COMPUTER NETWORK

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DIGITAL-TO-DIGITAL CONVERSION

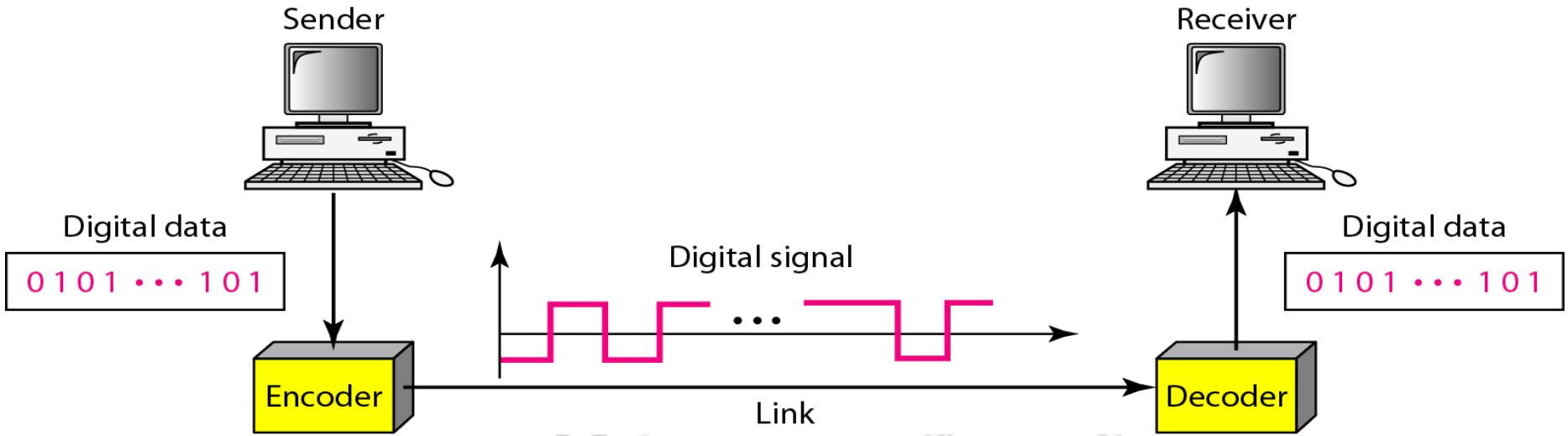
Digital-to-digital conversion

- In this section, we see how we can represent digital data by using digital signals
- The conversion involves three techniques:
  - line coding
  - block coding
  - scrambling
- Line coding is always needed block coding and scrambling may or may not be needed

Line Coding

- Converting a string of 1’s and 0’s (digital data) into a sequence of signals that denote the 1’s and 0’s
- Eg:
  - a high voltage level (+V) could represent a “1” AND
  - a low voltage level (0 or -V) could represent a “0”

Line coding and decoding



Mapping Data symbols onto Signal levels

- A data symbol can consist of a number of data bits
  - 1, 0 OR
  - 11, 10, 01, etc
- A data symbol can be coded into a single signal element or multiple signal elements
  - 1 → +V, 0 → -V
- The ratio ‘r’ is the number of data elements carried by a signal element

Relationship b/w data rate and signal rate

- Data rate
  - the number of bits sent per sec (bps)
  - it is often referred to the bit rate
- Signal rate
  - the number of signal elements sent in a second
  - it is measured in bauds
  - it is also referred to as the modulation rate or baud rate

Relationship b/w data rate and signal rate

Data

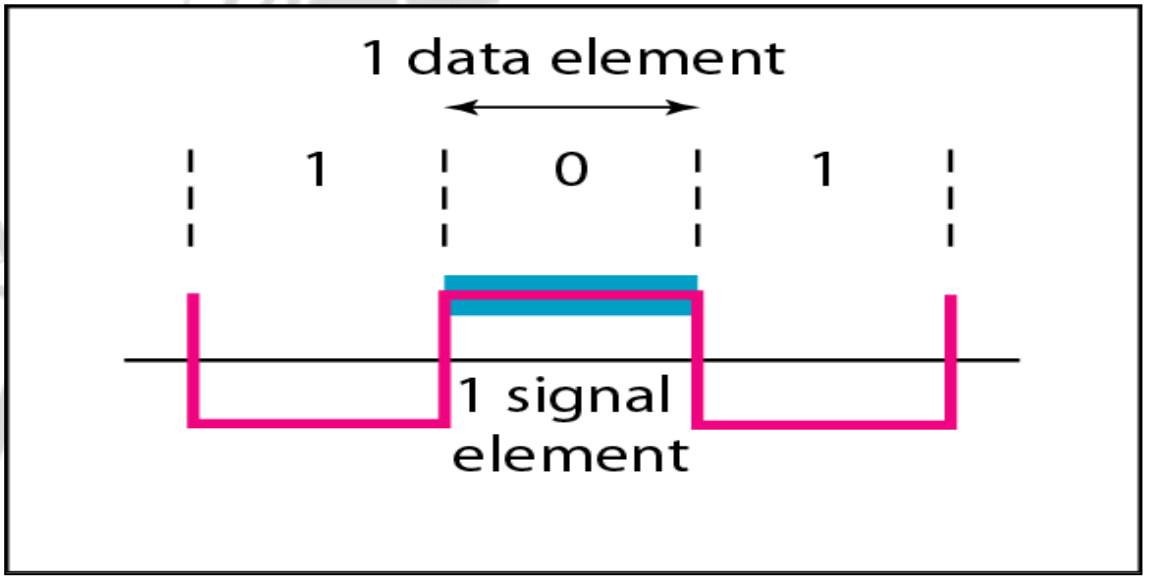
- A data element is the smallest entity that can represent a piece of information (bit)
- Data elements are what we need to send
- Data elements are being carried
- Data rate defines the number of data elements (bits) send in 1s
- Unit is bps

Signal

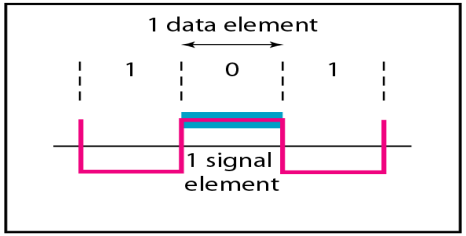
- A signal element is the shortest unit of the digital signal
- Signal element are what we can send
- Signal elements are the carriers
- Signal rate is the number of signal elements send in 1s
- Unit is baud

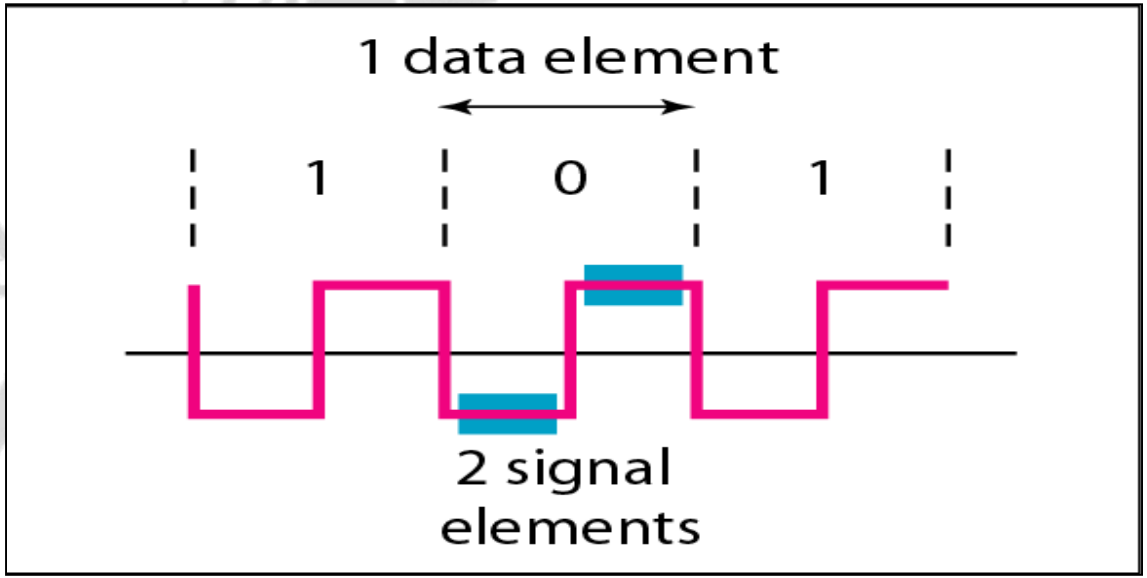
Data element vs data element

Data element vs data element



Data element vs data element





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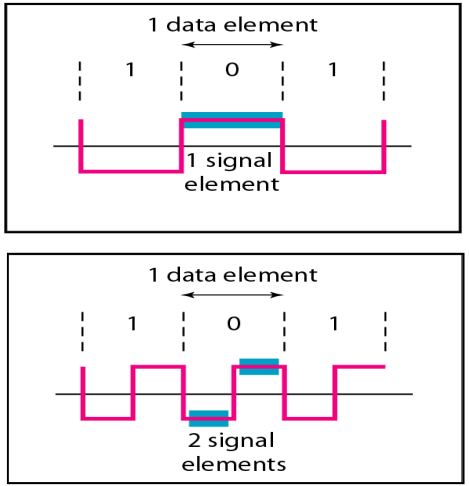
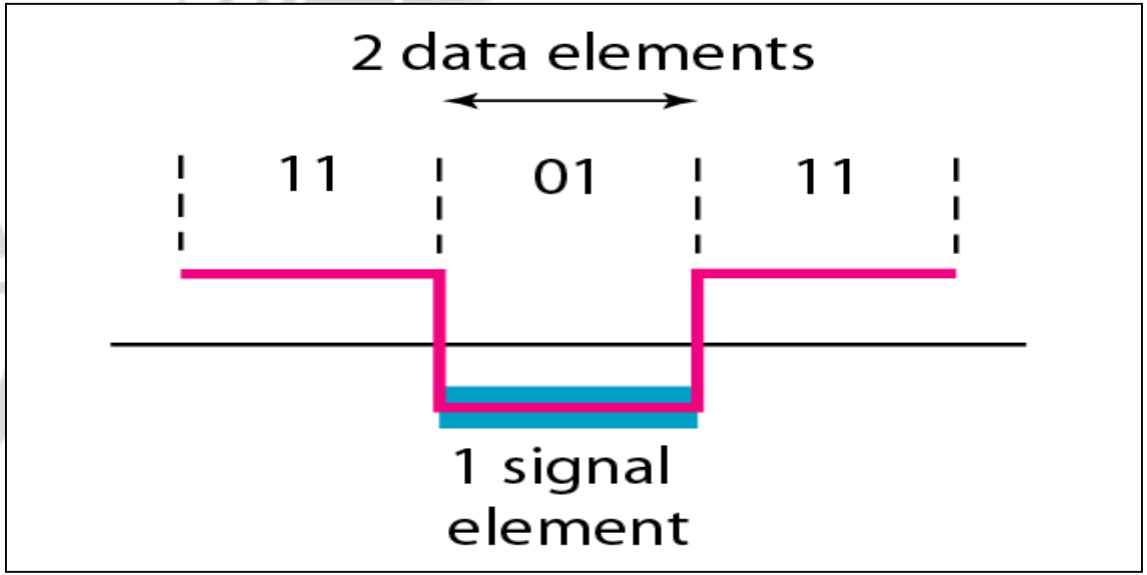
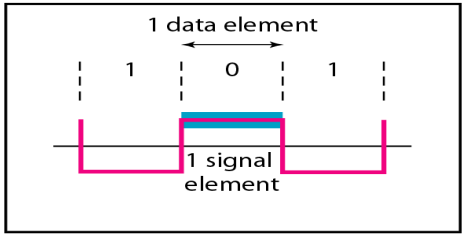
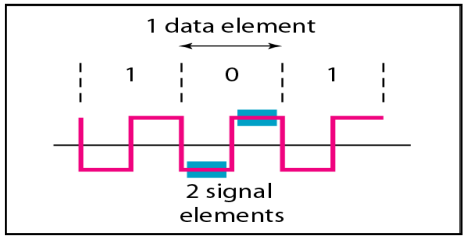
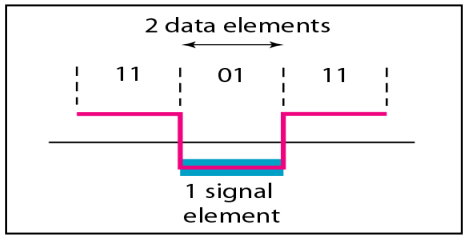


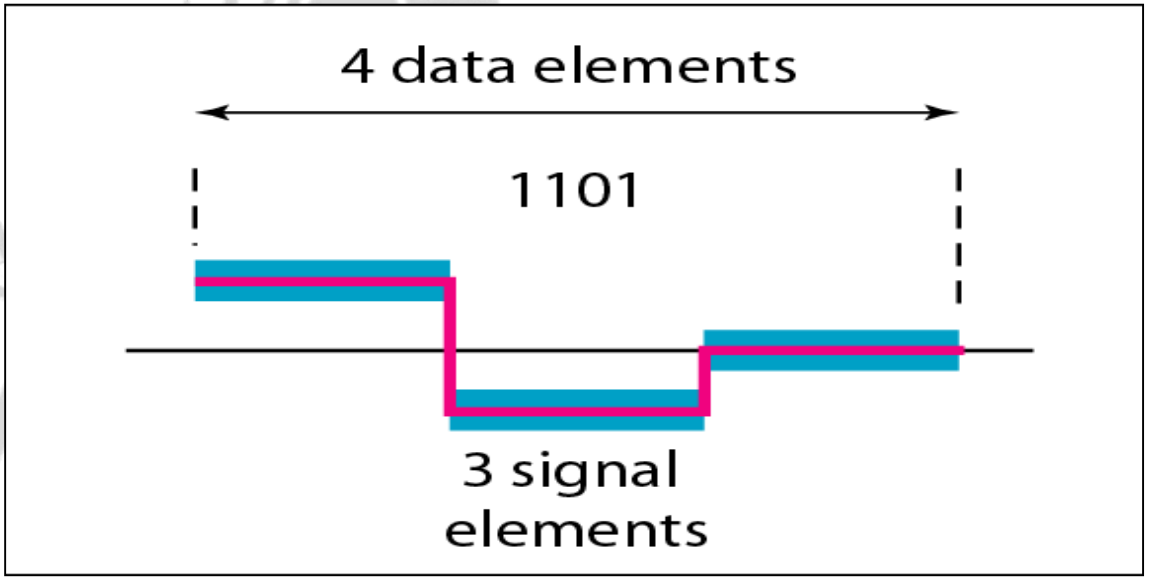


Data element vs data element









Baud rate

- The baud or signal rate can be expressed as:

$$S = c \times N \times 1/r \text{ bauds}$$

where,

c is the case factor (worst, best & avg.)

N is data rate

r is the ratio between data element & signal element

Baud rate

- Eg:
  - A signal is carrying data in which one data element is encoded as one signal element (r = 1). If the bit rate is 100 kbps, what is the average value of the baud rate if c is between 0 and 1?

Solution

- We assume that the average value of c is 1/2 . The baud rate is then

$$S = c * N * 1/r$$
$$= ½ * 100000 * 1$$
$$= 50000$$
$$= 50k \text{ baud}$$

Baud rate

- Eg:
  - Calculate the value of signal rate for each of the cases if data rate is 1 Mbps and c= 1/2

a. r = 1

b. r = 1/2

c. r = 2

d. r = 4/3

Line Coding

- Data as well as signals can either be digital or analog
- Line coding is the process of converting digital data to digital signals
- By this technique we converts a sequence of bits to a digital signal
- At the sender side digital data are encoded into a digital signal and at the receiver side the digital data are recreated by decoding the digital signal

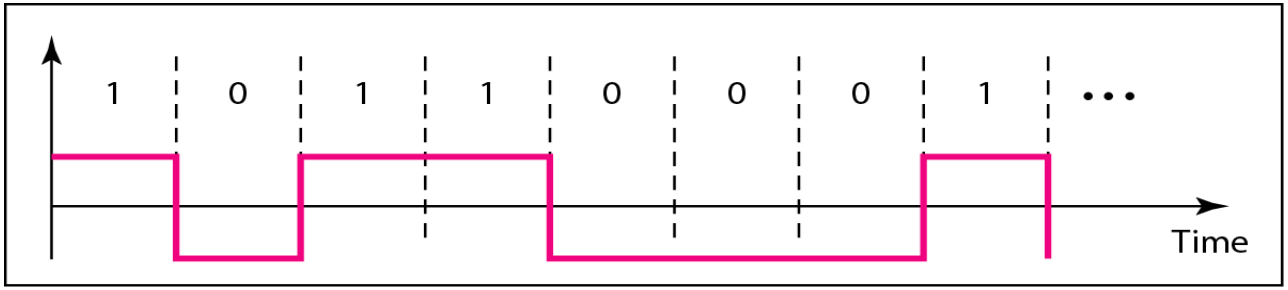
Line Coding

- We can divide line coding schemes into five categories
  - Unipolar (Eg: NRZ scheme)
  - Polar (Eg: NRZ-L, NRZ-I, RZ, and Biphase – Manchester and differential Manchester)
  - Bipolar (Eg: AMI and Pseudoternary).
  - Multilevel
  - Multi-transition

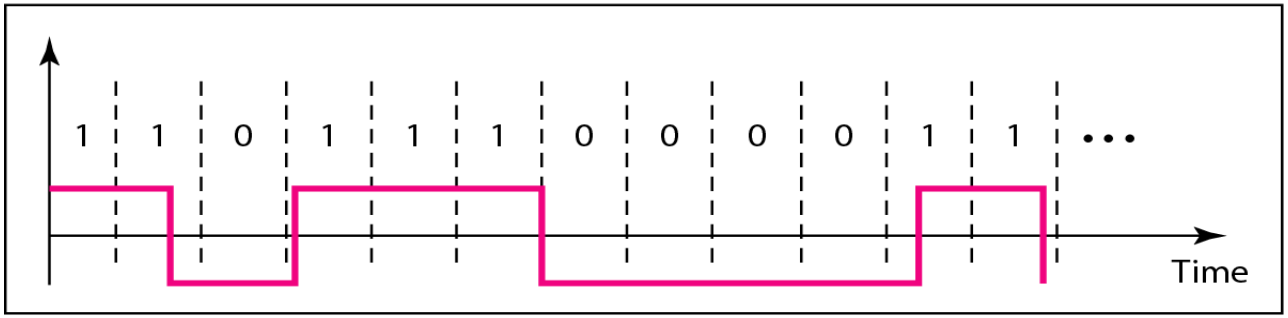
Characteristics of Line Coding techniques

- There should be self-synchronizing i.e., both receiver and sender clock should be synchronized
- There should have some error-detecting capability
- There should be immunity to noise and interference
- There should be less complexity
- There should be no low frequency component, as long distance transfer is not feasible for low frequency component signal
- There should be less base line wandering

Characteristics of Line Coding techniques



a. Sent



b. Received

- Eg:
  - In a digital transmission, the receiver clock is 0.1 percent faster than the sender clock. How many extra bits per second does the receiver receive if the data rate is 1 kbps? How many if the data rate is 1 Mbps?

Solution

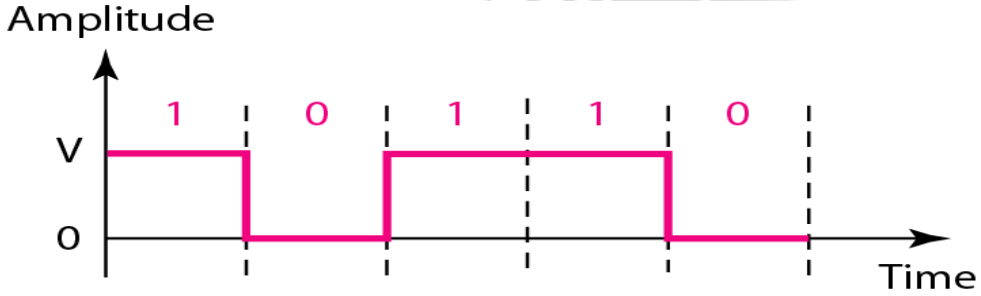
- At 1 kbps, the receiver receives 1001 bps instead of 1000 bps
- At 1 Mbps, the receiver receives 1,001,000 bps instead of 1,000,000 bps

Unipolar Line Coding Scheme

- All signal levels are on one side of the time axis
  - either above or below
  - Eg: NRZ (Non Return to Zero)
- The signal level does not return to zero during a symbol transmission
- The signal will change level at the edge of the time interval and not in between
- Disadvantages
  - Scheme is subject to baseline wandering
  - It has no synchronization or any error detection
  - It is simple but costly in power consumption

Unipolar - NRZ scheme

- Assumption: data element ‘1’ is on positive side of axis and data element ‘0’ is on the axis

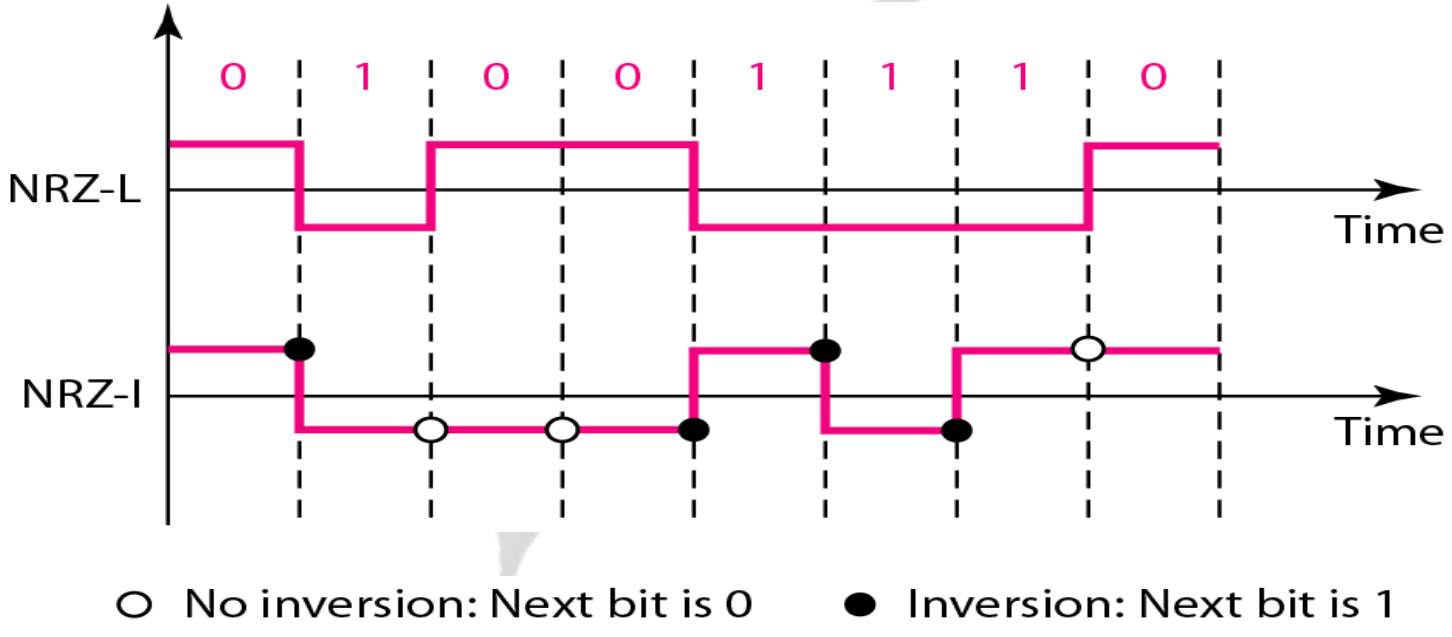


- NOTE: data element ‘1’ is on negative side of axis and data element ‘0’ is on the axis can also be assumed

Polar – NRZ Line Coding Scheme

- The voltages are on both sides of the time axis
- The signal level does not return to zero during a symbol transmission
- The signal will change level at the edge of the time interval and not in between
- Polar NRZ scheme can be implemented with two voltages
  - E.g. +V for 1 and -V for 0 or vice versa
- There are two versions:
  - NRZ - Level (NRZ-L) - positive voltage for one symbol and negative for the other
  - NRZ - Inversion (NRZ-I) - the change or lack of change in polarity determines the value of a symbol
    - E.g. a 1 symbol inverts the polarity a 0 does not

Polar NRZ-L and NRZ-I schemes



Polar NRZ-L and NRZ-I schemes

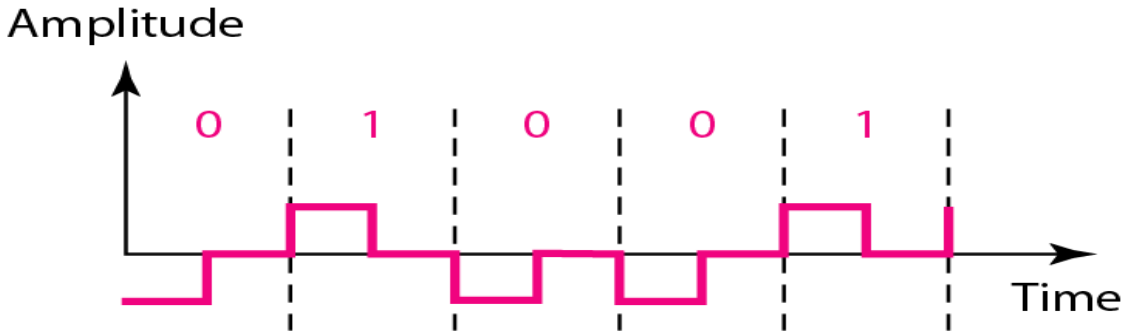
- In NRZ-L the level of the voltage determines the value of the bit
- In NRZ-I the inversion or the lack of inversion determines the value of the bit

Polar – RZ Scheme

- The Return to Zero (RZ) scheme uses three voltage values
  - +, 0, -
- Each symbol has a transition in the middle
  - Either from high to zero or from low to zero
- The signal will change level in between of the signal element or bit duration
- The signal will not change level at the edge of the time interval
- This scheme has more signal transitions (two per symbol) and therefore requires a wider bandwidth

Polar RZ scheme

- One bit duration, signal is returning to zero axis during the bit i.e., at the middle of the signal element transmission and not at the edge of the interval



Polar Biphase

- Manchester coding
  - combining the NRZ-L and RZ schemes
  - Every symbol has a level transition in the middle: from high to low or low to high
  - Uses only two voltage levels
- Differential Manchester coding
  - combining the NRZ-I and RZ schemes
  - Every symbol has a level transition in the middle. But the level at the beginning of the symbol is determined by the symbol value
  - One symbol causes a level change while the other does not

Polar Biphase