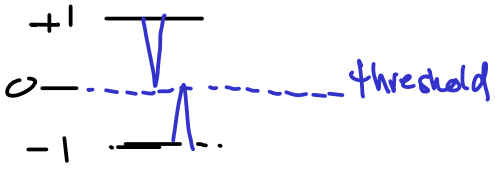
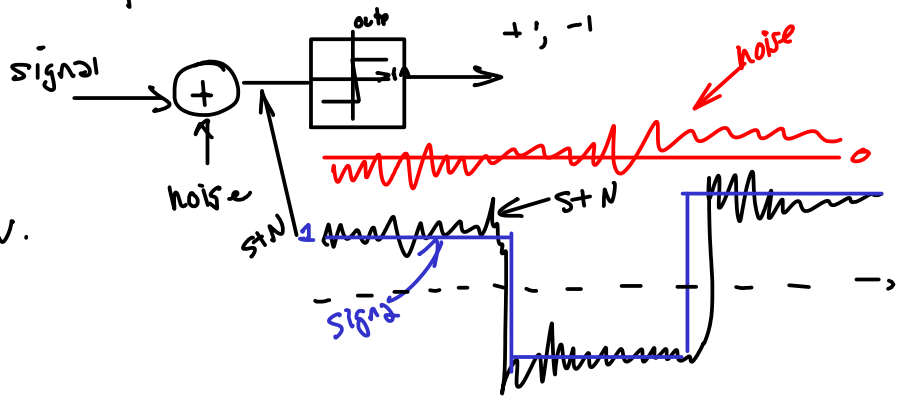
Line Codes

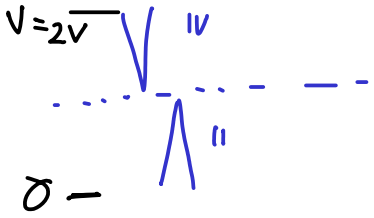
Exercise 1: What is the noise margin for a bipolar line code using levels of ± 1 V? What are the voltage levels for a unipolar line code with the same noise margin? What are the RMS voltages of these two line codes when transmitting a dotting sequence (alternating 1's and 0's)? Why might you use unipolar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

noise margin = voltage required to cause an error



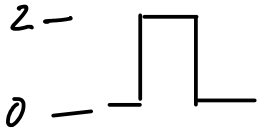
for ±1 noise margin is 1V.





$(-1)^2 = 1$ $(+1) = 1$ $+ = 2/2$ $= \sqrt{1} = 1$ = rms

square mean root



$(2)^2 \quad 4$

$+(0)^2 \quad 0$

$2 \quad \sqrt{2} = 1.4$ = rms voltg.

ppm = parts per million

1 ppm = 10^{-6}

1 % = 10^{-2}

100 ppm = 0.01 %

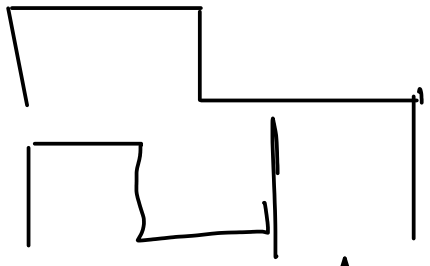
Exercise 2: A link operates at 100 Mb/s. What is the bit period? The transmitter and receiver have independent clocks (oscillators) with accuracies of 100ppm. What is the maximum difference between the two clock periods in ppm? In seconds?

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?

$f = 100 \times 10^6 = 10^8$

$T = \frac{1}{f} = 10^{-8} = 10 \times 10^{-9} = 10\,ns.$

$f = 106\,MHz$



← slower clock

$T_{slow} =$ ____

$f - 100ppm = 100 - \frac{100.}{100 \times 10^{-6}}$

$= 100 \times 10^6 - 1 \times 10^4$

$= 99.99$

← faster clock

$T_{fast} =$ ____

$f + 100ppm.$

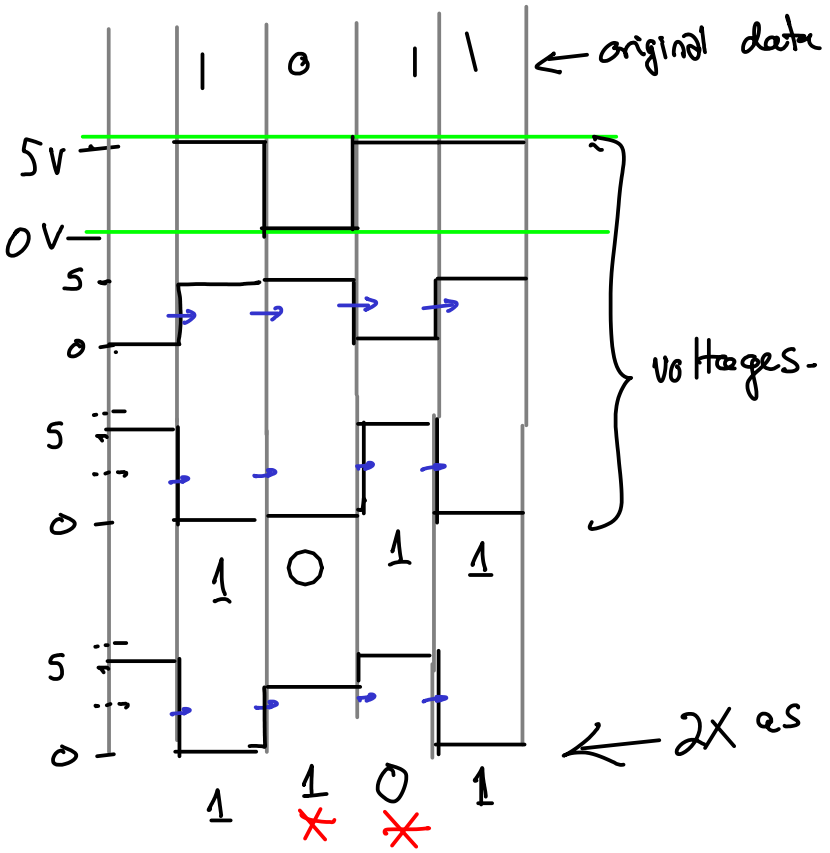
100.01

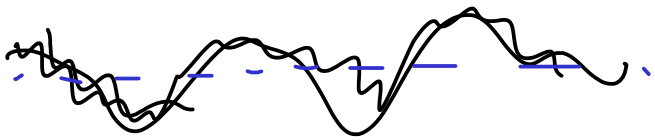
$\Delta T = T_{slow} - T_{fast} \approx 200ppm \cdot 10ns =$

approx $\frac{1}{200ppm} \times 10\%$ bits

$\approx$ 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.



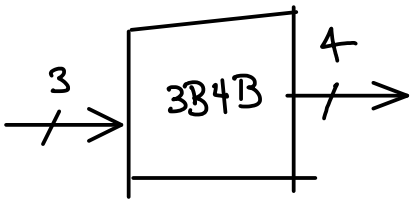


Exercise 4: How many combinations are there of 3 bits? Of 4 bits? How many bits might be input and output by an 8B10B code? What might a 4B3T code mean?

8 16

IN	OUT
000	0100
001	0010
010	1100
011	0111
100	1001
101	1110
110	0001
111	0101

16 6's 1's
16 1's



$2^3 = 8$ rows

$2^4 = 16$ possible outputs

000 001 → 0100 0010

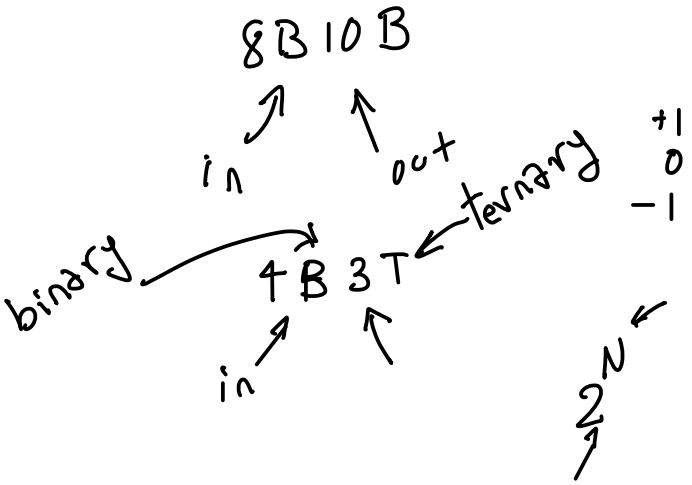
Start of frame.

1101 → ~~error!~~

0101 → 1111

0001 → End of frame.

1010 → idle pattern



16

$3 \times 3 \times 3 = 27$

3^3

0000	+ − −
0001	− 0 +
	0 0 −

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).

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?

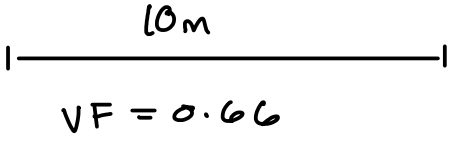
$$v = \frac{d}{t}$$

$$t = \frac{d}{v} = \frac{10}{c \cdot 0.66}$$

$c \approx 3 \times 10^8$

$$= 5 \times 10^{-8}$$

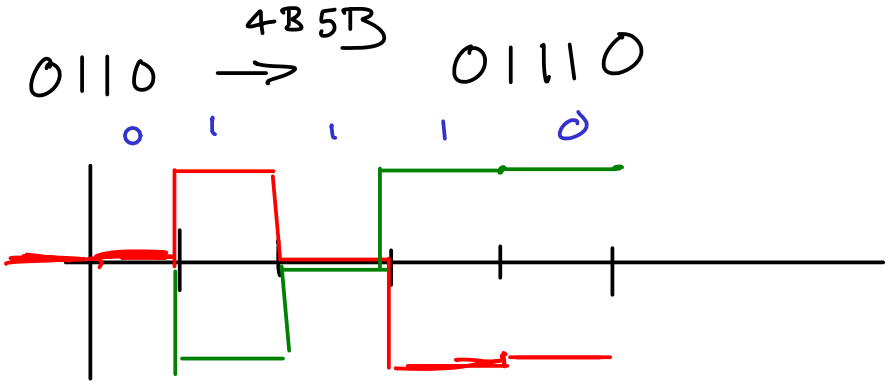
$$\approx \underline{50\,ns.}$$

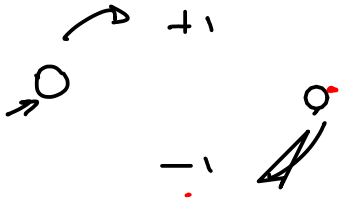


$f = 100$ kb/s $\quad T = 1 \times 10^{-5}\,s = 10\,\mu s$

$$\frac{5.0 \times 10^{-9}}{10 \times 10^{-6}} = 5 \times 10^{-3} = 0.5\,\%$$

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





Mid-Term Exam

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