Lecture 7 - Line Codes

Exercise 1: What is the noise margin for ~~a unipolar li~~ne code using levels of ± 1 V? What are the voltage levels for a ~~bipo-lar~~ lines with the same noise margin? What are the RMS voltages of these two line codes when transmitting a dotting sequence (alternating 1's and 0's)? Why might you use unipolar line codes anyways?

bipolar

1v

unipolar

0-2V

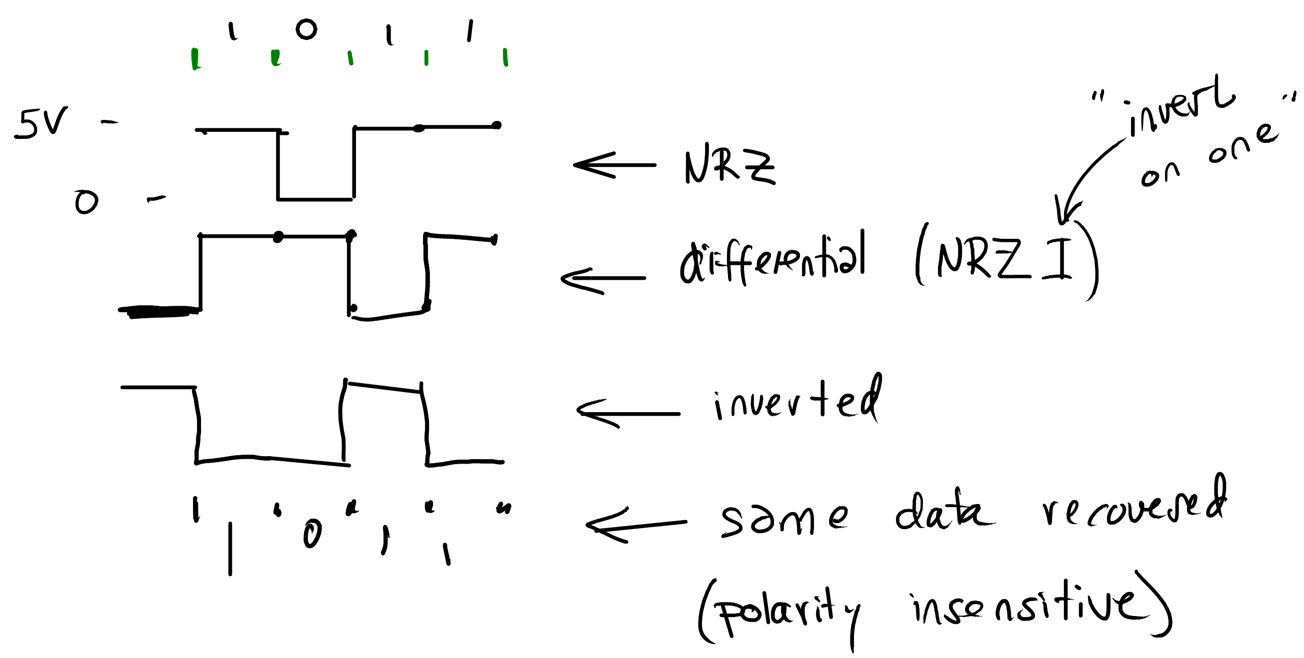
RMS: $\sqrt{\sum p_i v_i^2}$

bipolar: $\sqrt{\frac{1}{2}(+1)^2 + \frac{1}{2}(-1)^2} = 1$

unipolar: $\sqrt{\frac{1}{2}(0)^2 + \frac{1}{2}(2)^2} = \sqrt{2}$ ← needs more power for same noise margin

unipolar is simpler (only one voltage).

Exercise 2: Assume a 1 is transmitted as 5V and 0 as 0V. Draw the waveform for the bit sequence 1011. Draw the waveform if the bits are transmitted differentially with a 1 encoded as a change in level. Assume the initial value of the waveform is 0. Invert the waveform and decode it.



binary).

Exercise 3: How many combinations are there of 3 bits? Of 4 bits? How many bits might be input and output by an 8B10B code? What might a 4B3T code mean?

8

$2^3 = 8$

$2^4 = 16$

16

8in, 10 out

16, 3^3=27

The advantage of a block code is that the possible

8in, 10 out

4B3T: 4 binary
3 ternary

Exercise 4: Design your own 2B3B line code by choosing the output waveforms that have the lowest average DC value and giving preference to those that start and end at different levels (assume bipolar signalling).

2 B	3 B
0 0	+ − −
0 1	− + +
1 0	− − +
1 1	+ + −

DC value

−1 −1 −1 −3
− − + ✓ −1
− + − −1
− + + ✓ +1
+ − − ✓ −1
+ − + +1
+ + − ✓ +1
+ + + +3

÷3 = average

Exercise 5: A link operates at 100 Mb/s. What is the bit period? The transmitter and receiver have independent clocks (oscillators) with accuracies of ±100ppm. What is the maximum difference between the two clock periods in ppm? In seconds?

How many bits would it take for the two sides to drift by 10% of the bit period.

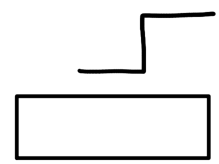
– $f = 100 \times 10^6$ $\quad T = \frac{1}{100 \times 10^6} = \frac{1}{10^8} = 10^{-8} = 10 \times 10^{-9}$
$= 10ns.$

– $\Delta_{max} = 200$ ppm $\quad 200 \times 10^{-6} \cdot 10 \times 10^{-9} = \underline{2 \times 10^{-12}}$

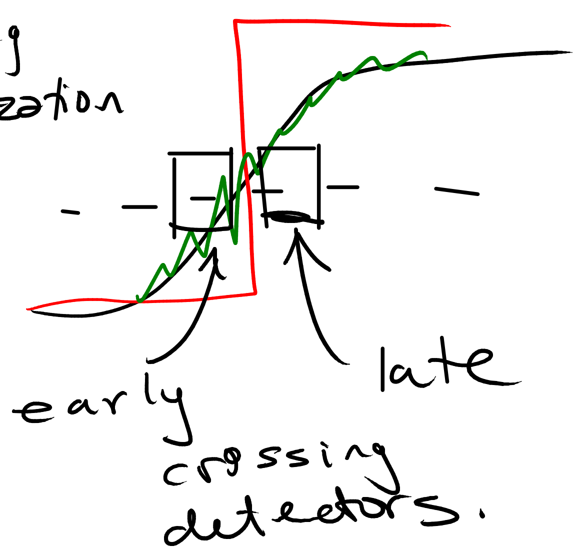
10 ns – 100 ppm $\quad$ 10 ns + 100 ppm.

10% accumulated error
= 10% of 10ns
= 1ns

$$\frac{1 \times 10^{-9}}{2 \times 10^{-12} \text{ s/bit}} = 500 \text{ bits.}$$



bit timing synchronization



(one method of many)

Exercise 6: A data link operates over a distance of 10m at 100 kb/s. If the velocity factor of the cable is 0.66, what is the propagation delay in microseconds? What fraction of the bit period does this represent?

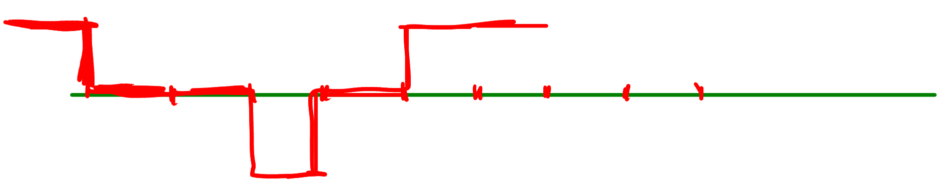
$$\frac{\frac{10m}{0.66\cdot 3\times10^{8} m/s}}{\frac{1}{100\times10^{3} s^{-1}}} = \frac{5\times10^{-8}}{10^{-5}} = 5\times10^{-3}$$

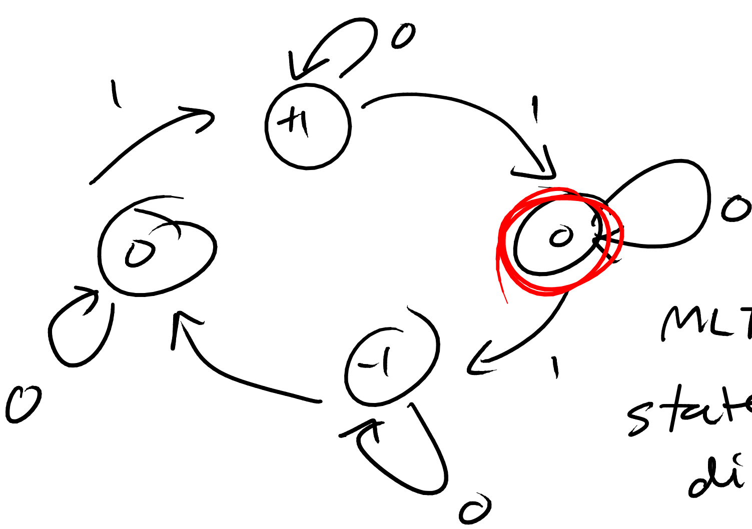
$= 5\%$ (small)

Exercise 7: How would the bit sequence 0110 be encoded using 4B5B followed by MLT3 assuming the starting level is 0V?

0110 → 01110

0 1 1 1 0





MLT-3 encoder state transition diagram