THE DASH FORMAT: AN OVERVIEW 2038 (A-9)

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ABSTRACT

The DASH Format (for Digital Audio, Stationary Heads) is a framework proposed by several manufacturers for professional digital audio recording, aiming at tape interchange and operational robustness. The previously published format has received important design changes in order to accommodate the requirements of 2-channel recording and of future, increased track densities. Its final version is presented, along with its recommended implementations for multichannel and 2-channel recorders.

1. Introduction

In audio recording, it is essential to provide the possibility of exchanging programs, tapes, and audio and control signals. The same requirements exist in digital audio, with the added difficulty that there is at present no generally accepted tape format, track geometry, recording code or error protection strategy for stationary-head recording.

This document presents a format for stationary-head digital audio recording. It is the result of technical discussions between three companies involved in professional digital audio, and represents an attempt at combining their experiences in a number of disciplines.

The DASH Format is primarily a set of rules for the recording and replay of digital audio and auxiliary information with stationary heads, in a way which ensures high audio quality, very low residual error rates, tape interchangeability and operational robustness. New technologies make it possible to implement the DASH Format in a very large number of ways, which is contrary to the need for standardised formats. A number of **recommended implementations** of the DASH Format are therefore listed and proposed for standardisation.

2. General Description

2.1 General Parameters

The DASH Format describes a recommended way to record and replay digital audio with stationary-head, professional equipment.

It is based on recording **16-bit digital audio samples** and auxiliary information on **separate, dedicated tracks.** The 16-bit format is compatible with today's conversion technology.

The DASH Format is based on the professional sampling frequency of **48.0 kHz** recommended by the AES, and - alternately - on the **44.1 kHz** relating to the Compact Disc. When 48.0 kHz is used, the standard tape speeds are **76.20 cm/s ("Fast"), 38.10 cm/s ("Medium") and 19.05 cm/s ("Slow"). Tape widths are 1/4" and 1/2".**

The DASH Format supports all operations commonly used in professional audio recording, i.e. manual and electronic editing, punching, and synchronous recording. Different head configurations, including such ones as provide read-after-write, can be used.

2.2 Digital Audio and Auxiliary Tracks

In the DASH Format, and for the two proposed tape widths proposed (1/4" and 1/2"), **four auxiliary tracks** are used in addition to those tracks dedicated to digital audio. The four auxiliary tracks are used for a control track which includes recorder data addresses, for cueing purposes, and for other possible applications.

2.3 Track Density and Tape Parameters

Today's established magnetic head technology allows for relatively high track densities, with a track pitch of approximately 0.5 millimeters (20 mils). This track pitch can be approximately halved to 0.25 millimeters or 10 mils if state-of-the-art thin-film heads are used, together with conventional tape guides. The DASH Format recognizes both technologies:

- with **normal track density,** 1/4" tape has 4 auxiliary tracks and 8 digital audio tracks. 1/2" tape has 4 auxiliary tracks and 24 digital audio tracks.

- with **double track density,** 1/4" has 4 auxiliary tracks and 16 digital audio tracks. 1/2" tape has 4 auxiliary tracks and 48.0 digital audio tracks.

The proposed track geometry ensures that auxiliary tracks can be read independently of track density. They also ensure that recorders with double-density heads will be able to read single-density tapes, although some operations of digital audio editing will be restricted if different track densities have been used in recording and editing.

There is at present no generally accepted standard or recommendation for the electrical and other parameters of magnetic tape as used for digital audio recording. The DASH Format does not yet, therefore, contain recommendations for electrical recording parameters on the tape, nor does it address tape thickness and tolerancing.

2.4 Recording Code and Data Format

Digital data are written onto the tape according to the rules of a recording code (channel code) with the properties of reducing bandwidth and limiting runs of identical bits; the code is called HDM-1, and is extremely simple to implement. A synchronisation pattern is provided by violation of the HDM-1 coding rules.

A **synchronisation pattern**, together with five auxiliary bits, has a length of 16 bits. It precedes a sequence of 16 16-bit data words, which are themselves followed by a 16-bit **Cyclic Redundancy Check (CRC)** word.

The 18-word sequence formed by a synchronisation word, 16 16-bit data words and a CRC word is called a **block.** At 48.0 kHz sampling frequency, and 76.20 cm/s tape speed, one block corresponds to 0.25 milliseconds of digital audio; at 48.0 kHz and 19.05 cm/s, it corresponds to 1 millisecond.

The purpose of the synchronisation pattern is to extract bits and words in their correct positions within a block. The purpose of the CRC is to provide a very high probability of **detecting** erroneous blocks in replay.

The longitudinal data density in the DASH Format is **independent** of tape speed, with a value of **1.51 kbits/mm, or 38.4 kbits per inch.** At 76.20 cm/s, this corresponds to a data rate per track of 1.152 Mb/s. The corresponding value is 288 kb/s at 19.05 cm/s. The density of 38.4 kbits per inch is now state-of-the-art, and no measurable improvement in robustness would ensue unless the density were reduced drastically.

2.5 Error Protection

The digital audio samples to be recorded on a track are **interleaved** and supplemented by **redundant information** for a very high probability of full error correction in the case of drop-outs. Redundant information is in the form of two check sums for every six words of digital audio, and is also interleaved (Cross Interleave Code). The interleaving and redundancy, together with careful handling, ensure safe digital recordings.

2.6 Editing Functions

All operations of **electronic editing** known from analog recording are also possible in the framework of the DASH Format, due to the existence of a reference track, and provided a corresponding head configuration is being used. This includes such functions as spot erase, punch, and dubbing, as well as synchronous recording. In addition, **manual (tapecut) editing** of adequate sound quality is possible.

2.7 CTL Auxiliary Track

The CTL auxiliary track is a **reference track** for all digital audio tracks. A synchronisation pattern on the CTL auxiliary track marks the beginning of a **sector. One sector** always corresponds to **four consecutive blocks** on the digital audio tracks. At 48.0 kHz and 76.20 resp. 19.05 cm/s, one sector edge corresponds to 1 resp. 4 milliseconds.

The CTL auxiliary track carries sequential **sector addresses,** which can be used as a time code internal to the recorder. The word length of the sector addresses is 28 bits, covering a time span well in excess of the possible duration of a tape.

2.8 Other Auxiliary Tracks

The three remaining auxiliary tracks can be used for mono or stereo cueing, for storing auxiliary data and for a conventional Time Code as used in analog recorders. At present, the functions and formats of the auxiliary tracks are left open.

3. Multichannel Designs at 76.20 cm/s

3.1 Definitions

An example of implementing the DASH Format is given by selecting the tape speed as 30 ips. On a 1/2" tape, and with normal track density, the number of tracks is 28, with the four auxiliary tracks and 24 digital audio tracks (one for each channel). On a 1/4" tape, and with normal density, the number of tracks is 12, with the four auxiliary tracks and 8 digital audio tracks (again, one for each channel). With double track density, four auxiliary tracks and 16 digital audio channels are provided. With a tape of 25 to 30 microns thickness (roughly 1 mil), playing times adequate for professional applications can be achieved.

3.2 Format Rules for 76.20 cm/s Recording

At 76.20 cm/s (30 ips) tape speed, the "Fast" version of the format is implemented. Its characteristic is that all samples belonging to one individual audio channel are recorded on one individual track. The high data rate of 1.152 Mb/s only requires, thanks to the use of the HDM-1 recording code, a bandwidth of some 400 kHz.

3.3 Implementation

Several recorders obeying the above format have been presented. Sony Corporation markets a 24-channel recorder, which has been described. Studer has presented an 8-channel recorder with similar functions. More implementations of the multichannel recorders, with channel numbers ranging from 8 to 24 (normal track density) and up to 48.0 (double track density) are envisaged. An example of implementation with double track density is a 16-channel, 1/4" recorder prototype presented by Matsushita.

4. Two-Channel Design at 19.05 cm/s

4.1 Definitions

In the 19.05 cm/s (7.5 ips) implementation of the DASH Format, the same recording density and track coding is used as in the 76.20 cm/s version. However, each digital audio channel is first split into four sub-channels at one-fourth the sampling frequency. Rather than being periodically subsampled,the sequence of digital audio words undergoes a patterned splitting with a short scrambling length, which can be described by a square matrix. The reason for using patterned splitting is that it preserves tapecut editability while strongly improving data recovery in case of single track loss.

The split sub-channels are error-protected independently, using the same strategy as in 76.20 cm/s recording. At replay, error detection and correction is again the same as in 76.20 cm/s recording, and is followed by a merging operation which restores the original data sequence of each channel.

4.2 Format Rules for 19.05 cm/s Recording

In 19.05 cm/s recording, the same error protection, detection and correction is used at in 76.20 cm/s recording. A difference is that CTL auxiliary track words now come every 4 milliseconds rather than every millisecond, as the tape moves four times slower. Another difference from 76.20 cm/s recording is that, as mentioned, a simple splitting and merging is used to translate between channels and sub-channels. In 19.05 cm/s recording, the data rate per track is 288 kb/s, corresponding to approximately 100 kHz of bandwidth.

4.3 Implementation

Digital recorders obeying the format rules for 19.05 cm/s recording are in development in a number of companies. Their operational features will be disclosed in the near future. The low tape speed ensures playing times which cover all practical requirements of today's recording studios and broadcasting stations.

5. Formatting Principles of DASH

5.1 Digital Audio Recording Code

Digital audio data are recorded in the HDM-1 code described in section 7 (Specifications). Implementation of HDM-1 encoders and decoders is comparable in complexity with that of other recording codes for magnetic recording. A synchronisation pattern and rules for the transition from data to synchronisation pattern and back are defined in Section 7. HDM-1 is a polarity-free, but not a dc-free code. The dc component at replay can be re-stored with simple, conventional techniques.

5.2 Digital Audio Block Formatting

Error protection involves a hierarchy of measures:

- in 19.05 and 38.10 cm/s recording, where channels are first divided into sub-channels, a splitting matrix is used. It preserves the pattern of odd and even samples of the audio channels as required for tapecut editing, and also contributes to simpler patterns of missing samples in the case of track loss. Each sub-channel (or each channel in 76.20 cm/s recording) is written, together with its error protection, onto one individual track

- odd and even samples are separated, and processed in identical ways, except for an odd-even delay of 204 blocks, or 2448 samples

- a first exclusive-or check sum P is computed from 6 audio samples

- a second exclusive-or check sum Q is computed from 6 interleaved audio samples and a check sum P, based on a unit interleave delay of 2 blocks or 24 samples (Cross Interleave Code)

- interleaving is performed on 6 audio samples, a check sum P and a check sum Q, based on a unit interleave delay of 17 blocks or 204 samples

- sequences of 16 words are created, each sequence consisting of 6 interleaved audio samples, two interleaved Q check words (even and odd), two interleaved P check words (again even and odd), and 6 interleaved audio samples

- each sequence of 16 words is complemented by auxiliary data relating to block numbering, overwrite number and control, and the CRC polynomial of the complemented data sequence is computed and appended

- blocks are created by starting with a synchronisation pattern, which violates HDM-1, and continuing with 5 bits of auxiliary data specific to each channel, the 16-word sequence and the CRC word, all of them coded in HDM-1. Consecutive blocks are written continuously on the tape, without any interblock gap.

The auxiliary data are two bits of block address within the sector, a 2-bit overwrite number (which helps detect correct, but unwanted blocks which have failed to be overwritten at re-recording due to overwrite drop-outs), and one bit for marking the possible use of pre-emphasis on the individual track.

5.3 Digital Audio Error Detection and Correction

At replay, the retrieved data are reformatted into blocks and each block is CRC-checked. If data and CRC do not match, this is interpreted as indicating that the complete block is unreliable. The probability of not detecting erroneous blocks is very low.

Blocks marked as erroneous correspond, thanks to interleaving, to scattered erroneous samples. These are corrected on the basis of the P and Q check sums. Undetected block errors can also be identified and corrected, as well as data from previous recordings which have failed to be overwritten. With a good error correction strategy, very long bursts of data can be completely corrected. For example, a drop-out destroying the replayed data over a length of more than 3 millimeters can be completely corrected.

5.4 Tapecut Editing

In the case of a tape cut, a number of effects occur:

- in the vicinity of the splice, data retrieval is seriously perturbed, and there is a severe burst of erroneous blocks

- in addition, the correct interleave relation no longer exists between words just before and just after the splice point

- finally, the sector address sequence will have a discontinuity

Smooth tapecut editing is achieved by interpolating the lead-in and lead-out signals, one half of which are missing, and additionally crossfading in the immediate vicinity of the splicing point. The achieved sound quality across a manual edit is comparable to that of a tapecut edit in analog recording.

5.5 CTL Auxiliary Track Formatting

The CTL auxiliary track is the reference track for all digital audio. It carries protected sector addresses, so that read or write errors can be detected. The low recording density allows reading of the CTL auxiliary track over a wide range of speeds.

A CTL word consists of 4 bits for synchronisation, 16 bits of control information for digital audio parameters, the 28-bit sector address, and a 16-bit CRC for error detection. The CTL auxiliary track data are written according to the rules of Biphase Mark coding, with the synchronisation word violating these rules. The data density is 2.13 kb/i; the data rate is 64 kb/s at 76.20 cm/s, and 16 kb/s at 19.05 cm/s.

The control information refers to the sampling rate (4 bits), and to the version of the DASH Format being used (3 bits). 9 bits are still undefined, and are reserved for later definition and use.

5.6 Other Auxiliary Tracks

The DASH Format is based on a total of 4 auxiliary tracks. For better compatibility with existing and future head technology, their positions differ in the cases of 1/4" and 1/2" tapes. On 1/4" tapes, the digital audio tracks occupy the centre of the tape, with two auxiliary tracks on each side. On 1/2" tapes, two auxiliary tracks occupy the centre of the tape, and the remaining two occupy the edges.

Due to evolving concepts in digital audio, there is no strict assignment of functions for all auxiliary tracks. At present, the functions and formats of the 3 remaining auxiliary tracks are left open.

6. Recommended Implementations

The DASH Format would allow an unduly large number of different implementations if the two possible track densities, the two possible tape widths, and the three possible tape speeds all were to receive consideration. In order to accelerate to development of recorders which support tape interchange, **only a few prefered implementations of the DASH options in density, width and speed are recommended, as listed below.**

6.1 Recommended Implementation in 19.05 cm/s recording

The only recommended implementation of DASH in 19.05 cm/s (7.5 ips) recording is that of the 2-channel recorder with 1/4" tape and normal or double density

6.2 Recommended Implementations in 38.10 cm/s recording

The recommended implementations of DASH in 38.10 cm/s recording are:

- the 8-channel recorder with 1/4" tape and double track density
- the 24-channel recorder with 1/2" tape and double track density

6.3 Recommended Implementations in 76.20 cm/s recording

The recommended implementations of DASH in 76.20 cm/s (30 ips) recording are:

- the 8-channel recorder with 1/4" tape and normal track density
- the 24-channel recorder with 1/2" tape and normal track density

- the 16-channel recorder with 1/4" tape and double track density
- the 48.0-channel recorder with 1/2" tape and double track density

7. Technical Specifications

7.1 Digital Audio Signal Parameters

Sampling Frequency: 48.0 kHz and 44.1 kHz, as outlined in the AES Digital Audio Technical Committee resolution

Digital Audio Sample: 16 bits, 2's complement, uniform quantisation

Pre-Emphasis: optional, with time constants of 50 and 15 microseconds

7.2 Recording Parameters

To be harmonized with recommendations from manufacturers and users, within the framework of essentially longitudinal, saturation digital recording at densities of approximately 40 kfc/i. Tape widths of 1/4" and 1/2" (6.30 and 12.66 mm) are used.

7.3 Tape Speeds

- with 48.0 kHz sampling frequency: 76.20, 38.10 and 19.05 cm/s (i.e. 30, 15 and 7.5 ips), wow and flutter tolerance 0.06%, peak, weighted, DIN 45 507.

- with 44.1 kHz sampling frequency: 44.1/48.0 of the above values, referred to as 70.01, 35.00 and 17.50 cm/s, or 27.6, 13.8 and 6.9 ips, with the same wow and flutter tolerances.

In both cases, the nominal speed tolerance is 0.01%.

7.4 Track Pattern and Track Assignment

Fig. 1 and Fig. 2 illustrate the track patterns and track assignments for 1/4" and 1/2" tapes in the DASH format.

7.5 Recording Code

Fig. 3 illustrates the rules for generating transitions in the recording current from incoming bit sequences.

7.6 Block Structure

Fig. 4 illustrates the content of digital audio data blocks as recorded (in HDM-1, except for the sync pattern) on tapes in the DASH format.

7.7 CTL Auxiliary Track Format

Fig. 5 illustrates the formatting of the CTL auxiliary track.

7.8 Track Alignment Tolerances

The CTL auxiliary track is, as mentioned, a reference track for all digital audio tracks. Fig. 6 indicates how this reference is defined, and which tolerances are specified between the CTL auxiliary track and the digital audio tracks.

8. References

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8.5 K. Kanai, N. Kaminaka, N. Nouchi, N. Nomura, and E. Hirota, "Thin Film Tape Heads for PCM Recorders," 66th AES Conv., no. 1636 (J-2), May 1980.

8.6 C. Brandes and R. Lagadec, "Improving DASH-L Robustness by Pre and Post Scrambling," Internal Report, Mar. 1982, (in Germany).

ıK.pltrak1.DSP

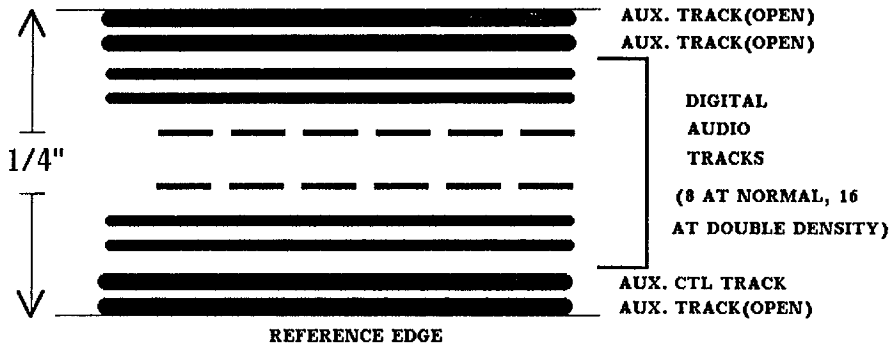


Fig. 1 : Track pattern, 1/4" tape

!K.pltrak2.DSP

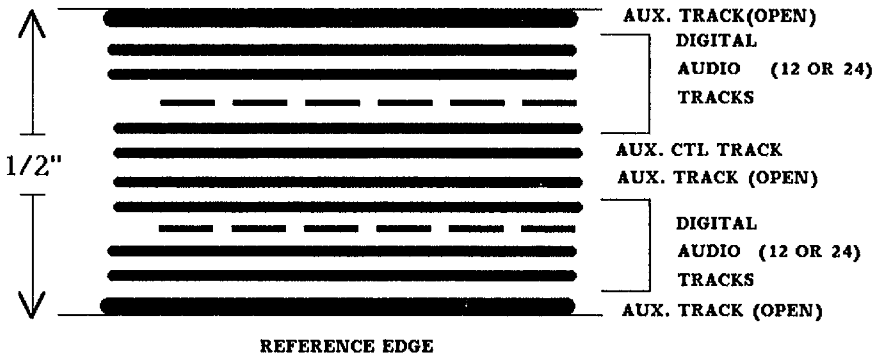
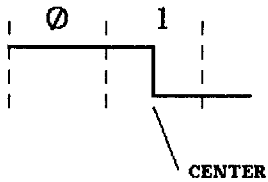


Fig. 2 : Track pattern, 1/2" tape

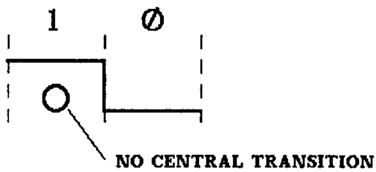
K.plcod.DSP

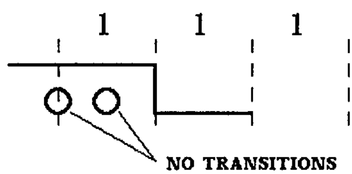
1. DATA TRANSITION 1-0 ALWAYS LEADS TO CENTER TRANSITION



2. CONDITIONS FOR EDGE TRANSITIONS:

1-0 TRANSITION NOT PRECEDED BY CENTER TRANSITION:





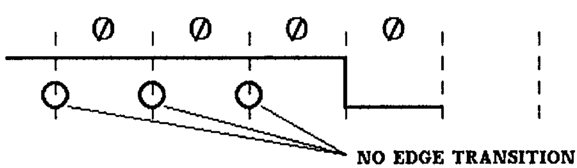


Fig. 3 : coding rules for HDM-1

'K.plblok.DSP

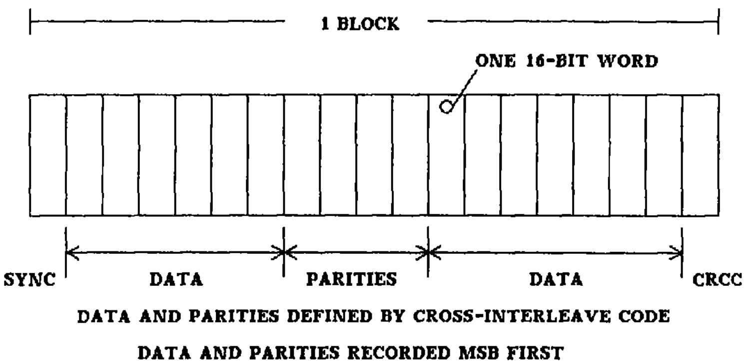


Fig. 4 : block structure of DASH format

ıK.plctl.DSP

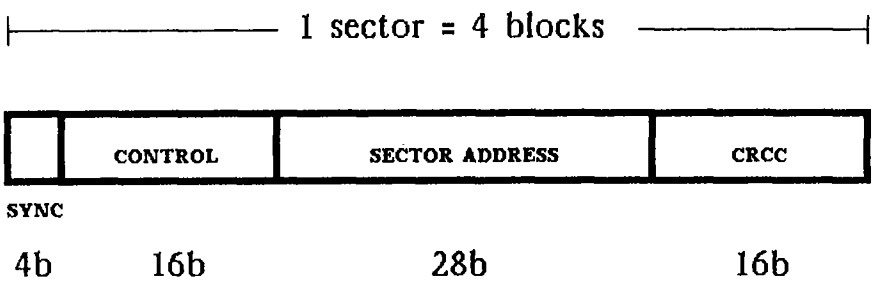


Fig. 5 : CTL aux. track format

ıK.pledge.DSP

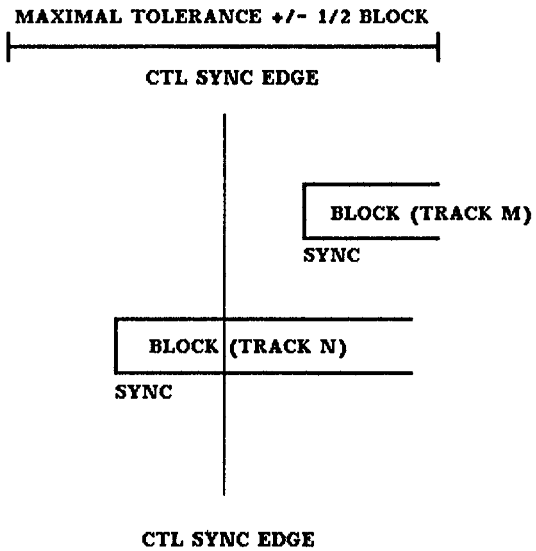


Fig. 6 : tolerance of block vs. CTL edges