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)	8 ____________ (100 max)	21 ____________ (100 max)
2 ____________ (100 max)	9 ____________ (100 max)	22 ____________ (100 max)
3 ____________ (100 max)	10 ____________ (100 max)	23 ____________ (100 max)
* lowest grade dropped		25 ____________ (100 max)

HIGHEST 8 LAB GRADES ×5/8	_______________	(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 1994 FINAL EXAM (May 20)

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 __________ (42 max)   3 __________ (60 max)   5 _________ (16 max)

2 __________ (50 max)   4 __________ (32 max)   TOTAL __________ (200 max)

Initials ________________________

Problem 1 (total 42 points):

Define the following terms (should take no more than 40 words)

a. (7 points) **Comparator circuit**

b. (7 points) **Harmonic** (of a periodic signal)

c. (7 points) **Data bus** (for connecting 2 or more parallel outputs)

Problem 1 (continued):

d. (7 points) **Differential Linearity Error** (of an A/D converter)

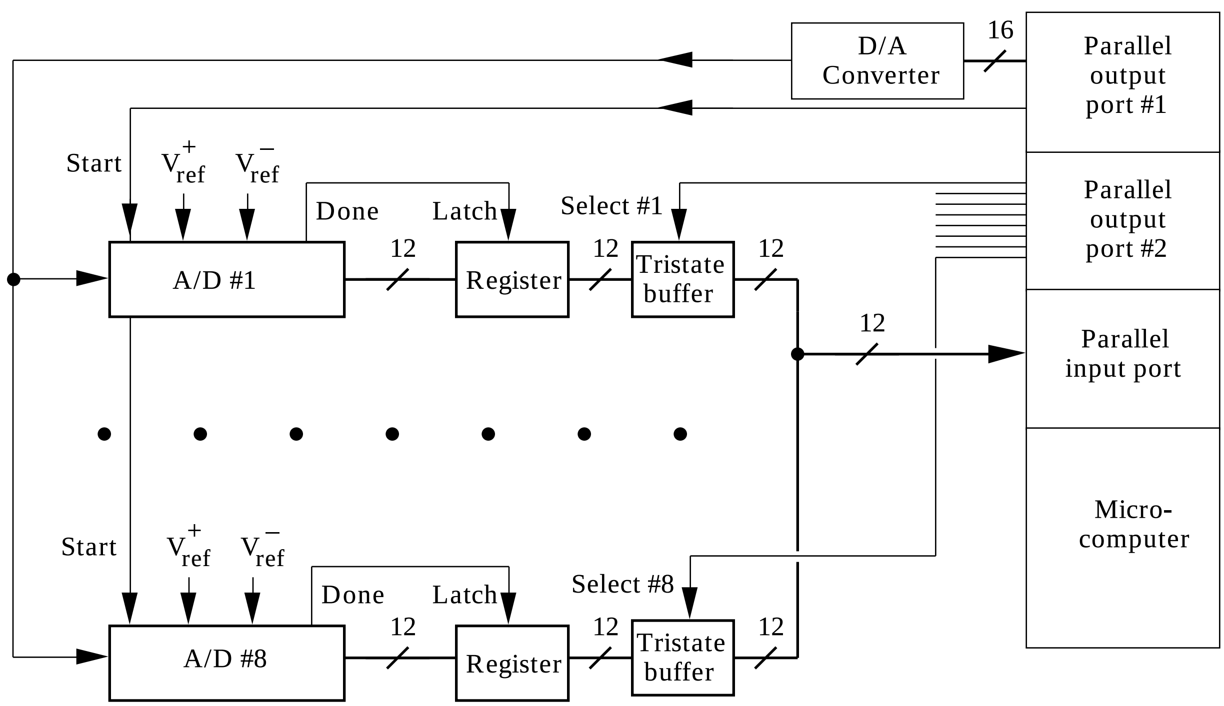
e. (7 points) **Fourier Convolution Theorem**

f. (7 points) **Spectral Leakage** (as seen in the FFT of a periodic signal)

Initials ______________________

Problem 2 (50 points)

The block diagram below shows a system for measuring the properties of eight 12-bit A/D converters automatically under computer control. The output of a single 16-bit D/A converter is used for all analog inputs. All eight A/Ds are started simultaneously and their outputs are latched onto 12-bit registers when they are done. The A/D conversion time is 10±1 μs.



a. (40 points) Describe the steps (both hardware and software) necessary to measure (i) the maximum absolute accuracy error, (ii) the minimum step size, and (iii) the maximum step size of each of the eight A/D converters. Assume that you know the reference voltages V_{ref}^{+} and V_{ref}^{-}. (Note: there are over ten steps)

Initials ________________________

Problem 2 (continued)

b. (10 points) Assuming that the parallel port read and write operations each take 10 μs and that the time to execute other program steps is negligible, how many seconds will the entire procedure take for the 8 A/D converters? (show work)

Initials ________________________

Problem 3 (60 points)

Imagine that many years ago, a spacecraft was sent to measure the magnetic fields in the great void between the sun and the nearest star. This information is transformed into an analog waveform that is exactly one second in duration and has frequencies extending from 1 Hz to 2,000 Hz. Because the spacecraft is far from earth and has limited battery power, the data signal is weak. However, there is a much larger background noise from the rest of the universe that adds to the weak data signal. This background noise is white (all frequencies are present with equal amplitude) and extends beyond 1 MHz.

To be able to detect the weak data signal, you use three techniques:

(i) the spacecraft sends the 1 s data signal over and over again with a period of exactly 1 s

(ii) the radio signal is low-pass filtered before sampling

(iii) you use your knowledge of the FFT of a periodic signal to further separate the background noise from the data signal

To do this, you perform the following steps:

1 receive and low-pass filter the radio signal (weak data signal plus background noise)

2 sample the filtered radio signal for exactly 100 s at 10,486 Hz (2^{20} = 1,048,576 samples)

3 take the FFT

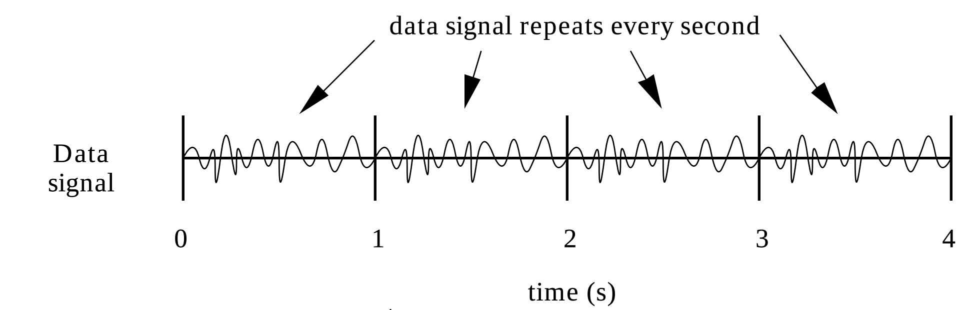
4 subtract as much of the background noise as possible

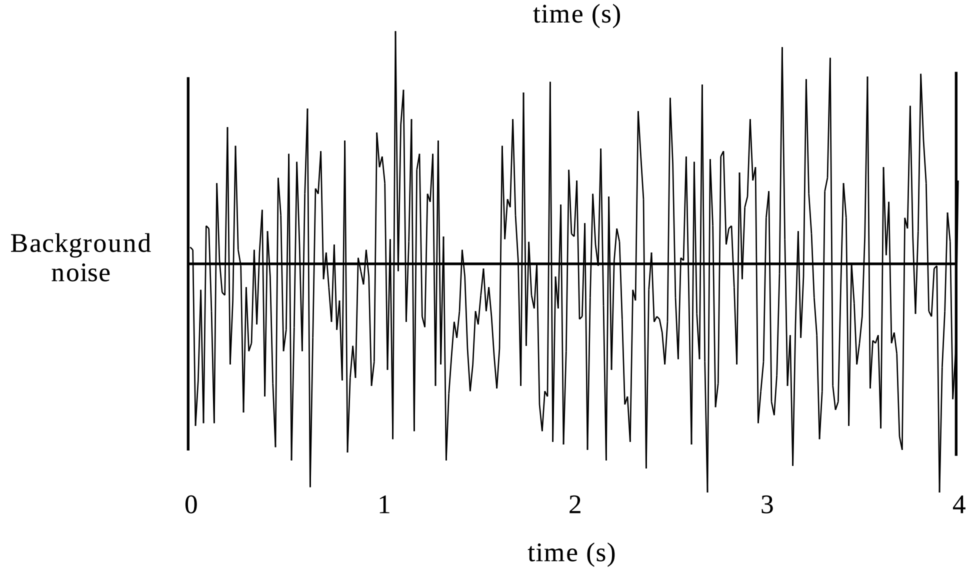
5 recover one cycle of the data signal

Note 1: A periodic signal with repeat frequency f_r contains only frequencies $f = m f_r$

Note 2: If a(t) = b(t) + c(t), then FFT(a) = FFT(b) + FFT(c)

Note 3: You may assume that the data signal does not change over 100 s.





a. (15 points) Describe (or sketch) the Fourier magnitudes M_n from the FFT in step 3 as a function of the frequency index n.

b. (5 points) To what frequency does the first Fourier magnitude M_1 correspond?

c. (10 points) Describe the gain vs. frequency relation that the low-pass filter should have.

d. (10 points) Explain whether a Hanning window would improve the recovered waveform.

Initials ________________________

e. (20 points) Describe in detail how a computer program would implement steps 2, 3, 4, and 5. (Note: there are over seven program steps)

Initials ________________________

Problem 4 (total 32 points):

After each of the four types of A/D converters listed below, write only the lettered characteristics that apply.

1. Successive approximation ____
2. Tracking ____
3. Dual slope (or integrating) ____
4. Flash ____

a. for N bits of resolution, conversion can take as many as 2^N operations
b. for N bits of resolution, conversion takes N operations
c. conversion is done continuously (i.e. one step for any change in input voltage)
d. requires a sample and hold for rapid, accurate conversion
e. limited to N = 10 bits at present
f. conversion accuracy does not depend on resistor accuracy
g. uses an internal D/A converter
h. uses one or more internal comparators
i. determines the output by counting pulses

Problem 5 (total 16 points):

After each of the four interfacing standards listed below, write only the lettered characteristics that apply:

1. RS-232 ____
2. RS-422 ____
3. IEEE-488 (GPIB) ____
4. VME ____

a. data transmitted serially (i.e. one bit at a time)
b. data transmitted in parallel (i.e. many bits transmitted simultaneously on as many wires)
c. can be implemented using existing telephone lines
d. allows up to 21 controllers (e.g. microprocessors) to interface with each other and with the circuits that they control
e. permits data transfer at or above 1000 bytes per second
f. permits data transfer at or above 1 million bytes per second
g. permits data transfer at or above 10 million bytes per second
h. serial data transfer using differential ±3 volt signals on a twisted pair of wires

Initials ________________________

Equations, some of which you might find useful:

$$V(n) = V_{\mathrm{ref}}^{-} + n\left(\frac{V_{\mathrm{ref}}^{+} - V_{\mathrm{ref}}^{-}}{2^N}\right) = V_{\mathrm{min}} + n\left(\frac{V_{\mathrm{max}} - V_{\mathrm{min}}}{2^N - 1}\right) \qquad \left|\frac{V_{\mathrm{out}}}{V_{\mathrm{in}}}\right| = \frac{1}{\sqrt{1 + (f/f_c)^{2n}}}$$

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

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

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

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

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

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

$$M_n = |H_n| = \sqrt{\mathrm{Re}(H_n)^2 + \mathrm{Im}(H_n)^2} \qquad \tan\varphi_n = \mathrm{Im}(H_n)/\mathrm{Re}(H_n)$$

$$\text{For } h_k = \sum_{i=0}^{N-1} a_i \cos(2\pi ik/N) + b_i \sin(2\pi ik/N) \qquad H_0 = Na_0 \quad H_n = (N/2)(a_n - jb_n)$$

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

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

If $a(t) = b(t)$ convolved with $c(t)$, then FFT(a) = FFT(b) multiplied by FFT(c)

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

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!