

Digital Encoding

- NRZ- L and NRZ- I
- Manchester
- Differential Schemes
- Differential Manchester
- 4B\5B
- Issues of efficiency and clocking.

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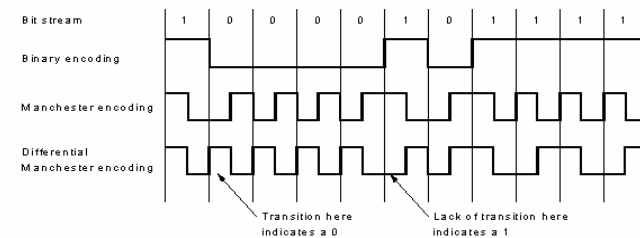


Fig. 4-20. (a) Binary encoding. (b) Manchester encoding. (c) Differential Manchester encoding.

Encoding (Notes)

- NRZ-L is used for short connections (RS232) but not for longer connections. Positive denotes a '0' and negative denotes a '1'. (L refers to level).
- **NRZ-I (Inverted)** is a differential scheme where a transition denotes a '1', and no transition denotes a '0'. With differential coding schemes a signal is decoded by comparison of the polarity of adjacent signal elements, rather than determining the absolute value of a signal element.

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- An advantage of this scheme is that it may be more reliable to detect a transition, in the presence of noise, rather than to compare a value to a threshold. Differential encoding on a twisted pair medium is also immune to the wires being crossed as the thresholds are not being examined, but the transitions are. After all a transition from +ive to -ive is just as much a transition as from -ive to +ive.
- There is a requirement for clocking information to be embedded in the data. One technique which does this is called *Manchester Encoding*, and a variation on it is called *Differential Manchester Encoding*. These schemes are called **biphase codes**.
- In the binary encoded signal there is no clock information, i.e. nothing to differentiate repeating digits.

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- In **Manchester Encoding**, each bit period is divided into two equal intervals, thus the name **biphase**. There is always a transition between these intervals (thus clocking). A binary '0' is represented as having the first interval set high and the second interval set low. A binary '1' is the reverse -- the first interval is low and the second high.
- Advantage: always a transition in each bit, thus making synchronisation between sender and receiver possible.
- Disadvantage: requires twice as much bandwidth as plain binary coding.
- Differential Manchester Encoding scheme distinguishes 1's and 0's by using a transition at the start of a period to indicate a '0' and no transition to represent a '1'. A transition in the middle of the period between the two intervals is still used to help provide clocking information, just as in Manchester Encoding.

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- This differential scheme is more complex to operate but is more immune to noise. An error must invert the signal before and after expected transitions to cause undetected errors. It also requires twice the bandwidth of ordinary binary encoding.
- In differential encoding schemes, it is the *transition* from one voltage level to another that distinguishes bit values, not the *voltage levels*. This makes the coding scheme more immune to noise.
- If there are two wires carrying a signal from one device to another and the wires are accidentally confused, then this does not affect the interpretation of the data as the transitions in voltage levels will still be correctly interpreted. The signal levels are not important, only the transition from one state to another.

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4b\5b Coding

- Greater efficiency may be achieved than that of Manchester Codes (50%). One such better scheme is 4B/5B.
- Each four bits are coded in a symbol with 5 *cells* where each cell contains a single signal element. So each group of four bits (nibble) is encoded as 5 bits. This raises the efficiency to 80% for this scheme, as opposed to Manchester encodings 50%.
- Synchronisation is achieved by including a second stage of encoding. Each cell of the 4B/5B stream is treated as a binary value itself and encoded using a NRZI scheme. This takes on the advantages of differential encoding.

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- Only 16 of the possible 32 bit patterns generated from 5 bit code are required to represent the 4 bit data patterns.
- The 5B codes selected to represent the 16 4-bit data blocks are such that a transition is present at least twice for each 5-cell (or 5-bit) code.
- This minimum transition rule aids synchronisation by including an element of clocking.
- 4b5b Coding is utilised in 100 Mb Ethernet

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100 Mbps 4B5B Code

- 4-bit 5-bit
- 0 0000 11110
1 0001 01001
2 0010 10100
3 0011 10101
4 0100 01010
5 0101 01011
6 0110 01110
7 0111 01111
8 1000 10010
9 1001 10011
A 1010 10110
B 1011 10111
C 1100 11010
D 1101 11011
E 1110 11100
F 1111 11101

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MLT

- A 100 MHz data stream that uses a 4B/5B encoding results in a 125 MHz signal.
- 125 MHz signal is itself encoded as a mult-level signal using three signal levels (instead of the two levels used in Manchester encoding).
- The three signal levels are -1, 0, +1.
- This reduces the bandwidth required on the physical cable to only 31.25 MHz, which is within the specification of the CAT5e cable used in UTP.

NRZ	0	0	0	1	0	0	1	0	1	1	0	1	0	
MLT-3	0	0	0	+	+	+	0	0	-	0	+	+	0	0

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8b/10b Coding in Gigabit Ethernet

- Gigabit Ethernet utilises five levels and 8b/10b encoding, to provide even more efficient use of the limited cable bandwidth, sending 1 Gbps within 100 MHz of bandwidth.
- The 10 bit code must contain either five ones and five zeros, or four ones and six zeros, or six ones and four zeros. This prevents a sequence of too many consecutive ones and zeros, assisting clock synchronisation.

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