Solutions to Midterm Exam 1

There were two versions of each question. The values and the answers for both versions are given below.

Question 1

A communication system uses 4 (or 3) bits to select a pulse that is at one of 16 (or 8) possible levels. One of these pulses is transmitted every 125 µs (or 250 µs).

(a) What is the symbol rate, in Hz?

(b) What is the bit rate, in bps?

Answer

In this question the pulses are the symbols because each pulse is the shortest independent portion of the signal. The symbol rate is the inverse of the symbol duration: $1/125\times10^{-6} = \boxed{8\,\text{kHz}}$ (or $1/250\times10^{-6} = \boxed{4\,\text{kHz}}$).

The bit rate is the number of bits transmitted per second. In this case it's the symbol rate times the number of bits per symbol: $4 \times 8 \times 10^3 = \boxed{32\,\text{kbps}}$ (or $3 \times 4 \times 10^3 = \boxed{12\,\text{kbps}}$).

Question 2

You need to measure the voltage at the output of a transducer that measures the vibration of a motor and have determined that the signal contains significant frequency components up to 60 kHz (or 30 kHz). The measured voltage ranges from 0 to 100 mV (or 1 V) at the point where this voltage is sampled.

(a) What is the minimum sampling rate that would ensure you are able to capture all of the features of the measured waveform?

(b) What is the minimum number of bits per sample required to quantize this waveform such that the spacing between the quantized signal levels is 1 mV?

Answer

(a) According to the Nyquist sampling theorem the minimum sample rate must be greater than twice the maximum frequency of the signal. In this case the minimum sampling rate is: $2 \times 60\,\text{kHz} = \boxed{120\,\text{kHz}}$ (or $2 \times 30\,\text{kHz} = \boxed{60\,\text{kHz}}$).

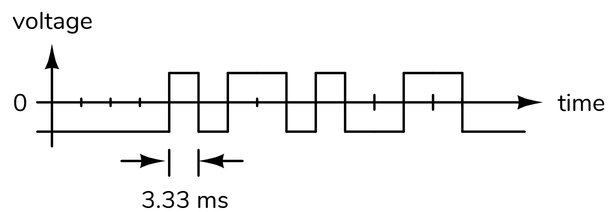
(b) The spacing between levels is $d = A/2^n$ where A is the voltage range and n is the number of bits. Solving for n, $n = \log_2(A/d)$.

For $A = 1$ V and $d = 1$ mV, $n = \log_2(1000) \approx 9.65$, so $\boxed{10 \text{ bits}}$ are needed.

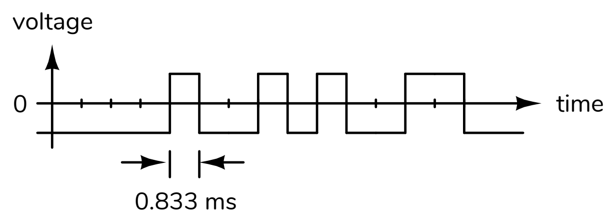
For $A = 100$ mV and $d = 1$ mV, $n = \log_2(100) \approx 6.64$, so $\boxed{7 \text{ bits}}$ are needed.

Question 3

The waveform below is an asynchronous serial interface ("RS-232") waveform used to transmit an 8-bit character:



or



(a) (i) What are the bit rate in bps and (ii) the baud rate in Hz?

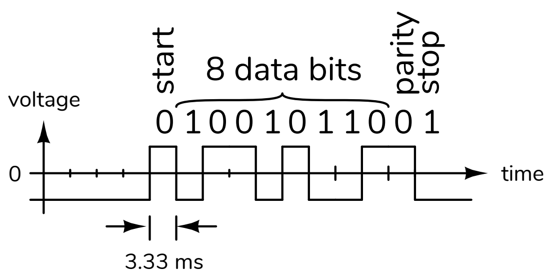
(b) What is the hexadecimal value of the character?

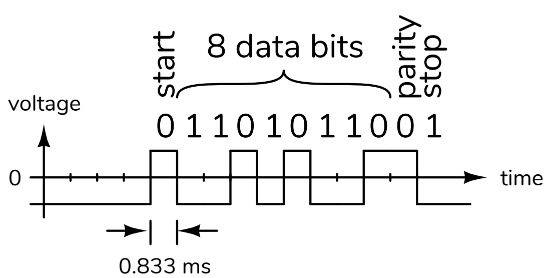
(c) Is parity being used? If so, what type?

Answer

(a) (i) For asynchronous serial interfaces the symbols are positive and negative (NRZ) pulses, each encoding one bit. So the bit rate is equal to the baud rate. (ii) The baud rate is the inverse of the baud (pulse) duration, $1/3.33\text{ ms} \approx$ 300 bps (or $1/0.833\text{ ms} \approx$ 1200 bps). This is also the bit rate.

(b) We can annotate the waveform as follows to indicate the start, data, parity and stop bits for the two versions of the question:





For the first version, the data bits, in order from m.s.b. to l.s.b. are 0110 1001 which is 0x69.

For the second version, the data bits, in order from m.s.b. to l.s.b. are 0110 1011 which is 0x6b.

(c) Is parity being used? If so, what type?

In the first version are a total of four '1' bits so even parity is being used. In the second version are a total of five '1' bits so odd parity is being used.

Question 4

The sequence of bytes shown below includes two Unicode characters encoded using UTF-8. The byte values are given in hexadecimal.

```
E5 AD 97 57 (or 57 E7 BA BF )
```

(a) What were the code points of each character? Give your answer in hexadecimal. Show your work.

(b) If either or both are ASCII characters, what is/are the character(s)? Your answer(s) should be letters or two-letter abbreviations for control codes, not the numerical value(s).

Answer

First version

(a) The byte, `E5`, is a prefix for a 3-byte UTF-8-encoded character. Deleting the bits indicated in Table 3-6 from `E5`, `AD` and `97` gives: 4 bits with value `0x5` (`0101`), 6 bits with value `0x2D` (`10 1101`), and 6 bits with value `0x17` (`01 0111`). Combining these we have the binary code point `0101 10 1101 01 0111` (`0101 1011 0101 0111`) which is `0x5B57` (字).

The next byte is `57` which is a prefix for a one-byte UTF-8-encoded character (ASCII). The code point is the same as the byte or `0x57`.

(b) The last byte is the ASCII character `W`.

Second version

(a) The first byte is `57` which is a prefix for a one-byte UTF-8-encoded character (ASCII). The code point is the same as the byte or `0x57`.

The byte, `E7`, is a prefix for a 3-byte UTF-8-encoded character. Deleting the bits indicated in Table 3-6 from `E7`, `BA`, and `BF` gives: 4 bits with value `0x7` (`0111`), 6 bits with value `0x3A` (`11 1010`), and 6 bits with value `0x3F` (`11 1111`). Combining these we have the binary code point `0111 11 1010 11 1111` (`0111 1110 1011 1111`) which is `0x7EBF` (线).

(b) The first byte is the ASCII character `W`.