**NIST TIME AND FREQUENCY BULLETIN**
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This bulletin is published monthly. Address correspondence to:

Eyvon M. Petty, Editor
Time and Frequency Division
National Institute of Standards and Technology
325 Broadway
Boulder, CO 8O3O5-3328
(3O3) 497-3295
Email: pettye@boulder.nist.gov

U.S. DEPARTMENT OF COMMERCE, GARY LOCKE, Secretary
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, Patrick D. Gallagher, Deputy Director

## 1. GENERAL BACKGROUND INFORMATION

### ACRONYMS AND ABBREVIATIONS USED IN THIS BULLETIN

ACTS - Automated Computer Time Service
BIPM - Bureau International des Poids et Mesures
CS - Cesium Standard
GPS - Global Positioning System
IERS - International Earth Rotation Service
LORAN - Long Range Navigation
MC - Master Clock
MJD - Modified Julian Date
NIST - National Institute of Standards and Technology
NOAA - National Oceanic and Atmospheric Administration
NVLAP - National Voluntary Laboratory Accreditation Program
SI - International System of Units
TA - Atomic Time
TAI - International Atomic Time
USNO - United States Naval Observatory
UTC - Coordinated Universal Time

ns - nanosecond
μs - microsecond
ms - millisecond
s - second
min - minute

## 2. TIME SCALE INFORMATION

The values listed below are based on data from the IERS, the USNO, and NIST. The UTC(USNO,MC) - UTC(NIST) values are averaged measurements from all available common-view GPS satellites (see bibliography on page 5). **UTC - UTC(NIST) data are on page 3.**

| 0000 HOURS COORDINATED UNIVERSAL TIME | | | |
|---|---|---|---|
| July 2009 | MJD | UT1-UTC(NIST) (±5 ms) | UTC(USNO,MC) - UTC(NIST) (±20 ns) |
| 2 | 55014 | 233 ms | 3 ns |
| 9 | 55021 | 235 ms | 0 ns |
| 16 | 55028 | 234 ms | -2 ns |
| 23 | 55035 | 234 ms | -6 ns |
| 30 | 55042 | 231 ms | -8 ns |

The master clock pulses used by the WWV, WWVH, and WWVB time-code transmissions are referenced to the UTC(NIST) time scale. Occasionally, 1 s is added to the UTC time scale. This second is called a leap second. Its purpose is to keep the UTC time scale within ±0.9 s of the UT1 astronomical time scale, which changes slightly due to variations in the Earth's period of rotation.

**NOTE:** No leap second was added at the end of June 2009.

Positive leap seconds, beginning at 23 h 59 min 60 s UTC and ending at 0 h 0 min 0 s UTC, were inserted in the UTC timescale on 30 June 1972, 1981-1983, 1985, 1992-1994, and 1997, and on 31 December 1972-1979, 1987, 1989, 1990,1995, 1998, and 2005.

The use of leap seconds ensures that UT1 - UTC will always be held within ±0.9 s. The current value of UT1 - UTC is called the DUT1 correction. DUT1 corrections are broadcast by WWV, WWVH, WWVB, and ACTS and are printed below. These corrections may be added to received UTC time signals in order to obtain UT1.

DUT1 = UT1 - UTC =
+0.2 s beginning 0000 UTC 11 June 2009
+0.3 s beginning 0000 UTC 12 March 2009
-0.6 s beginning 0000 UTC 20 November 2008
-0.5 s beginning 0000 UTC 07 August 2008
-0.4 s beginning 0000 UTC 13 March 2008

The difference between UTC(NIST) and UTC has been within ±100 ns since July 6, 1994. The table below shows values of UTC - UTC(NIST) as supplied by the BIPM in their *Circular T* publication for the most recent 310-day period in which data are available. Data are given at 10-day intervals. Five-day interval data are available in *Circular T*.

| 0000 Hours Coordinated Universal Time | | |
|---|---|---|
| **DATE** | **MJD** | **UTC-UTC(NIST) ns** |
| Jun. 27, 2009 | 55009 | 0 |
| Jun. 17, 2009 | 54999 | 4.7 |
| Jun. 07, 2009 | 54989 | 5.7 |
| May 28, 2009 | 54979 | 10.3 |
| May 18, 2009 | 54969 | 11.2 |
| May 08, 2009 | 54959 | 10.8 |
| Apr. 28, 2009 | 54949 | 9.7 |
| Apr. 18, 2009 | 54939 | 7.0 |
| Apr. 08, 2009 | 54929 | 10.0 |
| Mar. 28, 2009 | 54919 | 7.5 |
| Mar. 18, 2009 | 54909 | 7.1 |
| Mar. 08, 2009 | 54899 | 4.9 |
| Feb. 27, 2009 | 54889 | 4.3 |
| Feb. 17. 2009 | 54879 | 2.0 |
| Feb. 07, 2009 | 54869 | 1.7 |
| Jan. 28, 2009 | 54859 | 3.9 |
| Jan. 18, 2009 | 54849 | 3.9 |
| Jan. 08, 2009 | 54839 | 4.0 |
| Dec. 29, 2008 | 54829 | 4.1 |
| Dec. 19, 2008 | 54819 | 2.5 |
| Dec. 09, 2008 | 54809 | 0.7 |
| Nov. 29, 2008 | 54799 | 0.5 |
| Nov. 19, 2008 | 54789 | -1.0 |
| Nov. 09, 2008 | 54779 | -2.1 |
| Oct. 30, 2008 | 54769 | -3.3 |
| Oct. 20, 2008 | 54759 | -5.7 |
| Oct. 10, 2008 | 54749 | -5.4 |

## 3. PHASE DEVIATIONS FOR WWVB AND LORAN-C

WWVB - The values shown for WWVB are the time differences between the time markers of the UTC(NIST) time scale and the first positive-going zero voltage crossover measured at the transmitting antenna. The uncertainty of the individual measurements is ±0.5 μs. The values listed are for 1300 UTC.

LORAN-C - The values shown for LORAN-C represent the daily accumulated phase shift. The phase shift is measured by comparing the output of a LORAN receiver to the UTC(NIST) time scale for a period of 24 h. If data were not recorded on a particular day, the symbol (-) is printed. The stations monitored are Baudette, Minnesota (8970) and Boise City, Oklahoma (9610). The monitoring is done from the NIST laboratories in Boulder, Colorado.

**Note: The values shown for LORAN-C are in nanoseconds.**

| | | UTC(NIST)-WWVB (60 kHz) | UTC(NIST) - LORAN PHASE (ns) | |
|---|---|---|---|---|
| DATE | MJD | ANTENNA PHASE (μs) | LORAN-C (BAUDETTE) (8970) | LORAN-C (BOISE CITY) (9610) |
| 07/01/2009 | 55013 | 5. 65 | +16 | +15 |
| 07/02/2009 | 55014 | 5. 65 | +24 | -75 |
| 07/03/2009 | 55015 | 5. 65 | -35 | +30 |
| 07/04/2009 | 55016 | 5. 65 | +3 | -36 |
| 07/05/2009 | 55017 | 5. 65 | +88 | +45 |
| 07/06/2009 | 55018 | 5. 65 | -66 | +22 |
| 07/07/2009 | 55019 | 5. 65 | -4 | +8 |
| 07/08/2009 | 55020 | 5. 65 | -39 | +10 |
| 07/09/2009 | 55021 | 5. 65 | -11 | -33 |
| 07/10/2009 | 55022 | 5. 65 | -81 | +11 |
| 07/11/2009 | 55023 | 5. 65 | +8 | -15 |
| 07/12/2009 | 55024 | 5. 65 | -28 | +12 |
| 07/13/2009 | 55025 | 5. 65 | +55 | +11 |
| 07/14/2009 | 55026 | 5. 65 | -10 | +42 |
| 07/15/2009 | 55027 | 5. 65 | +88 | -9 |
| 07/16/2009 | 55028 | 5. 65 | -73 | +7 |
| 07/17/2009 | 55029 | 5. 65 | -98 | -13 |
| 07/18/2009 | 55030 | 5. 65 | -18 | +2 |
| 07/19/2009 | 55031 | 5. 65 | -3 | +19 |
| 07/20/2009 | 55032 | 5. 65 | +5 | -26 |
| 07/21/2009 | 55033 | 5. 65 | +46 | -13 |
| 07/22/2009 | 55034 | 5. 65 | -15 | +32 |
| 07/23/2009 | 55035 | 5. 65 | +53 | -10 |
| 07/24/2009 | 55036 | 5. 65 | -8 | +5 |
| 07/25/2009 | 55037 | 5. 65 | -26 | -99 |
| 07/26/2009 | 55038 | 5. 65 | -19 | +24 |
| 07/27/2009 | 55039 | 5. 65 | -2 | +45 |
| 07/28/2009 | 55040 | 5. 65 | +38 | +3 |
| 07/29/2009 | 55041 | 5. 65 | -22 | -10 |
| 07/30/2009 | 55042 | 5. 65 | +6 | -18 |
| 07/31/2009 | 55043 | 5. 65 | +22 | +34 |

## 4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS

| OUTAGES OF 5 MINUTES OR MORE | | | | | | PHASE PERTURBATIONS 2 ms | | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | Jul 2009 | MJD | Began UTC | Ended UTC | Freq. | Jul 2009 | MJD | Began UTC | End UTC |
| WWVB | 07-09-09 | 55021 | 0547 | 0649 | 60 kHz | | | | |
| WWVB | 07-12-09 | 55024 | 2303 | 2356 | 60 kHz | | | | |
| WWVB | 07-29-09 | 55041 | 0703 | 0829 | 60 kHz | | | | |
| WWV | | | | | | | | | |
| WWVH | | | | | | | | | |

## 5. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS

Primary frequency standards developed and operated by NIST are used to provide accuracy (rate) input to the BIPM. NIST-F1, a cold-atom cesium fountain frequency standard, has served as the U.S. primary time and frequency standard since 1999. The uncertainty of NIST-F1 is currently about 5 parts in $10^{16}$.

The AT1 scale is run in real-time by use of data from an ensemble of cesium standards and hydrogen masers. It is a free-running scale whose frequency is maintained as nearly constant as possible by choosing the optimum weight for each clock that contributes to the computation.

UTC(NIST) is generated as an offset from our real-time scale AT1. It is steered in frequency towards UTC by use of data published by the BIPM in its Circular T. Changes in the steering frequency will be made, if necessary, at 0000 UTC on the first day of the month, and occasionally at mid-month. A change in frequency is limited to no more than ±2 ns/day. The frequency of UTC(NIST) is kept as stable as possible at other times.

UTC is generated at the BIPM by use of a post-processed time-scale algorithm and is not available in real-time. The parameters that we use to generate UTC(NIST) in real-time are therefore based on an extrapolation of UTC from the most recent available data.

## 6. BIBLIOGRAPHY


Allan, D.W.; Hellwig, H.; and Glaze, D.J., "An accuracy algorithm for an atomic time scale," Metrologia, Vol.11, No.3, pp.133-138 (1975).

Allan, D.W.; Davis, D.D.; Weiss, M.A.; Clements, A.; Guinot, B.; Granveaud, M.; Dorenwendt, K.; Fischer, B.; Hetzel, P.; Aoki, S.; Fujimoto, M.; Charron, L.; and Ashby, N., “Accuracy of international time and frequency comparisons via global positioning system satellites in common-view,” IEEE Transactions on Instrumentation and Measurement, Vol. IM-34, pp.118-125 (1985).

Heavner, T.P.; Jefferts, S.R.; Donley; E.A.; Shirley, J.H. and Parker, T.E., “NIST F1; recent improvements and accuracy evaluations,” Metrologia, Vol. 42, pp. 411-422 (2005).

Jefferts, S.R.; Shirley, J.; Parker, T.E.; Heavner, T.P.; Meekhof, D.M.; Nelson, C., Levi, F.; Costanza, G.; De Marchi, A.; Drullinger, R.; Hollberg, L.; Lee, W.D.; and Walls, F.L., “Accuracy evaluation of NIST-F1,” Metrologia, Vol. 39, pp. 321-336 (2002).

Lewandowski, W. and Thomas, C.; “GPS Time transfer,” Proceedings of the IEEE, Vol. 79, pp. 991-1000 (1991).

Parker, T.E.; Jefferts, S.R.; Heavner, T.P.; and Donley, E.A., “Operation of the NIST-F1 caesium fountain primary frequency standard with a maser ensemble, including the impact of frequency transfer noise,” Metrologia, Vol. 42, pp. 423-430 (2005).

Weiss, M.A.; Allan, D.W.; “An NBS Calibration Procedure for Providing Time and Frequency at a Remote Site by Weighting and Smoothing of GPS Common View Data,” IEEE Transactions on Instrumentation and Measurement, Vol. IM-36, pp. 572-578 (1987).

Table 7.1 lists parameters that are used to define UTC(NIST) with respect to our real-time scale AT1. To find the value of UTC(NIST) - AT1 at any time T (expressed as a Modified Julian Day, including a fraction if needed), the appropriate equation to use is the one for which the desired T is greater than or equal to the entry in the $T_0$ column and less than the entry in the last column. The values of $x_{ls}$, x, and y for that month are then used in the equation below to find the desired value. The parameters x and y represent the offsets in time and frequency, respectively, between UTC(NIST) and AT1; the parameter $x_{ls}$ is the number of leap seconds applied to both UTC(NIST) and UTC, as specified by the IERS. Leap seconds are not applied to AT1.

Table 7.1

$UTC(NIST) - AT1 = x_{ls} + x + y*(T - T_0)$

| Month | $x_{ls}$ (s) | x (ns) | y (ns/d) | $T_0$ (MJD) | Valid until 0000 on: (MJD) |
|---|---|---|---|---|---|
| Sep 09 | -34 | -338721.7 | -38.3* | 55075 | 55105 |
| Aug 09 | -34 | -337534.4 | -38.3 | 55044 | 55075* |
| Jul 09 | -34 | -336691.8 | -38.3 | 55022 | 55044 |
| Jul 09 | -34 | -336349.8 | -38.0 | 55013 | 55022† |
| Jun 09 | -34 | -335209.8 | -38.0 | 54983 | 55013 |
| May 09 | -34 | -334791.8 | -38.0 | 54972 | 54983 |
| May 09 | -34 | -334027.8 | -38.2 | 54952 | 54972† |
| Apr 09 | -34 | -333225.6 | -38.2 | 54931 | 54952 |
| Apr 09 | -34 | -332880.9 | -38.3 | 54922 | 54931† |
| Mar 09 | -34 | -331693.6 | -38.3 | 54891 | 54922 |
| Feb 09 | -34 | -330621.2 | -38.3 | 54863 | 54891 |
| Jan 09 | -34 | -329931.8 | -38.3 | 54845 | 54863 |
| Jan 09 | -34 | -329432.6 | -38.4 | 54832 | 54845† |
| Dec 08 | -33 | -328895.0 | -38.4 | 54818 | 54832 |
| Dec 08 | -33 | -328240.5 | -38.5 | 54801 | 54818† |
| Nov 08 | -33 | -327085.5 | -38.5 | 54771 | 54801 |
| Oct 08 | -33 | -326392.5 | -38.5 | 54753 | 54771 |
| Oct 08 | -33 | -325894.6 | -38.3* | 54740 | 54753† |
| Sep 08 | -33 | -324745.6 | -38.3 | 54710 | 54740 |
| Aug 08 | -33 | -323558.3 | -38.3 | 54679 | 54710 |
| Jul 08 | -33 | -322792.3 | -38.3 | 54659 | 54679 |
| Jul 08 | -33 | -322369.9 | -38.4 | 54648 | 54659† |
| Jun 08 | -33 | -321211.9 | -38.6 | 54618 | 54648 |

**† Rate change in mid-month**
***Provisional value**

**Corrections made to data due to typographical errors.**