SMPTE EG 35:2012
Revision of EG 35-1999

SMPTE ENGINEERING GUIDELINE

Time and Control Code Time Address Clock Precision for Television, Audio and Film

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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 Part XIII of its Operations Manual.

SMPTE EG 35 was prepared by Technology Committee 33TS.

Introduction

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

SMPTE ST 12-1 Time Code was originally developed for purposes of editing, machine synchronization and machine control. The format of the Time Address label in the time code has led to the use of the time code for applications related to time keeping and the distribution of clock time information. Because television systems with a frame rate of 30/1.001 Hz (nominally 29.97 Hz) and 60/1.001 Hz (nominally 59.94 Hz) do not have an integral number of frames in a 24-hour day, there is a limitation to the precision of time code for clock time distribution applications.

1 Scope

There is a desire for some applications to relate the time code time address to clock system time and to use this time code as a clock time reference. This guideline is specifically applicable to video systems operating at a frame rate of 30/1.001 Hz ("29.97") or 60/1.001 Hz ("59.94") although its principles are applicable to other systems. It outlines methods and procedures to achieve and maintain specified degrees of precision between a time code and clock time/date.

This guideline applies to systems where the time code is synchronized to video; however, it can also be relevant to time code synchronized to other references.

2 Sources of Error and Deviations from Precision Clock Time

Beyond errors that occur due to the imprecision of the reference oscillator, systematic errors will occur for video systems operating at a frame rate of 30/1.001 (29.97) Hz or 60/1.001 (59.94) Hz. This is because the video frame rate is not an integer. Normally, the video frequencies are derived from a stable and precise oscillator. Table 1 illustrates the relationship between the various rates for NTSC systems. Similar relationships between the reference oscillator and the resulting vertical frame rate exist for other 30/1.001-Hz and 60/1.001-Hz systems.

Table 1 – Basic frequencies for NTSC 525/29.97 video systems

Parameter	Formula	Frequency	Description
F_{sc}	5.0 MHz x 63/88	3,579,545.454545 Hz	Color subcarrier
F_h	F_{sc} x 2/455	15,734.26573427 Hz	Horizontal scanning rate
F_v	F_h / 525	29.97002997 Hz	Vertical frame rate

Based on this vertical frame rate, there are approximately 2,589,410.59 video frames per 24-hour day. In 30/1.001 fps drop-frame time code, the digits roll over to 00:00:00:00 after 2,589,408 frame counts. Thus, if at the precise beginning of one day the video is precisely at the start of a frame and the time code is at 00:00:00:00, then at the beginning of the next day the video will be 59% into a frame and the time code will have rolled over to 00:00:00:02.

For progressive video systems operating at a frame rate of 60/1.001 (59.94) Hz, there are approximately 5,178,821.179 video frames per 24-hour day. Since the frame rate of these systems exceeds the frame count capacity of the time address, the frame count increments only every other frame and thus counts at 30/1.001 fps (as specified in Section 12 of SMPTE ST 12-1). In 30/1.001-fps drop-frame time code, the digits roll over to 00:00:00:00 after 2,589,408 frame counts. Thus, if at the precise beginning of one day the video is precisely at the start of a frame and the time code is at 00:00:00:00, then at the beginning of the next day the video will be 59% into a frame pair and the time code will have rolled over to 00:00:00:02.

Precision of the time address will also be affected by jitter, wander, and other system latencies. The reader is referred to the second note in Section 5.1.2 of SMPTE ST 12-1 on precision of calculations.

2.1 Systematic Drift Corrected by Drop-Frame Counting for 29.97-Hz Related Television Systems

Throughout the day, the difference between the 29.97-Hz video frame (frame pair for 59.94-Hz systems) rate and the 30 frame-per-second nominal time address count is compensated by the drop-frame counting mode. Two frame counts are skipped at the beginning of each minute with the exception of minutes 00, 10, 20, 30, 40, and 50. This results in 108 frame counts per hour being skipped from the counting sequence and a cyclic build-up and correction of an offset between time address and clock time. This is illustrated in Figure 1 for a 10-minute interval.

Note that there is no drop frame counting mode for 24/1.001 (23.98) Hz systems, so it is not possible to correct for the systematic drift between the time address and clock time for these systems.

2.2 Uncorrected Systematic Drift for 29.97-Hz Related Television Systems

The drop-frame counting mode overcompensates for the systematic drift that occurs between the time address and clock time. With a perfect reference, the residual drift amounts to approximately 2.59 frames per day.

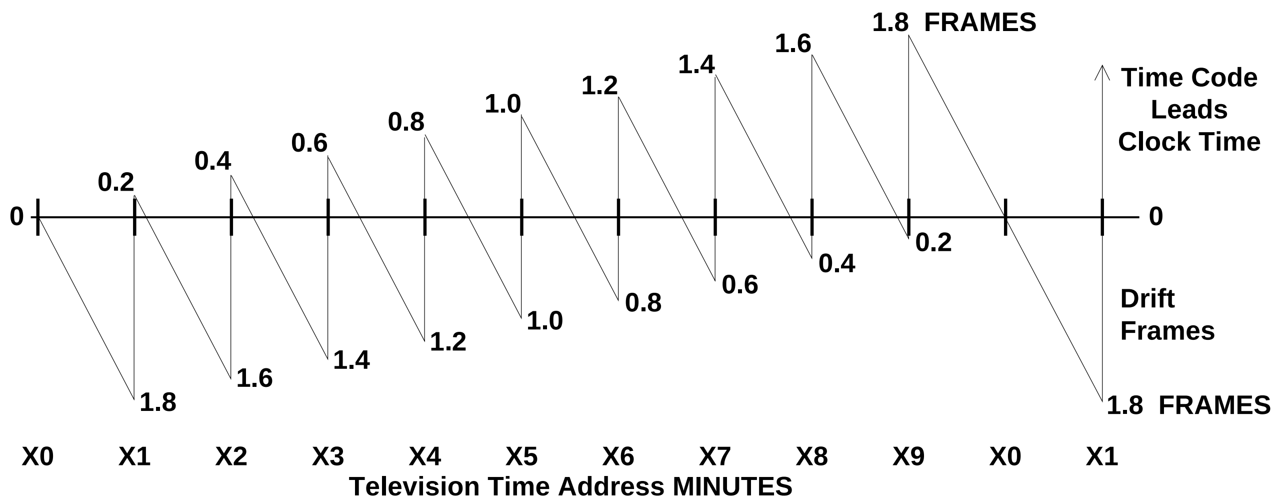

Figure 1 – Periodic offset drift of time address versus clock time for 29.97-Hz systems

2.3 Offset from Zero at Beginning of a Day

There is no standard to define the alignment between video frames and any midnight epoch.

For 29.97-Hz and 59.94-Hz systems, the consequence is that there can be an initial offset between the start of the video frame labeled with time code 00:00:00:00 and the beginning of a day (midnight). If color frame identification is applied to the time address, this will amount to an initial offset of up to two frames (67 ms) for 29.97-Hz and 59.94-Hz systems. Without color frame identification, this is reduced to one frame or 33 ms for 525/29.97 systems.

For 25-Hz and 50-Hz systems, the consequence is that there can be an initial offset between the start of the video frame labeled with time code 00:00:00:00 and the beginning of a day (midnight). If color frame identification is applied to the time address, this will amount to an initial offset of up to four frames (160 ms). Without color frame identification, this is reduced to one frame or 40 ms.

The variability is either positive or negative depending on the procedure used by the time code generating equipment to implement color field identification and compensate for changes.

For 25-Hz television systems, there is an integer number of frames in a day, and thus this offset will be constant from day to day. However, for 29.97-Hz systems, there is a non-integer number of frames in a day, and thus there will be a different offset at the beginning of each day.

For 25-Hz television systems that are implementing color field identification, the imposition of a leap second time correction will change the color field identification, thus imposing a corresponding time address offset change. See Section 3.2.2 for more information about leap seconds.

2.4 Reference Clock Errors

The above clauses on offset and drift between time address and precision clock time presume a precisely controlled video reference. Additional errors will be introduced if the television system is not referenced to a precision clock source.

3 Maintaining Time Precision

Depending on the application, a number of measures can be taken to reduce or eliminate the offset between the time code time address and precision clock time.

3.1 Phasing of Video to Clock System

For television systems that have an integral number of frames in a day, it could be possible to phase the television reference to a precision oscillator and clock system. System design and implementation would have to take into consideration delays and latency in the equipment and the transmission of the television signal.

3.2 Slaving of Time Address to Clock System

Normally the time code time address must be slaved (or “jam synced”) to the clock system. This jam sync is usually performed at a consistent time each day to minimize the size of correction that needs to be made to the time address.

3.2.1 Timing of clock system slaving

Since some equipment depends on the regular counting of the time address, any disturbance to the normal counting sequence creates a potential for operational errors. Corrections to the time address to achieve synchronization with a clock system are usually done at a time when it will have a minimal possibility of disturbing other equipment that depends on a regular incrementing of the time address.

This can be timed for a period of the day when operations are idle. For many editing applications, the use of time code values close to the midnight rollover is avoided. Thus a slave operation just before midnight might be appropriate.

3.2.2 Leap second corrections

Because of small differences between precision clock time and time based on the rotational speed of the earth, periodic adjustments to precision clock time are made in increments of one second. The last minute of the day on which an adjustment is made has 61 seconds or 59 seconds. To minimize disturbances to equipment depending on time code counting sequence, the last second in the day is repeated or omitted as described in Annex A.2 of SMPTE ST 12-1. See Section 0 for information on the effect of leap seconds on the offset of the time address from clock time at the beginning of the day.

4 Time Zone and Date Encoding

The date and time zone information is coded in the binary groups in accordance with SMPTE ST 309.

Annex A Bibliography

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 12-1:2008) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 12M-1-2008). Documents with the same root number (e.g. 12-1) and publication year (e.g. 2008) are functionally identical.

SMPTE ST 12-1:2008, Television — Time and Control Code

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

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

Recommendation ITU-R TF.457-2 1997, Use of the Modified Julian Date by the Standard-Frequency and Time-Signal Services

Recommendation ITU-R TF.460-6 2002, Standard-frequency and time-signal emissions

Annex B Summary

For integer frame-rate systems, it is feasible to easily synchronize and phase the reference video to a precision clock time reference. However, with variable equipment processing delays, maintaining time precision in a large system will be more difficult.

The relationship between a time code time address and clock time will also be affected by clock system corrections, such as the insertion of a leap second and transfers from standard time to daylight saving time.