Exercise Solutions for EEE 113

Communications - Basics of Communication Systems

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1.1 Suppose we sample a signal at frequency F_s. If we collect 9.1 kilo-samples in 4.7 seconds, what is F_s in Hz (samples/second)? Please provide your answer in at least 5 significant figures.

— Needed:	
☐ $F_s = ?$	Sampling frequency.
— Given:	
☐ $S = 9.1$ kilo-samples	Amount of samples.
☐ $t = 4.7$ seconds	Amount of time.
$\Rightarrow F_s = \frac{9.1 \text{ kilo-samples}}{4.7 \text{ seconds}}$	$F_s = \frac{S}{t}$
$\Rightarrow F_s = 1936.1$ Hz	Final answer.
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1.2 Compact discs record two channels (left and right) of music at a sampling frequency of $F_s = 44.1$ kHz for each channel. If each sample is encoded with 16 bits, and one byte is 8 bits, how many bytes are required to store 51.2 seconds of music?

— Needed:	
☐ $B_T = ?$	Total amount of bytes needed.
— Given:	
☐ $c = 2$ channels	Amount of channels.
☐ $F_s = 44.1$ kHz/channel	Sampling frequency.
☐ $b_s = 16$ bits/sample	Amount of bits in a sample.
☐ $b_B = 8$ bits/byte	Amount of bits in a byte.
☐ $t = 51.2$ seconds	Amount of time.
— Let:	
☐ F_T	Total sampling frequency.
☐ S_T	Total amount of samples.
☐ b_T	Total amount of bits.
$\Rightarrow F_T = 44.1$ kHz/channel $\cdot$ 2 channels	Note that we need two channels.
$\Rightarrow F_T = 88.2$ kHz	
$\Rightarrow S_T = 88.2$ kHz $\cdot$ 51.2 seconds	$S_T = F_T t$
$\Rightarrow S_T = 4.51584 \times 10^6$ samples	
$\Rightarrow b_T = 4.51584 \times 10^6$ samples $\cdot$ 16 bits/sample	$b_T = S_T b_s$
$\Rightarrow b_T = 72.25344 \times 10^6$ bits	
$\Rightarrow B_T = \frac{72.25344 \times 10^6 \text{ bits}}{8 \text{ bits/byte}}$	$B_T = \frac{b_T}{b_B}$
$\Rightarrow B_T = 9.03168 \times 10^6$ bytes	Final answer.
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1.3 Consider a system that uses 8-bit ASCII codes to encode letters. How long (in microseconds) will it take to transmit the bit sequence encoding "Hello-World!" if we use a bit time of 4 samples per bit, and transmit samples at a rate of 1 MHz?

— Needed:	
☐ $t = ?$	Amount of time needed.
— Given:	
☐ $b_c = 8$ bits/character	Amount of bits per character.
☐ $c = 12$ characters	Amount of characters in the string.
☐ $b_t = 4$ samples/bit	Bit time.
☐ $F_{Tx} = 1$ MHz	Transmission frequency.
— Let:	
☐ b_T	Total amount of bits.
☐ S_T	Total amount of samples.
$\Rightarrow b_T = 12$ characters $\cdot$ 8 bits/character	$b_T = cb_c$
$\Rightarrow b = 96$ bits	
$\Rightarrow S_T = 96$ bits $\cdot$ 4 samples/bit	$S_T = b_T b_t$
$\Rightarrow S_T = 384$ samples	
$\Rightarrow t = \frac{384 \text{ samples}}{1 \text{ MHz}}$	$t = \frac{S_T}{F_{Tx}}$
$\Rightarrow t = 384$ microseconds	Final answer.
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1.4 The process of converting a discrete-time continuous-valued signal into a digital signal by expressing each sample as a finite number of digits is called (a); (b) is the difference between sampled analog signal and digitized signal; (c) refers to the difference between the minimum and maximum value of the discrete-time signal; (d) is the assignment of a unique binary number to each quantization level.

$\Rightarrow$ a: quantization	Final answer.
$\Rightarrow$ b: quantization error	
$\Rightarrow$ c: dynamic range	
$\Rightarrow$ d: coding	
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1.5 An analog waveform is described as

$$x(t) = 2u(t) - 5u(t-1) + 3u(t-2) + 3u(t-3) - 2u(t-4) - u(t-5)$$

where $u(t)$ is the continuous-time unit step function. If the quantization level is 0.02, determine the minimum number of bits needed to represent the full range of the analog signal $x(t)$.

— Needed:	
☐ $b_m = ?$	Minimum amount of bits needed.
— Given:	
☐ $Q = 0.02$	Quantization step size.
☐ $M = 3$	Maximum value of the waveform.
☐ $m = -5$	Minimum value of the waveform.
— Let:	
☐ R	Dynamic range.
☐ L	Amount of quantization levels.
$\Rightarrow R = 3 - (-5)$	$R = M - m$
$\Rightarrow R = 8$	
$\Rightarrow L = \frac{8}{0.02}$	$L = \frac{R}{Q}$
$\Rightarrow L = 400$ levels	
$\Rightarrow b_m = \lceil \log_2 400 \text{ levels} \rceil$	$B_m = \lceil \log_2 L \rceil$
$\Rightarrow b_m = \lceil 8.64385618977 \rceil$	
$\Rightarrow b_m = 9$ bits	Final answer.
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