NAME (please print) ____

STUDENT (SID) NUMBER ___________________________

UNIVERSITY OF CALIFORNIA

College of Engineering
Electrical Engineering and Computer Science Department
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)

HIGHEST 8 LAB GRADES x7/8 ________________ (700 max)

MID-TERM ___________________ (100 max)

FINAL EXAM _________________ (200 max)

TOTAL COURSE GRADE _________ (1000 max)

COURSE LETTER GRADE

Spring 1990 FINAL EXAM

May 17, 1990

Answer the questions on the following pages completely, but as concisely as possible. The exam is to be taken ***closed book***. Although the exam was designed to be completed in two hours, you can use the full three hour assigned period. Use the reverse side of the exam sheets if you need more space. Calculators are OK but not needed. Total 200 points. **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.

FINAL EXAM GRADE :

1 __________ (42 max) 3 __________ (38 max) 5 _________ (30 max)

2 __________ (30 max) 4 __________ (60 max)

TOTAL __________ (200 max)

Initials ________________________

Problem 1 (total 42 points):

Define the following terms (30 words or less)

A) (7 points) **Sample and Hold Amplifier**

B) (7 points) **Transition Voltages** (of an A/D converter)

C) (7 points) **Frequency Aliasing**

Problem 1 (continued):

D) (7 points) **Glitch** (in a D/A converter)

E) (7 points) **Digital Filter**

F) (7 points) **Power Supply Sensitivity** (of a D/A converter)

Initials ________________________

Problem 2 (total 30 points):

Briefly describe the operation of the following A/D converters. Be sure to include the number of sequential "steps" need for a typical conversion.

A) (10 points) **Successive Approximation**

B) (10 points) **Flash**

C) (10 points) **Tracking**

Problem 3 (38 total points):

As a new electrical engineer at the Dynamic Data Devices Corporation, you are asked to design an automated (i.e. computer controlled) system for the assembly line testing of a new type of 12-bit A/D converter. The A/D converter requires a “start conversion” signal and after conversion provides a “data ready” signal that is reset by the next “start conversion”.

You are provided with (1) a microcomputer equipped with 16-bit parallel I/O ports similar to those you used in the laboratory exercises and (2) a 16-bit D/A converter with 1/2 LSB absolute accuracy.

A) (18 points) Draw a block diagram of the major components of the system, including an A/D circuit being tested. Show and label all important data and control lines.

Problem 3 (continued):

B) (5 points) How would you measure the absolute accuracy of the A/D?

C) (5 points) How would you measure the linearity (relative to the end points)?

D) (5 points) How would you measure the differential linearity?

E) (5 points) What is the typical accuracy of the quantities measured in parts B, C, and D in terms of 1 LSB (least significant bit) of the A/D?

circle one choice: $1 \quad \frac{1}{2} \quad \frac{1}{4} \quad \frac{1}{16} \quad \frac{1}{64} \quad \frac{1}{256} \quad \frac{1}{4096} \quad \frac{1}{65536}$

Problem 4 (total 60 points):

Design a microcomputer-based system for the high-fidelity sampling and digital storage of music (like the compact audio disk or digital audio tape). The design requirements are as follows:

- The signal frequency range is from 10 Hz to 20,000 Hz.
- Only consider music that is detected with microphones, such as classical or opera.
- The maximum microphone output signal is 10 mV peak to peak (p-p).
- The microphones and amplifiers produce white noise (constant noise power in each frequency band) from 0 Hz to 100 kHz.
- The A/D converter you are using has a –5 V to +5 V input range.
- The digital resolution must be < 0.002% (2×10^{-5}) of the full A/D range.
- Your design will include a device for storing large quantities of digital data. (In the recording industry, magnetic tape is used to store the digital master recordings).
- The time interval between samples must be constant to one part in 10^6.
- You have rejected commercially available data acquisition circuits as being too slow, too inaccurate, or too costly and have decided to design your own using parallel I/O ports and counter/timer circuits similar to those in the laboratory exercises.

A) (30 points) Draw a block diagram of your design, starting from one of the microphones and showing all necessary components and interconnections.

Problem 4 (continued):

B) (5 points) According to the Nyquist theorem, what is the minimum sampling frequency necessary for subsequent recovery of the signal?

C) (5 points) Practically, what would be a good design value for the sampling frequency of the system? Explain your reasoning.

D) (5 points) Describe the A/D requirements in terms of number of bits and conversion time.

Initials ________________________

Problem 4 (continued):

E) (5 points) Which type of A/D converter would be most appropriate? Explain. (Consider integrating, tracking, successive approximation, and flash)

F) (5 points) What capacity (in megabytes) is required for the digital storing of 1 hour of music at the sampling rate from part C above?

G) (5 points) What is the maximum aperture time jitter of the sample-and-hold amplifier that will guarantee 1/2 LSB accuracy at the maximum frequency of 20,000 Hz? (1 ns = 10^{-9} s)

circle one choice: 121 ns 12.1 ns 1.21 ns 0.121 ns 0.0121 ns

Initials ________________________

Problem 5 (total 30 points):

To measure the harmonic distortion of a high fidelity audio amplifier, you use a pure sinewave input of exactly 100 Hz and sample the amplifier output for exactly 2 seconds at a sampling frequency of 32,768 Hz. You then take the Fast Fourier Transform of the digital data. Assume that the Fourier coefficients are defined as in the laboratory exercises.

A) (6 points) To what frequencies (in Hz) do the first and second Fourier coefficients (F_0 and F_1) correspond?

B) (6 points) What Fourier coefficient corresponds to the highest frequency that can be reliably sampled and what is that frequency?

C) (6 points) Assuming that the amplifier can amplify the 100 Hz tone perfectly with no distortion, which Fourier coefficients would be non-zero?

D) (6 points) Assuming that the amplifier introduces some distortion that causes the output to be a distorted sinewave described by both even and odd harmonics, which Fourier coefficients would be non-zero? (Note: the even harmonics are zero only for symmetric waveforms such as the square or triangle waves you used in the laboratory exercises.)

E) (6 points) If (1) the audio tone were changed to 100.25 Hz, (2) you do not multiply the data by a windowing function, and (3) the amplifier has no distortion, what would the Fourier Transform look like? (Describe large, small, and zero components.)

Initials ________________________

Equations, some of which you might find useful:

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

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

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

$$\text{rms} = \sqrt{\tfrac{1}{m}\sum R_i^2} \qquad R_i = a + bn_i - V_i$$

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

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

$$F_n = \sum_{k=0}^{N-1} f_k e^{-i2\pi nk/N} \qquad f_k = \sum_{n=0}^{N-1} \frac{F_n}{N} e^{+i2\pi nk/N} \qquad |F_n| = \sqrt{\text{Re}(F_n)^2 + \text{Im}(F_n)^2}$$

$$\text{For } f_k = \sum_{j=0}^{N-1} a_j \cos(2\pi jk / N) + b_j \sin(2\pi jk / N) \qquad F_0 = Na_0 \quad F_n = (N/2)(a_n - ib_n)$$

$f_{max} = f_s/2$ $\quad T = 1/f_s$ $\quad S = NT$ $\quad \Delta f = 1/S$

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

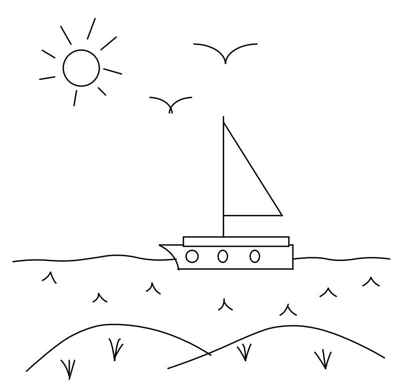
$$t = \frac{\Delta}{\sqrt{\text{Var}(\Delta)}} = \frac{\bar{a} - \bar{b}}{\sqrt{\text{Var}(\bar{a}) + \text{Var}(\bar{b})}} = \frac{\bar{a} - \bar{b}}{\sqrt{\text{Var}(a)/m_a + \text{Var}(b)/m_b}}$$

$$t = \frac{\bar{d}}{\sqrt{\text{Var}(\bar{d})}} = \frac{\bar{d}}{\sqrt{\left(\frac{1}{m}\right)\left(\frac{1}{m-1}\right)\left(\sum d_i^2 - m\bar{d}^2\right)}}$$

$$f_{max} = \frac{1}{2^{N+1}\pi T} \qquad e^{i\theta} = \cos\theta + i\sin\theta$$

$2^8 = 256$ $\qquad 2^{10} = 1{,}024$ $\qquad 2^{12} = 4{,}096$

$2^{14} = 16{,}384$ $\qquad 2^{15} = 32{,}768$ $\qquad 2^{16} = 65{,}536$



Have a pleasant summer!