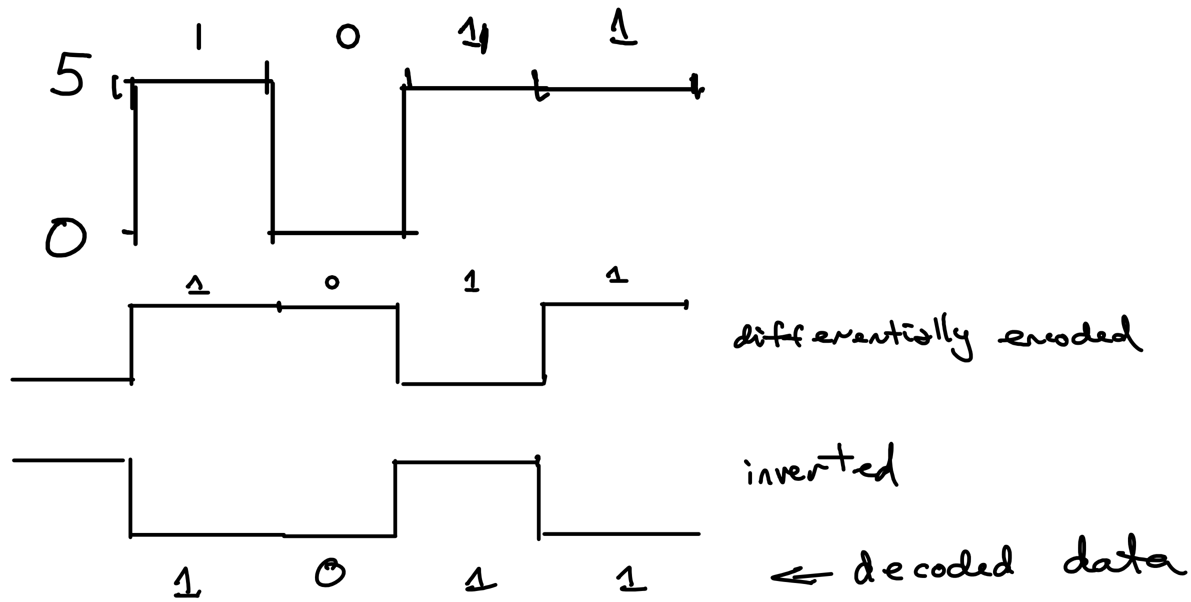
Lecture 7 - Line Codes

Exercise 1: Approximately what bandwidths and center frequencies might be used by each of the following: Telephones? AM broadcasting? Ethernet LAN? A cable TV channel? Which are baseband channels?

	center f	bandwidth	lowest	highest	type
Telephone			300 ~	4 KHz	baseband
AM broadcast		10 KHz	580 KHz	1.6 MHz	passband
Ethernet LAN			DC	≈ 300 MHz	baseband
cable TV		5 MHz	50 MHz	900 MHz	passband

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.



Exercise 3: You receive the sequence of bits 10001101 and are told that bit stuffing was used to limit runs of 0 to three or fewer. What was the original data sequence?

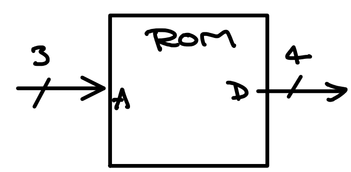
tx bits	1	0	0	0	$\boxed{}$	1	0	1
count →	0	1	2	3	0	0	1	0

	1	0	0	0	~~1~~	0	0	1
rx bits	1	0	0	0	~~X~~	1	0	1
count →	0	1	2	3	0	0	1	0
	0	1	2	3	stuffed bit 0	1	2	0

original → sequence

1000 101 ← unstuffed
1000 001 ← unstuffed } recovered bits.

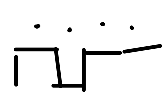
Exercise 4: How many combinations are there of 3 bits? Of 4 bits? How many bits might be input and output by an 8B10B code? What might a 4B3T code mean?



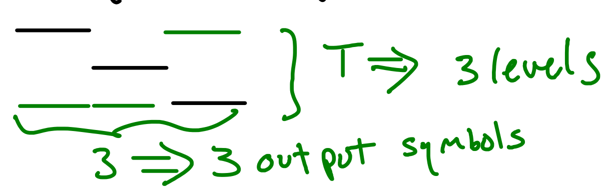
$$2 \times 2 \times 2 = 2^3 = 8$$

$$2 \times 2 \times 2 \times 2 = 2^4 = 16$$

8B 10B — 8 bits in, 10 bits out



4B 3T — 4 bits in, 3 ternary values (e.g. voltage levels) out



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). (& have fewest xstn.s).

4340 2B3B

input (2B)	output (3B)	3B output
0 0	− − +	0 0 1
0 1	− + +	0 1 1
1 0	+ − −	1 0 0
1 1	+ + −	1 1 0

output symbol	DC (avg.) value	transitions
− − −	~~−3~~	0
− − +	−1	1 ✓
− + −	−1	2
− + +	+1	1 ✓
+ − −	−1	1 ✓
+ − +	+1	2
+ + −	+1	1 ✓
+ + +	~~+3~~	0

Exercise 6: 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?

$$\text{bit period} = \frac{1}{f_{bit}} = \frac{1}{100\times10^6} = 10\,ns$$

one higher one lower, clock period, 100ppm

$2\times 10\,ns \times 10^{-4}$

$2\times 10\times10^{-9}\times10^{-4} = 20\times10^{-13} = 2\times10^{-12}$

$10^6 = 1\times10^6$

10×10^{-6}

approx.

$\pm$ 100ppm maximum difference if tx is opposite error than receiver

strictly correct.

e.g. Tx 100 + 100ppm MHz

Rx 100 − 100ppm MHz.

$100\,ppm = \frac{100}{1\times10^6} = 10^{-4}$

$= \frac{10^2}{10^6} =$

$100 + 100\cdot10^{-4}$ MHz

$10^8 + 10^8\cdot10^{-4} = 10^8 + 10^4 = 100{,}010{,}000$

$= 99990000$

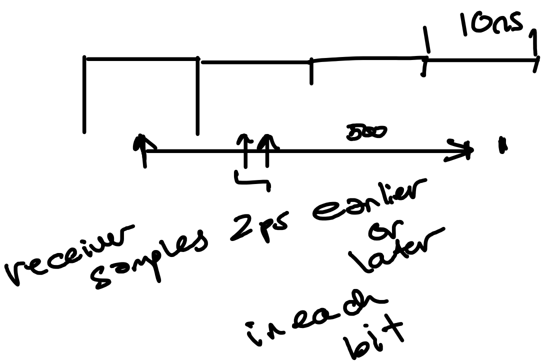
Δ = 200ppm = 2 ps

does Δ% differene of frequeny

have same result as Δ% difference in period?

$$(1+\Delta)\frac{1}{T} \overset{?}{=} \frac{1}{(1+\Delta)T}$$

NO



10% of period is 1 ns $= 10^{-9}$ s.

bits is $\frac{1\times10^{-9}}{2\times10^{-12}} \; \frac{s/bit}{s} = 500$ bits

Exercise 7: 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).

$2^{10} \approx 1000$

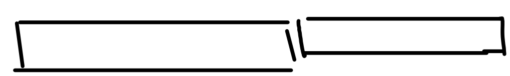
$2^{20} \approx 10^6$

$2^{30} \approx 10^9$

$\left(\frac{1}{2}\right)^{30} \approx \frac{1}{4\times10^9}$

$2^{20} = 10^6$

2



$\left(\frac{1}{2}\right)^{50} \quad \frac{1}{10^{15}}$

assuming we look at groups of 50 bits independently.

at 1 Gb/s $\frac{10^9}{50}$ groups/second.

Exercise 8: 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?

$$\tau = \frac{d}{v} = \frac{10m}{\underline{0.66} \times \underline{3} \times 10^{8} \, m/s} = \frac{1 \times 10^{1}}{2 \times 10^{8}} = 0.5 \times 10^{(1-8)}$$

$$= 0.5 \times 10^{-7} = 50 \text{ ns}$$

$f_b = 100 \text{ kb/s}$

$$T_b = \frac{1}{100 \times 10^{3}} = 1 \times 10^{-5} = 10 \mu s.$$

$$\text{fraction} = \frac{50}{10{,}000} \simeq \frac{5}{1000} = 0.5\%$$