NAME (please print) ____

STUDENT (SID) NUMBER ______________________________

UNIVERSITY OF CALIFORNIA

College of Engineering
Electrical Engineering and Computer Sciences
Berkeley

EECS 145M: Microcomputer Interfacing Lab

LAB REPORTS:

1 __________ (100 max)	2 __________ (100 max)	3 __________ (100 max)
8 __________ (100 max)	9 __________ (100 max)	10 __________ (100 max)
21 __________ (100 max)	22 __________ (100 max)	23 __________ (100 max)
24 __________ (100 max)	26 __________ (200 max)	

TOTAL OF 5 LAB GRADES	__________	(500 max)
LAB PARTICIPATION	__________	(100 max)
MID-TERM #1	__________	(100 max)
MID-TERM #2	__________	(100 max)
FINAL EXAM	__________	(200 max)
TOTAL COURSE GRADE	__________	(1000 max)

COURSE LETTER GRADE

Spring 1995 FINAL EXAM (May 19)

Answer the questions on the following pages completely, but as concisely as possible. The exam is to be taken ***closed book***. Use the reverse side of the exam sheets if you need more space. Calculators are OK but not needed. **In answering the problems, you are not limited by the particular equipment you used in the laboratory exercises.** Many formulae from the course have been provided for you on the last page.

Partial credit can only be given if you show your work.

FINAL EXAM GRADE :

1 __________ (30 max)	2 __________ (15 max)	3 __________ (15 max)
4 __________ (40 max)	5 __________ (40 max)	6 __________ (30 max)
7 __________ (30 max)		TOTAL __________ (200 max)

Initials ________________________

Problem 1 (total 30 points):

A microcomputer has a parallel I/O port and 8 external digital devices are connected to the parallel output port to form a parallel output bus. The I/O port has 16 bits of input, 16 bits of output, and all external devices have 8 bits of input.

b. (15 points) Sketch a block diagram showing and labeling all essential components and interconnections. (You only need to sketch two of the external devices- use dots to represent the other 6.)

b. (15 points) Describe all the steps necessary for the microcomputer to write data to one specific external device and not to the others, using full handshaking.

Initials ________________________

Problem 2 (total 15 points):

Describe the operation of the successive approximation analog to digital converter

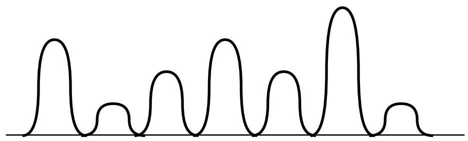
Problem 3 (total 15 points):

List the steps involved in using the microcomputer to (1) sample a periodic signal to which a comparable amount of random white noise has been added, and (2) determine the period

Initials ________________________

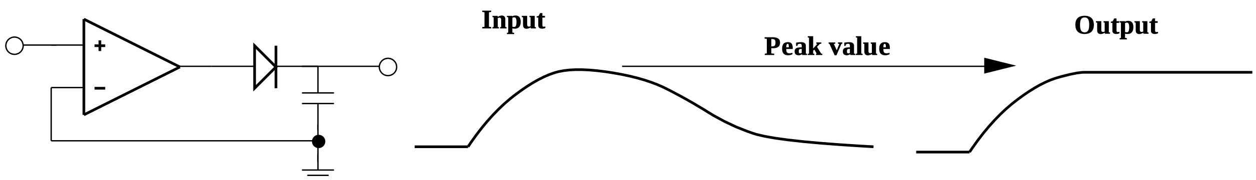
Problem 4 (40 points)

You have been asked to design a peak-reading A/D converter system as part of a larger digital communication system. To overcome bandwidth limitations, discrete pulse heights are used to code digital information. Your system must (1) hold the maximum input level, (2) determine when a peak has passed, (3) sample the held peak value, (4) store the digital value, and (5) reset the peak detector. For simplicity, assume that the peaks never overlap.



3, 1, 2, 3, 2, 4, 1

- A simple peak detector can be made using an op-amp, a diode, and a capacitor as shown below:



- Your system must also generate handshaking signals for the A/D conversion and provide a reset switch for the hold capacitor.
- You have decided to use the Precision Monolithics, Inc. PKD-01 monolithic peak detector with an external 1000 pF holding capacitor. A simplified version of the data sheets is attached to the end of the exam.
- The A/D conversion will be done with the analog input of the IBM DACA board plugged into an IBM PC, as used in the 145M lab. The input voltage range is –10 to + 10 volts, and the output is 12 bits. The circuit has a “ready for data” digital output (high = busy, low = ready) and a “data available” digital input (conversion starts on a low-to-high edge).
- The sampling time of the IBM PC/DACA board is 50 µs, including handshaking.

a. (15 points) Sketch a block diagram of your system. Clearly indicate any comparators, resistors, capacitors, etc. that you think are necessary for a working design.

b. (15 points) Describe the handshaking procedure that your system uses. Provide a timing diagram showing all important signal and control lines.

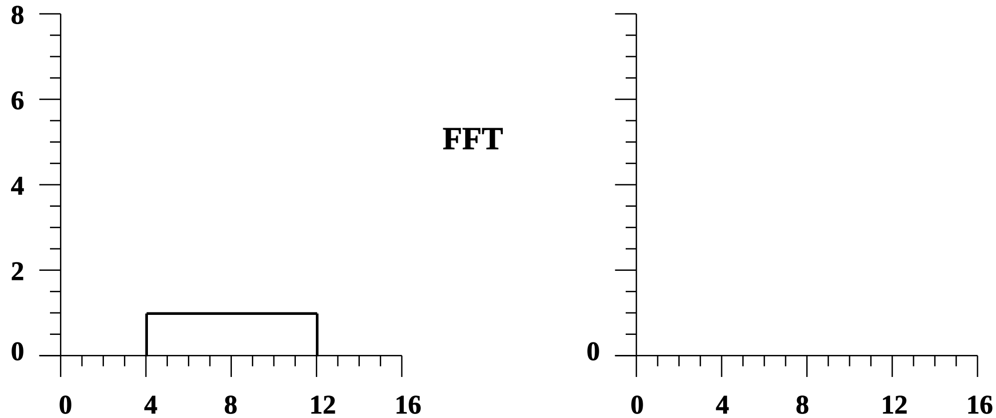
c. (5 points) Based on the conversion time of the IBM DACA board and the PKD-01, estimate the maximum allowable pulse rate.

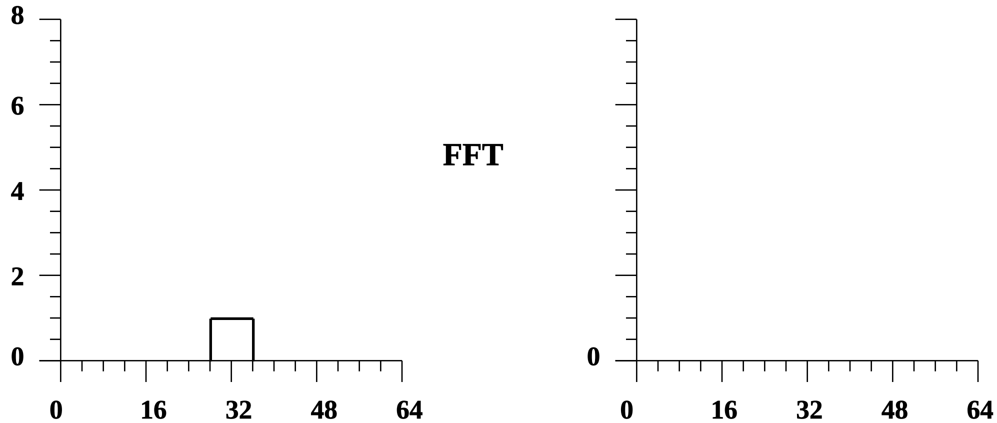
d. (5 points) Estimate the error caused by capacitor droop for a 5 volt input signal. Give your results both in units of volts and LSB.

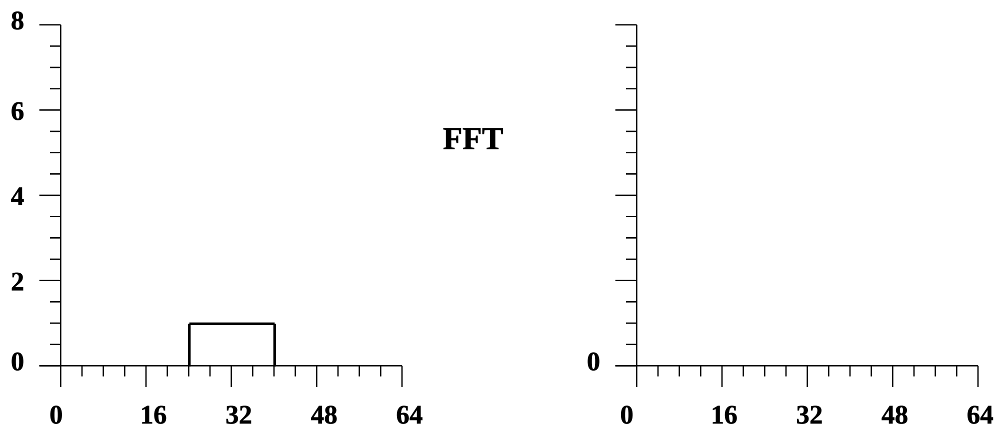
Initials ________________________

Problem 5 (40 points)

a. (10 points) For each of the following waveforms, roughly sketch the magnitudes of the FFT coefficients. Note the scale on the x-axis in each case. Clearly showing the differences among the three cases is more important than getting the shape of the FFT magnitude exactly right.
Hint: first compute the DFT at 0 Hz, then mark frequencies where the Fourier transform is zero, then fill in the rest of the transform.

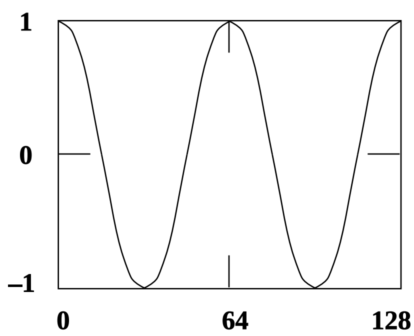


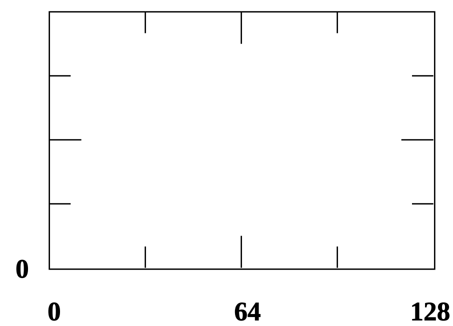


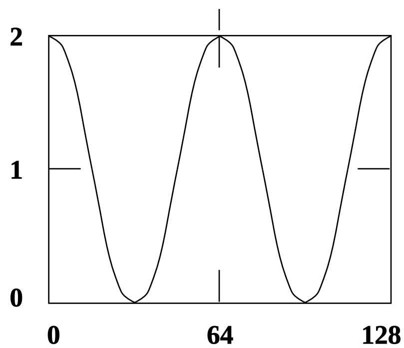


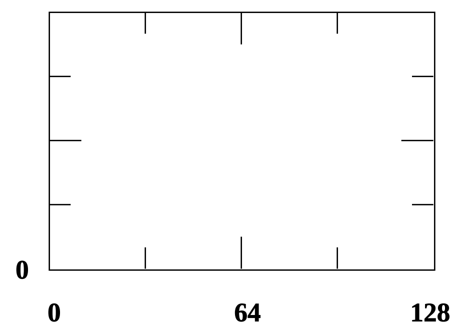
Initials ________________________

b. (10 points) For each of the following waveforms, calculate the non-zero values of the 128-point DFT. Sketch the magnitudes below:

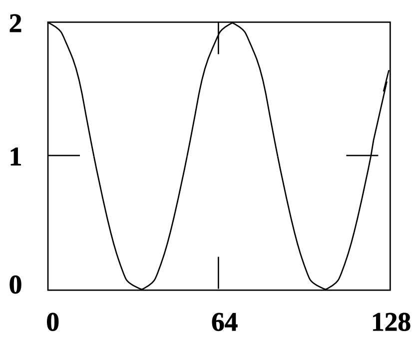


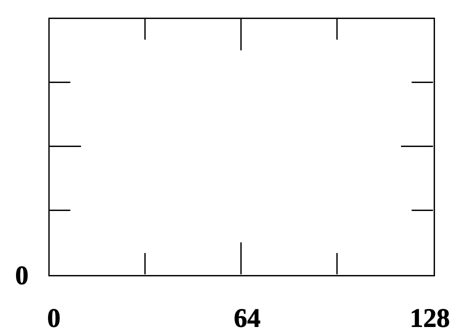




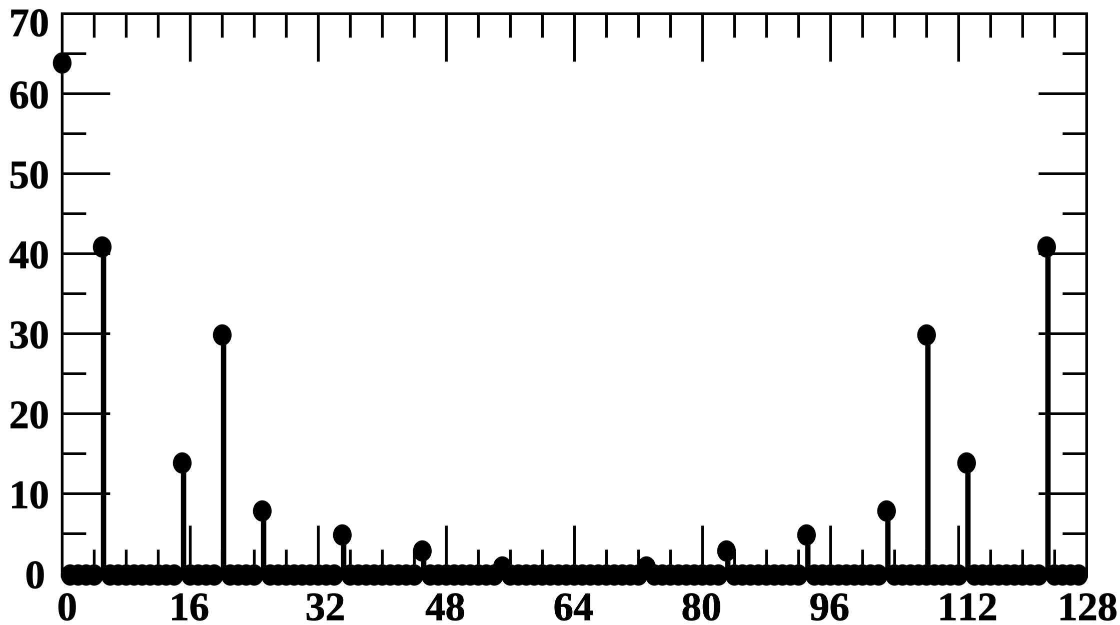


c. (10 points) Sketch the magnitudes of the DFT of the following waveform





d. (10 points) After answering the above questions, you are satisfied that you understand Fourier transforms, and you go into the lab. You decide to sample exactly 5 cycles of a 15 Hz square wave (after anti-aliasing filtering) and compute the FFT. The magnitude of your FFT coefficients are plotted below. Explain the non-zero values at n = 5, 15, 20, 25, 35, 45, 55, 73, 83, 93, 103, 108, 113, and 123. (You do not need to explain the amplitudes, just why they are non-zero.)



Initials ________________________

Problem 6 (total 30 points):

You are assigned the task of designing a system for measuring the velocity of moving objects (like automobiles), by sending out 50 kHz sound waves and measuring the Doppler-shifted echoes. You decide to detect, amplify, and sample the echo using hardware similar to (but faster than) what you used in the 145M lab. The echo is weak and the amplifier you use has a high gain and a bandwidth of 1 MHz. Note that most of the objects in the field of view are stationary.

The Doppler frequency shift Δf is given by $\Delta f/f = v/v_s$, where f is the initial frequency, v is the velocity of motion, and v_s = 300 m/s is the velocity of sound. For objects moving toward the sound detector, the frequency increases.

a. (15 points) Sketch a block diagram of your system, labeling all essential components, lines, and signals

b. (5 points) What is your sampling frequency?

c. (5 points) For an accuracy of 0.1 m/s, how many samples are required?

d. (5 points) Sketch the magnitudes of the FFT coefficients in the situation where these is an object moving toward the sound detector at 30 m/s.

Initials ________________________

Problem 7 (total 30 points):

Your are given linear, time invariant system that acts as a single-stage low pass filter plus a damped oscillator so that a step change at the input results in output oscillations that exponentially decay with time. The impulse response c(t) is the sum of a decaying exponential and a decaying harmonic

$c(t) = e^{-t/\tau} + 2e^{-t/\tau}\cos(2\pi f_0 t)$, where f_0 = 100 Hz and τ = 1 s

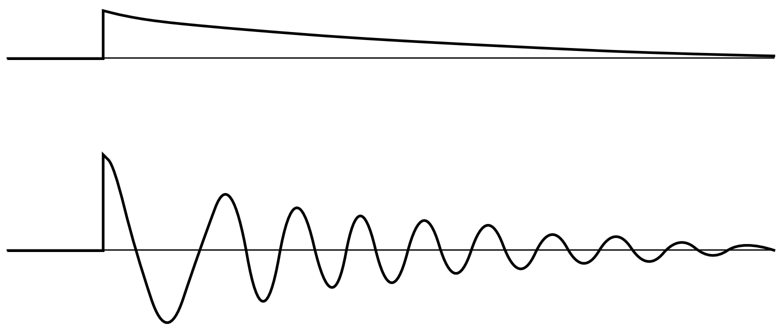


Figure 1 Impulse response c(t) = the sum of a decaying exponential and a decaying cosine wave.

a. (10 points) Derive the equation of the Fourier transform of the impulse response (explain your reasoning)

b. (10 points) Sketch the Fourier transform (magnitudes only) of the impulse response

c. (10 points) How would you compute the input that would make a square wave output?

Note that the Fourier transform of the decaying exponential is included below.

Initials ________________________

Equations, some of which you might find useful:

$$V(n) = V_{\text{ref}}^- + n\left(\frac{V_{\text{ref}}^+ - V_{\text{ref}}^-}{2^N}\right) = V_{\min} + n\left(\frac{V_{\max} - V_{\min}}{2^N - 1}\right)$$

$$\left|\frac{V_{\text{out}}}{V_{\text{in}}}\right| = \frac{1}{\sqrt{1 + (f/f_c)^{2n}}}$$

$$n = \left[\frac{V - V_{\text{ref}}^-}{\Delta V} + \frac{1}{2}\right]_{INTEGER} \qquad V(n-1,n) = V_{\text{ref}}^- + (n - 0.5)\Delta V \qquad \Delta V = \frac{V_{\text{ref}}^+ - V_{\text{ref}}^-}{2^N - 1}$$

$$G(a) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left[-\frac{1}{2}\left(\frac{a-\mu}{\sigma}\right)^2\right] \qquad \mu \approx \bar{a} = \frac{1}{m}\sum_{i=1}^{m} a_i \qquad rms = \sqrt{\frac{1}{m}\sum R_i^2} \qquad R_i = a + bn_i - V_i$$

$$a = \frac{st - rq}{ms - r^2} \quad \text{and} \quad b = \frac{mq - rt}{ms - r^2} \qquad \text{where} \quad r = \sum n_i \quad s = \sum n_i^2 \quad q = \sum n_i V_i \quad t = \sum V_i$$

$$\sigma^2 = \text{Var}(a) = \left(\frac{1}{m-1}\right)\sum_{i=1}^{m} R_i^2 = \left(\frac{1}{m-1}\right)\sum_{i=1}^{m}\left(a_i - \bar{a}\right)^2 \qquad Var(\bar{a}) = Var(a)/m$$

$$H(f) = \int_{-\infty}^{\infty} h(t)\, e^{-j2\pi ft}\, dt \qquad \text{If } h(t) = \begin{cases} A & \text{for } |t| \le T_0/2 \\ 0 & \text{for } |t| > T_0/2 \end{cases}, \text{ then } H(f) = AT_0\frac{\sin(\pi T_0 f)}{\pi T_0 f}$$

$$\text{If } h(t) = 0 \text{ for } t < 0; \quad h(t) = Ae^{-t/\tau} \text{ for } t \ge 0, \text{ then } H(f) = A\Big/\sqrt{1 + 4\pi^2 f^2 \tau^2}$$

$$H_n = \sum_{k=0}^{M-1} h_k e^{-j2\pi nk/M} \qquad h_k = \sum_{n=0}^{M-1}\frac{H_n}{M}\, e^{+j2\pi nk/M}$$

$$F_n = |H_n| = \sqrt{\text{Re}(H_n)^2 + \text{Im}(H_n)^2} \qquad \tan\varphi_n = \text{Im}(H_n)\big/\text{Re}(H_n)$$

$$\text{For } h_k = \sum_{i=0}^{M-1} a_i \cos(2\pi ik/M) + b_i \sin(2\pi ik/M) \qquad H_0 = Ma_0 \quad H_n = (M/2)(a_n - jb_n)$$

$f_{max} = f_s/2$ $\Delta t = 1/f_s$ $S = M\Delta t$ $\Delta f = 1/S$ $h(t) = 0.5[1.0 - \cos(2\pi t/S)]$

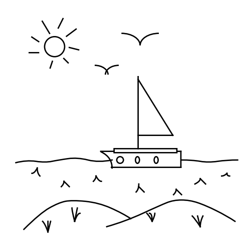
$$y_i = A_1 x_{i-1} + A_2 x_{i-2} + \ldots + A_M x_{i-M} + B_1 y_{i-1} + \ldots + B_N y_{i-N}$$

If $a(t) = \int_{-\infty}^{+\infty} b(t')c(t - t')\,dt' = b(t) \quad c(t)$, then FFT(a) = FFT(b) multiplied by FFT(c)

$$f_{\max} = \frac{1}{2^{N+1}\pi T} \qquad e^{j\theta} = \cos\theta + j\sin\theta \qquad V(t) = V(0)\, e^{-t/RC}$$

N =	8	9	10	11	12	13	14	15	16
2^N =	256	512	1,024	2,048	4,096	8,192	16,384	32,768	65,536

Have a pleasant summer!



Initials ________________________

If $h_k = \begin{cases} A & \text{for } 0 \le k < k_1 \\ 0 & \text{for } k_1 \le k < M \end{cases}$, then $F_n = \begin{cases} Ak_1 & \text{for } n = 0 \\ \left| \dfrac{AM \sin(\pi n k_1 / M)}{\pi n} \right| & \text{for } 0 < n < M - 1 \end{cases}$