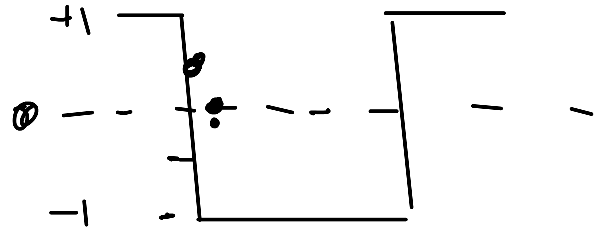
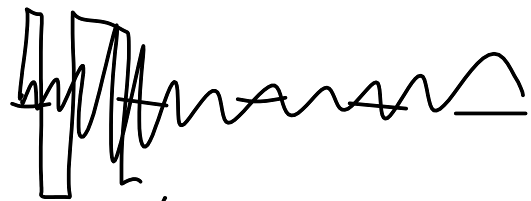
Lecture 5 - Line Codes

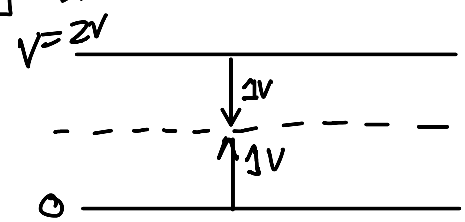
Exercise 1: What is the noise margin for a ~~uni~~ bipolar line code using levels of ± 1 V? What are the voltage levels for a ~~bi~~ unipolar lines with the same noise margin? What are the RMS voltages of these two line codes when transmitting a dotting sequence (alternating 1's and 0's)? Why might you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

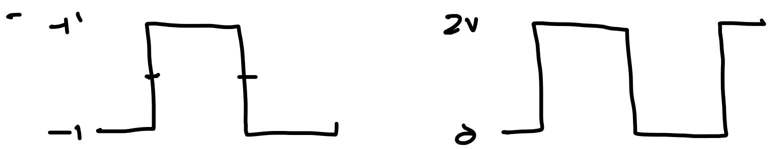




$$+1 - 0.5 = 0.5$$

- noise margin : = 1V
- voltage levels of 0, 2V has some noise





- unipolar line codes are less power efficient but simpler.

$$\text{rms voltage} = \sqrt{\sum_i P_i V_i^2}$$

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

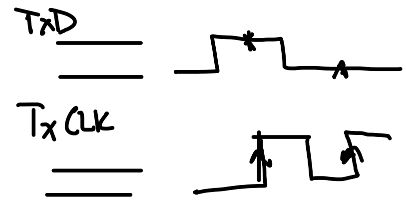
$$= \sqrt{1} = 1$$

$$\text{unipolar} = \sqrt{\frac{1}{2}(0)^2 + \frac{1}{2}(2)^2}$$

$$= \sqrt{0+2} = \sqrt{2} = 1.414\ldots$$

Exercise 2: 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?

The timing error due to a frequency (period) difference accumulates over time. How many bits will it take for the accumulated error to equal 10% of the clock period?



$200\text{ppm} = \frac{200}{10^6}$

$f_b = 100\,\text{Mb/s} \rightarrow T_b = \frac{1}{100\times10^6} = \underline{10\times10^{-9}} = 10^{-8}\,\text{s}$

max difference = 200 ppm

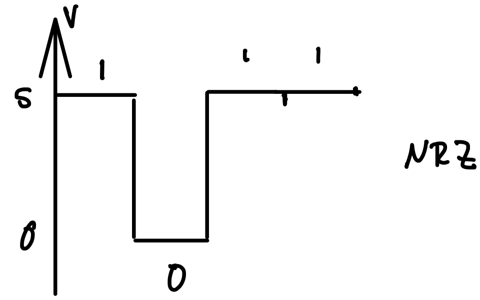
$\underbrace{200\times10^{-6}} \cdot 10\times10^{-9} = 2000\times10^{-15}$

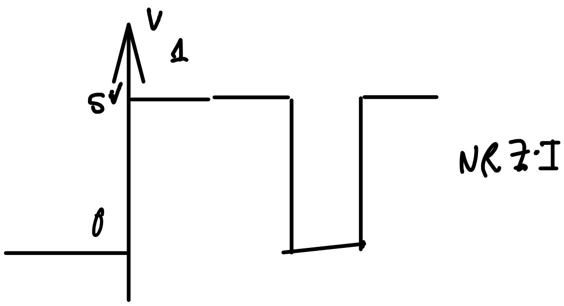
$= 2\times10^{-12}\,\text{s}$ time difference per bit

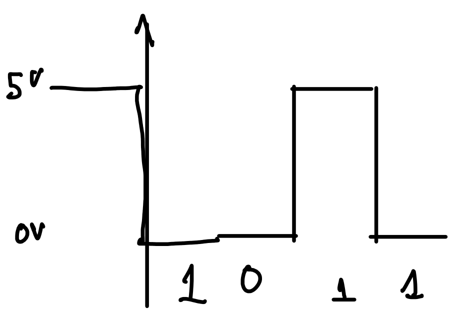
$\underbrace{10\% \cdot 10^{-8}}\ \text{s} = N \cdot \underline{2\times10^{-12}}\ \text{s/bit}$

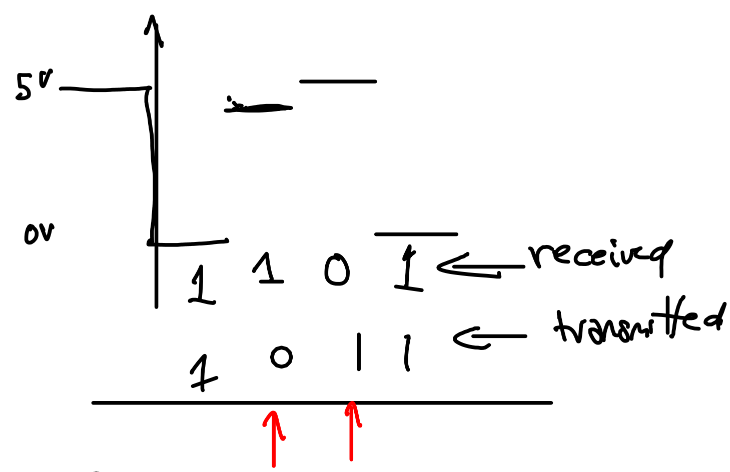
$N = \frac{10^{-9}}{2\times10^{-12}} = \frac{1}{2}\times10^{3} = 500$ bits

Exercise 3: 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.









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

3 bits → 2^3 combination

4 bits → 2^4 combinatiss

$\underline{8B}$ $\underline{10B}$

8 bits in   10 bits out

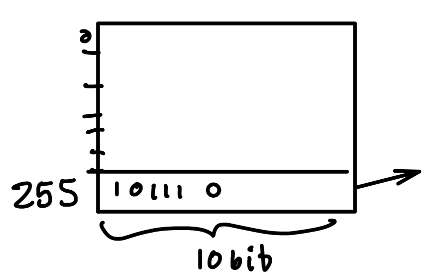
4B 3T

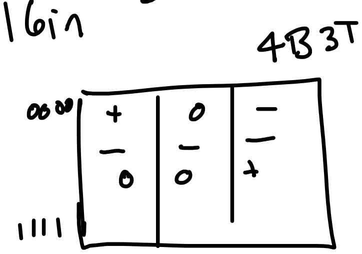
4 bits

16 in   27 out

$3 \times 3 \times 3 = 3^3$

$= 27$





Exercise 5: 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).

00	−	−	+
01	−	+	+
10	+	−	−
11	+	+	−

Ed's 2B3B Line code.

			aveg
~~−~~	~~−~~	~~−~~	~~−3~~
−	−	+	−1
~~−~~	~~+~~	~~−~~	~~−1~~
−	+	+	+1
+	−	−	−1
~~+~~	~~−~~	~~+~~	~~+1~~
+	+	−	+1
~~+~~	~~+~~	~~+~~	~~+3~~

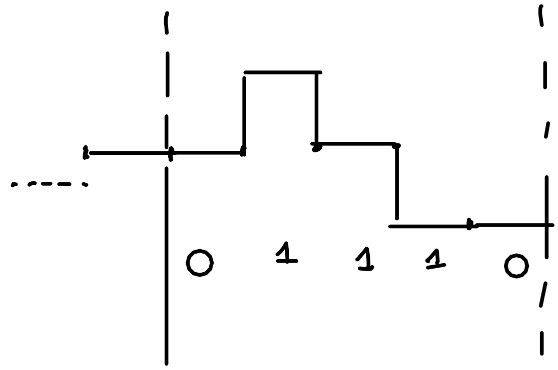
Exercise 6: A data link operates over a distance of 10m at 100 kb/s. If the velocity factor of the cable is 0.66, what is the propagation delay in microseconds? What fraction of the bit period does this represent?

$$\text{delay} = \frac{10\,\text{m}}{0.66 \cdot 3\times10^{8}\ \text{m/s}} = 5\times10^{-8}\ \text{s} = 50\ \text{ns.}$$

$$\text{fraction} = \frac{50\times10^{-9}}{\frac{1}{100\times10^{3}}} = \frac{50\times10^{-9}}{10^{-5}} = 50\times10^{-4} = 0.5\ \%$$

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

0110 → 01110



Exercise 9: What is the probability of having 30 consecutive 1's in a stream of random bits? Of 50 consecutive ones? How often would this happen at a bit rate of 1 Gb/s? (Hint: 1 Gb/s is about 2^{30} bits/second, there are about 2^{25} seconds per year).