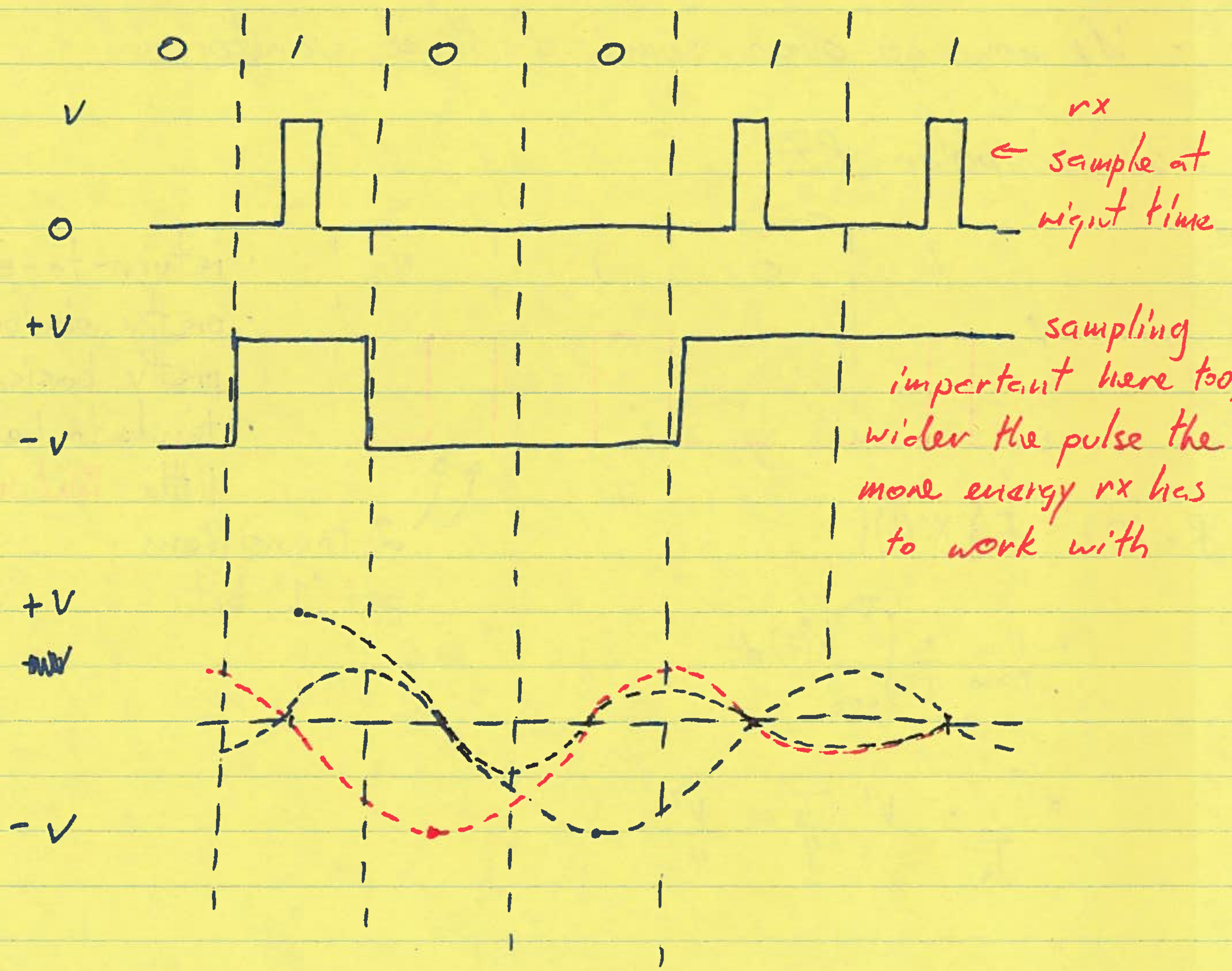
L7 Baseband Transmission (Line Coding)

7.1 Waveform Representation of Bits

- PCM is the binary end-product of A/D conversion
- The bits could have come directly from some digital source themselves as far as the transmitter is concerned
- But when we transmit these over a real channel we need to express them in terms of some REAL CONTINUOUS WAVEFORM

e.g.



- clearly we have some choice in choosing a useful waveform representation

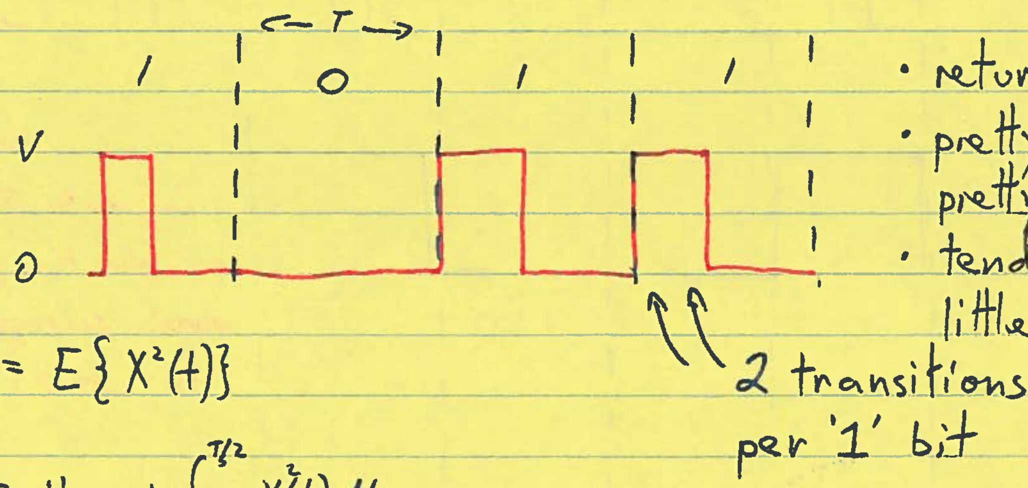
- this is a form of modulation (we multiply our digital levels by some waveform) but without actually introducing a high frequency carrier

- rather the signal largely (not always totally) remains baseband (most of its avg. power lumped around DC)

- this type of modulation is often referred to as LINE CODING

- We now go over some of these waveforms

7.2 Unipolar RZ



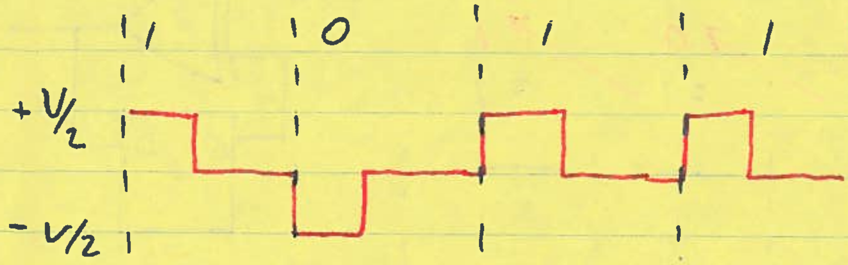
- return-to-zero
- pretty obvious & pretty basic
- tends to be a little BW hungry

$$R_x(0) = E\{X^2(t)\}$$

$$= \lim_{T\to\infty} \frac{1}{T_s} \int_{-T/2}^{T/2} X^2(t)\,dt$$

$$= \frac{1}{T_s} \cdot V^2 \cdot \frac{T_s}{4} = \frac{V^2}{4}$$

7.3 Bipolar RZ (AMI alternate mark inversion RZ)



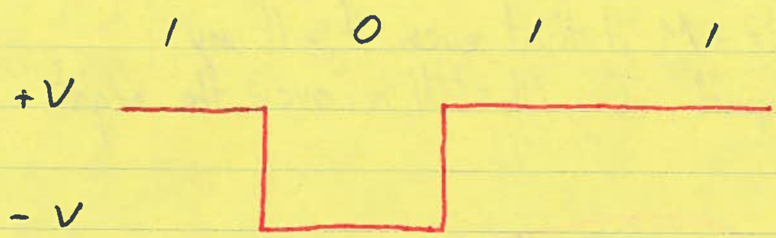
- same basic properties
- can be a little more energy efficient
  ↓
  varying symmetrically from $+\frac{V}{2}$ to $-\frac{V}{2}$

$$R_x(0) = \lim_{T\to\infty} \frac{1}{T_s}\int_{-T_s/2}^{T_s/2} x^2(t)\,dt = \frac{1}{T_s}\cdot\frac{V^2}{4}\cdot\frac{T_s}{2}$$

$$= \frac{V^2}{8}$$

- good for timing, always get a transition

7.4 NRZ-L (Level) (Polar NRZ)/(NRZ Change)



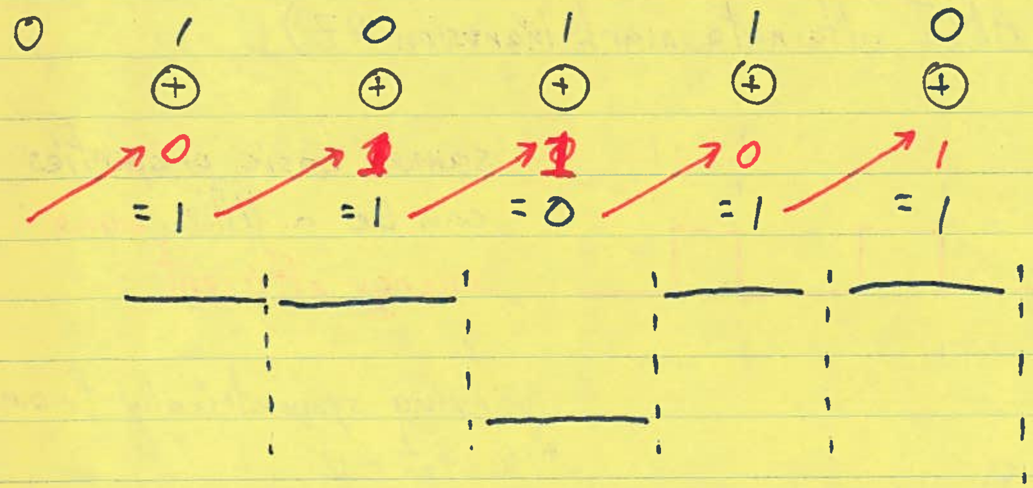
- less BW needs
- timing problems

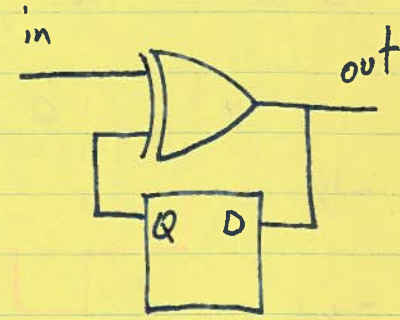
7.5 Differential NRZ NRZ-M (Mark) (Differentian Encoding)

~~'Hi' (mark) represents change in bits 'Lo' (space)~~

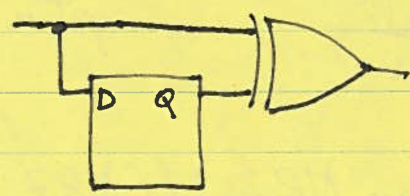
a schem with memory

- if bit to send differs from last bit send → send a 1 (mark)
- " " " " same as " " " → send a 0 (space)





- NRZ-M decoder?



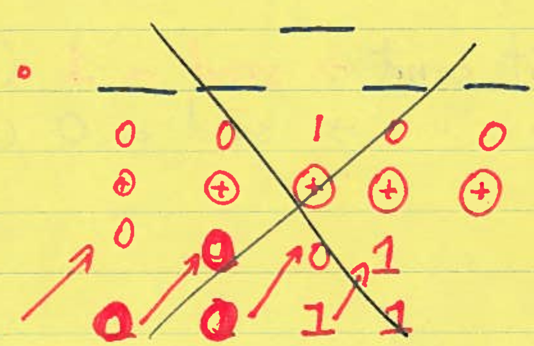
- again comparing current + previous

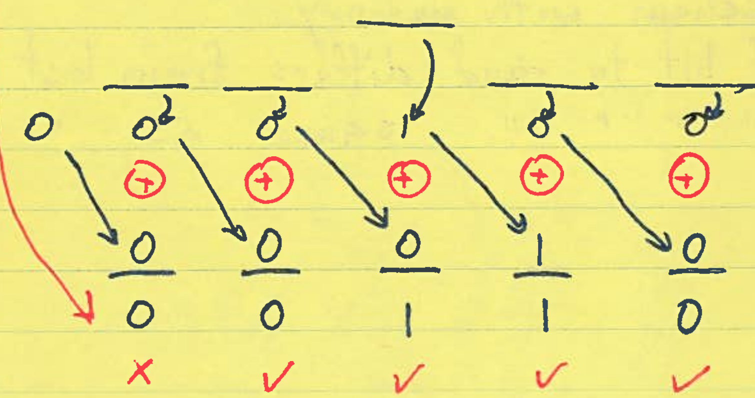
- nice property of NRZ-M it that even if all my received bits are flipped, I will still recover the right sequence

(maybe after brief initial error) since I'm comparing the difference between adjacent bits in time

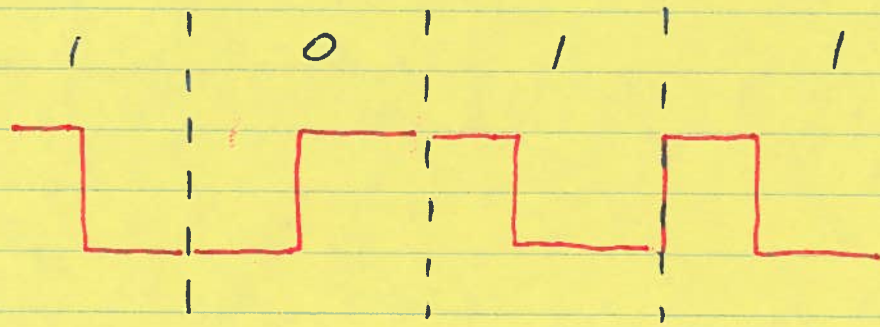
- flipped twisted pair
- 180° flip in wireless

e.g. if receive





7.6 Phase Encoded / Bi-ϕ-L / Manchester Coding



- good for synch since guarantees transition

- a form of 1B2B coding... send 2 pulses for every bit
- other ~~that~~ techniques like 4B5B
  - $\leq$ 5 consecutive 1's & 0's
  - balances 1's & 0's such that no more than 2 apart over any stream (better DC removal)
  - 8B10B
  - 64B66B (10G Ethernet)

7.7 Spectra (for sigs with variation of V: 0 → V, $-V/2 \to +V/2$