LINE CODING

Line coding refers to the process of converting digital data into digital signals. Whenever we transmit data, it is in the form of digital signals, so with the help of line coding, we can convert a sequence to bits (or encoding) into a digital signal which is then again converted into bits by the receiver (or can be said as decoded by the receiver). For all this to happen we need line coding schemes that could also be able to avoid overlapping and distortion of signals.

Some necessary characteristics of line coding schemes:

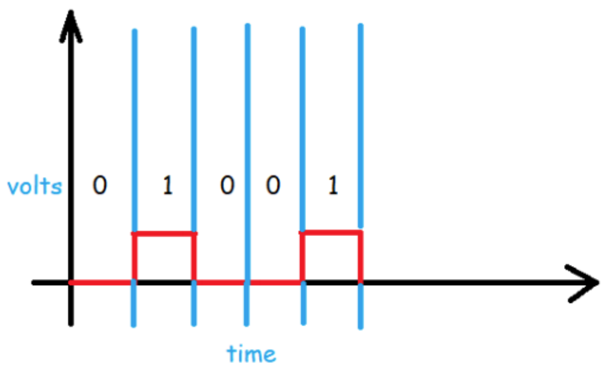
- Less complexity.
- Should have noise and interference tolerance.
- No DC component (or say low-frequency component) should be there because it can't be transferred to larger distances.
- The last baseline wandering should be there (baseline wander: low-frequency noise having nonlinear and non-stationary nature).
- Should have error detection capability.
- It should be self-synchronized.

There are three types of line coding schemes:

1. Unipolar
2. Polar
3. Bipolar

Unipolar Line Coding

In Unipolar we are simply representing a signal in a graphical form where positive voltage represents logical or binary 1 and zero voltage represents logical zero. We can say that it's the simplest line code. The drawback of this scheme is that it is not self-clocking which means that it can't be decoded without a separate clock signal or any other synchronization source. And as we discussed in the characteristics section there should be no DC component present that it significantly contains, which can be halved by returning to zero in the middle of the bit period.



NRZ (Non-Return to Zero):

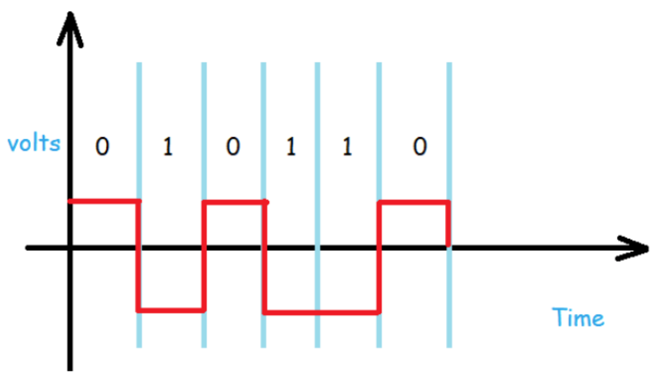
The term **Non-Return to Zero (NRZ)** means that the signal (the red line in the above diagram) will not return to zero in the middle of the bit (i.e. either 0 or 1). Unipolar schemes were generally designed as NRZ schemes. But if we compare it to the polar NRZ scheme, this scheme leads to wastage of power i.e. the normalized power (i.e. the power required to send 1-bit per resistance) is almost double as compared to polar NRZ.

Because of all these reasons unipolar encoding is not normally used in data communications today.

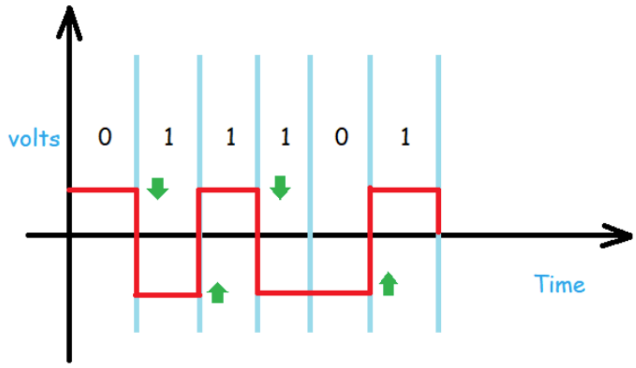
Polar Line Coding

As its name suggests **polar** which means it will have both positive and negative values for voltages or amplitude, it is quite like the NRZ scheme but, here we have NRZ-L (i.e. NRZ-Level) and NRZ-I (i.e. NRZInvert).

Let's see how these are represented:



In the above diagram, we can simply notice that the high volt is for logical 0 and the low volt is for logical 1. This is the representation of **NRZ-Level**.

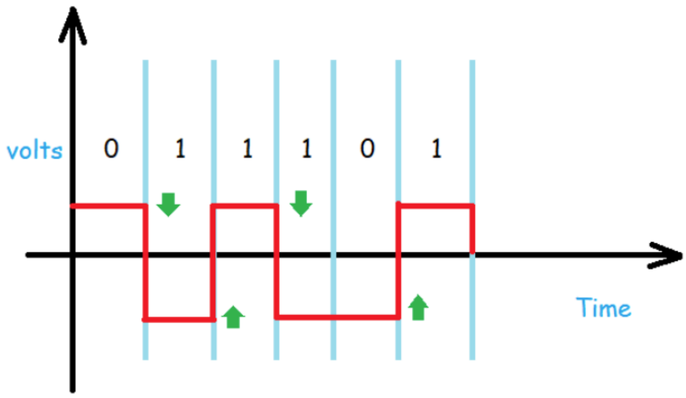


Now in this one, the idea is that whenever we encounter logical 1, the signal will be inverted, but when it encounters logical 0, it remains on the same side. This is the **NRZ-Invert**.

The Baseline wandering is a problem for both of them, but for NRZ-L it is twice as bad as compared to NRZ-I, because of the transition at the boundary for NRZ-I. similarly, the self-synchronization problem is similar in both for a long sequence of 0's, but for a long sequence of 1's, it is more severe in NRZ-L.

Return to Zero (RZ):

Return to zero proved to be a nice alternative or say a solution to NRZ drawbacks. Unlike NRZ, RZ uses three values of voltage i.e. positive, negative, and zero. And as the name suggests it returns to zero in the middle of each bit.



The idea behind the above representation is that logical 1 is represented as half-positive and half-zero volts and logical 0 is represented as half-negative and half-zero volts.

Now, this scheme also has some drawbacks which are as follows:

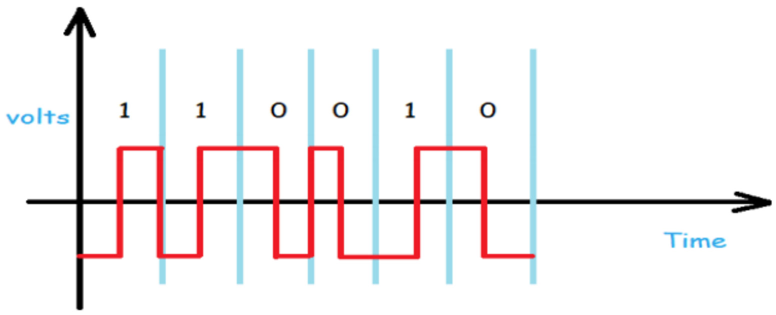
Requires a large bandwidth for transmission.

Complex encoding as it uses three levels of voltages

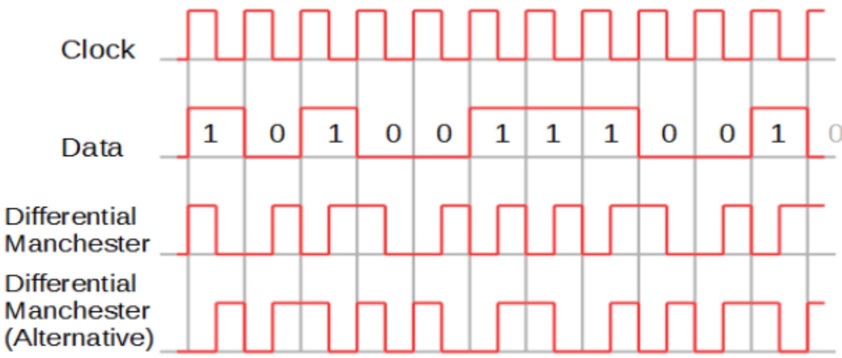
This scheme is not used nowadays and is replaced by Manchester encoding & Differential-Manchester encoding.

Manchester & Differential-Manchester Encoding:

We can say that Manchester encoding is a combination of RZ and NRZ-L. here, instead of using three values of voltages, we use only two, here logical 1 is represented in two halves, the first half consists of a negative voltage, and the second half is represented as a positive voltage, and logical 0 is also represented in two halves, the first half consists of a positive voltage and the second-half is represented as a negative voltage. The transition in the middle of the bit provides synchronization.



The Differential-Manchester encoding can be said as the combination of RZ & NRZ-I. here, we use the same logic as we used in NRZ-I i.e. inversion will take place when we encounter logical 1, and if we encounter logical 0 then no inversion.

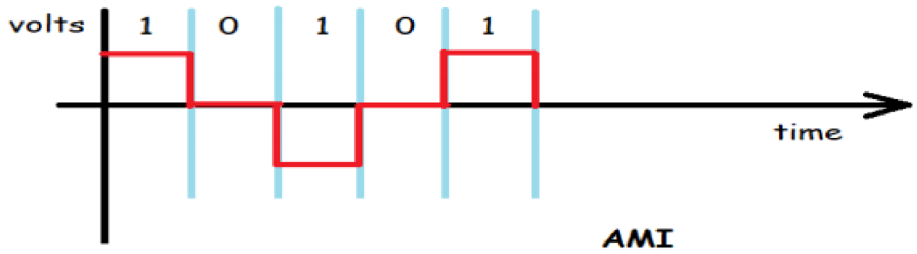


Manchester encoding had a huge impact since it was able the solution several problems related to NRZ-L on the other hand Differential Manchester overcome the problems associated with NRZ-I since there is no baseline wandering and no low-frequency component or DC component because every logical bit was having positive and negative voltage contribution.

The area where Manchester encoding and Differential Manchester encoding are limited is the bandwidth. The minimum bandwidth of Manchester encoding and Differential Manchester encoding is twice that of NRZ.

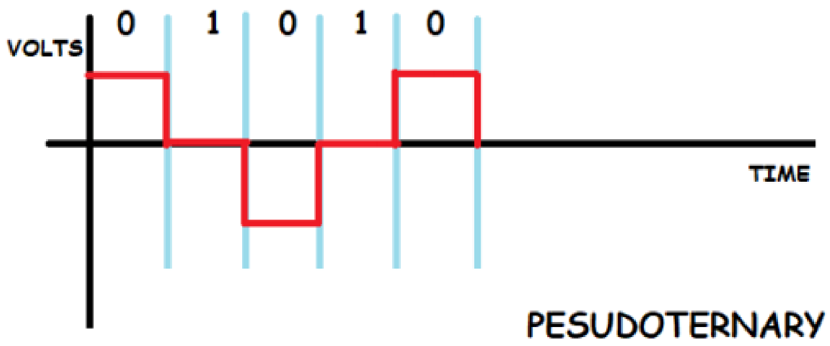
Bipolar Line Coding

Bipolar consists of three voltage levels which are positive negative and zero. While representing, the voltage level for one bit of data is at zero, and the other bit inverts transits, or alternates between positive and negative voltage.



ALTERNATE MARK INVERSION(AMI): the representation here follows a simple logic that, for representing logical 0 we use zero voltage, and while representing logical 1 we use alternating positive and negative voltages, which can be seen in the image below.

Pesudoternary: this is the opposite of AMI, as we kept logical 0 at 0 volts or neutral in the above section, here we will be keeping logical 1 as neutral (i.e. at 0 volts) and we will keep alternating logical zero, we can see that in the image below.



The bipolar scheme or encoding proved to be an alternative for NRZ encoding because bipolar has the same signal rate as NRZ. Also, it was not having any low frequency or DC component in it, as one bit is represented by zero volts and the other is represented by alternating voltages.

Conclusion

Line coding is a critical component in modern communication systems that ensures accurate transmission of digital data over communication channels. Different line coding schemes offer varying levels of efficiency and noise tolerance, making it important to choose the appropriate scheme for specific applications.

Manchester, Differential Manchester, and NRZ coding are some common line coding schemes used today. Understanding the basics of line coding and how it can impact communication system performance is crucial for designing and optimizing systems for different applications. As communication technologies continue to evolve, the importance of line coding in ensuring reliable data transmission will remain paramount.

Frequently Asked Questions(FAQs)

1. What are the different types of line coding techniques?

Line coding techniques can be broadly categorized into four types: unipolar, polar, bipolar, and Manchester encoding. Unipolar encoding uses a single voltage level, while polar encoding uses two voltage levels to represent the data. In bipolar encoding, three voltage levels are used, and in Manchester encoding, the signal changes polarity in the middle of each bit.

2. What are the advantages of using line coding techniques?

Line coding techniques have several advantages, such as reducing the error rate during transmission, ensuring reliable data communication, increasing bandwidth efficiency, and facilitating error detection and correction.

3. What are some examples of line coding techniques?

Unipolar encoding examples include non-return-to-zero (NRZ) and non-return-to-zero inverted (NRZI). Polar encoding examples include amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). Bipolar encoding examples include alternate mark inversion (AMI) and pseudo-ternary encoding. Manchester encoding is another example of a line coding technique.

4. How are line coding types and techniques used in digital communication?

Line coding techniques are critical in digital communication, as they help convert digital data into a format that can be transmitted over a communication channel. Using different line coding types and techniques makes it possible to maximize bandwidth efficiency and minimize the errors that occur during data transmission. Line coding is used in various applications, including telecommunications, computer systems, and networking.