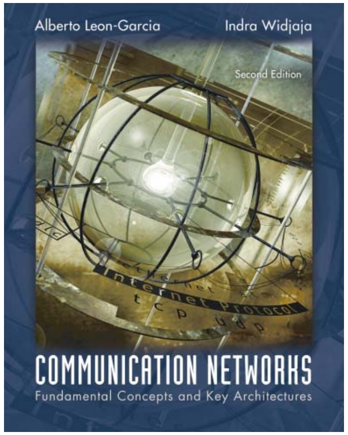
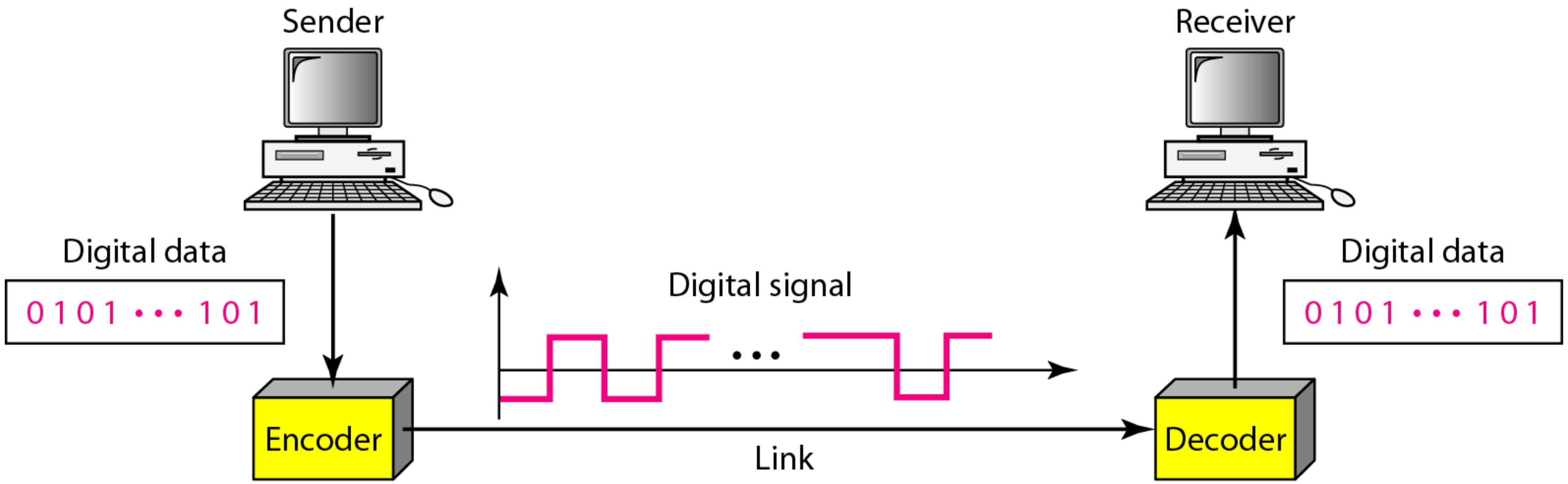
Chapter 3
Digital Transmission Fundamentals



Line Coding
Modems and Digital Modulation

Digital transmission of Digital Signals



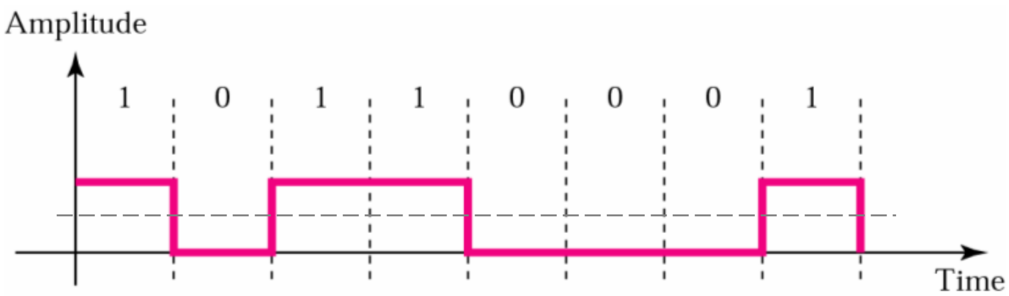
Digital transmission of Digital Signals

Data Level vs. Signal Level

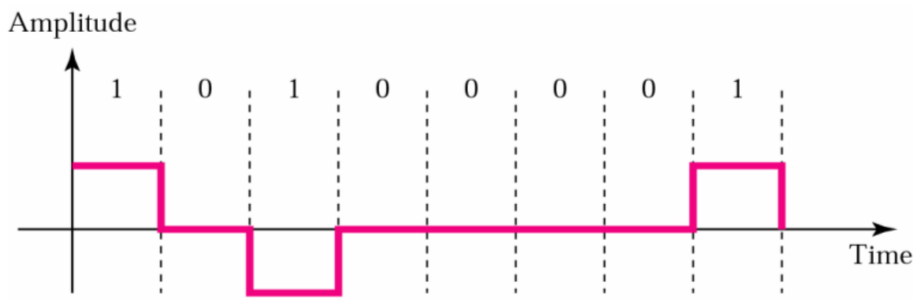
- data levels – number of values / levels used to represent data (typically only two: 0 & 1)

- signal levels – number of values / levels allowed in a particular signal

DC



Two signal levels, two data levels.



Three signal levels, two data levels.

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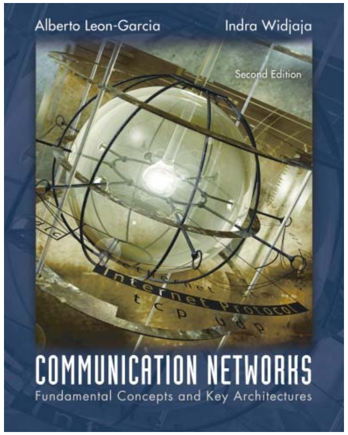
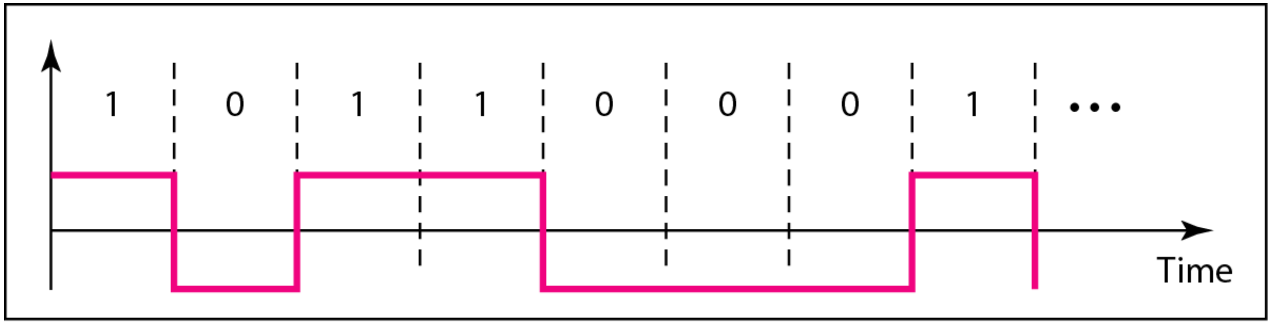


Line Coding

What is Line Coding?

- Mapping of binary information sequence into the digital signal that enters the channel
- process of converting binary data (sequence of bits) to a digital signal
- digital signal depends 'linearly' on information bits, i.e. bits are transmitted 'one-by-one' – different from block coding
  - Ex. "1" maps to +A square pulse; "0" to –A pulse



Line Coding: Design Consideration

DC Component in Line Coding

– some line coding schemes have a residual (DC) component, generally undesirable

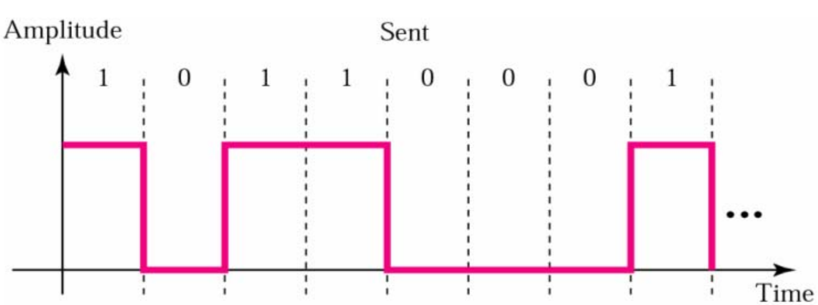
- transformers do not allow passage of DC component
- DC component ⇒ extra energy – useless!

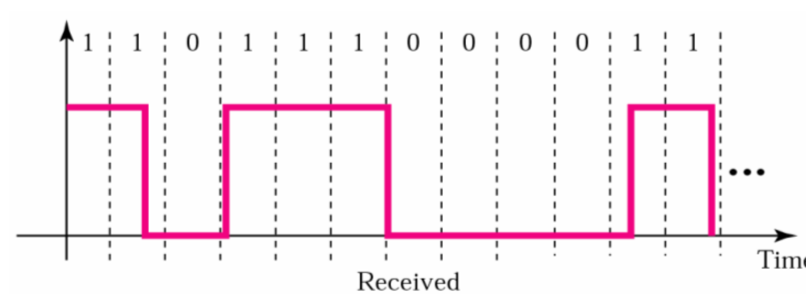
Self-Synchronization (Clocking)

– to correctly interpret signal received from sender, receiver's bit interval must correspond exactly to sender's bit intervals

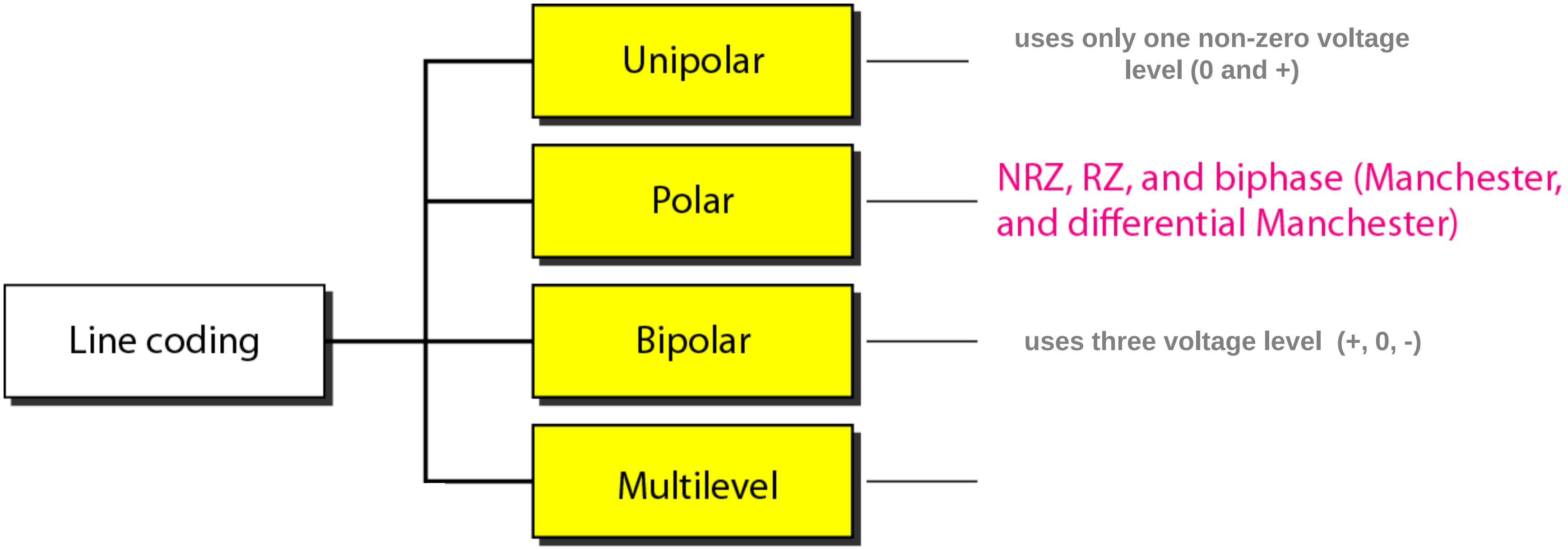
- if receiver clock is faster/slower, bit intervals are not matched ⇒ receiver might misinterpret signal
- self-synchronizing digital signals include timing information in itself, to indicate the beginning and end of each pulse

56 kbps ⇒ 0.0178 ms

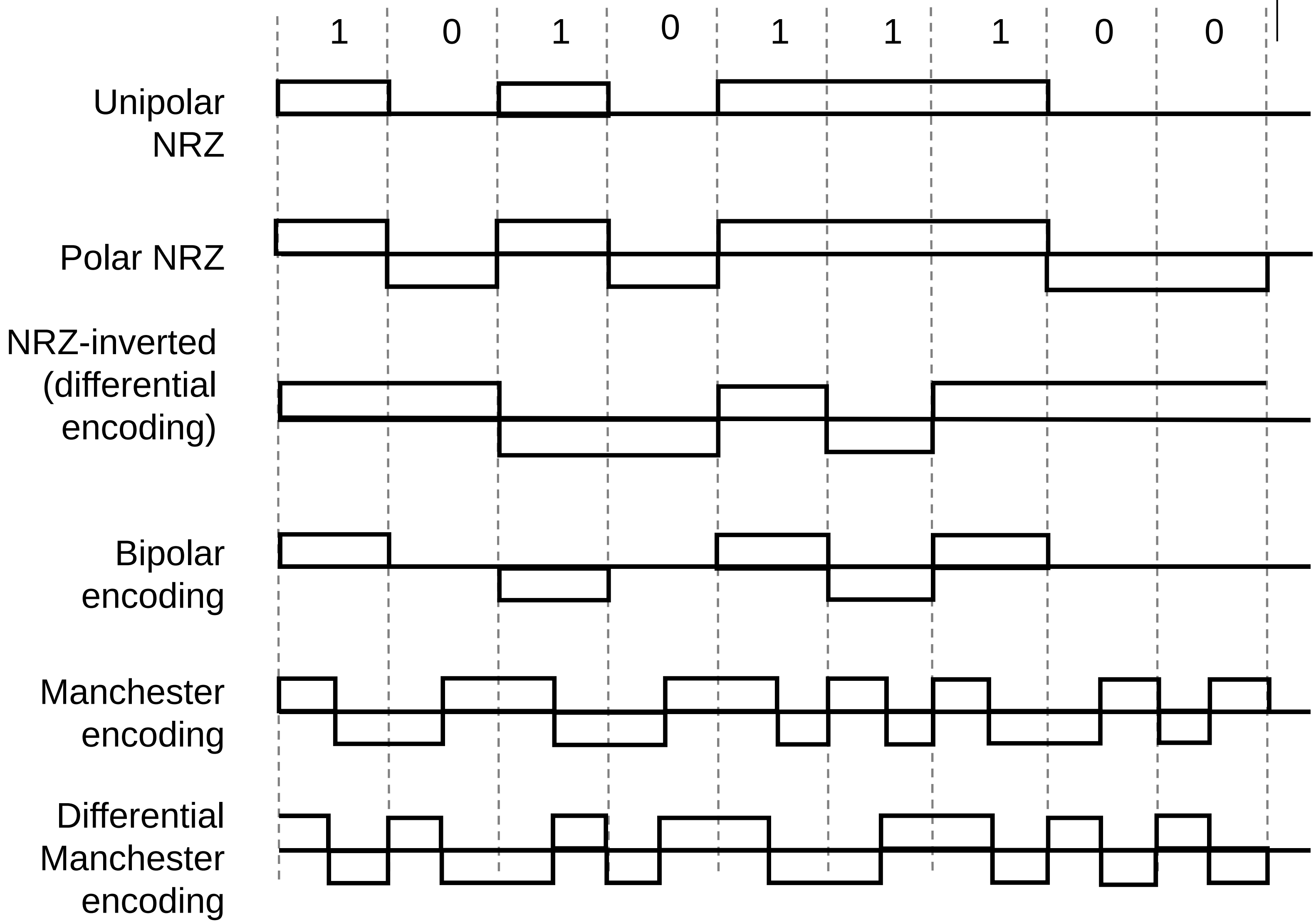




Line Coding Schemes



Line coding examples

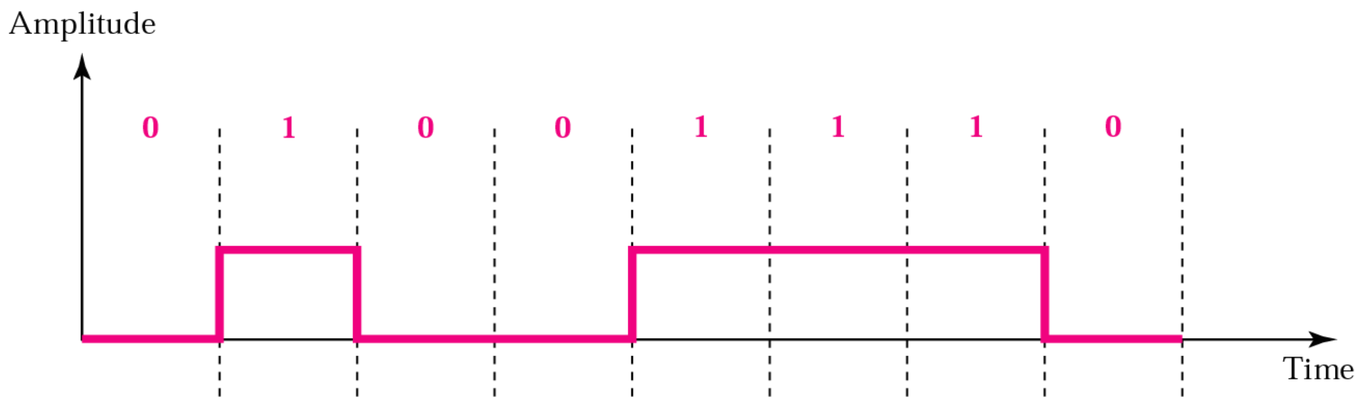


Unipolar Code

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 ☹

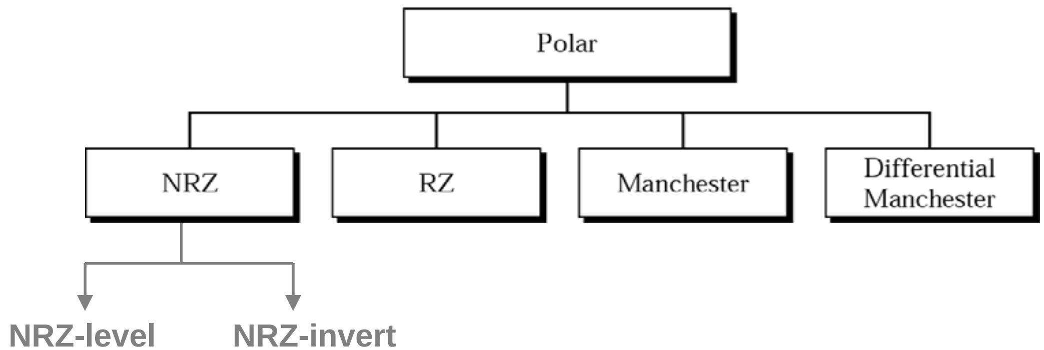


Polar Coding

Polar Line Coding – uses <u>two non-zero voltage level</u> for representation of two data levels – one positive and one negative

- "DC-problem" alleviated ☺

- 4 main types of polar coding:



(1) Nonreturn to Zero (NRZ)

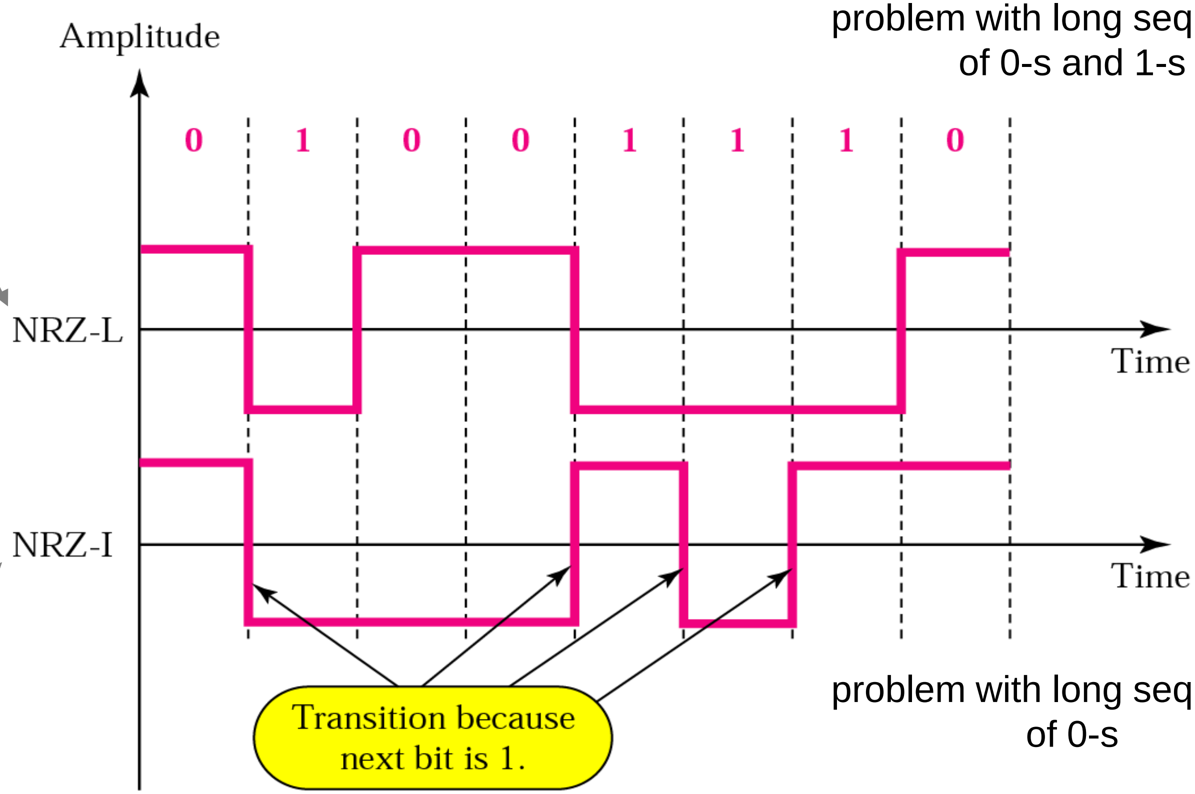
- NRZ-level: signal level represents particular bit, (e.g.) 0 = positive volt. , 1 = negative volt.
  - lack of synchronization for long series of 1-s & 0-s ☹

- NRZ-invert: inversion of voltage level represents bit 1, no voltage change represents bit 0
  - 1s in data streams enable synchronization
  - long sequence of 0-s still a problem ☹

Polar Coding (NRZ)

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

Data is represented by signal level.



Logical ‘1’ is represented by <u>change</u> in signal level.

problem with long sequences of 0-s

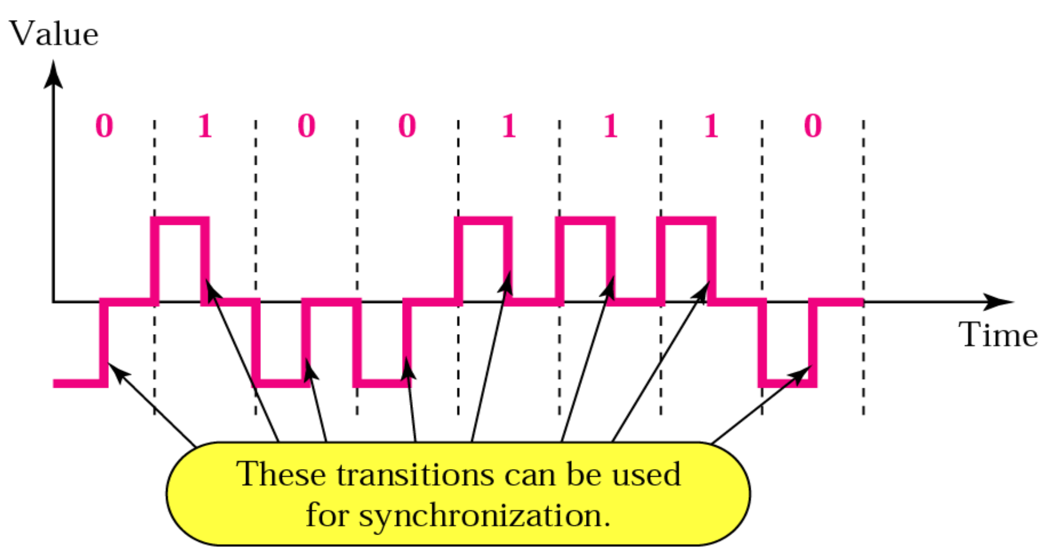
NRZ-I is better than NRZ-L, but it still does not provide complete synchronization.

To ensure complete synchronization, there must be a signal change for each bit.

Polar Coding (RZ)

(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, <u>regardless of bit sequence</u> ☹



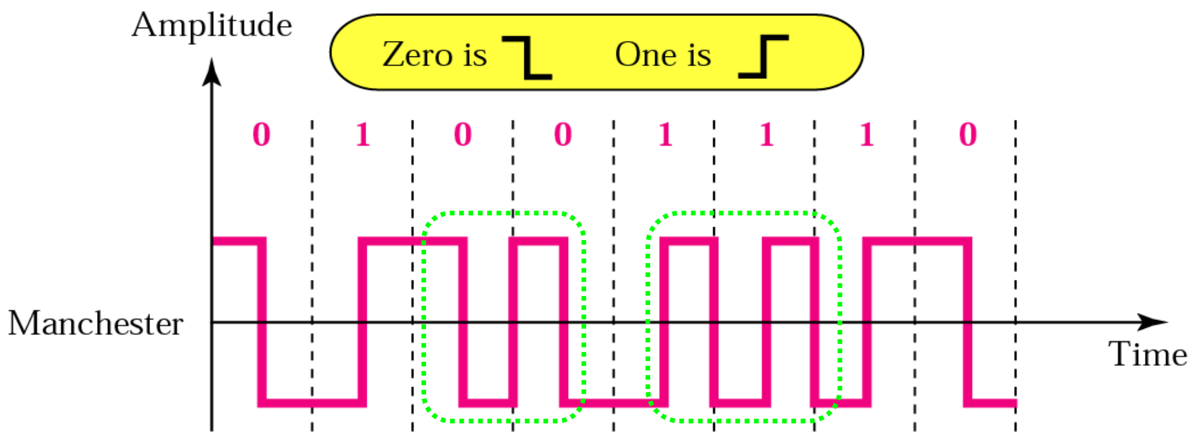
Non-zero level ⇒ beginning of a new bit.

Manchester code

(3) Manchester

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

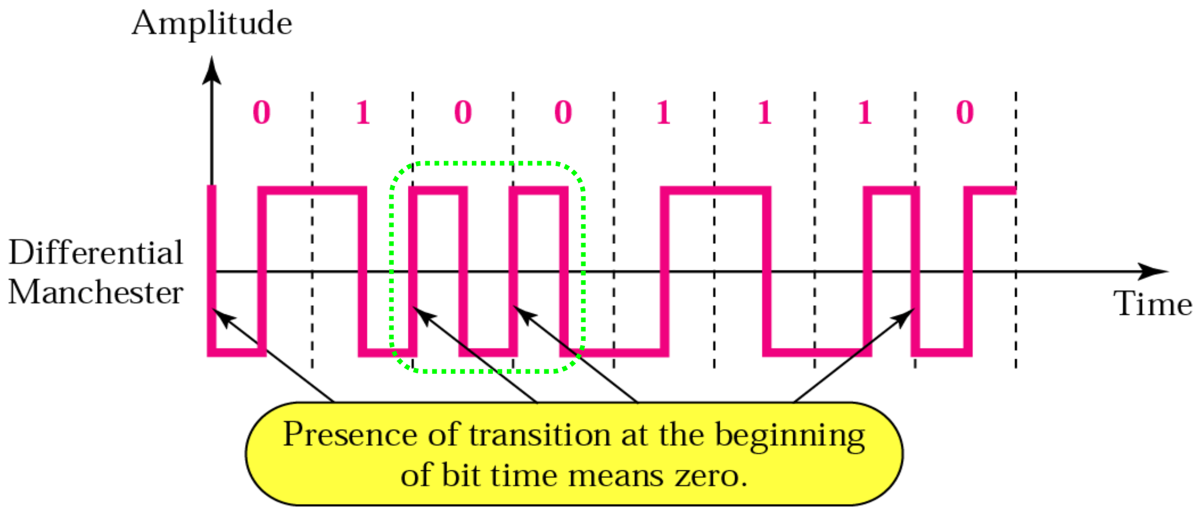
- 0 = pos-to-neg transition, 1 = neg-to-pos transition
- perfect synchronization ☺
- there is always transition at the middle of the bit, and maybe one transition at the end of each bit
- fine for alternating sequences of bits (10101), but wastes bandwidth for long runs of 1-s or 0-s ☹
- used by IEEE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



Differential Manchester code

(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

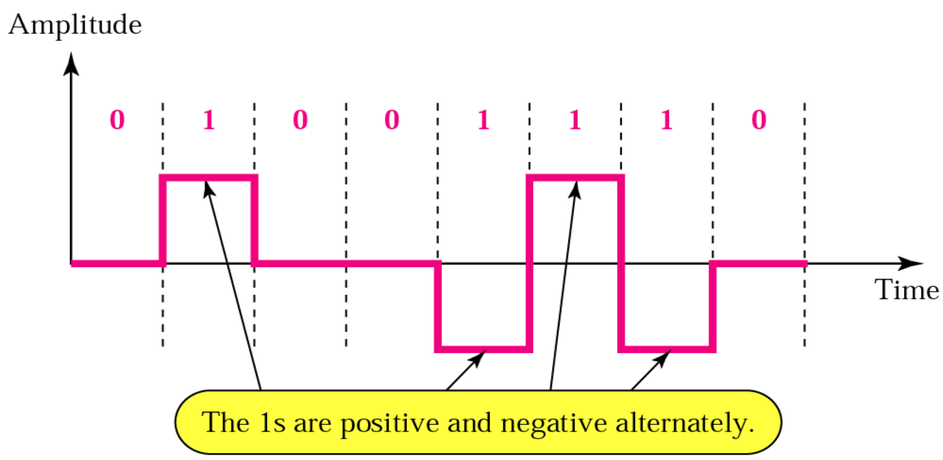
- 0 = transition, 1 = no transition
- perfect synchronization ☺
- fine for long runs of 1s, but wastes bandwidth for long runs of 0-s ☹
- used by IEEE 802.5 (Token Ring)



Bipolar Code

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
- e.g. if 1st 'bit 1' is represented by positive amplitude, the 2nd will be represented by negative amplitude, the 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)

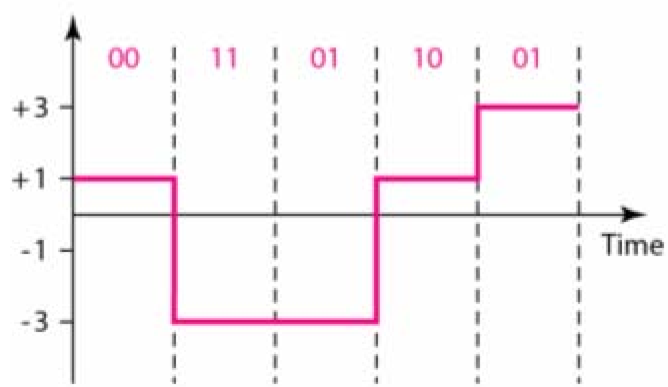
2B1Q (2 Binary 1 Quaternary) Coding

– 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

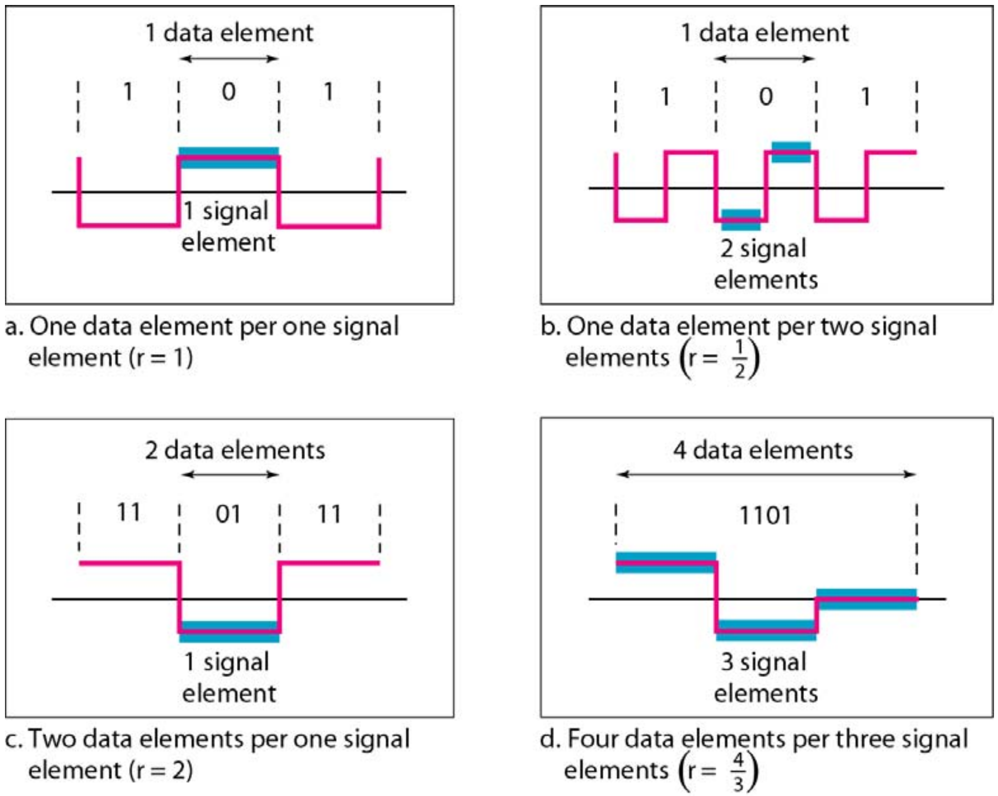


Assuming positive original level

Data Rate vs. Baud Rate

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

Signal Rate – number 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).

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