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SMPTE ENGINEERING GUIDELINE

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

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 29.97 Hz although its principles may be 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 may also be relevant to time code synchronized to other references.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this guideline. At the time of publication, the edition indicated was 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 standard indicated below.

SMPTE 309M-1999, Transmission of Date and Time Zone Information in Binary Groups of Time and Control Code

3 Sources of error and deviations from precision clock time

Beyond errors that may occur due to the imprecision of the reference oscillator, systematic errors will occur for video systems operating at a frame rate of 29.97 Hz. This is due to the video frame rate not being an exact 30 Hz. By definition, the frequencies may be referenced from a stable and precise 5.0-MHz oscillator. Table 1 illustrates the relationship between the various rates.

Based on these rates, there are 2,589,410.59 video frames per 24-hour day. Similarly based on 30 f/s drop-frame time code, there are 2,589,408 frame counts in a 24-hour time code day. 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 00:00:00:02.59.

Precision of the time address will also be affected by jitter, wander, and other system latencies.

3.1 Progressive drift corrected by drop-frame counting for 29.97-Hz systems

Throughout the day, the difference between the 29.97-Hz video frame rate and the 30 frame-per-second nominal time address count is compensated by the

Table 1 – Basic frequencies for 525/29.97 video systems

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

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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.

3.2 Uncorrected progressive drift for 29.97-Hz 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 2.59 frames per day.

3.3 Offset from zero at beginning of a day

In addition to systematic drift of the time address versus clock time, there is also the initial offset between the beginning of each day and the start of video frame 00:00:00:00 of the time code day. If color frame identification is applied to the time address, this variability may amount to two frames (67 ms) for 525/29.97 (NTSC) systems and four frames (160 ms) for 625/25 (PAL) systems. Without color frame identification, this is reduced to one frame or 33 ms for 525/29.97 systems and 40 ms for 625/25 systems.

The variability may be 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 should be constant from day to day. However, for 29.97-Hz systems, there is a noninteger 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.

3.4 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.

4 Maintaining time precision

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

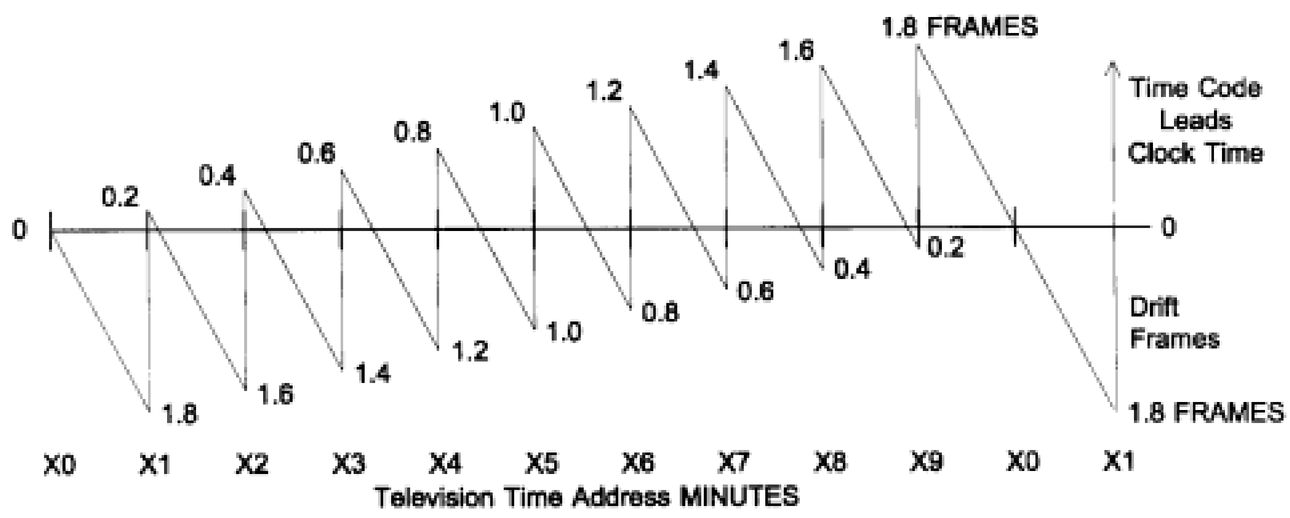

Figure 1 – Periodic offset drift of time address versus clock time for 29.97-Hz systems

4.1 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.

4.2 Slaving of time address to clock system

Naturally the time code time address must be slaved to the clock system. This should be performed at a consistent time each day to minimize the number of corrections that need to be made to the time address. 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.

4.2.1 Timing of clock system slaving

Where possible, corrections to the time address to achieve synchronization with a clock system should be done at a time when it will have a minimal possibility of disturbing other equipment that may depend on a regular incrementing of the time address.

This may 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 may be appropriate.

4.2.2 Leap second corrections

Clock system corrections may occur about twice a year. To minimize disturbances to equipment depending on time code counting sequence, the last second in the day may be repeated or omitted.

4.3 Subcarrier shift

To reduce or eliminate the effects of not having an integral number of frames in a day and of not having the same number of frames in a clock day as in a time code day, it might be possible to shift the video system frequencies. For 29.97-Hz systems, there are three magnitudes of shift that might be applied.

For 25-Hz systems, the video frame rate does not require any compensation to achieve and maintain compensation.

4.3.1 Correction to zero frame-per-day drift

By shifting the color subcarrier frequency downward by about 3.58 Hz, there would be the same number of video frames in a day as there are time code frames in 24 hours of drop-frame time code. This represents a one-part-per-million shift. This could eliminate any need to correct the time address periodically. The video could be phased to the clock system. Within a closed system, the time code time address could be maintained in precise and deterministic alignment with precise clock time.

While presenting several simplifications to time code and clock system operation, the magnitude of the shift to video rates could create other more disturbing results when interfaced with other equipment that depends on a more precise adherence to the standard video frequencies. Problems would also arise when interfacing with other systems that are not similarly shifted (see table 2).

Table 2 – Shifted video frequencies to eliminate drift

Parameter	Formula	Frequency	Shift
Reference oscillator	F_{ref}	4,999,995.00 Hz	1.0 ppm
F_{sc}	$F_{ref} \times 63/88$	3,579,541.88 Hz	–3.58 Hz
F_h	$F_{sc} \times 2/455$	15,734.25 Hz	
F_v	F_h / 525	29.97 Hz	

4.3.2 Correction to 2.00 frame-per-day drift (for 29.97-Hz television systems)

If the system frequencies are shifted so that there is an integer number of video frames in a day, then it would be possible to maintain a constant phase between video and clock time on a daily basis. This shift is within current specifications for video reference signals. The correction required to compensate for the residual drift between the time address and clock time would be fixed at two frames per day. This correction could be scheduled to minimize potential errors which could arise due to the deviation from regular counting of the time address (see table 3).

To correct the time code on a systematic basis, the additional compensation of two frames per day, a leap frame compensation mode could be added to the existing drop-frame counting mode rules. The leap-frame compensation would not drop frame counts 23:59:00:00 and 23:59:00:01 as normally defined for drop-frame compensation.

4.3.3 Correction to 2.50 frame-per-day drift

If the system frequencies are shifted so that there is an integer number of half video frames in a day, then it would be possible to maintain a constant phase between video and clock time over a four-day cycle. This very small correction of only 34 parts per billion (34×10^{-9}) is well within the tolerance range of high-precision reference oscillators. The correction required to compensate the time code for the residual drift between the time address and clock time could be fixed at ten frames over a four-day period. This correction could be scheduled to minimize potential errors which could arise due to the deviation from regular counting of the time address (see table 4).

To correct the time code on a systematic basis, the additional compensation of ten frames per four-day cycle, a leap-frame compensation mode could be added to the existing drop-frame counting mode rules. The currently defined drop-frame compensation would be modified to include leap-frame compensation where each day the frame counts 23:59:00:00 and 23:59:00:01 would not be dropped and every four days when the modified Julian date is exactly divisible by four, frame counts 23:58:00:00 and 23:58:00:01 would not be dropped.

5 Phasing of time code and video to clock time

For applications requiring absolute precision, the video and its related time codes may be phased to a precision clock source at the moment of midnight rollover. The alignment point for signals shall be defined as follows:

– For linear time code (LTC), this shall be the boundary between bit 79 (last bit of the sync word) and the beginning of bit zero (frames units 1's bit) of the time code.

Table 3 – Shifted video frequencies to fix drift at 2.00 frames per day

Parameter	Formula	Frequency	Shift
Reference oscillator	F_{ref}	4,999,998.86 Hz	0.23 ppm
F_{sc}	$F_{ref} \times 63/88$	3,579,544.64 Hz	–0.815 Hz
F_h	$F_{sc} \times 2/455$	15,734.262 Hz	
F_v	F_h / 525	29.97002 Hz	

Table 4 – Shifted video frequencies to fix drift at 2.50 frames per day

Parameter	Formula	Frequency	Shift
Reference oscillator	F_{ref}	4,999,999.827 Hz	–34 ppb
F_{sc}	$F_{ref} \times 63/88$	3,579,545.331 Hz	–0.124 Hz
F_h	$F_{sc} \times 2/455$	15,734.2652 Hz	
F_v	F_h / 525	29.97003 Hz	

– For video signals, this shall be the defined location for the alignment of the start of LTC with the video signal.

6 Time zone and date encoding

The date and time zone information shall be coded in the binary groups in accordance with SMPTE 309M.

Annex A (informative)
Summary

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

For noninteger frame-rate systems, such as NTSC, a compromise may be made with the defined system frequencies to achieve and maintain synchronization with clock time. A study is needed to investigate the effect on audio, compression, and communications systems as to how these frequency shifts will affect the operation of these related systems.

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.

Some of the methods that are presented here are beyond the normal precision requirements of many television applications.

Annex B (informative)
Bibliography

SMPTE 12M-1999, Television, Audio and Film — Time and Control Code

SMPTE 170M-1999, Television — Composite Analog Video Signal — NTSC for Studio Applications

ITU-R TF.457-1, Use of the Modified Julian Date by the Standard-Frequency and Time-Signal Services