

CHAPTER 3

TIME CODE and SYNCHRONIZATION

GENERAL	2
THE TIME CODE FORMAT.....	2
TIME CODE IN / OUT CONNECTION	3
DISPLAYING A TIME CODE	3
TIME CODE SETTINGS	3
SETTING OF THE INTERNAL GENERATOR	4
<i>Time Code Format Selection</i>	4
<i>Setting The Time</i>	4
<i>Setting The User Bits</i>	4
SELECTING THE RECORDING SOURCE	4
JAM SYNC	5
SELECTING THE OPERATING MODE OF THE USER BITS	5
TIME CODE ASSEMBLE MODE	5
SETTING TIME/USER DATA FROM EXTERNAL.....	5
TIME CODE SYNCHRONIZATION.....	6
<i>OffSet</i>	6
<i>Chase Reference</i>	6
<i>Sync Mode</i>	6
OPERATIONAL THEORY IN TIME CODE	7
CONVERTING 24 FPS TO 30 FPS.....	7
THE 3:2 PULL DOWN	7
HD AND 23.976 FPS	7
WHAT ALL THIS MEANS	8
WHAT SHOULD MY NAGRA V BE SET TO?.....	8

(The NV-TC option must be installed for the time code system to operate)

GENERAL

Up until now the audio / video domain has always related the word SYNCHRONISATION with the speed and direction of a tape transport, as is the case with an analogue machine using centre track time code. That is to say that the speed of the transport is directly controlled with respect to an incoming time code signal, and if this time code were to be reversed then the machine itself will reverse. In modern digital recorders, especially computer based formats the notion of time code as a whole is different. In the case of the NAGRA V the term synchronisation possibilities, covers aspects of time code, external references, and the effects upon the outputs, clocks etc. In addition, features such as the pre-recording buffer, and different sampling rates all have their own effect on the time code system and its operation.

THE TIME CODE FORMAT

Unlike previous time code NAGRA recorders, the NAGRA V does not record a continuous time code signal, as is the case with traditional longitudinal formats. The NAGRA V simply records a time “stamp” at the start of each recording and according to the selected frame rate and sampling frequency, the time code value at any given point after that stamp is simply calculated by counting the number of samples of digital audio.

This time stamp is recorded in the header of the .WAV file, which is in fact the “BWF” or broadcast wave file format. This time code information is then readable by any computer device capable of reading a Broadcast wave file format.

The time code system of the NAGRA V can be set to record all the currently accepted standard time code frame rates which are as follows:

24	FPS	-Film applications
25	FPS	-PAL/SECAM Video and film to video applications
29.97	FPS	-NTSC black and white television
29.97	DF	-NTSC colour television
30	FPS	-Film applications (NTSC)
30	DF	-Film to video (NTSC)

In addition the NAGRA V can record any of the above frame rates either accelerated or retarded by 0.1% in order to deal with all the possible anomalies of the NTSC “Pull up / down” which means:

<i>Frame rate –0.1%</i>	<i>Actual frame rate</i>	<i>Frame rate + 0.1%</i>
23.976	24	24.024
24.975	25	25.025
29.940	29.97	30
29.97	30	30.03

These different frequencies are recorded when the selection is made in the **Ref. Freq** menu.

IMPORTANT: When the reference frequency menu is set to master +0.1% (or –0.1%) the entire machine will speed up (or slow down). That is to say the time code AND the sampling frequency of the audio. For example, setting the machine to 29.97 at 48 kHz sampling frequency, and then selecting MASTER + 0.1% in the reference frequency menu means that the machine will actually accelerate by 0.1% and the result would be 30 frame time code at a sampling frequency of 48.048 kHz. The $\pm 0.1\%$ will be stored in the memory of the machine when the power is turned off and will remain accurate for one week.

The time code system of the NAGRA V will also accommodate the traditional USER BITS modes of DATE and FREE according to needs. All the settings and different selections concerning the internal time code system of the NAGRA V are made using the MENU system. (See TIME CODE MENU). Each of the time code operations is explained in detail below.

TIME CODE IN / OUT CONNECTION

The time code input and output is located on a 5 pole LEMO connector on the right side of the machine. The pin connections correspond to that of the IV-STC, T-Audio-TC, NAGRA-D.



<u>Pin #</u>	<u>Connection</u>
1	Ground
2	Time code input
5	Time code output

DISPLAYING A TIME CODE

The display on the front panel of the NAGRA V is used to display time code. Various different time code indications can be displayed according to the selection made in the display menu. The chosen time code (Internal Generator or External time code) can be displayed in either TIME or USER format. DELTA TC, which is the changing difference between the external reference and the time code on the index during the synchronising process, can also be displayed.

TIME CODE SETTINGS

If the modulometer illumination switch is moved briefly to the BAT position twice in quick succession the display will scroll through the presently selected time code generator and synchroniser settings, the default values are as follows:

25 fps	(Generator format)
INT. GEN.	(Record source)
TC EXT	(Chase reference)
FIX. CLK.	(Sync mode)

SETTING OF THE INTERNAL GENERATOR

Time Code Format Selection

Go to the **Time Code** menu (see menus) and move to the right using the arrow keys to the **Format** menu which will indicate the currently selected frame rate. Pressing the vertical arrow keys will scroll through the different formats. Once the desired format is shown on the display press the EXE key and the new selection will be made. A single beep will be heard to indicate that the command has been accepted and the display will return to previously displayed option (Take, Remain etc.)

The accepted time code formats of the internal generator are as follows:

24fps
25fps
29.97fps
29.97df
30fps
30df

The internal generator will count across midnight at all frame rates and keep perfect time. However the date will not change in the USER bits on the stroke of midnight when the generator is set to 29.97FPS or at 30df as neither of these two frame rates are coherent with real time. At these two frame rates the memory will continue counting for a week accurately. After that time a re-jam of the internal generator should be performed.

Setting The Time

The internal generator of the NAGRA V can be set either using the arrow keys on the front panel, or from an external time code source. Once the internal generator has been set from the EXT source the counting is continued by means of the internal generator, hence there is no need to have a cable link permanently. Jam sync is also possible and will be discussed later.

Move to the **Time Code** menu and press the right arrow to move the display to **Gen** display, allowing access to all the settings of the internal generator. Move to the right to **Format** and then scroll through the possible choices until **Set Gen.** is displayed. Move to the right and then scroll through the options to the **Set Time** position. Moving right from here will display the time code digits, which can be modified using the arrow keys. When the desired time is set press the EXE key.

Simply pressing the EXE key when FROM EXT is displayed in the Gen. menu sets the time code from an external reference.

Setting The User Bits

The user bits are set in exactly the same manner as the TIME portion of the time code via **the Set User** menu. Each digit is then set using the arrow keys. The user bits can be set to any value from 0 to F (Hex) if they are in Free User mode. Alternatively they must correspond to the DD.MM.YY.xx format if in the DATE mode.

SELECTING THE RECORDING SOURCE

From the format display, press the down arrow and the display will indicate **Rec. Src.** allowing the selection of the time code source to be recorded. The options are, INTERNAL, JAM SYNC, EXTERNAL or ASSEMBLE. Simply press EXE to select the desired source when displayed. When the ASSEMBLE is selected and the machine is set to record, a seamless time code assemble will be performed each time a new take is started.

JAM SYNC

In the JAM sync position, the internal time code generator of the NAGRA V will automatically be set as soon as a VALID time code is connected to the time code input connector. If the cable providing the external time code signal is left connected to the machine, a new JAM SYNC will be performed automatically as soon as the machine detects a difference between the internal time code generator and the external signal of more than 2 mS. An automatic JAM SYNC will also occur if a difference in the USER information is detected between the incoming signal and the information in the internal generator of the machine. For the JAM sync function to operate when the cable is connected, certain conditions are verified before the set is made and these are: The incoming TC must be VALID and at the correct speed ($\pm 1\%$) for 10 consecutive frames. Frozen or Reverse time code will not provoke a JAM to occur. This means that connecting the external signal to the machine for one second is largely long enough for the machine to check all the parameters and set the generator.

SELECTING THE OPERATING MODE OF THE USER BITS

From the FORMAT position press the down arrow twice and the display will show USER MODE. When pressing the right arrow now, the operator can select the operating mode of the internal generator for the user portion of the time code signal. There are four different modes that can be selected. The most important selection here is between the DATE or FREE positions. The user bits must be in the same format as the external source if setting is to be made in either direction. The other two possibilities for the user bits are FREE INC or DATE INC. These two are essentially the same as the normal date and free modes except the right-most two digits are automatically incremented by one, from 00 to 99, each time the machine is put into the record mode.

TIME CODE ASSEMBLE MODE

Each time the machine is put into REC mode a full time code assemble will be performed. This is done by calculating the time code value of the last frame of the previous take (taking into account the sampling frequency) and using the next consecutive frame number as the time stamp for the beginning of the next index. The index number will also be incremented at the same time. Pressing the STOP key to create a new index during recording will also perform a time code assemble irrespective of the time code setting.

SETTING TIME/USER DATA FROM EXTERNAL

From the FORMAT position scroll through the menu to the **Set Gen.** position and then move to the right and select FROM EXT. This will immediately take the next correct, valid moving time code which arrives on the LEMO connector and will set the internal generator. The internal generator will then continue to count from this value irrespective of the external time code arriving.

TIME CODE SYNCHRONIZATION

The time code system of the NAGRA V is fitted with an internal time code chase synchroniser. The synchroniser performs in much the same way as the internal synchroniser of the NAGRA T-AUDIO TC. It has the possibility to synchronise the machine either to an external time code that is fed to the LEMO connector on the side of the machine, or to lock it to a video sync reference fed to the BNC connector. Chase synchronisers in the digital domain are different from those used in analogue machines. If, for example, the machine is synchronised to a reference that is not at the correct speed, then the entire machine will change speed accordingly and digital output of the machine will not be at the correct sampling frequency which will cause problems during digital transfers.

The internal synchroniser of the NAGRA V is activated, by pressing SHIFT while selecting the PLAY position of the main function switch. While the machine is in the sync mode, if the STOP key is pressed then the machine will pause and upon the next press of the STOP key the synchronisation process will be resumed. The internal synchroniser of the NAGRA V has various different parameters and operating modes. The four principal sections are OFFSET, CHASE REFERENCE, SYNC MODE and REACTION TIME, each of which is described below:

Offset

The offset is the programmable difference between the time code reference and the time code coming from the recorder. This can be set in the same manner as the time code values, by using the arrow keys to set the value followed by the EXE key. An offset can be reset to zero at any time by executing the RESET function in the menu.

Chase Reference

The chase reference menu has three choices, TC EXT, TC INC and VIDEO. In the TC EXT position the internal synchroniser will lock to the incoming time code exactly. In the TC INC position, as soon as the SYNC function is activated, the synchroniser will read the external time code reference value and the value of the time code on the take to be synchronised and will immediately calculate the difference between them. This difference is then stored in the OFFSET register and remains a fixed offset until the next time the SYNC operation is activated.

In the VIDEO position the time code will be locked to the incoming video signal connected to the BNC connector on the side of the machine. The synchroniser will lock the 0 frame of the time code to the rising edge of the sync pulse in the video signal.

Sync Mode

There are two different modes in which the internal synchroniser can operate. One is called the VAR CLK (variable clock) mode and the other is the FIX CLK (fixed clock).

Fix Clk

In the FIX CLK mode the machine will always follow the external reference. Once the machine is in the LOCKED state the internal synchroniser will no longer influence the transport and the playback speed is controlled entirely by the reference frequency (REF FREQ menu). If however the synchroniser of the NAGRA V sees an error of more than 1 frame, it will re-engage itself to correct the synchronisation error. This is the recommended operating mode. In this mode the maximum variation accepted is 100ppm.

Var Clk

This mode is designed to allow the machine to follow an external reference that is not the same as the REF FREQ using the internal synchroniser. This setting allows the internal synchroniser to modify the internal clocks in such a way as to follow this REF FREQ (for example NTSC / NTSC 60). In this mode, the digital output is not available and the quality of the analogue outputs may be slightly degraded. In this mode variations of up to $\pm 4\%$ in the reference signal will be tolerated.

OPERATIONAL THEORY IN TIME CODE

CONVERTING 24 FPS to 30 FPS

30 fps Time Code is used when transferring film to 29.97 fps video for video/workstation editing or when transferring to magnetic (Sprocket) film. The following chart shows the frames that are coincident between 30 fps and 24 fps.

	24fps	30fps	Real Time
Frame #	0	0	Start of the Second
Frame #	4	5	166.6667 mS
Frame #	8	10	333.3333 mS
Frame #	12	15	500 ms (Half a Second)
Frame #	16	20	666.6667 mS
Frame #	20	25	833.3333 mS

As shown in the chart above, every fourth frame at 24 fps matches every fifth frame at 30 fps. The film transfers at a rate of 23.976 fps when converted to video at 29.97 fps during the 3-2 pull down. At the same time the audio is also slowed down from 30 fps to 29.97 fps. This results in an exact match in the video transfer. Recording 30 fps time code at 48 kHz means that the transfer house has to sample your tape at 47.952 kHz (using special decks) to achieve the 0.1% pull down if the audio signal is to remain in the digital domain. If the audio recorder supports the 48.048 kHz sampling rate then the tape can be played back at 48KHz, which produces the same 0.1% pull down using the standard available decks while keeping the audio in the digital domain.

THE 3:2 PULL DOWN

NTSC video frames are composed of two interlaced fields, each containing half the picture information. One field contains all the odd scan lines, the other all the even scan lines. When 24 frame film is transferred to NTSC, the first film image is placed in three successive video fields and the second frame image is placed in the next two successive video fields. This process is repeated until the end of the film. Artefacts of this process can be seen if you play the videotape in very slow motion. This process is needed in order to transform the 24 frames of film into 30 complete video images. In order to make this compatible with the NTSC video format the 24 frames of film are slowed down by the Telecine by 0.1% (to 23.976 fps) and the resulting video signal is no longer 30 fps but 29.97fps.

HD AND 23.976 FPS

High Definition Cameras are capable of running 24 fps progressive scan (24P). This is different to NTSC, which is 29.970 interlaced. If you use 24P, it must be converted to 29.97 fps NTSC for video assist or editing on an Avid. When running 24P HD video, the audio TC must run at 30 fps. Currently the down conversion from 24P is not practical. A solution is to run the HD camera at 23.976. The High Definition conversion to NTSC video can then use the available standards converters. The following chart shows the frames that are coincident between 23.976 and 29.97 NTSC.

	23.976fps	29.97fps	Real Time
Frame #	0	0	Start of the Second
Frame #	4	5	166.8333 mS
Frame #	8	10	333.6667 mS
Frame #	12	15	500.5 ms (Half a Second)
Frame #	16	20	667.3333 mS
Frame #	20	25	834.1667 mS

Again, every fourth frame at 23.976 fps matches every fifth frame at 29.970 fps. What does this mean to the audio Time Code? Just run it at 29.97 fps! The same sync relation from the 3-2 pull down chart holds true. The difference being that there is no speed change on the audio or video and the sampling rate can stay at 48KHz.

WHAT ALL THIS MEANS

Understanding the 3-2 pull down and how 24 fps and 30 fps relate it is easy to see how 23.976 fps and 29.970 fps relate as well. Don't be confused by these "new" numbers. 23.976 fps is used so that down conversion for contemporary video assist is a simple real time matter. The good news is that there really is nothing new.

WHAT SHOULD MY NAGRA V BE SET TO?

As a rule one should always check with the post production facility first to see how the next stage in the production is going to be handled. Below is a table for your guidance.

APPLICATION	TC Frame Rate (fps)	Sampling Frequency (kHz)	Reference Frequency
Shooting Video in PAL / SECAM countries	25	44.1 / 48	Master
Shooting Film in PAL / SECAM countries	25	44.1 / 48	Master
Shooting Film in NTSC countries	29.97	44.1 / 48	Master +0.1%
Shooting Video in NTSC countries	29.97df	44.1 / 48	Master
Shooting 24P HD video	29.97	44.1 / 48	Master
<i>(To be continued)</i>			