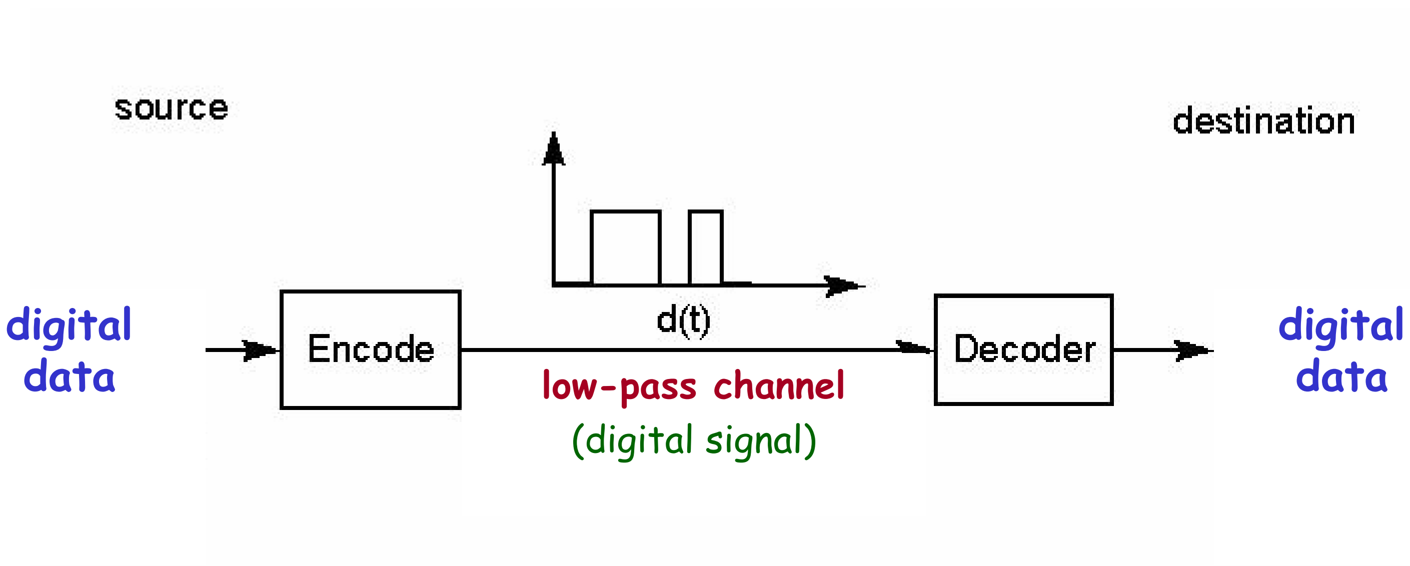
Digital Transmission of Digital Data:

Line and Block Coding, Digital Transmission Modes

Required reading:
Garcia 3.6

CSE 3213, Fall 2010
Instructor: N. Vlajic

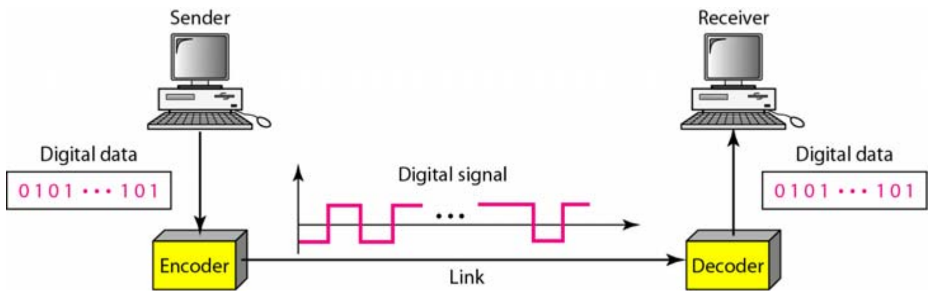
Analog vs. Digital Transmission (cont.)



Line Coding: Design Consideration

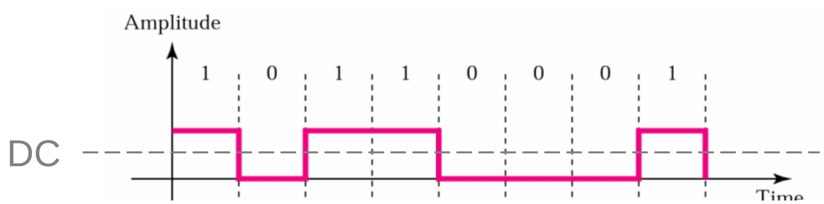
Line Coding – **process of converting binary data (sequence of bits) to a digital signal**

- **digital signal depends 'linearly' on information bits - bits are transmitted 'one-by-one' - different from block coding**

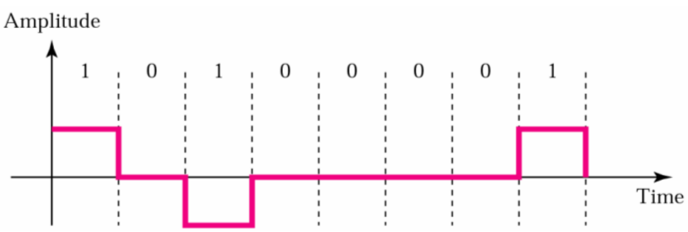


Data vs. Signal Level

- **data levels** – **number of values / levels used to represent data** (typically only two: 0 and 1)
- **signal levels** – **number of values / levels allowed in a particular signal**



Two signal levels, two data levels.



Three signal levels, two data levels.

Line Coding: Design Consideration (cont.)

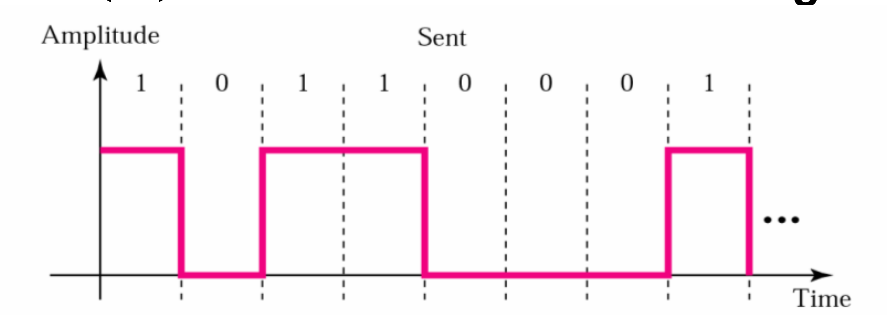
DC Component in Line Coding – some line coding schemes have a residual (DC) component, which is generally undesirable

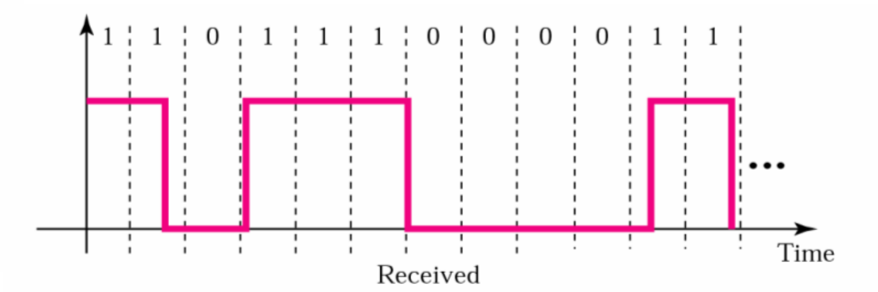
- transformers do not allow passage of DC component
- DC component ⇒ extra energy – useless!

Self-Synchronization (Clocking) – to correctly interpret signal received from sender receiver's bit interval must exactly correspond to sender's bit intervals

- if receiver clock is faster/slower, bit intervals not matched ⇒ receiver misinterprets signal
- self-synchronizing digital signals include timing information in itself, to indicate the beginning & end of each pulse (see pp. 8-10)

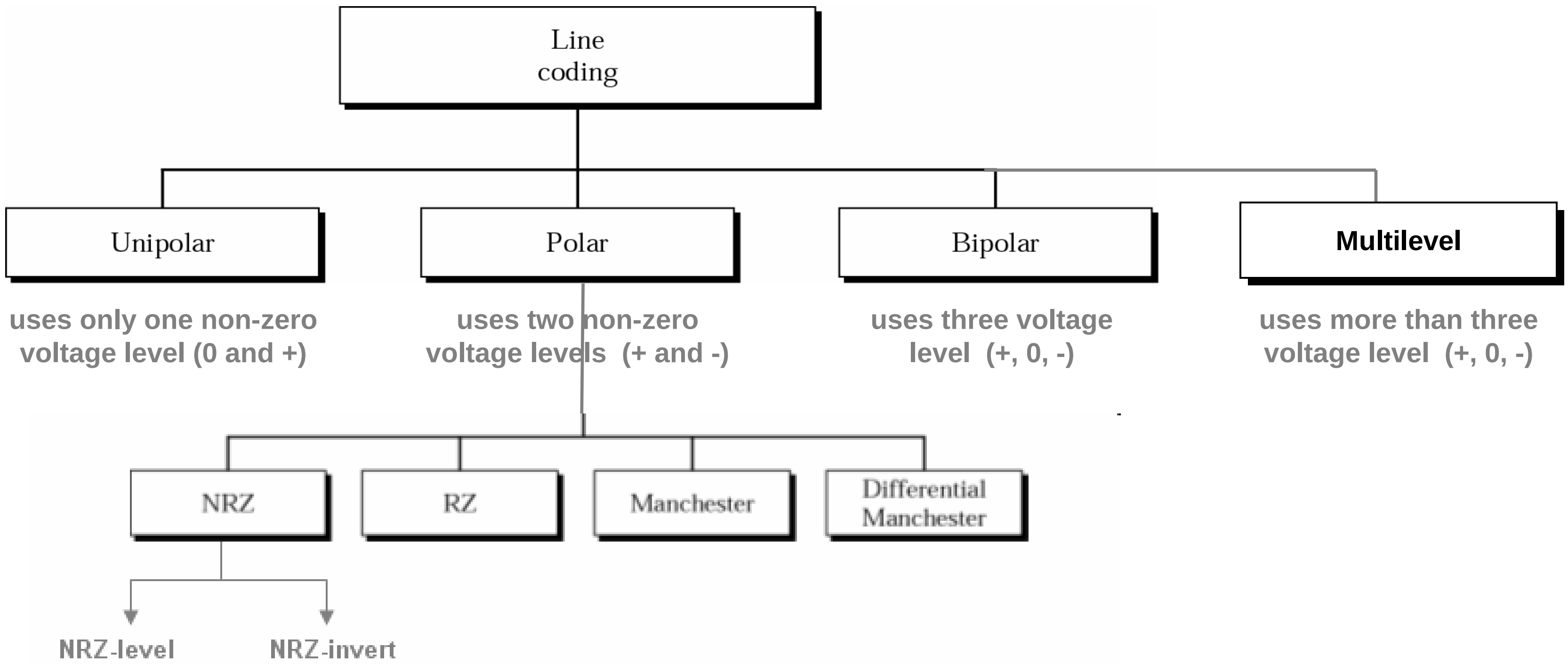
56 kbps ⇒ 0.0178 ms





Line Coding: Design Consideration (cont.)

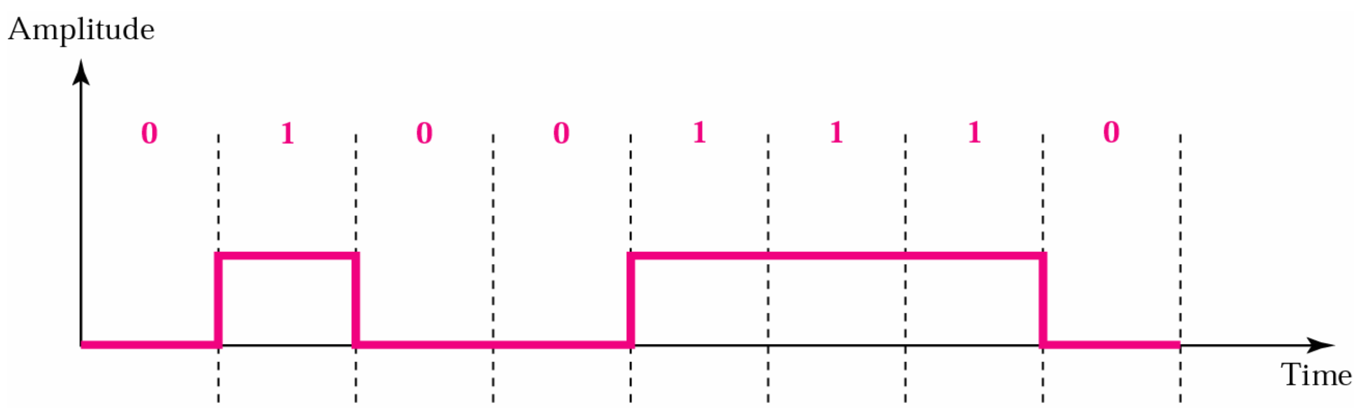
Line Coding Schemes – can be divided into four broad categories



Line Coding: Unipolar

Unipolar Line Coding – **uses only <u>one non-zero</u> and one zero voltage level**

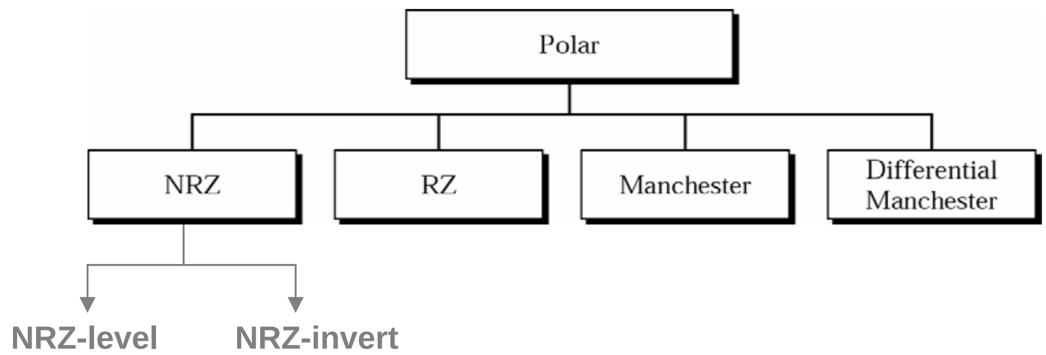
- **(e.g.) 0 = zero level, 1 = non-zero level**
- **simple to implement, but obsolete due to two main problems:**
  - **DC component present ☹**
  - **lack of synchronization for long series of 1-s or 0-s ☹**



Line Coding: Polar

Polar Line Coding – uses two non-zero voltage level for represent. of two data levels - one positive & one negative

- "DC-problem" alleviated ☺
- 4 main types of polar coding:



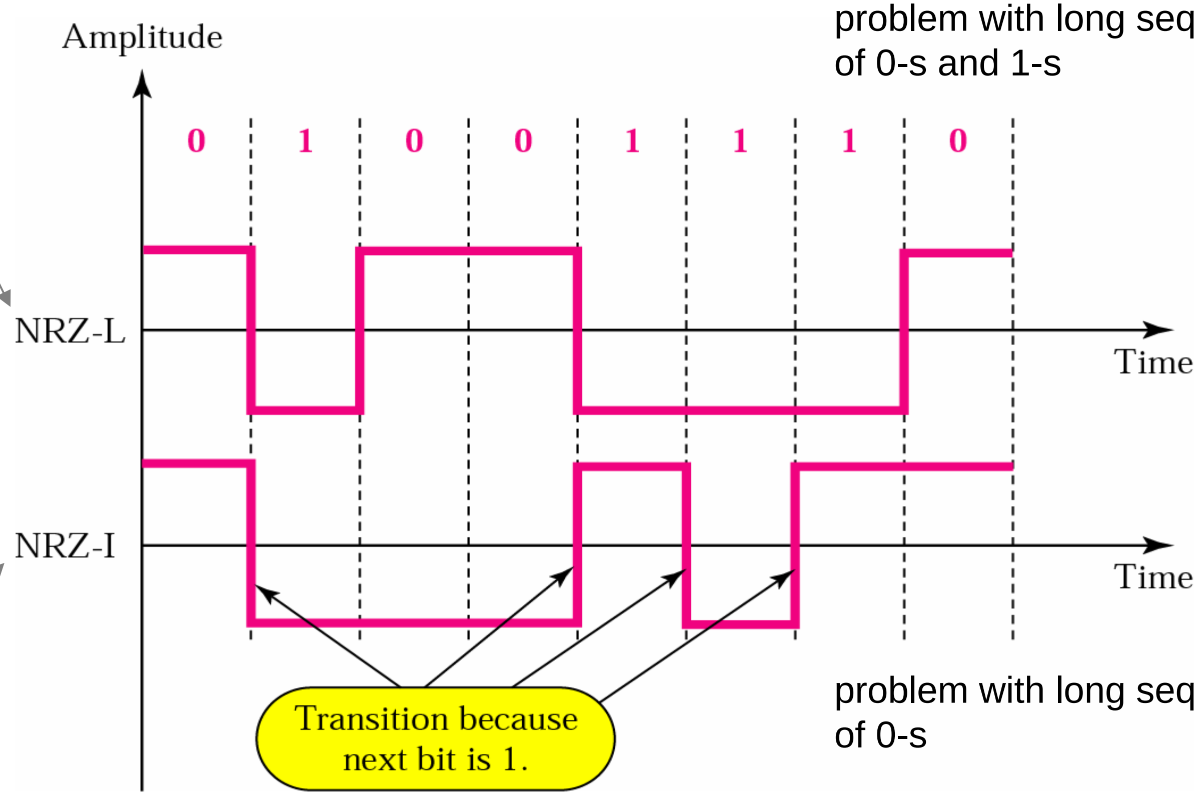
(1) Nonreturn to Zero (NRZ)

- NRZ-level: signal level represents particular bit, (e.g.) 0 = positive volt. , 1 = negative volt.
  - poor synchronizat. for long series of 1-s & 0-s ☹
- NRZ-invert: inversion of voltage level = bit 1, no voltage = bit 0
  - 1s in data streams enable synchronization
  - long sequence of 0-s still a problem ☹

Line Coding: Polar (cont.)

problem with long sequences of 0-s and 1-s

Data is represented by signal level.



Logical ‘1’ is represented by change in signal level.

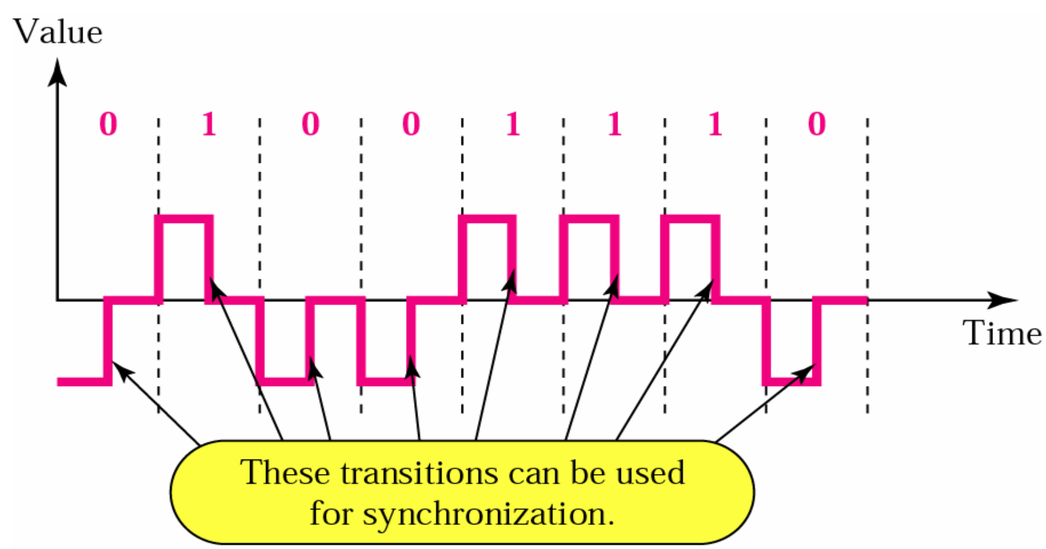
problem with long sequences of 0-s

NRZ-I is better than NRZ-L, but it still does not provide complete synchronization.
To ensure complete synchronization, there must be a signal change for each bit.

Line Coding: Polar (cont.)

(2) Return to Zero (RZ) – **(e.g.) 0 = negative volt., 1 = positive volt., AND signal must return to zero halfway through each bit interval**

- **perfect synchronization** ☺
- **drawback – 2 signal changes to encode each bit ⇒ pulse rate is x2 rate of NRZ coding, i.e. more bandwidth is required, regardless of bit sequence** ☹

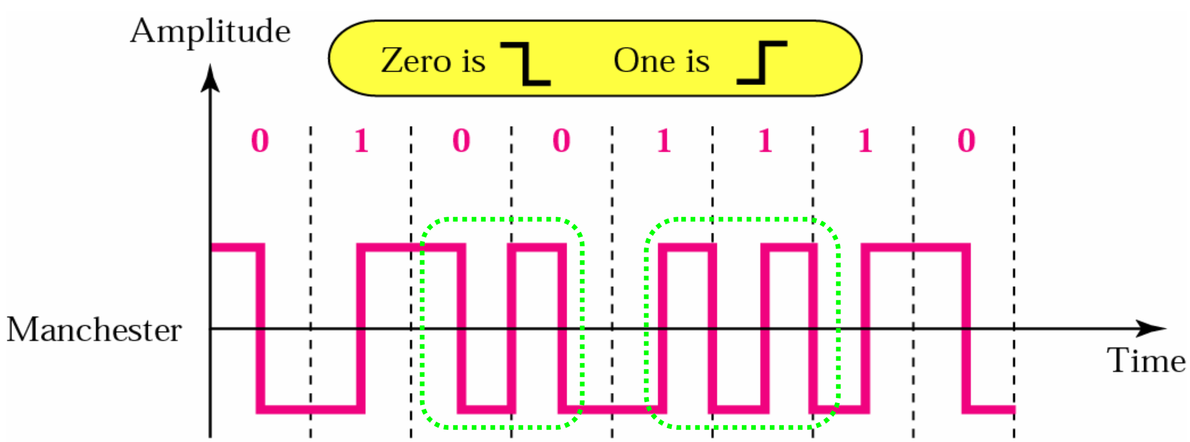


Non-zero level ⇒ beginning of a new bit.

Line Coding: Polar (cont.)

(3) Manchester – inversion at the middle of each bit interval is used for both synchronization and bit representation

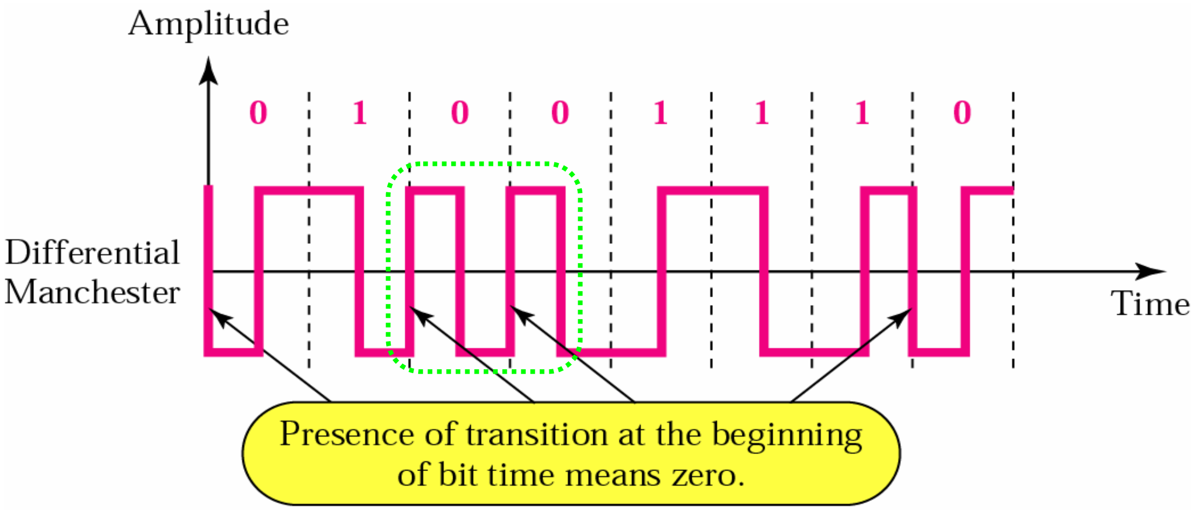
- **0 = pos-to-neg transition, 1 = neg-to-pos transition**
- **perfect synchronization ☺**
- **there is always transition at the middle of the bit, and maybe one transition at the end of each bit**
- **fine for alternating sequences of bits (10101), but wastes bandwidth for long runs of 1-s or 0-s ☹**
- **used by IEEE 802.3 (Ethernet)**



Line Coding: Polar (cont.)

(4) Differential Manchester – inversion in the middle of bit interval is used for synchronization – presence or absence of additional transition at the beginning of next bit interval identifies the bit

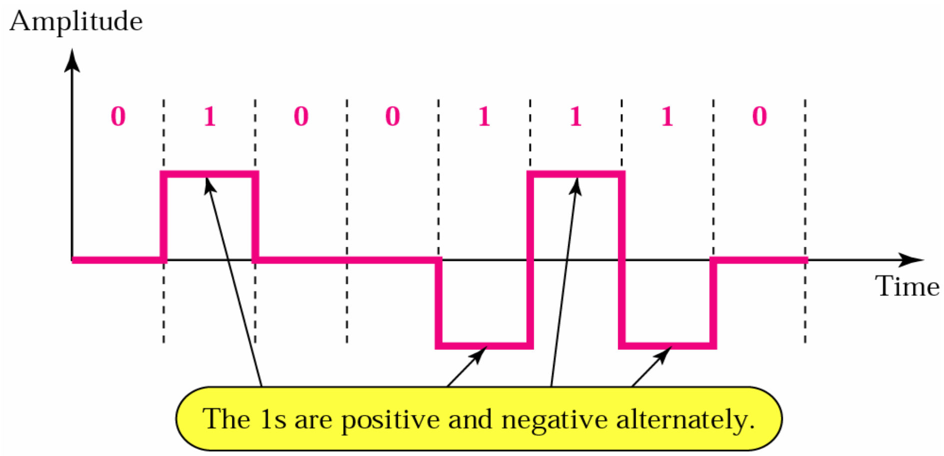
- **0 = transition, 1 = no transition**
- **perfect synchronization ☺**
- **fine for long runs of 1s, but wastes band-width for long runs of 0-s ☹**
- **used by IEEE 802.5 (Token Ring)**



Line Coding: Bipolar

Bipolar Line Coding – uses two non-zero and zero voltage level for representation of two data levels

- **0 = zero level**; **1 = alternating pos and neg level**
- **if 1st 'bit 1' is represented by positive amplitude, 2nd will be represented by negative amplitude, 3rd by positive, etc.**
- **less bandwidth required than with Manchester coding (for any sequence of bits)** ☺
- **loss of synchronization is possible for long runs of 0-s** ☹



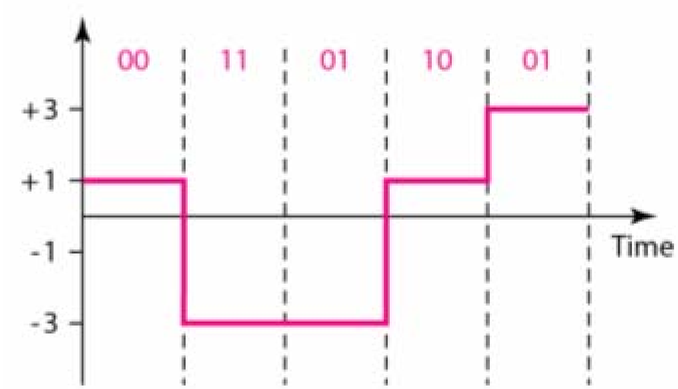
Line Coding: Multilevel

2B1Q (2 Binary 1 Quaternary) Coding – **data patterns of size 2 bits are encoded as one signal element belonging to a four-level signal**

- **data is sent two time faster than with NRZ-L**
- **receiver has to discern 4 different thresholds**

	Previous level: positive	Previous level: negative
Next bits	Next level	Next level
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

Transition table

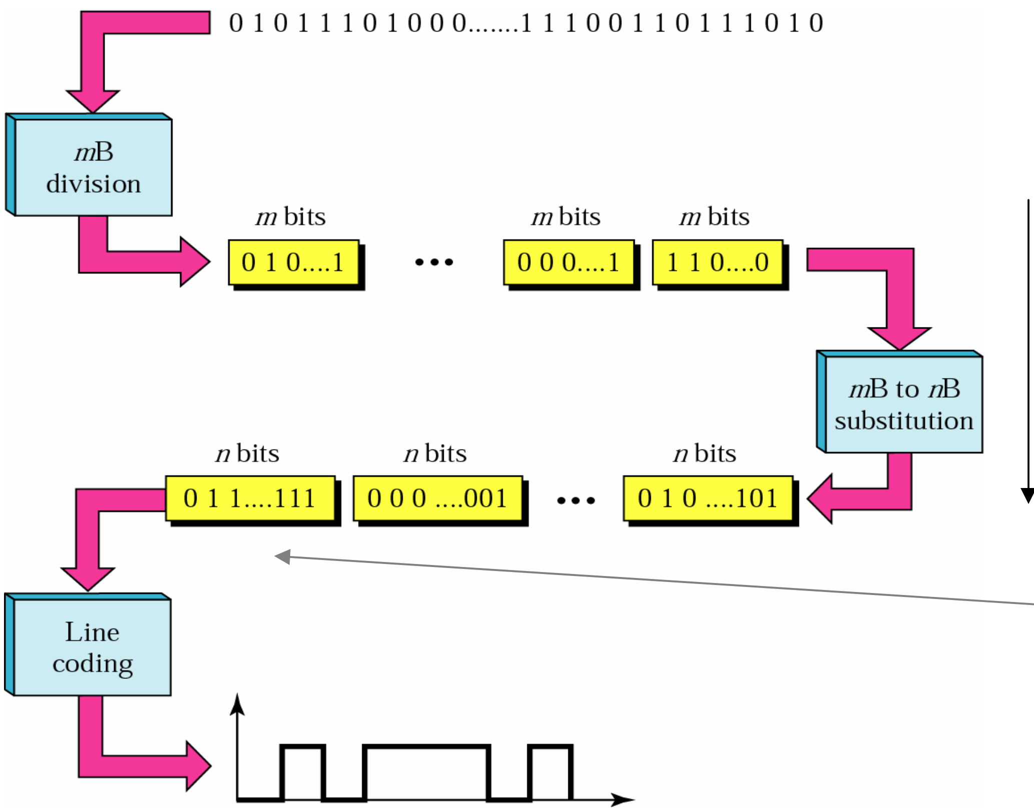


Assuming positive original level

Block Coding

Block Coding – **unlike line codes which operate on a stream of information bits, block codes operate on block of information bits**

- **redundant bit(s) are added to each block of information bits to ensure synchronization and error detection**



Example:
substitute m information bits with n (new) well-chosen bits that do not have more than three consecutive 0s and 1s
(easy to synchronize with any of the line coding schemes)

If one or more bits is changed so that if one of the unused 5-bit blocks is received ⇒ receiver can easily detect the error.

Drawback: longer encoding / decoding time and ???.

Block Coding (cont.)

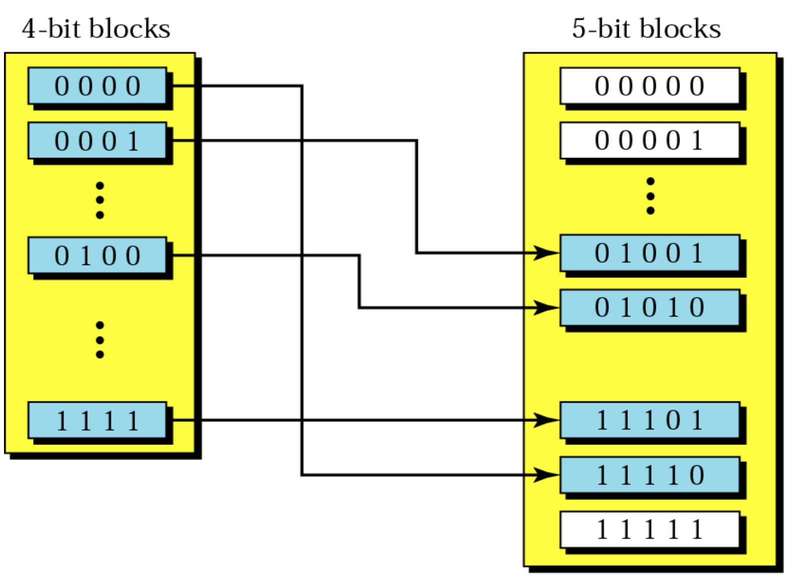
Example [4B/5B block code]

Every 4 bits of data is encoded into a 5-bit code.

The 5-bit codes are normally line coded using NRZ-invert (longer sequences of 1 are tolerated)!!!

The selection of the 5-bit code is such that each code contains no more than one leading 0 and no more than two trailing 0s.

Therefore, when these 5-bit codes are sent in sequence, no more than three consecutive 0s are encountered.



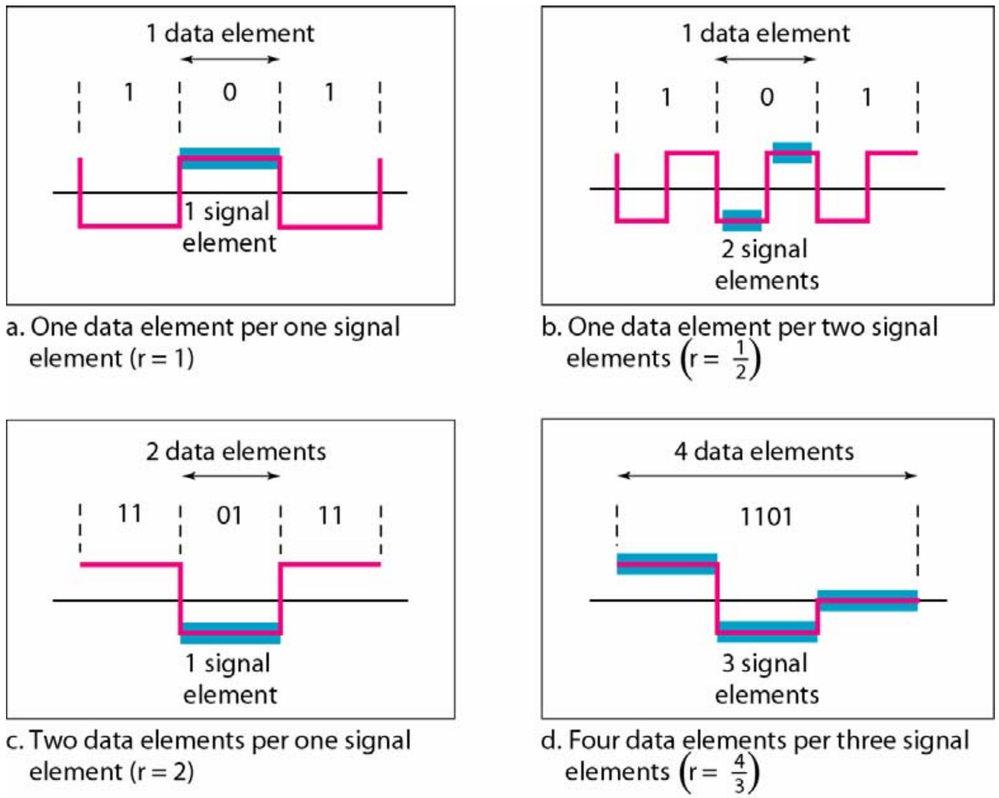
Data	Code	Data	Code
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
0111	01111	1111	11101

4B/5B coding is used in the optical fiber transmission system (FDDI).

Data Rate vs. Baud Rate

Data Rate – **# of data elements (bits) sent in 1 sec – unit: bps**

Signal Rate – **# of signal elements/pulses sent in 1 sec – unit: baud**



a. One data element per one signal element ($r = 1$)

b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$

c. Two data elements per one signal element ($r = 2$)

d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

One goal of data communications is to increase data rate (speed of transmission) **while decreasing signal rate** (bandwidth requirements).

Data Rate vs. Baud Rate (cont.)

r = data rate / signal rate – **ratio between data & signal rate**

Signal rate observed in case of a particular data-bit stream: – **depends on N [bps], 1/r [bit/pulse], and the actual data pattern**

- **signal rate for a pattern of all 1-s or all 0-s may be different from that for a patter of alternating 1-s and 0-s**

$$S = \underbrace{c}_{\text{case factor}} \cdot N \cdot \frac{1}{r} \;\; \text{[pulses/sec]}$$

Data Rate vs. Baud Rate (cont.)

Example [data vs. signal rate]

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, assuming c is between 0 and 1?

Answer:

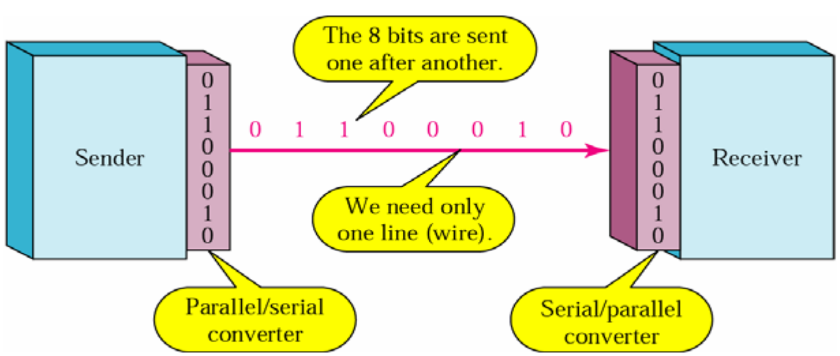
$C_{average}$ = 0.5

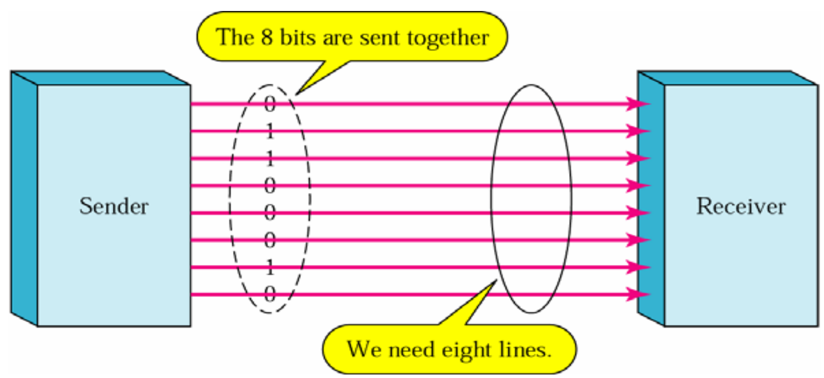
$$S = c \cdot N \cdot \frac{1}{r} = \frac{1}{2} \cdot 100{,}000 \cdot \frac{1}{1} = 50{,}000\ [\text{pulses/sec}] = 50\ [\text{kbaud}]$$

Digital Transmission Modes

How do we send bits / pulses over wire?

- **Serial Mode**: 1 bit is sent with each clock tick
  - one communication channel / wire is needed
- **Parallel Mode**: multiple bits are sent with each clock tick
  - multiple channels / wires, bundled in one cable, are required
  - **advantage**: n-times faster than serial mode
  - **disadvantage**: cost = 8x wires (used only over short distances)





Exercise

1. Pulse rate is always _______________ the bit rate.
   (a) greater than
   (b) less than
   (c) greater than or equal to
   (d) less than or equal to

2. Which encoding type always has a nonzero average amplitude?
   (a) unipolar
   (b) polar
   (c) bipolar
   (d) all the above

3. Which of the following encoding methods does not provide for synchronization.
   (a) NRZ-L
   (b) RZ
   (c) NRZ-I
   (d) Manchester

4. Block coding can help in _______________ at the receiver.
   (a) synchronization
   (b) error detection
   (c) attenuation
   (d) (a) and (b)