The Right Time

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Real Time and Video Time

What time is it? The general public expects broadcasters to provide them with the correct time. Broadcasters also need a time reference to run their automation systems. It all sounds very simple and in PAL countries maybe it is, but in NTSC countries, it is not quite so simple.

In countries using 625 line, 50 Hz television systems, there are exactly 25 video frames per second (Fps). But in NTSC countries the number of frames per second is not a whole number. There are 29.97 video frames per second and broadcasters have a choice of either running their clocks from 60Hz time code, which is not locked to video, or 29.97Fps, DROP-FRAME time code which is locked to video. Drop frame time code was invented to overcome the time difference between NTSC video time and real time of day.

Video Time

NTSC is based on a sequence of 30 frames, but as NTSC is running at the slower rate of 29.97 frames per second, the 30 frame sequence takes longer than one second to complete. Time code is measured in Hours, Minutes, Seconds and Frames, but in the NTSC world, the "seconds" are actually longer than real seconds. Standard (non-drop frame) time code drifts away from real time by a factor of 1000/1001, or 3.6 seconds every hour. In other words, in a one hour period, the slower 29.97Fps video contains only 107,892 (27.98 x 60 x 60) frames, whereas 30Fps video would display 108,000 (30 x 60 x 60) frames per hour (an extra 108 frames). The non-drop frame time code at 29.97Fps will take 1 hour and 3.6 seconds to complete 108,000 frames and the time code will read 01:00:03:18. Drop frame time code, was invented to correct this discrepancy. Contrary to common belief, drop-frame time code does not drop any video frames. It is only the frame count within the time code which is modified, to drop the extra 108 "counted" frames and restore the duration to a true time period of 1 hour. Drop-frame time code does this by skipping the first two frames of every minute (2 frames x 60 minutes = 120 frames), except on the 10s of minutes (2 frames x 6 = 12, as there are 6 x 10 minutes in the hour). 120 – 12 = 108. Tables 1 to 3 illustrate the differences.

Frame rate	**Video frames per hour**	**Time code after 108,000 video frames**	**Time code after 1 hour**
30 non-drop	108,000	01:00:00:00	01:00:00:00
29.97 non-drop	107,892	01:00:00:00	00:59:56:12
29.97 drop-frame	107,892	01:00:03:18	01:00:00:00

Table 1 - Non-drop frame and drop-frame time code

Note that the actual video frame rate is 29.97002617 Fps instead of the approximate value of 29.97. Drop-frame time code does not correct for this and the resulting error is about 75 milliseconds per day or approximately ½ second per week. This error is usually corrected on a daily basis by using the "jam-sync" method, described later.

Real Time

Some Master Clock systems generate non-drop frame time code at 60Hz and this time can be accurately locked to GPS or to a national time standard source. The master clock will also have it's own high stability oscillator, so that accurate time can be maintained for short periods in the event that the connection to the GPS or other reference is lost.

60Hz time code, however, is unrelated to NTSC video, so this signal cannot be used for automation systems or for anything involving NTSC video. To solve this problem, some manufacturers offer a separate jam-sync device. Such a device is referenced to both video time code and true time of day time code and at specific times, the unit can be triggered to re-write the time code to line up with the video. The jam-sync will normally be carried out in the early hours of the morning, at a non-sensitive time of day.

A 29.97Fps Drop-Frame video time code generator can also be programmed to jam the output time code to the real time clock at certain non-sensitive times. Table 2 shows the accumulated time errors.

Duration	Drop Frame Time code	Video (non-drop) Time code
1 hour	3.1 ms	3.6 secs
1 day	75.7 ms	1.4 min
1 week	528 ms	10 min

Table 2 - Time Drift in NTSC Time codes

Continuous jam-sync is a possibility and is offered by some manufacturers. This may be used if the automation system can tolerate the jitter induced by the difference in frame rates of 30 and 29.97Fps. In most cases this is not a practical solution.

GPS, UTC and Leap seconds

No discussion of "real time" is complete without defining what is meant by real time. There are many different times zones around the globe and the airlines and other organizations, use Universal Coordinated Time (UTC) to provide a single international time standard. Universal Coordinated Time is sometimes referred to as Greenwich Mean Time, because it is the time in Greenwich Village, England, on the zero degree line of longitude when daylight saving time is not applied. Today, precise time is inexpensively available on GPS receivers, but GPS time is not actually the same time as UTC, because the earth's speed of rotation is not exactly 60x60x24 seconds per day. It is approximately

1ms slower. So although the GPS system uses precise atomic clocks, which were synchronized to UTC on January 6, 1980, since then there has been an accumulated time drift of 13 seconds between precise GPS time and UTC. This difference has been corrected periodically by adding *leap seconds**, to keep the world's time to within 0.9 seconds of the correct astrological time. GPS time is not corrected for leap seconds, however leap second data is carried on the signal in the form of the accumulated number of leap seconds since January 6, 1980. Master clock systems use GPS time, together with the leap second count, to determine current UTC.

Time offsets for local time and daylight saving time, are best introduced locally and various products are available to handle these issues.

> ** Leap seconds are introduced when necessary and usually at midnight on June 30 or December 31 as decreed by the International Earth Rotation Service (IERS) based in Paris, France.*
> *http://hpiers.obspm.fr/eop-pc/*
> *Since they were first introduced, leap seconds have always been positive (a second has been added). A record of leap second insertions can be found at http://www.boulder.nist.gov/timefreq/pubs/bulletin/leapsecond.htm*

Video Timing and the SPG

Video timing is like automobile engine timing. Neither has anything to do with real time, but more to do with ensuring that things happen at the right time in a sequence. If you don't want to see annoying glitches in your TV picture, all video signals need to be properly "timed" at the input to a video switcher The television station's Sync Pulse Generator (SPG) has the job of synchronizing all video signals within a facility. And, as you may want to mix signals from different facilities, all SPGs need to operate on the same frequency. This requires that SPGs all be fitted with a high stability oscillator – same requirement as for a master clock.

Early generation SPGs were required to supply separate sync pulses for H drive, V drive, color burst and other signals necessary to synchronize a wide variety of products from different manufacturers. These pulses are no longer necessary as most analog and digital products can now lock to color black (black burst). For convenience, many modern SPGs provide several black burst outputs with independently adjustable timing. This is useful when supplying synchronizing references to cameras and other devices, which are at different distances from the central switcher. Video arriving from cameras at the end of long cables, will experience longer delays, so sync references to these cameras should be advanced, compared with reference signals being supplied to closer cameras. Digital Video Effects (DVE) equipment will also delay video signals, so black burst signals feeding DVEs might also need to be advanced.

In recent years, HDTV has come onto the scene and this creates a string of new requirements. Tri-level sync signals are needed for various different video frame rates and different numbers of lines per frame.

Audio Synchronization
To avoid audio "pops", all broadcast digital audio feeds, need to be frequency locked to 48KHz and also phase referenced to the video. There is therefore a need for a digital audio reference signal (DARS).

TV Station Computers
It is not only the broadcast automation system which requires true time of day. There will also be many computers on the house network, which need accurate time. Network Time Protocol (NTP) was designed for this purpose.

All In One Box
To accommodate all of these requirements, Evertz has introduced a combined Sync Pulse Generator and Master Clock. The new 1RU product, known as the 5600MSC, has it's own high stability oscillator (a common requirements for all these devices) with external reference to GPS or to another time standard authority via modem.

5600MSC Master Clock / Master SPG

The new product, complete with all available options, provides the following impressive array of reference signals:

- 6 color black signals, independently timeable in frames, lines and cycles of subcarrier.
- 6 Tri-Level Sync outputs, independently timeable in frames, lines and samples
- 1 Frequency Reference, 10 MHz input/output
- 1 NTSC or PAL Test Signals
- 1 DARS output (balanced and unbalanced)
- 1 AES Tones (balanced and unbalanced)
- 1 Stereo Analog Audio Tones (balanced)
- 2 SDI Digital Black
- 2 SDI Test Signals
- 2 HDSDI Black
- 2 HDSDI Test Signals
- 1 NTP (Network Time Protocol) output
- 2 Different and programmable LTC time codes
- 2 GPI inputs and 2 GPI outputs

The 6 genlock outputs may be configured as 6 black burst, 3 black burst and 3 tri-level sync or 6 tri-level sync. However these might be configured, all of these outputs are independently timeable. Different HDTV tri-level sync signals, such as 1080i/60 and 720p/60 can be available simultaneously, as can NTSC and PAL black bursts.

The 10MHz reference may be used either to lock the 5600MSC to a cesium or rubidium crystal source, or to provide a high stability frequency reference to another device, e.g. another SPG.

There is wide range of analog, SDI and HDSDI test signals available and these can be field upgradeable if necessary. The digital audio signals are available both on a balanced 110 ohm Phoenix connector and on unbalanced 75 ohm BNCs.

There are two time code outputs. The primary output is available on a balanced XLR and on a separate auxiliary 9 pin 'D' connector. The secondary time code is available on the 'D' connector only. These two time codes can support various combinations of requirements, such as:

- 60Hz and 29.97Fps drop frame
- 23.98Fps non-drop 29.97Fps non-drop
- UTC and Local Time (29.97Fps drop-frame or 25Fps)
- Local Time (or UTC) and advanced time to accommodate down stream delays.

An automatic changeover is available for use with two 5600MSCs, to ensure continuity of time and synchronization signals to the television facility.

Dolby E and the "bit bucket"

Dolby E provides us with a method of transporting 8 audio channels (instead of 2) in one AES digital audio bit stream. The Dolby E audio data is usually frame locked to the video and can be vulnerable when Dolby embedded audio data, encounters a frame synchronizer. To illustrate this, Fig 1 shows how a frame synchronizer works. The incoming feed needs to be locked in time to the local studio SPG. This is achieved using a frame buffer, or "bit bucket". If the incoming feed is not in time with the local studio sync pulses, the digital bits in the incoming feed must accumulate in the buffer and wait until the first bits are in time with the local signal, before being released. Bits are always flowing into the buffer and out of the buffer. If the rate of flow into the buffer is the same as the rate flowing out of the buffer, the buffer will never empty and will never over-flow. If the bits are flowing in faster than they are flowing out, the buffer will fill up at some point and it will be necessary to drop a frame. If the bits are flowing in too slowly, the buffer will empty and it will be necessary to repeat a frame. In both cases the audio will be disrupted. Evertz frame synchronizers handle embedded AES audio by de-embedding, correcting the audio timing and then re-embedding the audio into the SDI bit stream. This is not possible with Dolby E, unless a Dolby decoder and a Dolby encoder are used. If we wish to guarantee Dolby audio continuity through a frame synchronizer, a simpler method should therefore be found.

This is where GPS comes to the rescue. If the local 5600MSC is locked to GPS and the remote feed is also locked to a 5600MSC-G (GPS) at the sending end, the two signals will be frequency locked and no frames will ever be dropped or repeated. The frame synchronizer will be needed only to time the incoming feed to the local station.

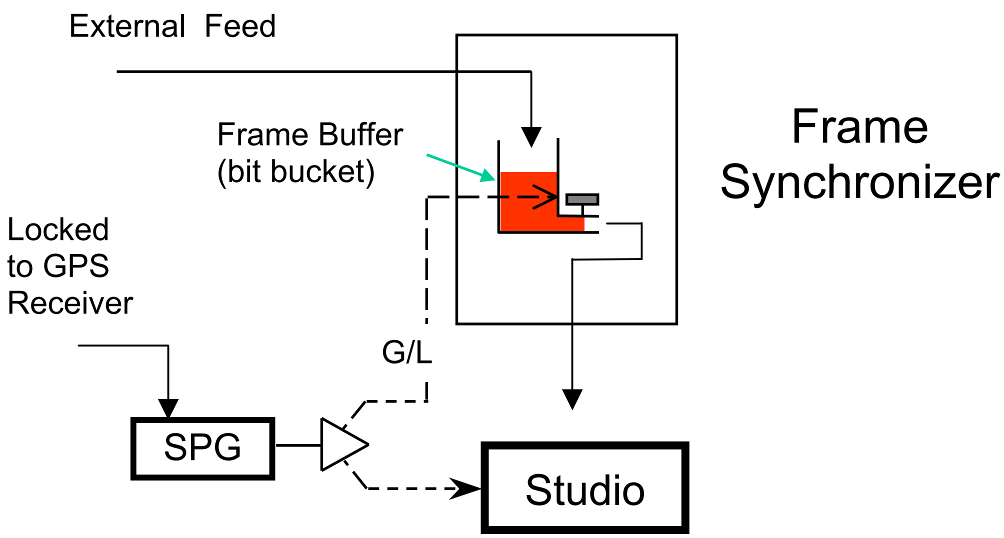

Fig 1. Dolby E and the Frame Synchronizer “bit bucket”

Summary

One of the best sources of reference for both frequency and time of day, is the Global Positioning System. From a GPS receiver, the Master Clock can derive UTC and should also be able to add the appropriate time offset and provide corrected local time. Table 3 contains a list of the various corrections which need to be made by the Master Clock.

		Offset	**Master Clock Update**
1	Earth speed drift/day	1ms	Leap second correction made approximately every 18 months as determined by IERS.
2	NTSC drift/day	75ms	Usually daily
3	Local Time	-	At time of installation only
4	Daylight Saving time	1 hour	Twice per year

Table 3 - Required Time Corrections

The above corrections are made to the time code outputs, without disturbing any of the video signals. This correction is called a *jam-sync*. NTSC has a 4 field color sequence and PAL* has an 8 field color sequence, so to avoid disturbing the video, there will be a discrepancy between UTC and the time code output, after a color correction of the time code numbers occurs. The maximum discrepancies for NTSC drop frame time code will be 2 fields (33ms) after a daily jam-sync and for PAL (EBU time code) it will be 2 fields (40ms), after a leap second insertion. In NTSC countries, if you jam-sync daily, drop frame time code may also be used to drive slave clocks. The maximum time drift will be 75ms. 60Hz time code is not related to video and is not affected by jam-sync operations.

The Evertz 5600MSC may be programmed in advance, to make time and time code number changes automatically without disturbing the video.

** The PAL 8 field television system runs at 50 fields per second, so one field has a duration of 20ms and one PAL cycle is completed in 160ms. At this rate there are 6.25 PAL cycles per second. When a leap second is added, the extra 0.25 cycles (2 fields or 40ms) cannot be accommodated.*