Lecture 7

Exercise 1: Approximately what frequency ranges are used by each of the following: Telephones? AM broadcasting? Ethernet LAN? Cable TV? Which are baseband channels?

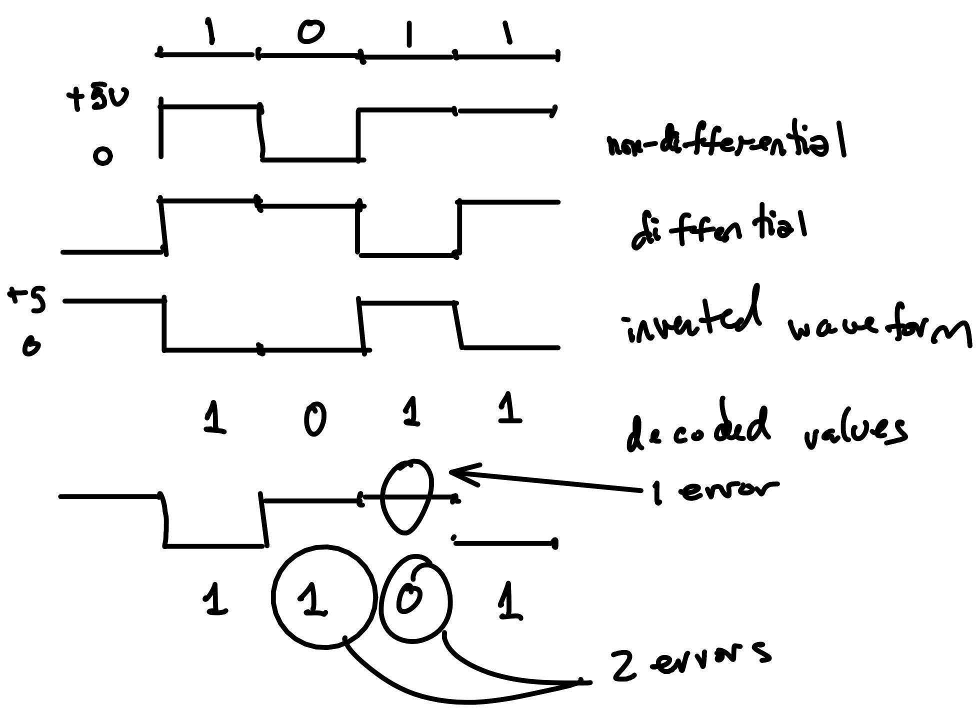
telephones: 0 - 4kHz — Baseband

AM Broadcasting: 580 - 1600 KHz ≈ 10 KHz channels. — Passband (modulated)

Ethernet LAN: 100's of MHz (Cat5 cable) — Baseband

TV: 50 MHz → 1 GHz — Not baseband.

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 is the original data sequence?

1 0 0 0 1 1 0 1

0 1 2 3 0 0 1 0 ← count of consecutive 0's

↑ stuffed bit

1 0 0 0 1 0 1 ← recovered data

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?

$2^3 = 8$

$2^4 = 16$

8B10B → 8 bits in, 10 bits out

2^8 different input words

2^{10} possible output words

4B3T

2^4

16

3^3 ← 3 symbols, 3 possible levels

$3 \times 3 \times 3 = 27$

4	
0000	+ 0 −
0001	− − −
0010	+ + 0
1111	

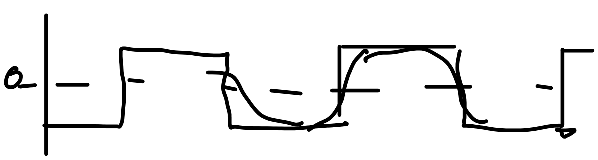
Exercise 5: Design your own 2B3B line code by choosing the output waveforms that have the lowest average DC value and [those that start and end with ~~the same~~ different level] (assuming bipolar output levels).

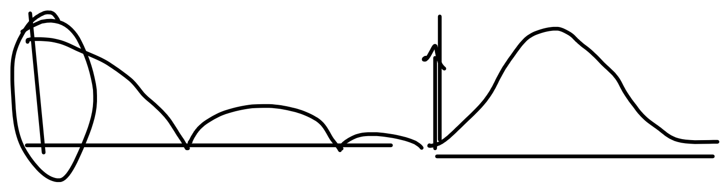
have minimum number of transitions

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

✓ start & end w/ same value

			# transition
→ 0 0 0 ✓	− − −	−3	0
0 0 1	− − +	−1 ✓	1
0 1 0 ✓	− + −	−1	2
0 1 1	− + +	+1 ✓	1
1 0 0	+ − −	−1 ✓	1
1 0 1 ✓	+ − +	+1	2
1 1 0	+ + −	+1 ✓	1
1 1 1 ✓	+ + +	+3	0

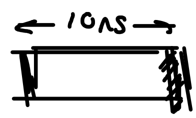




Exercise 6: A link operates at 100 Mb/s. What is the bit period? The transmitter and receiver have independent clocks (oscillators) with accuracies of 100ppm. What is the maximum difference between the two clock periods in ppm? In seconds?

$1\,\text{ppm} = 10^{-6}$

$100\,\text{ppm} = 10^{-6}\cdot 10^{2} = 10^{-4}$



$$T = \frac{1}{f} = \frac{1}{100\times10^{6}} = 10^{-8} = 10\times10^{-9} = 10\,\text{ns}$$

tx = 100 MHz ± 100 ppm   rx = 100 MHz ± 100 ppm

max difference = 200 ppm

min bit duration = 10 ns − $\underbrace{10\,\text{ns}}_{10^{-8}} \cdot \underbrace{100\,\text{ppm}}_{10^{-4}}$ $= 10\times10^{-9} - 10^{-12}$

max " "

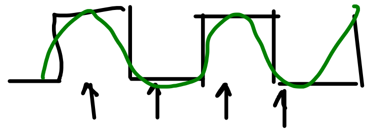
$= 10 - 0.001$ ns

$= 9.999$

200 ppm × 10 ns =

$10^{-12} = 10^{-9}\,10^{-3} = .001$ ns

$$10^{-n} \equiv 1\times10^{-n} \qquad 10\times10^{-n}$$



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).

prob. of 30 consecutive 1's $= \underbrace{\frac{1}{2} \times \frac{1}{2} \times \cdots \frac{1}{2}}_{30 \text{ times}} = \frac{1}{2^{30}}$

$$\approx \frac{1}{2^{10} \cdot 2^{10} \cdot 2^{10}} \approx \frac{1}{10^3 \cdot 10^3 \cdot 10^3} = \frac{1}{10^9} \quad \left(\text{about } \frac{1}{1 \text{ billion}}\right)$$

for 50 bits: $\frac{1}{2^{50}} = \frac{1}{(2^{10})^5} = \frac{1}{(10^3)^5} = \frac{1}{10^{15}}$

To keep things simple, consider every 30-bit word independently (framing)

Then the time between all-zero words will vary randomly but on average we will see the all-zero word once every 10^9 words which takes $10^9 \cdot \frac{30}{10^9} = 30s$

So, once every 30 s.

for 50 bits, once every 10^{15} words which takes

$$10^{15} \frac{50}{10^9} = 50 \times 10^6 s = 50 \times 2^{20} s \approx 2^5 \cdot 2^{20} \approx 1 \text{ time per year}$$

about

($2^5 \rightarrow 32$)

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?

huh? wrong lecture?