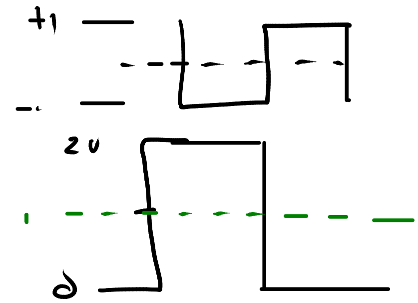
Line Codes

Exercise 1: What is the noise margin for a ~~unipolar~~ bipolar line code using levels of ± 1 V? What are the voltage levels for a ~~bipolar~~ 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?



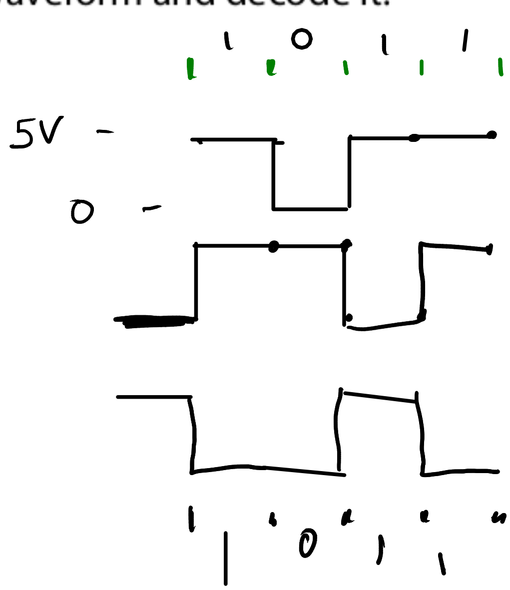
- noise margin = 1V
- unipolar may be simpler (only one voltage)

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

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

unipolar signalling requires more power for the same noise margin.

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.



← NRZ

← differential (NRZ I) "invert on one"

← inverted

← same data recovered (polarity insensitive)

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?

$2^3 = 8$

$2^4 = 16$

8B10B

IN OUT

3T

0000	+1 0 -1
0001	+1 +1 +1

16 — 16 / 27

IN	OUT
000	1010
001	0110

~~0000~~

~~0111~~

+1
0
-1

ternary (3 values)

4B 3T

$2^4 \to 3^3 = 27$

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

0 0	-1 -1 +1
0 1	- + +
1 0	+1 -1 -1
1 1	+1 +1 -1

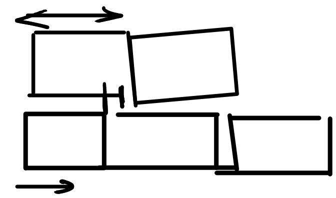
DC value

-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?

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?



$f_b = 100 \times 10^6$ Hz $\quad T_b = 10^{-8}$ s = bit period

$\Delta T_b = 100 - (-100) = 200$ppm = maximum difference in ppm (fraction of bit period)

$\Delta T_b = 200 \times 10^{-6} \times 10^{-8} = 200 \times 10^{-14}$ s = time error per bit

10% of $T_b = 0.1\,T_b = 10^{-9}$ s = max accumulated error

$$\# \text{bits} = \frac{10^{-9}}{200 \times 10^{-14}} = 500 \text{ bits}$$

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?

$$v = v_f \cdot c \approx 200 \times 10^6 \text{ m/s}$$

$$d = 10\text{m}$$

$$t = \frac{10\text{m}}{200 \times 10^6 \text{ m/s}} = \frac{10}{0.2 \times 10^9} = 5 \times 10^{-9} = 5\text{ns}.$$

$$f_b = 100 \text{ kb/s} \qquad T_b = \frac{1}{f_b} = \frac{1}{10^5} = 10^{-5} = 10\mu s.$$

$$\frac{5\text{ns}}{10\mu s} = \frac{5 \times 10^{-9}}{10 \times 10^{-6}} = 0.5 \times 10^{-3} = 0.05\%$$

$$= 500 \text{ ppm}$$

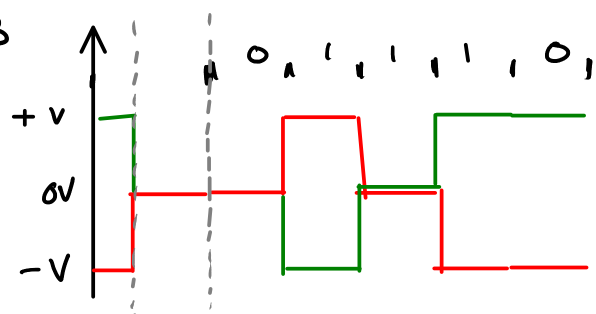
Exercise 7: How would the bit sequence 0110 be encoded using 4B5B followed by MLT3 assuming the starting level is 0V?

0 1 1 1 0	6	0 1 1 0	Data 6
0 1 1 1 1	7	0 1 1 1	Data 7

← 4B5B encoding table (from the IEEE 802.3 standard)

① 4B5B 0110 → 01110

② MLT3



two possible solutions depending on previous change