A Professional DAT for Audio and Video Application

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A PROFESSIONAL DAT FOR AUDIO AND VIDEO APPLICATION

by

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1. Abstract

This paper describes a development of professional RDAT. Time code recording is very important for practical applications. After standardization of a time code recording format, RDAT can be widely used as a useful and convenient recording medium in the professional audio field.

JVC has developed a professional RDAT that is well suited for audio post production in video post production processes.

The main topics discussed in the paper are: time code recording and playback, sampling frequency, system synchronization, and system control.

2. Introduction

RDAT was developed and introduced as a consumer product in 1987. It possesses audio quality quite satisfactory for use in numerous professional applications. Based on technology that was developed for universal use, that is by consumers as well as professionals, its technical performance is very good while its cost is low. A recording format standard universally developed and agreed to assures that RDAT tapes can be exchanged and played anywhere in the world. Already, early versions of professional RDAT ACR's have begun to be used for a variety of other video and other professional audio production applications. These as well as other serious applications such as mastering and editing require not only AES/EBU digital inputs and outputs, but the ability to record and play back location information, specifically, SMPTE time code. The IEC has thus studied all requirements and created and a draft specification to include SMPTE time code as part of the information recorded by RDAT.

We have developed a professional RDAT audio tape recorder which can be synchronized to television signals and utilize SMPTE time code to accurately identify and locate digital audio recorded anywhere on the tape. These attributes permit convenient implementation of the RDAT within video production and post production systems. This paper discusses the design considerations leading to the technical evolution resulting in this RDAT product.

3. Recording Time Code for Professional Use

When RDAT first began to be used for professional purposes, accurate location of audio along the length of the tape became an important requirement. Recording a time code such as SMPTE time code seemed to be a desirable goal. Consumer RDAT, however, conforms to an absolute time standard which sets frame frequency at 33.3Hz. Employing a television related time code, and also synchronization to television systems such as NTSC with a 29.97Hz frame rate is therefore difficult. Some alternative solutions considered were as follows:

a. Time code can be recorded on a longitudinal (stationary head) track, optional track 1 or 2 located at each edge of the tape in the same way that longitudinal time code, "LTC", is recorded on video tape by video tape recorders. (SEE FIGURE 1.)

b. Time code for professional use is recorded without conversion in the sub-code packs on the helically scanned (rotary head) tracks.

c. Data for the conversion of time code between that of RDAT and the professional, video related SMPTE time code is recorded in the sub-code packs.

Method (a.) is considered unsatisfactory because a separate, stationary record/playback head is required. Additionally, time code cannot be reproduced and read reliably during high speed search due to the severe time code playback frequency response requirements imposed by rapid passage of tape past a stationary R/P head in the search mode.

Methods utilizing data recorded in the sub-code packs attracted several suggestions and currently, method (c.), that of recording time code conversion data in the sub-code packs is being considered most seriously. The JVC DAT utilizes the prevalent method outlined in the current IEC draft specification to record SMPTE time code on professional RDAT recordings.

The sub-code area consists of eight blocks of data at each end of every RDAT track. Data is stored in the form of packs and seven packs are written in an overlapped manner to permit easy readout during high speed search. (SEE FIGURE 2.)

The IEC draft specification proposes conversion of the external SMPTE time code to time identification corresponding to the RDAT 33.3 frame cycle and the phase difference between the external SMPTE 29.97 frame, and DAT 33.3 frame cycles. The converted external SMPTE time code is stored as standard RDAT time identification in the packs.

The proposed method conforms to the RDAT standard and possesses the following features:

a. Easy interface with LSI circuits used for RDAT ACR's.

b. Once converted to RDAT time identification, conversion from NTSC to PAL, or PAL to NTSC can be accomplished.

c. Editing is possible because RDAT time identification for the sound corresponds to SMPTE time code for the video picture.

d. A frame error of only one frame results when the absolute time originally recorded on the·RDAT tape is converted to the time identification that corresponds to the external SMPTE time code.

4. Time Code Processing

The JVC RDAT ACR records external time code after it is decoded by a time code reader IC and microprocessor. Delay time of the audio A/D converter and digital filter is compensated by adding a fixed amount of time to the incoming external time code thus assuring that the time code and audio correspond accurately with each other. During playback, the SMPTE time code is created by a time code generator IC after conversion from the RDAT time identification data. A ring buffer memory is used to delay the playback audio signal and assure that it corresponds accurately with the SMPTE time code outputted from the RDAT.

(SEE FIGURE 4.)

5. Input Mode Selection Concept

The following are the two most significant applications for this RDAT audio cassette recorder/player.

a. Video application

When applied to an NTSC video signal, a sampling frequency of 48kHz is utilized to correspond to the NTSC frame rate of 29.97Hz. These two frequencies are related through multiplication and therefore permit satisfactory implementation of phase-locked loop circuits. This functional mode 1 utilizes SMPTE time code which can be selected between drop, and non-drop frame types. Mode 1 function automatically seeks to synchronize to an external analog video input signal.

(SEE FIGURE 5.)

b. Compact disk mastering

A sampling frequency of 44.1kHz is required to create compact disk recordings. This functional mode 2 utilizes a video frame synchronization of 30Hz which best relates to the 44.1kHz f_s mathematically. In addition, current PCM processors function at a 30Hz frame rate standard.

Mode 2 is considered to be used mainly for digital signal inputs following editing and other post-production processes as well as for internal analog/digital conversion.

Input selections can be stored for as long as one month through a backup memory system incorporated in the RDAT.

Status indicator LED's located on the front panel illuminate to show that the PLL circuit is locked to video sync, and that time code is present at its input to this RDAT.

6. Sampling Frequency

Various users have contributed opinions regarding sampling frequency capabilities of the RDAT. One opinion calls for integrating tapes that contain different sampling frequencies to avoid errors and confusion. Another was to call for high quality sampling at 48kHz of original source material for compact disk mastering. In this case, sampling frequency conversion to 44.1kHz is essential.

The following characteristics must be considered for ideal f_s conversion:

a. There must be no ripple as a result of the sampling rate conversion.

b. There can be no deterioration in the dynamic range of the length of the input data word.

(FIGURE 5 SHOWS A BLOCK DIAGRAM OF THE GENERAL SAMPLING RATE CONVERSION CIRCUITS)

This block diagram shows an input signal of f_s = 48kHz passing through an anti-aliasing filter. It is then interpolated to a frequency of 44.1kHz and directed to the output buffer.

The anti-aliasing filter must possess a sharp attenuation characteristic corresponding to an f_s of 44.1kHz and its passband must contain no ripple.

During interpolation, an algorithm has to control the dynamic range of the signal carefully. Read-out clock at the output buffer must have no jitter.

Very accurate digital signal processing is made possible today through the use of modern DSP LSI integrated circuits. This LSI can be applied very specifically to sampling rate conversion in digital audio equipment.

7. Output Mode Monitor

For convenience of the user, this RDAT displays via LED indicators, mode 1/mode 2, and drop/non-drop frame operation functions. Additionally, error indications are stored and retained after they occur so an operator may see at a later time that an error has occurred. The error indicator can be reset by depressing the error switch.

8. Synchronization to External Video Signals (FIGURE 6)

Figure 6 shows how video sync signals are processed so that the master clock of the RDAT is locked to sync. Genlocked sampling frequencies of either 44.1 or 48kHz are first created by a phase-locked loop. These locked sampling frequencies are then converted to a higher frequency by a second PLL. The locked high frequency is utilized to create an RDAT master clock frequency that is locked to, and in phase with the incoming video sync signal.

During playback, the time code signal that is recorded in the sub-code areas is decoded to SMPTE time code format utilizing a microprocessor and time code generator circuit. While external video sync and the master clock are locked during this process, phase difference between the SMPTE and RDAT data frame is not reproduced.

A ring buffer memory circuit, controlled by the microprocessor, delays the audio signal as required to assure that it is in perfect phase, that is perfectly in time with the SMPTE time code signal.

9. RDAT Connectors and Signal Interfaces for Professional Use

a. Balanced analog audio input and output

INPUT - XLR, +4dBm reference level,

Z_{in} = 22,000 Ohms

OUTPUT - XLR, Z_{out} = 47.0 Ohms

b. AES/EBU digital audio input and output

INPUT - XLR (AES/EBU standard I/F)

OUTPUT - XLR (AES/EBU standard I/F)

c. SMPTE time code input and output

INPUT - XLR, 2 Vp-p Z_{in} = High Impedance

OUTPUT - XLR, 2 Vp-p Z_{out} = Low Impedance

d. External video sync input and loop-through output

INPUT - BNC with switched 75 Ohm termination
0.5 - 2 Vp-p (Composite)

OUTPUT - BNC

e. Internal video sync output

OUTPUT - BNC, 1.5 Vp-p (Composite) Z_{out} = 75 Ohms

The RDAT ACR is equipped with an internal video sync signal generator which can be used as a source for the RDAT master clock in place of an external sync signal input. In this case, the internal sync signal is provided to an output connector on the RDAT and can be used as a genlock signal source for associated video equipment.

f. Remote control

PARALLEL - 45 pin

SERIAL - 9 pin "D" style

Operational functions that can be controlled via the remote control connectors, and the pin assignments of the parallel connector are shown in (FIGURE 7). "Forward kick" and "brake kick" functions support the "chase" function to permit more rapid synchronization of RDAT playback to that of a video cassette recorder. RDAT status data is provided in the form of "tally" output signals indicating that the RDAT is functioning in one of the following modes: pause, fast forward, play, stop, rewind, or record.

10. Other Features and Capabilities

In addition to the specific video related features described, the RDAT possesses the following capabilities for normal RDAT operation.

a. Analog/digital converter

- Delta sigma A/D conversion by 64 times over-sampling
- 4th order noise shaping
- 3rd order FIR digital filter (anti-aliasing)
- DC offset servo (less than ±1 LSB)

b. Digital/analog converter

- 256 times oversampling 1 bit D/A converter
- 2nd order noise shaping

c. Automatic head cleaning roller

The RDAT is equipped with a head cleaning roller to minimize the user's need to perform routine cleaning and maintenance. The head is cleaned automatically for about one half second when power to the RDAT is switched on and when a tape cassette is ejected from the transport. A switch is provided which permits the operator to deploy the cleaning roller for about 1 second at his discretion.

d. The amount of headroom available between a desired peak input level and full scale input level can be selected, stored in memory, and displayed on the front panel of the RDAT.

e. Fade in/out selector switch

- Depressing the "fade" switch while the RDAT is in "record pause" mode results in commencement of "record" operation and a 5 second fade in of the audio signal to the normal record level.

- Depressing the "fade" switch while the RDAT is in the "record" mode results in a 10 second fade out of the audio signal followed by a switch of the RDAT to its "record pause" operational mode.

11. Conclusion

The RDAT standard was established initially to assure that digital audio tapes can be interchanged satisfactorily between all RDAT ACR's available for consumer use. As is often the case, standards and products conceived originally for consumer use, yield similar but improved and more sophisticated products that contain unique features, and are intended specifically for professional use. The RDAT digital audio tape recorder is one such product. Professional RDAT reveals that there is no technological boundary separating consumer and professional products. More often now, product cost is being considered as much as technical performance before professional users choose products for particular applications. In the future, we plan to exploit the RDAT standard even beyond the capabilities of the product described in this paper to satisfy requirements presented to us by the community of professional audio users.

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MINUTES, the AES Digital Audio Recorder Study Group, Nov. 1988.

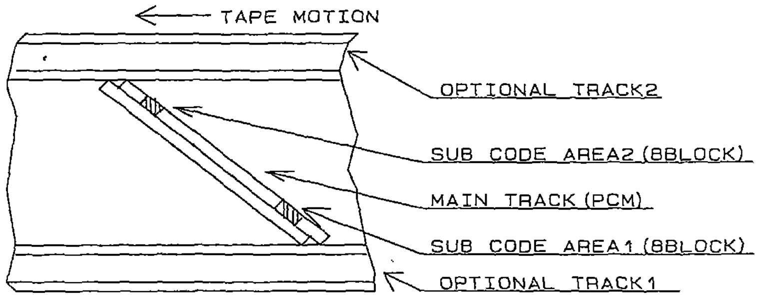


FIG 1 DAT TAPE FORMAT

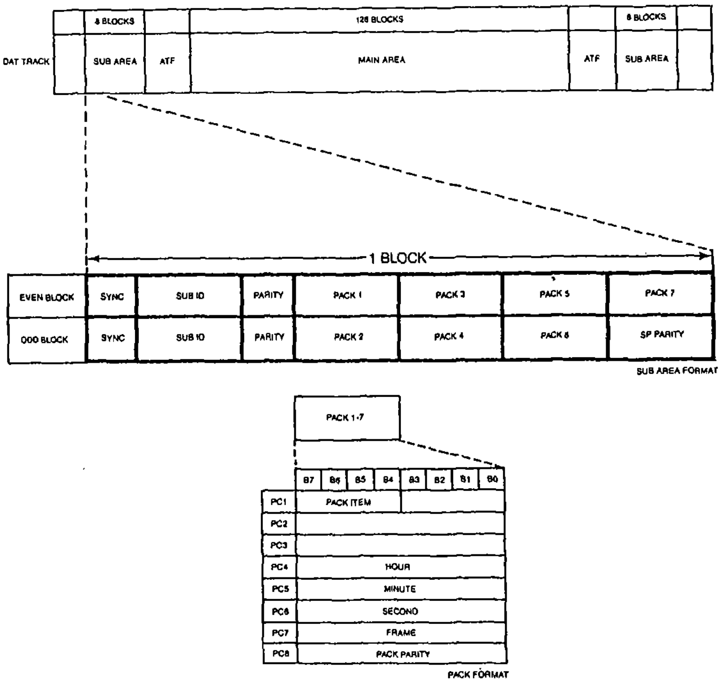
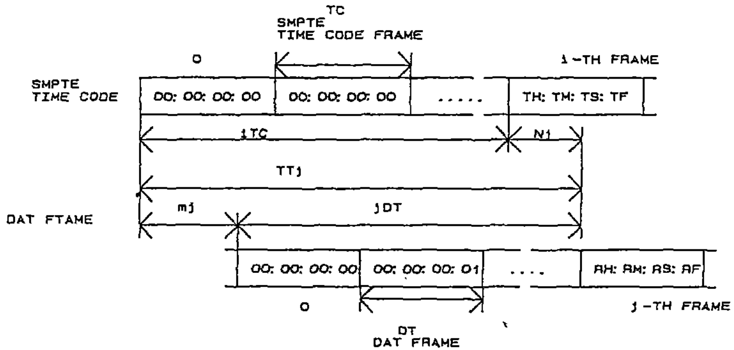


FIG 2 PACK CONFIGURATION IN SUB CODE AREA



SMPTE TIME CODE (TH: TM: TS: TF) IS CONVERTED TO DAT TIME (RH: TM: TS: TF) AND TC MARKER

TTj: TIME OF SMPTE TIME CODE AT THE BEGINNING OF THE j-TH DAT FRAME

TCM (TC MARKER) = INT (mj / Tfs) : Tfs IS A PERIOD OF SAMPLING CLOCK.

FIG 3 TIME CODE CONVERSION (IN THE CASE OF SMPTE)

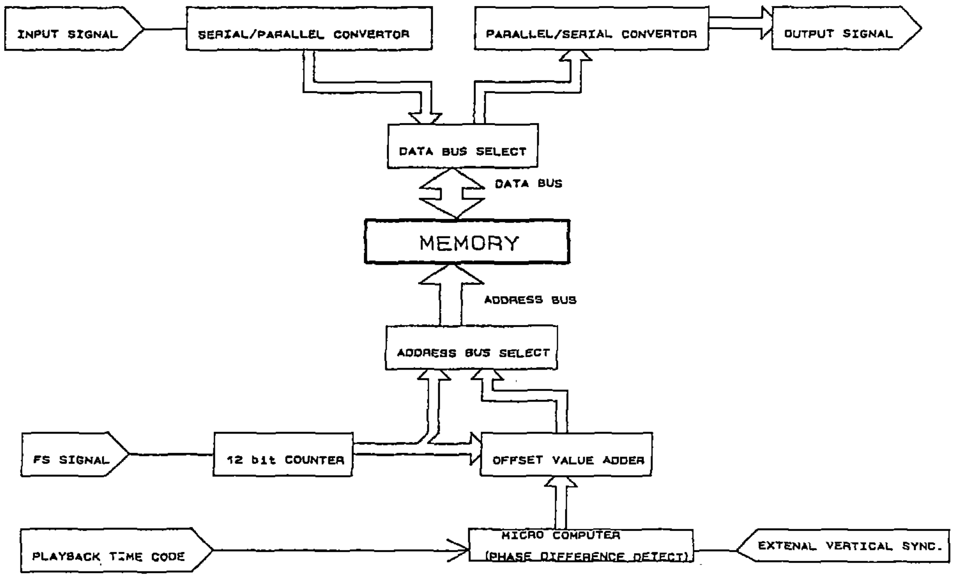
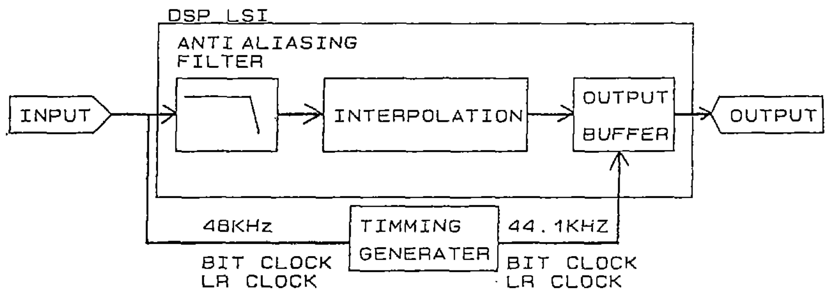


FIG 4 RING BUFFER MEMORY

FIG 5 FS CONVERSION BLOCK' DIAGRUM



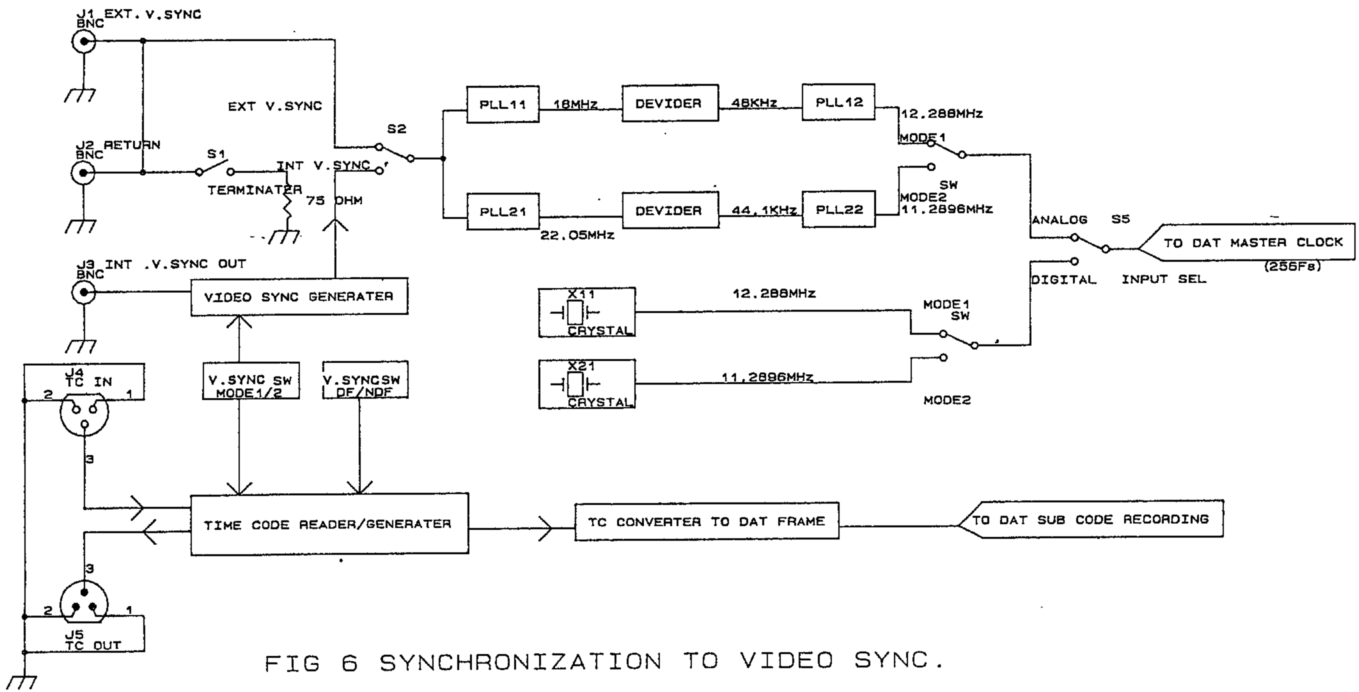
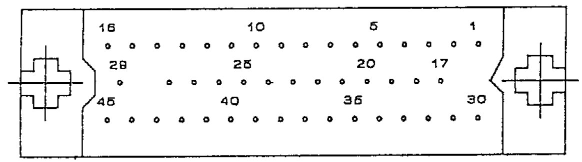


FIG 6 SYNCHRONIZATION TO VIDEO SYNC.

REMOTE CONTROL 1 (45PIN)



1. GND
2. RECORD
3. STOP
4. PLAY
5. FF
6. REWIND
7.
8.
9.
10. PAUSE
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23. PAUSE TALLY
24.
25.
26. FF TALLY
27. PLAY TALLY
28. STOP TALLY
29. REWIND TALLY
30. REC TALLY
31.
32. CTL PULSE
33.
34. +12V
35.
36.
37. FORWARD KICK
38.
39. BRAKE KICK
40.
41.
42. CHASE
43.
44.
45. EJECT (OPEN/CLOSE)

FIG 7