SMPTE EG 40:2016
Revision of SMPTE EG 40:2012

SMPTE ENGINEERING GUIDELINE

Conversion of Time Values between SMPTE ST 12-1 Time Code, MPEG-2 PCR Time Base and Absolute Time

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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 its Standards Operations Manual.

SMPTE EG 40 was prepared by Technology Committee 32NF.

Introduction

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

This Engineering Guideline provides a set of formulas for common time related conversions in the hope that implementers will do these calculations in a similar and interoperable manner.

An earlier revision of this document used the term "absolute time" to refer to time that may be more clearly termed "local wall clock time." This is the time of day in the local time zone typically measured by "the clock on the wall" and not necessarily tightly tied to an International standardized time reference (UTC, GPS, etc.).

Other SMPTE Engineering documents may provide for defined calculations to convert "local wall clock time" to an International standardized time reference (UTC, GPS, etc.).

1 Scope

This guideline specifies a set of formulas for converting between “SMPTE 12M time code” (correctly SMPTE ST 12-1 time code), MPEG-2 systems layer program clock reference (PCR) time base, and local wall clock time. Included are formulas for converting SMPTE ST 12-1 time address values and MPEG-2 PCR time base values to local wall clock time, and formulas for converting SMPTE ST 12-1 time address values directly to/from MPEG-2 PCR time base values. Local wall clock time conversion formulas are useful for converting between different frame rates of SMPTE ST 12-1 time code; e.g., a 24-fps SMPTE time code running at 23.976 fps could be converted to true time and then to a 29.97 drop frame SMPTE time code value. Finally, a discussion of how ST 12-1 time code may be carried within the coded video structures of both MPEG-2 and MPEG-4 AVC is provided.

2 Conformance Notation

This Engineering Guideline is purely informative and meant to provide tutorial information to the industry. It does not impose Conformance Requirements and avoids the use of Conformance Notation.

Engineering Guidelines frequently provide tutorial information about a Standard or Recommended Practice and when this is the case, the user should rely on the Standards and Recommended Practices referenced for interoperability information.

3 Informative References

At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this guideline 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 170:2004, Television — Composite Analog Video Signal — NTSC for Studio Applications

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

SMPTE ST 339:2015, Format for Non-PCM Audio and Data in AES3 — Generic Data Types

SMPTE ST 340:2015, Format for Non-PCM Audio and Data in AES3 — ATSC A/52 Digital Audio Compression Standard for AC-3 and Enhanced AC-3 Data Types Compression Standard for AC-3 and Enhanced AC-3 Data Types

AES11-2009 (r2014): AES Recommended Practice for Digital Audio Engineering — Synchronization of Digital Audio Equipment in Studio Operations

IEC 60461:2010, Time and Control Code

ISO/IEC 14496-2:2004, Information Technology — Coding of Audio-Visual Objects — Part 2: Visual

Recommendation ITU-R BT.1700 (02/2005), Characteristics of Composite Video Signals for Conventional Analogue Television Systems

Recommendation ITU-T H.222.0 | ISO/IEC 13818-1 (2014), Information Technology — Generic Coding of Moving Pictures and Associated Audio Information: Systems

Recommendation ITU-T H.262 | ISO/IEC 13818-2 (2012), Information Technology — Generic Coding of Moving Pictures and Associated Audio Information: Video

Recommendation ITU-T H.264 | ISO/IEC 14496-10 (2014), Advanced Video coding for Generic Audiovisual Services

4 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

4.1 AVC

An abbreviation for Advanced Video Coding, documented in ISO/IEC 14496-10.

4.2 GPS

An abbreviation for Global Positioning System.

4.3 local wall clock time

This is the time of day in the local time zone typically measured by “the clock on the wall” and not necessarily tightly tied to an International standardized time reference (UTC, GPS, etc.).

4.4 MPEG-2

A suite of standards distributed as parts under the identifier ISO/IEC 13818. Part 1 is MPEG-2 Systems. Part 2 is MPEG-2 visual (video coding).

4.5 MPEG-4

A suite of standards distributed as parts under the identifier ISO/IEC 14496. Part 2 is MPEG-4 visual. Part 10 is AVC.

4.6 PCR

An abbreviation for Program Clock Reference. (Note: See ISO/IEC 13818-1.)

4.7 UTC

An abbreviation for Coordinated Universal Time.

4.8 WWV

The call sign of the United States National Institute of Standards and Technology's (NIST) HF ("shortwave") radio station in Fort Collins, Colorado.

5 Arithmetic Operators

The arithmetic operators used in the conversion formulas are defined as follows:

+	Addition
–	Subtraction
x	Multiplication
/ or —	Division
=	Assignment
==	Equal to (comparative)
<	Less than
%	Modulus operator
int (x)	Largest integer not greater than x
ceil (x)	Smallest integer not less than x

6 Basic Conversion Formulas

The following formulas define the conversion between SMPTE ST 12-1 time code time-address values and the MPEG-2 PCR time base values, referred to as PCRtb. The resulting PCR time base value may or may not be equal to the program clock reference base (PCRB) counter used in the MPEG-2 transport system; however, it will always be synchronous with the actual PCRB counter, differing by a constant. The formulas given here are limited to the resolution of the PCRB counter that is 1/300 of the MPEG-2 system clock frequency of 27 MHz (i.e., 90 kHz). Conversion to the full PCR counter resolution is not considered in these formulas. Time values are in units of seconds.

This document does not account for the existence of frame rates greater than 30 Hz. Section 12 of SMPTE ST 12-1 provides the necessary constraints for utilization of SMPTE ST 12-1 time code time-address values with 50-Hz and 60-Hz progressive scanning systems. The reader is cautioned that many applications of this guideline may require attention to video system frame rate before doing a calculation related to time code.

Note: The results of dividing the integer frame rates by 1.001 do not result in precise decimal numbers, for example, 30/1.001 is 29.970029970029... (to 12 decimals). This is commonly abbreviated as 29.97. In a similar manner, it is common to abbreviate 24/1.001 as 23.98, 48/1.001 as 47.95, and 60/1.001 as 59.94. These abbreviations are used throughout this document. Sufficient precision is necessary in calculations to assure that rounding or truncation operations will not create errors in the end result. This is particularly important when calculating audio sample alignments or when long-term time keeping is required.

6.1 Conversion of SMPTE ST 12-1 Time-Address Value to Local Wall Clock Time

These formulas presume an alignment between midnight (time zero) and time-address 00:00:00:00. For systems with an integer number of frames per day, this alignment may be achieved and maintained. For systems with a noninteger count of frames per day, such as with 29.97-Hz frame rates, there will be a daily phase variation between midnight and time-address 00:00:00:00.

6.1.1 General

$$time = \left(\frac{frame\_count}{frame\_rate}\right)$$

where:

$frame\_count$ = total number of elapsed frames since time address 00:00:00:00

6.1.2 23.98... frames/sec non-drop frame

$$time = \left(\frac{1}{24} \times \frac{1001}{1000}\right) \times \left(frames + 24 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= \left(\frac{1001}{24{,}000}\right) \times (frames + 24 \times seconds + 1440 \times minutes + 86{,}400 \times hours)$$

6.1.3 24 frames/sec

$$time = \left(\frac{1}{24}\right) \times \left(frames + 24 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= \left(\frac{1}{24}\right) \times (frames + 24 \times seconds + 1440 \times minutes + 86{,}400 \times hours)$$

6.1.4 25 frames/sec

$$time = \left(\frac{1}{25}\right) \times \left(frames + 25 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= \left(\frac{1}{25}\right) \times (frames + 25 \times seconds + 1500 \times minutes + 90{,}000 \times hours)$$

6.1.5 29.97... frames/sec drop frame

$$time = \left(\frac{1}{30} \times \frac{1001}{1000}\right)$$
$$\times \left(frames + 30 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right) - 2 \times minutes + 2 \times \text{int}\left(\frac{minutes}{10}\right) - 108 \times hours\right)$$
$$= \left(\frac{1001}{30{,}000}\right) \times \left(frames + 30 \times seconds + 1798 \times minutes + 2 \times \text{int}\left(\frac{minutes}{10}\right) + 107{,}892 \times hours\right)$$

6.1.6 29.97... frames/sec non-drop frame

$$time = \left(\frac{1}{30} \times \frac{1001}{1000}\right) \times \left(frames + 30 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= \left(\frac{1001}{30{,}000}\right) \times (frames + 30 \times seconds + 1800 \times minutes + 108{,}000 \times hours)$$

6.1.7 30 frames/sec

$$time = \left(\frac{1}{30}\right) \times \left(frames + 30 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= \left(\frac{1}{30}\right) \times (frames + 30 \times seconds + 1800 \times minutes + 108{,}000 \times hours)$$

6.2 Conversion of Local Wall Clock Time to MPEG-2 PCRtb Value

$$PCRtb = \text{int}(time \times 90{,}000) \ \% \ 2^{33}$$

(Since the PCRtb is based on a 33-bit digital counter and the local wall clock time value can exceed this limit, a correction has been included that constrains the PCRtb value to 33-bits.)

6.3 Conversion of SMPTE ST 12-1 Time-Address Value to MPEG-2 PCRtb

6.3.1 General

$$PCRtb = \left(\frac{frame\_count}{frame\_rate}\right) \times 90{,}000$$

where:

$frame\_count$ = total number of elapsed frames since time address 00:00:00:00

Note: In the formulas below, 3750 = 90,000 / 24 and 3600 = 90,000 / 25.

6.3.2 23.98… frames/sec non-drop frame

$$PCRtb = \text{ceil}\left(\frac{1001}{24{,}000} \times 90{,}000 \times \left(frames + 24 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)\right)$$
$$= \text{ceil}\left(\frac{1001}{24{,}000} \times 90{,}000 \times (frames + 24 \times seconds + 1440 \times minutes + 86{,}400 \times hours)\right)$$
$$= \text{ceil}\left(\frac{1001 \times 90{,}000}{24{,}000} \times frames + 90{,}090 \times seconds + 5{,}405{,}400 \times minutes + 324{,}324{,}000 \times hours\right)$$

6.3.3 24 frames/sec

$$PCRtb = 3750 \times \left(frames + 24 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= 3750 \times (frames + 24 \times seconds + 1440 \times minutes + 86{,}400 \times hours)$$
$$= 3750 \times frames + 90{,}000 \times seconds + 5{,}400{,}000 \times minutes + 324{,}000{,}000 \times hours$$

6.3.4 25 frames/sec

$$PCRtb = 3600 \times \left(frames + 25 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= 3600 \times (frames + 25 \times seconds + 1500 \times minutes + 90{,}000 \times hours)$$
$$= 3600 \times frames + 90{,}000 \times seconds + 5{,}400{,}000 \times minutes + 324{,}000{,}000 \times hours$$

6.3.5 29.97... frames/sec drop frame

$$PCRtb = 3003 \times \left(frames + 30 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right) - 2 \times minutes + 2 \times \text{int}\left(\frac{minutes}{10}\right) - 108 \times hours\right)$$
$$= 3003 \times \left(frames + 30 \times seconds + 1798 \times minutes + 2 \times \text{int}\left(\frac{minutes}{10}\right) + 107{,}892 \times hours\right)$$
$$= 3003 \times frames + 90{,}090 \times seconds + 5{,}399{,}394 \times minutes + 6006 \times \text{int}\left(\frac{minutes}{10}\right) + 323{,}999{,}676 \times \text{hours}$$

6.3.6 29.97... frames/sec non-drop frame

$$PCRtb = 3003 \times \left(frames + 30 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= 3003 \times (frames + 30 \times seconds + 1800 \times minutes + 108{,}000 \times hours)$$
$$= 3003 \times frames + 90{,}090 \times seconds + 5{,}405{,}400 \times minutes + 324{,}324{,}000 \times hours$$

6.3.7 30 frames/sec

$$PCRtb = 3000 \times \left(frames + 30 \times \left(seconds + 60 \times (minutes + 60 \times hours)\right)\right)$$
$$= 3000 \times (frames + 30 \times seconds + 1800 \times minutes + 108{,}000 \times hours)$$
$$= 3000 \times frames + 90{,}000 \times seconds + 5{,}400{,}000 \times minutes + 324{,}000{,}000 \times hours$$

6.4 Conversion of MPEG-2 PCRtb Value to Local Wall Clock Time

$$time = \left(\frac{PCRtb}{90{,}000}\right)$$

6.5 Conversion of Local Wall Clock Time to SMTPE ST 12-1 Time-Address Value

6.5.1 General

$$frame\_count = \text{int}(frame\_rate \times time)$$
$$h = \text{int}\left(\frac{frame\_count}{frame\_rate \times 60 \times 60}\right)$$
$$hours = h \,\%\, 24$$
$$minutes = \text{int}\left(\frac{frame\_count - frame\_rate \times 60 \times 60 \times h}{frame\_rate \times 60}\right)$$
$$seconds = \text{int}\left(\frac{frame\_count - frame\_rate \times 60 \times (minutes + 60 \times h)}{frame\_rate}\right)$$
$$frames = frame\_count - frame\_rate \times \left(seconds + 60 \times (minutes + 60 \times h)\right)$$

(To support time values ≥ 24 hours, e.g. wall clock time during a leap second, while constraining the SMPTE ST 12-1 time-address hours value to be < 24, a correction has been included in the formulas that generate the hours values.)

6.5.2 23.98... frames/sec non-drop frame

$$frame\_count = \text{int}\left(24 \times \frac{1000}{1001} \times time\right)$$

$$h = \text{int}\left(\frac{frame\_count}{24 \times 60 \times 60}\right)$$

$$= \text{int}\left(\frac{frame\_count}{86{,}400}\right)$$

$$hours = h \,\%\, 24$$

$$minutes = \text{int}\left(\frac{frame\_count - 24 \times 60 \times 60 \times h}{24 \times 60}\right)$$

$$= \text{int}\left(\frac{frame\_count - 86{,}400 \times h}{1440}\right)$$

$$seconds = \text{int}\left(\frac{frame\_count - 24 \times 60 \times (minutes + 60 \times h)}{24}\right)$$

$$= \text{int}\left(\frac{frame\_count - 24 \times 60 \times minutes - 24 \times 60 \times 60 \times h}{24}\right)$$

$$= \text{int}\left(\frac{frame\_count - 1440 \times minutes - 86{,}400 \times h}{24}\right)$$

$$frames = frame\_count - 24 \times \big(seconds + 60 \times (minutes + 60 \times h)\big)$$

$$= frame\_count - 24 \times seconds - 24 \times 60 \times minutes - 24 \times 60 \times 60 \times h$$

$$= frame\_count - 24 \times seconds - 1440 \times minutes - 86{,}400 \times h$$

6.5.3 24 frames/sec

$$frame\_count = \text{int}(24 \times time)$$

$$h = \text{int}\left(\frac{frame\_count}{24 \times 60 \times 60}\right)$$

$$= \text{int}\left(\frac{frame\_count}{86{,}400}\right)$$

$$hours = h \,\%\, 24$$

$$minutes = \text{int}\left(\frac{frame\_count - 24 \times 60 \times 60 \times h}{24 \times 60}\right)$$

$$= \text{int}\left(\frac{frame\_count - 86{,}400 \times h}{1440}\right)$$

$$seconds = \text{int}\left(\frac{frame\_count - 24 \times 60 \times (minutes + 60 \times h)}{24}\right)$$

$$= \text{int}\left(\frac{frame\_count - 24 \times 60 \times minutes - 24 \times 60 \times 60 \times h}{24}\right)$$

$$= \text{int}\left(\frac{frame\_count - 1440 \times minutes - 86{,}400 \times h}{24}\right)$$

$$\begin{aligned} frames &= frame\_count - 24 \times \big(seconds + 60 \times (minutes + 60 \times h)\big) \\ &= frame\_count - 24 \times seconds - 24 \times 60 \times minutes - 24 \times 60 \times 60 \times h \\ &= frame\_count - 24 \times seconds - 1440 \times minutes - 86{,}400 \times h \end{aligned}$$

6.5.4 25 frames/sec

$$frame\_count = \text{int}(25 \times time)$$

$$\begin{aligned} h &= \text{int}\left(\frac{frame\_count}{25 \times 60 \times 60}\right) \\ &= \text{int}\left(\frac{frame\_count}{90{,}000}\right) \end{aligned}$$

$$hours = h \,\%\, 24$$

$$\begin{aligned} minutes &= \text{int}\left(\frac{frame\_count - 25 \times 60 \times 60 \times h}{25 \times 60}\right) \\ &= \text{int}\left(\frac{frame\_count - 90{,}000 \times h}{1500}\right) \end{aligned}$$

$$\begin{aligned} seconds &= \text{int}\left(\frac{frame\_count - 25 \times 60 \times (minutes + 60 \times h)}{25}\right) \\ &= \text{int}\left(\frac{frame\_count - 25 \times 60 \times minutes - 25 \times 60 \times 60 \times h}{25}\right) \\ &= \text{int}\left(\frac{frame\_count - 1500 \times minutes - 90{,}000 \times h}{25}\right) \end{aligned}$$

$$\begin{aligned} frames &= frame\_count - 25 \times \big(seconds + 60 \times (minutes + 60 \times h)\big) \\ &= frame\_count - 25 \times seconds - 25 \times 60 \times minutes - 25 \times 60 \times 60 \times h \\ &= frame\_count - 25 \times seconds - 1500 \times minutes - 90{,}000 \times h \end{aligned}$$

6.5.5 29.97... frames/sec drop frame

$$frame\_count = \text{int}\left(30 \times \frac{1000}{1001} \times time\right)$$

$$\begin{aligned} h &= \text{int}\left(\frac{frame\_count}{30 \times 60 \times 60 - 108}\right) \\ &= \text{int}\left(\frac{frame\_count}{107{,}892}\right) \end{aligned}$$

$$hours = h \,\%\, 24$$

$$\begin{aligned} minutes &= \text{int}\left(\frac{1}{1800}\right. \\ &\quad \times \Big(frame\_count + 2 \\ &\quad \left. \times \text{int}\left(\frac{frame\_count - (107892 \times h)}{1800}\right) - 2 \times \text{int}\left(\frac{frame\_count - (107892 \times h)}{18000}\right) - 107{,}892 \times h\Big)\right) \end{aligned}$$

$$
\begin{aligned}
seconds &= \operatorname{int}\left(\frac{1}{30}\right. \\
&\left.\times\left(frame\_count - 30\times 60\times(minutes + 60\times h) + 2\times minutes - 2\times \operatorname{int}\left(\frac{minutes}{10}\right) + 108\times h\right)\right) \\
&= \operatorname{int}\left(\frac{1}{30}\right. \\
&\left.\times\left(frame\_count - (30\times 60 - 2)\times minutes - 2\times \operatorname{int}\left(\frac{minutes}{10}\right) - (30\times 60\times 60 - 108)\times h\right)\right) \\
&= \operatorname{int}\left(\frac{1}{30}\times\left(frame\_count - 1798\times minutes - 2\times \operatorname{int}\left(\frac{minutes}{10}\right) - 107{,}892\times h\right)\right)
\end{aligned}
$$

$$
\begin{aligned}
frames &= frame\_count - 30\times\big(seconds + 60\times(minutes + 60\times h)\big) + 2\times minutes - 2 \\
&\times \operatorname{int}\left(\frac{minutes}{10}\right) + 180\times h \\
&= frame\_count - 30\times seconds + (30\times 60 - 2)\times minutes - 2\times \operatorname{int}\left(\frac{minutes}{10}\right) \\
&- (30\times 60\times 60 - 180)\times h \\
&= frame\_count - 30\times seconds - 1798\times minutes - 2\times \operatorname{int}\left(\frac{minutes}{10}\right) - 107{,}892\times h
\end{aligned}
$$

6.5.6 29.97... frames/sec non-drop frame

$$
\begin{aligned}
frame\_count &= \operatorname{int}\left(30\times\frac{1000}{1001}\times time\right) \\
h &= \operatorname{int}\left(\frac{frame\_count}{30\times 60\times 60}\right) \\
&= \operatorname{int}\left(\frac{frame\_count}{108{,}000}\right) \\
hours &= h\ \%\ 24 \\
minutes &= \operatorname{int}\left(\frac{frame\_count - 30\times 60\times 60\times h}{30\times 60}\right) \\
&= \operatorname{int}\left(\frac{frame\_count - 108{,}000\times hours}{1800}\right) \\
seconds &= \operatorname{int}\left(\frac{frame\_count - 30\times 60\times(minutes + 60\times h)}{30}\right) \\
&= \operatorname{int}\left(\frac{frame\_count - 30\times 60\times minutes - 30\times 60\times 60\times h}{30}\right) \\
&= \operatorname{int}\left(\frac{frame\_count - 1800\times minutes - 108{,}000\times h}{30}\right) \\
frames &= frame\_count - 30\times\big(seconds + 60\times(minutes + 60\times h)\big) \\
&= frame\_count - 30\times seconds - 30\times 60\times minutes - 30\times 60\times 60\times h
\end{aligned}
$$

$$= frame\_count - 30 \times seconds - 1800 \times minutes - 108{,}000 \times h$$

6.5.7 30 frames/sec

$$frame\_count = \text{int}(30 \times time)$$

$$h = \text{int}\left(\frac{frame\_count}{30 \times 60 \times 60}\right)$$

$$= \text{int}\left(\frac{frame\_count}{108{,}000}\right)$$

$$\text{hours} = \text{h} \,\%\, 24$$

$$minutes = \text{int}\left(\frac{frame\_count - 30 \times 60 \times 60 \times h}{30 \times 60}\right)$$

$$= \text{int}\left(\frac{frame\_count - 108{,}000 \times h}{1800}\right)$$

$$seconds = \text{int}\left(\frac{frame\_count - 30 \times 60 \times (minutes + 60 \times h)}{30}\right)$$

$$= \text{int}\left(\frac{frame\_count - 30 \times 60 \times minutes - 30 \times 60 \times 60 \times h}{30}\right)$$

$$= \text{int}\left(\frac{frame\_count - 1800 \times minutes - 108{,}000 \times h}{30}\right)$$

$$frames = frame\_count - 30 \times \big(seconds + 60 \times (minutes + 60 \times h)\big)$$

$$= frame\_count - 30 \times seconds - 30 \times 60 \times minutes - 30 \times 60 \times 60 \times h$$

$$= frame\_count - 30 \times seconds - 1800 \times minutes - 108{,}000 \times h$$

6.6 Conversion of MPEG-2 PCRtb Value to SMPTE ST 12-1 Time-Address Value

6.6.1 General

$$frame\_count = \text{int}\left(\frac{frame\_rate \times PCRtb}{90{,}000}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.1.

6.6.2 23.98... frames/sec non-drop frame

$$frame\_count = \text{int}\left(24 \times \frac{1000}{1001} \times \frac{PCRtb}{90{,}000}\right)$$

$$= \text{int}\left(\frac{4}{15} \times \frac{PCRtb}{1001}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.2.

6.6.3 24 frames/sec

$$frame\_count = \text{int}\left(\frac{24 \times PCRtb}{90{,}000}\right)$$

$$= \text{int}\left(\frac{PCRtb}{3750}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.3.

6.6.4 25 frames/sec

$$frame\_count = \text{int}\left(\frac{25 \times PCRtb}{90{,}000}\right)$$
$$= \text{int}\left(\frac{PCRtb}{3600}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.4.

6.6.5 29.97... frames/sec drop frame

$$frame\_count = \text{int}\left(30 \times \frac{1000}{1001} \times \frac{PCRtb}{90{,}000}\right)$$
$$= \text{int}\left(\frac{PCRtb}{3003}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.5.

6.6.6 29.97... frames/sec non-drop frame

$$frame\_count = \text{int}\left(30 \times \frac{1000}{1001} \times \frac{PCRtb}{90{,}000}\right)$$
$$= \text{int}\left(\frac{PCRtb}{3003}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.6.

6.6.7 30 frames/sec

$$frame\_count = \text{int}\left(\frac{30 \times PCRtb}{90{,}000}\right)$$
$$= \text{int}\left(\frac{PCRtb}{3000}\right)$$

Calculate hours, minutes, seconds, and frames as per formulas in Section 6.5.7.

7 Conversion Formulas with Audio Sample Number Extension

For time stamped audio elementary streams (SMPTE ST 339), a time stamp value may contain a sample number extension to the SMPTE ST 12-1 time-address value. The sample number indicates which specific audio sample, relative to the start of the audio frame, aligns with the given SMPTE ST 12-1 time-address value. This allows accurate calculation of an MPEG PCRtb value that matches the first sample of the audio frame.

The following formulas indicate modifications to the above conversion formulas when the sample number extension is factored into the calculations. The formulas assume an audio sample rate of 48 kHz for all video frame rates. The result of the calculations is a PCRtb value that corresponds to the time of the first sample in the audio frame (or audio access unit).

7.1 Conversion of SMPTE ST 12-1 Time-Address Value with Sample Number to Local Wall Clock Time

Calculate $time1$ based on the formulas in Section 6.1. Calculate a new time value that adjusts for the sample number value as follows:

$$time = time1 - \left(\frac{1}{48{,}000}\right) \times sample\_number$$

The above conversion is not valid for time address value 00:00:00:00.

7.2 Conversion of SMPTE ST 12-1 Time-Address Value with Sample Number to MPEG-2 PCRtb Value

Calculate $PCRtb1$ based on the formulas in Section 6.3. Calculate a new $PCRtb$ value that adjusts for the sample number value as follows:

$$PCRtb = \text{int}\left(PCRtb1 - \left(\frac{15}{8} \times sample\_number\right)\right)$$

The above conversion is not valid for time address value 00:00:00:00.

7.2.1 29.97... frame rate

For the 29.97 frame rate (drop frame or nondrop frame), the noninteger relationship between audio samples and video frames (8008 samples over 5 frames per SMPTE ST 272) will result in a slight discrepancy in the calculated value of $PCRtb$ depending on the phasing of audio samples within a given frame. In most applications, this discrepancy is negligible; however if a calculation is required, the following formulas can be applied:

$$PCRtb = \text{int}\left(PCRtb1 + FFoffset - \left(\frac{15}{8} \times sample\_number\right)\right)$$

where the value of $FFoffset$ (Five Frame offset) is determined as follows:

$$\begin{aligned}
&\text{if } \left((frame_count \ \%\ 5) == 1\right) \{FFoffset = -1.125\} \\
&\text{else if } \left((frame_count \ \%\ 5) == 2\right) \{FFoffset = -0.375\} \\
&\text{else if } \left((frame_count \ \%\ 5) == 3\right) \{FFoffset = -1.5\} \\
&\text{else if } \left((frame_count \ \%\ 5) == 4\right) \{FFoffset = -0.75\} \\
&\text{else } \{FFoffset = 0.0\}
\end{aligned}$$

The above offsets assume an alignment of audio samples and PCR values at time address 00:00:00:00. The conversion is not valid for time address value 00:00:00:00.

7.3 Conversion of Local Wall Clock Time to SMTPE ST 12-1 Time-Address Value with Sample Number

Calculate a $12M\_time\_address1$ value following the formulas in Section 6.5. Calculate the final value of $12M\_time\_address$ and $sample\_number$ with the formulas below.

$$\begin{aligned}
&\text{if } \left(time - \left(\frac{frame_count}{frame\text{-}rate}\right) == 0\right) \\
&\{ \\
&\quad sample_number = 0 \\
&\} \\
&\text{else} \\
&\{
\end{aligned}$$

$12M\_time\_address = 12M\_time\_address1 + 1\text{frame}$

$$sample\_number = \text{int}\left(\frac{8}{15} \times \left(\left(\frac{frame\_count + 1}{frame\_rate}\right) - time\right)\right)$$

}

The above conversion is valid for time values within the first 24 hour time period relative to the corresponding time code (e.g., < 86400 seconds for 30-Hz frame rate).

7.4 Conversion of MPEG-2 PCRtb Value to SMPTE ST 12-1 Time-Address Value with Sample Number

Calculate a $12M\_time\_address1$ value following the formulas in Section 6.6. Calculate the final value of $12M\_time\_address$ and $sample\_number$ with the formulas below.

if $\left(PCRtb - \left(frame_{count} \times (90{,}000/frame\_rate)\right) == 0\right)$

{

$sample\ number = 0$

}

else

{

$12M\_time\_address = 12M\_time\_address1 + 1\text{frame}$

$$sample\_number = \text{int}\left(\frac{8}{15} \times \left(\frac{90{,}000 \times (frame\_count + 1)}{frame\_rate} - PCRtb\right)\right)$$

}

The above conversion is valid for PCR values within the first 24 hour time period relative to the corresponding time code (e.g., < 7,776,000,000 for 30-Hz frame rate).

7.4.1 29.97... frame rate

For the 29.97 frame rate (drop frame or nondrop frame) the noninteger relationship between audio samples and video frames (8008 samples over 5 frames per SMPTE ST 272) will result in a slight discrepancy in the calculated value of the sample number depending on the phasing of audio samples within a given frame. In most applications this discrepancy is negligible; however, if a precise calculation is required, the following formulas can be applied:

if $\left(PCRtb - \left((frame\_count/5) \times 15{,}015\right) == 0\right)$

{

$sample\_number = 0$

}

else

{

$12M\_time\_address = 12M\_time\_address1 + 1\text{frame}$

$$sample\_number = \text{int}\left(\frac{8}{15} \times \left(\left(3003 \times (frame\_count + 1)\right) - PCRtb + FFoffset\right)\right)$$

if $(sample\_number < 0)$

{

$sample\_number = sample\_number + 1602$

$12M\_time\_address = 12M\_time\_address + 1\text{frame}$

}

}

where the value of $FFoffset$ (Five Frame offset) is as defined in Section 7.2.1.

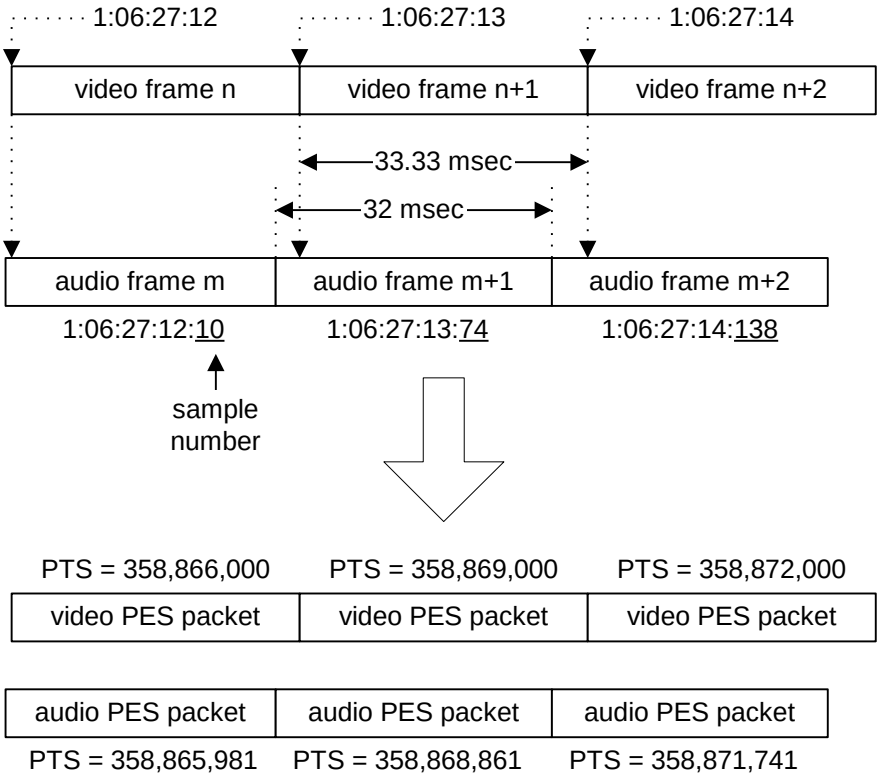
The above offsets assume an alignment of audio samples and PCR values at time address 00:00:00:00. The above conversion is valid for PCR values within the first 24 hour time period relative to the corresponding time code.

7.4.2 23.98... frame rate

For the 23.98 frame rate, an integer relationship between audio samples and video frames (2002 samples per frame per AES11) exists, so there are no discrepancies in the calculated value of the sample number.

Annex A Examples

The following shows example conversion calculations for a series of audio and video frames that are converted to/from MPEG-2 program elementary stream (PES) packets, each containing a presentation time stamp (PTS). This example assumes a video frame rate of 30 frames/sec and an audio frame size of 1536 samples at a 48 kHz sampling rate (see SMPTE ST 340 Section 4.1).



A.1 SMPTE ST 12-1 Time Code to MPEG-2 PCR Time Base Conversion

video frame n time_code = 1:06:27:12

PCRtb = 3000 x 12 + 90,000 x 27 + 5,400,000 x 6 + 324,000,000 x 1

= 358,866,000

audio frame m time_code = 1:06:27:12:10

PCRtb = int(358,866,000 - (15/8 x 10)) = int(358,865,981.25)

= 358,865,981

video frame n+1 time_code = 1:06:27:13

PCRtb = 3000 x 13 + 90,000 x 27 + 5,400,000 x 6 + 324,000,000 x 1

= 358,869,000

audio frame m+1 time_code = 1:06:27:12:74

PCRtb = int(358,869,000 - (15/8 x 74)) = int(358,868,861.25)

= 358,868,861

video frame n+2 time_code = 1:06:27:14

PCRtb = 3000 x 14 + 90,000 x 27 + 5,400,000 x 6 + 324,000,000 x 1

= 358,872,000

audio frame m+2 time_code = 1:06:27:12:138

PCRtb = int(358,872,000 - (15/8 x 138)) = int(358,871,741.25)

= 358,871,741

A.2 MPEG-2 PCR Time Base to SMPTE ST 12-1 Time Code Conversion

video frame n PTS = PCRtb = 358,866,000

frame_count = int(358,866,000 / 3000) = 119,622

hours = int(119,622 / 108,000) % 24 = int(1.11) % 24 = 1

minutes = int((119,622 - 108,000 x 1) / 1800) = int(11,622 / 1800) = int(6.46) = 6

seconds = int((119,622 - 1800 x 6 - 108,000 x 1) / 30) = int(822 / 30) = int(27.4) = 27

frames = 119,622 - 30 x 27 - 1800 x 6 - 108,000 x 1 = 12

audio frame m PTS = PCRtb = 358,865,981

frame_count = int(358,865,981 / 3000) = int(119,621.99) = 119621

hours = int(119,621 / 108,000) % 24 = int(1.11) % 24 = 1

minutes = int((119,621 - 108,000 x 1) / 1800) = int(11,621 / 1800) = int(6.46) = 6

seconds = int((119,621 - 1800 x 6 - 108,000 x 1) / 30) = int(821 / 30) = int(27.36) = 27

frames = 119,621 - 30 x 27 - 1800 x 6 - 108,000 x 1 = 11

time_code = 1:06:27:11 + 1frame = 1:06:27:12

sample_number = int(8/15 x ((3000 x 119,621) - 358,865,981 + 3000))

= int(8/15 x 19) = int(10.1) = 10

video frame n+1 PTS = PCRtb = 358,869,000

frame_count = int(358,869,000 / 3000) = 119,623

hours = int(119,623 / 108,000) % 24 = int(1.11) % 24 = 1

minutes = int((119,623 - 108,000 x 1) / 1800) = int(11,623 / 1800) = int(6.46) = 6

seconds = int((119,623 - 1800 x 6 - 108,000 x 1) / 30) = int(823 / 30) = int(27.43) = 27

frames = 119,623 - 30 x 27 - 1800 x 6 - 108,000 x 1 = 13

audio frame m+1 PTS = PCRtb = 358,868,861

frame_count = int(358,868,861 / 3000) = int(119,622.95) = 119,622

hours = int(119,622 / 108,000) % 24 = int(1.11) % 24 = 1

minutes = int((119,622 - 108,000 x 1) / 1800) = int(11,622 / 1800) = int(6.46) = 6

seconds = int((119,622 - 1800 x 6 - 108,000 x 1) / 30) = int(822 / 30) = int(27.4) = 27

frames = 119,622 - 30 x 27 - 1800 x 6 - 108,000 x 1 = 12

time_code = 1:06:27:12 + 1frame = 1:06:27:13

sample_number = int(8/15 x ((3000 x 119,622) - 358,868,861 + 3000))

= int(8/15 x 139) = int(74.1) = 74

video frame n+2 PTS = PCRtb = 358,872,000

frame_count = int(358,872,000 / 3000) = 119,624

hours = int(119,624 / 108,000) % 24 = int(1.11) % 24 = 1

minutes = int((119,624 - 108,000 x 1) / 1800) = int(11,624 / 1800) = int(6.46) = 6

seconds = int((119,624 - 1800 x 6 - 108,000 x 1) / 30) = int(824 / 30) = int(27.47) = 27

frames = 119,624 - 30 x 27 - 1800 x 6 - 108,000 x 1 = 14

audio frame m+2 PTS = PCRtb = 358,871,741

frame_count = int(358,871,741 / 3000) = int(119,623.91) = 119,623

hours = int(119,623 / 108,000) % 24 = int(1.11) % 24 = 1

minutes = int((119,623 - 108,000 x 1) / 1800) = int(11,623 / 1800) = int(6.46) = 6

seconds = int((119,623 - 1800 x 6 - 108,000 x 1) / 30) = int(823 / 30) = int(27.43) = 27

frames = 119,623 - 30 x 27 - 1800 x 6 - 108,000 x 1 = 13

time_code = 1:06:27:13 + 1frame = 1:06:27:14

sample_number = int(8/15 x ((3000 x 119,623) - 358,871,741 + 3000))

= int(8/15 x 259) = int(138.1) = 138

Annex B Placement of SMPTE ST 12-1 Time Code into MPEG-2 or MPEG-4 AVC Video

B.1 Placement in MPEG-2 Video

MPEG-2 video (ITU-T H.262 | ISO/IEC 13818-2) provides a structure named “time_code” which takes 25-bits to encapsulate the drop frame flag, and the time code codeword’s hours, minutes, seconds, and frames, and places this into the MPEG-2 Group of Pictures header. Readers should consult ITU-T H.262 | ISO/IEC 13818-2, Section 6.3.8 for full specifics.

Note: ITU-T H.262 | ISO/IEC 13818-2 points to IEC 60461, which is an equivalent document to SMPTE ST 12-1.

B.2 Placement in MPEG-4 Part 2 Video

MPEG-4 video Studio Profile (ISO/IEC 14496-2) provides a structure named “time_code_smpte12m” which takes 64-bits to encapsulate the SMPTE ST 12-1 codeword, and places this into the MPEG-4 Group of Studio Video Object Plane. Readers should consult ISO/IEC 14496-2 Annex P for full specifics.

B.3 Placement in MPEG-4 AVC Video

In contrast to MPEG-2 video, MPEG-4 Part 10 AVC (ITU-T H.264 | ISO/IEC 14496-10) does not provide a structure with clear reference to either IEC 60461 or SMPTE ST 12-1. It does provide a “Picture timing SEI message” which can encapsulate a codeword’s hours, minutes, seconds, and frames (although the frame count may be omitted with clear signaling that has been done). It handles drop frame through a non-obvious pair of variables named “counting_type” and “cnt_dropped_flag.”

AVC (ITU-T H.264 | ISO/IEC 14496-10) technically requires 60-Hz video to count 0 .. 59, but many current implementations mimic SMPTE and count 0 .. 29 with duplications. Further, AVC is explicit in how to convert its coded value to actual time (see Annex D.2.2, equation D-1). Note that this equation uses the time_offset value to avoid all the arithmetic in this document for dealing with drop-frame counting. Note that many implementations do not code time_offset or always code it as zero.

Readers should consult ITU-T H.264 | ISO/IEC 14496-10 Annex D and specifically Annex D.1.2 and Annex D.2.2 for full specifics.