intervals for UTC dates that are more than about six months in the future.

On July 5, 2005, the Head of the Earth Orientation Center of the IERS sent a notice to IERS Bulletins C and D subscribers, soliciting comments on a U.S. proposal before the ITU-R Study Group 7's WP7-A to eliminate leap seconds from the UTC broadcast standard before 2008. (The ITU-R is responsible for the definition of UTC.) *The Wall Street Journal* noted that the proposal was considered by a U.S. official to be a "private matter internal to the ITU", as of July 2005.[15] It was expected to be considered in November 2005, but the discussion has since been postponed.[16] Under the proposal, leap seconds would be technically replaced by leap hours as an attempt to satisfy the legal requirements of several ITU-R member nations that civil time be astronomically tied to the Sun.

A number of objections to the proposal have been raised. Dr. P. Kenneth Seidelmann, editor of the Explanatory Supplement to the Astronomical Almanac, wrote a letter[17] lamenting the lack of consistent public information about the proposal and adequate justification. Steve Allen of the University of

California, Santa Cruz cited the large impact on astronomers in a *Science News* article.[18] He has an extensive online site[19] devoted to the issues and the history of leap seconds, including a set of references about the proposal and arguments against it.[20]

In 2011, Chunhao Han of the Beijing Global Information Center of Application and Exploration said China had not decided what its vote would be in January 2012, but most Chinese scholars consider it important to maintain a link between civil and astronomical time due to Chinese tradition. The 2012 vote was ultimately deferred.[21]

Arguments against the proposal include the unknown expense of such a major change and the fact that universal time will no longer correspond to mean solar time. It is also answered that two timescales that do not follow leap seconds are already available, International Atomic Time (TAI) and Global Positioning System (GPS) time. Computers, for example, could use these and convert to UTC or local civil time as necessary for output. Inexpensive GPS timing receivers are readily available and the satellite broadcasts include the necessary information to convert GPS time to UTC. It is also easy to convert GPS time to TAI as TAI is always exactly 19 seconds ahead of GPS time. Examples of systems based on GPS time include the CDMA digital cellular systems IS-95 and CDMA2000. In general, computer systems use UTC and synchronize their clocks using NTP (Network Time Protocol). Systems that cannot tolerate disruptions caused by leap seconds can base their time on TAI and use PTP (Precision Time Protocol).

At the 47th meeting (http://www.navcen.uscg.gov/pdf/cgsicMeetings/47/CGSIC_agenda_final.htm) of Civil Global Positioning System Service Interface Committee in Fort Worth, Texas in September 2007, it was announced that a mailed vote would go out on stopping leap seconds. The plan for the vote was:[22]

- April 2008: ITU Working Party 7A will submit to ITU Study Group 7 project recommendation on stopping leap seconds
- During 2008, Study Group 7 will conduct a vote through mail among member states
- October 2011: The ITU-R released its status paper, *Status of Coordinated Universal Time (UTC) study in ITU-R*, in preparation for the January 2012 meeting in Geneva; the paper reported that, to date, in response to the UN agency's 2010 & 2011 web based surveys requesting input on the topic, it had received 16 responses from the 192 Member States with "13 being in favor of change, 3 being contrary."[23]

- January 2012: The ITU makes a decision.

In January 2012, rather than decide yes or no per this plan, the ITU decided to postpone a decision on leap seconds to the World Radio Conference in 2015. France, Italy, Japan, Mexico and the US were reported to be in favor while Canada, China, Germany and the UK were reportedly against.[24] Others including Nigeria, Russia and Turkey called for more study. The BBC states the ITU decided further study of broader social implications was needed.[25]

Examples of problems caused by the leap second

A number of organizations reported computer problems following the June 30, 2012, leap second. Among the sites which reported problems were reddit (Apache Cassandra), Mozilla (Hadoop),[26] Qantas Airlines,[27] and various sites running Linux.[28]

Workarounds for leap second issues

Instead of inserting a leap second at the end of the day, Google servers implement a *leap smear*, extending seconds slightly over a time window prior to the leap second.[29]

It has been proposed that media clients using the Real-time Transport Protocol inhibit generation or use of NTP timestamps during the leap second and the second preceding it.[30]

See also

- Clock drift, phenomenon where a clock gains/loses time compared to another clock
- Leap year, a year containing one extra day
- Unix time, a common representation of time for computer systems
- Delta-T (ΔT), the time difference obtained by subtracting Universal Time from Terrestrial Time
- Shortwave radio stations that continuously broadcast UTC
  - CHU
  - WWV

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Notes

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16. ^ Leap second talks are postponed (http://news.bbc.co.uk/2/hi/science/nature/4420084.stm) by BBC News
17. ^ UTC redefinition or change (http://igscb.jpl.nasa.gov/mail/igsmail/2005/msg00114.html) by Kenneth Seidelmann
18. ^ Cowen 2006
19. ^ UTC might be redefined without Leap Seconds (http://www.ucolick.org/~sla/leapsecs/) by Steve Allen
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Further reading

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External links

- UTC vs UT1 1972–2005 (http://hpiers.obspm.fr/eop-pc/earthor/utc/leapsecond.html)
- IERS Bulletins C provided by Earth Orientation Center (http://hpiers.obspm.fr/eop-pc/products/bulletins/bulletins.html)
- IERS information about Bulletin C and when leap seconds may occur (http://hpiers.obspm.fr/eoppc/bul/bulc/BULLETINC.GUIDE)
- IERS Bulletins (http://www.iers.org/IERS/EN/Publications/Bulletins/bulletins.html), both current and historical bulletins from www.iers.org
- USNO article on leap seconds (http://tycho.usno.navy.mil/leapsec.html)
- USNO Leapsecs mailing list (until January 2007) (http://rom.usno.navy.mil/archives/leapsecs.html) (with an archive (http://www.mail-archive.com/leapsecs@rom.usno.navy.mil/))
- USNO Leapsecs mailing list (current) (http://six.pairlist.net/mailman/listinfo/leapsecs) (with an archive (http://six.pairlist.net/pipermail/leapsecs/))
- Leap Seconds in NTP, GPS, DCF77 (http://www.meinberg.de/english/info/leap-second.htm)
- Dynamic differences between UTC and TAI (http://www.leapsecond.com/java/gpsclock.htm)
- How to Watch a Leap Second (http://www.leapsecond.com/notes/leap-watch.htm)
- *The Year 2005 to Have 'Leap Second' Added*, NPR audio segment by Joe Palca (http://www.npr.org/templates/story/story.php?storyId=4734092)
- NIST FAQ about leap year and leap second (http://tf.nist.gov/general/leaps.htm)
- Time Scales in Satellite Geodesy (http://www.gmat.unsw.edu.au/snap/gps/gps_survey/chap2/214time.htm)
- UTC and the Future of the Leap Second (http://www.navcen.uscg.gov/pdf/cgsicMeetings/45/29a%20UTCLeapSecond.ppt)

UTC redefinition

- The leap second: its history and possible future (http://www.cl.cam.ac.uk/~mgk25/time/metrologia-leapsecond.pdf)
- UTC might be redefined without Leap Seconds (http://www.ucolick.org/~sla/leapsecs/)
- Summary of the US Working Group proposal (http://www.ucolick.org/~sla/leapsecs/nc1985wp7a.html)
- Opposition to the change (http://igscb.jpl.nasa.gov/mail/igsmail/2005/msg00114.html)
- Efforts to abolish leap seconds (http://www.cl.cam.ac.uk/~mgk25/time/leap/)

Categories: Timekeeping
