

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)
≠	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”

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

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

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

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

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.

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