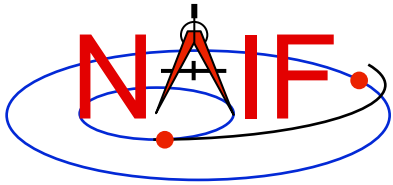


Navigation and Ancillary Information Facility

Leapseconds and Spacecraft Clock Kernels

LSK and SCLK

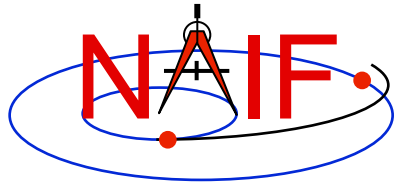
April 2016



Topics

Navigation and Ancillary Information Facility

- **Kernels Supporting Time Conversions**
 - LSK
 - SCLK
- **Forms of SCLK Time Within SPICE**
- **Backup**

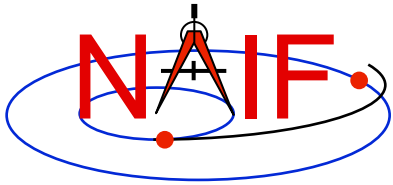


SPICE Time Conversion Kernels

Navigation and Ancillary Information Facility

In most cases one or two kernel files are needed to perform conversions between supported time systems.

- **LSK - The leapseconds kernel is used in conversions between ephemeris time (ET/TDB) and Coordinated Universal Time (UTC).**
- **SCLK - The spacecraft clock kernel is used in conversions between spacecraft clock time (SCLK) and ephemeris time (ET/TDB).**
 - **It's possible there could be two or more clocks associated with a given spacecraft.**

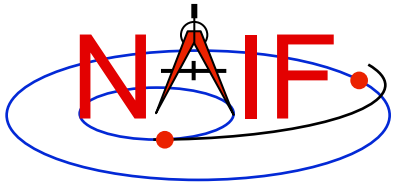


The Leapseconds Kernel (LSK)

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The leapseconds kernel contains a tabulation of all the leapseconds that have occurred, plus additional terms.

- **Used in ET \leftrightarrow UTC and in ET \leftrightarrow SCLK conversions.**
 - Utility programs using LSK: *spkmerge*, *chronos*, *spacit*, etc.
 - Subroutines using LSK: STR2ET, TIMOUT, ET2UTC, etc.
- **Use FURNISH to load it.**
- **NAIF updates the LSK when a new leap second is announced by the International Earth Rotation Service (IERS).**
 - The latest LSK file is always available from the NAIF server.
 - » The latest is always the best one to use.
 - Announcement of each new LSK is made using the “spice_announce” system.
 - » http://naif.jpl.nasa.gov/mailman/listinfo/spice_announce
 - Updates can occur **ONLY** on January 1st and July 1st



LSK File Example

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KPL/LSK

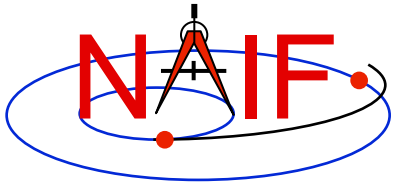
. . . <comments> . . .

\begindata

DELTET/DELTA_T_A = 32.184
DELTET/K = 1.657D-3
DELTET/EB = 1.671D-2
DELTET/M = (6.239996D0 1.99096871D-7)

DELTET/DELTA_AT = (10, @1972-JAN-1
11, @1972-JUL-1
12, @1973-JAN-1
13, @1974-JAN-1
14, @1975-JAN-1
. . . <more leapsecond records> . . .
32, @1999-JAN-1
33, @2006-JAN-1
34, @2009-JAN-1)

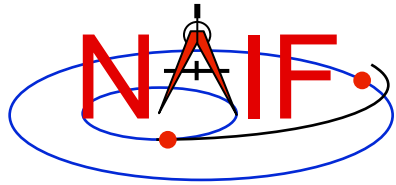
\begintext



Out of Date LSKs

Navigation and Ancillary Information Facility

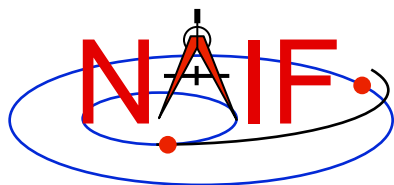
- **An out-of-date leapseconds kernel can be used successfully for conversions that occur at epochs **prior** to the epoch of the first missing leapsecond.**
 - Any conversions of epochs occurring after the epoch of a missing leapsecond will introduce inaccuracies in multiples of one second per missed leapsecond.
- **Using the latest leapseconds kernel to perform conversions at epochs more than six months ahead of the last leapsecond listed may result in an error if, later on, a new leapsecond is declared for a time prior to the epochs you processed.**



The Spacecraft Clock Kernel (SCLK)

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- **The spacecraft clock kernel contains data used in conversions from SCLK to other time systems.**
- **It is required by Toolkit utilities and routines that utilize SCLK time.**
 - For example, the SPICE CK subsystem makes heavy use of spacecraft clock time.
- **Use FURNISH to load it.**
- **Ensure you have the correct version of the SCLK file for your spacecraft since this kernel may be updated rather frequently.**
 - SCLK files are usually maintained on a flight project's database.
 - » For JPL operated missions they can always be found on the NAIF server as well.
 - When using a CK, “correct SCLK” means compatible with that CK.
 - » For reconstructed CKs, this is most likely the latest version of the SCLK.
 - » For “predict” CKs, this is probably the SCLK kernel used when the CK was produced.



SCLK File Example

Navigation and Ancillary Information Facility

KPL/SCLK

. . . <comments> . . .

\begindata

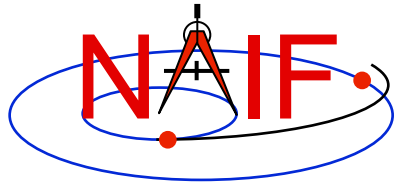
```
SCLK_KERNEL_ID          = ( @2009-12-07/18:03:04.00 )
SCLK_DATA_TYPE_74      = ( 1 )
SCLK01_TIME_SYSTEM_74  = ( 2 )
SCLK01_N_FIELDS_74     = ( 2 )
SCLK01_MODULI_74       = ( 4294967296 256 )
SCLK01_OFFSETS_74      = ( 0 0 )
SCLK01_OUTPUT_DELIM_74 = ( 1 )
```

```
SCLK_PARTITION_START_74 = ( 0.00000000000000E+00
. . . <more partition start records> . . .
2.4179319500800E+11 )
```

```
SCLK_PARTITION_END_74   = ( 2.0692822929300E+11
. . . <more partition end records> . . .
1.0995116277750E+12 )
```

```
SCLK01_COEFFICIENTS_74 = (
0.00000000000000E+00   -6.3119514881600E+08   1.00000000000000E+00
1.2098765056000E+10   -5.8393434781600E+08   1.00000000000000E+00
. . . <more coefficient records> . . .
2.4179319365000E+11   3.1330950356800E+08   9.9999997500000E-01 )
```

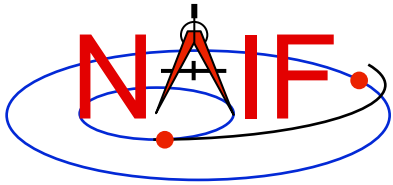
\begintext



Forms of SCLK Time Within SPICE

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- **SCLK time in SPICE is represented in two different ways:**
 - a character string
 - a double precision number called “ticks”
- **A SCLK character string is composed of one or more cascading integer numbers – similar to a digital clock.**
 - This form is derived from clock values represented by sets of bits or bytes, found in downlinked telemetry, whether for science or engineering/housekeeping data.
- **A SCLK value encoded as a double precision number (called “ticks”) is used within SPICE because it’s easy to convert this to other time systems, such as ephemeris time (ET, also called TDB).**



Sample SCLK String

Navigation and Ancillary Information Facility

The Cassini orbiter SCLK time string consists of three fields separated by delimiters.

Partition
Delimiter

1 / 1609504792 . 123

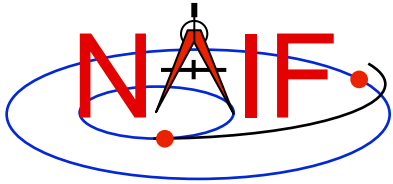
Clock Field Delimiter*
(**not** a decimal point)

Partition: Accounts for
clock resets or counter
roll-over.

Least Significant Clock Field:
Ranges from 0 to 255. Nominally
1/256th of a second increment.

Most Significant Clock Field:
Ranges from 0 to 4294967295 ($2^{32}-1$). Nominally
1 second increment.

* Several SCLK delimiter characters are available in SPICE. See "SCLK Required Reading" for details.



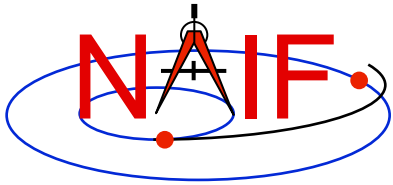
What is a Partition?

Navigation and Ancillary Information Facility

①/1609504792.123

The portion of the SCLK string circled above indicates the partition to which the remaining portion of the string is related.

- A partition is a NAIF-created construct to handle spacecraft clock rollovers or resets.
- When referring to epochs in the first partition, the leading '1/' may be omitted.
- Many modern spacecraft don't use a partition other than 1.

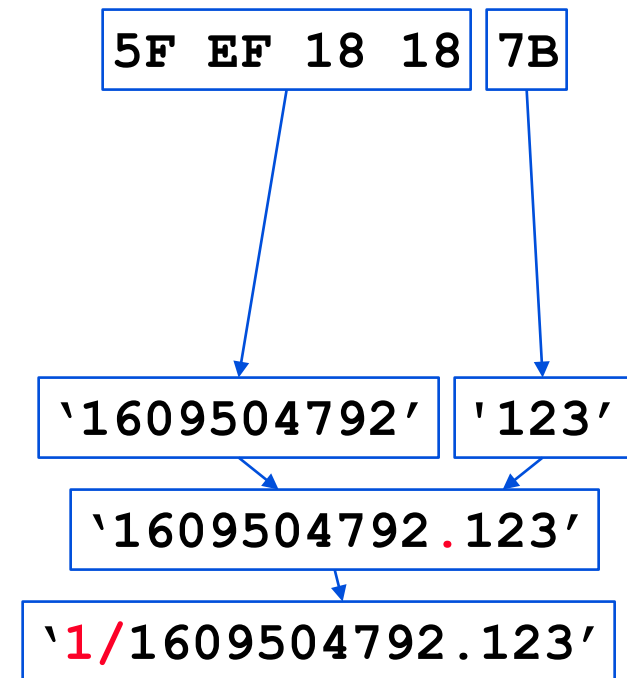


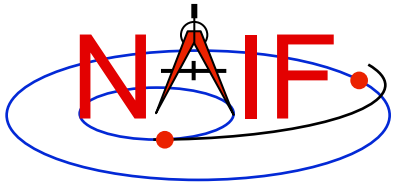
Constructing an SCLK String

Navigation and Ancillary Information Facility

Usually SCLK tags in raw telemetry are represented by sets of bits or bytes. Such tags must be converted to SCLK strings used in SPICE. This is an example of how it is done for the sample CASSINI SCLK string from previous slides.

- Start with a 5-byte CASSINI TLM SCLK
 - The first four bytes are an unsigned integer representing seconds
 - The last byte is an unsigned byte representing fractional seconds (as a count of 1/256 second ticks)
- Convert integer and fractional seconds to two strings
- Concatenate strings together using a recognized delimiter ('.', ':', etc)
- Add the partition number and delimiter
 - Optional, for most modern missions it may be omitted (not so for Chandrayaan-1)



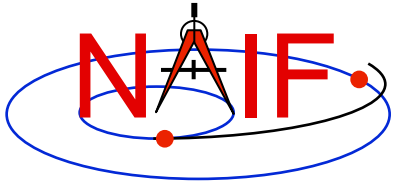


Encoded SCLK (Ticks)

Navigation and Ancillary Information Facility

The representation of SCLK time in the SPICE system is a double precision encoding of a SCLK string.

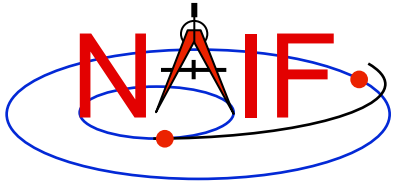
- **Encoded spacecraft clock values represent “ticks since spacecraft clock start.”**
 - The time corresponding to tick “0” is mission dependent and does not necessarily relate to launch time. It is often an arbitrary epoch occurring before launch.
- **A tick is the smallest increment of time that a spacecraft clock measures.**
 - For example, in the case of the Cassini orbiter this is nominally 1/256th of a second.
- **Encoded SCLK increases continuously independent of leapseconds, clock resets, and clock rollovers.**



Additional Info on LSK and SCLK

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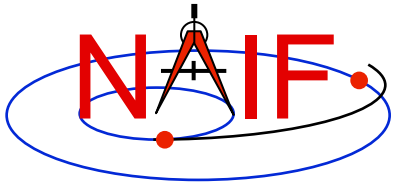
- **For more information about LSK, SCLK, and time conversions, look at the following documents**
 - Time Required Reading
 - SCLK Required Reading
 - Time tutorial
 - Most Useful SPICELIB Routines
 - headers for the routines mentioned in this tutorial
 - CHRONOS User's Guide
 - Porting_kernels tutorial
- **Related documents**
 - Kernel Required Reading
 - CK Required Reading



Backup

Navigation and Ancillary Information Facility

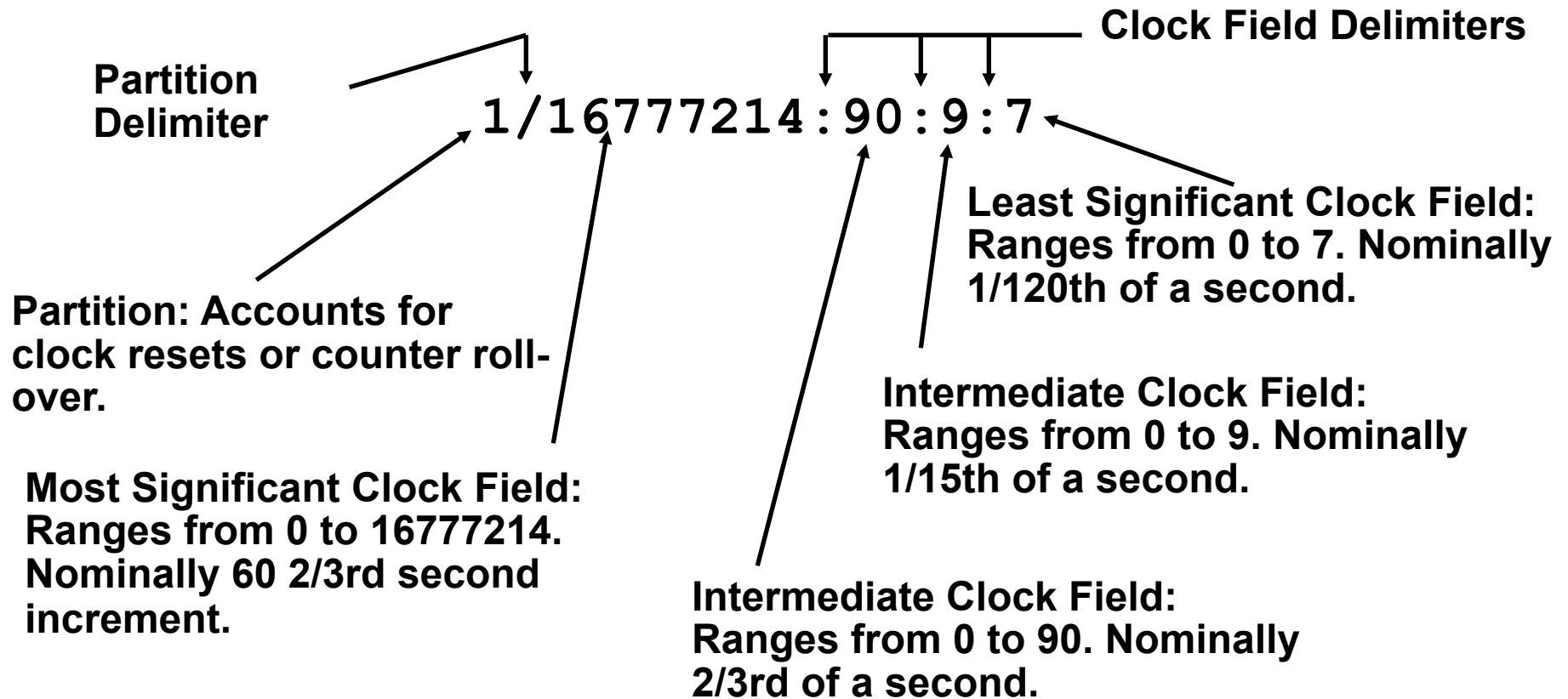
- **Examples of SCLK strings**
- **SCLK Interface Routines**

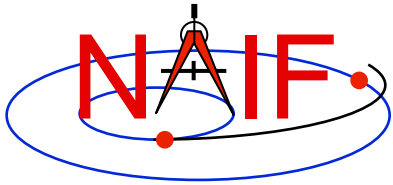


Sample Galileo SCLK String

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The Galileo spacecraft SCLK time string consists of five fields separated by delimiters.





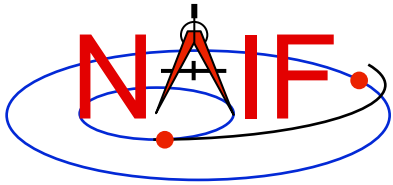
More Sample SCLK Strings

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The following are examples of SCLK strings* from missions using SPICE.

- **Cassini**
1/1334314108.134
- **DS1**
1/67532406.010
- **Galileo**
1/16777214:90:9:7
- **Genesis**
1/666230496.204
- **MGS**
1/655931592.103
- **MPF**
1/559627908.058
- **Mariner 9**
1/11542909
- **Mars Odyssey**
1/687231994.091
- **NEAR**
1/40409721942
- **Stardust**
1/697451990.042
- **Viking 1&2**
1/32233616
- **Voyager 1&2**
1/05812:00:001
- **Mars Express**
1/0090979196.29713
- **Venus Express**
1/0033264000.50826
- **Rosetta**
1/0101519975.65186

- * When clock strings are used as arguments in modules they must be contained in quotes:
- Single quotes for Fortran
 - Double quotes for C
 - Single quotes for IDL and MATLAB



SCLK Interface Routines

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Convert SCLK times using the following routines

| | |
|--------------------------------------------|---------------------------------------|
| SCS2E (SC, SCLKCH, ET) | (SCLK String⇒ET) |
| SCE2S (SC, ET, SCLKCH) | (ET⇒SCLK String) |
| SCT2E (SC, SCLKDP, ET) | (Encoded SCLK⇒ET) |
| SCE2C ¹ (SC, ET, SCLKDP) | (ET⇒Continuous Encoded SCLK) |
| SCE2T (SC, ET, SCLKDP) | (ET⇒Discrete Encoded SCLK) |
| SCENCD (SC, SCLKCH, SCLKDP) | (Encode SCLK string to number) |
| SCDECD (SC, SCLKDP, SCLKCH) | (Decode SCLK number to string) |

¹ Use SCE2C (not SCE2T) for C-kernel data access.