AN ASSOCIATE METHOD OF CODE-MASK READOUT

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Current masks are used in displacement encoders and in oscilloscope encoding devices. The size and performance of code masks are determined by the acceptable error Δ in the code tracks (incorporating the error from the reading elements) and the number of code tracks and reading elements for the given number of quantization levels. The smaller the number of reading elements and code tracks, the fewer of them need to be made with minimal error, and the smaller the weight and size of the device.

An associative readout method allows one to increase the tolerance on the code tracks relative to that for simultaneous encoding, while reducing the number of reading heads and code tracks relative to previous methods. Associative readout can be used in devices giving any positional pattern. In a generalized positional system of notation, a number X is written as

\[ X = x_m \prod_{i=1}^{m-1} r_i + x_{m-1} \prod_{i=1}^{m-2} r_i + x_{m-2} \prod_{i=1}^{m-3} r_i + \ldots + x_2 r_1 + x_1, \]

where \( r_i \) is a positive integer termed the base for digit \( i = \frac{1}{r_i}; r_i \geq 2; \) \( x_i \) is the figure in a digit, and \( 0 \leq x_i \leq r_i - 1 \).

If \( r_i = r \), the generalized positional system degenerates into an ordinary positional system of base \( r \).

Readout unambiguity is provided in an associative system within a digit by one-variable encoding, i.e., the structure of the code tracks is defined by the one-dimensional code. The sequence of \( r \) different code combinations of \( n \) symbols (0 and 1) is called an \( n \)-element one-variable code of length \( r \) when any pair of adjacent code combinations differ in one character (the first and last combinations are considered as adjacent).

Unambiguity in readout between two adjacent digits is provided by using a binary signal \( H_i \) as one of the elements in the one-variable code, which is provided by the structure of the code tracks for digit \( i \); this quantity corresponds to half the range of measurement for the preceding digit. The measurement range for digit \( i - 1 \) equals the quantization step in digit \( i \):

\[ q_i = q_{i-1} r_{i-1} = q_1 \prod_{k=1}^{i-1} r_k, \]

where \( q_i \) is the quantization step for digit \( i \).

To any value of a measured parameter there corresponds a signal \( H_i \) either zero or one; if the parameter varies monotonically, \( H_i \) takes values in the sequence \( 0, 1, 0, 1, \ldots \). The parts of the code mask corresponding to the values \( H_i = 0, 1 \) will be considered as code parts of some code track \( H_j \). From part \( H_i = 1 \) we draw up the first half of the measurement range for digit \( i - 1 \).

The operating principle is considered via the example of Fig. 1, which shows the code tracks for digit \( i (i \neq 1) \); the base for digit \( i \) is \( r_i = 3 \), and the digit figures \( x_i = \{0, 1, 2\} \) represent parts of the code mask corresponding to the \( r_i \) ranges of the preceding digit, i.e., the six \((2r_i)\) code parts of track \( H_i \) represented by the numbers \( j = 1, 2, 3, 4, 5, 6, 1, 2, 3, \ldots \).

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The digit number \( x_i = 0 \) corresponds to two code parts \( H_{ij} \), where \( j = 1 \) and 2, \( x_i = 1 \) are parts where \( j = 3 \) and 4, while \( x_i = 2 \) are parts where \( j = 5 \) and 6. The parts \( H_{ij} \) are numbered via the digit code tracks \( d_1, d_2, d_3 \) whose structure is specified by a code of length \( 2\eta = 6 \); the ends of the code parts in the digit code tracks lie approximately at the centers of the code parts \( H_i \). It can be shown that the set of code tracks \( H_1, d_1, d_2, d_3 \) represents a code of length \( 4\eta = 12 \); each code combination in this one-variable code will be considered as unit constituent in the Boolean variables \( H_i, d_1, d_2, d_3 \). Each digit figure corresponds to a Boolean sum of four unit constituents; the first pair contains a variable \( H_i \), while the second pair contains \( H_j \), and in each pair the unit constituents differ only in one character. Any digit figure \( x_i \) may be represented as the Boolean sum of two Boolean products, each of which does not contain a character from one of the digit code tracks. The figures are interpreted from the set of signals (direct or inverted) from all the reading heads for a digit except one. In the present example, the digit figures \( x_i = 0, 1, 2 \) may be represented as Boolean sums as follows:

\[
\begin{align*}
H_i d_2 \overline{d_3} + \overline{H_i} \overline{d_1} \overline{d_2} \\
H_i \overline{d_2} \overline{d_3} + \overline{H_i} d_1 \overline{d_2} \\
H_i d_1 \overline{d_3} + \overline{H_i} d_1 \overline{d_2}
\end{align*}
\]

There is no effect on the encoding of the digit figures from shift in the ends of the code parts for the digit code tracks if these do not lie outside the limits of the \( H_i \) code parts. The permissible error \( \Delta_1 \) in the digit code tracks is determined by the length of the \( H_i \):

\[
\Delta_1 < q_i \frac{\prod_{k=1}^{i-1} r_k - 1}{2}.
\]

The error \( \Delta_1 \) for the first digit tracks is as for all code tracks in any device for one-variable encoding with equal numbers of quantization levels.

One matches digit 1 to the next one via the signal \( H_{i+1} \), which equals the following Boolean sum:

\[
H_{i+1} = \bigvee_{l=1}^{r_i} H_{il} ; \text{ in the above example,}
\]

\[
H_{i+1} = H_i \overline{d_2} \overline{d_3} + \overline{H_i} \overline{d_1} \overline{d_3} + H_i d_3 \overline{d_3} = (H_i + d_1) \overline{d_3}.
\]

If \( r_i \) is an even number, then \( H_{i+1} \) may be realized simply by means of a OR circuit, whose input receives the signals from the digit figures \( x_i = 0, 1, 2, \ldots, (r_i/2)-1 \).