Solutions to Final Exam

Question 1

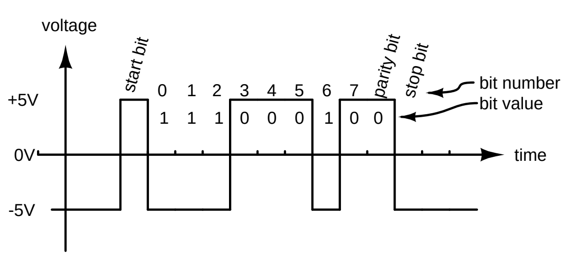
(a) Each waveform is a symbol and the symbol rate is the inverse of the symbol duration so the symbol rate is $\frac{1}{3\times10^{-6}} \approx 333$ kHz.

(b) The information in message i is $-\log_2(P_i)$ bits. The average information per message (the "entropy") is $\sum_i -P_i \log_2(P_i) = 0.25\log_2(0.25) + 0.75\log_2(0.75) \approx 0.811$ bits/message. The message rate is the symbol rate so the average information rate is approximately $0.811 \times 333 = 270$ kb/s.

(c) The baud rate is the inverse of the minimum time between signal level transitions. From the diagrams, the waveform can change at most once per microsecond so the baud rate is 1 MHz.

Question 2

The question read: *The following waveform shows an ASCII character being transmitted over an RS-232 interface using even parity.* You were also told there are fewer than 10 data bits (which is always the case in practice).



(a) The character begins with a start bit (high) followed by data bits, a parity bit that makes the number of ones even and one or more stop bits. ASCII characters require at least 7 bits. If there were 7 data bits (bits 0–6) the stop bit would be incorrect (H). If there were 9 or 10 data bits (also very unusual) the parity would be wrong (odd). Thus to obtain even parity followed by one or more stop (low) bits the only possible choice is 8 data bits.

(b) The voltage levels in time order are LLLH HHLH which is 1110 0010. In MS to LS order this is 0100 0111 or 0x47. This corresponds to the letter 'G'.

Question 3

The capacitance for the measured length was 23 pF and the inductance was 120 nH.

(a) The characteristic impedance is given by:

$$\sqrt{\frac{L}{C}} = \sqrt{\frac{120 \times 10^{-9}}{23 \times 10^{-12}}} = 72\ \Omega$$

(b) The characteristic impedance of co-ax cable is given by:

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

In the question we are given the dielectric constant $\varepsilon_r = 1.8$ and the shield diameter, $D = 0.5$ cm, so we can solve for the inner conductor diameter:

$$d = \frac{D}{\exp\left(\frac{Z_0\sqrt{\varepsilon_r}}{60}\right)} \approx 1\ \text{mm}$$

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Question 4

(a) This is not a linear-phase channel because the phase shift is not a linear function of delay.

(b) The apparent phase shift due to a delay τ is given by: $\theta = -2\pi f\tau$ from which we can solve for the delay $\tau = \frac{-\theta}{-360f} = \frac{-35}{-360\times0.5\times10^6} = 194$ ns.

Question 5

There were two version of the question. One version had received signal levels of $\mu = 0$ and $\mu = 7$ V, a decision threshold of $x = 3$ V and a noise rms voltage of $\sigma = 2$ V. The other version had levels that were half of these values which resulted in the same normalized threshold and thus the same error rates.

(a) When a 0 V level is received an error will be made if the voltage plus noise is larger than the decision threshold. The normalized threshold $t = \frac{x-\mu}{\sigma} = \frac{3-0}{2} = 1.5$ and the Gaussian CDF $P(t) \approx 0.933$. The probability of error is the probability that the signal is greater than this is and is $1 - P(t) = 1 - 0.933 = 6.7\%$.

(b) When a 7 V level is received an error will be made if the voltage plus noise is less than the decision threshold. The normalized threshold $t = \frac{x-\mu}{\sigma} = \frac{3-7}{2} = -2$ and the Gaussian CDF $P(t) \approx 2.3\%$. This is the probability of error.

(c) If both levels are equally likely (i.e. both have a probability of $\frac{1}{2}$), the average probability of error is $\frac{1}{2} \times 6.7 + \frac{1}{2} \times 2.3 = 4.5\%$.

Question 6

(a) On a channel such as this one that meets the Nyquist no-ISI criteria the maximum symbol rate that can be transmitted without ISI is twice the -6 dB bandwidth. In this case, 2×50 kHz $=$ 100 kHz.

(b) There were two versions of this question, one with 8-level signalling ($\log_2(8) = 3$ bits/symbol) and one with 16-level signalling ($\log_2(16) = 4$ bits/symbol).

For 8-level signalling we can transmit 3 bits/symbol so the bit rate would be $3 \times 100 = 300$ kb/s. For 16-level signalling the corresponding bit rate would be $4 \times 100 = 400$ kb/s.

Question 7

(a) The number of bytes in the IP frame payload will be the total packet length minus the header length. The value in the total length field is hex 34 (52 decimal) and the IHL field has value 5 so there are $5 \times 4 = 20$ bytes in the header. Thus the payload must have $52 - 20 = 32$ bytes.

(b) The IP header's protocol field has the value 6.

(c) The destination address is hex `0a 00 00 01` or 10.0.0.1. This is in one of the address ranges reserved for private networks (10.0.0.0/8) so a host with this address cannot be "on the internet."

(d) We can compute the IP header checksum by (i) setting the checksum field to zero and summing of all other 16-bit values: 4500 + 0034 + 0101 + 4000 + ff06 + 0100 + 0002 + 0a00 + 0001 = 1993e; (ii) adding the MS to the LS 16 bits to get 993f and (iii) complementing all of the bits to get 66c0.

There were two versions of this question, one with a checksum of `66 c0` (the correct checksum) and one with a checksum of `d1 0b` (an incorrect checksum).