SMPTE Made Simple

A Time Code Tutor by TIMELINE

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Introduction

When the television broadcast industry moved from film and live performance to prerecorded video production, a method was required to reliably synchronize and edit the new medium. Historically, film rushes were lined up at the clapper board and rubber stamped with footage numbers. Film was mechanically held in sync by the sprocket holes. Unfortunately, video tape has neither of these attributes. This problem made it impossible to get the music, pictures, dialogue, and effects to all begin and run at the same time.

The solution was SMPTE time code. SMPTE is a signal that contains specific address information that can be recorded on audio or video tape. This address information is then used to accurately position the audio or video.

Why SMPTE?

In 1971, the **S**ociety of **M**otion **P**icture and **T**elevision **E**ngineers chose SMPTE as the industry standard for synchronization. It became officially known as SMPTE/EBU Time Code when the society was joined by its overseas counterpart, the European Broadcast Union (EBU). Since SMPTE/EBU is quite a mouthful, most people just say SMPTE.

What Can You Do with SMPTE?

There are hundreds of uses for SMPTE time code in every branch of audio production – records, video, film, advertising, and industrial productions all use SMPTE. Let's start with the how and why of some of the most basic applications.

Synchronizing Multiple Audio Machines

Imagine you are a recording engineer. You've just used up all the available tracks on your multitrack machine, but your project is not even close to being done. How are you going to add extra tracks? The answer is to use a second multitrack recorder.

But that solution raises another question. How do you lock the two machines together so that the music plays back in perfect synchronization – the first time, and every time? You could cross your fingers and try to hit the Play buttons on both machines at exactly the same moment, but the odds of this approach working even once are *very* slim.

The best solution is to use SMPTE time code *and* a **TimeLine** synchronizing system. A **TimeLine Lynx-2** or **Micro Lynx** generates time code that is recorded onto the audio tapes. The time code is then used as a common reference point. The time code acts as the glue that holds the two machines in sync.

On playback, a SMPTE time code reader reads time code from one tape recorder and passes the timing data to a synchronizer connected to the other tape recorder. Based on this incoming time code, the synchronizer regulates the playback speed of the *slave* recorder so that it always stays in perfect sync with the *master* recorder.

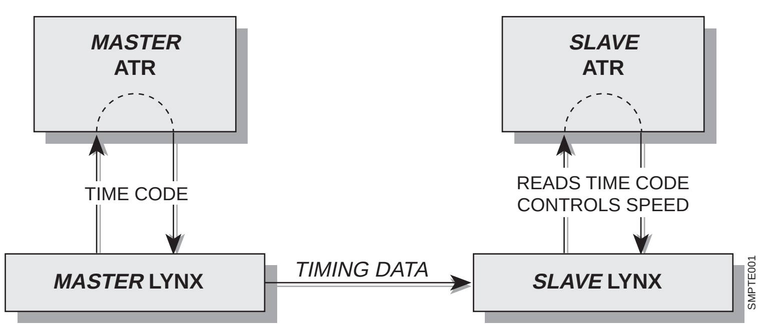

Figure 1. Basic SMPTE Time Code Setup

This simple example is the basis for all SMPTE applications. For instance, if you are locking to film or video using a digital audio workstation or a sequencer, you substitute the appropriate controlling device to suit the equipment for that application.

Locking to Picture

Suppose you have footage on videotape, and you need to create an audio track to go with it. The audio track could be music, dialogue, effects, or all three. How do you lock the sound to picture?

The solution is to use SMPTE and a **Micro Lynx** or two **Lynx-2** modules, exactly as described in the previous audio example. SMPTE works just as well with video as it does with digital or analog tape. You can use SMPTE to lock video to analog, digital to analog, and even lock sound sources that don't use tape.

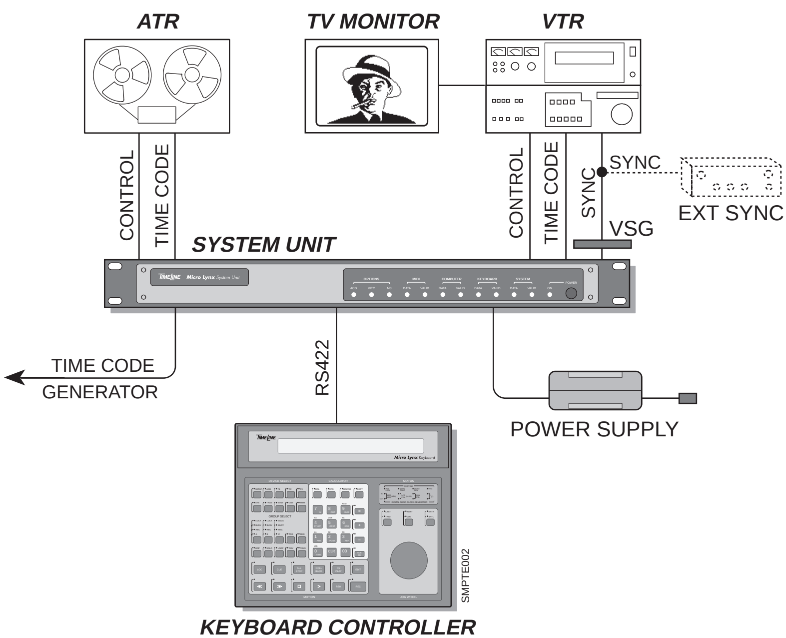

Figure 2. Synchronize to Video

MIDI, Mix Automation and More

If you have a MIDI sequencer and some synthesizers that you want to lock to your multitrack tape or to picture, the **TimeLine Micro Lynx** can translate SMPTE time code into the MIDI data that the sequencer needs to lock to tape.

SMPTE can be used to control just about anything that has micro-processor intelligence. For instance, mixing console automation will run to time code. Therefore, it can be locked to tape and other time code devices for complete system automation.

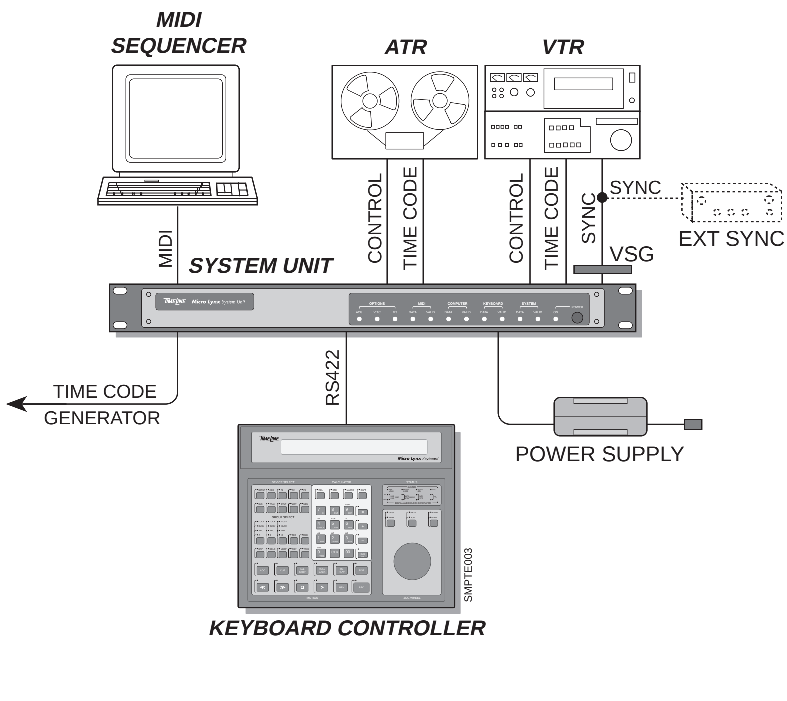

Figure 3. MIDI Sequencer and Time Code

Complete Systems

The ultimate SMPTE application is the complete studio system. Just as two devices can be locked to a common time reference, so can a whole roomful. Tape machines, consoles, synthesizers, effects processors, and hard disk recorders can all be locked together using SMPTE. With an efficient controller like the **Micro Lynx** Keyboard, all of these different machines can be operated as easily as a single set of transport controls. Using this approach, SMPTE can be used to build large, multi-machine networks for video editing and music recording.

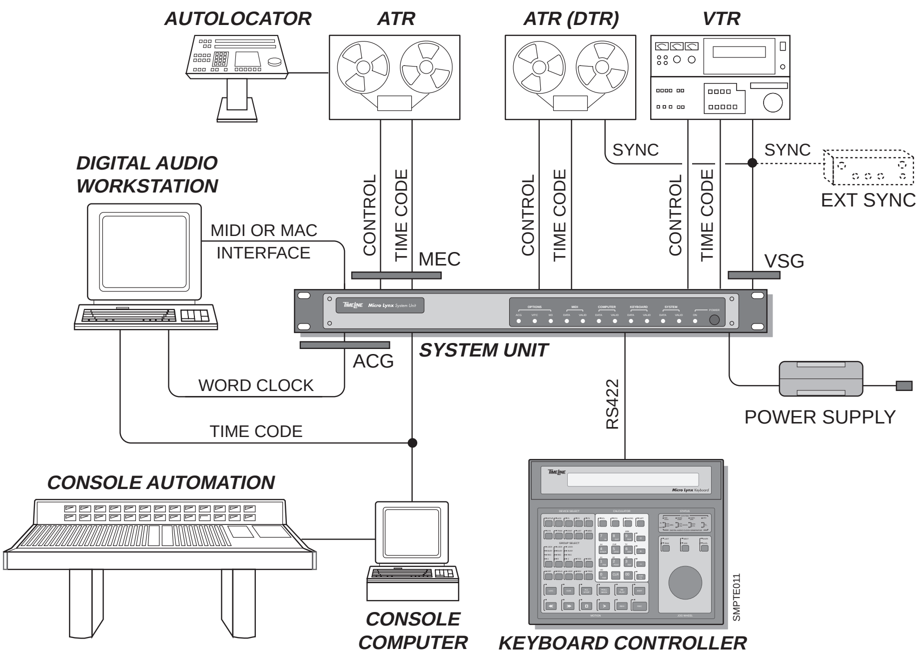

Figure 4. Complete Studio System

How Does SMPTE Do It?

If you know precisely where a piece of program is and how fast it's playing, you can use this information to control other machines so that they are all in the right place at exactly the same time. SMPTE does this; it is an *absolute timing reference* that indicates both the speed and position of a tape as it travels across a tape machine transport.

What You Can Do with a Speed Reference

Many pre-SMPTE sync codes could only indicate speed. The most widely used was a control track or pilot tone. A pilot tone is an audio signal derived from a stable source (historically 60 Hz AC wall current). By reducing the voltage with a suitable transformer, the resulting continuous sine wave could be recorded on tape.

Machine speed is normally regulated by monitoring tach pulses from the tape machine's capstan motor. These pulses indicate how many times the capstan revolves in a given time interval, in the same way an automobile's tachometer indicates how fast an engine is turning.

When playing back a tape with a pilot tone, the sine wave on tape is compared with a reference sine wave coming from the wall current or some other guaranteed signal.

If the tape slows down, the frequency of the pilot tone, or the number of cycles that tick by each second, will *decrease*. If the tape speeds up, the frequency will *increase*. A controlling device, tied into the tape machine's capstan motor, senses the difference between the reference tone and the pilot tone on tape; and varies the speed of the tape machine motor to make the two match up again.

This process of matching tape machine speed to a stable reference is called *resolving* or *phase locking*. The two sets of sine waves are brought *in phase* with one another, so they match up perfectly, peak-for-peak and trough-for-trough.

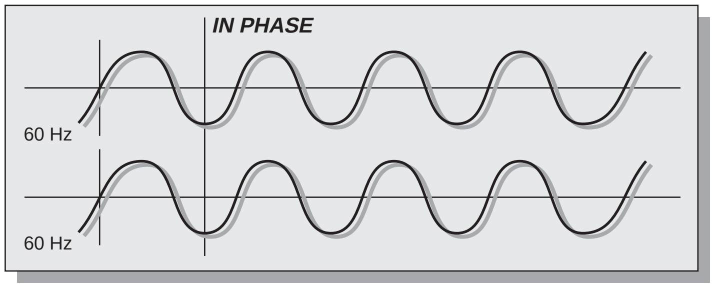

Figure 5. Two Sine Wave Signals in Phase

Just as the pilot tone on one tape machine is made to match the reference source, it can also be made to match the pilot tone on a second master tape machine. So, a pilot tone can be used to synchronize the speed of the two tape machines.

The Problem with Pilot Tone

However, there is a problem, one sine wave looks exactly like another. Although the slave machine can phase lock with the master, the slave has no way of knowing whether the master is playing the first verse or the third chorus of a song or if the master is three-and-a-half seconds into a scene or at the beginning. Pilot tone is severely limited as a tool for synchronization. The same is true for other speed-only sync codes such as Frequency Shift Key (FSK) and Din Sync.

To work, both the master and slave must be carefully lined up at the beginning of playback. There is no way to run the machines accurately to the middle of the program material because the slave never knows where the master is. The slave only knows how fast the master is playing.

SMPTE: What You Can Do with a Speed and Position Reference

SMPTE indicates not only tape speed, but also tape position. SMPTE time code is a complex digital signal. It is equivalent to the simple, analog pilot tone signal, but it also has a unique number assigned to each cycle of the sine wave.

Time code is recorded onto tape as an audible signal. The signal is a rapid-fire series of blips, which are *read* by a microprocessor as a unique number. This number is an address that consists of separate numbers for hours, minutes, seconds, and fractions of a second that are called frames.

If you have a gunshot at the climactic scene of a suspense melodrama, SMPTE can tell you the exact address or location on tape of the gunshot. SMPTE tells you that the gunshot occurs 1 hour, 31 minutes, 12 seconds, and 19 frames into the film. You can move to the exact spot on tape where that gunshot occurs and replace the existing blast with a more convincing sample from the sound effects engineer.

Using SMPTE, the master machine can find *anything* on a tape, and all of the slave machines will chase the master to the same spot. This is a long way from just locking one sine wave to another and rolling from the top. SMPTE brings you into the realm of *position accuracy.*

Anatomy of a SMPTE Frame

A SMPTE frame or word consists of 80 bits that convey SMPTE's message in hours, minutes, seconds, and frames. Each bit is represented by a binary 1 or 0 that is specifically encoded for recording onto tape. The method used is called biphase encoding. This coding reverses the signal polarity halfway through a bit to represent a 1 and leaves the bit polarity unchanged to represent a 0. A continuous string of these 80-bit words is recorded linearly along the tape to form the time code.

Each frame is broken up into 16 groups of 4 bits and a 16-bit sync word.

- Eight 4-bit groups are assigned to the hours, minutes, seconds, and frame number.
- Eight 4-bit groups are user bits. They are reserved for information such as ID, reel numbers, session, dates, or another time code number.
- The remaining bits form a sync word, to provide direction information and mark the end of the 80-bit frame.
- The time code reader uses the direction sense bits to determine whether the tape is running forward or backward.
- The sync word is a series of preset 1s that allow the speed and phase of the two time codes to be read and compared by the **Lynx** or **Micro Lynx** module to establish synchronization.

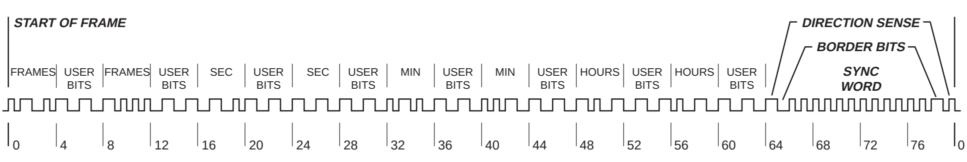

Figure 6. Time Code Address

SMPTE words (one for each frame) are recorded along the length of the tape; hence the name Longitudinal Time Code (LTC). The code's design and organization make it suitable for a very wide range of play speeds, both forward and backward.

The frequency of the LTC signal is always proportional to the tape speed. However, the signal cannot be read in stop or freeze-frame mode. Consequently video frequently uses another form of time code: Vertical Interval Time Code (VITC), which can be reliably read in stop and at very slow play speeds.

Time Code Formats

There are 60 minutes in an hour; 60 seconds in a minute, but how many frames are there in a second? *Frame rate* is the term used to express the number of frames per second in SMPTE time code. Frame rate was originally measured as one-half the power line frequency.

Since there are different power line frequencies in the U.S. and Europe, time code has several different formats, defined by the frame rate used in each country.

National Television Standards Committee (NTSC)

Wall current in the U.S. has a frequency of 60 Hz, which makes 30 frames per second the standard frame rate for American black and white television.

Phase Alternate Line (PAL)

In Europe, the standard wall current frequency is 50 Hz. Therefore, the standard for European color television, the PAL format, is 25 frames per second.

Drop Frame (DF)

What about American color TV? When it was invented by RCA, they reduced the American black and white frame rate of 30 frames per second to 29.97 frames per second, to allow both color encoding and compatibility with existing black and white television sets. This format became the standard color TV format for America.

The problem is that 30-frame time code running at this rate measures slightly slower than real time.

60 sec x 30 frames/sec	= 1800/min x 60 min/hr	= 108,000 frames
60 sec x 29.97 frames/sec	= 1798.2/min x 60 min/hr	= 107,892 frames
	Difference	= 108 frames

So for every hour, the time code is 108 frames short. In editing, if you are just a few frames off, you might make your lead guitarist end his solo two chords early. To correct this problem, a time code format called Drop Frame (DF) was developed. Drop frame skips the first two frame counts in each minute (with the exception of minutes 00, 10, 20, 30, 40, and 50) to force the time code to match the clock time.

Film

Film has run at a frame rate of 24 frames per second ever since Thomas Edison invented it. Although this is a non-standard time code, sometimes it is used in the field.

Different Frame Rate Formats

The important thing to remember is that SMPTE conveys two pieces of information: tape speed and tape position.

Frame rate, is the speed at which the code will run. Frame type (30/DF/25/24) is the way frame positions are counted.

30 Thirty frames per second can be drop frame or non drop frame. If you select drop frame, the actual frame count is reduced by 108 frames per hour.

25 Twenty-five frames per second is the European standard.

24 Twenty-four frames per second is the film standard.

Table 1. Frame Rates

Counting Rate (Hz)	Counting Method (Frames per Second)	Displayed Time Accuracy	Application
24	24 frame	Real Time	Motion pictures & film
25	25 frame	Real Time	EBU standard for European television
29.97[1]	30 drop frame[3]	Real Time	NTSC standard for USA & Japan
29.97[1]	30 non-drop frame[4]	0.1 % Slow	USA & Japan
30.00[2]	30 drop frame[3]	0.1 % Fast	Non-standard
30.00[2]	30 non-drop frame[4]	Real Time	USA & Japan

Notes:

1. 29.97: Generated by all color television sync generators (i.e., almost all sync generators built after 1970). This speed is the speed at which a black burst signal runs. (Do not confuse a black burst with black and white. A black burst is a standard color signal with a color of black.) Use this as your standard frame rate unless you are an expert and have a reason not to.

2. 30.00: Usually available only in the internal crystal mode of a time code generator, or from black-and-white television sync generators. Don't use this non-standard speed unless you are an expert and have a good reason. This speed is sometimes used in conjunction with motion picture film systems.

3. Skips 108 frames/hour at regular intervals.

4. Many users prefer 30 (full frame) counting because no numbers skip in the counting sequence, even though the elapsed time accuracy at 29.97 frame rate is slightly different from real time.

VITC

Vertical Interval Time Code (VITC) is another form of SMPTE that is used only with video, and is printed horizontally at the beginning of each field, as part of the video signal. Longitudinal Time Code (LTC) is printed linearly along an audio track.

Unlike LTC, VITC cannot normally be added to a video tape after the picture has been recorded. It must be recorded with the video signal when the original tape is generated.

Each picture has 525 lines (625 for PAL). The lines are divided into two interlaced (odd and even) fields to facilitate picture clarity. First, 262 even lines are scanned. Then the scanner returns to the beginning of the picture and scans the 263 odd lines. As the lines are scanned, a number of lines at the top and bottom of the picture are never displayed; they are blank space. These lines are available for storing information. VITC is recorded on two of these spare lines, at the top of each field. One complete VITC data word is recorded on each line.

VITC uses a 90-bit data word instead of the 80-bit data word used by LTC. The extra bits are used to provide error correction and to prevent bad time code values from being read. VITC allows accurate reading of tape position even when the tape is stopped in freeze frame (something that LTC can't do). VITC is often used in conjunction with LTC in applications that involve both audio and video.

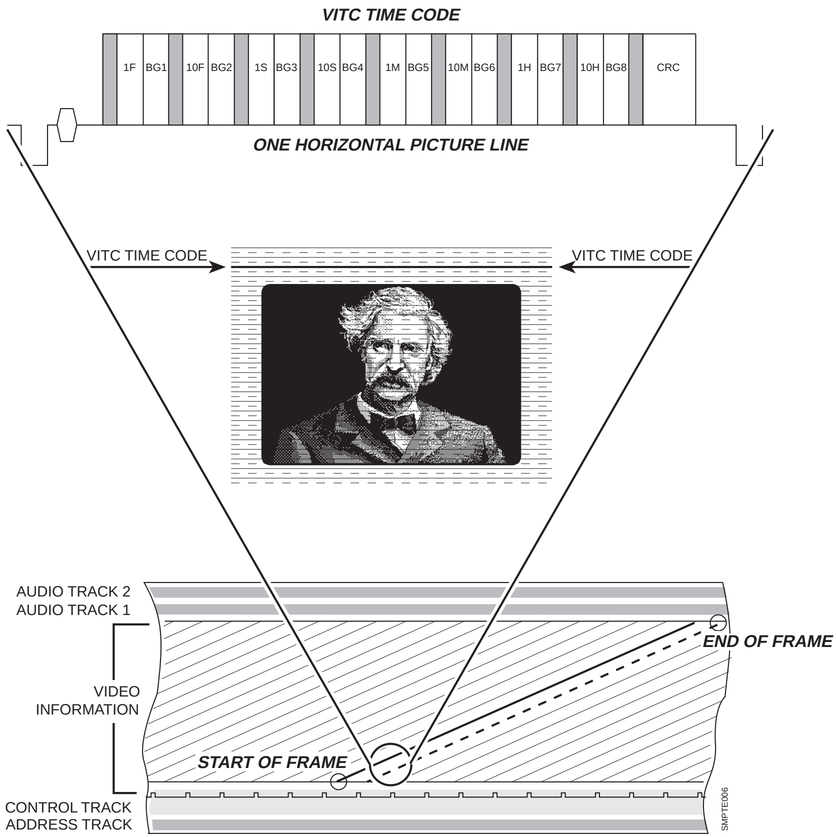

Figure 7. Video Tape and VITC Time Code

SMPTE, MIDI and MTC

MIDI is not the same as SMPTE, even though both are binary codes. They each carry very different types of information.

SMPTE, as we've seen, answers the questions "Where are we," and "How fast are we going?"

MIDI however, answers an equally vital but different question, "What do we do now?" It answers that question for synthesizers, drum machines, and other electronic music devices. MIDI is the language that a computer uses when it tells a synthesizer, "Play middle C, play it *mezzo forte*, and play it now!"

But when is now? If we're talking about playing back an electronic composition in concert, now is a relative term. Now might be the third beat of the fourteenth measure, and whether that beat hits at 10:31 or 10:32 PM is something no one usually notices. However, if that beat has to coincide with the cocking of an assassin's pistol in a feature film thriller, or coincide with a soul-wrenching wail from a vocalist on audio tape, it becomes necessary to pin down when now is.

Traditionally, a MIDI sequencer was slaved to SMPTE. Many popular sequencers can read incoming SMPTE and lock their musical tempos (their beats per minute) to the time code.

This solution works beautifully, but it leaves the film or TV composer with the awkward situation of going back and forth between two dissimilar sets of numbers. While his sequencer counts beats and measures, his work print, cue list, director's instructions and everything else that pertains to the visual side of the equation, all count in hours, minutes, seconds, and frames. The two sets of numbers never coincide neatly, which forces the composer to pull all sorts of tricks on his sequencer.

MIDI is a computer code that uses 8-bit data words or bytes that cannot contain SMPTE's 80-bit word. This limitation is why MIDI Time Code (MTC) was invented. MTC takes SMPTE time code and translates it into the MIDI data format. To translate SMPTE into MIDI, the MIDI time code format transmits a MTC message byte every 1/4 frame. The first two 1/4 frame bytes contain only the frames. The next two MTC bytes convey the seconds, the next two the minutes, the next two the hours, and so forth.

This process takes exactly two SMPTE frames to complete. As soon as one complete SMPTE address is transmitted, the MTC generator updates the time code by two frames and starts again.

The **TimeLine Micro Lynx** can take SMPTE from a master tape and generate MTC. Using MTC, the film/TV composer can now use a cue-sheet style program, as well as conventional music, and work exclusively with hours, minutes, seconds, and frames.

Although SMPTE and MTC are not the same thing, they make a powerful combination when the **Micro Lynx** puts them together.

Using SMPTE

Any SMPTE time code application involves three basic functions. First you need a generator to produce the actual SMPTE signal that goes onto tape. Second, you need a reader to read the SMPTE time code from tape. Finally, there's the job itself, i.e., what you want to accomplish.

SMPTE can be used with a resolver, to ensure that a single tape machine runs at a consistent speed. It can also be used with an autolocator that stores a number of SMPTE addresses in memory and chases to those addresses on command, or when you want to lock one or more devices to a master tape machine with a synchronizer.

In the early days, a different device was often required to perform each of these functions. Today, products from **TimeLine** perform them all. The **Lynx-2 Time Code Module** with a **Keyboard Control Unit** is a compact, high-end, high-performance unit. The **Micro Lynx** is a high-performance time code system for project or smaller studio systems.

Things To Know About Generating Time Code

Time code that is generated and striped on tape will ultimately be played back and read, so you must determine the optimum level for your master tape before you generate the time code. Master tapes are generally printed at about -6 dB. If you print code at a level that is too low, the reader will have trouble reading it. If you print the code too hot, it will bleed audibly onto adjacent tracks. Even when they are printing at the correct level, many engineers leave a blank track next to the time code track called a guard band. In multitrack formats, time code is usually printed on the outermost track to eliminate the need to leave two blank tracks (one track on either side of the time code). For example, time code is usually printed on track 24 on a multitrack machine.

When printing time code in video and digital audio applications, make sure that the time code generator and machines are properly referenced together. Your generator *must* be connected to the same external video sync signal as the video or digital machine, otherwise, when synchronizing, the video machines will start off in the right place, but will slowly drift apart.

With digital audio machines, the sample rate or word clock should be locked to the time code. Normally, you lock to the time code by using a video sync signal as a common timing reference for the generator and the digital machine. Set both to "EXT VID" before printing time code. If you don't have a sync pulse generator, the **Micro Lynx Video Sync Generator** (**VSG**) option card can be installed and used to generate a referenced composite sync signal for your video or digital machine.

Specific types of video sync include *black burst*, *color bars* and *composite*. These video sync signals are often collectively called *house sync*, or the signal that's universal throughout the production facility or house. To reference your generator to video sync, set it to "EXT VID" mode and connect a video sync signal. Referencing to video sync ensures that the tapes you are striping will have a common reference and will sync properly on playback.

Reshaping Time Code

Reshaping, or cleaning up the time code signal, should be done when you are dubbing time code from one tape to another. If you just copy time code from one tape to another without reshaping it, the time code will deteriorate quickly because of generation loss, and eventually it will become unusable. Reshaping is not recommended when the time code on tape has begun to deteriorate badly.

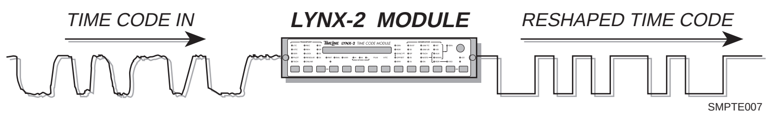

Figure 8. Reshaping Time Code

When reshaping, existing code is passed through the reader, which puts out “squared-up” code. If a tape has been copied several times or is very worn, the time code is likely to have dropouts or bad spots that a time code reader won’t be able to read. The reshape output of a time code reader can only put out a clean copy of its input. So if the code drops out completely, the reshaped output will have a corresponding dropout. To overcome this, the code must be regenerated rather than reshaped.

Regeneration or Jam Sync

Jam Sync, is a generator function that offers a better alternative to reshaping. It is used to create a new time code that is related to an existing time code on tape. It is very useful for repairing a break in an existing time code track, or creating a continuous time code track from an edited or discontinuous track. Code is read up to the last good address, then the generator uses the next consecutive address to generate new code.

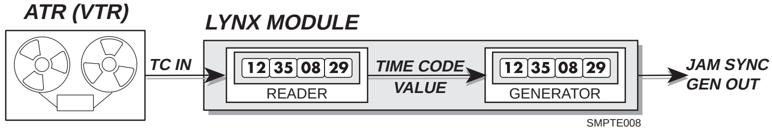

Figure 9. Jam Sync

Jam sync is used extensively in video editing; where different pieces of tape, each with different time code, are spliced together. Jam sync provides the resulting program with continuous time code. **TimeLine's Micro Lynx** and **Lynx-2** both have manual and automatic jam modes, that let you quickly repair or create new time code tracks to overcome the problems detected with bad code.

About Time Code Readers

A wide band reader, like the **Lynx-2 Time Code Module** or **Micro Lynx**, reads time code even at the high tape speeds used for Fast Forward and Rewind. Wide band reader capabilities are essential, since SMPTE addresses provide the only accurate means of locating positions on tape.

If time code on tape becomes unreadable, the **TimeLine** readers automatically search for the next best sync source on tape. After SMPTE, the reader searches for serial time code, then pilot tone, and finally tach pulses that are derived from the rotation of the tape machine's capstan motor.

Synchronizer Essentials

A synchronizer reads time code from two or more machines. Then, by manipulating the speed of each machine's capstan, the synchronizer forces the two machines to play tape at the same speed. This process is called *locking*. The **Micro Lynx** system offers *phase* or *sync lock* mode.

Phase or Sync Lock

Phase or *Sync Lock* emulates the old control track or pilot tone method of synchronization. The **TimeLine** system reads the time codes, synchronizes the transport, and takes any deliberate offsets into account. Once the system is locked, the slaves only use the speed information that is derived from the time code. Specific time code addresses are ignored.

This setup allows the tape machines to stay locked even if the time code relationships change. The time code change is reported, but the synchronizer makes no corrective action.

Advanced Applications

Video Editing

Video editing is the process of assembling raw footage into a finished television program. Shooting the raw footage is part of *television production*, and video editing is part of the *post-production* process.

An average television program such as a sitcom or a documentary has action that constantly shifts from one scene to another – from indoors to outdoors, for example. Within a given scene, the perspective also shifts from one camera to another. Each camera shoots the scene at a different angle.

During editing, multiple video machines are each loaded with footage of different scenes that have been shot by different cameras. The potential for chaos is great. Fortunately, each reel of raw footage is striped with SMPTE time code, and each frame has a specific and unique location or address. In some cases, both LTC and VITC are on the tape.

During editing, selected scenes of raw footage are transferred onto a master video tape in the sequence they will appear in the finished show. The master video tape contains the master or program time code.

A video editor locks the source video machines loaded with raw footage to the master video machine. Additionally, one or more audio tape machines may be locked to the master. These machines contain the production audio, which includes the dialogue and incidental sounds recorded during shooting of the raw footage.

Video editing is normally a two-stage operation. Offline editing is first. The person editing the show receives work tapes, i.e., copies of all the raw footage, with time code "burned in" so that it's visible in one corner of the picture. Any footage initially shot on film, is usually transferred to video at this point. From the work tapes, a basic sequence of scenes is selected. For example, the second scene should be the bar room brawl that occurs, say, between addresses' 05:40:59:11 and 05:44:12:22 on one of the raw footage reels. In the finished program, this scene needs to start exactly six minutes, five seconds and nine frames (00:06:05:09) into the show and run to 00:09:18:20.

When all the scenes have been sequenced in this manner, an Edit Decision List (EDL) is compiled. The EDL is a complete, computerized directory of the location of the scenes in the show, along with the addresses that locate each scene in the raw footage.

Later, the project moves to online editing. The EDL is downloaded, and the final video master is assembled from the original raw footage. This raw footage was set aside while the work tapes endured the rigors of the offline editing.

Audio-For-Video

Just like the raw video footage, all of the audio elements that go into a video production must be assembled. This procedure is generally known as *audio-for-video* or *audio post-production.* There are several different branches of audio post because many different types of sound sources go into a typical video show.

First, there's *production* audio, which includes the dialogue and sounds recorded during shooting. Often, incidental noises on the set, flubbed lines, and other uncontrollable aspects of the shoot make the production audio unusable. The alternatives are the other main branches of *post-production* audio.

For dialogue, there's *Automated Dialogue Replacement (ADR)* in which actors re-record production dialogue in the controlled acoustic environment of a sound studio. This replacement dialogue is recorded onto an audio tape that is locked to a video work print, which the actors carefully watch as they read their lines.

The second branch is *Foley*, which is named after the man who invented it. Specialized actors called *Foley walkers* record sounds such as footsteps, coat zippers, and car door slams. They do their recording while watching a work print that's synchronized using SMPTE and a **TimeLine** synchronizer to an audio tape machine that records the sounds they make.

Third, are the *sound effects.* This audio is the spectacular stuff–explosions, rocket blasts, gunshots. Today, most sound effects work, as well as some Foley, is created using digital audio samplers. Samplers are devices that can be locked to SMPTE through MTC or MIDI.

Music, that all-important audio element, is supplied by the composer, who works to rough cuts (preliminary edits) of the finished show and ultimately to the finished video master. The composer may record real instruments onto audio tape that is locked to picture using SMPTE and Lynx modules, or he may work with MIDI instruments that are locked to tape by a **Micro Lynx** .

Ultimately, there are a number of different *Audio Tape Machines*

(ATRs) or *film dubbers* with the finished music, dialogue, and effects. These ATRs are locked to the video master using a **TimeLine** system controller, such as the **Keyboard Control Unit** or **Console Control Unit**. Then the multiple audio sources are balanced by a mixing console to provide a finished audio master for the program. Because this can be quite an elaborate process, many modern post-production facilities use automated mixing consoles that store mix data, such as fader moves, and mutes in computer memory.

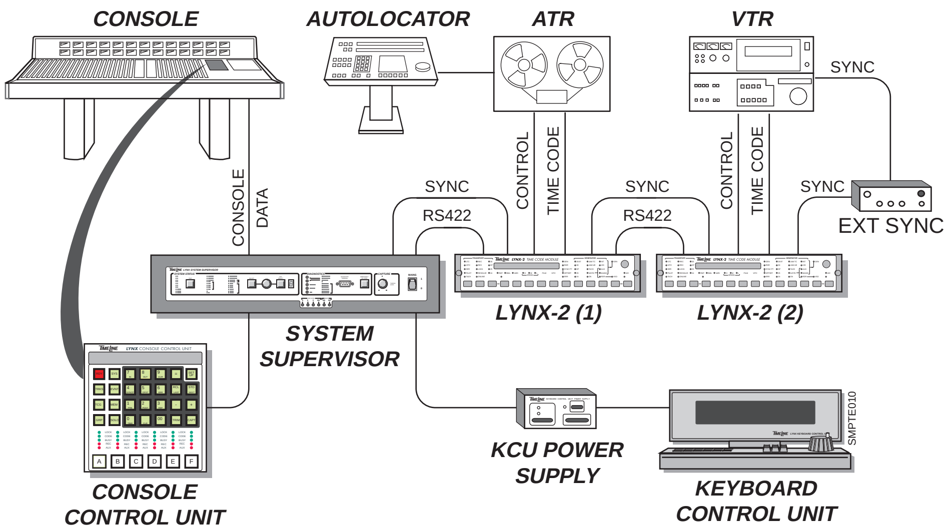

Figure 10. Automated Mixing System

The Modern Electronic Recording Studio

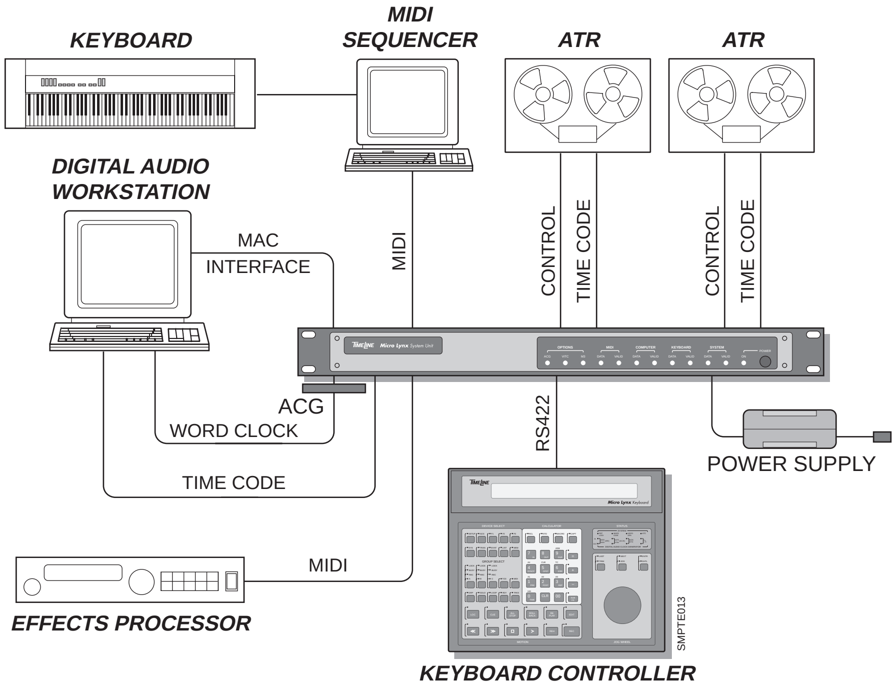

Figure 11. The "Modern" Electronic Studio

With the number of machines involved and the use of SMPTE time code, many record projects and other music recording applications are as elaborate as video post-production. Two multitrack tape machines are typically locked together by the **Micro Lynx** to provide enough audio tracks for instruments and vocals. Some productions require more than two interlocked multitracks. Console fader automation is the norm for record mix downs, and an absolute necessity for dance mixes.

In addition, many projects also involve *virtual tracks.* Virtual tracks are MIDI synthesizer and drum machine parts that are synchronized to tape, and played back live in real time, rather than being recorded onto multitrack. The **Micro Lynx** provides the all-important SMPTE to MIDI translation.

MIDI is also the protocol used to automate effects processors, such as digital reverbs, and harmonizers. These MIDI devices can change programs midsong, and even perform real time individual parameter changes midprogram. Some mixing consoles, particularly those designed for personal use and project studios also have MIDI automated switching or mixing features.

Just about every device in the recording studio, including tape machines, consoles, effects processors, and electronic instruments, can now be automated using SMPTE, MIDI, and the appropriate **TimeLine** equipment.

SMPTE and the Digital Audio Workstation

The *Digital Audio Workstation (DAW)* is an important tool for post-production and music recording. The DAW records, edits, manipulates, and mixes multiple tracks of audio in a single digital environment. It's a self-contained, self-sufficient system. At some point however, the DAW must sync with the real world and eventually be slaved to picture or a master tape machine.

This situation can present a problem. DAWs are always referenced to their own internal sample rate clock and can use time code to locate and park at a specific SMPTE address. When that address comes up on the master tape, the DAW goes into play, but it's running "wild" because it isn't locked to anything except its own internal clock. This scenario is only a little better than attempting to press two start buttons on two machines at the same time.

The **Micro Lynx Digital Audio Clock Generator** (**ACG**) Card option solves the problem. It provides a way to reference the digital audio workstation to the master time code using word clock (sample rate) data or AES/EBU digital audio bit stream, which contains timing data. The ACG card generates a digital audio clock that is locked to the **Micro Lynx** system reference, and the DAW uses it to lock and run its internal sample rate clock.

You can even varispeed the master tape. The Digital Audio Clock Card automatically adjusts the ACGs word clock rate. If the tape speeds up or slows down, the DAW will adjust to match the new play speed (within the limits of the disk system).

As we enter the digital era, time code continues to be an important, practical solution for communication and control of multiple pieces of equipment. And the **TimeLine Micro Lynx** and **Lynx-2** machine control systems offer the most complete solution to tame SMPTE and MIDI time code.

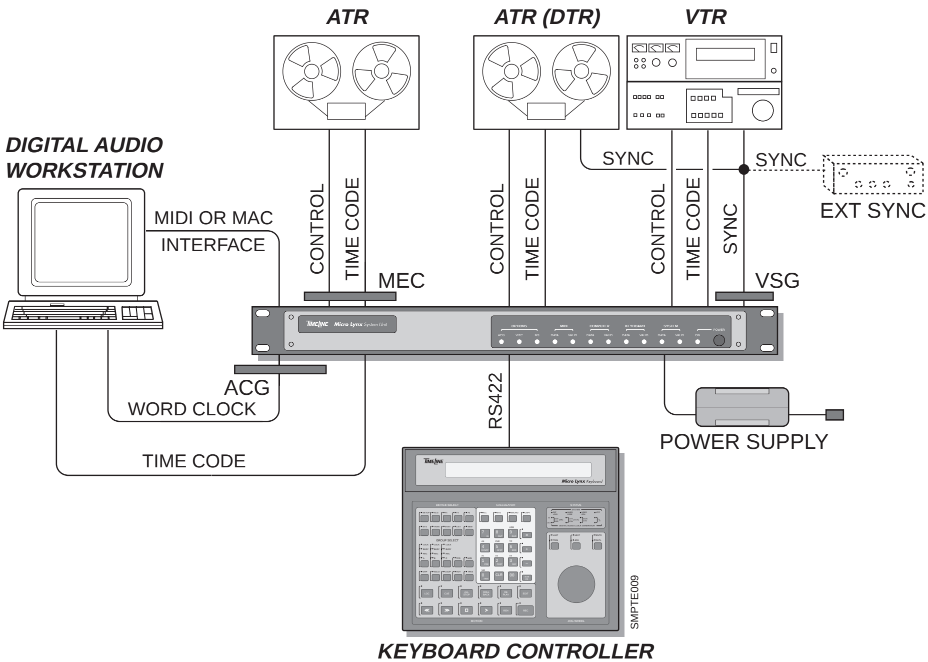

Figure 12. Micro Lynx with a Digital Audio Workstation

The SMPTE Future

SMPTE Time Code and MTC are already being used for applications far beyond their original purpose. Outside the worlds of music recording and video post-production, SMPTE is used to automate light shows at rock concerts, control laser beams at theme park attractions, and trigger flashpot explosions.

SMPTE has many uses and people will think of new ways to use it as time goes on. But, the basics of SMPTE will never change. Now that you know them, you're ready for the future.

SMPTE Made Simple — Step By Step

Working with Film or Video

Goal: To create, edit, mix, and layback to the original master or cut a final audio track for film or video.

1. Get direct copy of the time code master with a window dub (where the SMPTE time code shows up in a little window at the bottom of the screen).

2. Record time code to tapes that are to be used in the production. Preset a time code generator to the master tape time code. For analog audio, set the transport to fixed speed and record time code to the time code track or an edge track if a multi-track recorder. For digital audio, reference the transport and the time code generator to video sync and record to the time code track. Allow at least 15 seconds before the master time for synchronization. Additionally, dub a copy of the original master copy that you received in Step 1 above. You will work from this production master. *This is very important so you don't wear out your original while you work.*

3. Set start times and the correct time code format to match for all applications software being used. The time code format for NTSC video is drop frame code running at 29.97 fps. Remember if you are using a Digital Audio Workstation, you will need to ensure it is properly referenced. This may require the use of a Digital Audio Clock Generator such as the **Micro Lynx ACG Card**, to resolve the workstation sample rate clock. All software should be set to chase to external time code.

4. Replace the master copy with the new working dub, set the transports to external control and slave all machines and software to this. Begin your work.

5. Make sure the synchronizer and all of the transports you are using are resolved to house video sync. It is very important that each transport play each tape at exactly the correct speed all referenced to a common source. In this way time code

striped tapes can be played back on a machine in a different studio and will still be accurate to the original.

6. After completing the production and before mixing, replace the master dub with the original master copy, lock machines, and confirm timing of program material making sure that no drift occurs over time.

7. Mix program to final format required for layback. This would either be a deck that is resolved and has a pre-striped tape (Step 3 above), or a deck that the final mix is recorded to while simultaneously regenerating time code.

8. Layback the mixed audio program to the original master by syncing the final mix tape to the master video tape and inserting the audio program on to the audio tracks of the master tape. It is at this step when working with film, a Mag audio track (or "full coat") would be cut and sent to the lab to be combined with the master negative.

9. Finally, archive files, make safety copies, complete track sheet and tape box information, turn off lights, and go home.

Music Only Production

Goal: To use SMPTE time code for synchronizing analog or digital multitrack audio tape recorders and computer-based MIDI software systems and digital audio workstations.

1. The most important point to remember even in music-only production is to resolve all machines being used – both when working with tape that is being striped for the first time or with pre-striped tapes. That way time code will always run at the correct speed.

2. Always regenerate or reshape time code when copying from one tape to a new tape. Simply copying the time code from machine to machine is not optimal as the time code degrades each time it is copied.

3. Always print time code on an edge track (usually track 8 on an 8 track ATR, track 16 on a 16 track ATR, etc.) and try to leave the adjacent track free of any recorded audio as there is a tendency for time code to bleed or be heard on the adjacent track. Optimize the record levels so that time code is printed at about -5 db and no lower than -12 db. Listen closely to make sure that time code can not be heard in your audio program.

4. Use non-drop frame time code running at 29.97 fps (NTSC rate) as this is the standard for music only production.

Glossary

24	'24' refers to both the film-standard speed and code type.
25	'25' refers to both the EBU/PAL speed and code type.
29.97	'29.97' refers to a SMPTE frame rate only, in frames-per-second.
30	'30' refers to a SMPTE frame rate only, in frames-per-second.
Address	SMPTE/EBU time code address. Also referred to as time code value. A specific and unique address in the time code data stream. A set of SMPTE or EBU time code numbers indicating a specific position on tape. A complete SMPTE address includes hours, minutes, seconds, and frames.
ADR	Automated Dialog Replacement. A technique for replacing production dialog in the studio.
AES/EBU	A professional standard for the high speed transfer of two channels of digital audio data. Developed jointly by the Audio Engineering Society (AES) & the European Broadcast Union (EBU).
Amplitude	Signal displacement from a zero point. The amplitude of an analog signal is the measurement of voltage increase or decrease.
Analog Audio	One means of recording and reproducing sound, using fluctuating electronic voltages to replicate audio waveforms.
ATR	Audio Tape Recorder.
Autolocator	A device that can hold multiple tape locations in memory and chase to those locations on command, using SMPTE addresses, tach pulses, or control track pulses to find a desired point on tape.
Bandwidth	The frequency range of a signal.
Binary Numerical System	A system for expressing numerical values using two digits, 0 and 1. The binary system is used in digital audio, SMPTE, MIDI, and other microprocessor-related data formats.

Biphase Encoding The way in which SMPTE time code gets encoded onto tape. It expresses binary ‘1’ and binary ‘0’.

Biphase encoding reverses the signal polarity halfway through a bit to represent a ‘1’ and leaves the bit polarity unchanged to represent a ‘0’.

BIT Short for BInary digiT; a number which is either one or zero.

Blanking Interval The blanking interval occurs at the end of a frame. Video information is absent during the blanking interval. The interval occurs when the CRT electron gun scanner goes from the bottom right corner of the screen to the beginning of the next field in the top left corner.

BNC Bayonet-Nut Coupler. Used for the connection of video and high frequency clock signals.

Byte A group of related binary data or a word, which can be read, interpreted, and acted on by a microprocessor. A byte is made up of bits, which can be either a 0 or 1.

Capstan On a tape recorder the motor driven spindle that drives the tape across the heads. A synchronizer controls the capstan motor to keep the tape in sync.

Code Type See Time Code Type

Configuration See Setup Mode. The process of defining the user-selected operational parameters, such as defining a specific transport or lifter-defeat mode.

Control Track A synchronizing signal on the edge of a tape, which provides a reference for tracking control and tape speed.

CPU Central Processing Unit. A computers central microprocessor, responsible for all system logic and memory organization.

DAW Digital Audio Workstation. Usually refers to a computer-based, hard disk recording and editing environment.

Decibel (dB) The unit of measurement used to describe a sounds amplitude. The measurement is relative and logarithmic.

DF Drop frame. See drop frame

Differential Input Input amplifier that is designed to amplify the difference between two signals and reject common signals.

Differential Output Output amplifier designed to provide two signals that are completely identical but with opposite phase.

Digital Literally "using digits". A Computer is a typical digital device.

Digital Audio Audio signal that has been converted (digitized) into a stream of binary numbers for storing or transmitting, that are equivalent to the original analog audio signal.

Display Numeric display. Time Code/Message Display.

Drop Frame Drop frame is one of the two SMPTE code types, and is the NTSC color television standard. When using this code type, 108 specific frame numbers are "dropped" for each hour of time code. See the Appendix for more detailed time code information.

EBU EBU time code is a 25-frame code running at 25 fps.

Edit Decision List (EDL) A list, either on paper or in computer memory, of time code addresses indicating successive scenes of source video footage that make up a complete program.

EDL See Edit Decision List.

ERR Error or offset error. Indicates that the display shows the difference between the actual position of the machine in relation to where the system expects it to be.

EXT VID A source of external video sync used by the synchronizer as a timing reference. Can be color black, black burst, color bars or composite sync.

Filter A digital or analog process which has the effect of removing unwanted frequencies from an audio signal.

Foley The process of adding incidental sounds, such as footsteps, door slams, etc., to a video program or motion picture; named after the man who invented it.

Format See Time Code Format.

Frame A single image on a motion picture film or a television picture formed from two interlaced fields. One complete video scanning cycle, one complete SMPTE time code word.

Frame Lock Frame lock maintains synchronization between the Master and Slave transports, using the position information available in the time code address.

Frame Rate The number of frames that go by in one second of audio, film or video tape. Film and different types of video all have different frame rates.

30	30 fr/s	Monochrome TV, & audio
NTSC	29.97 fr/s	Color videotape, TV operations
PAL	25 fr/s	European TV, European Broadcast, & audio
Film	24 fr/s	Film cameras & projectors

Frequency The number of wave cycles that occur in a given period of time (one second). The unit of measurement is the Hertz (Hz).

Generate Running the system time code generator so that time code is available at the rear panel GEN OUT jack.

Generator A time code generator. Each synchronizer has a time code generator. This generator receives its speed reference from one of the internal or external sources.

GEN REF Generator reference. Also referred to as reference source.

Groups A group of machines that have a defined positional relationship. Machines are placed in group mode for synchronization. Machines in a group will operate together as if they were a single transport.

GRP See Groups.

Guard Band A track of multitrack tape adjacent to the sync track (such as SMPTE or Control Track), which is left unrecorded in order to prevent the time code from bleeding onto the audio program material.

HH:MM:SS:FF	Hours:Minutes:Seconds:Frames. A SMPTE time code address or value.
Initialize	Completely clear the synchronizers RAM. Press and hold the **CLR** key while you power-up the module.
INT XTAL	A system speed reference that is derived from the unit's internal crystal. This reference should be selected when an external reference (video or word clock) is not required.
Jam Sync	A technique used to start a time code generator from another running time code. It can be used to recreate missing time code or to external existing time code on tape.
Jam Time Code	The Jam Time Code or Jam Sync function. See Jam Sync.
KCU	Keyboard Control Unit. TimeLine's external machine control unit. The KCU provides centrally-controlled access to all synchronizers in a system.
LCD	Liquid Crystal display. The KBD display is of this type.
LED	Light emitting diode.
Lifter	A tape transport's head lifter mechanism. Tape machines normally lift the tape off the heads when in wind (FFW/RWD). The synchronizer intelligently controls the machines lifter operation, to read time code when required.
Local Transport	The machine or transport that the synchronizer is connected to and controlling.
Lock	Transport is synchronized with the system reference GEN REF.
LTC	Longitudinal Time Code. Time code information encoded in binary coded decimal (BCD) form which is recorded as an audio signal on a designated track of a VTR or an ATR.
Machine	Machine refers to the generic concept of tape record/playback hardware.
Machine Control	The wide ranging field of transport control. This covers basic transport operation, synchronization and more complex functions such as electronic editing.

MACROS Preprogrammed or user programmed keys permitting complex key sequences to be stored and executed by pressing a single key. Sometimes known as smart keys.

MIDI Musical Instrument Digital Interface. This serial data language is used by microprocessors in synthesizers, sequencers, drum machines, signal processors, and computers. It provides musical pitch and rhythm information, synthesizer performance parameters, song position markers, stop/start/continue commands for sequencers and computers, and synchronizing data called MIDI Clock, which is based on 24 pulses per quarter-note. MIDI is frequently used with SMPTE for sync-to-tape functions.

MIDI is transmitted between microprocessors at 32.125 kBits per second. It can also be used by lighting systems and mixing consoles.

MIDI Time Code A MIDI system real time message that assigns a unique address for a specific moment in time. MIDI Time Code takes two frames to transmit a complete address in bursts of data that are transmitted every 1/4 frame.

Motion Controls The basic set of six transport control keys (Play, Stop, Rec, Reh, Rwd & FF) and the six additional transport control functions (Loc, Cue, Allstop, Rlb, replay & Edit).

MTC See MIDI Time Code.

Multitrack A tape machine, analog or digital which has more than two audio tracks.

N/A Not available. Not active. Not applicable.

Non Drop Frame NDF or ND is one of the two SMPTE code types and is the black & white television standard. When using this code type, every frame of time code is counted in real time. See the Appendix for more time code information.

Non-contiguous Not a continuous, predictable sequence. i.e., 1, 2, 4, 5, 6, 8, 9 is a non-contiguous number sequence.

NTSC A system of coding color information for television transmission used primarily in the USA and Japan. Named after the National Television System Committee.

Offset Offset is the difference between two time codes at the point at which they are to be synchronized. Offsets are subframe-accurate and are displayed using the HH:MM:SS:FF format. Offsets are always applied to the slave machines.

Oversampling A process by which a computer interpolates between adjacent digital audio numbers to provide in-between values and reduce quantization error.

PAL Phase Alternate Line. PAL is another name for the 25 time code format, which is the standard for European color and B&W television.

Phase Lock A mode of synchronizer operation that uses phase information derived from SMPTE time code and, after initial synchronization, ignores specific frame addresses. It is also called Sync Lock.

Pilot Tone The Pilot output signal is a sinusoidally-shaped output, which is always two times the frame rate of the time code that is being referenced or generated.

Post-production Activities that take place after the raw footage has been shot for a video program or motion picture. Includes video editing and a number of audio processes, such as ADR, Foley, and mixing.

Production The initial stages in the making of a film or television program, which includes the shooting of raw footage and recording of production audio.

RAM Random Access Memory. The module’s configuration parameters are stored in battery-backed RAM. And recalled each time the unit is turned on.

Rate Frame rate or speed. See Frame Rate or Speed.

REF SRC Reference source. The signal used to determine the rate at which the generator and synchronizer will run. The reference source can be thought of as the system time base. The reference source can be internal crystal, external video, MAINS, or external pilot tone or the time code reader (VSO).

Register The generator register is the module's memory buffer that holds numeric time code values that are entered or captured. Each synchronizer also has reader, sync point, offset, user bit and error registers.

Reshape The output signal is the same as the input signal, but it has been reshaped with correct rise time values and a fixed voltage output. This type of output does not correct for bit or timing errors.

Resolving A technique for regulating the play speed of a tape machine by matching the rate of pulses recorded on tape with a pulse rate from another stable source or a master tape machine.

RLB See Rollback.

Rollback The rollback function is used to rewind machines by a predetermined amount from the current position. The default rollback time is 15 seconds.

S-PDIF A consumer standard similar to AES/EBU for the high speed transmission of digital audio data. Jointly developed by Sony and Philips.

Sequencer A device that can record performance data for synthesizers and other electronic instruments and then, on playback, pass that data on to the instruments so that they'll play what has been recorded. Modern sequencers use MIDI as their communications protocol.

Serial A type of computer interface where all data is sent down a single wire or pair of wires one bit at a time. Examples of serial interfaces are RS422 & RS232.

Serial Port The physical computer connection through which serial data is transmitted and received.

Setup Mode	The process of defining the user-selected operational parameters, such as defining a specific transport or lifter-defeat mode.
Shuttle	Fast-wind. Fast-forward or Rewind.
SMPTE	Society of Motion Picture and Television Engineers. An industry standards committee. The group responsible for developing SMPTE time code.
SOLO	Literally "using alone". A tape transport in solo will be controlled by itself, without affecting other transports in the system.
Speed	Speed, Frame Rate and Rate are synonymous. Time code speed is counted in frames-per-second (fps). SMPTE time code has two speeds: 30 fps and 29.97 fps.
SU	See System Unit
SUBF UBITS	Sub frame user bits.
Sync Lock	See Phase Lock.
Sync Word	Included at the end of every 80-bit time code word is a 16-bit Sync Word. The sync word provides direction and Phase-lock speed information, and marks the end of each time code word.
Synchronizer	A device that reads time codes recorded on two or more tape machines, compares the codes, and adjusts the machine's tape positions and speeds based on the results of that comparison.
System BUS	When two or more synchronizers are used to form a system, a communications link must be established between the modules. This is done by looping from one module to the next, via the RS422 ports on the rear panel of the system unit.
System Unit	The rack mounting part of the Micro Lynx machine control system. The unit contains the control (CP) and machine control (MC) microprocessors.

TCA	Time Code Address. The HH:MM:SS:FF bits of the TC word.
TCG	See Time Code Generator.
Time Code Format	Time code format defines both the frame rate and code type being used. Example: To describe a time code format as 30 NDF is to say that the frame rate is 30 fps and the code type is non-drop frame. Simply saying either 30 or drop frame defines only part of the SMPTE time code.
Time Code Generator	A special signal generator designed to generate and transmit SMPTE time code at one of the international formats & rates.
Time Code Reader	A counter designed to read and display SMPTE time code.
Time Code Type	The word "type" is the key to understanding this phrase. *Type* defines the counting method that is employed by the time code module. There are two SMPTE types: 30 (also called non-drop "ND" or non-drop frame "NDF") and drop frame (DF). EBU and film types are the same as their respective speeds, 25 and 24.
Toggle	To toggle is to consecutively press a key several times in order to step through a series of choices.
Track	A place for the storage of audio information. Analog tape recorders have one or more physical tape tracks. MIDI sequencers and digital audio workstations provide areas of memory to store control or audio data.
Track Select	The process of enabling (arming) specific tape machine tracks for recording.
Transport	Transport refers to a part or subassembly of a machine, i.e., a transport connector or a transport cable.
TRS	Tip - Ring - Sleeve. A 1/4", balanced termination plug or jack. Typically wired T = +, R = -, S = shield.
Type	See Time Code Type.
UB	See User Bit.

User Bit — Each time code frame or word consists of 80 bits that convey SMPTE/EBU time code information. Thirty-two of those bits are user bits, and are available for storing information such as IDs, reel numbers, session dates or another time code number.

Value — Values are generally time code addresses. They may also be a custom user bit IDs.

Video Sync — A reference video signal generated by an extremely stable source. This signal is used to control the speed of video machines, digital audio machines and is used as a timing reference to ensure accurate synchronization.

Virtual Tracks — Used to describe any circumstance whereby the method for reproducing audio tracks is not directly analogous to the linear tape track format. Hard disk systems (DAW's) and MIDI sequencers are typical examples.

MIDI performance commands can be stored in a sequencer. Because the sequencer can "play" these parts in real time, synchronized to tape, they can be regarded as extra or "virtual" tracks, not on the tape, but present nonetheless.

VITC — Vertical Interval Time Code. An alternative to the LTC format of SMPTE time code. It is recorded in the blanking interval of the video signal, which is not used for the picture.

VSO — Variable Speed Override. Variable Speed Oscillator.

VTR — Video Tape Recorder.

Wideband — A signal that is distributed over most or all of the frequency spectrum. A wide band input amplifier is capable of processing signals that are well outside the audio bandwidth.

Word Clock — An extremely stable synchronization signal that is used to control the rate at which digital audio data is converted or transmitted.

Workstation — See DAW.