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Kelsey Rodriguez, Editor

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*Physical Measurement Laboratory*

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## Abstract

The Time and Frequency Bulletin provides information on performance of time scales and a variety of broadcasts (and related information) to users of the NIST services.

## Keywords

Clocks; dissemination; frequency; GPS; oscillators; time.

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## 1. Time Scale Information

The values listed in the table below are based on data from the IERS, the USNO, and NIST. The UTC(USNO, MC) – UTC(NIST) values are obtained from the BIPM. UTC – UTC(NIST) data are on page 3.

**Table 1.** Variation in UT1 – UTC(NIST) and UTC(USNO, MC) – UTC(NIST) Time Scales.

| 0000 HOURS COORDINATED UNIVERSAL TIME | | | |
|---|---|---|---|
| July 2023 | MJD | UT1 – UTC(NIST) (±1 ms) | UTC(USNO, MC) – UTC(NIST) (±5 ns) |
| 4 | 60129 | -33.5 ms | -0.8 ns |
| 9 | 60134 | -31.0 ms | -0.2 ns |
| 14 | 60139 | -27.8 ms | 0.1 ns |
| 19 | 60144 | -21.8 ms | 0.2 ns |
| 24 | 60149 | -19.6 ms | 0.7 ns |
| 29 | 60154 | -17.4 ms | 0.9 ns |

The 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.

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 time scale on 30 June 1972, 1981, 1983, 1985, 1992-1994, 1997, 2012, 2015 and on 31 December 1972-1979, 1987, 1989, 1990, 1995, 1998, 2005, 2008, 2016.

NO leap second will be introduced at the end of December 2023.

The insertion 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 the received UTC time signals in order to obtain UT1.

**Table 2**. Corrections made to DUT1.

| | |
|---|---|
| DUT1 = UT1 – UTC = | -0.1 s beginning 0000 UTC 17 July 2021<br>-0.2 s beginning 0000 UTC 02 May 2019<br>-0.1 s beginning 0000 UTC 17 January 2019<br>+0.0 s beginning 0000 UTC 21 September 2018<br>+0.1 s beginning 0000 UTC 15 March 2018<br>+0.2 s beginning 0000 UTC 30 November 2017<br>+0.3 s beginning 0000 UTC 29 June 2017<br>+0.4 s beginning 0000 UTC 30 March 2017<br>+0.5 s beginning 0000 UTC 26 January 2017<br>+0.6 s beginning 0000 UTC 01 January 2017<br>-0.4 s beginning 0000 UTC 17 November 2016 |

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 recent periods where data are available. Data are given at ten-day intervals. Five-day interval data are available in *Circular T*.

**Table 3.** UTC – UTC(NIST).

| **0000 Hours Coordinated Universal Time** | | |
|---|---|---|
| **DATE** | **MJD** | **UTC-UTC(NIST), ns** |
| Jul. 24, 2023 | 60149 | 0.8 |
| Jul. 14, 2023 | 60139 | 0.8 |
| Jul. 04, 2023 | 60129 | -0.2 |
| Jun. 24, 2023 | 60119 | -0.8 |
| Jun. 14, 2023 | 60109 | -0.5 |
| Jun. 4, 2023 | 60099 | -0.6 |
| May 25, 2023 | 60089 | -2.0 |
| May 15, 2023 | 60079 | -2.2 |
| May 5, 2023 | 60069 | -0.8 |
| Apr. 25, 2023 | 60059 | 0.9 |
| Apr. 15, 2023 | 60049 | 1.8 |
| Apr. 5, 2023 | 60039 | 1.6 |
| Mar. 26, 2023 | 60029 | 0.1 |
| Mar. 16, 2023 | 60019 | -0.3 |
| Mar. 6, 2023 | 60009 | -1.1 |
| Feb. 24, 2023 | 59999 | -2.0 |
| Feb. 14, 2023 | 59989 | -1.5 |
| Feb. 4, 2023 | 59979 | 0.7 |
| Jan. 25, 2023 | 59969 | 1.6 |
| Jan. 15, 2023 | 59959 | 1.6 |
| Jan. 5, 2023 | 59949 | 0.8 |
| Dec. 26, 2022 | 59939 | 1.9 |
| Dec. 16, 2022 | 59929 | 1.9 |
| Dec. 6, 2022 | 59919 | 0.1 |
| Nov. 26, 2022 | 59909 | -0.7 |
| Nov. 16, 2022 | 59899 | 1.2 |
| Nov. 6, 2022 | 59889 | 2.3 |

## 2. Broadcast Outages Over Five Minutes and WWVB Phase Perturbations

**Table 4.** Broadcast Outages and Phase Perturbations.

| OUTAGES OF 5 MINUTES OR MORE | | | | | | PHASE PERTURBATIONS 2 ms | | | |
|---|---|---|---|---|---|---|---|---|---|
| Station | July 2023 | MJD | Began UTC | Ended UTC | Freq. | July 2023 | MJD | Began UTC | End UTC |
| WWVB | 12<br>22 | 60137<br>60147 | 2111<br>0134 | 2124<br>0144 | 60 kHz<br>60 kHz | None | | | |
| WWV | 20 | 60146 | 1500 | 1615 | 2.5, 5, 10, 15, 20, 25 MHz | None | | | |
| WWVH | None | | | | | None | | | |

## 3. 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 and to provide the best possible realization of the SI second. Cold-atom cesium fountain frequency standards, currently NIST-F3 and NIST-F4, have served as the U.S. primary standards of time and frequency since 1999. The uncertainty of the primary standards is currently 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 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.

UTC(NIST) is generated as an offset from our real-time scale AT1. Time steps are never used. Instead, the frequency is steered so that the time output remains close to UTC. This is accomplished by using data published by the BIPM in its *Circular T* and by weekly estimates of UTC, which are published by the BIPM as rapid UTC or UTCr. Changes in the frequency may be made as often as once per week and are limited to $\pm 2.3 \times 10^{-14}$. The frequency of UTC(NIST) is kept as stable as possible at other times.

## 4. UTC NIST – AT1 Parameters

Table 5 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 Date, 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 5.** UTC(NIST) - AT1.

| **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) |
| Jul 23 | -37 | -528329.56 | -38.38 | 60126 | 60157 |
| Jun 23 | -37 | -527252.8 | -38.38† | 60124 | 60126 |
| Jun 23 | -37 | -527449.97 | -38.23† | 60103 | 60124 |
| Jun 23 | -37 | -527181.31 | -38.38 | 60096 | 60103 |
| May 23 | -37 | -526912.65 | -38.38† | 60089 | 60096 |
| May 23 | -37 | -526644.69 | -38.28† | 60082 | 60089 |
| May 23 | -37 | -526415.61 | -38.18† | 60076 | 60082 |
| May 23 | -37 | -525998.38 | -37.93 | 60065 | 60076 |
| Apr 23 | -37 | -525315.64 | -37.93† | 60047 | 60065 |
| Apr 23 | -37 | -525049.08 | -38.08† | 60040 | 60047 |
| Apr 23 | -37 | -524858.18 | -38.18 | 60035 | 60040 |
| Mar 23 | -37 | -524514.56 | -38.18† | 60026 | 60035 |
| Mar 23 | -37 | -523714.88 | -38.08† | 60005 | 60026 |
| Mar 23 | -37 | -523676.90 | -37.98 | 60004 | 60005 |
| Feb 23 | -37 | -523183.16 | -37.98† | 59991 | 60004 |
| Feb 23 | -37 | -522617.21 | -37.73 | 59976 | 59991 |
| Jan 23 | -37 | -522390.83 | -37.73† | 59970 | 59976 |
| Jan 23 | -37 | -522126.02 | -37.83† | 59963 | 59970 |
| Jan 23 | -37 | -521595.00 | -37.93† | 59949 | 59976 |
| Jan 23 | -37 | -521443.88 | -37.78 | 59945 | 59949 |
| Dec 22 | -37 | -521066.08 | -37.78† | 59935 | 59945 |
| Dec 22 | -37 | -520838.80 | -37.88† | 59929 | 59935 |
| Dec 22 | -37 | -520267.60 | -38.08 | 59914 | 59929 |
| Nov 22 | -37 | -520002.44 | -37.88† | 59907 | 59914 |
| Nov 22 | -37 | -519513.25 | -37.63† | 59894 | 59907 |
| Nov 22 | -37 | -519210.61 | -37.83† | 59886 | 59894 |
| Nov 22 | -37 | -519134.55 | -38.03 | 59884 | 59886 |
| Oct 22 | -37 | -518411.98 | -38.03† | 59865 | 59884 |
| Oct 22 | -37 | -518146.47 | -37.93† | 59858 | 59865 |
| Oct 22 | -37 | -517956.07 | -38.08 | 59853 | 59858 |
| Sep 22 | -37 | -517346.79 | -38.08† | 59837 | 59853 |
| Sep 22 | -37 | -517157.14 | -37.93† | 59832 | 59837 |
| Sep 22 | -37 | -516816.22 | -37.88 | 59823 | 59832 |

† Rate change in mid-month

*Provisional value

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## Appendix A. List of Symbols, Abbreviations, and Acronyms

**ACTS**
Automated Computer Time Service

**BIPM**
Bureau International des Poids et Mesures

**GPS**
Global Positioning System

**IERS**
International Earth Rotation Service

**MC**
Master Clock

**min**
minute

**MJD**
Modified Julian Date

**ms**
Millisecond

**NIST**
National Institute of Standards and Technology

**ns**
Nanosecond

**SI**
International System of Units

**TA**
Atomic Time

**TAI**
International Atomic Time

**s**
Second

**USNO**
United States Naval Observatory

**UT1**
Universal Time (Astronomical)

**UTC**
Coordinated Universal Time

**µs**
Microsecond