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Application No.: 84 302 815 .0  
Publication No.: 123 563  
Title of invention: Converting digital signals

Classification: G11B 5/09

**D E C I S I O N**  
of 25 February 1992

Applicant: SONY Corporation

Headword:

EPC Article 56

Keyword: "inventive step - no"

**Headnote**



Case Number : T 330/91 - 3.5.2

**D E C I S I O N**  
**of the Technical Board of Appeal 3.5.2**  
**of 25 February 1992**

**Appellant :** SONY Corporation  
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**Decision under appeal :** Decision of Examining Division 2.210.067 of the  
European Patent Office dated 13 November 1990  
refusing European patent application  
No. 84 302 815.0 pursuant to Article 97(1) EPC.

**Composition of the Board :**

**Chairman :** E. Persson  
**Members :** W.J.L. Wheeler  
J.A. van Voorthuizen

## Summary of Facts and Submissions

I. The present appeal contests the decision of the Examining Division refusing Appellant's European patent application No. 84 302 815.0. The reason for the refusal was that the claimed subject-matter did not involve an inventive step having regard to the normal skill of a person skilled in the art and the following prior art document:

D1: FR-A-2 468 968.

II. The Appellant filed amended Claims 1 and 10 with the Statement of Grounds of Appeal, to be considered as the main request. Claim 1 is now worded as follows:

"A method of providing a digital signal having at least two signal levels, a dc component substantially equal to zero and a predetermined maximum time between level transitions, the method comprising:

dividing a base digital signal into a series of base words each with n bits of data;

converting said base digital signal into a converted digital signal by matching a converted word with each said base word, each said converted word having m bits of data;

said converted words including a plurality of primary combinations of m bits having a dc component substantially equal to zero when NRZI-coded and a plurality of secondary combinations of m bits having a dc component with an absolute value of two when NRZI-coded;

supplying said secondary combinations so that a portion of said converted digital signal including a pair of said

second combinations has a dc component substantially equal to zero when NRZI-coded; and

generating said converted digital signal as an NRZI-coded digital signal;

characterised by:

said base words having eight bits of data;

said converted word having ten bits of data;

said predetermined maximum time between level transitions being  $3.2T$ , where  $T$  is the duration of the signal representing one bit;

the minimum time between level transitions being  $0.8T$ ;

said converted digital signal having a maximum number of consecutive digital zeros equal to three;

said primary combinations beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeros anywhere therein; and

said secondary combinations having convention dc components, defined as the dc component when the preceding combinations ends at a lower signal level when NRZI-coded, of  $+2$  and  $-2$ , beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeros anywhere therein."

Claim 10 is now worded as follows:

"Converting apparatus for providing a digital signal having at least two signal levels, a dc component substantially equal to zero and a predetermined maximum time between level changes, the apparatus comprising:

dividing means (2) for dividing a base digital signal into a series of base words each with n bits of data;

programmed memory means (3) for converting each said base word into a matching converted word, each with m bits of data;

said memory means (3) being such that said converted words include a plurality of primary combinations of m bits having a dc component substantially equal to zero when NRZI-coded and a plurality of secondary combinations having a dc component with an absolute value of two when NRZI-coded, and such as to provide said secondary combinations with dc components when NRZI-coded so that a portion of said converted signal including a pair of said second combinations has a dc component substantially equal to zero when NRZI-coded;

combining means (4) for accepting said converted words from said memory means (3) and supplying said converted words in a series to form said converted signal; and

modulating means (6) for supplying said converted signal in NRZI-code;

characterised by:

said base words having eight bits of data;

said converted word having ten bits of data;

said predetermined maximum time between level changes being  $3.2T$ , where  $T$  is the duration of the signal representing one bit;

the minimum time between level changes being  $0.8T$ ;

said converted digital signal having a maximum number of consecutive digital zeroes equal to three;

said memory means (3) being such that said primary combinations begin with a maximum of two digital zeroes, end with a maximum of one digital zero, and have a maximum of three consecutive digital zeros anywhere therein; and

said secondary combinations having convention dc components, defined as the dc component when the preceding combination ends at a lower signal level when NRZI-coded, of +2 and -2, beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeros anywhere therein."

Claims 1 and 10 of the main request differ from those refused by the Examining Division only in that the following words have been inserted:

"said predetermined maximum time between level transitions being  $3.2T$ , where  $T$  is the duration of the signal representing one bit;

the minimum time between level transitions being  $0.8T$ ;"

Claims 2 to 9 are dependent on Claim 1 and Claims 11 to 18 are dependent on Claim 10.

III. The Appellant also filed the following versions of Claims 1 and 10, to be considered as an auxiliary request:

"1. A method of magnetic recording comprising providing a digital signal for recording having at least two signal levels, a dc component substantially equal to zero and a predetermined maximum time between level transitions, the method comprising:

dividing a base digital signal into a series of base words each with n bits of data;

converting said base digital signal into a converted digital signal by matching a converted word with each said base word, each said converted word having m bits of data;

said converted words including a plurality of primary combinations of m bits having a dc component substantially equal to zero when NRZI-coded and a plurality of secondary combinations of m bits having a dc component with an absolute value of two when NRZI-coded;

supplying said secondary combinations so that a portion of said converted digital signal including a pair of said second combinations has a dc component substantially equal to zero when NRZI-coded; and

generating said converted digital signal as an NRZI-coded digital signal and magnetically recording said NRZI-coded digital signal;

characterised by:

said base words having eight bits of data;

said converted word having ten bits of data;

said predetermined maximum time between level transitions being  $3.2T$ , where  $T$  is the duration of the signal representing one bit;

the minimum time between level transitions being  $0.8T$ ;

said converted digital signal having a maximum number of consecutive digital zeros equal to three;

said primary combinations beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeros anywhere therein; and

said secondary combinations having convention dc components, defined as the dc component when the preceding combinations ends at a lower signal level when NRZI-coded, of +2 and -2, beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeros anywhere therein."

"10. In a magnetic recording apparatus, a converting apparatus for providing a digital signal having at least two signal levels, a dc component substantially equal to zero and a predetermined maximum time between level changes, the converting apparatus comprising:

dividing means (2) for dividing a base digital signal into a series of base words each with  $n$  bits of data;

programmed memory means (3) for converting each said base word into a matching converted word, each with  $m$  bits of data;

said memory means (3) being such that said converted words include a plurality of primary combinations of  $m$  bits having a dc component substantially equal to zero when NRZI-coded and a plurality of secondary combinations having a dc component with an absolute value of two when NRZI-coded, and such as to provide said secondary combinations with dc components when NRZI-coded so that a portion of said converted signal including a pair of said second combinations has a dc component substantially equal to zero when NRZI-coded;

combining means (4) for accepting said converted words from said memory means (3) and supplying said converted words in a series to form said converted signal; and

modulating means (6) for supplying said converted signal in NRZI-code for magnetic recording;

characterised by:

said base words having eight bits of data;

said converted word having ten bits of data;

said predetermined maximum time between level changes being  $3.2T$ , where  $T$  is the duration of the signal representing one bit;

the minimum time between level changes being  $0.8T$ ;

said converted digital signal having a maximum number of consecutive digital zeroes equal to three;

said memory means (3) being such that said primary combinations begin with a maximum of two digital zeroes,

end with a maximum of one digital zero, and have a maximum of three consecutive digital zeros anywhere therein; and

said secondary combinations having convention dc components, defined as the dc component when the preceding combination ends at a lower signal level when NRZI-coded, of +2 and -2, beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeros anywhere therein."

- IV. The Appellant argued essentially that the claims had to be considered as defining a combination of features, including those of the preamble. It was the combination which had to be judged, not the individual features considered in isolation. The choice of the predetermined maximum time between level transitions ( $T_{max}$ ) was not arbitrary. Moreover, it did not follow from there being no more than three consecutive zeroes that each converted word had to begin with a maximum of two zeroes and end with a maximum of one zero; that was a further selection step. The claimed combination was not the result of normal design procedure, as was shown by the following facts: when the DAT system of recording was demonstrated in 1981 (see IEEE Transactions on Consumer Electronics, Vol. CE-32, No. 3, August 1986, page 408), an improved modulation code was urgently needed to make the DAT system viable. A large number of companies were working on this problem, but none of them solved it before, more than a year after the demonstration, the basic Japanese application corresponding to the present application was filed (26 April 1983). The corresponding US patent issued in July 1986.
- V. The Appellant requested that the decision under appeal be set aside and a patent granted on the basis of the claims

according to the main request (see point II above), or on the basis of the claims according to the auxiliary request (see point III above). There was no request for oral proceedings.

### Reasons for the Decision

1. The appeal is admissible.
2. Document D1 (FR-A-2 468 968) discloses a method and apparatus for magnetically recording a digital signal. Before being recorded, the signal is converted into a NRZI-coded digital signal having at least two signal levels, a dc component substantially equal to zero and a predetermined maximum time between level transitions. The converting method disclosed in D1 comprises:

dividing a base digital signal into a series of base words each with  $n$  bits of data ( $n = 3$  in the example shown in Fig. 1);

converting said base digital signal into a converted digital signal by matching a converted word with each said base word, each said converted word having  $m$  bits of data ( $m = 4$  in the example shown in Fig. 1);

said converted words including a plurality of primary combinations having a dc component substantially equal to zero when NRZI-coded (1111, 1101, 0010, 0111, 0101, 1010) and a plurality of secondary combinations having a dc component with an absolute value of two when NRZI-coded (1110, 0001, 1001, 0110);

supplying said secondary combinations so that a portion of said converted digital signal including a pair of said

second combinations has a dc component substantially equal to zero when NRZI-coded; and

generating said converted digital signal as an NRZI-coded digital signal and magnetically recording said NRZI-coded digital signal.

Thus D1 discloses a method having all the features specified in the preamble of Claim 1 of the main and auxiliary request. This is not disputed by the Appellant. Indeed, the claims have been drafted having regard to D1 as the closest prior art.

3. As far as the characterising features of Claim 1 of the main and auxiliary request are concerned, the Board notes that, although D1 does not mention the specific example of said base words having eight bits of data and said converted words having ten bits of data, it does make it clear that the method disclosed there is not limited to the example of three to four bit conversion shown in Figure 1 (see the claims in D1 and the description from page 30, line 33, to page 31, line 5). Furthermore, the last sentence of this passage points out that the number of words corresponding to one or two (that is the number of primary and secondary combinations in the terminology of the present application) may be chosen freely within the limits of technical feasibility. In the example shown in Fig. 1, none of the primary combinations begins with more than two digital zeroes, ends with more than one digital zero, or has more than three consecutive digital zeroes anywhere therein; the secondary combinations have convention dc components of +2 and -2; and, although one of the secondary combinations (0001) begins with more than two digital zeroes, none of them ends with more than one digital zero, or has more than three consecutive digital zeroes anywhere therein. However, D1 does not explicitly

mention that these limitations on the number of consecutive zeroes should be retained if the number of bits in the words is increased.

4. The method according to Claim 1 of the main or auxiliary request therefore differs from the prior art known from D1 in that:

(a) the base words have eight bits of data and the converted words have ten bits of data;

(b) said predetermined maximum time between level transitions is  $3.2T$ , where  $T$  is the duration of the signal representing one bit, the minimum time between level transitions being  $0.8T$ ;

(c) said converted digital signal has a maximum number of consecutive digital zeroes equal to three;

(d) said ten bits long primary combinations begin with a maximum of two digital zeroes, end with a maximum of one digital zero, and have a maximum of three consecutive digital zeroes anywhere therein; and

(e) said ten bits long secondary combinations have convention dc components of +2 and -2, begin with a maximum of two digital zeroes, end with a maximum of one digital zero, and have a maximum of three consecutive digital zeroes anywhere therein.

5. The Appellant acknowledges in the Statement of Grounds of Appeal, point 4(b), that at the time of the demonstration of the DAT system in 1981 it was well known that it was difficult to record dc and low-frequency signals magnetically and that to be successful the DAT system would necessitate high-density recording. Furthermore, as appears from page 1 of the patent application itself, it

was known that when NRZI-coding was used, a series of digital zeroes (represented by no level transitions in the signal) would be reproduced with reduced fidelity. It was, therefore, obvious to try to find a NRZI-coding system in which the dc component was substantially equal to zero, the maximum number of consecutive zeroes that could occur was as low as possible, and the number of extra "one" bits inserted to avoid long sequences of consecutive "zero" bits was as low as possible.

6. As discussed in paragraphs 2 and 3 above, D1 discloses a method of magnetically recording a digital signal having all the features specified in the preamble of Claim 1 of the main and auxiliary request. In the three to four bit conversion shown in Fig. 1 of D1, four consecutive zeroes occur when the secondary combination 0001 follows 1110, 0010 or 1010, otherwise there are never more than three consecutive zeroes. The teaching of D1 is not limited to three to four bit conversion.
  
7. In the opinion of the Board, given the urgent need for a new NRZI-coding system explained in paragraph 5 above, it was obvious to investigate the possibilities offered by applying the teaching of D1 to conversions other than three to four conversions to see if a conversion could be found in which the maximum number of consecutive zeroes could be limited to three. In view of the high-density recording requirement, it was obvious to investigate those conversions which introduce the fewest extra bits, namely  $n$  to  $n+1$  conversions and  $n$  to  $n+2$  conversions for which the ratio  $n:n+2$  was less than the 3:4 ratio of the example shown in Fig. 1 of D1. Furthermore, it must be considered to lie within the normal ability of a person skilled in the art to be able to analyse the converted word bit patterns of  $n$  to  $n+1$  and  $n$  to  $n+2$  conversions for  $n = 3, 4, 5$  and so on until a conversion is found which offers

enough primary and secondary combinations having no more than three consecutive zeroes anywhere therein and such that the number of consecutive zeroes which can come together at the end of one combination and the beginning of the next is also never more than three.

8. Following this obvious line of investigation, the person skilled in the art would inevitably come to the eight to ten conversion and discover that out of the 1024 possible 10-bit combinations there are:

137 primary combinations which have a maximum of three consecutive digital zeroes anywhere therein, begin with no more than three digital zeroes, end with a digital one, and have no dc component when NRZI-coded;

193 primary combinations which have a maximum of three consecutive digital zeroes anywhere therein, begin with no more than two digital zeroes, end with a maximum of one digital zero, and have no dc component when NRZI-coded;

a sufficient number of combinations which have a maximum of three consecutive digital zeroes anywhere therein, begin with no more than two digital zeroes, end with a maximum of one digital zero, and have a dc component with an absolute value of two when NRZI-coded, from which it is possible to select the 63 secondary combinations needed to make up the total to 256 to provide a unique converted word for each of the different 8-bit base words.

9. The Board therefore concludes that it was obvious to select:

base words having eight bits of data and converted words having ten bits of data;

primary combinations beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeroes anywhere therein; and

secondary combinations having convention dc components, defined as the dc component when the preceding combination ends at a lower signal level when NRZI-coded, of +2 and -2, beginning with a maximum of two digital zeroes, ending with a maximum of one digital zero, and having a maximum of three consecutive digital zeroes anywhere therein.

10. As a consequence of the above obvious selection there will be a maximum of three consecutive digital zeroes in the converted digital signal. If the conversion is done in real time, which is necessary for the DAT system of magnetic recording, the minimum time between level transitions in the NRZI-coded signal will be  $0.8T$ , and the predetermined maximum time between level transitions will be  $3.2T$  (i.e.  $4 \times 0.8T$ ), where  $T$  is the duration of the signal representing one bit of the base signal.
11. Thus, in the opinion of the Board, it was obvious to a person skilled in the art, looking for a solution to the problem stated in paragraph 5 above and aware of the teaching of D1, to devise the method according to Claim 1 of the main or auxiliary request and apparatus according to Claim 10 of the main or auxiliary request. The Board therefore agrees with the Examining Division that the claimed subject-matter does not involve an inventive step over the cited prior art.
12. Regarding the Appellant's circumstantial arguments, the fact that no novelty-destroying citation has been cited cannot outweigh the reasons given in paragraphs 2 to 11 above. The fact that US patent 4 598 267 (corresponding to

the present application) was granted is irrelevant: D1 was not taken into account.

Order

For these reasons, it is decided that:

The appeal is dismissed.

The Registrar



M. Kzehl

The Chairman



E. Persson

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*RR*