

Conference Paper

Line Codes for Communication Systems

António D. Reis¹, José F. Rocha², Atílio S. Gameiro², and Jose P. Carvalho¹

¹Universidade da Beira Interior

²Universidade de Aveiro

Abstract

The coder is a generic device where exist a big types diversity. In base digital systems, the coder is a device that codifies the active input position in a number, normally, binary natural. If we have N inputs they are codified with n bits, $N=2^n$. This is a parallel coder. The line coder is a serial coder, that transforms a bits sequence, normally NRZ (No Return to Zero) in an electric sequence appropriated to the transmission line. The objective of this work is to develop some of the line codes more utilized in communication systems.

Keywords: Line codes, Digital systems, Transmission systems

Corresponding Author:

António D. Reis
adreis@ubi.pt

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1. Introduction

The line codification is a data formatting technique, that operates over the data source, initially in unipolar NRZ. It transforms a binary sequence in their electric representation [1–10].

In base digital systems, the coder codifies the position of an active input and converts them in a number, normally, binary natural of n bits, where $N = 2^n$.

Fig. 1 shows the conventional coder, which is a normal coder of parallel output.

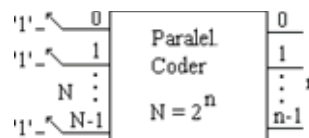


Figure 1: Conventional coder of parallel output

The line coder is a special coder of serial output, that is specially prepared to format a data sequence and to send it to a transmission line (Fig. 2).

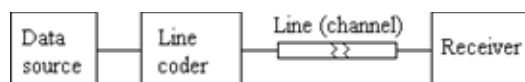


Figure 2: Line coder of serial output

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The source generates the data, the line coder transforms it adequately, the line transmits it and the receiver receives it. Following, we present the principal characteristics of the line code. After, we present the line codes and their most highlight characteristics. Then, we present the results. Finally, we present the conclusions.

2. Typical Characteristics of the Line Codes

The line code intends to introduce the following desirable characteristics:

- Null continuous component or constant without fluctuation. (to permit the usage of couplers AC)
- Many transitions, with timing information. (for clock recovering)
- Spectrum narrow of band and of low frequency. (to minimize the interference)
- Transparency for the diverse messages. (for adequation to all the messages)
- Univocal decodification. (without ambiguities)
- Elevate immunity to additive perturbations. (signal binary is the preferable by the detection facility)
- Capacity of errors correction. (to minimize errors)
- Facility of equalization the channel characteristics. (for adaptation to the channel)
- Linear relation of the signals codified and decodified. (for filtering transversal adaptive)
- Information for block alignment, if necessary. (for the line codes of blocks)

Posteriorly, we will see some coders that implement the codes.

3. Line Codes More Usual

We present here, some of the line codes more usual, to try to satisfy the desired characteristics. The data sources (audio, video, etc.) provide the data in the simple form, normally, unipolar NRZ. This form is a line code, but of weak characteristics.

In most situations, the systems interact in the presence of all, so this code serves fully.

However, when the systems are distant, it is necessary to make transformations, to transmit with good quality.

3.1. Unipolar code NRZ (reference standard)

This representation is the simpler and suggestive, the Boole values, V ('1') correspond to a voltage around 5V and F ('0') to a voltage around 0 V. We go to normalize the voltage 5V to 1V. We consider the sequence 0101000010.

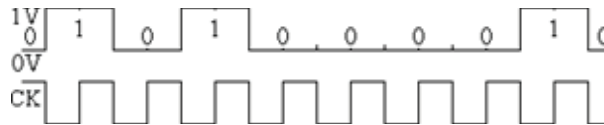


Figure 3: Unipolar code NRZ

This form is the simplest, but few synchronism. This code maintains the representation without transformations.

NRZ <-> Switches of level ('0'<->'1') and maintains itself without to return to zero. The RZ (Return to Zero) switches of level and returns to zero at period middle.

It is used for digital recording in magnetic supports.

3.2. Polar code NRZ

The wave limits are +1 and -1. The codified wave takes the value 1 when the bit to codify is 1 and takes the value -1 when the bit to codify is 0 (Fig. 4).

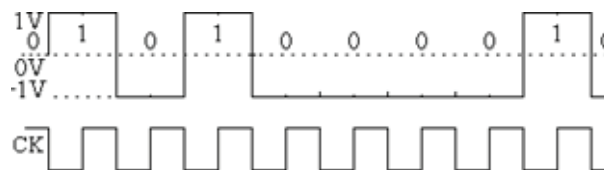


Figure 4: Polar code NRZ

It has the same vantages and disadvantages of the unipolar NRZ. It is used for digital recording in magnetic supports.

3.3. Bipolar code NRZ or AMI (Alternate Mark Inversion)

The wave limits are +1, 0, -1. The wave takes the value 0V when the bit to codify is 0 and takes the value 1V and -1 alternately when the bit to codify is 1 (Fig.5).

It is used in interfaces RDIS. This code and the previous have the problem of the long sequences of '0's, they have deficit of synchronism.

To solve this problem it were created the codes CMI (Code Mark Inversion) and the HDB3 (High Density Bipolar with 3 '0' maximum).

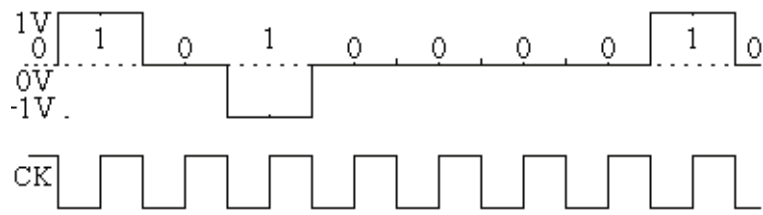


Figure 5: Code AMI (Alternate Mark Inversion)

3.4. Code CMI (Code Mark Inversion)

The wave limits are +1 and -1. The bit '1' is represented precisely as in AMI: one impulse of T seconds of alternate polarity. However, the bit '0' is represented by the cycle d=0.5 (-1, +1). The electric wave will be (Fig. 6).

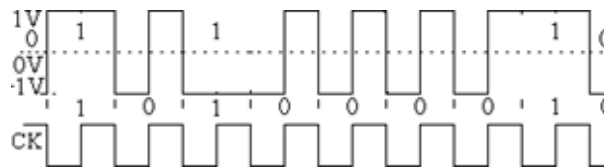


Figure 6: Code CMI

It has the advantage of greater synchronism information and the disadvantage of increasing the wideband.

3.5. Code HDB3 (High Density Bipolar with 3 '0' max)

The wave limits are +1, 0 and -1. In the absence of more than three zeros consecutive this code is equal to the AMI. The '1' is represented by the pulse T of alternate polarity.

Case arise four or more consecutive '0's are introduced extra pulses of duration T (pulses V and B) (Fig. 7)

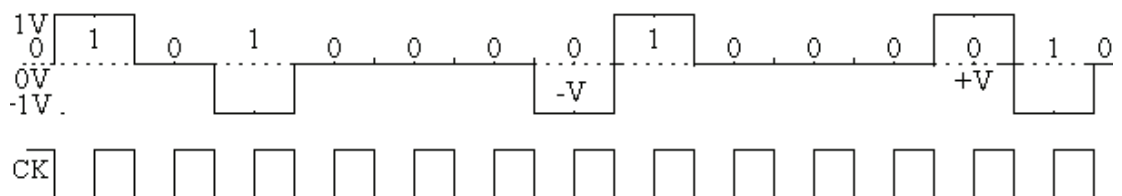


Figure 7: Code HDB3

The pulse V (Violation) violates the rule AMI of the alternation, it has the same polarity as the codification of the previous '1'.

The pulse B (balancing) is introduced in opposition if 2 pulses V consecutive have the same polarity. This coder store 3 bits, what is a disadvantage.

It has the advantage of a DC component more stable.

3.6. Code Manchester unipolar or 1B2B

The wave limits are +1 and 0. The code manchester is a bit code and also a block code, since a bit / block 1B is converted in a block 2B of 2 bits.

To codify the block 1B of 1 bit (2 words 0, 1), we have in the block 2B of 2 bits four words (00, 01, 10, 11). We use for the dictionary 2 words (01, 10) and the other two (00, 11) are prohibited. The prohibited ones are used in the receiver to make the alignment. See table of this code

TABLE 1: Codification Manchester

Dec.	A0	B1 B0
0	0	0 1
1	1	1 0

In the receiver when appear the prohibited words (ex. 8 in 64) is made the window shift of 1 bit (B_1B_0). After the alignment the errors stop.

The '0' is codified for 01 and the '1' is codified as 10. The wave takes the values +1 and 0 (Fig. 8)

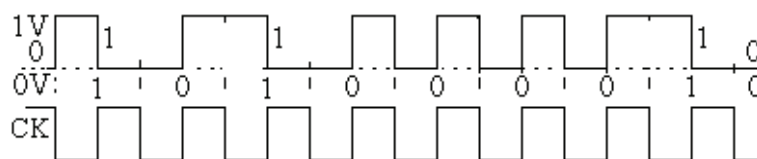


Figure 8: Code Manchester

3.7. Code Manchester differential

The code manchester differential also uses the transition at middle of the interval, only to provide more synchronization. The condition of a '0' is represented by the presence of a transition at the beginning of the bit interval, and that of a '1' is represented by the absence of a transition at the beginning of this interval (Fig. 9).

The limits are +1 and 0. This code is more difficult to implement than the previous one.

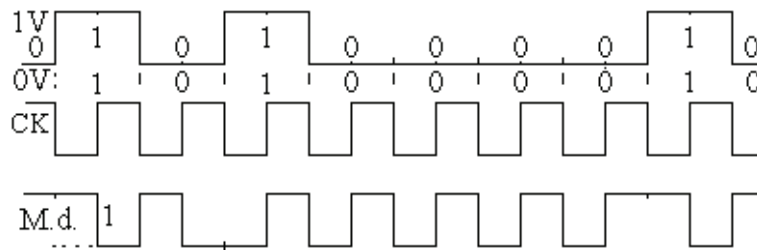


Figure 9: Code Manchester differential

3.8. Code of block 2B1Q (2 bits 1 quaternary)

The wave limits are +3, +1, -1, -3. It is a line code of block. It converts a block of two bits (binary digit) in a unique digit quaternary (four levels). In the input, we have $4^2=16$ combinations, then all the output quaternary symbols are used. The output bit transmission rate is reduced at middle of the original debit $t_{x0} = 1/2 t_{xi}$. See table of this code.

TABLE 2: Codification 2B 1Q

Dec.	Pol. Greatness	Symbol quaternary	Voltage (volts)
2	1 0	+3	2.7
3	1 1	+1	0.9
1	0 1	-1	-0.9
0	0 0	-3	-2.7

The previous sequence will have the following quaternary electric wave (Fig. 10)

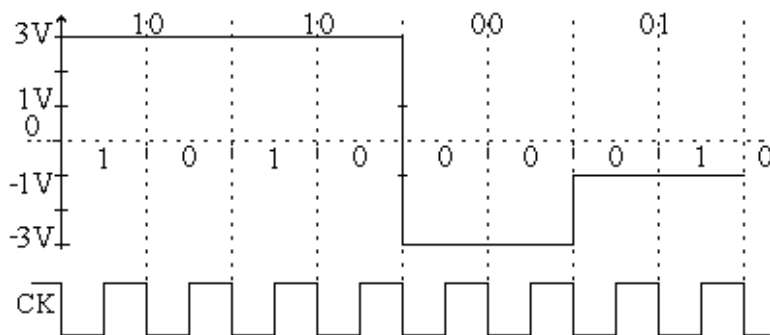


Figure 10: Code of block 2B1Q

Each 2 bits of input are converted in an output quaternary symbol.

3.9. Code of block 4B3T (4 bits 3 ternary)

This code converts a block of 4 binary digits in a block of 3 ternary digits (3 levels).

The $16=2^4$ possible input blocks have available $27=3^3$ possible output blocks. There is 6 output blocks with null disparity used (0-+, -+0, -0+, 0+-, +-0, +0-), other with null disparity prohibited (000), 20 with disparity used (-3, -2, -1, +1, +2, +3). A total of $26 = 6 + 2 \cdot 10$ outputs used. The difference between the positive levels (+) and negatives (-) is called accumulated disparity. This disparity go being stored, to control the functionment at each moment, as the codification takes place. The choose of the following ternary blocks is made according with the passed history and follows a state diagram (Fig. 11).

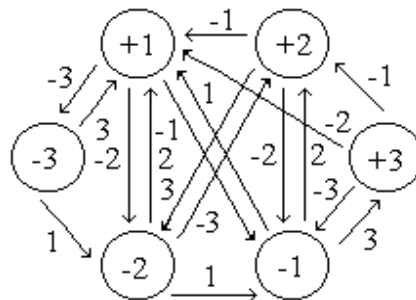


Figure 11: Diagram of states transition

The output transmission rate is lesser than the input $t_{x0} = 3/4 t_{xi} = 0.75 t_{xi}$.

This code will be presented, in separate, since it needs more space.

3.10. Codes of blocks of the type mBnB (m bits n bits)

The codes of blocks of the type mBnB convert an input block of m bits in an output block of n bits. With bits the n must be greater than m, but near. These codes are very much used in fiber optics. These use bits. So, the output bit rate is greater than the input one, $t_{x0} = n/m t_{xi}$. From the various hypotheses stand out the codes 1B2B (manchester), 3B4B, 5B6B, 7B8B. The augment of the transmission rate decreases with the increasing of m, but the complexity also increases with m. Considering these two parameters, we choose the code more appropriated to the situation. We developed these coders, in separated, in other works.

4. Project, Tests and Results

Following, we present the project, tests and results [5].

4.1. Project

Initially, it is necessary to project the coder - decoder (architecture) with the capacity to execute the desired task.

After, it is necessary to create the clock synthesizer (controller) that gives unity to the system and marks the work rhythm.

In follow, it is necessary to test theoretically the project with a sequence test, for example '1' and '0' alternated. Then the pair coder - decoder is mounted and tested in an ebonite board.

Finally, it is implemented in a printed circuit board.

4.2. Testes

The pair Cod - Decod is initially connected by a cooper cable. Following, it is integrated in the complete system.

In the transitory state of alignment occur the inherent errors, but after in the permanent state, they disappear.

4.3. Results

The encoder and decoder that we developed were especially those of block mBnB particularly the 1B2B (manchester), 3B4B, 5B6B, 7B8B.

The pair Cod - Decod was integrated in the global system were the fiber optic of transmission had a gap (air space) that simulated 50 km.

In according with the CCITT (Consultative Committee for International Telephony and Telegraphy), the measured error rate (BER - Measured) was 10^{-15} , which is lesser than the standard value required by the CCITT (BER-CCITT) of 10^{-12} . These errors 3 - 5 in a period of 24h, has nothing to do with the pair Cod - Decod, but rather with the fortuitous errors of the synchronizer, when deciphering between '1' or '0', in a signal degraded and noisy to the human eye.

5. Conclusions

We present various line codes, with highlight for the line codes of block of the type mBnB (1B2B, 3B4B, 5B6B, 7B8B). These coders transmit a number of '1's equal to the number of '0's.

The coder prepares the data to be transmitted with great quality and security.

The pair encoder - decoder consists in the code mBnB programmed in the encoder PROM, with input serial - parallel and output parallel - serial. After, the code mBnB inverted is placed in the decoder PROM, with input serial - parallel and output parallel - serial. So, the original data is recovered. The pair coder decoder needs in the emitter of a clock generator and in the decoder of a synchronizer (clock recover) that controls all the system. In the transitory state of alignment occur some errors that disappear in the permanent state.

Some fortuitous errors, with the Cod-Decod integrated in the system, are due to the deciphering of the '1's and '0's.

So, the errors rate obtained BER- measured was 10^{-15} , which is lesser than the required BER- CCITT that is 10^{-12} .

This review article is very useful for the interconnection of other specific articles.

Acknowledgments

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