

University of Pennsylvania
Department of Electrical and System Engineering
Digital Audio Basics

ESE150, Spring 2022

Midterm

Monday, Feb 28

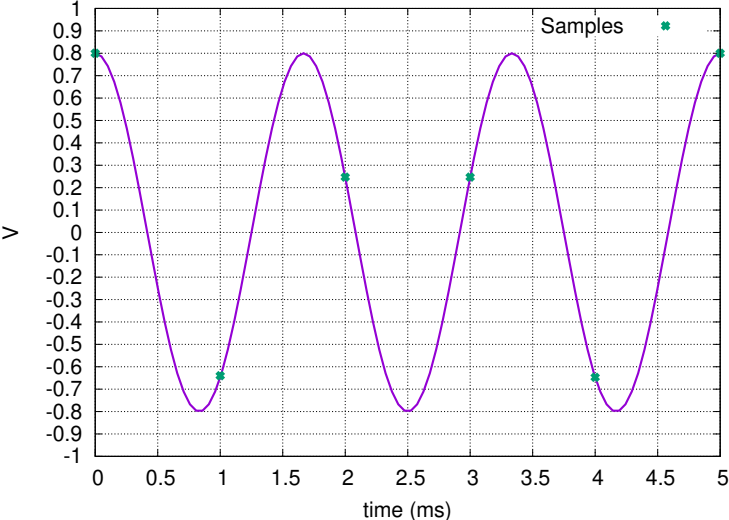
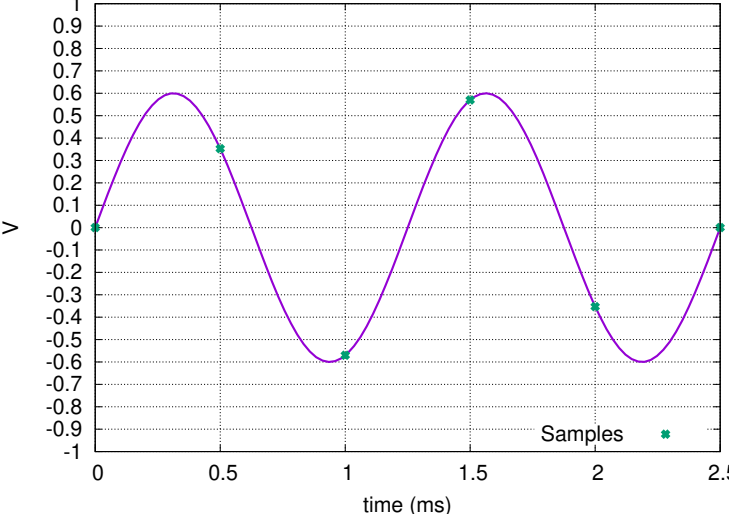
- Exam ends at 12:55PM; begin as instructed (target 12:05PM)
- Do not open exam until instructed to begin exam.
- Problems weighted as shown.
- Calculators allowed.
- Closed book = No text or notes allowed.
- Provided reference materials on next to last page.
- Show work for partial credit consideration.
- Unless otherwise noted, answers to two significant figures are sufficient.
- Sign Code of Academic Integrity statement (see last page for code).

I certify that I have complied with the University of Pennsylvania's Code of Academic Integrity in completing this exam.

Name:

1	2			3					4		5		
	a	b	c	a	b	c	d	e	a	b	a	b	c
16	5	5	10	2	2	4	9	4	14	8	5	7	9

1. Consider the following sampling cases, complete the table entries.

Waveform and Sample	Waveform Frequency (Hz)	Sample Frequency (Hz)	Inferred Frequency (Hz) from Samples	Properly Sampled?
 <p>The plot shows a cosine wave with a period of 2 ms. The y-axis is labeled 'V' and ranges from -1 to 1. The x-axis is labeled 'time (ms)' and ranges from 0 to 5. The wave starts at (0, 0.8). Samples are marked with green asterisks at t = 0, 1, 2, 3, 4, 5 ms. The sample values are approximately 0.8, -0.7, 0.2, 0.2, -0.7, 0.8.</p>				
 <p>The plot shows a cosine wave with a period of 2 ms. The y-axis is labeled 'V' and ranges from -1 to 1. The x-axis is labeled 'time (ms)' and ranges from 0 to 2.5. The wave starts at (0, 0). Samples are marked with green asterisks at t = 0, 0.5, 1, 1.5, 2, 2.5 ms. The sample values are approximately 0, 0.4, -0.6, 0.6, -0.4, 0.</p>				

2. Consider PCM sampling at 12KHz with 10b quantization.

(a) What is the maximum frequency this PCM sampling can correctly capture?

(b) How many bits per second does the PCM sampling require?

(c) Using a 25 ms window, this sample rate can identify 150 frequencies. Assuming there are at most 3 frequencies to encode per human critical band, you can still use 10b amplitude per frequency, and you operate on 25 ms sound frames, how many bits per second to encode this frequency time-window representation?

3. Consider the following quote from Benjamin Franklin:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
e	n	e	r	g	y		a	n	d		p	e	r	s	i	s	t	e	n	c	e

22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	c	o	n	q	u	e	r		a	l	l		t	h	i	n	g	s

This has 41 symbols from a set of 18 unique symbols.

symbol		a	c	d	e	g	h	i	l	n	o	p	q	r	s	t	u	y	sum
count	5	2	2	1	6	2	1	2	2	5	1	1	1	3	3	2	1	1	41

(a) How many bits to encode this using a uniform encoding where each symbol is encoded using the same number of bits?

(b) What property or properties of this quote make it amenable to lossless compression?

(c) What is the Shannon Entropy lower bound for encoding this entire quote?

$$\text{Lower Bound} = - \sum_i \log_2(P(c[i])) \quad (1)$$

Hint: there are only 5 different counts, so 5 different $P(c[i])$ values to calculate.

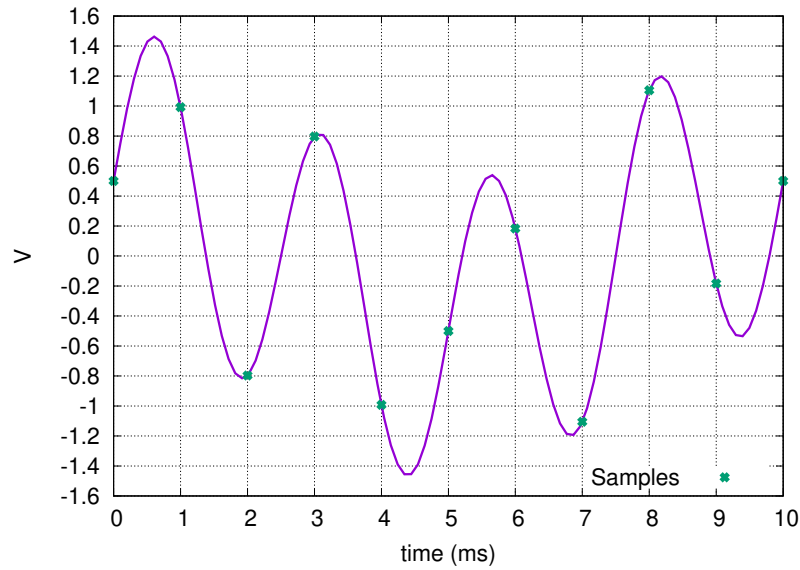
(d) Consider the following set of variable-length binary encodings. Assign each symbol to an encoding to minimize the encoded length.

encode	110	100	011	1110	1011	1010	0100	0001	0000
symbol									
encode	11111	11110	01010	00111	00110	00101	00100	010111	010110
symbol									

(e) For the above assignment, how many bits are required to encode the quote?

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4. Given the following waveform and associated samples at 1000Hz, identify the frequencies present.



Time (t)	0 ms	1 ms	2 ms	3 ms	4 ms	5 ms	6 ms	7 ms	8 ms	9 ms
Sample Value	0.5	1.0	-0.8	0.8	-1.0	-0.5	0.18	-1.1	1.1	-0.18

- (a) Which of the following frequencies are present in the waveform:

Frequency	100	200
Present?		

(given the limited precision of the samples and sine/cosine values below; treat final values between 0.1 and -0.1 to zero.)

- (b) Are there any other frequencies present? How do you know?

t	0 ms	1 ms	2 ms	3 ms	4 ms	5 ms	6 ms	7 ms	8 ms	9 ms
$\cos(2\pi 100t)$	1.0	0.81	0.31	-0.31	-0.81	-1.0	-0.81	-0.31	0.31	0.81
$\sin(2\pi 100t)$	0.0	0.59	0.95	0.95	0.59	0.0	-0.59	-0.95	-0.95	-0.59
$\cos(2\pi 200t)$	1.0	0.31	-0.81	-0.81	0.31	1.0	0.31	-0.81	-0.81	0.31
$\sin(2\pi 200t)$	0.0	0.95	0.59	-0.59	-0.95	0.0	0.95	0.59	-0.59	-0.95

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5. Consider an alien first-encounter situation. When the aliens go to speak, you hear nothing. However, nearby dogs bark back in response to the aliens.

(a) Why is it likely the dogs can hear them but you cannot?

(b) If you listened to the aliens through a PCM transmission, you also hear nothing. What would likely happen if you removed the anti-alias filter prior to time-domain sampling at 44 KHz for the PCM recording?

(c) Assuming the aliens do communicate entirely with sound waves, describe a better way to determine (i) what you need to do to fully capture alien communication and (ii) render it in a form humans can hear.

Human auditory critical bands:

Band Number	Low	High
1	20	100
2	100	200
3	200	300
4	300	400
5	400	510
6	510	630
7	630	720
8	720	920
9	920	1080
10	1080	1370
11	1270	1480
12	1480	1720
13	1720	2000
14	2000	2320
15	2320	2700
16	2700	3150
17	3150	3700
18	3700	4400
19	4400	5300
20	5300	6400
21	6400	7700
22	7700	9500
23	9500	12000
24	12000	15500

Code of Academic Integrity

Since the University is an academic community, its fundamental purpose is the pursuit of knowledge. Essential to the success of this educational mission is a commitment to the principles of academic integrity. Every member of the University community is responsible for upholding the highest standards of honesty at all times. Students, as members of the community, are also responsible for adhering to the principles and spirit of the following Code of Academic Integrity.*

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A. Cheating Using or attempting to use unauthorized assistance, material, or study aids in examinations or other academic work or preventing, or attempting to prevent, another from using authorized assistance, material, or study aids. Example: using a cheat sheet in a quiz or exam, altering a graded exam and resubmitting it for a better grade, etc.

B. Plagiarism Using the ideas, data, or language of another without specific or proper acknowledgment. Example: copying another person's paper, article, or computer work and submitting it for an assignment, cloning someone else's ideas without attribution, failing to use quotation marks where appropriate, etc.

C. Fabrication Submitting contrived or altered information in any academic exercise. Example: making up data for an experiment, fudging data, citing nonexistent articles, contriving sources, etc.

D. Multiple Submissions Multiple submissions: submitting, without prior permission, any work submitted to fulfill another academic requirement.

E. Misrepresentation of academic records Misrepresentation of academic records: misrepresenting or tampering with or attempting to tamper with any portion of a student's transcripts or academic record, either before or after coming to the University of Pennsylvania. Example: forging a change of grade slip, tampering with computer records, falsifying academic information on one's resume, etc.

F. Facilitating Academic Dishonesty Knowingly helping or attempting to help another violate any provision of the Code. Example: working together on a take-home exam, etc.

G. Unfair Advantage Attempting to gain unauthorized advantage over fellow students in an academic exercise. Example: gaining or providing unauthorized access to examination materials, obstructing or interfering with another student's efforts in an academic exercise, lying about a need for an extension for an exam or paper, continuing to write even when time is up during an exam, destroying or keeping library materials for one's own use., etc.

* If a student is unsure whether his action(s) constitute a violation of the Code of Academic Integrity, then it is that student's responsibility to consult with the instructor to clarify any ambiguities.