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 ____________	2 ____________	3 ____________
8 ____________	9 ____________	10 ____________
21 ____________	22 ____________	23 ____________
24 ____________		

Total of 4 Lab Grades	____________	(400 max)
Total of 5 Question Sections	____________	(100 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 1996 FINAL EXAM (May 17)

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 ________ (20 max)	2 ________ (50 max)	3 ________ (40 max)
4 ________ (50 max)	5 ________ (40 max)	TOTAL ________ (200 max)

Initials ________________________

Problem 1 (total 20 points):

A student has a computer with an analog output port with a 12-bit D/A converter that has an output range from 0 to 5 volts. The student attempts to produce a ***triangle*** wave that rises from 0 V to 5 V, then falls to 0 V, then rises to 5 V, then falls to 0 V, etc. by sending the following sequence of numbers to the D/A:
0, 1, 2, . . ., 4999, 5000, 4999, . . ., 2, 1, 0, 1, 2, . . ., 4999, 5000, 4999, . . ., 2, 1, 0, etc.

a. (10 points) Sketch the waveform actually produced at the analog output port (ignore the tiny steps that correspond to the D/A output steps). Label the vertical axis, but do not worry about the time axis.

b. (10 points) Show how you could improve on what the student did.

Initials ________________________

Problem 2 (50 points)

Interface an analog data conversion circuit (Figure 1) to the digital input port of a microcomputer. The analog data conversion circuit has the following features:

- S/H input
- A/D conversion is started with a low-to-high edge
- A/D conversion complete is signaled with a high-to-low edge (and reset to high when the A/D start conversion is reset to low)

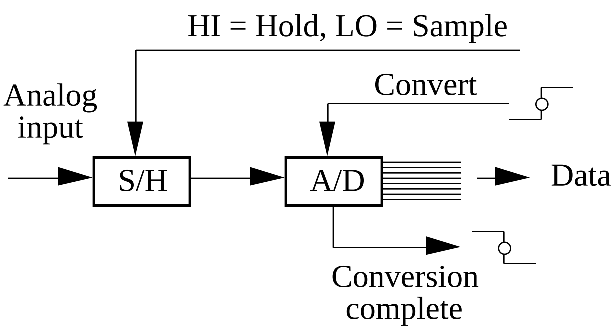

Figure 1 Analog data conversion circuit, using a sample and hold amplifier and an A/D converter.

The digital input port (similar to the one used in the 145M laboratory exercises 3, 8, and 9) has the following features:

- An output line BI CTS that can be set high or low by program control
- A status register BI STROBE that can be set high or low by an external circuit and its logic state read by the program

  (You may let $\overline{\text{BI HOLD}}$ float high for transparent mode)

a. (20 points) Draw a block diagram of your circuit design, showing and labeling all essential components and connections.

Initials ________________________

Problem 2 (continued)

b. (15 points) Assuming that the program initiates analog data acquisition, describe the sequence of steps that occur, including handshaking.

c. (15 points) Sketch a timing diagram (logic level vs. time) of the signal and handshaking lines.

Initials ________________________

Problem 3 (total 40 points):

You have been chosen to design a microcomputer system for timing the swimming events in the Summer Olympic Games. The timer interval to be measured is started by the sound of the starter's pistol and is stopped when the swimmer makes contact with a switch (called a "touch plate") mounted on the side of the pool.

The requirement for your design is:

- The system must measure the time difference between the start and stop events to an accuracy of 100 μs and display the result (in units of s) on the output display screen. (You will also want to write the information to a file, but don't worry about that for this exam.)

You have the following components:

- A microphone with preamplifier
- A comparator (two analog inputs, one digital output)
- A microcomputer with 16-bit digital input port (read time 1 μs) and 32-bit digital timer (clock frequency 1 MHz).
- A "touch plate" circuit that produces a 5 Volt signal when the plate is touched.

a. (20 points) Sketch your design, showing and labeling all essential components and lines.

Initials ________________________

Problem 3 (continued)

b. (20 points) Describe the events (hardware and software) that must take place from the start event to the display of the time difference.

Initials ________________________

Problem 4 (50 points)

Design a microcomputer-based data acquisition system that does the following:

1. The microcomputer asks the user for the number of samples (from 1 to 65,000), the time interval between samples (from 0.1 µs to 6 ms), and the name of the output data file.
2. The microcomputer interfaces with a special-purpose external circuit (to be designed by you).
3. The external circuit takes the specified number of samples and stores them in a high speed random access memory circuit.
4. The microcomputer reads the random access memory and writes the data to an output file on disk.

You are provided with a computer with the following components:

1. disk drive
2. I/O port having 16 input and 16 output lines. Reading or writing takes 1 µs.
3. A special digital counter/timer interface circuit that has:

   Two 16-bit counters (A and B) that can be set to any number and then count down to zero.

   Counter A is wired to count down at 10 MHz. When counter A reaches zero, it reloads its original number, generates an external pulse which is also sent to counter B, and resumes counting down.

   Counter B is reduced by one count whenever it receives a pulse from counter A. All 16 bits of counter B are available on external lines, and the number is guaranteed to be valid only on the **leading** edge of the counter A external pulse.

You are also provided with the following components for your external circuit:

1. A 10-bit flash A/D converter with 50 ns conversion time. Conversion is initiated by a “start conversion” input pulse and the digital output data are guaranteed to be valid only on the **leading** edge of a “conversion complete” pulse.
2. A memory circuit with 16 address lines (input), 16 input data lines, 16 output data lines, and two logic lines, a “write” and “read”. The leading edge of the “write” pulse latches data from the 16 input data lines into the memory location specified by the address lines. A pulse on the “read” line causes data to be read from the specified memory address and after a 10 ns delay, is present on the 16 output data lines for the duration of the “read” pulse.
3. A 16-bit D-type flip flop, where all bits are latched on a common clock edge
4. Any other components you may need, but keep it simple

Initials ________________________

Problem 4 (continued)

a. (20 points) Draw the block diagram for the microcomputer, counter/timers, external circuits, and the lines that connect them. Label all essential components, control lines, and data lines.

Initials ___________________________

Problem 4 (continued)

b. (20 points) Describe in step-by-step sequence how your program and external circuit works. (There is no need to write detailed C code- just a flow chart in list form)

c. (10 points) Draw a timing diagram (logic level vs. time) for all control and data lines.

Initials ________________________

Problem 5 (total 40 points):

Your project is to determine the input waveform that will make a high-power amplifier with limited frequency response produce square waves with sharp corners. You connect a square wave with exactly 10 Hz repetition frequency to the amplifier input, sample the amplifier output for exactly 1 s at a sampling frequency of 65,536 Hz, and take the Discrete Fourier Transform using the FFT function.

a. (10 points) If the amplifier has a flat response from below 20 Hz, –3 dB at 20 Hz, and 6 dB per octave rolloff above 20 Hz, sketch or describe the magnitude of the Fourier coefficients.

b. (10 points) For a general frequency response, how would you use the complex FFT coefficients of the output (with 10 Hz input) to determine the input waveform that would cause the power amplifier to output a good square wave with ***10 Hz*** repetition frequency? (Hint: use additional FFT calculations if necessary)

Problem 5 (continued)

c. (10 points) For a general frequency response, how would you use the complex FFT coefficients of the output (with 10 Hz input) to determine the input waveform that would cause the power amplifier to output a good square wave with ***20 Hz*** repetition frequency?

d. (10 points) How reliable is your method (using the FFT of the output with 10 Hz input) in producing square wave output with low repetition frequencies (say, 5 Hz), or with high frequencies (say, 10 kHz)? Explain your reasoning.

Initials ___________________________

Equations, some of which you might find useful:

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

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

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

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

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

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

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

$$\boldsymbol{H_n = \sum_{k=0}^{M-1} h_k e^{-j2\pi nk/M} \qquad h_k = \sum_{n=0}^{M-1}\frac{H_n}{M}e^{+j2\pi nk/M}} \qquad \text{dB} = 20\log_{10}$$

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

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

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

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

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

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

$$n = \frac{\ln\left[\left(G_1^{-2} - 1\right)\Big/\left(G_2^{-2} - 1\right)\right]}{2\ln\left[f_1/f_2\right]} \qquad f_c = f_1\left(G_1^{-2} - 1\right)^{-1/2n} = f_2\left(G_2^{-2} - 1\right)^{-1/2n}$$

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!