

The Leap Second

The rotation of the Earth on its axis and its orbit around the Sun have served as the basis for timekeeping since the dawn of history. The day was divided into 24 hours, each of 60 minutes, each of 60 seconds. Because the length of the apparent solar day (as shown, for example, by a sundial) varies in a regular way during the year it became necessary to average-out this effect and define a mean solar day. This explains the name Greenwich Mean Time (GMT), a time scale in which the mean position of the sun at noon, averaged over the year, is above the Greenwich meridian (longitude zero).

Over the centuries the accuracy of time measurement has steadily improved and it was realised that there were irregularities in the Earth's rate of rotation. In effect, the length of the seconds of Universal Time (UT1, as GMT is now officially known) varies slightly to keep in step with the changes in the Earth's rotation. In 1955 the first atomic clock that was much more regular than the Earth itself, or indeed any other type of clock then in existence, was brought into operation at the National Physical Laboratory. Constructed by Louis Essen and Jack Parry, it was based on measurements of a particular vibration of the caesium-133 atom. Over the next few years the frequency (or rate) of the NPL caesium clock was compared with the astronomical second calculated by the United States Naval Observatory (USNO), and as a result of this work in 1967, by international agreement, the second was defined in the International System of units of measurement (SI) as the duration of 9,192,631,770 periods of the chosen vibration of the caesium-133 atom.

The SI second, which is believed to be of constant duration under fixed conditions, is used to make a time scale called International Atomic Time (TAI), which is a simple count of SI seconds labelled conventionally using minutes, hours and days. As TAI is not linked to the Earth's rotation, a clock and calendar based on TAI gradually become more and more out of step with UT1. So TAI is of little use to anyone who wishes their clock to keep in step with the heavens. Traditional navigation, using observation of the sun, moon and stars, is one application that requires knowledge of UT1 to within a few seconds. Another is the use of UT1 by astronomers as a measure of the Earth's rotation angle, allowing them to point their telescopes at any desired object.

The solution adopted was to construct a second atomic time scale called Coordinated Universal Time, which is abbreviated in all languages as UTC, as the basis of international timekeeping. It combines all the regularity of atomic time with most of the convenience of UT1 (or GMT), and many countries have adopted it as the legal basis for time. UTC is adjusted regularly by small amounts to keep it close to UT1. From 1 January 1972, the seconds of UTC have been exactly the same length as those of TAI, and they occur at the same instants. UTC is kept always within 0.9 seconds of

UT1 by the insertion of extra seconds as necessary (known as positive leap seconds). It could happen that seconds would need to be removed (negative leap seconds), but so far all leap seconds have been positive.

When a leap second is inserted, it is done in the last minute of either December or June, or exceptionally March or September, immediately prior to midnight or 00:00:00 hours UTC. The decision as to whether a leap second is required is taken by the Earth Orientation Center of the International Earth Rotation and Reference Systems Service (IERS), approximately 6 months in advance.

An example of the sequence of seconds around the insertion of a leap second follows (using UTC date and time):

2005 December 31 23h 59m 58s
2005 December 31 23h 59m 59s
2005 December 31 23h 59m 60s
2006 January 01 00h 00m 00s
2006 January 01 00h 00m 01s

There are 61 seconds in a minute containing a positive leap second. A leap second occurs at the same instant throughout the world, when the familiar 'six pips' radio time signal gains an extra pip before the long pip marking the hour, to become a 'seven pip' signal. A mid-year leap second falls during summer time in the UK, one hour ahead of UTC, so the extra second is inserted at 01:00 BST on 1 July.

A cumulative record of leap seconds since the offset (TAI-UTC) was set to exactly 10 seconds on 1972-01-01 is given below. Each date listed is the UTC day immediately after the leap second, and the figure after the date is the number of seconds difference between TAI and UTC during the period from that date until the subsequent leap second, in the sense (TAI-UTC). The positive difference means that TAI is 'ahead' of UTC.

1972-07-01 11 s	1985-07-01 23 s
1973-01-01 12 s	1988-01-01 24 s
1974-01-01 13 s	1990-01-01 25 s
1975-01-01 14 s	1991-01-01 26 s
1976-01-01 15 s	1992-07-01 27 s
1977-01-01 16 s	1993-07-01 28 s
1978-01-01 17 s	1994-07-01 29 s
1979-01-01 18 s	1996-01-01 30 s
1980-01-01 19 s	1997-07-01 31 s
1981-07-01 20 s	1999-01-01 32 s
1982-07-01 21 s	2006-01-01 33 s
1983-07-01 22 s	2009-01-01 34 s