



Method for the control of track following in a recorder

The invention relates to a method in accordance with the first part of claim 1.

When recording in oblique tracks, in particular for analogue and digital tape recording devices for picture and/or sound, it is necessary that each of the, in general, two heads exactly finds its track during the reproduction. To this end, for VHS, a pulse is recorded on a longitudinal track of the magnetic tape when a particular head dips down on to the tape. During the reproduction, the pulse is evaluated and serves for the control of the tape/head servo regulation. Entailed by the influence of tape stretching and adjustment tolerances, a means for adjusting the pulse position by the user, the so-called tracking, is provided in such types of device.

The 8 mm video system contains a so-called ATF (automatic track following) with which the track maintaining information is inserted into the channel in use. Thereby, during recording, a predetermined sequence of specific low frequency signals, and in each case, one per track, is interleaved in a frequency gap of the useful signal spectrum. During reproduction, the head reads its user information out of the track, but in addition, as a result of the low azimuthal coupling of the low frequency signals, the track maintaining information from the two adjacent tracks. The track following is controlled by means of an amplitude comparison of the signals from the right and left neighbouring track.

In the DAT system (Digital Audio Tape) for the digital recording of audio signals, the useful signal and the track following signal are recorded at separate locations whereby a so-called "run-in" region for the synchronisation of the clock rate recovery is placed in front of the useful signal and the ATF frequencies are obtained during the recording by division of the signal clock rate.

For the digital recording of video, especially for HDTV, the recording data rate is high and a spatially separate recording of signals on the tape is hardly tenable since the amount of tape surface which is needed is then intolerably high.

A special generation of the ATF signal is also known (IEEE Transactions on Consumer Electronics, August 88, page 597 - 605) in which the "run-in" region is associated with the clock rate recovery and the ATF information is formed by a cyclical variation of the DC component of the data items in the channel. The variation of the digital sum in each cycle of 10 bits permits the generation of triangular signals having various basic frequencies, each of different amplitudes, as permanent additional functions to the 8/10 channel modulation (matching the input signal to the capabilities of the recording channel).

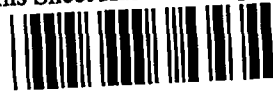


These known solutions have, to a greater or lesser extent, the following disadvantages:

In general, only triangular shaped signals can be produced which means a large content of higher harmonics and a correspondingly high harmonic distortion factor. Generally, different frequencies have undesirably different amplitudes even during the generation. If a permanent ATF signal is additionally produced, a balancing of priorities is necessary if two self contradictory requirements are to be fulfilled. Errors in the ATF sequence can thereby arise because the error rate of the useful signal should not rise e.g. through over stepping of the run length and the loss of synchronisation associated therewith. The possibilities for channel matching are in general distinctly limited. Without the inclusion of ATF, only 256 (8 bits) are selected from 1024 possible output combinations (10 bits) in the 8/10 modulation. These 256 bits are selected with regard to their disparity to 0 (sum of all H bits - sum of all L bits), which is not always possible, and are optimised as regards their run length so that the low and high frequency components are reduced. The not-used combinations (code words) 1024 - 256 can be ignored. Their appearance during the reproduction is an indication for the occurrence of an error. This so-called "erasure" may be used to advantage for error correction. By inclusion of the ATF, the code word range is appreciably larger, and especially advantageous code words (disparity = 0) can be used infrequently. The additional amount of circuitry is generally substantial since the digital sum value is controlled by two variable sources. The basic 8/10 conversion would give an optimised data word which would still have to be tested as to its suitability as an ATF code word (checking of the disparity and, if necessary, a search for a new code word).

The object of the invention is to develop a method for the control of the track following in a recorder which does not require the recording of various ATF frequencies and which makes possible the production of an ATF signal having a smaller number of harmonics and a low harmonic distortion factor. This object is achieved by the invention defined in claim 1. Advantageous developments of the invention are specified in the appendant claims.

Thus with the invention, the continuous ATF production in an oblique track is replaced by one or more short term ATF burst frequencies that occur in gaps in the useful data such as run-in, run-out and edit gaps within the track. The ATF frequency bursts are recorded throughout the whole track at constant frequency. The production of the ATF burst occurs at the clock rate of the channel modulation so that a clock rate recovery synchronisation during the ATF phase during the reproduction is easily possible. For the further improvement of the clock rate recovery, the ATF words are so designed that at least two flanks occur within a word. This is also done from the point of view that, for the purposes of synchronisation of the whole system, a block synchronisation pulse is provided which is not otherwise used in the system. The



discrimination is nearly always effected by means of a particular run length of this synchronisation pulse which, in the present case, has the value 7. Consequently, no signal that is produced may equal this value so that a maximum length of 6 successive H or L bits represents the system limits. The value may be varied for systems having other boundary conditions.

The ATF bursts appear approximately sinusoidal or as an otherwise formed train of oscillations of which different frequencies are present in adjacent tracks. To this end, data words having different digital sums are placed together in sequence. There thus exists a highest frequency of clock-rate/40 with which, 4 steps define a triangle of low amplitude whereby the resolution is better with increasing length of the sequence. However, an optimal matching to the transient behaviour of the evaluation circuit, the azimuthal damping of the heads and the low frequency properties of the tape recording channel, only permits of a usable frequency range of ca 200 kHz - 2 MHz.

The invention will be explained more fully hereinafter with the help of the drawing. Therein

Fig. 1 shows a block circuit diagram for the realisation of the method in accordance with the invention,

Fig. 2 curves for explaining the block circuit diagram in accordance with Fig. 1,

Fig. 3 further curves for explaining the method of operation,

Fig. 4 the waveform of the digital sums for a triangular signal and a signal approximating to a sine curve, .

Fig. 5, 6 developments of the Figure 4 for another ATF frequency,

Fig. 7 the signal profile of the sum variation signals,

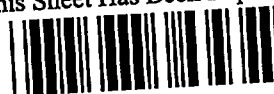
Fig. 8 one possibility for realising the block "ATF selection",

Fig. 9 in exemplary fashion, the sequence of code words,

Fig. 10 an optimised sinusoidal ATF signal and

Fig. 11 a circuit for the realisation of the control loop.

Figure 1 shows a block circuit diagram for a system which functions according to the method in accordance with the invention. A 50 MHz signal, which represents the bit-clock is generated in the oscillator 1. In addition, a divided-by-10 rate is made available as the so-called word-clock. An external head switching signal KS coming from the head drum servo system marks the drop-on time point of a read/write head onto the tape, and thus the start of a track, by means of its flank change. KS is supplied to the function group



logic 2 which is illustrated in more detail by the components 3, 4, 5 in the lower part of Fig. 1. The output signal A is the reset signal RES for the counter 6 having a width of 16 bits i.e. 64000 possible counting states, which increments with each positive flank of the word-clock.

The position of the counter, which is illustrated in Fig. 3d, is compared with different fixed values in the 16 bit comparator 7 and, upon equality, switching signals are generated which are referenced as EN1 and EN2 in Fig 3. EN1 controls the enable input of the PROM (programmable read only memory) which converts the 8 bit wide useful data into 10 bit wide channel data. EN2 is the enable signal for the function group ATF selection which carries out the modification of the digital sum words in dependence on the track.

The example of Fig. 4 illustrates the waveform of the digital sums for a frequency of $\text{clock-rate}/80 = 8 \times 10$ bit words in the case of a triangular signal (equidistant modification of the sum) and an approximately sinusoidal signal.

Fig. 5 shows an example for clock-rate/120 which has distinctly higher amplitude values.

Fig. 6 shows the constant amplitude ratios of different frequencies for different upper harmonic content of the individual signals.

The signal waveform of the sum variation signals is illustrated in Fig. 7. The example depicts an 8/10 modulation having a clock sequence of 50 MHz, a run length limitation of 6 and three ATF frequencies.

Fig. 8 shows one possibility for realising the block "ATF selection". The various tracks of a full frame can be marked with the aid of the track length counter 8 (incrementation once per track by means of A, resetting of the counter during the first track of a full frame by means of TR1Flag). A decoding logic 9 allocates the appertaining ATF frequency to each track. For each ATF frequency, the ATF production generates a sequence of addresses which, in their turn, select the appertaining ATF code words from a PROM.

Fig. 9 shows in exemplary fashion, the sequence of code words which are selected in order to generate the ATF frequency $f_1 = \text{ck}/80$. The ATF production can be realised by a PROM and the corresponding state stores or alternatively by programmable logic devices (PLD's). Thereby, in dependence on ATFSEL (1, 2), a certain sequence of states is run-through whereby, for each state, a specific address is emitted which once more selects the corresponding ATF code word, see also Figures 7, 4, 5.

The production of a sinusoidal optimised ATF signal can be effected additionally at the bit level.



Such an optimisation is dealt with in Fig. 10. A digital sum value, which approximates as nearly as possible to the sine value using unit step functions of the magnitudes ± 1 , is formed e.g. by extraction from a table, for each sine value at respective intervals of 3° . The illustration is restricted to the range $0 - 90^\circ$ and represents the approximation for two pilot tones (clock-rate/120 and clock-rate/160). The maximum amplitude is limited to ± 0.6 but, it may be increased considerably in accordance with the permitted run length. Although the approximation is a coarse one, very good harmonic distortion factors for the generated sinusoidal signal are nevertheless established. The illustration was initially foreseen for a 10 bit raster and thereby provides one simple method for the dimensioning of the values in the table. In practice, it has proved advantageous to carry out a comparison operation in the bit domain.

Since this method can be run-through in a control loop, it is to be rated as of utmost importance for the implementation at the chip level. A circuit of such a control loop is given in Fig. 11. In Fig. 11,

PROM-ATF frequencies, means: Selection of the counter value for the counter 10 which is necessary for the current ATF frequency with the aid of the signal "frequency selection".

PROM-sine table, means: This contains the 4 bit sine values in complementary binary form.

The module 9 contains a PROM look-up table, means: Therein occurs the conversion of the counter position of the counter 12 characterising the current digital sum (RDS) into an offset-free value in complementary binary form.

The production of ATF signals is not limited to an 8/10 modulation but may also be applied to any sort of block code. Furthermore, the approximation to a sinusoid may also be advantageously built up with code words of odd number sums whereby the edges of the blocks then become blurred and the sinusoid is produced by a sequence of e.g. 120 bits and an equal sized number of code words exist which are longer or shorter than the average of all the code words. The arrangement of the bit codes (e.g. 10 bit wide output words) would then have to be departed from for this, which could make the implementation more difficult.



Claims

1. Method for the control of track following in a recorder using recording in oblique tracks of a magnetic tape without inactive areas between the tracks, wherein data gaps occur in the useful data sequence due to the change of tracks, characterised in that, the time period containing the data gaps is filled with a predetermined sequence of cyclical modifications of the digital sum, wherein a number of cycles forms a symmetrical train of oscillations and the modification of the sum is controlled in synchronism with the clock rate with which the items of useful data are also clocked.
2. Method in accordance with Claim 1, characterised in that, the step size for the formation of the digital sum is different from data gap to data gap.
3. Method in accordance with Claim 1, characterised in that, the data gaps are formed by run-in, run-out and/or edit gaps.
4. Method in accordance with Claim 1, characterised in that, the train of oscillations has a different duration from data gap to data gap.
5. Method in accordance with Claim 1, characterised in that, the modulation of the useful data of the signal channel is switched off during each of the data gaps.
6. Method in accordance with Claim 1, characterised in that, the modulation of the useful data of the signal channel during each of the data gaps is formed by a selection from a plurality of particular data words.
7. Method in accordance with Claim 1, characterised in that, the variation of the digital sum filled up during the data gaps is interrupted during certain time periods such as for block synchronisation signals or items of counting information.
8. Method in accordance with Claim 7, characterised in that, the phase of the train of oscillations is maintained unchanged during the period of interruption.
9. Method in accordance with Claim 1, characterised in that, the change of the digital sum adheres to defined limits of the run length whereby the run length of the sum word is always at least one order of magnitude smaller than that of the block synchronisation signal.
10. Method in accordance with Claim 1, characterised in that, the code words for the control of track following are selected such that the limit of the run length is adhered to even for arbitrary sequences of valid words.

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11. Method in accordance with Claim 1, characterised in that, the data words for the formation of the digital sum each comprise at least two flanks.

12. Method in accordance with Claim 1, characterised in that, the step size i.e. the difference in the number of H bits and L bits within a defined time period is so modified that a sinusoidal waveform of the train of oscillations is obtained.

13. Method in accordance with Claim 1, characterised in that, the step size is so modified that all of the trains of oscillations of different duration which are produced have the same amplitude.

14. Method in accordance with Claim 1, characterised in that, the lengths of the code words within a train of oscillations are different.

15. Method in accordance with Claim 14, characterised in that, the deviation in the length of the code words within a train of oscillations is equally great in the negative and in the positive direction.

16. Method in accordance with Claim 1, characterised in that, the digital sum is formed by a bit by bit comparison with sine/cosine values.

17. Method in accordance with Claim 16, characterised in that, when the digital sum is smaller than the respective instantaneous sine/cosine value, the current digital sum is then decreased by 1.

18. Method in accordance with Claim 16, characterised in that, when the digital sum is greater than the respective instantaneous sine/cosine value, the current digital sum is then increased by 1.

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