A closed-book quiz based on QP5 will be held at the beginning of class on November 22, Tuesday. QP5 solutions will be posted on Friday. The generic crib sheet (on Moodle) will be either distributed along with the quiz, or projected in front of the class.

**Problem 1**

Show that Manchester line coding (also called split phase line coding, details on page 388 in the textbook) has no DC component, that is, the PSD $S_y(f) = 0$ for $f = 0$ Hz. Assume that perfectly rectangular pulses are available for constructing this line coding signal.

**Problem 2**

Between On/Off NRZ and Bipolar RZ line coding standards, which one has:

(a) Better noise tolerance?

(b) No DC component, irrespective of the choice of $p(t)$?

(c) Error detection/correction capabilities?

(d) Lower bandwidth, for the same bit rate $R_b$ bits/sec?

**Problem 3**

Page 393 in the textbook describes the High Density Bipolar (HDB) standard, which solves the problem of losing timing while having too many zeros in a row while using Bipolar RZ. Sketch the waveform for the following bit sequence, using the HDB3 standard: 10001100001

**Problem 4**

Consider the following pulses:

$$p_1(t) = \frac{\sin(\pi R_b t)}{\pi R_b t}$$

$$p_2(t) = \frac{\sin(\pi R_b t)}{\pi R_b t (1 - R_b t)}$$

$$p_3(t) = \frac{\sin(\pi R_b t)}{\pi R_b t (1 - R_b t)(1 - 0.5R_b t)}$$

where $R_b = \frac{1}{T_b}$. Consider three standards corresponding to $i = 1, 2$ and 3, where the pulse $p_i(t)$ is transmitted to represent binary 1, and the pulse $-p(t)$ to represent binary 0 (that is, a polar signaling standard). A pulse is transmitted every $T_b$ seconds.
(a) Do these three standards each satisfy Nyquist’s criteria for no inter-symbol interference (ISI)? In other words, if we transmit pulse $p_i(t)$ (or $-p_i(t)$ if we are transmitting binary 0) at time $t = 0$, will it interfere with the pulses for any of the other bits at times $\pm T_b, \pm 2T_b, \pm 3T_b, \ldots$?

**Hint:** You might have to take limits to evaluate the pulse functions. For example, if you wanted to evaluate the sinc function at 0, that is, find $\text{sinc}(0)$, you would use $\lim_{x \to 0} \frac{\sin(x)}{x} = 1$.

(b) If any of the above pulses cause ISI, will we be able remove the effects of ISI at the receiver? That is, for each of the three standards, will we be able to actually decode what bits are being transmitted? If so, explain how. You can assume that the first 3 bits transmitted are zeros, and this is known to the receiver.

**Hint:** Think about HW7 Problem 2, which we solved in class. There, we received the value $y_k = a_k + a_{k-1}$ whenever we transmitted $a_k$, that is, a sum of the current pulse amplitude and the amplitude of the previous pulse ($a_k$ is the pulse amplitude assuming polar signaling, so it is +1 if the transmitted bit is 1 and -1 if the transmitted bit is 0). There is more than one way to recover the original bits from $y_k$, but here is one easy way:

Assume $a_0 = 0$ (or any known quantity, even +1 or -1), so when we receive $y_1 = a_1 + a_0$, we can subtract $a_0$ from $y_1$ to get $a_1$. Since $y_1 - a_0$ is +1 for bit 1 and -1 for bit 0, we can decode the bit for $k = 1$. For $k = 2$, $y_2 = a_2 + a_1$, and since we know $a_1$ already, we can subtract it form $y_2$ and get $a_2$, and so on. In general, assuming we know $a_{k-1}$, we can consider $y_k - a_{k-1}$ which will be either +1 or -1, depending on whether the $k$-th bit is 1 or 0, respectively. In this manner, we can still decode our bits, even though we have ISI.