Time Systems and Dates:

Universal Time, GPS Time, Julian Dates

James R. Clynch

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Universal Time/Universal Time Coordinated

Time of day is based on the rotation of the earth. In theory, 24 hours is the time interval between sun zeniths, averaged over a year. One sun zenith to the next is the sum of the true rotation of the earth on its axis and the rotation of the earth about the sun.[1] The average over a year takes into account the small variation of the velocity of the earth in it's yearly orbit of the sun.

In nation time laboratories all over the world time is kept with atomic clocks. An average of these time scales is generated and called Universal Time Atomic (UTA). The abbreviation UT is not used consistently in popular literature. To an astronomer it means a special time frame, called UT1, that is determined by the real spinning of the earth. In a lot of non-scientific literature, it means Universal Time Coordinated, UTC, which used to be called Greenwich Mean Time (GMT). UTC is just atomic clock based time (UTA) plus or minus leap seconds inserted to keep it within 0.9 seconds of "earth time" – UT1.

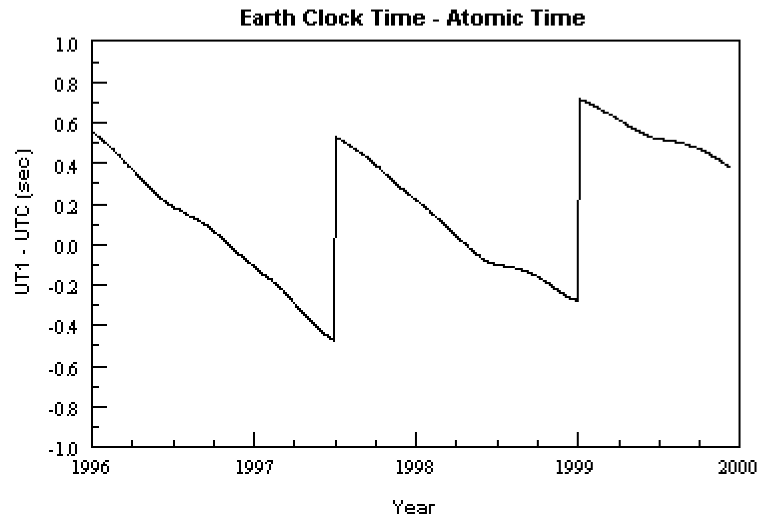
UTC is what you hear from time stations WWV, CHU etc. UTC, plus an offset for time zones, is what we use in everyday life. UT1 is principally of interest to astronomers who have to know the precise orientation of the earth for observations.

However the world does not rotate smoothly about it spin axis. This can easily be measured with atomic clocks. A plot of the difference between atomic clock time (UTC) and "earth" time shows a slow drift with some small irregularities. This difference is shown in the plot below. The jumps are were leap seconds has been introduced into Universal Time Coordinated (UTC) to keep the difference under 0.9 seconds.

Every year or so, using the "world as a clock" is about a second off from atomic time. Since 1972 the world timing community has agreed to insert or take out 1 second of time in the UTC time scale to keep the earth rotation aligned to within a second of atomic time. This is done on either January 1 or July 1 of a given year. To date there have only been extra seconds inserted, none taken out. This is like the insertion of February 29 into leap years. Therefore these have been called leap seconds.

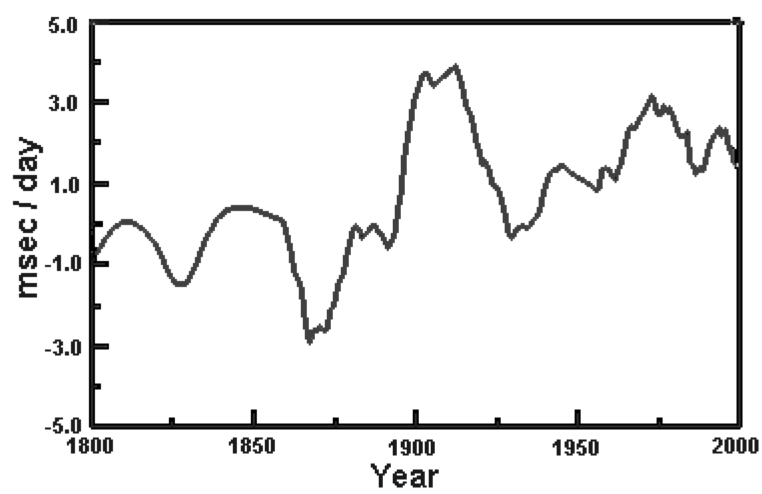
A detailed discussion of leap seconds can be found on the US Naval Observatory web site maia.usno.navy.mil/eo/leapsec.html . The 33rd leap second was introduced January 1, 2006. There is active discussion (in 2006) about abandoning the leap second.

[1] (The true rotation based time scale is called sidereal – and will not be discussed here. See discussions on astronomy to find out about this.

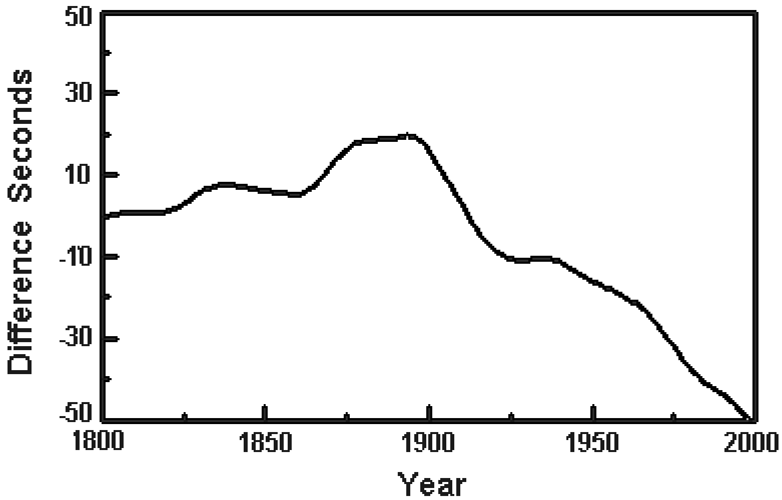


The current slow negative drift in the difference of the two time scales is not constant over decades and comes back. The source of these variations are many, some unknown. Tidal effects can be predicted over centuries, but there have been changes due to things like the 1990's el Nino event and even large geomagnetic storms.

A data set of this difference in time scales is available at the International Earth Rotation Service (IERS) on the web at hpiers.obspm.fr . This data set goes back to 1623. It is based on an analysis of astronomical events and historic data. The data after 1860 is thought to be reliable and after 1956 very good atomic clock data was used. Below is plotted the difference in the length of a day, in milliseconds, and the accumulated difference from the value in 1800.



Yearly Average
Length of Day - Nominal Value



Accumulated Earth Clock Error From 1800
IERS Measurements and Analysis

This is based on the work of Morrison of the Royal Greenwich Observatory.
use of leap seconds. This would allow the “earth time” to drift off from UTC.

GPS TIME

Occasionally there is need to use the details of how GPS labels time tags. In general this does not come up for the user. The GPS message contains information that allows a receiver to convert GPS Time into Universal Time, UT, (really UTC or Universal Time Coordinated) or any time zone.

GPS Time is a uniformly counting time scale begun at the 1/5/1980 midnight. January 6, 1980 is a Sunday. GPS Time counts in weeks and seconds of a week from this instant. The weeks begin at the Saturday/Sunday transition. The days of the week are numbered, with Sunday being 0, 1 Monday, etc.

GPS week 0 began at the beginning of the GPS Time Scale. Within each week the time is usually denoted as the second of the week. This is a number between 0 and 604,800 (60 x 60 x 24x 7). Sometimes the second-of-week (SOW) is split into a day of week (DOW) between 0 and 6 and a second of day (SOD) between 0 and 86400.

Because GPS time does not have leap seconds, it will change by 1 second with respect to UTC whenever a leap second is inserted into UTC. The two time scales were aligned when GPS time began on January 6, 1980. Whenever a leap second was introduced after that, the two time scales separated by an additional second. The offsets, to 2006, are shown in the table below. To date all the shifts have been positive. They could be negative in the future.

GPS to UTC Offset

Beginning On Date	GPS - UTC (sec)
Jan 6 1980	0
Jul 1 1981	1
Jul 1 1982	2
Jul 1 1983	3
Jul 1 1985	4
Jan 1 1988	5
Jan 1 1990	6
Jan 1 1991	7
Jul 1 1992	8
Jul 1 1993	9
Jul 1 1994	10
Jan 1 1996	11
Jul 1 1997	12
Jan 1 1999	13
Jan 1 2006	14

The navigation message of the GPS satellites contains the number of seconds offset between GPS and UTC time. This allows receivers to display UTC rather than GPS time.

Julian Date and MJD

In everyday life we use month, day and year to denote a date. However adding and subtracting dates is complicated. Astronomers use a time scale that counts uniformly in days they call the Julian Date (JD). This count does not have any leap years. (Or even any years as it counts days.) They set the origin of this date system far back in time, at January 0, 4173 BC at noon. This scale is counted in days and fractions of a day. January 1, 2000 at noon is JD = 2,451,545.0 . Days used to be started at noon, hence the use of noon as the reference time. In fact, astronomical publications used noon as the day dividing line until 1925.

Julian dates are large numbers and sometime hard to handle. A offset JD scale is commonly used in science today. It is called the Modified Julian Date (MJD). The introduction of this scale was used to place the day transition at midnight, agreeing with the civilian days.

MJD is defined as the Julian Date minus 2,400,000.5 . Thus January 1, 2000 at noon is MJD of 51,544.5 .

YEAR	**Julian Date**	**Modified Julian Date**	
	Jan 0	**Jan 0**	**Jan 0**
	Noon UT	**Noon UT**	**Midnight**
1950	2433282	33281.5	33282
1960	2436934	36933.5	36934
1970	2440587	40586.5	40587
1980	2444239	44238.5	44239
1990	2447892	47891.5	47892
2000	2451544	51543.5	51544
2010	2455197	55196.5	55197
2020	2458849	58848.5	58849
2030	2462502	62501.5	62502
2040	2466154	66153.5	66154
2050	2469807	69806.5	69807