Abstract: - In many telephone networks the use line coding allows us to adequate the signal to the channel. Some parameters like distance, transmission media, bit rate and bandwidth; defines the performance of a line coding technique. In this paper, the design and implementation of an educational tool is widely analyzed. The tool described here can synthesized a lot of line codes, because the main goal of this work is to emphasize the advantages of each line code.

Key-words: - Line coding, base-band transmission, Bandwidth, PSTN, Hierarchical Networks.

1 Introduction
The base-band communication process can face some problems according to an specific application. Some of these problems are: signal propagation in the transmission media, link distances, clock stabilities, equipment mobility, performance in very noisy channels and the final limited bandwidth [1] [2] [3].

The use of line coding can reduce the consequences of several of the impairments mentioned above. Besides, the use of baseband transmission can be used in PCM systems for real-time applications like voice and video. In these sort of systems the sample time may be divided for many users (Time Division Multiplex TDM), see Figure 1. This feature increases the bit rate and the clock instabilities. Public Switched Telephone Network (PSTN) is one of the most important examples of line coding [4] [5] [6] [7].

2 Line Coding
If the bit rate is slow a Non-Return to Zero (NRZ) is enough. This kind of line code can be divided in three variations NRZ-L, NRZ-M and NRZ-S (L for level, M for mark and S for space). In Figure 2 NRZ-L for unipolar systems is plotted.

In this paper, the tool design and implementation is analyzed in detail. The output signal can vary the bit rate and the voltage levels of each line code.

The paper is organized in five sections, section one is dedicated to an introduction, in section two the line coding techniques are presented, section three the architecture of the module, in section four the main results of this work are shown and, the section five are the conclusions.

Fig. 2 Unipolar NRZ-L.
transmission media. The level of dissipation is increased if the link distance is also incremented.

A typical solution to this impairment is to use a bipolar variation of NRZ-L. In Figure 2 a bipolar NRZ-L is illustrated.

Bipolar NRZ-L produces a small DC component if the probability of each polarity is approximately equal to each other; but the real applications have random information sources. Then, in general is necessary to employ a different line code variation. In Figure 4 a Manchester line code is shown.

Manchester o bi-phase codes can eliminate the DC component, because each binary symbol is divided in two parts with an identical duration and different polarities. The main disadvantage of this line code is a large bandwidth as a result of a lot of transitions. Telephone networks have adopted a line code where the polarity of a binary symbol is positive and negative alternatively. In Figure 5 the Alternate Mark Inversion (AMI) code is illustrated.

AMI is widely used because has some important advantages: very low DC component and very short bandwidth. But this technique has a problem, because a large number of consecutive 0V levels can produce a synchronization loss.

In order to preserve synchronization, there are several kinds of substitution of zeros. In Figure 6 a line code variation designed to substitute eight consecutive zeros (B8ZS). The substitution involves additional transitions, whom can be identified by destination using a non-alternate rule named violation (V).

B8ZS is employed in T1 carrier for North-American telephone hierarchy; but in a higher bit rate this technique does not work well. In European standard a four-zero substitution is required for the first telephone hierarchy (HDB3). This code is illustrated in Figure 7.
There are line codes that they do not follow a level rule. This variation is named space or mark variations. In Figure 8 NRZ-S is plotted, where a zero determines the change of the rule in NRZ line code.

Spaced and marked line codes offer a very well performance in noisy applications, because its rules allows us to identify the transitions of zeros and ones in a binary system.

Finally, in non binary systems is possible to code several bits in a single level. In Figure 9 a four-level line code is shown. The most important limitation to multi-level line code are the determination of two almost equal levels.

3 Module implementation

The module analyzed here can generate all of the line codes exposed in section two, including a lot of line codes with mixed features. It is possible to defined new line codes and storage them in the module memory.

In Figure 10 the simplified block diagram of the module is illustrated.

The microcontroller receives the line code selected by keyboard and the output changes its rules for the next clock pulse. If necessary the Digital to Analog converter can give 256 output levels (128 positive and 128 negative levels for all of the line codes). This feature allows us to use a lot of commercial devices and telephone interfaces.

The bit rate of all of line codes can be changed in 8 defined values. If a very strange bit rate is necessary it is possible to use the external clock to adjust this parameter.

4 Results

The module was proved for a lot of combinations of the line codes presented here. The module allows to compare many line codes for educational and training purposes.

From Figure 11 to Figure 14 some of the line codes generated are shown.
All of the wave forms were obtained with a clock frequency equal to 1 MHz (internal clock of the microcontroller); but this frequency can be increased to 32 MHz. This is important because maximum frequency of the input is 10% approximately of the microcontroller clock frequency.

5 Conclusions
The prototype presented can generate many line coding techniques.

The main goal of this module is to teach line coding in universities and training centers, because a lot of systems employ base band digital transmission, like telephone, telemetry and automation industrial systems.

This paper describes a cheap and easy to use prototype, designed to compare many line codes according to: the DC component, synchronization preservation, bandwidth and performance in noisy channels. The commercial options to this work are quite expensive and, they normally are designed to some line codes, few bit rates and fixed voltage levels.

Now the results of this paper are being employed to build a new prototype to enhance the features described before.

References:
[5] www.ece.utep.edu/courses/web3376/EE3376/Lab%204.html