Cpr E 489 Spring 2024
Homework #1
Due Date: 2/6/2024 (Tue) by 11:59 PM
Type or scan your answers and submit on Canvas

1. (15 points) A baseband channel with a bandwidth of 20 KHz is used by a digital transmission system. Suppose the ideal pulses are sent at the Nyquist rate, and the pulses can take 1024 different levels. There is no noise in the system. What is the bit rate of this system? Justify your answer.

Nyquist Rate = Rmax = 2W pulses / second (max baud rate)

Rmax = 2(20 kHz)

Rmax = 40 kHz

Bit Rate = (baud rate) x (#bits per pulse)

Bit Rate = (40 kHz) x (log2(1024)) = 400 Kbps

2. (15 points) Suppose that multi-level square pulses are used in a digital transmission system, and the maximum pulse amplitude is ±1 Volts. Suppose that the amplitude of the additive noise is uniformly distributed between (–0.11, +0.16) Volts. What is the maximum number of levels of pulses this transmission system can use before the noise may start introducing errors? Justify your answer.

C (channel capacity bits/sec) = W (bandwidth Hz) ( 1 + SNR)'

SNR =avg. signal power / avg. noise power

SNR = 1 / (avg(-.11, .16))

= 7.407 levels

Or you can do

1 to negative 1, so 2 total volts for signal. A signal in top can have max negative value and the signal on the bottom can have a max positive value. This adds to be .27 volts worth of noise. So each layer should have .27 cushioning. Divide 2 total volts by .27 for each layer. This gives 7.407

3. (15 points) Suppose we wish to transmit at a bit rate of 270 Kbps reliably over a noisy AWGN (Additive White Gaussian Noise) communication channel with a bandwidth of 30 KHz. <u>What is the minimum SNR (Signal to Noise Ratio) (in dB) required to accomplish this?</u> Justify your answer.

C = w * log2(1+SNR)

270 Kbps = 30 KHz * log2(1 + SNR)

9 = log2(1+SNR)

512 = 1 + SNR

511 = SNR

SNR = 10 * log10(511) dB

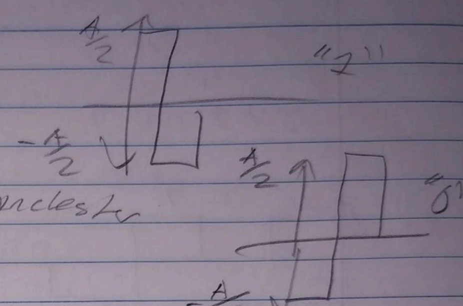
SNR = 27.08 dB

4. (25 points) For bit stream 10000001, <u>sketch the waveform</u> for each one of the following line coding schemes that we learned in the class. (Assume that the waveform in the bit interval prior to 10000001 ends at a <u>negative</u> voltage level.)

a. 1B2B.
b. 2B1Q (please use the version discussed in the 1/25 and 1/30 lectures).
c. NRZ-Inverted.
d. Differential Manchester.
e. B6ZS (Bipolar with 6 Zeros Substitution).

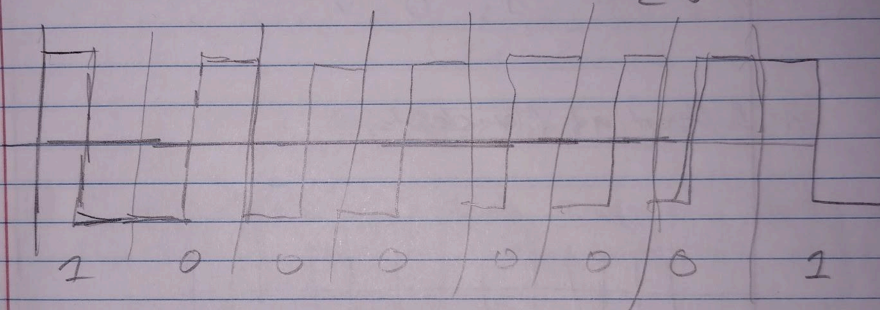
# HW 1

4. 1 0 0 0 0 0 0 1



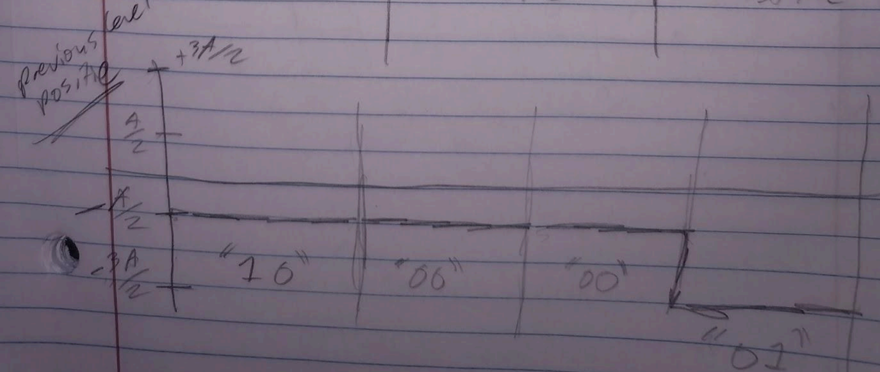

a) 1B 2B

1 binary bit → 1B, 2 binary pulse → 2B = Manchester




b) 2B 1Q

| Next Bits | Previous Level "+" Next Level | Previous Level "−" Next Level |
| --- | --- | --- |
| "00" | +A/2 | −A/2 |
| "01" | +3A/2 | −3A/2 |
| "10" | −A/2 | +A/2 |
| "11" | −3A/2 | +3A/2 |

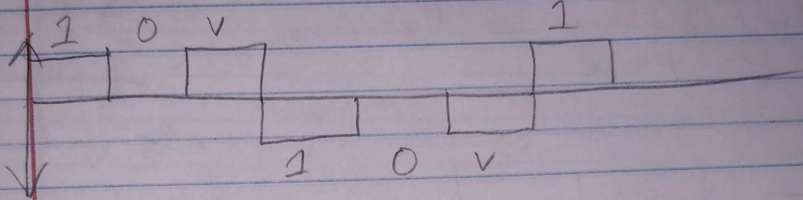


e. B6ZS, Bipolar with 6 zero sub

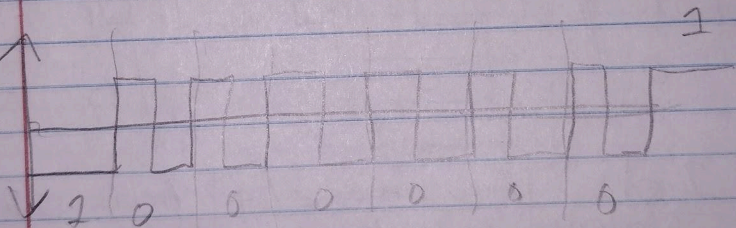
000,000

↓

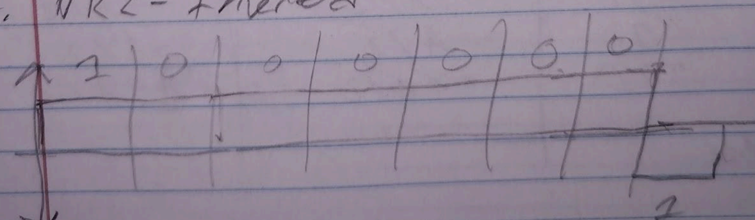
0 V 1 0 V 1




d. Differential Manchester




c. NRZ-Inverted



5. (30 points) Suppose that two check bits are added to five information bits ($i_4$, $i_3$, $i_2$, $i_1$, $i_0$). The first check bit $c_1$ is the even parity check of the first two information bits ($i_4$, $i_3$), and the second check bit $c_0$ is the even parity check of the final three information bits ($i_2$, $i_1$, $i_0$). The codeword is ($i_4$, $i_3$, $i_2$, $i_1$, $i_0$, $c_1$, $c_0$).

   a. (15 points) What fraction of errors is undetectable? Justify your answer.

   b. (15 points) What fraction of 2-bit errors is undetectable? Justify your answer.

Even amount of

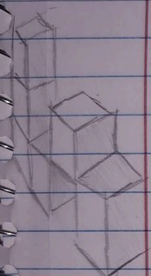
Undetectable when 2 bits are flipped in the same group

$+\binom{4}{2} = 6$

$i_4\, i_3\, c_1$ & $i_2\, i_1\, i_0\, c_0$

$\binom{3}{2} = 3$

$\binom{3}{2} * \binom{4}{2}$ $+$



$= \frac{3!}{2!(3-2)!} * \frac{4!}{2!(4-2)!} = 3 * 6 = 18$

OR 4 bits ALL Flipped $+$

$i_4\, i_3\, c_1$ & $i_2\, i_1\, i_0\, c_0$

$\binom{3}{2} * \binom{4}{4} = 3 * 1 = 3$

$+\binom{4}{4} = 1$

31 undetectable combinations

Total errors

$\binom{7}{1} * \binom{7}{2} * \binom{7}{3} * \binom{7}{4} * \binom{7}{5} * \binom{7}{6} * \binom{7}{7}$

$= 7 + 21 + 35 + 35 + 21 + 7 + 1$

$\frac{31}{127} = .244$

b) $\dfrac{\binom{3}{2} + \binom{4}{2}}{\binom{7}{2}} = \dfrac{9}{21}$