TIME CODE BOOKLET

SMPTE/EBU Time Code and its Application

A GUIDE TO SMPTE/EBU TIME CODE AND IT'S APPLICATION

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SOURCES:

Webers, Tonstudiotecknik
Webers, Bild und Ton synchron
Woram, The Recording-Studio Handbook

Preface

Until very recently, the nature and usage of SMPTE time code in relation to audio/video recording was understood by only a very small elite of the production industry. The time code-based synchronizer, which allowed accurate and reliable synchronization of multiple tape transports, was a massively expensive and apparently esoteric item, and as such was only within the budget of the largest and most successful recording and production companies.

As time progressed, numerous synchronization systems purportedly offering an economical alternative appeared on the market. Often these systems did not adhere to either the SMPTE standard time code format, or to any other recognizable industry norm, the result of which being questionable reliability and total non-compatibility among synchronizers, transports and tapes.

The continued expansion of the video medium and its impact on audio recording at all levels has precipitated the need for an inexpensive, reliable and SMPTE-standard compatible system, offering a consolidated approach to audio/video synchronization and production.

FOSTEX has filled this need with its Professional Multitrack series, offering SMPTE/EBU time code synchronizers, wide-band readers, programmable generators and a full complement of transport interfaces, as well as a generation of audio recorders designed for the synchronization/production environment.

FOSTEX recognizes that in addition to efficient and economical hardware solutions, today's recordist requires an understanding of the mechanisms by which these solutions are achieved. We present the following text as a concise, but thorough grounding in time code technology and application, and hope thereby to put in better perspective the capabilities and limitations of today's timecode systems.

Time Code — How does it work?

Although time code has only come into common usage within the relatively recent past, the history of its development spans roughly thirty years. In order to fully appreciate the technical challenges that brought time code into being, we must look back to the very early days of video recording.

In 1956, the AMPEX corporation introduced the quad-head video tape recorder—an innovation greeted with great enthusiasm. They had developed a new process of recording pictures which, in contrast to the predominant film medium, offered low cost and remarkable flexibility.

A problem became immediately evident, however: how does one edit a video recording? It was necessary to allow for the creation of a final programme from a variety of individual takes. In working with traditional motion picture film, it was possible to examine the film and locate the appropriate cutting marks, as the sprocket holes offered a reliable reference by which to identify an edit point. Video tape offers no sprocket holes, nor can visual examination of a piece of video tape yield any indication of the information recorded there; furthermore, since the video signal is recorded diagonally across the tape, it cannot be edited by the cut-and-splice process applied to film and audio tape. It rapidly became apparent that some degree of automation was required in order to make video tape editing a feasible process.

In the beginning mechanical tape counters offered some clue as to the position of the tape, but their accuracy was compromised by slippage, as was their usefulness by the need to reset the counter at the beginning of the progremme.

In 1963, the recording of an electronic pulse onto an audio track of the video tape was introduced as an electronic alternative to the mechanical counter. This is the control pulse (CTL Pulse) that remains a standard feature of video recorders today, an "electronic sprocket-hole" that can be counted and referred to as a positional and as a timing reference. Although more accurate than the mechanical counter, this system can suffer from dropouts and missed pulses due to poor tape-to-head contact at fast wind speeds; like the mechanical counter, it must be reset at the start of the programme; and any count errors that occur can accumulate to cause a wide discrepancy between counter reading and actual tape position. Evidently, a more reliable method of identifying tape position was required, if precision and repeatability of editing were to be preserved.

The solution to these problems first appeared in 1967, with the proposal that an actual numeric value—a digital representation of the time position of each video frame—be encoded on the tape, along with the video picture. This mechanism would allow the absolute identification of each frame, without susceptability to cumulative errors or the need to begin playback from a known point on the tape. In 1972 this mechanism was adopted by the SMPTE (Society of Motion Picture and Television Engineers) and by the EBU (European Broadcast Union), who established the time code standards with which we are familiar today. The standards adopted by the SMPTE and the EBU differ slightly—largely due to the dissimilar television standards existing in North America and Europe—but are fundamentally alike, and we commonly refer to them collectively as SMPTE/EBU Time Code.

LTC versus VITC

Time code was originally developed in a form to be recorded on an auxiliary audio channel of the video recorder, as a waveform of characteristics similar to an audio signal and recorded continuously along the length of the tape—thus the designation Longditudinal Time Code (LTC). LTC is today the most common form of time code, and is in fact the only one directly applicable to audio tape recorders; for the sake of completeness, however, we will digress briefly to identify the other major variation of time code technology, which came about as an answer to some of the limitations of LTC in a video editing environment.

As long as the subject video recorder is playing back at or close to its normal play speed, LTC recorded on an audio track is available and easily readable. The frequency of the LTC signal is proportional to tape speed, of course, and at high fast wind speeds can rise past the frequency response of the recorder's reproduce system and become unreadable; at extremely low speeds, the LTC signal can disappear completely. This limitation of LTC in video editing, where much time is spent in slow and freeze-frame modes, led to the development of a time code format that could be recorded as part of the video signal itself.

This code, inserted in the video signal in the gap between visible frames known as the vertical blanking interval, offered the advantage of being readable under any circumstances where a picture is available, and became known as Vertical Interval Time Code (VITC). Although apparently well suited to the business of video editing, VITC brings with it some major limitations:

- VITC cannot be used with audio recorders, which necessitates support of both VITC and LTC in the studio if synchronization with audio transports is desired;
- VITC cannot be written on tape before or after recording of the video signal, as the two are interwoven on the same recording path.

LTC thus remains more common than VITC, particularly where audio production is involved, as it offers great simplicity and flexibility of use. In continuing our examination of SMPTE/EBU time code, then, we will deal exclusively with LTC.

The Structure of LTC

As we have seen, a numeric code is recorded alongside each video picture, or frame, in order to uniquely identify each picture and to determine its position in the original sequence of frames. The simplest coding would involve consecutively numbering frames from some defined start point, beginning with "1" and continuing ad infinitum; of course, we could use numbers, letters, or any other sequence that seemed appropriate. In fact, a sequence of real time units was deemed most useful, as this could fulfill a dual function: identification of individual frames, and indication of elapsed time in a natural and comprehensible form. Further, a tape recorded with time code preset to the actual time of day could yield a complete record of exactly when an event took place, a valuable feature in news gathering, sports recording and surveillance.

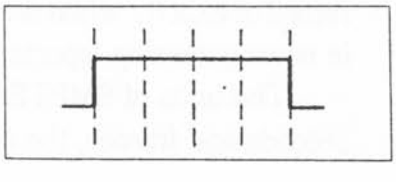
The units of SMPTE/EBU time code are hours, minutes, seconds and frames, the actual time value of the frame being dependant on the time code standard in use. In North America, where the NTSC television standard prevails, there are 30 video frames per second and the value of the frame unit in time code thus ranges from 0 to 29—each frame lasting 1/30 of a second. In Europe, the video frame rate is defined as 25 fps (frame-per second) according to the PAL standard, and we thus have a SMPTE/EBU time code frame of 1/25 second to accommodate this lower rate. In dealing with film at 24 fps, the SMPTE/EBU frame is worth 1/24 second.

SMPTE/EBU time code allows us to identify each video picture individually, by assigning a time value to each frame and encoding this on the tape. This code takes the form of a digital "word", or collection of 0's and 1's, and in addition to the hours/minutes/seconds/frames value it also holds several other pieces of helpful or essential information: control bits, user bits, and the sync word. The exact function of these will be examined shortly; first, let's look at the detail of the encoding process.

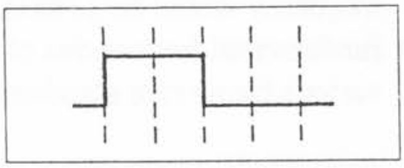
The Recording Format

When we speak of a digital signal, we refer to a series of information units, each unit having one of two possible states: these states are commonly designated 0 and 1. Although a single information unit, or bit, is not particularly informative by itself, a collection of bits taken together in an organized sequence can represent some very useful information. Electrically speaking, a bit can be represented in several ways; the mechanism chosen for SMPTE/EBU time code is called Biphase Modulation.

One of the major demands made of the SMPTE/EBU LTC is that it be readable at a wide range of play speeds. If, for example, we simply define a 0 as a low signal level and a 1 as a high one, we can represent a four-bit piece of information as follows:

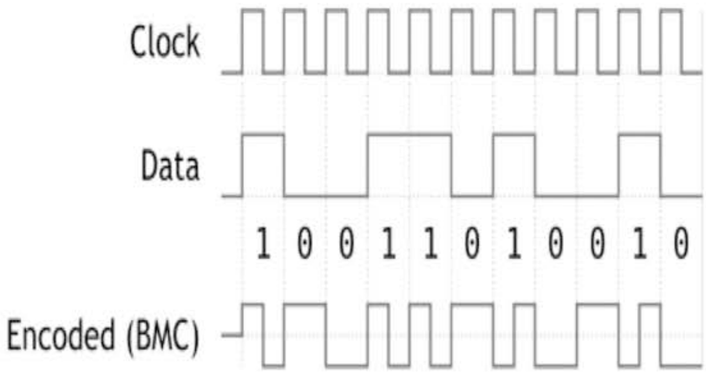


When we play this signal back at twice the normal play speed, however, it takes on a completely different meaning:



This system demands that the device attempting to read the digital signal know something about the speed, or frequency of the signal at recording and at playback—a requirement that is highly inconvenient to our time code application.

In Biphase Modulation, we instead define that there will be a change of level at the beginning of every bit—this gives us an indication that information follows. Then, a bit with a value of 1 will feature another level change in the middle of the bit; a 0 bit will not feature a level change, and the signal will remain the same until the beginning of the next bit. This diagram shows a 12 bit data segment encoded by our first method, and then by Biphase Modulation:



The clear advantage in Biphase Modulation is that the absolute bit rate is irrelevant, as long as it is fairly constant; the time code reader only has to compare the relative lengths of the high and low states in order to clearly distinguish between 0 and 1 at any playback speed.

Another criterion important to the SMPTE/EBU time code recording format is that the fundamental frequencies of the bit stream be near the centre of the frequency response of a typical audio recorder. For example, in the PAL television standard of 25 frames per second, each frame has a duration of 40 milliseconds. During this period, an 80 bit time code word must be written to the tape, and so each bit will last

0.5ms. If all bits in the time code were set to 1, this would correspond to a frequency of 2.0kHz; if all bits were 0, the frequency would be 1.0kHz. The following table lists the fundamental frequencies of SMPTE/EBU time code under various frame rate standards:

Frame rate	All bits="0"	All bits="1"
24 F/s	90Hz	1920Hz
25 F/s	1000Hz	2000Hz
30 F/s	1200Hz	2400Hz

At any frame rate, then, a real time code signal composed of both 0's and 1's alternates between roughly 1 and 2kHz, right in the middle of the frequency range of the average audio recording channel. The time code signal is of course also composed of many other harmonic frequencies—it is essentially a square wave signal—which could lead to all sorts of unwanted side-effects: crosstalk, distortion and so on. For this reason the SMPTE/EBU standard limits the rise time of the wave edge, keeping the harmonic content of the code within a reasonable range. Following are some of the more significant electrical standards imposed by the SMPTE and the EBU:

	EBU	SMPTE
Period length	$500\pm2.5\mu s$	$416.7\pm4.2\mu s$
Rise and fall time	$50+15, -10\mu s$	$25\pm5\mu s$
Maximum overshoot, undershoot, tilt	5% of peak to peak amplitude	2% of peak to peak amplitude

In generally, the SMPTE/EBU time code format is quite durable and reliable in the context of the audio performance expected of audio and video recorders today. In fact, barring massive dropouts or exasperatingly poor audio calibration, the only factor which can seriously degrade the intelligibility of a code is the presence of a noise reduction system in the recording path. Depending on the method and the quality of noise reduction, the time code signal can be distorted to a lesser or greater extent, and for this reason it is a standard rule of thumb to disable noise reduction on any channels that are to be used for time code recording.

The Encoded Information in LTC

Having established the characteristics of the SMPTE/EBU time code signal, and the mechanism by which it is recorded and read, we can turn our attentions to the actual information content of the code.

The most significant segment of the LTC frame is the numeric address of the frame itself. As previously seen, this value is represented in units of hours, minutes, seconds and frames; a particular frame might have an address such as 14 hours, 36 minutes, 9 seconds and 15 frames, indicating that this frame is offset by that amount of time from an arbitrary start point. (Notice that it is not necessary that the time code on a tape start from zero—in fact it is more often not the case). We would write this address in the form 14:36:09:15.

The frame address is encoded in the time code word as eight separate information blocks in a form called Binary Coded Decimal (BCD). Under this coding scheme, each individual decimal digit of the frame number is written separately in binary form. As each decimal digit can have a value ranging from 0 to 9, a maximum of four binary digits (or bits) are required for each of the eight binary blocks as shown below:

Decimal	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

The frame units digit, a 5, would exist in the time code as the sequence 0101, with the rightmost (or "least significant") binary digit appearing first. Somewhat later on in the LTC frame appears the encoding of the frame tens number; but as this can only ever have a value of 0, 1 or 2 (recall the maximum of 29 frames), only 2 bits are allocated to describing it, and in our example would appear as the sequence 0.1.

Each of the eight decimal digits are encoded in this way throughout the time code frame, and occupying only as many bits as are necessary to describe the possible range of each:

frames, seconds, minutes and hours units:	**4 bits**
seconds tens and minutes tens:	**3 bits**
frames tens and hours tens:	**2 bits**

Interespersed with these eight groups are several other groups containing format information, some unused bits, and a quite substantial allocation for user data. These so-called "user bits" are in fact eight groups of four bits each, to which no specific meaning has been ascribed and which can be used to store whatever information the user may feel important. Some relevant examples might be the date of the recording, time of day, initials of the cameraman or engineer, or other data. These data groups may be interpreted as letters and numbers according to the ASCII or ISO-7 standards for character coding, allowing a total of 4 characters to be reperesented in each frame; more commonly they are read simply as eight hexadecimal numbers—each digit representing a number from 0 to 9 or letter from A through F.

In order to prevent ASCII characters from being interpreted as hexadecimal numbers (and vice-versa), the EBU standard assigns bits 27 and 43 as Binary Group Flags, which are set to indicate the intended interpretation. The SMPTE variation of LTC does not formally recognize these flags, and simply designates bits 27 and 43 as unassigned bits.

Essentially then, time address groups and user bit groups are alternated throughout the length of the time code word: frame units data occupies the first 4 bits of the code, the first user group the next 4, the frames tens value the subsequent 2 bits, and so on, up to and including bit 63. Along the way there remain a number of spaces filled by the aforementioned Binary Group Flags, several unassigned bits, and two special control bits worthy of further mention.

The first of these bits is the product of a slight anomaly in North American video standards. Under NTSC video, the exact television frame rate is in fact 29.97 fps; SMPTE time code, however, counts exactly 30 frames every second, and this means that a generator creating time code frames at the same rate as the TV/video frames will eventually accumulate a significant real-time error. In fact, after one hour of running time, the code address would be short by 108 frames, or 3.6 seconds.

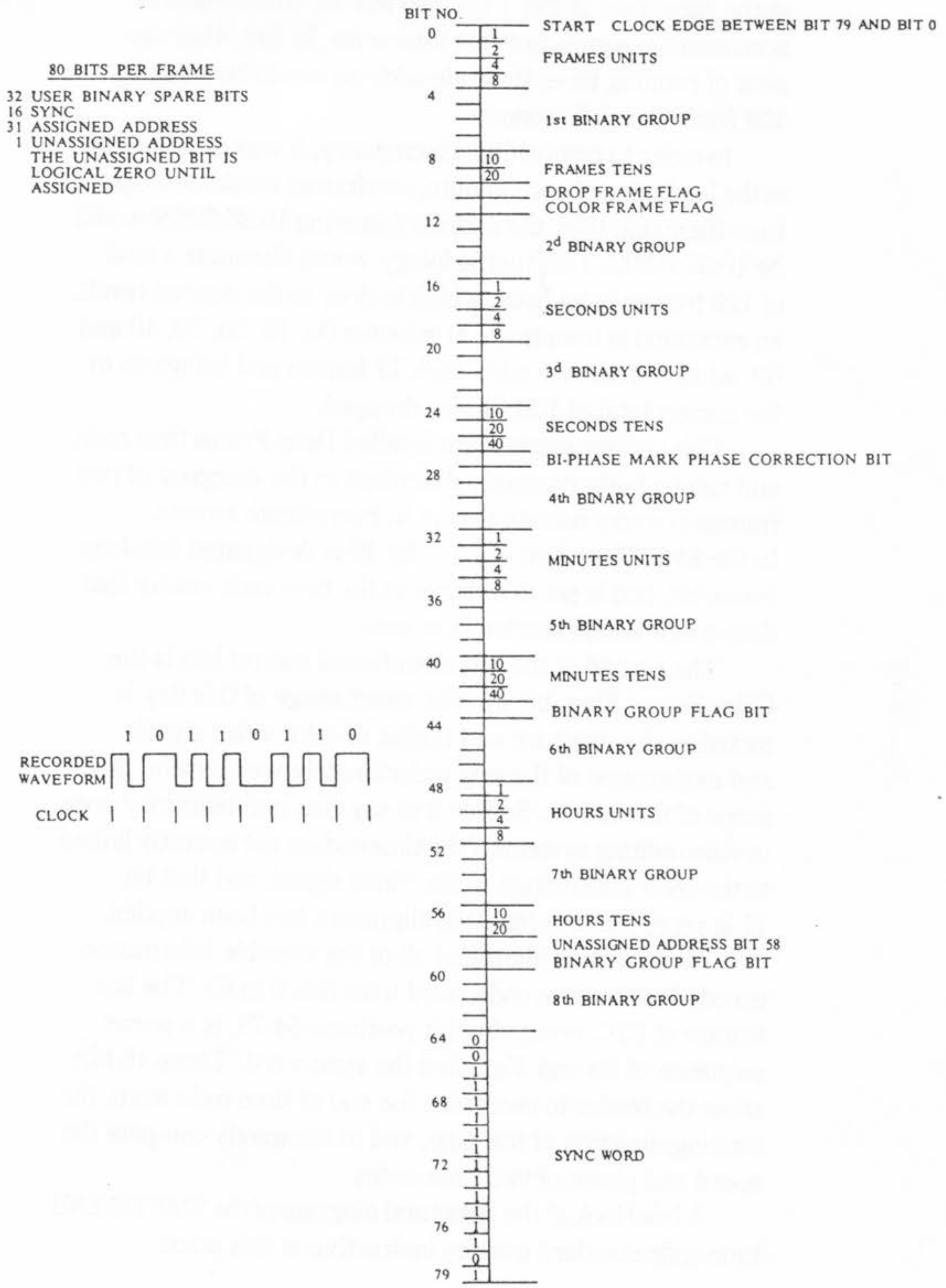
In order to resolve this discrepancy, it was decided that at the beginning of each minute, two frames would be dropped from the count; thus, the address following 16:36:59:29 would be 16:37:00:02. This methodology would eliminate a total of 120 frames in an hour, which is close to the desired result; an exception is then made at minutes 00, 10, 20, 30, 40 and 50, which effectively adds back 12 frames and brings us to the correct total of 108 frames dropped.

This curious mechanism is called Drop-Frame time code, and can be fairly concisely described as the dropping of two frames in every minute except in every tenth minute. In the SMPTE variant of LTC, bit 10 is designated the drop-frame bit, and is set to indicate to the time code reader that drop-frame compensation is in use.

The second of the aforementioned control bits is the Color Frame Flag, bit 11. The exact usage of this flag is rooted in the structure and timing of color video signals, and explanation of these is unfortunately well beyond the scope of this article. Suffice it to say that problems may arise in video editing systems if the time code is not correctly linked to the color information in the video signal, and that bit 11 is set to indicate that this alignment has been applied.

We have thus identified all of the variable information encoded in the time code word from bits 0 to 63. The last feature of LTC, occupying bit positions 64-79, is a preset sequence of 0's and 1's called the sync word. These 16 bits allow the reader to recognize the end of time code word, the running direction of the tape, and to accurately compare the speed and phase of two time codes.

A brief look at the structural diagram of the SMPTE/EBU time code standard may be instructive at this point.



Longitudinal Bit Assignment

ANSI/SMPTE 12M-1986

Time Code — Applications

At the beginning of this booklet, we briefly mentioned the circumstances surrounding the early development of time code. The initial thrust behind the establishment of time coding standards lay in the editing of magnetically recorded video images, and this function remains central to the applications of SMPTE/EBU timecodes today.

It is a standard working procedure in film and television production to select from a batch of recorded 'takes' the best possible segments, and to assemble these into a final programme with help of mechanical or electronic editing methods. Manual techniques, such as those used in editing film or magnetic audio tape, are hardly applicable to video recordings; electronic assistance is essential. As individual video takes are transferred from one or more playback transports to the master recorder, we must be able to accurately control the start point and length of each segment, and its position in the final programme sequence.

To begin with, this requires frame-accurate tracking of both source and destination transports; further, it necessitates that all of the transports employed in the editing process be precision-locked such that each begins to scan a new frame at exactly the same instant, allowing complete pictures to be passed smoothly from player to recorder.

For time code to be useful in fulfilling both of these ends, it is important that each 80 bit time code word correspond exactly to one video frame. A code recorded on an audio or cue track of a video recorder, then, must be synchronized with the video signal, so that each time code word begins simultaneously with the vertical sync pulse that indicates the start of a new video frame. When this synchronization is accomplished, each picture will 'contain' exactly one complete time code word. Most SMPTE/EBU time code generators provide an 'external sync' mode which can detect the vertical sync pulse in a video signal, and use this pulse as a timing reference for time code generation.

Three major video editing techniques exist today:

1) Assemble editing

The final programme is built up by appending the next appropriate segment to the master recording, and progressing gradually from beginning to end.

In this case, all signals (video, audio, cue, timecode, CTL pulse) can be passed from the player to the recorder. A minimum of two transports—one player and one recorder—are required.

2) Insert editing

In this technique, a new segment is recorded over (or inserted into) part of the existing programme, but preserving the CTL track and time code that already existed on the master recorder. Again, at least two transports are essential.

3) A/B Roll editing

This method implicates two playback machines which, during normal editing, are run alternately; both operate simultaneously to achieve mixing. Obviously, a total of three transports are required.

In the usage of assemble editing, it is apparent that some care must be taken in the recording of time code on the master recorder. If the time code for each segment is copied from the source transport, the resultant master tape will contain a jumble of discontinuous time codes which will preclude further automatic editing and confuse any subsequent manual attempts. It is customary, when assemble editing under time code control, to source the recorder's time code from a generator which, during the pre-roll period, locks up to the previously recorded segment's code in both timing and in numeric value. At the edit point, the generator continues counting from the address at which the previous code left off, yeilding a continuous code on the master tape. This process is referred to as 'jam sync,' and is an essential feature of full-function time code generators.

A variation of the concept of jam sync is applied when it is necessary to copy a time code from one tape to another, which is a situation that occurs with alarming frequency in both audio and video applications. Every time that a code is simply dubbed from one recorder to another, it waveform is distorted due to the difficulty that analogue magnetic recorders have in processing square waves. After one or more dubbings the time code may be rendered completely illegible. In order to copy time codes without distortions, a process of regeneration, or continuous jam sync, is applied. The code that is to be copied is fed into a time code reader/generator, and the output of that generator is locked to the timing and address value of the incoming code. A completely fresh waveform, identical in content to the original, is thus available to the destination recorder. Regeneration should always be used when attempting to copy time codes.

Time Coding Audio Recorders

The SMPTE/EBU time code signal must be allocated one audio signal path on any tape on which it is to be recorded. In the case of video recorders, this is generally on of the available audio channels, or even a dedicated timecode track in some formats. When using audio multitrack transports, one of the regular audio channels is designated for time code recording, generally an outside track. However, conventional 2 channel, half-track recorders offered no facility for recording a time code, without limiting the programme material to mono. A variation of the traditional half-track 1/4″ format, which inserts an extremely narrow third recording path between the major audio tracks, has resolved this deficiency and has been very well accepted as it maintains compatibility with the original format.

As per the draft of IEC (International Electromechanical Commission), the international standard for the so-called twin track format with central time code track on 6.3mm tape lays out the track spacings thus:

Audio tracks:	2mm
Centre track:	2mm
Time code track:	0.38mm

A few manufacturers do not equip the cue track record and playback amplifiers with pre- and de-emphasis circuitry such as is standard for the audio tracks. This equalization boosts high frequencies during the record process, and its absence minimizes the possibility of cue track crosstalk into the main audio channels. However, this approach also limits the frequency response capability of the track, rendering it almost useless for conventional audio recording; other manufacturers therefore apply similar circuitry to the cue and audio record/playback amplifiers.

There also exist among manufactuers some differences of opinion concerning the optimal head configuration of the three-track time code format. Some delegate a completely separate head for recording of the time code track. This concept, although simpler with respect to head design, implicates a fixed time difference between the time code and the main audio heads, and necessitates the inclusion of time code delay circuitry to maintain physical alignment of the code and corresponding audio signals on the tape. Digital delay devices have been incorporated in a number of these recorders, operating at a fixed delay time preset according to the distance between heads and tape speed.

Another solution involves the use of two rather unusual combination heads: one is equipped for audio erase and cue track playback, whilst the other provides cue track erase and record functions. While this method offers some design and operational advantages, it too requires inclusion of a digital delay line to resolve the offsets in head position.

By treating the cue track as simply a third audio track, and by accomplishing erase, record and playback of time code via the same heads as are used for audio, the problem of offset time code position can be eliminated. This approach requires careful head and electronic design in order to avoid crosstalk problems, but yields an infinitely more elegant and economical solution. FOSTEX adopted this format for three-track recorders using 3 track in-line head, and as a result of careful attention to the magnetic and electronic parameters of the cue track, FOSTEX offers excellent performance with respect to cue-to-audio crosstalk levels.

Synchronization

A time code may thus be recorded in parallel with the audio signal on such a three-track machine. In order to synchronize this transport with others by means of the time code, a device capable of comparing time codes and controlling the speed of one of these transports is required. Typically, a synchronizer is composed of two time code readers, a computer that compares the output of these readers, and a controller capable of speed and function control over one transport, designated the 'slave'. All of these elements are generally incorporated in a single chassis, possibly excluding the operator's control facilities and display, which are often remotely mounted. The control/display unit, in addition to providing readout of the time code values and basic transport control, may offer the ability to program a desired time 'offset' between the codes of the two recorders, as well as control of overall system function. As time code can provide extremely accurate position and elapsed time references, it is also common to find incorporated in synchronization systems auto-location features including locate, loop and programmable punch in/out referenced to time code.

In summary, then, we have identified several major fields of application for SMPTE/EBU time codes: audio/video synchronization, increasing the number of audio tracks available by locking two multitrack recorders, automation in editing, and auto-locator function. Additionally, SMPTE/EBU time codes can be used to accomplish synchronization between magnetic tape transports and MIDI (Musical Instrument Digital Interface) sequencers, an area of interest that has recently become popular. We will examine specific instances of each of these in the following chapter.

System Configurations

The FOSTEX synchronization system is based on the 4030 Synchronizer. As the audio and video transports of various manufacturers each use a different set of electrical standards for external machine control, FOSTEX offers a variety of interface units to adapt these machines to the FOSTEX protocol; FOSTEX transports can of course be directly connected to the 4030. The 4035 Controller expands the capabilities of the 4030 and offers a convenient user interface.

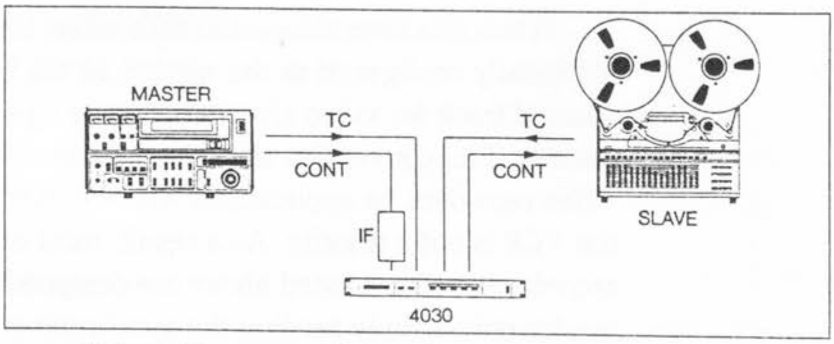
The Model 4030 Synchronizer incorporates two SMPTE/EBU time code readers, a computer that processes and compares the readers' outputs, and a control system that can manipulate the transport connected as 'slave' according to the computer's directives and thus achieve synchronization. Control of the slave transport's capstan speed is the most sensitive aspect of this control function, and the 4030 offers two distinct methods of control: a direct current voltage level, and a variable frequency signal for recorders equipped with direct drive PLL capstans. The electrical characteristics of the capstan servo output are as follows:

Voltage control:	Range	−14V to +18V
	Output impedance	1k Ohm
Frequency control:	Range	2kHz to 30kHz
	Output impedance	22 Ohm
	Output level	TTL compatible

Additionally, there are TTL open-collector outputs for control of play, fast-forward, rewind, stop and record modes. The versatility of these outputs allow the 4030 to control a wide variety of tape transports.

The time code inputs automatically adapt to the SMPTE and EBU standard frame rates of 24, 25, 30 and 30DF, as well as accepting PAL and NTSC composite video signals and 48-60Hz sync pulses. The 4030 can read time codes over a range of 1/2 to 2 times normal play speed; above and below this range, the 4030 can accept tach pulses (or CTL pulse in video) of 4Hz to 5kHz in order to maintain its positional reference. Some time code readers, including that of the Model 4010, are able to read time codes over a very wide range of speeds, but this feature is not particularly useful as a means of interfacing audio recorders to synchronizers. The audio transport must be modified so that the tape contacts the heads in fast wind modes, increasing head erosion significantly; further, the audio reproduce amplifiers require modification in order to pass the very high frequencies generated by LTC at these speeds. As a result, the combined time code/tach pulse mechanism is the preferred method for obtaining positional information on audio transports.

The 4030 occupies one unit of standard 19″ rack space, and can accomplish basic chase-lock function between two transports, whereby the slave simply emulates all of the motions of the master transport.



Major differences often exist between tape transports, with respect to the electrical and mechanical characteristics of their external control ports. An interface unit is required to adapt these units to the 4030's own protocol, a process that may involve matching of voltages and impedances, adjustments of timing and logic considerations, and compilation of control signals not directly supplied by the transport.

FOSTEX Interfaces for the following transports are currently available:

INTERFACES	
8750b	Sony VO-5630, VO-5800, VO-5850
8751b	Sony BVU-800, BVU-820, BVW-10/15/40
8753	Sony VO-5800, VO-5850 Master/Slave
8754	Sony BVU-800, BVU-820, BVW-10/15/40, Master/Slave
8755b	JVC BR-8600, CR-850, CR-8250
8756	JVC BR-6400
8758b	Panasonic NV8500, AG6800
8770	Studer A-800 (FM Servo)
8771	Studer A-80 MK 2/3/4 (DC Servo)
8772	Studer A-810
8775	Ampex MM-1200
8778	MCI JH-110B/C
8779	MCI JH-16/24
8780	Otari MTR 90
8781	Otari MTR 10/12/MX70/MX80
8782	Otari 5050 MK 3 (16 Pol.)
8783	Otari 5050 MK 3 (34 Pol.)
8784	Otari MTR 90 MK 1
8785	Tascom 40/50/60 Series/MS—16
8786	Tascom 85-16B
8788	Otari MTR 10 MK 2
8791	Sony PCM 3324

When synchronizing audio with video, the video recorder is typically configured as the master, as the building up of a sound track for video always occurs in a picture-oriented manner. This convention also allows the use of consumer-type video recorders, in applications where external control of the VCR is not a priority. As a result, most of the video recorder interfaces listed above are designed for usage as master only, simply feeding the synchronizer with the requisite status and motion information, and passing control signals to the VCR.

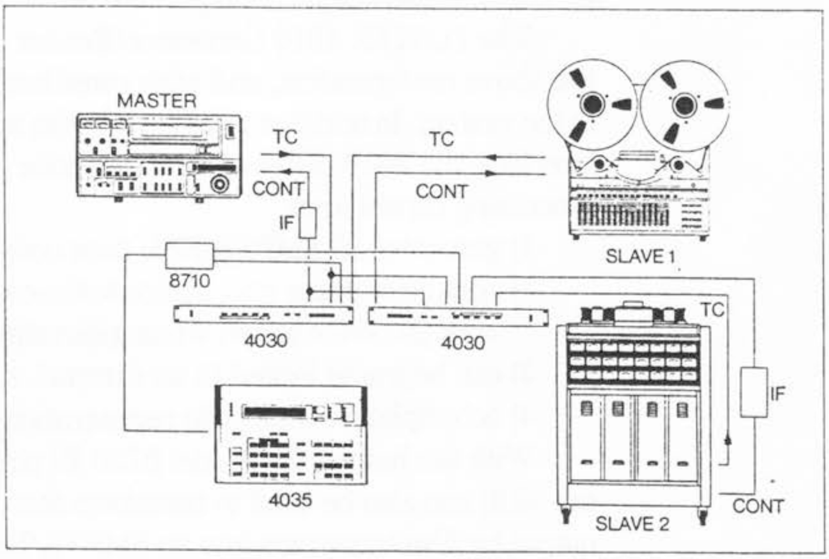
The 4035 Controller can be used to further enhance the system's capabilities. Fundamentally, it offers the following capabilities:

1) Remote control of the various recorders connected to the system, to a maximum of 4 transports.
2) Ten position auto-locate. As well as automatic searching to specified points on the tape, the controller allows loops, zone limits and automated punch-in/out operations to be performed.
3) Synchronizer control and display panel. The numeric readout can display the current timecode addresses of master or slave, the current standing offset or difference value, and also supports input and editing of data. The keypad allows programming of offsets both step-wise and numerically, as well as setup of the various synchronizer control parameters. A maximum of three 4030's may be directly addressed by the controller.

In theory, an infinite number of slaves may be synchronized to a single master, by connecting the master time code and status/motion signals to the inputs of each slave's synchronizer. In practice, though, such a system is complicated and probably unnecessary. The FOSTEX 4035 controller is limited to direct control over three synchronizers—and thus four transports—as this is the largest number encountered in common usage; at any rate, further transports can always be added as simple chase-only slaves.

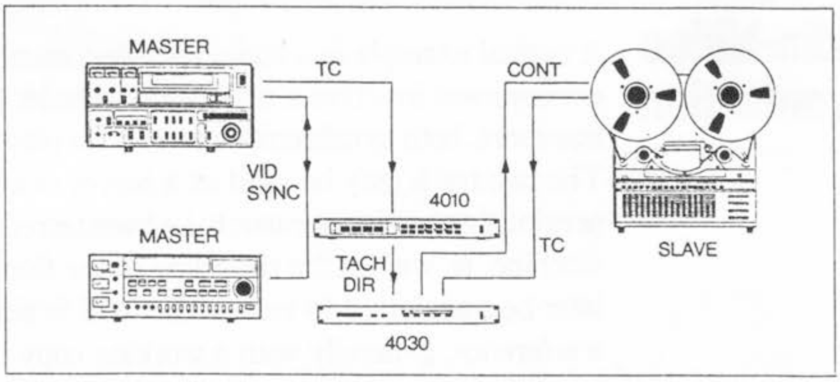
Audio-Video Synchronization

A typical example in a audio-for-video sound editing environment involves a multitrack recorder and a half-track transport, both synchronized to a video playback machine. The two track may be used as a source of effects and previously completed music to be transferred to the multitrack machine, as well as the recording of the final mix which will later be transferred to video. The VCR is simply used as a reference, generally with a working copy of the production to minimize wear on the original master. Such a system might be configured as follows:



An alternate configuration of the master VCR is possible, whereby a wide-band time code reader is used in lieu of the master transport interface unit. This is particularly appropriate where the VCR is itself controlled by a video editing system which already occupies the VCR's external control facilities. Naturally, the VCR must continue to provide time code signals while in fast wind modes, and be able to reproduce the high frequencies output at those speeds; video recorders equipped with a dedicated cue track are designed to provide this.

The video master is thus controller from the editor's seat, and the synchronizers are fed with all necessary information via the high-speed reader:



As previously mentioned, wide-band readers are generally not recommended for audio recorders, due to the extent of modifications required and the increased head wear.

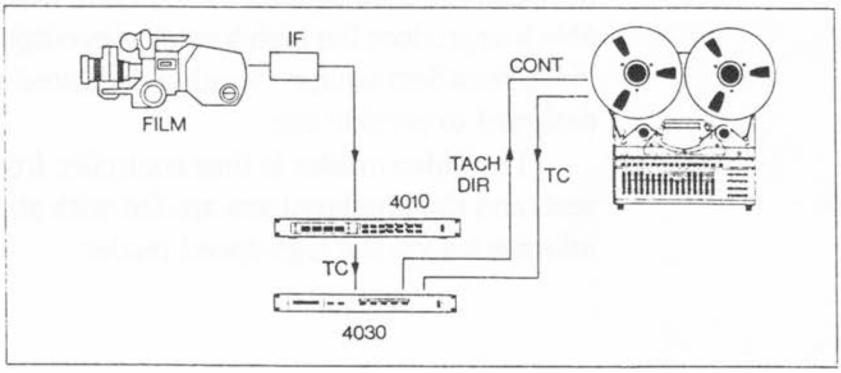
The FOSTEX 4010 Generator/Reader can be used in the above configuration, and adds considerable flexibility to the system. In addition to its function as a master transport interface, the 4010 offers several timecode generating and processing capabilities:

1) generates all SMPTE/EBU time code formats
2) adds color frame information to the code synchronously with the video signal while generating LTC
3) can be frame locked to an external video sync source
4) accomplishes time code regeneration and jam-sync

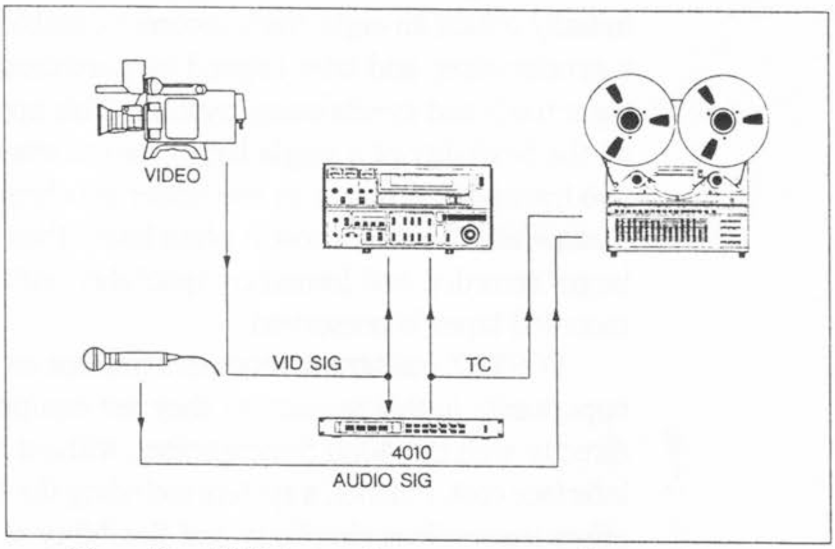
With the help of the Model 8720 Bi-phase Interface, the 4010 can also be used to transform the bi-phase pulses output by film transports into an SMPTE/EBU time code, that can then be used for synchronization of other devices with the 4030 Synchronizer.

The 4010 also offers 2 external event switches, which can be used to trigger various functions at a predetermined point in time.

The following diagrams depict various applications of the 4010 in typical circumstances.



In this instance, the FOSTEX 4010 and 8720 Interface are used to convert the bi-phase signals from a film camera or projector to time code, enabling the synchronous operation of an external audio recorder. The 8720 decodes the bi-phase signal into separate direction and clock signals, which the 4010 uses to generate an appropriate time code. In this manner, live audio may be recorded to the three-track whilst shooting the film, and then subsequently reassembled with the image in the studio.



Here, the 4010 is used to generate a time code synchronous with the video signal from a camera. This time code is simultaneously recorded on the video and audio recorders' cue tracks, along with the live picture and sound programmes. The audio and video portions may be later synchronized for editing and playback thanks to this time code, via the 4030 Synchronizer.

As the 4010 supports jam-sync function, the camera can be switched on and off at any time during the taping, causing the 4010 to revert to its internal sync reference; thus, the usefulness of the code in identifying the time at which a frame was shot is preserved.

Indeed, a flexible wide-band reader and synchronous generator significantly enhance the capabilities of a time code synchronization system. As previously noted, however, the use of a wide band reader with multitrack audio recorders is hardly ever recommended this is why FOSTEX has chosen to offer the 4010 as an optional device, in order to maintain simplicity and economy of the overall synchronization system.

Audio-Audio Synchronization

It would appear to be an irrefutable law of multitrack recording that there are simply never enough tracks. This situation is one with which anyone in the business of audio recording is all too familiar, and which drives innumerable studio owners to major equipment upgrades with remarkable frequency.

Time code synchronization can play a major role in surmounting this obstacle to a studio's growth. One might initially obtain an eight track recorder capable of supporting a synchronizer, and later expand by purchasing a second eight track and synchronizer system. This approach offers all the flexibility of a single larger format transport, as the two transports function as one under synchronizer control; meanwhile, the direct cost is often lower than that of the larger recorder, and format compatibility with previously recorded tapes is preserved.

FOSTEX multitrack recorders present an excellent opportunity in this respect, as they are equipped to function directly with the 4030 Synchronizer, without additional interface cost. Further, a system including the 4035 Controller offers tremendous simplicity and flexibility of operation, consolidating the operational features of each transport in a single control unit, as well as providing automatic locating, looping and punch-in/out capabilities.

Another benefit of the dual-multitrack approach appears in live recording. A single small, lightweight multitrack machine can be carried on location for the initial live recording process, minimizing difficulties of transportation and allowing the studio to continue to function on one recorder. The live tape can then be returned to the studio for additional overdubs and edits on the second transport.

Evidently, a studio equipped for audio-audio synchronization is well advanced towards adding video playback capability for audio production. Another unit of some interest in this regard is the FOSTEX 460, which integrates an 8 input recording mixer with a fully synchronizer-ready 4 track cassette transport. This system allows very economical entry to audio-for-video production work and live audio/video recording, while protecting the user's investment when it comes time for expansion to 8 track capability.

One final application of audio-audio synchronization deserves mention. As the cost of time in large audio studios continue to rise, it becomes increasingly attractive for the individual artist/home recordist to accomplish as much of a production as possible outside the major studio. Time code synchronization allows the basic tracks to be transferred from the primary multitrack master to a more portable format, enabling a musician to work on a particularly troublesome segment at home and at his leisure. When a satisfactory take is achieved, it can be dubbed back to the multitrack master tape via time code synchronization.

Audio-MIDI Synchronization

It is perhaps appropriate in the final chapter of this text to turn to a relatively new application of SMPTE/EBU time codes, and one which is of great interest to musicians in particular: synchronization of recorders with electronic musical instruments using the Musical Instrument Digital Interface, otherwise known as MIDI. MIDI, like the SMPTE/EBU time code, is an internationally accepted digital communications standard adapted specifically to the transmission of musical information. This standard is composed of a variety of codes that represent musical events—such as the striking of a note, the passage of a beat—and these events can be digitally stored (one might say 'recorded') in a music sequencer. The sequencer can then be instructed to output the sequence of musical events to a keyboard or other sound-generating device, with a result that is highly similar to playing back a conventional audio recording. This process has both advantages and disadvantages with respect to conventional recording techniques; without dwelling on these, suffice it to say that the ability to combine audio recording and digital sequencing in the production of a musical project is highly desireable.

There exist two ways of combining these rather dissimilar recording media. The first involves creating a digital sequence, playing it back through the desired sound generating devices, and recording these to conventional multitrack tape; one can then overdub the requisite acoustic tracks that could not be produced via digital sequencing. Unfortunately, most of the inherent flexibility of MIDI sequencing is lost in this process, as the final versions of the sequenced material must be committed to tape early on in the production process. The second, and infinitely more exciting approach involves synchronization of the MIDI sequencer to the multitrack recorder, allowing the user to work in both media concurrently.

This has been accomplished in numerous units that use a recorded sync tone to generate MIDI clock data; these suffer from many of the same drawbacks associated with mechanical and electronic counters in audio and video tape recorders, as discussed earlier. Most notably, in order for the sequencer to synchronize correctly with the tape transport, both must be started from the beginning of the programme; this seriously impedes efficient editing of short segments in the middle of a piece, and often rendering the production a rather frustrating experience. Clearly, the absolute positional reference provided by SMPTE/EBU time code has an application here.

The FOSTEX 4050 Autolocator is a unit designed to handle the task of time code/MIDI synchronization. It reads SMPTE/EBU time code from the magnetic tape transport, which maintains its compatibility to the rest of the synchronization world; it then translates this code into MIDI data, allowing the user to operate the recorder and sequencer as a single entity throughout all stages of production. As the tape recorder is put through its paces, the attached sequencer will faithfully follow as a slave, much as would another transport under control of the 4030 Synchronizer.

Additionally, as its name suggests, the 4050 offers a variety of transport control and auto-location facilities, including 16 track record-select function. To delve fully into the many features and capabilities of the 4050 would certainly exceed the scope of this article; it is perhaps sufficient to suggest that the 4050 opens the way to a degree of flexibility and efficiency that promises to become the standard in music production over the coming years.

In Conclusion...

At this point, our brief examination of the theory and practice of SMPTE/EBU time code draws to a close. Naturally, we cannot hope to have dealt with every aspect of this rapidly changing field, nor to have provided a thorough technical treatment of the topic for the design engineer. Nonetheless, we trust that we have succeeded in clearing some of the mystery surrounding tape recorder synchronization, and in identifying some useful ideas for the application of this very exciting technology.

Finally, we should like to encourage that any further questions or suggestions that may arise be directed to us, and to assert our commitment to respond to your needs in both our literature and in our future products.

Sincerely,
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