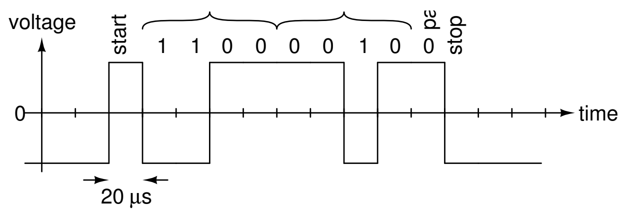
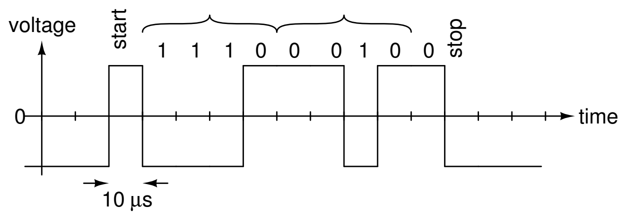
Final Exam Solutions

Question 1

The following waveform is used to transmit one character over an asynchronous serial ("RS-232") interface. The interface transmits 8 data bits per character. There were two versions of the waveform:





(a) The bit rate is the reciprocal of the bit duration. For the first waveform this is $\frac{1}{20\times10^{-6}} = 50$ kbps. For the second it is $\frac{1}{10\times10^{-6}} = 100$ kbps.

(b) The baud rate is the reciprocal of the minimum time between signal level transitions. In this case it is the same as the bit rate (50 or 100 kHz).

(c) The data bits are transmitted in order from least-significant to most-significant with a high voltage indicating a logical 0. For the first figure the 8 transmitted bits in order from MS to LS are: 0100 0011 (0x43) and for the second figure 0100 0111 (0x47).

(d) Parity is being used because an additional (0) bit was transmitted. For the first figure the number of '1' bits is 3 (odd) so odd parity is being used. For the second figure the number of '1' bis is 4 (even) so even parity is being used.

(e) If the value is consdered as a character, the values are within the ASCII range (0 to 0x7f) so an ASCII character was transmitted. From the ASCII table the character was either upper-case 'C' (0x43) or upper-base 'G' (0x47).

Question 2

A section of 75Ω coaxial cable uses 16-gauge (AWG) center conductor and a foamed polyethylene dielectric with a dielectric constant (relative permittivity) of $\varepsilon_r = 1.5$.

(a) The diameter of n-gauge wire is:

$$d \approx 0.5 \times 2^{-\frac{(n-24)}{6}} = 8 \times 2^{-\frac{n}{6}} \text{ mm}$$

for 16-gauge wire is $8 \times 2^{-\frac{16}{6}} = 1.26$ mm.

(b) The characteristic impedance is related to the ratio of the shield to center conductor by:

$$Z_0 \approx \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right) \quad \Omega$$

from which we can solve for the shield diameter D:

$$D = d \exp\left(Z_0 \frac{\sqrt{\varepsilon_r}}{60}\right)$$

and for $Z_0 = 50\ \Omega$ $D \approx 3.5$ mm and for $Z_0 = 75\ \Omega$ $D \approx 5.8$ mm

(c) The velocity factor is $VF = \frac{1}{\sqrt{\varepsilon_r}}$. The time to travel 100 m is $\tau = \frac{d}{v} = \frac{100}{\text{VF}\cdot 3\times10^8} \approx 0.41\ \mu$s.

Question 3

A 1 kHz sine wave is applied to the input of an amplifier. The power levels of the output frequency components are determined to vary as:

$$P_n = \frac{P_0}{3^n}$$

in one version of the question or,

$$P_n = \frac{P_0}{2^n}$$

in the second for $n = 0 \ldots 3$ where P_0 represents the power of the 1 kHz output and P_n is the power of the component at frequency $n+1$ kHz. The powers of the other harmonics are negligible (assume zero).

A notch filter at the filter output removes the 1 kHz component. The sum of the remaining harmonic powers ($P_1 + P_2 + P_3$) is measured to be 100 mW.

(a) The output power at 1 kHz (P_0) can be computed as:

$$\sum_{n=1}^{3} P_n = P_0 \sum_{n=1}^{3} \frac{1}{2^n} = 0.875 P_0 = 100\,\text{mW}$$

from which $P_0 \approx 114$ mW. Similarly, for $P_n = \frac{P_0}{2^n}$,

$$\sum_{n=1}^{3} P_n = P_0 \sum_{n=1}^{3} \frac{1}{3^n} = 0.481 P_0 = 100\,\text{mW}$$

from which $P_0 \approx 208$ mW.

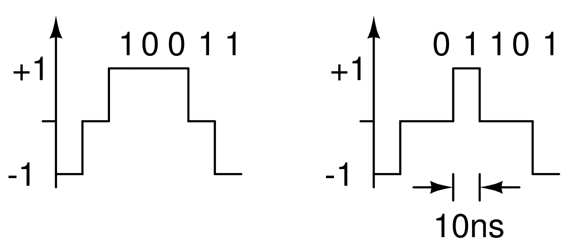
(b) Total Harmonic Distortion (THD) of the amplifier is defined as:

$$\text{THD} = \sqrt{\frac{P_1 + P_2 + P3 + \ldots}{P_0}}$$

which can be computed as $\sqrt{\frac{100}{114}} = 0.937$ or about 94% for the first version of the question and $\sqrt{\frac{100}{208}} = 0.693$ or about 69% for the second.

Question 4

An MLT-3 line code is used to transmit the bits 10011 or 01101 at 100 Mb/s. The output waveform are shown below assuming the outputs during the two previous bit intervals were -1 V and 0 V:



as shown, a '0' results in no change in level and a '1' results in a change in level by 1 V but the level stays between +1 or -1.

Question 5

A system computes CRCs by dividing the message, represented as a polynomial with coefficient from GF(2), by a 4-bit generator polynomial $G(x) = x^3 + 1$.

(a) Since the polynomial has 4 terms, the length of the remainder in bits is 3.

(b) If the message (not including the CRC) is 111 or 100, the value of CRC is computed by appending 3 zero bits and doing long subtraction to find the remainder as shown below:

```
       -------
1001  |111000
       1001
       ----
        1110
        1001
        ----
         1110
         1001
         ----
          111
```

```
       -------
1001  |100000
       1001
       ----
        0010
        ----
         0100
         ----
          100
```

so the CRCs are the remainders: 111 and 100.

Question 6

A communication system uses a code with the following codewords:

000
110
011
101

or

110
011
000
101

(a) The distances between each codeword and the ones below it are shown below:

000
110 2
011 2 2
101 2 2 2

110
011 2
000 2 2
101 2 2 2

and the minimum distance for all codes is 2.

(b) If the channel introduces one error into a transmitted codeword:

  (i) The receiver be able to detect the error because 1 (the number of errors) is less than or equal to $d - 1$.

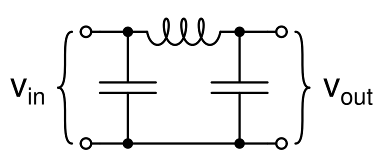
  (ii) The receiver not be able to correct the error because the number of errors (1) is greater than $\lfloor \frac{d-1}{2} \rfloor = 0$.

Question 7

(a) A system transmitting at a data rate of b kbps and a symbol rate of R kHz is transmitting $\log_2(M) = \frac{b}{R}$ bits/symbol which requires M different symbols.

For $b = 256$ kbps and $R = 64$ kHz there are 4 bits/symbol which requires 16 different symbols. For $b = 128$ kbps and $R = 32$ kHz there are also 4 bits/symbol which also requires 16 different symbols.

(b) The filter schematic below:



(i) Passes DC voltages because the inductor passes DC. (ii) Has an attenuation that increase with frequency because the impedance (reactance) of the series element (the inductor) increases and the impedance of the shunt elements (the capacitors) decreases. (iii) This is therefore a low-pass filter.

(c) A network with links between continents (e.g. 2000 km) introduces delays (e.g. $2 \times 10^6/3 \times 10^8 \approx 7$ ms which are long relative to the frame length if the link is operating at high speed (e.g. 10 Gb/s) using relatively short (e.g. Ethernet-length, 64 bytes, 512 bits minimum, duration $=512/10^{10} \approx 51$ ns) frames.

In this situation stop-and-wait ARQ would result in low throughput. If only a very small fraction of the frames (e.g. one per hour) are lost due to errors the there won't be much difference in throughput between go-back-N and selective-repeat ARQ and either would be suitable (although go-back-N would be less expensive to implement).