
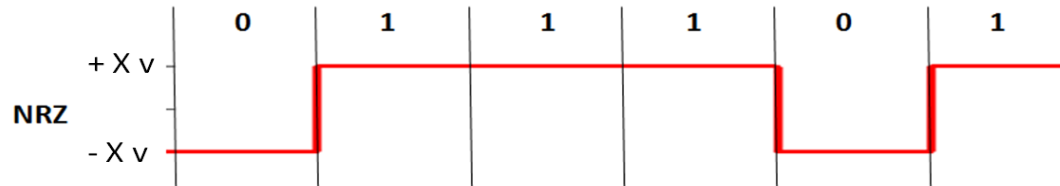


Line Codes

Kameswari Chebrolu

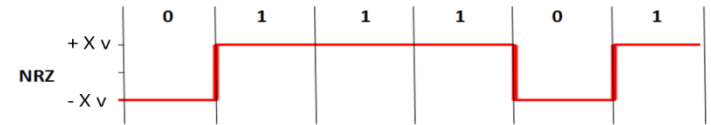
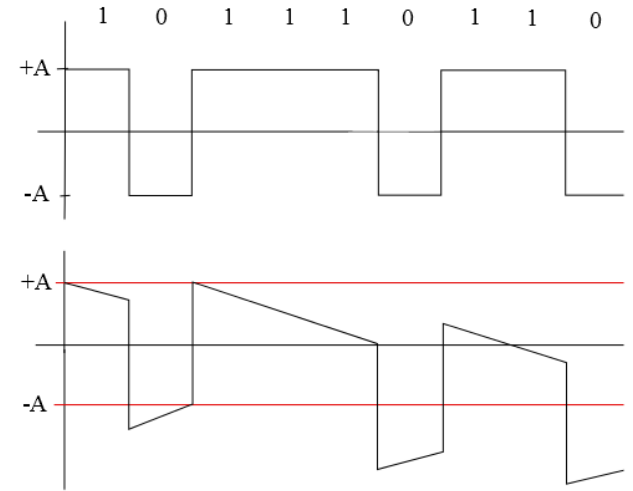
Quick Recap

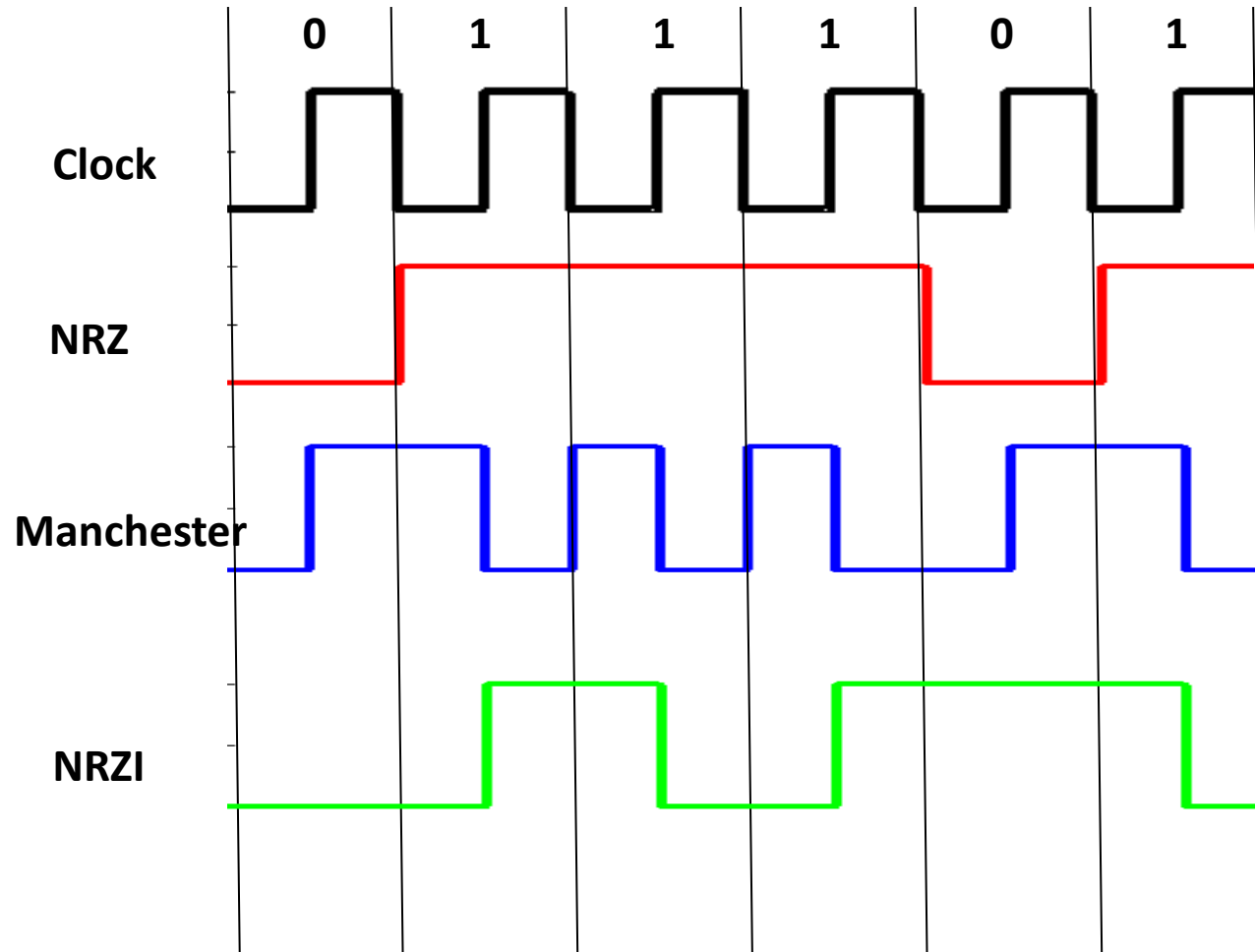
- Data: 10111011  Wire Pair
- Line coding converts bits to voltage or power levels
- Non Return to Zero (NRZ): Represent 0 and 1 by two different levels



Decoding

- How does a receiver decode the data i.e determine bits from waveform?
- Compare with a threshold
 - Receiver maintains average of the signal, uses average to distinguish between low and high signals
- Clock to determine bit durations
 - Receiver's clock need to be perfectly synchronized with the sender, otherwise it results in errors
 - Clock should preferably be derived from the received signal itself
 - Transitions in received signal help recover the clock



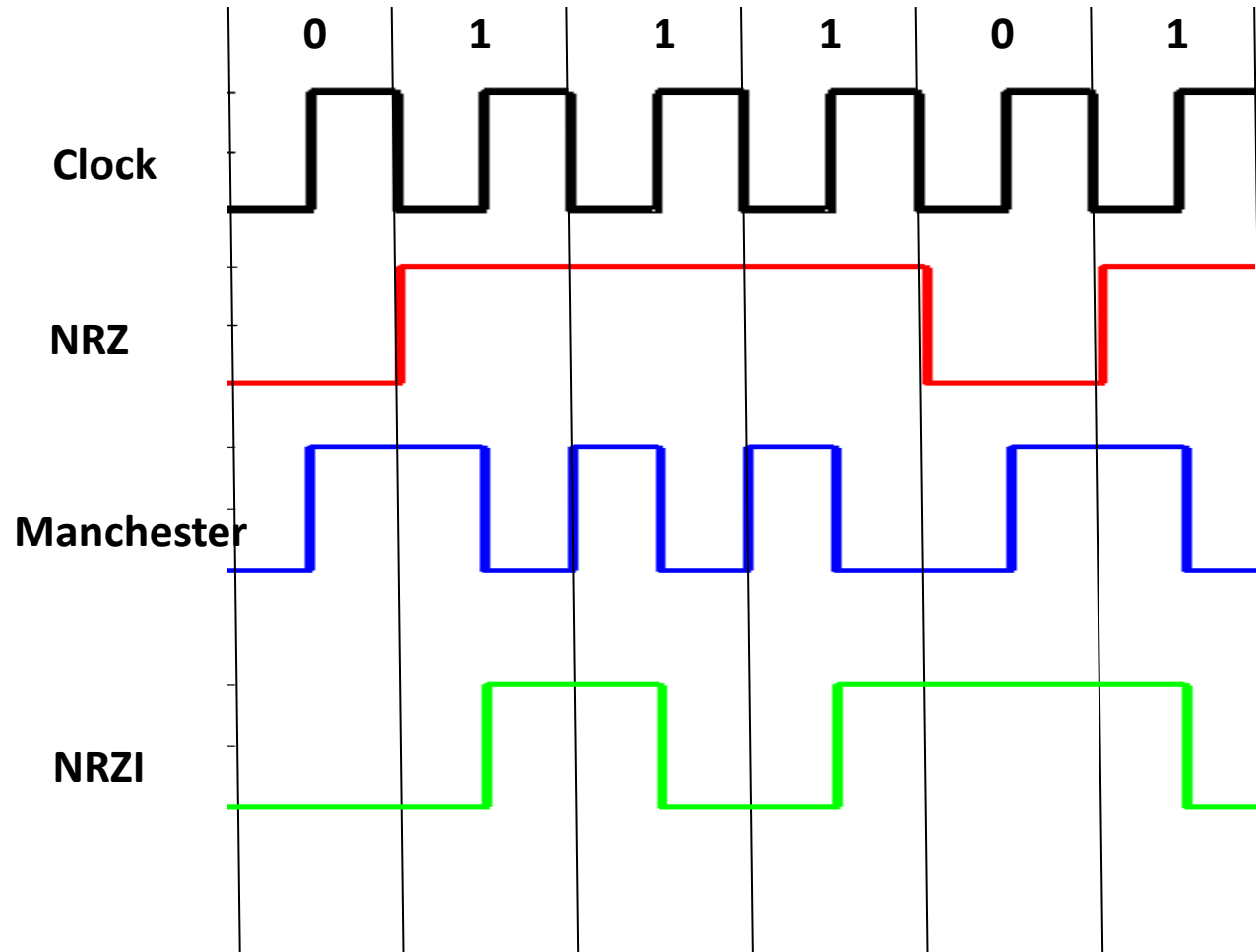


Problems with NRZ

- Consecutive 1s or 0s
 - Changes the average leading to errors (*baseline wander*)
 - Lesser number of transitions leads to clock drift between sender and receiver
- Goal of Line Encoding: Provide enough number of transitions in the signal (over a specified interval)

NRZ-Inverted (NRZI)

- Form of differential encoding
 - To encode a 1, make a transition
 - To encode a 0, stay at the current signal
- Used in USB

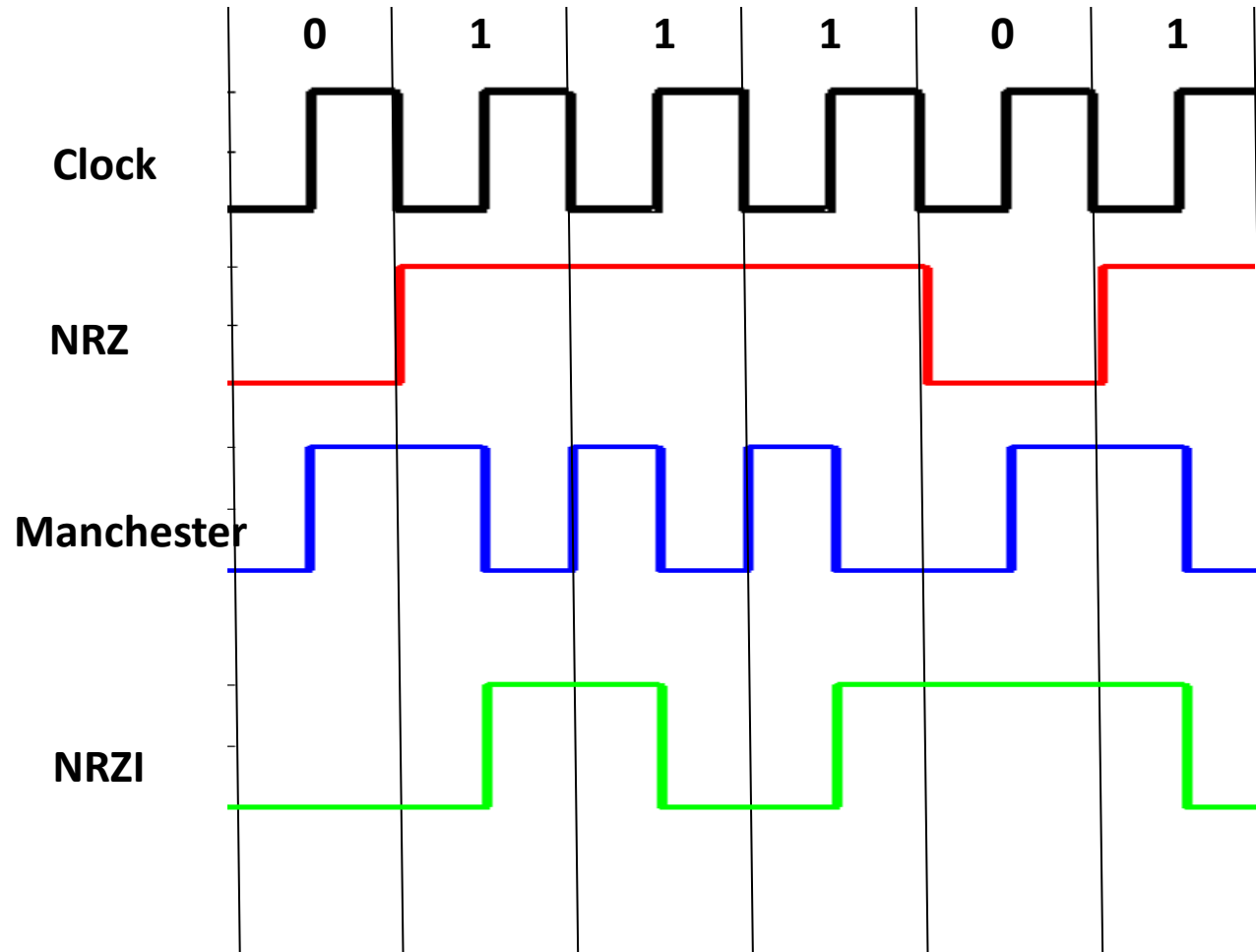


NRZ-Inverted (NRZI)

- Advantages:
 - Works well in presence of noise (detecting transitions easier than comparison with threshold)
 - Eliminated baseline wander
 - Accidental inversion of leads from device to twisted pair has no effect
- Solves problem of consecutive 1's but not 0's
 - Clock recovery is difficult in presence of consecutive 0's
 - Signal can have a dc component

Manchester Encoding

- Transmits XOR of the NRZ encoded data and the clock
 - 0 is encoded as low-to-high transition
 - 1 as high-to-low transition
- Used in Ethernet (10Mbps)



Manchester Encoding

- Advantages:
 - Eliminates both baseline wander
 - Easy synchronization (self-clocking)
 - No DC component
- Disadvantage: Only 50% efficient
 - Maximum encoding rate is twice that of NRZ (more number of transitions) → Require more bandwidth
 - One could send twice as many bits in the same time period with NRZ, NRZI

4B/5B Encoding

- Used in Ethernet (100Mbps), FDDI
- Every 4 bit of actual data is encoded into a 5 bit code
- The 5 bit code words have
 - No more than one leading 0
 - No more than two trailing 0s
- Solves consecutive 0s problem
- The 5 bit codes are sent using NRZI (solves consecutive 1's problem)
- Achieves 80% efficiency

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

Summary: Encoding

- Encoding transforms string of bits to voltage levels
- Goal of many encoding techniques
 - Provide enough transitions for clock recovery
 - Achieve above while minimizing bandwidth
- Looked at a variety of line codes: NRZ, NRZI, Manchester, 4B/5B
 - Each has certain advantages and disadvantages

Summary: Physical Layer

- Goal of physical layer is to transfer bits on a link
- Hardware components: Node, Links
- Data Transformation: Line codes and Passband modulation
- Theory behind data-rates, error rates and delays experienced on links
- Looked at encoding techniques (line codes) used in popular **wired** links