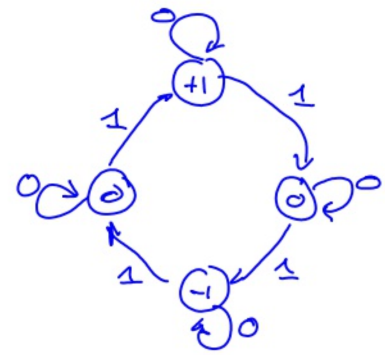
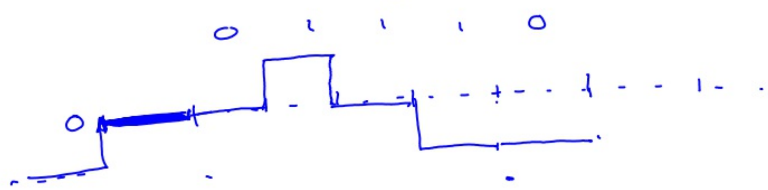
Line Codes

Exercise 1: How would the bit sequence 0110 be encoded using 4B5B followed by MLT3 assuming the starting level is 0V?



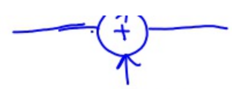
4B → 5B

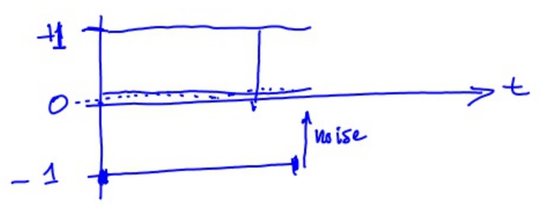
0110 → 01110



Exercise 2: What noise level is required to cause an error when using a bipolar line code with 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?

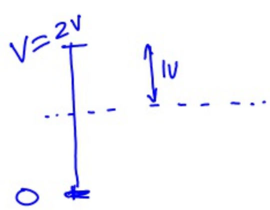
line codes anyways?



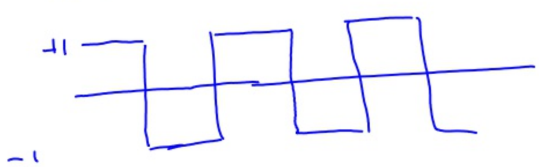


any voltage > 1V (-1)
< -1V (+1)

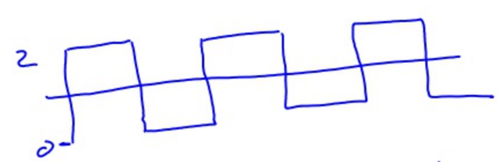
noise margin = 1V.



for same noise margin needs levels of 0, 2V.



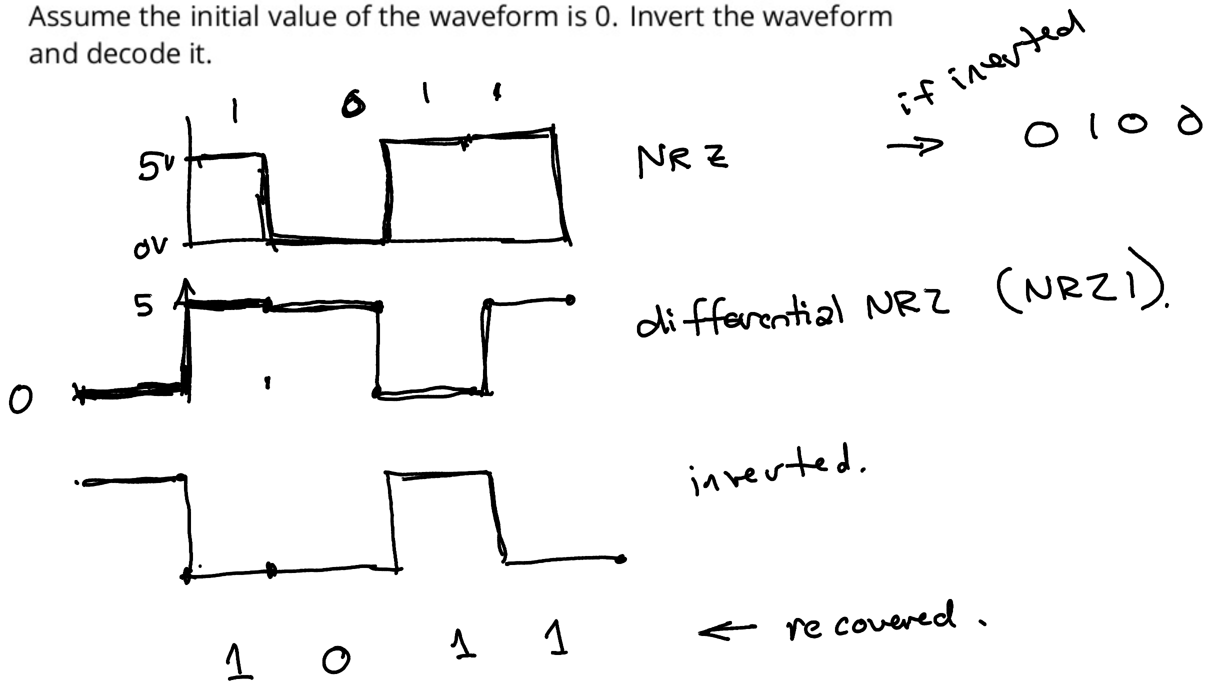
$rms = \sqrt{(\pm 1)^2} = 1\ V_{rms}$

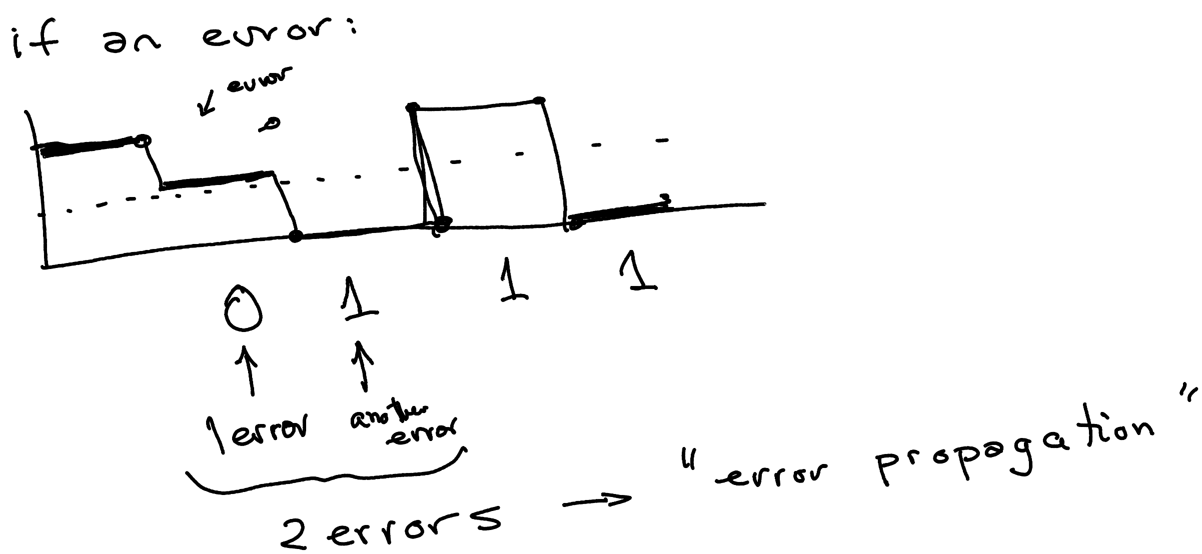


$rms = \sqrt{\frac{0^2 + 2^2}{2}} = \sqrt{2}\ V_{rms} \approx 1.4V.$

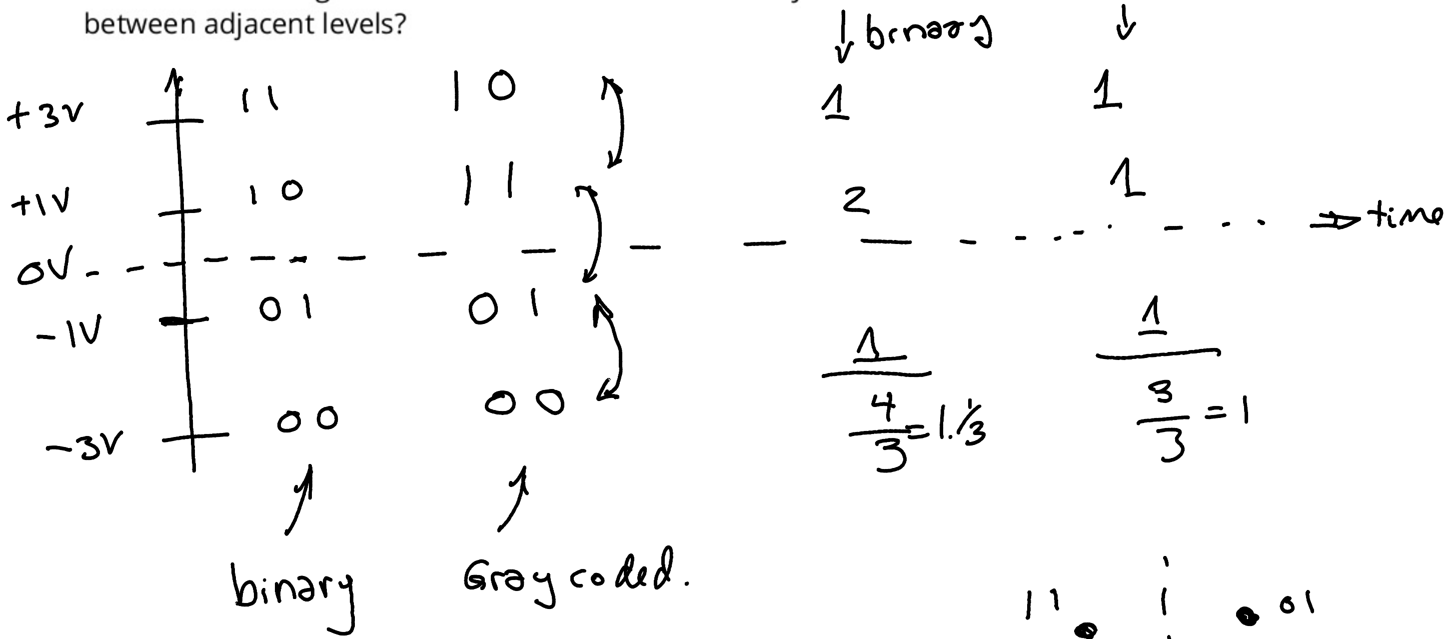
bipolar signals have lower rms voltages (power) with same noise performance.

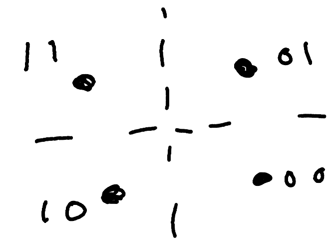
Exercise 3: Assume a 1 is transmitted as 5V and 0 as 0V. Draw the waveform for the bit sequence 1011. Draw the waveform if the bits are transmitted differentially with a 1 encoded as a change in level. Assume the initial value of the waveform is 0. Invert the waveform and decode it.





Exercise 4: Show the binary and Gray-coded encodings for PAM4. What is the average number of bits in error if the only errors are between adjacent levels?





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?

$f_b = 100 \text{ MHz}$

$T_b = \frac{1}{10^8} = 1\times10^{-8} = 10 \text{ ns}$

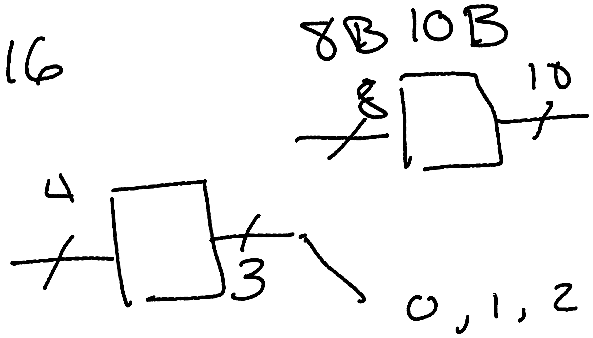
max diffence when one is $f_b + 100$ ppm
other is $f_b - 100$ ppm

diffevence = 200ppm

$200\text{ppm} \cdot 10\text{ns} = 200\times10^{-6} \cdot 10\times10^{-9} = 2\times10^{-12}\text{ s}$ (2ps/bit)

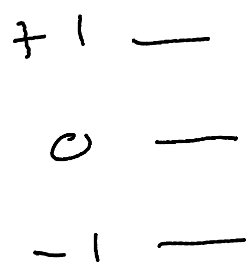
Exercise 6: How many combinations are there of 3 bits? Of 4 bits? How many bits might be input and output by an 8B10B code? What might a 4B3T code mean?

$2^3 = 8$ $\quad$ $2^4 = 16$



4B 3T →

16 input



+ + +
+ + −
+ − +
+ − −
⋮

$3 \times 3 \times 3 = 3^3 = 27$

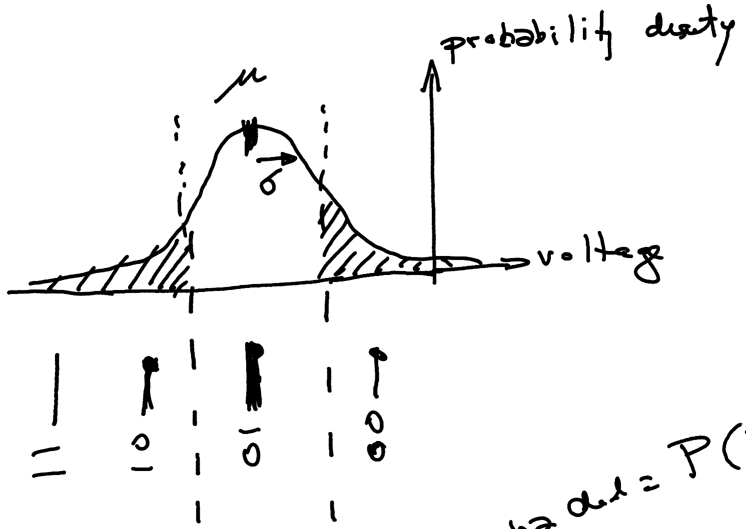
Exercise 7: Design your own 2B3B line code by choosing the output waveforms that have the lowest average DC value and giving preference to those that start and end at different levels (assume bipolar signalling).

not done

Exercise 8: What (minimum) delay does a B8ZS encoder add? Receiver? Why is there a zero between successive same-polarity pulses?

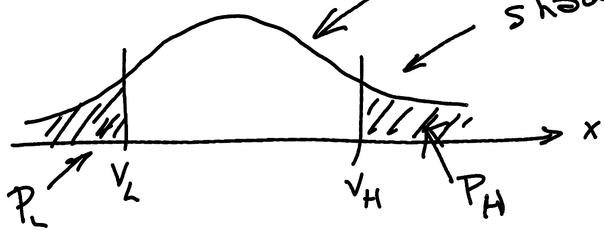
not done

Probalities with two thresholds



unshaded $= P(V_L < x < V_H)$

shaded $= P(x > V_H$ or $x < V_L)$



$P_{shaded} = 1 - P_{unshaded}$.

$P_{shaded} = P_L + P_H$

$P_L =$

$P_H = 1 - P(x < V_H)$