Time Scales and Time Zones, Some Notes and Definitions

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If this paper has reached you without the attendant Power Point presentation, please contact the author. There are helpful diagrams and illustrations in the presentation which are not duplicated in this paper.

Conclusions

1. The term “UTC” is commonly used in two senses, to designate a time scale, and to designate a time zone. This has been a cause for confusion.

2. The documentation on the subject of time provided by NIST is excellent and complete, but they do not acknowledge the above problem, or else they do not believe it is a problem.

3. We suggest the use of “UTC time scale” and “UTC time zone” so specify which sense of the term is being used.

4. GPS receivers normally make internal corrections and produce a time output which is very close to UTC time scale. That is, GPS receivers do not normally output GPS time scale, but a time which is very nearly UTC time scale.

5. When a time is labeled UTC, we should understand that it is expressed with no hours offset from the time zone at the prime meridian, and should not assume that the time was produced by a device which is necessarily well synchronized to UTC time scale.

6. For serious commercial or scientific purposes, particularly those involving more than one time zone, use UTC time scale with no offset. That is, ignore local time zones, and daylight savings time shift.

Organization

Definition and discussions of various terms in the general field of time zones and time scales are presented alphabetically.

Accuracy

Accuracy is the degree of conformity of a measured or calculated value to its definition. Accuracy is related to the offset from an ideal value. In the world of time, accuracy is used to refer to the time offset of a device. For example, time offset is the difference between a measured on-time pulse and an ideal on-time pulse that coincides exactly with UTC. In recent years, the term uncertainty has been given preference over accuracy when a quantitative measure is stated. Accuracy is often used in a qualitative sense. For example, we might say that a time measurement has an uncertainty of 1 microsecond, and that the accuracy of the measurement is very good. Also see definition of "resolution."

Daylight Savings Time

A chart of daylight savings changeover dates is included. This matter is of particular concern now, with the change in rules for establishing the changeover dates which will take effect in Spring of 2007. The dates which are preprogrammed into GPS clocks will become incorrect beginning in the Spring of 2007. This makes it necessary to somehow change those preprogrammed dates, or else change these clocks to output UTC time scale with no offset. Obviously the author favors the latter solution. This solution has the advantage that the change can be done anytime between now and March 11, 2007. The changeover involves making settings using the front panel of the clock, i.e., it can be done without opening the case of the clock.

GOES

An acronym for the Geostationary Operational Environmental Satellites operated by the National Oceanic and Atmospheric Agency (NOAA). Although the satellite system still exists, GOES is no longer a source of synchronous time broadcasts. This function has been taken over by GPS.

Global Positioning System (GPS)

A constellation of satellites controlled and operated by the United States Department of Defense (USDOD). The constellation includes at least 24 satellites that orbit the Earth at a height of 20,200 km in six fixed planes inclined 55˚ from the equator. The orbital period is 11 h 58 m, which means that a satellite will orbit the earth twice per day. By processing signals received from the satellites, a GPS receiver can determine its own position with an uncertainty of < 10 m.

The GPS satellites broadcast on two carrier frequencies: L1, at 1575.42 MHz, and L2, at 1227.6 MHz. Each satellite broadcasts a spread-spectrum waveform, called a pseudo-random noise (PRN) code on L1 and L2, and each satellite is identified by the PRN code it transmits. There are two types of PRN codes. The first type is a coarse acquisition (C/A) code with a chip rate of 1023 chips per millisecond. The second type is a precision (P) code with a chip rate of 10230 chips per millisecond. The C/A code is broadcast on L1, and the P code is broadcast on both L1 and L2. GPS reception is line-of-sight, which means that the antenna must have a clear view of the sky. The signals can be received nearly anywhere on Earth where a clear sky view is available.

The primary purpose of GPS is to serve as a radio navigation system, but it has also become perhaps the dominant system for the distribution of time. Each satellite carries either rubidium or cesium oscillators, or a combination of both. The on-board oscillators provide the reference for both the carrier and code broadcasts. They are steered from USDOD ground stations and are referenced to Coordinated Universal Time (UTC) maintained by the United States Naval Observatory (USNO). By mutual agreement UTC(USNO) and UTC(NIST) are maintained within 100 ns of each other.

There are several types of time and frequency measurements that involve GPS, including one-way, common-view, and carrier-phase measurements. To view one-way GPS data received at Boulder and compared to UTC(NIST), visit the GPS data archive.

GPS Receivers

A sampling of available GPS receivers produced the following:

UTC(USNO) plus or minus 1 microsecond (only need one satellite with correct position)

UTC(USNO) plus or minus 1 millisecond peak, < 10 microsecond typical, plus or minus 1 microsecond with option. Specified with SA on, however SA is now normally off.

GPS Time

The GPS system time scale is unique to the GPS system itself. UTC can be obtained from a GPS receiver if the receiver is configured to convert GPS time to UTC, and nearly all GPS receivers are so configured. The GPS satellites themselves use the GPS time scale as their timing reference.

GPS time differs from UTC by the integral number of leap seconds that have occurred since the origination of the GPS time scale (January 6, 1980); this value is equal to 14 seconds as of now. It also differs by a small number of nanoseconds (nearly always < 25 ns) that continuously changes. The integer second difference is needed to correct the time-of-day solution. This small number of nanoseconds represents the difference between the GPS time scale on-time marker (OTM) and an estimation of the OTM for the UTC time scale maintained by the United States Naval Observatory, called UTC(USNO).

The current difference between the UTC(USNO) estimate and GPS time is always broadcast from the satellites, and this correction is applied to the 1 pulse per second output produced by many receivers. Therefore, a GPS receiver configured to produce UTC is technically producing a very good estimate of UTC(USNO), which differs by only nanoseconds from "true" UTC, or from the version of UTC produced by NIST, called UTC(NIST).

The NIST GPS data archive shows current difference between UTC(NIST) and UTC as received from GPS, via UTC(USNO). The difference is small, seldom exceeding 30 ns.

http://tf.nist.gov/service/gpstrace.htm

Provided that the GPS receiver is configured to apply as the (presently) 14 s correction, the fractional second difference between UTC and GPS time is very small.

Greenwich Mean Time (GMT)

GMT as a time scale no longer exists, since it was replaced by other astronomical time scales many years ago, and those astronomical times scales were subsequently replaced by the atomic time scale UTC. However, the term GMT is still in use, and when used, should be understood to be a time zone designation rather than a time scale. GMT time zone is the time zone at the prime meridian, which passes through Greenwich, England.

IRIG Time Codes

The time codes originally developed by the Inter-Range Instrumentation Group (IRIG), now used in government, military and commercial fields. There are many formats and several modulation schemes, but they are typically amplitude modulated on an audio sine wave carrier. The most common version is probably IRIG-B, which sends day of year, hour, minute, and second data on a 1 kHz carrier frequency, with an update rate of once per second.

Leap Second

Leap seconds are declared as necessary to keep the difference between UTC and within 900 ms. With the most recent leap second, on 051231, the total number of leap seconds since the beginning of UTC time scale reached 23. Leap seconds have always been positive, however there may come a time when it is necessary to declare a negative leap second.

Leap Year

Leap years generally occur every 4th year, in the years which are divisible by 4. However the actual length of a year is 365.242 days, not 365.250 days, as commonly stated. For this reason, century years such as 1900, 2000, and 2100 are leap years only in those cases where they are divisible by 400. 1900 was not a leap year, 2000 was a leap year, and 2100 will not be a leap year.

NIST - National Institute of Science and Technology
NOAA - National Oceanic and Atmospheric Agency

Prime Meridian

The meridian which passes through the observatory at Greenwich England was designated as the initial or “prime” meridian at a conference on Washington in the year 1884. The time zone in use at that location is actually centered on the prime meridian, that is, the time zone extends 7.5 degrees to both east and west of the prime meridian. The longitude at the prime meridian is zero.

Resolution

The degree to which a measurement can be determined. For example, if a time interval counter has a resolution of 10 ns, it could produce a reading of 3340 ns or 3350 ns but not a reading of 3345 ns. This is because 10 ns is the smallest significant difference the instrument can measure. Any finer measurement would require more resolution. The specification for an instrument usually lists the resolution of a single measurement, sometimes called the single shot resolution. It is usually possible to obtain more resolution by averaging. See also the definition of “Accuracy.”

Second

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 definition was added to the International System (SI) of units in 1967. The abbreviation for second is the lower case letter “s” with no period, unless the “s” happens to occur at the end of a sentence.

millisecond (ms) - one thousandth of a second (10-3 s).
microsecond - one millionth of a second (10-6 s).
nanosecond (ns) - one billionth of a second (10-9 s).

Time Scale

An agreed upon system for keeping time. All time scales use a frequency source to define the length of the second, which is the standard unit of time interval. Seconds are then counted to measure longer units of time interval, such as minutes, hours, and days. Modern time scales such as UTC define the second based on an atomic property of the cesium atom, and thus standard seconds are produced by cesium oscillators. Earlier time scales (including earlier versions of Universal Time) were based on astronomical observations that measured the frequency of the Earth's rotation.

Time Zones

A time zone is a geographical region that maintains a local time that usually differs by an integral number of hours from other time zones. Time zones were initially instituted by the railroads in the United States and Canada during the 1880's to standardize timekeeping. Within several years the use of time zones had expanded internationally.

Ideally, the world would be divided into 24 time zones of equal width. Each zone would have an east-west dimension of 15˚ of longitude centered upon a central meridian. This central meridian for a zone is defined in terms of its position relative to a universal reference, the prime meridian (often called the zero meridian) located at 0˚ longitude. In other words, the central meridian of each zone has a longitude divisible by 15˚. When the sun is directly above this central meridian, local time at all points within that time zone would be noon. In practice, the boundaries between time zones are often modified to accommodate political boundaries in the various countries. A few countries use a local time that differs by one half hour from that of the central meridian.

For "public" time, there are 24 world time zones, and each of these time zones have been given letter designations which apparently have a military origin. Each time zone as well has various names in the countries through which it passes. There are 24 principal time zones, and obviously 26 letters in the English alphabet. The letter "J" is not used, and there is one time zone that is designated as both "M" and "Y". The letters are not assigned in the obvious order. Several web sites deal with the time zones and conversions between them, for example: http://www.worldtimezone.com/

Some examples are as follows:

Offset	Letter	Also Called
-8	U Uniform	Pacific Standard Time (PST)
-7	T Tango	Mountain Standard Time (MST)
-6	S Sierra	Central Standard Time (CST)
-5	R Romeo	Eastern Standard Time (EST)
-4	Q Quebec	Atlantic Standard Time (AST)
-3	P Papa	Greenland Standard Time (GST)
-2	O Oscar	Greenland Eastern Standard Time (VTZ)
-1	N November	Azores Time (AT)
0	Z Zulu	Western Europe Time (WET)

Unfortunately, the last listed time zone is also called by several names which originated as the names of time scales, not time zones. These are Greenwich Mean Time (GMT), Universal Coordinated Time (UTC), and Universal Time (UT).

USNO - United States Naval Observatory

Universal Time (UT) Family

Before the acceptance of atomic time scales such as TAI and UTC in the 1960s, astronomical time scales were used for everyday timekeeping. These time scales are still used today, but mostly for applications related to astronomy. They are based on mean solar time. The mean solar second is defined as 1/86,400 of the mean solar day, where 86,400 is the number of seconds in the mean solar day. This mean solar second provides the basis for Universal Time (UT). Several variations of UT have been defined, so the term UT is now longer in use as a time scale.

UT0 - The original mean solar time scale, based on the rotation of the Earth on its axis. UT0 was first kept by pendulum clocks. As better clocks based on quartz oscillators became available, astronomers noticed errors in UT0 due to polar motion, which led to the UT1 time scale.

UT1 - The most widely used astronomical time scale, UT1 is an improved version of UT0 that corrects for the shift in longitude of the observing station due to polar motion. Since the Earth's rate of rotation is not uniform, UT1 is not completely predictable, and has an uncertainty of +/- 3 milliseconds per day.

UT2 - Mostly of historical interest, UT2 is a smoothed version of UT1 that corrects for known deviations in the Earth's rotation caused by angular momenta of the Earth's core, mantle, oceans, and atmosphere.

UT as a time scale no longer exists, as it was replaced by these other astronomical time scales many years ago, and astronomical times scales have for most applications been subsequently replaced by the atomic time scale UTC. However, the term UT is still in use, and when used, should be understood to be a time zone designation rather than a time scale. UT time zone is the time zone at the prime meridian, which passes through Greenwich England.

UTC

The letters UTC are from the French form of this term. In English language, both "Universal Coordinated Time" and "Coordinated Universal Time" are used, and obviously neither of these corresponds to UTC. Confusion arises because "UTC" is commonly used in two completely different senses, as a time scale and as a time zone designation. We have provided two definitions for UTC as a time scale and UTC as a time zone, below.

UTC as a Time Scale

The international atomic time scale that serves as the basis for timekeeping for most of the world. UTC is coordinated by the Bureau International des Poids et Measures (BIPM) in Sevres, France. The BIPM averages data collected from more than 200 atomic time and frequency standards located at about 80 laboratories, including the National Institute of Standards and Technology (NIST). As a result of this averaging, the BIPM generates two time scales, International Atomic Time (TAI), and Coordinated Universal Time (UTC). These time scales realize the SI second as closely as possible. UTC runs at the same frequency as TAI. However, it differs from TAI by an integral number of seconds. This difference increases when leap seconds occur. When necessary, leap seconds are added to UTC on either June 30 or December 31. The purpose of adding leap seconds is to keep atomic time (UTC) within ±0.9 s of an older time scale called UT1, which is based on the rotational rate of the Earth. Leap seconds have been added to UTC at a rate averaging about 8 every 10 years, beginning in 1972. Keep in mind that the BIPM maintains TAI and UTC as "paper" time scales. The major metrology laboratories use the published data from the BIPM to steer their clocks and oscillators and generate real-time versions of UTC, such as UTC(NIST). You can think of UTC as the ultimate standard for time-of-day, time interval, and frequency. Clocks synchronized to UTC remain within less than one second of UT1.

UTC as a Time Zone

When UTC is disseminated, it is commonly expressed with zero hours offset from the time zone at the prime meridian, which passes through Greenwich England. Unfortunately this has led to the use of the letters UTC as an expression for this 'zero offset' time zone. A similar thing happened previously with GMT.

Examples

15:37:47.591 UTC - This should be understood to mean that the time has no offset from the time zone at the prime meridian, which passes through Greenwich England. This time expression should not be understood to impart any information regarding the method or quality of synchronization Universal Coordinated Time scale. It should be understood that no information has been provided regarding the synchronization of the device which produced the time.

15:37:47.591 GMT or UT - These should be understood to mean that the time has no offset from the time zone at the prime meridian, which passes through Greenwich England. It should be understood that no information has been provided regarding the synchronization of the device which produced the time. These terms are in fact the names of time scales which are no longer in use.

15:37:47.591 Z, Zulu, or UTZ - These should all be understood to mean that the time has no offset from the time zone at the prime meridian, which passes through Greenwich England. It should be understood that no information has been provided regarding the synchronization of the device which produced the time. These terms are “pure” time zone terms, and are not associated with any time scale, past or present. The authors prefers these time zone terms.

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Author Bibliography

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References

We have “lifted” many direct quotations from the NIST website in this work, particularly from the glossary which appears at the following address. However, the definitions presented in this work have been edited for this purpose, i.e. they are not exactly as presented by NIST. You can consult the official NIST definition at this address: http://tf.nist.gov/timefreq/general/glossary.htm

“NIST Time and Frequency Services,” Michael A. Lombardi, NIST Special Publication 432, 2002 Edition, available at: www.nist.gov/timefreq

(A wealth of other information and interesting links may be found at the above address.)

“Guide for the Use of the International System of Units (SI),” Barry N. Taylor, NIST Special Publication 811, 1995 Edition, available at: http://physics.nist.gov/cuu/Units/bibliography.html

Major Time Zones of Canada & US

Offset	Name	Abbreviation
0	Universal Time Zone	UTZ
-1		
-2		
-3		
	Atlantic Daylight Time	ADT
-4	Atlantic Standard Time	AST
	Eastern Daylight Time	EDT
-5	Eastern Standard Time	EST
	Central Daylight Time	CDT
-6	Central Standard time	CST
	Mountain Daylight Time	MDT
-7	Mountain Standard time	MST
	Pacific Daylight Time	PDT
-8	Pacific Standard Time	PST

Time Zone Conversions

To Convert From		To UTZ Add	To ADT Add	To AST EDT Add	To EST CDT Add	To CST MDT Add	To MST PDT Add	To PST Add
UTZ		0	-3	-4	-5	-6	-7	-8
		1	-2	-3	-4	-5	-6	-7
		2	-1	-2	-3	-4	-5	-6
	ADT	3	0	-1	-2	-3	-4	-5
AST	**EDT**	4	1	0	-1	-2	-3	-4
EST	**CDT**	5	2	1	0	-1	-2	-3
CST	**MDT**	6	3	2	1	0	-1	-2
MST	**PDT**	7	4	3	2	1	0	-1
PST		8	5	4	3	2	1	0
		9	6	5	4	3	2	1

Conversions: ms, cycles, degrees

(60 Hz)

ms	cycles	degrees
1000	60	
500	30	
100	6	
50	3	
33.3	2	
16.7	1	360
15.3	11/12	330
13.9	5/8	300
12.5	3/4	270
11.1	2/3	240
9.7	7/12	210
8.3	1/2	180
6.9	5/12	150
5.6	1/3	120
4.2	1/4	90
2.8	1/6	60
1.4	1/12	30
0	0	0

Daylight Saving Time
In the United States
1990 Through 2015

In spring, move clocks forward one hour.
In fall, turn clocks backward one hour.

Year	DST Begins 2 a.m. (First Sunday in April)	DST Ends 2 a.m. (Last Sunday in October)
1990	April 1	October 28
1991	April 7	October 27
1992	April 5	October 25
1993	April 4	October 31
1994	April 3	October 30
1995	April 2	October 29
1996	April 7	October 27
1997	April 6	October 26
1998	April 5	October 25
1999	April 4	October 31
2000	April 2	October 29
2001	April 1	October 28
2002	April 7	October 27
2003	April 6	October 26
2004	April 4	October 31
2005	April 3	October 30
2006	April 2	October 29

DST Start and End date changes beginning March 2007

Year	DST Begins 2 a.m. (Second Sunday in March)	DST Ends 2 a.m. (First Sunday in November)
2007	March 11	November 4
2008	March 9	November 2
2009	March 8	November 1
2010	March 14	November 7
2011	March 13	November 6
2012	March 11	November 4
2013	March 10	November 3
2014	March 9	November 2
2015	March 8	November 1