SMPTE STANDARD

Generation and Alignment of Interface Signals to the SMPTE Epoch

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Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in Standards Operations Manual.

SMPTE ST 2059-1 was prepared by the Technology Committee 32NF.

Intellectual Property

SMPTE draws attention to the fact that it is claimed that compliance with this Standard may involve the use of one or more patents or other intellectual property rights (collectively, "IPR"). The Society takes no position concerning the evidence, validity, or scope of this IPR.

Each holder of claimed IPR has assured the Society that it is willing to License all IPR it owns, and any third party IPR it has the right to sublicense, that is essential to the implementation of this Standard to those (Members and non-Members alike) desiring to implement this Standard under reasonable terms and conditions, demonstrably free of discrimination. Each holder of claimed IPR has filed a statement to such effect with SMPTE. Information may be obtained from the Director, Standards & Engineering at SMPTE Headquarters.

Attention is also drawn to the possibility that elements of this Standard may be subject to IPR other than those identified above. The Society shall not be responsible for identifying any or all such IPR.

Introduction

This section is entirely informative and does not form an integral part of this Engineering Document.

This Standard is one part of a series of documents defining a mechanism for creating, distributing and using time synchronization messages in motion imaging and related systems, including but not limited to television, digital cinema and film. This Standard specifically deals with the deterministic generation of interface signals.

Video and Audio systems often operate in a synchronous manner wherein all signals are locked to the same master generator's timebase with a deterministic phase of signals with respect to that master generator. This is accomplished using reference signals such as black burst or tri-level sync for video, DARS for audio and SMPTE ST 12-1 Time Code. These signals are delivered to equipment to be synchronized through dedicated tree-shaped distribution infrastructures. Equipment uses these signals to derive their output signal timing.

Using distribution of precision time, definition of an Epoch ("SMPTE Epoch") and the relationship of signals to that Epoch, equipment can generate legacy reference signals for use in locking legacy equipment, or can internally derive the timing of video and audio essence signals on their interfaces. In addition, equipment requiring Time Code and/or Time Code-like time and date can internally derive it.

This method differs significantly from existing methods of direct distribution of end-use signals, such as video, DARS or Time Code. Slave devices receiving precision time must synthesize the necessary signals locally.

This Standard defines a point in time, the SMPTE Epoch, and the phase relationship (alignment) of various signals to it. Distributing elapsed time since the SMPTE Epoch to equipment enables that equipment to generate signals with deterministic frequency and phase. In addition, this standard specifies the logic and formulae to deterministically generate signals.

One means of distributing time is through the use of the IEEE 1588-2008 Precision Time Protocol (PTP). The SMPTE ST 2059-2 Profile for PTP specifies operating parameters and additional metadata for the professional broadcast environment.

1 Scope

This Standard defines:

1) A point in time, the SMPTE Epoch, which is used for alignment of all real-time signals referenced in this Standard;

2) The alignment of these signals to the SMPTE Epoch;

3) Formulae which specify the ongoing alignment of these signals to time since the SMPTE Epoch;

4) Formulae which specify the calculation of SMPTE ST 12-1 Time Address values and SMPTE ST 309 date values from SMPTE Profile IEEE 1588-2008 PTP data.

Note: Implementers are encouraged to read both SMPTE ST 2059-1 and SMPTE ST 2059-2 as a pair.

2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:”

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword “reserved” indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword “forbidden” indicates “reserved” and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; followed by formal languages; then figures; and then any other language forms.

3 Normative References

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 170:2004) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 170M-2004). Documents with the same root number (e.g. 170) and publication year (e.g. 2004) are functionally identical.

The following Standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

SMPTE ST 12-1:2014, Time and Control Code

SMPTE ST 125:2013, SDTV Component Video Signal Coding 4:4:4 and 4:2:2 for 13.5 MHz and 18 MHz Systems

SMPTE ST 170:2004, Television — Composite Analog Video Signal — NTSC for Studio Applications

SMPTE ST 274:2008, Television —1920 × 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates

SMPTE ST 293:2003, Television — 720 × 483 Active Line at 59.94-Hz Progressive Scan Production —Digital Representation

SMPTE ST 296:2012, 1280 × 720 Progressive Image 4:2:2 and 4:4:4 Sample Structure — Analog and Digital Representation and Analog Interface

SMPTE ST 309:2012, Transmission of Date and Time Zone Information in Binary Groups of Time and Control Code

SMPTE ST 318:1999, Television and Audio — Synchronization of 59.94- or 50-Hz Related Video and Audio Systems in Analog and Digital Areas — Reference Signals

SMPTE ST 2048-2:2011, 2048 × 1080 Digital Cinematography Production Image FS/709 Formatting for Serial Digital Interface

SMPTE ST 2059-2:2015, SMPTE Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications

AES3-3:2009, AES Standard for Digital Audio — Digital Input-Output Interfacing — Serial Transmission Format for Two-Channel Linearly-Represented Digital Audio Data — Part 3: Transport

AES11:2009, AES Recommended Practice for Digital Audio Engineering — Synchronization of Digital Audio Equipment in Studio Operations

Recommendation ITU-R BT.601-7 (03/2011), Studio Encoding Parameters of Digital Television for Standard 4:3 and Wide-Screen 16:9 Aspect Ratios

Recommendation ITU-R BT.1358-1-2007, Studio Parameters of 625 and 525 Line Progressive Television Systems

Recommendation ITU-R BT.1700-2005, Characteristics of Composite Video Signals for Conventional Analogue Television Systems

4 Definition of Terms and Acronyms

4.1 AES

Audio Engineering Society. This is a professional society and Standards Development Organization focused on audio.

4.2 Alignment Point

The Alignment Point is a defined temporal reference point in a signal.

4.3 Daily Jam

As defined in SMPTE ST 2059-2.

4.4 DARS

An AES3 Digital Audio Reference Signal conforming to AES11.

4.5 DST

Daylight Saving Time. This is an offset to local time in effect in summer months in many countries.

4.6 EAV

End Active Video. This codeword represents the end of the active video line and the beginning of the horizontal blanking interval.

4.7 Epoch

An Epoch is a point in time chosen as the origin of a new or distinctive era. Time is counted from the epoch so that events can be specified unambiguously thereafter. In the context of this application of the term, the ‘new or distinctive era’ is characterized as one where the phase of signals with a specified relationship to the Epoch is established.

4.8 IEEE

Institute of Electrical and Electronic Engineers. This is a professional association and Standards Development Organization.

4.9 ITU

International Telecommunications Union. This is a specialized agency of the United Nations that is responsible for issues that concern information and communication technologies.

4.10 Local Time

As defined in SMPTE ST 2059-2.

4.11 LTC

Linear Time Code. This is the time code specified in SMPTE ST12-1, originally intended for recording on a longitudinal audio track of a tape recorder.

4.12 MJD

Modified Julian Date. The Modified Julian Date. is a zero based Gregorian calendar day number with an origin of 00:00:00 hours UTC time, 1858-11-17. MJD is specified by a number with five significant figures.

4.13 NTSC

National Television Standards Committee. This is a color encoding system for analog composite television used in broadcast television systems in most countries broadcasting 480i.

4.14 PAL

Phase Alternate Line. This is a color encoding system for analog composite television used in broadcast television systems in most countries broadcasting 576i.

4.15 PTP

Precision Time Protocol as defined in IEEE Standard 1588-2008.

4.16 SAV

Start of Active Video. This codeword represents the end of the horizontal blanking interval and the beginning of the active video line.

4.17 TAI

International Atomic Time (**TAI**, from the French name **Temps Atomique International**) This time reference scale was established by the BIPM (Bureau International des Poids et Mesures) on the basis of atomic clock readings from various laboratories around the world.

4.18 Time Address

The Time Address of a frame (of video) as defined by SMPTE ST 12-1.

4.19 UTC

Coordinated Universal Time. This is the primary time standard by which the world regulates clocks and time.

5 Arithmetic Operators

The arithmetic operators used in the conversion formulae in this document are defined as follows:

+	Addition
−	Subtraction
×	Multiplication
/	Division
%	Modulus operator (remainder from the division of two integers)
int(x)	Rounds the element ‘x’ to the nearest integer towards zero
ceiling(x)	Rounds the element ‘x’ to the nearest integer towards positive infinity
>	greater than
≥	greater than or equal to
<	less than

=	assignment
==	equal to (comparative)
$\neq$	not equal to

Note: These definitions differ slightly from earlier SMPTE documents (EG40) and are intended to be more precise in definition.

Note: Implementers must be aware that sufficient precision is necessary in calculations to ensure that rounding or truncation operations will not create errors in the end results.

6 SMPTE Epoch and Signal Alignment

The SMPTE Epoch shall be 1970-01-01T00:00:00TAI, which is the same as the PTP Epoch specified in IEEE Standard 1588-2008.

Note: The SMPTE Epoch is 63072010 seconds before 1972-01-01T00:00:00Z (UTC).

Periodic signals in scope of this standard shall have a defined Alignment Point and shall be aligned such that the Alignment Point would have occurred at the SMPTE Epoch and the signals subsequently maintained their periodicity in accordance with the master time reference used for their generation.

7 Video Signal Generation

For video signals documented in this Standard the Alignment Point is the beginning of vertical sync in an analog signal or the corresponding sample in a digital signal. When color framing is employed, the Alignment Point corresponds to the first field of the color field sequence. For interfaces not documented in this standard the Alignment Point shall be defined in those Standards.

Note: For video signals stored as files, vertical interval may or may not be germane. This document addresses video signals at an interface.

Video signals shall be generated using alignment to the SMPTE Epoch and the formulae in the following sections (or by an alternative method yielding the identical results).

The following tables and formulae describe the relationships of SMPTE and ITU-R standardized legacy video signals with respect to time since the SMPTE Epoch for each video signal interface. This does not imply that generators need to directly use these equations in the implementation of signals; however any implementation shall produce results identical to those produced by the equations.

Note: The following tables utilize variables derived directly from the underlying SMPTE and ITU-R legacy video standards. As a result of this, there are several variables (e.g., "Cf" or "CF") which are in effect case sensitive, and may differ between legacy SD and legacy HD usage. This is due to the fact that the underlying SMPTE and ITU-R legacy video standards evolved over time, and were not written necessarily with the thought that readers might be referring to more than one simultaneously nor that signals would be generated using an underlying core synchronization mechanism based on time. Implementers need to be careful in application of the following equations to tie back to the underlying legacy standards.

The values in the tables are derived from the reference SMPTE and ITU-R standards for the individual image formats and their interfaces. The following variables and terms are used in the tables and formulae in this section:

Cf is the duration of a color field sequence in fields.
Note: This is not the same as variable “CF” defined in Section 9.

ColorField is the value of the color field counter (one-based). ColorField value 1 is the 1st field of the color field sequence (as defined in the reference standards).

H is the duration of an entire video line in sample clock periods.

HA is the duration of an active video line in sample clock periods.

L is the line number of the vertical Alignment Point (as defined in the reference standards).

LineNumber is the value of the vertical counter (one-based). LineNumber 1 is line 1 of the frame (as defined in the reference standards).

NextAlignmentPoint is the value of **t** at the next Alignment Point for that signal.

NextColorFrameAlignmentPoint is the value of **t** at the next Alignment Point for that signal where the color frame sequence is also aligned.

P is the sample number of the horizontal Alignment Point (as defined in the reference standards).

R is the video frame rate in frames per second.

SampleWordNumber is the value of the horizontal counter (zero-based). SampleWordNumber 0 is the 1st active sample of the line (as defined in the reference standards).

SR is the frequency of the sample clock in Hz.

t is elapsed continuous time from SMPTE Epoch in seconds.
Note: This is the same as PTP time for PTP-based implementations.

T is the period of the sampling clock in seconds.

Tenfield is the value of the ten-field counter (one-based). Tenfield value 1 corresponds to the start of the ten-field sequence identification (as defined in SMPTE ST 318).

V is the duration of a complete frame in lines.

7.1 Analog Standard Definition Television

For analog standard definition television, the Alignment Point shall be (as defined in the associated reference standards) the horizontal 0h point at the beginning of the vertical alignment line L, and in the case of composite signals, the frame containing color field 1. See Figure 7 of SMPTE ST 170. The 0h point is defined as the half amplitude point of the leading edge of the horizontal sync pulse at the beginning of a line. This is shown in Figure 5 of SMPTE ST 170 and Figure 1 of ITU-R BT.1700. Line numbers increment at 0h.

Note: ‘Analog Standard Definition Television’ includes both legacy video black burst (color black) reference signals as well as legacy analog video essence signals.

Table 1 – Signal generation – Analog SD Television

Television System	Frame Rate [Hz] R	Reference Standard	Vertical Alignment Line L	Total Lines V	Color sequence duration [fields] Cf
NTSC 525 lines	30/1.001	SMPTE ST 170	4	525	4
625 PAL 625 lines	25	ITU-R.BT.1700	1	625	8
525 PAL[1] 525 lines	30/1.001	ITU-R.BT.1700	1	525	8

Note 1: 525 PAL is often colloquially referred to as "PAL-M"

$$NextAlignmentPoint = \frac{int\big((t \times R) + 1\big)}{R}$$

$$NextColorFrameAlignmentPoint = \frac{int\big((t \times \mathrm{R\ x\ 2\ /\ Cf}) + 1\big)}{\mathrm{R\ x\ 2\ /\ Cf}}$$

$$LineNumber = \big(int\big(t \times R \times V + (L-1)\big)\ \%\ V\big) + 1$$

$$ColorField = \left(int\left(2 \times \frac{t \times R \times V + (L-1)}{V}\right)\ \%\ Cf\right) + 1$$

Note: The value of ColorField changes at the beginning of the field, not at the alignment point.

7.1.1 SMPTE ST 318 Ten-Field Sequence Identification

SMPTE ST 318 defines the use of composite analog video signals for reference signal purposes. SMPTE ST 318 further defines the generation and encoding of a ten-field Sequence Identification signal for use in 30/1.001 frame rate systems. The video frame carrying the field identified as the first in the sequence shall be aligned to the SMPTE Epoch. This corresponds to an output value of one in the equation below.

$$TenField = \left(int\left(2 \times \frac{t \times R \times V + (L-1)}{V}\right)\ \%\ 10\right) + 1$$

7.2 Digital Standard Definition Television

For digital standard definition television, the Alignment Point shall be the horizontal alignment sample P of the vertical alignment line L as shown in Table 2. The horizontal alignment sample P is the Y sample that is coincident with the 0h point of the corresponding analog signal. Line numbers increment immediately after the last sample of the digital active line (at the first word of the EAV sequence).

Table 2 – Signal Generation – Digital Standard Definition Television

Television System	Frame Rate [Hz]	Reference Standard	Horizontal Alignment (Y Sample) P	Vertical Alignment Line L	Y samples per total line H	Y Samples per active line HA	Total Lines V	Sample Clock Frequency SR [Hz]
525 line Interlaced 13.5 MHz Sampling	30/1.001	SMPTE ST 125	736	4	858	720	525	13.5×10^6
625 line Interlaced 13.5 MHz Sampling	25	SMPTE ST 125	732	1	864	720	625	13.5×10^6
525 line Interlaced 18 MHz Sampling	30/1.001	SMPTE ST 125	981.5	4	1144	960	525	18×10^6
625 line Interlaced 18 MHz Sampling	25	SMPTE ST 125	976	1	1152	960	625	18×10^6
525 Line Progressive 27 MHz Sampling	60/1.001	SMPTE ST 293 ITU-R BT.1358-1	736	7	858	720	525	27×10^6
625 Line Progressive 27 MHz Sampling	50	ITU-R BT.1358-1	732	1	864	720	625	27×10^6

$$T = \frac{1}{SR}$$

$$NextAlignmentPoint = \left(int\left(\frac{t}{H \times V \times T} + 1\right) \times \ (H \times V \times T)\right)$$

$$SampleWordNumber = \left(int\left(\frac{t}{T}\right) + P\right)\ \% \, H$$

$$LineNumber = \left(\left(int\left(\frac{\left(\frac{t}{T} + P - HA\right)}{H}\right) + (L-1)\right)\ \% \, V\right) + 1$$

7.3 Analog High Definition Television

For analog High Definition (HD) television, the Alignment Point is defined as horizontal 0h point at the beginning of the line 1. The horizontal 0h point is defined as the positive zero-crossing of the tri-level sync pulse at the beginning of a line.

Note: ‘Analog High Definition Television’ includes both tri-level sync signals and HD analog video essence signals.

Table 3 – Signal generation – Analog High Definition Television

Television System and Reference Standard	Frame Rate [Hz]	Reference Standard System Number	Clocks per total line H	Total Lines V	Sample Clock SR Frequency [Hz]
750 line progressive (1280 x 720 active image area) SMPTE ST 296	60	1	1650	750	74.25×10^6
	60/1.001	2	1650	750	$74.25 \times 10^6 / 1.001$
	50	3	1980	750	74.25×10^6
	30	4	3300	750	74.25×10^6
	30/1.001	5	3300	750	$74.25 \times 10^6 / 1.001$
	25	6	3960	750	74.25×10^6
	24	7	4125	750	74.25×10^6
	24/1.001	8	4125	750	$74.25 \times 10^6 / 1.001$
1125 line progressive and interlaced (1920 x 1080 active image area) SMPTE ST 274	60	1	2200	1125	148.5×10^6
	60/1.001	2	2200	1125	$148.5 \times 10^6 / 1.001$
	50	3	2640	1125	148.5×10^6
	30	4 & 7	2200	1125	74.25×10^6
	30/1.001	5 & 8	2200	1125	$74.25 \times 10^6 / 1.001$
	25	6 & 9	2640	1125	74.25×10^6
	24	10	2750	1125	74.25×10^6
	24/1.001	11	2750	1125	$74.25 \times 10^6 / 1.001$
1125 line progressive (2048 x 1080 image container) SMPTE ST 2048-2	60	1	2200	1125	148.5×10^6
	60/1.001	2	2200	1125	$148.5 \times 10^6 / 1.001$
	50	3	2640	1125	148.5×10^6
	48/1.001	4	2750	1125	$148.5 \times 10^6 / 1.001$
	48	5	2750	1125	148.5×10^6
	30	6	2200	1125	74.25×10^6
	30/1.001	7	2200	1125	$74.25 \times 10^6 / 1.001$
	25	8	2640	1125	74.25×10^6
	24	9	2750	1125	74.25×10^6
	24/1.001	10	2750	1125	$74.25 \times 10^6 / 1.001$

$$T = \frac{1}{SR}$$

$$NextAlignmentPoint = \left(int\left(\frac{t}{H \times V \times T} + 1 \right) \times \ (H \times V \times T) \right)$$

$$SampleWordNumber = \left(int\left(\frac{t}{T} \right) + P \right) \ \% \ H$$

$$LineNumber = \left(int\left(\frac{t}{H \times T} \right) \ \% \ V \right) + 1$$

7.4 Digital High Definition Television

For digital high definition television, the Alignment Point shall be the horizontal alignment sample P of line 1. The horizontal alignment sample P is defined in the reference standards as 260 samples before the first sample of the digital active line (immediately after the end of SAV) for 750 line formats and 192 samples before the first sample of the digital active line (immediately after the end of SAV) for 1125 line formats. Line numbers increment immediately after the last sample of the digital active line (at the first word of the EAV sequence).

Table 4 – Signal Generation – Digital High Definition Television

Television System and Reference Standard	Frame Rate [Hz]	Reference Standard System Number	Horizontal Alignment (Y Sample) P	Y samples per total line H	Y Samples per active line HA	Total Lines V	Sample Clock Frequency SR [Hz]
750 line progressive (1280 x 720 active image area) SMPTE ST 296	60	1	1390	1650	1280	750	74.25×10^6
	60/1.001	2	1390	1650	1280	750	$74.25 \times 10^6 / 1.001$
	50	3	1720	1980	1280	750	74.25×10^6
	30	4	3040	3300	1280	750	74.25×10^6
	30/1.001	5	3040	3300	1280	750	$74.25 \times 10^6 / 1.001$
	25	6	3700	3960	1280	750	74.25×10^6
	24	7	3865	4125	1280	750	74.25×10^6
	24/1.001	8	3865	4125	1280	750	$74.25 \times 10^6 / 1.001$
1125 line progressive and interlaced (1920 x 1080 active image area) SMPTE ST 274	60	1	2008	2200	1920	1125	148.5×10^6
	60/1.001	2	2008	2200	1920	1125	$148.5 \times 10^6 / 1.001$
	50	3	2448	2640	1920	1125	148.5×10^6
	30	4 & 7	2008	2200	1920	1125	74.25×10^6
	30/1.001	5 & 8	2008	2200	1920	1125	$74.25 \times 10^6 / 1.001$
	25	6 & 9	2448	2640	1920	1125	74.25×10^6
	24	10	2558	2750	1920	1125	74.25×10^6
	24/1.001	11	2558	2750	1920	1125	$74.25 \times 10^6 / 1.001$
1125 line progressive (2048 x 1080 image container) SMPTE ST 2048-2	60	1	2008	2200	2048	1125	148.5×10^6
	60/1.001	2	2008	2200	2048	1125	$148.5 \times 10^6 / 1.001$
	50	3	2448	2640	2048	1125	148.5×10^6
	48/1.001	4	2008	2750	2048	1125	$148.5 \times 10^6 / 1.001$
	48	5	2008	2750	2048	1125	148.5×10^6
	30	6	2558	2200	2048	1125	74.25×10^6
	30/1.001	7	2558	2200	2048	1125	$74.25 \times 10^6 / 1.001$
	25	8	2448	2640	2048	1125	74.25×10^6
	24	9	2558	2750	2048	1125	74.25×10^6
	24/1.001	10	2558	2750	2048	1125	$74.25 \times 10^6 / 1.001$

$$T = \frac{1}{SR}$$

$$NextAlignmentPoint = \left(int\left(\frac{t}{H \times V \times T} + 1\right) \times \ (H \times V \times T) \right)$$

$$SampleWordNumber = \left(int\left(\frac{t}{T}\right) + P\right) \% \, H$$

$$LineNumber = \left(int\left(\frac{\frac{t}{T} + P - HA}{H}\right) \% \, V\right) + 1$$

7.5 Ultra High Definition Television (UHDTV)

UHDTV interfaces shall contain the specification of their SMPTE Epoch Alignment Point and formulae for their signal generation as part of the interface standard document.

8 Audio Signal Generation

Signals are generated using alignment to the SMPTE Epoch and associated formulae. The following formulae describe the relationships of AES standardized audio signals with respect to time since the SMPTE Epoch. This does not imply that generators need to directly use these equations in the implementation of signals; however any implementation shall produce results identical to those produced by the equations.

The values in the formulae are derived from the reference AES standards. The following variables and terms are used in the formulae in this section:

FCnt is the frame position within an AES3 block (zero-based).
NextAlignmentPoint is the value of **t** at the next Alignment Point for that signal.
SR is the frequency of the AES3 audio sample clock in Hz.
t is elapsed continuous time from SMPTE Epoch in seconds.
Note: This is the same as PTP time for PTP-based implementations.
Tsamp is the sample clock period.
tsCnt is the time slot position within an AES3 subframe (zero-based).
TtsClk is the time slot clock period.

8.1 AES3 Digital Audio

AES3 Digital Audio signals shall be generated using alignment to the SMPTE Epoch and the associated formulae.

Note: AES11 specifies alignment of either the X or Z preamble of the signal to video vertical sync. This standard further constrains alignment by specifying that at the SMPTE Epoch the AES alignment is the Z preamble.

Note: “Digital Audio” includes both digital audio reference signals (DARS) as well as digital essence signals.

The Alignment Point shall be the start of the AES3 digital audio block Z preamble (See AES3-3).

$$Tsamp = \frac{1}{SR}$$

$$NextAlignmentPoint = \left(int\left(\frac{t}{(192 \times Tsamp)} + 1\right) \times (192 \times \ Tsamp)\right)$$

$$TtsClk = \frac{Tsamp}{2 \times 32}$$

To calculate the time slot position within a subframe, tsCnt, in terms of clocks of period TtsClk:

$$tsCnt = int\left(\frac{t}{TtsClk}\right)\ \%\ 32$$

To calculate the current frame position within a block, FCnt:

$$FCnt = int\left(\frac{t}{Tsamp}\right)\ \%\ 192$$

Note: FCnt has a value of zero for the frame containing the Z preamble.

8.2 Audio/Video Alignment Cadence

In 60/1.001-based and 30/1.001-based video systems with 48 kHz synchronous audio embedded in ancillary data space, there exists a video to audio alignment cadence which results in periodic alignment of audio and video. For example, 8008 audio samples are distributed over 5 video frames at the 30/1.001 frame rate. The “ten-field Sequence Identification” optionally signaled in SMPTE ST 318 can be used to control the cadence when embedding AES3 digital audio signals in SDI video signals. See SMPTE ST 272, SMPTE ST 299-1, SMPTE ST 318 and AES11 for additional information.

For video systems with fractions of AES3 frames in one video frame, alignment of video and audio will occur on every nth frame (e.g. n = 5 at 30/1.001 frames-per-second), which means that every nth Alignment Point of the video signal is coincident with the start of the X or Z preamble of the AES3 signal and shall comply with the requirements of AES11 Section 5.3.4 (Video reference). AES11 further states that the frame when alignment occurs will be the frame identified by an indicator included in the video reference, which shall be the ten-field sequence identification of SMPTE ST 318. The Epoch alignment specifications in this document result in the aligned frame being the one containing the first field of the SMPTE ST 318 ten-field sequence.

9 SMPTE ST 12-1 Time Code Generation

9.1 Introduction and Overview (Informative)

Generation of SMPTE ST 12-1 time-of-day Time Code is divided into generation of the SMPTE ST 12-1 LTC codeword and calculation of the SMPTE ST 12-1 Time Address value for the payload. Time Code generation requires the use of several metadata elements of the SMPTE Profile defined in SMPTE ST 2059-2.

The Master and Slave share a high precision representation of the facility clock (the Local PTP time.) The 1588 SM TLV messages carrying the SMPTE Profile metadata are issued once per second and may experience slight delays from network transit times and internal processing in the slave before being ready for use. These delays need to be considered when designing and implementing slave devices.

The SMPTE ST 12-1 Time Address value for the payload is calculated from the PTP time using the SMPTE Profile Metadata as defined in SMPTE ST 2059-2. This typically yields the time-of-day portion of local time (as defined in SMPTE ST 2059-2).

The SMPTE ST 12-1 Time Code Binary Groups can optionally include the date encoded in SMPTE ST 309 format. SMPTE ST 2059-1 defines the formulae to calculate the year, month and day or Modified Julian Date (MJD) information.

Slave devices perform a 'jam' function which causes the current local time to be forced into the Time Code Time Address. This is performed at device startup and initialization, and daily in many systems.

For 1/1.001 based systems, there is not an integer number of Time Code codewords in a day. These systems use drop frame Time Code and require a Daily Jam event to remove the time error accumulated by the drop frame counting rules. The jam event places a Time Address value into the Time Code payload at a specified time of day from which counting continues. SMPTE EG 35 "Time and Control Code Time Address Clock Precision for Television, Audio and Film" provides background on the time errors in drop frame Time Code and the issue with a non-integer number of frames in a day.

The Daily Jam is usually set to occur at an operationally convenient time, typically during the early morning hours in local time, and is not always coincident with the application time defined by civil authorities for leap second or DST adjustments. At the Daily Jam time transmitted in the SMPTE Profile, a new value of local time is calculated and placed into the Time Address of the next Time Code codeword, from which point counting continues. When Time Code color frame identification is in effect, further calculations are used to establish the correct subsequent video frame in the color frame sequence at which to jam the new Time Address value.

In systems with Daily Jam in use, discontinuities in the SMPTE ST12-1 Time Address (such as Leap Seconds and Daylight Saving Time changes) take effect at the Daily Jam event time. In systems without Daily Jam in use, discontinuities are applied manually at a time determined by the operator of the facility.

Note that the SMPTE ST 12-1 LTC codeword is indirectly aligned to the related video frame via the formulae and is within the tolerances specified in SMPTE ST 12-1.

This Standard provides formulae which describe the relationships of SMPTE ST 12-1 Time Code with respect to IEEE 1588-2008 PTP time when aligned to the SMPTE Epoch. Other methods and formulae which achieve identical results can be used.

9.1.1 Regarding Generation of SMPTE ST 12-1 Codewords (Informative)

Section 9.4.4 describes a function which converts local time to year, month and day. The calculations in the following sections (9.4.2.x and 9.4.3.x) depend on some of the values produced by this function.

SMPTE ST 12-1 codewords must be associated with the correct video frame (or field, as the case may be). For example, in certain implementations this could be the video frame that is acquired at a given PTP time. That implementation could also insert the SMPTE ST 12-1 codewords in an ANC Packet associated with that frame. In other implementations the SMPTE ST 12-1 codeword must flow in a compression engine's pipeline with the associated video frame until the codeword can be inserted in the compression engine's output bitstream or associated with the frame by some other means.

9.1.2 Considerations Regarding Daily Jam Events (Informative)

As described elsewhere, in operations using fractional frame rates (n/1.001), a Daily Jam event is required to re-align the SMPTE ST 12-1 time-of-day addresses with Local Time. Such Daily Jam events will also factor in Daylight Savings adjustments as well as Leap Seconds. In operations not using fractional frame rates, a single Daily Jam event may be introduced operationally to handle Daylight Savings adjustments and Leap Second adjustments.

It is recommended that the choice of Daily Jam time be adopted with consideration of external events such as Daylight Savings adjustments or Leap Second adjustments and to not have an operational impact due to the discontinuity of the time address value.

9.2 Definitions and Variable Names

The following variables and terms are used in the formulae in the following sections:

BitNumber is the zero-based number of the bit of the LTC codeword (as defined in SMPTE ST 12-1).

CF is the duration of a color field sequence in frames.
Note that this is not the same as variable "Cf" defined in Section 7.

colorFrameIdentificationMode is a flag that specifies if color frame identification (alignment) to the SMPTE Epoch is used. This is the "Color Frame Identification" bit in the "timeAddressCountMode" field in the SMPTE Profile.

currentLocalOffset is offset in seconds of Local Time from PTP time. This is the "currentLocalOffset" field in the SMPTE Profile.

currentLocalOffsetActive is the active offset in seconds of Local Time from PTP time. This factors in the currentLocalOffset and timeOfNextJump information.

dayLightSavingMode is a flag that specifies if Daylight Saving time is in effect**.** This is the "Current Daylight Saving" bit in the "daylightSaving" field in the SMPTE Profile.

DD is day of a SMPTE ST 309 date carried in a Time Address value.

dropFrameMode is a flag that specifies if drop frame or non-frame drop is used. This is the "Drop Frame" bit in the "timeAddressCountMode" field in the SMPTE Profile.

Ff is the LTC codeword rate in codewords per second. This can be indicated by the "Default System Frame Rate" field in the SMPTE Profile.

FF is frames of Time Address value.

$\mathbf{FF_{pdjam}}$ is frames of Time Address value at the previous Daily Jam event.

HH is hours of Time Address value.

$\mathbf{HH_{pdjam}}$ is hours of Time Address value at the previous Daily Jam event.

jumpSeconds is the size of the next discontinuity, in seconds, of Local Time. This is the "jumpSeconds" field in the SMPTE Profile.

leapSecondJump is a flag that is true when the next discontinuity of Local Time will be due to the insertion or deletion of a leap second. This is bit 0 of the "leapSecondJump" field in the SMPTE Profile.

MJD (modified Julian date) is an abbreviated version of the Julian date (JD) dating method. See SMPTE ST 309 for details.

MM is minutes of a SMPTE ST 309 date carried in a Time Address value.

$\mathbf{MM_{pdjam}}$ is minutes of Time Address value at the previous Daily Jam event.

Mo is month of a SMPTE ST 309 date carried in a Time Address value.

NextAlignmentPoint is the value of **t** at the next Alignment Point for LTC codewords.

previousJamLocalOffset is the offset in seconds of Local Time from PTP time that was active at the previous daily jam event. This is "previousJamLocalOffset" field the in the SMPTE Profile.

previousDayLightSavingMode is a flag that specifies if Day Light Saving is in effect at the previous Daily Jam event. This is the "Daylight Saving at previous Daily Jam time" bit in the "daylightSaving" field in the SMPTE Profile.

SS is seconds of Time Address value.

$\mathbf{SS}_{\mathbf{pdjam}}$ is seconds of Time Address value at the previous Daily Jam event.

t is elapsed continuous time from SMPTE Epoch in seconds.
Note: this '**t**' is the same as PTP time for PTP-based implementations.

$\mathbf{t}_{\mathbf{epdjamPTP}}$ is exact time of the previous Daily Jam event in PTP time.

timeOfNextJam is the PTP time of the next Daily Jam event. This is the "timeOfNextJam" field in the SMPTE Profile.

timeOfNextJump is the PTP time of the Next Jump event. This is the "timeOfNextJump" field in the SMPTE Profile.

timeOfPreviousJam is the PTP time of the previous Daily Jam event. This is the "timeOfPreviousJam" field in the SMPTE Profile.

YY is year of a SMPTE ST 309 date carried in a Time Address value.

9.3 Generation of the SMPTE ST 12-1 LTC Codeword

The SMPTE ST 12-1 LTC codewords shall be generated using alignment to the SMPTE Epoch. As required by SMPTE ST 12-1, the Alignment Point of the LTC codeword is defined as the half-amplitude point of the first transition of bit 0. The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

$$NextAlignmentPoint = (int(t \times Ff) + 1)/Ff$$

$$BitNumber = int(t \times 80 \times Ff)\ \%\ 80$$

Note: This alignment point is usually coincident with the corresponding video NextAlignmentPoint in most systems.

9.4 Generation of the SMPTE ST 12-1 Time-of-Day Time Address Value

9.4.1 Introduction and Overview

The time address of the Daily Jam time ("timeOfNextJam") and "currentLocalOffset" shall be as provided by SMPTE ST 2059-2. Local Time (as defined in SMPTE ST 2059-2) shall be the time used for generation of SMPTE ST 12-1 Time Address values. "currentLocalOffset" (as specified in SMPTE ST 2059-2) includes any adjustments for daylight saving time (summer time) as required by the rules of the responsible authority and may be adjusted by local operational requirements.

If the "TimeOfNextJam" field is in use, the Local Time value shall be jammed into the Time Address at the time of the Daily Jam. Therefore, leap seconds, daylight saving time and other time discontinuities in "Local Time" are transferred to the Time Address at the "TimeOfNextJam".

Non-1/1.001 Time Code can be directly calculated, however 1/1.001-based Time Code requires additional application of rules to accommodate management of the daily accumulation of error. When color frame identification in the Time Address is required, additional calculations are necessary. The Color Frame Flag in the SMPTE ST 12-1 codeword shall be set to logical 1 when the Time Code is color frame aligned. If color frame identification in the time code is required, the rules are defined in SMPTE ST 12-1.

SMPTE EG 40 defines conversion from local wall clock time to the SMPTE ST 12-1 Time Address value, and makes the assumption that the Daily Jam event occurs at midnight. This standard defines formulae based on the SMPTE EG 40 formulae, however this standard removes the midnight jam assumption and supports a user defined Daily Jam time. The SMPTE ST 12-1 Time Address values and binary groups can be used for LTC, VITC and ATC generation.

In addition, this standard defines formulae so that SMPTE ST 309 might optionally be used to encode the date in the SMPTE ST 12-1 binary groups. SMPTE ST 309 states that if the date is specified in MJD format, the time address portion of the time code represents UTC without any offset.

9.4.2 Generation of the SMPTE ST 12-1 Time Address value

The SMPTE ST 12-1 Time Address value payload shall be calculated using the following steps (or equivalents which produce the identical results) that are expanded in detail in the subsections below:

Step 1: (Startup) Calculate exact date, time, and Time Address value of the previous Daily Jam event.

Step 2: (Increment time) Determine time of next codeword (NextAlignmentPoint).

Step 3: (Test Daily Jam) Check if Daily Jam event has occurred.

Step 4: (Update Daily Jam Values) If Daily Jam event has occurred, calculate exact date, time, and Time Address value of the local Daily Jam event.

Step 5: (Output) Calculate the SMPTE ST 12-1 Time Address value and the SMPTE ST 309 date using exact date, time, and Time Address value of the previous Daily Jam event.

Step 6: (Continue) Go back to Step 2.

9.4.2.1 Step 1: (Startup) Calculate exact date, time, and Time Address value of the previous Daily Jam event

The outputs of this step are the exact time ($t_{epdjamPTP}$) and Time Address value (HH_{pdjam}, MM_{pdjam}, SS_{pdjam}, and FF_{pdjam}) of the previous Daily Jam event. The previous Daily Jam event is the most recent Daily Jam event. This is a conceptual event and it might not have actually occurred (e.g. a cold start).

Note: The steps below must be followed even in systems not using Daily Jam.

The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

1. Calculate time of previous Daily Jam in PTP time

$$t_{pdjamPTP} = timeOfPreviousJam$$

2. Calculate the number of codewords (n_j) since Epoch at or just after Jam time:

$$n_j = ceiling\left(t_{pdjamPTP} \times Ff\right)$$

If color frame identification is in effect (colorFrameIdentificationMode = 1), calculate the offset to the first frame of the color frame sequence. Color frame identification is only applicable for 25 Hz and 30/1.001 Hz systems.

$$if Ff = 30/1.001 \; then$$

$$CF = 2$$

$$else \; if Ff = 25 \; then$$

$$CF = 4$$

$$endif$$

a. Calculate number of codewords (n_{cf}) to the beginning of the color field sequence

$$n_{cf} = (CF - (n_j \,\%\, CF)) \,\%\, CF$$

b. Calculate the adjusted number of codewords to the beginning of the color field sequence

$$n_j = n_j + n_{cf}$$

3. Calculate exact time of Daily Jam in PTP time adjusted to beginning of next codeword (or codeword at beginning of color frame sequence if color field identification is in effect)

$$t_{epdjamPTP} = \frac{n_j}{Ff}$$

4. Calculate exact time of Daily Jam on Local Time scale

$$t_{epdjamLocal} = t_{epdjamPTP} + previousJamLocalOffset$$

$$if (t\_epdjamLocal < 0)$$
$$t\_epdjamLocal = t\_epdjamLocal + (24 \times 60 \times 60)$$

5. Set Time Address value to time of Daily Jam:

$$HH_{pdjam} = int\left(\frac{t_{epdjamLocal}}{60 \times 60}\right) \,\%\, 24$$

$$MM_{pdjam} = int\left(\frac{t_{epdjamLocal}}{60}\right) \,\%\, 60$$

$$SS_{pdjam} = 0$$

$$if (Ff == 25) \; and \; (colorFrameIdentificationMode == 1) \; then$$

$$FF_{pdjam} = 1$$

$$else$$

$$FF_{pdjam} = 0$$

$$endif$$

9.4.2.2 Step 2: (Increment time) Determine time of next codeword (NextAlignmentPoint)

The time (*t*) of the next codeword (NextAlignmentPoint) shall be as determined in Section 9.3.

Note: The value of 't' is used in the steps below.

9.4.2.3 Step 3: (Test Daily Jam) Check if Daily Jam event has occurred

The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

1. Calculate currentLocalOffsetActive

$$if(t \geq timeOfNextJump)\ and\ (timeOfNextJump\ is\ not\ 0)\ then$$

$$currentLocalOffsetActive = currentLocalOffset + jumpSeconds$$

$$else$$

$$currentLocalOffsetActive = currentLocalOffset$$

$$endif$$

2. Calculate time of Daily Jam in PTP time

$$t_{jamPTP} = timeOfNextJam$$

3. Calculate the number of codewords since Epoch at or just after Jam time

$$n_j = ceiling\left(t_{jamPTP} \times Ff\right)$$

If color frame identification is in effect (colorFrameIdentificationMode = 1), calculate the offset to the first frame of the color frame sequence. Color frame identification is only applicable for 25 Hz and 30/1.001 Hz systems.

$$if\ Ff == 30/1.001\ then$$

$$CF = 2$$

$$else\ if\ Ff == 25\ then$$

$$CF = 4$$

$$endif$$

a. Calculate number of codewords to the beginning of the color field sequence

$$n_{cf} = \left((CF) - \left(n_j \,\%\, CF\right)\right) \%\, CF$$

b. Calculate adjusted number of codewords to the beginning of the color field sequence

$$n_j = n_j + n_{cf}$$

4. Calculate exact time of Daily Jam in PTP time adjusted to beginning of next codeword (or codeword at beginning of color frame sequence if color field identification is being applied)

$$t_{edjamPTPWorking} = n_j \div Ff$$

5. Determine if the Daily Jam event has occurred:

$if\left(t == t_{edjamPTPWorking}\right)\ then$

/* Daily Jam has occurred */

Calculate exact date, time, and Time Address value of the Daily Jam event using the method in Section 9.4.2.4 (“Step 4”)

$else$

Go to Step 5 (See Section 9.4.2.5).

$endif$

There should not be more than one Daily Jam event between two successive midnights (local time).

9.4.2.4 Step 4: (Update Daily Jam Values) If Daily Jam event has occurred, calculate exact date, time, and Time Address value of the local Daily Jam event

The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

1. Update exact time of Daily Jam in PTP time

$$t_{epdjamPTP} = t_{epdjamPTPWorking}$$

2. Calculate exact time of Daily Jam on Local Time scale

$$t_{epdjamLocal} = t_{epdjamPTP} + currentLocalOffsetActive$$

3. Set Time Address to time of Daily Jam:

$$HH_{pdjam} = int\left(\frac{t_{epdjamLocal}}{60 \times 60}\right) \% \ 24$$

$$MM_{pdjam} = int\left(\frac{t_{epdjamLocal}}{60}\right) \% \ 60$$

$$SS_{pdjam} = 0$$

$$if(Ff == 25) \ and \ (colorFrameIdentificationMode == 1) \ then$$

$$FF_{pdjam} = 1$$

$$else$$

$$FF_{pdjam} = 0$$

$$endif$$

9.4.2.5 Step 5: (Output) Calculate the SMPTE ST 12-1 Time Address value and the SMPTE ST 309 date using exact date, time, and Time Address value of the previous Daily Jam event

The following formulae (or an alternative method yielding the identical results) shall be used to calculate the SMPTE ST 12-1 Time Address value:

1. Calculate the elapsed time from the previous Daily Jam event

$$t_e = t - t_{epdjamPTP}$$

2. Convert elapsed time from the previous Daily Jam event into a frame count.

$$f_e = int(t_e \times Ff)$$

3. Calculate the SMPTE ST 12-1 Time Address time value by adding the number of frames since the previous Daily Jam event to the Time Address value at previous Daily Jam event.

   The HH, MM, SS and FF of the SMPTE 12-1 Time Address value are calculated by adding f_e to HH_{pdjam}, MM_{pdjam}, SS_{pdjam} and FF_{pdjam} using the equations in Section 9.4.3 and the value of dropFrameMode.

4. Calculate the SMPTE ST 309 date value.

   Set date (YY, Mo, DD, MJD) to date calculated using the method set out in Section 9.4.4 with

$$t_{elocal} = (t_{epdjamLocal} + \left(int\left(\frac{HHnotmod24}{24}\right) \times 24 \times 60 \times 60\right))\ .$$

9.4.2.6 Step 6: (Continue) Go back to Step 2 (See Section 9.4.2.2)

Note: This step is necessary only if generating a continuous stream of codewords.

9.4.3 Adding Elapsed Frames Since the Previous Daily Jam Event to the Time Address Value at Previous Daily Jam Event

The value of *dropFrameMode* shall be the same as the value of the “Drop Frame” bit in the “*timeAddressCountMode*” field in the SMPTE ST 2059-2 SMPTE Profile.

The following variables and terms are used in the formulae in the following sections:

f_e	Number of LTC codewords since the previous Daily Jam event
Ff	Frame Rate of LTC code word e.g. 30000 / 1001 Hz
$dropFrameMode$	Drop-frame (DF) or Nondrop-frame (NDF)

9.4.3.1 Introduction

The Time Address value of the previous Daily Jam event is defined in Section 9.4.2.5 and consists of the following fields:

$$HH_{pdjam}, MM_{pdjam}, SS_{pdjam}, \text{ and } FF_{pdjam}$$

The Time Address can be represented equivalently as:

$$framecount = \text{“frames since midnight”}$$

The “frames since midnight” representation is more convenient for arithmetic operations, such as adding a certain number of frames.

The following calculation shall be used add f_e frames:

1. Convert the Time Address to $framecount$
2. Add f_e to frame count
3. Convert result back to the new Time Address.

The new Time Address value consists of the following fields:

$$HH, MM, SS \text{ and } FF$$

Note: The equations below are based on those in SMPTE EG 40, Sections 5.1 and 5.5.

9.4.3.2 24, 25 and 30 frames-per-second

Per SMPTE ST 12-1, for these frame rates, $dropFrameMode$ shall be set to Non-drop frame; (indicating drop frame calculations are not to be used.) The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

1. Calculate Time Address of previous Daily Jam Event as frames since midnight:

$$framecount = FF_{pdjam} + \left(Ff \times \left(SS_{pdjam} + \left(60 \times \left(MM_{pdjam} + \left(60 \times HH_{pdjam}\right)\right)\right)\right)\right)$$

2. Add number of LTC codewords since previous Daily Jam Event

$$framecount' = framecount + f_e$$

3. Calculate new Time Address value:

$$HH = int\left(\frac{framecount'}{Ff \times 3600}\right)$$

$$HHnotmod24 = HH$$

$$MM = int\left(\frac{framecount' - (Ff \times 3600 \times HH)}{Ff \times 60}\right)$$

$$\mathrm{SS} = \mathrm{int}\left(\frac{framecount' - \left(Ff \times 60 \times \left(MM + (60 \times HH)\right)\right)}{Ff}\right)$$

$$\mathrm{FF} = framecount' - \left(Ff \times \left(\mathrm{SS} + 60 \times \left(MM + (60 \times HH)\right)\right)\right)$$

$$\mathrm{HH} = HHnotmod24 \,\%\, 24$$

9.4.3.3 24 / 1.001 and 30 / 1.001 frames-per-second, Non Drop Frame

The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

$dropFrameMode$ shall be set to Non-drop frame

$$if\ Ff == 24/1.001\ Hz\ then$$

$$Ff_{nom} = 24\ Hz$$

$$if\ Ff == 30/1.001\ Hz\ then$$

$$Ff_{nom} = 30\ Hz$$

1. Calculate Time Address of previous Daily Jam Event as frames since midnight:

$$framecount = FF_{pdjam} + \left(Ff_{nom} \times \left(SS_{pdjam} + \left(60 \times \left(MM_{pdjam} + \left(60 \times HH_{pdjam}\right)\right)\right)\right)\right)$$

2. Add number of LTC codewords since previous Daily Jam Event

$$framecount' = framecount + f_e$$

3. Calculate new Time Address:

$$HH = int\left(\frac{framecount'}{Ff_{nom} \times 3600}\right)$$

$$HHnotmod24 = HH$$

$$MM = int\left(\frac{framecount' - (Ff_{nom} \times 3600 \times HH)}{Ff_{nom} \times 60}\right)$$

$$\mathrm{SS} = \mathrm{int}\left(\frac{framecount' - \left(Ff_{nom} \times 60 \times \left(MM + (60 \times HH)\right)\right)}{Ff_{nom}}\right)$$

$$\mathrm{FF} = framecount' - \left(Ff_{nom} \times \left(\mathrm{SS} + 60 \times \left(MM + (60 \times HH)\right)\right)\right)$$

$$HH = HHnotmod24 \,\%\, 24$$

9.4.3.4 30 / 1.001 frames-per-second, Drop Frame

The following formulae (or an alternative method yielding the identical results) shall be used for these calculations:

$dropFrameMode$ shall be set to Drop frame

$$Ff_{nom} = 30\ Hz$$

1. Calculate Time Address of previous Daily Jam Event as frames since midnight:

$$\begin{aligned} framecount &= FF_{pdjam} \\ &+ \left(30 \times SS_{pdjam}\right) + \left(1798 \times MM_{pdjam}\right) + \left(2 \times \mathrm{int}\left(\frac{MM_{pdjam}}{10}\right)\right) \\ &+ \left(107892 \times HH_{pdjam}\right) \end{aligned}$$

2. Add number of LTC codewords since previous Daily Jam Event

$$framecount' = framecount + f_e$$

3. Calculate new Time Address:

$$HH = \mathrm{int}\left(\frac{framecount'}{107892}\right)$$

$$HHnotmod24 = HH$$

$$MM = \text{int}\left(\frac{1}{1800} \times \left(framecount' + 2 \times \text{int}\left(\frac{framecount' - 107892 \times HH}{1800}\right) - 2 \times \text{int}\left(\frac{framecount' - 107892 \times HH}{18000}\right) - 107892 \times HH\right)\right)$$

$$SS = int\left(\frac{1}{30} \times \left(framecount' - 1798 \times MM - 2 \times int\left(\frac{MM}{10}\right) - 107892 \times HH\right)\right)$$

$$FF = framecount' - 30 \times SS - 1798 \times MM - 2 \times int\left(\frac{MM}{10}\right) - 107892 \times HH$$

$$HH = HHnotmod24 \; \% \; 24$$

9.4.4 Generation of the SMPTE ST 309 Date

This section defines the formulae to convert a local time into one of the date formats required by SMPTE ST 309. SMPTE ST 309 permits the date to be carried in the Gregorian calendar format years, months and day of month or as a Modified Julian Day number. The Modified Julian Day number is an integer counter of the days beginning at 1858-11-17, which is Modified Julian Day Number 0.

These calculations are similar to the functions such as *gmtime* which are provided by many operating systems and languages. These equations shall be used with the same “local time” value used to generate the Time Address, to ensure that the date changes coincident with the Time Address 00:00:00:00.

t_{elocal} Is the input local time passed to this function and is derived in the earlier sections which call this function. It is expressed in seconds from 1970-01-01T00:00:00 on the local time scale.

The Gregorian date consists of the following fields:

$$YY, Mo \text{ and } DD$$

The Modified Julian Day consists of the following field:

$$ModifiedJulianDay$$

The following formulae (or an alternative method yielding the same results) shall be used for these calculations:

1. Initialize with the year = 1970

$$Y = 1970$$

2. Initialize with the number of days from beginning of 1970

$$D = \mathrm{int}\left(\frac{t_{elocal}}{24 \times 60 \times 60}\right)$$

3. Calculate Modified Julian Day number

$$ModifiedJulianDay = D + 40587$$

4. Estimate year. If days negative, subtract 1

$$Y_g = Y + int({}^{D}/_{365})$$

$$\begin{aligned}&\mathrm{if}\,(D < 0)\\ &Y_g = Y_g - 1\end{aligned}$$

5. Calculate days from beginning of that year

$$D = D - (Y_g - Y) \times 365 - \mathrm{LeapsThroughEndOf}(Y_g - 1) + \mathrm{LeapsThroughEndOf}(Y - 1)$$

6. Update year

$$Y = Y_g$$

7. Revise year if necessary

$$\begin{aligned}&\mathrm{if}(D < 0\ OR\ (IsLeap(Y)\ \mathrm{AND}\ D \geq 366)\ \mathrm{OR}\ ((not\ \mathrm{IsLeap}(Y))\ \mathrm{AND}\ D \geq 365)\ )\\ &\quad Go\ back\ to\ step\ 4\end{aligned}$$

Function definitions:

$$\begin{aligned}&\mathrm{LeapsThroughEndOf}(y)\\ &\qquad \mathrm{return}\ int\ ({}^{y}/_{4}) - int\ ({}^{y}/_{100}) + int\ ({}^{y}/_{400})\end{aligned}$$

$$\begin{aligned}&\mathrm{IsLeap}\ (y)\\ &\quad \mathrm{if}\ (\ (y \,\%\, 4) == 0\ \mathrm{AND}\ ((y \,\%\, 100) \neq 0\ \mathrm{OR}\ (y \,\%\, 400) == 0)\ )\ \mathrm{then}\\ &\qquad\qquad \mathrm{return\ True}\\ &\qquad \mathrm{Else}\\ &\qquad\qquad \mathrm{return\ False}\end{aligned}$$

8. Calculate the month and day of month.

   The month (Mo) is calculated using Table 5. The "Start day in Leap Year" column shall be used if the year is a leap year. Otherwise the "Start day" column shall be used. *Mo* shall be the month with the greatest start day that is less than or equal to the day of the year D_D.
   The day of the month (D_D) shall be

   $$D_D - \textit{Start day for the selected month} + 1$$

Table 5 – Start day of each month

Month	Mo	Start day	Start day in Leap Year
January	01	00	00
February	02	31	31
March	03	59	60
April	04	90	91
May	05	120	121
June	06	151	152
July	07	181	182
August	08	212	213
September	09	243	244
October	10	273	274
November	11	304	305
December	12	334	335

Annex A Alignment Points (Informative)

Discussion of Alignment Points

Consider a sampled waveform with periodic alignment points and the following parameters:

T	sample period
N	number of samples between alignment points
t	current time since epoch

For a non-sampled (analogue) waveform, $N = 1$ and $T = (period\ between\ alignment\ points)$

Alignment points in general

An alignment point occurs at the epoch, $t(alignmentpoint) = 0$

Alignment points in general occur at: $t(alignmentpoint) = n \times N \times T$ for all integer n

Next alignment point

The most recent alignment point relative to current time (t_c) occurred at:

$$t(mostrecentalignmentpoint) = N \times T \times \mathrm{int}\left({t_c}/{(N \times T)}\right)$$

The next alignment point occurs at:

$$t(nextalignmentpoint) = N \times T \times \left(\mathrm{int}\left({t_c}/{(N \times T)}\right) + 1\right)$$

Annex B Bibliography (Informative)

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 272:2004) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 272M-2004). Documents with the same root number (e.g. 272) and publication year (e.g. 2004) are functionally identical.

SMPTE ST 272:2004, Television — Formatting AES/EBU Audio and Auxiliary Data into Digital Video Ancillary Data Space

SMPTE ST 299-1:2009, 24-Bit Digital Audio Format for SMPTE 292 Bit-Serial Interface

SMPTE ST 2036-1:2014, Ultra High Definition Television — Image Parameter Values for Program Production

SMPTE ST 2036-3:2012, Ultra High Definition Television — Mapping into Single-link or Multi-link 10 Gb/s Serial Signal/Data Interface

SMPTE EG 35:2012, Time and Control Code Time Address Clock Precision for Television, Audio and Film

SMPTE EG 40:2012, Conversion of Time Values Between SMPTE ST12-1 Time Code, MPEG-2 PCR Time Base and Absolute Time

IEEE Standard 1588-2008, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

Recommendation ITU-R BS.647-3 (03/2011), A Digital Audio Interface for Broadcasting Studios

Recommendation ITU-R BS.2032 (01/2013), Synchronization of Digital Audio Sample Clock to Video References