Name (Last, First) ____

UNIVERSITY OF CALIFORNIA

College of Engineering
Electrical Engineering and Computer Sciences Department

EECS 145M: Microcomputer Interfacing Laboratory

Spring Midterm #2
Monday, April 19, 1999

- Closed book (equation sheet handed out with this midterm)
- Calculators OK
- You must show your work to get full credit

PROBLEM 1 (50 points)

Design a computer-controlled system for the automatic testing of 12-bit A/D converters.

You are provided with the following:

- A microcomputer equipped with
  one 16-bit parallel input port and
  two 16-bit parallel output ports
- A 16-bit D/A converter with ±1 LSB absolute accuracy error, ±0.5 LSB linearity error, and ±0.5 LSB differential linearity error.

You may assume the following:

- The A/D converters are plugged in manually and tested by your computer system one at a time
- The A/D converter requires a "start conversion" low-to-high signal and after conversion provides a "data ready" low-to-high signal that goes low when "start conversion" goes low.
- The A/D reference voltages are V_{ref}^{-} = 0.0000 V and V_{ref}^{+} = 4.095 V
- The D/A reference voltages are V_{ref}^{-} = 0.0000 V and V_{ref}^{+} = 4.096 V
- The 16-bit parallel output ports are in "transparent" mode. A 16-bit word *A* written to output port *n* (*n* = 1, 2) using the command PutSingleValue(*n*, *A*) immediately appears on the output lines of port *n* and does not change until a new value is written.
- The 16-bit parallel input port is also in "transparent" mode. The program can read the port at any time using the command *B* = GetSingleValue(1), where *B* is a 16-bit word.
- To be able to handle an arbitrary A/D conversion time, you must wait for the "data ready" signal before reading the A/D.

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1a. [25 points] Draw a block diagram of the major components, including the A/D circuit being tested. Show and label *all* essential components, data lines, and control lines.

1b. [10 points] How would you measure the maximum absolute accuracy error of the A/D? (Explain the procedure in steps or with a flow diagram.)

1c. [5 points] How would you measure the maximum linearity error?

1d. [5 points] How would you measure the maximum differential linearity error?

1e. [5 points] With what accuracy could this system measure the quantities in parts **b.**, **c.**, and **d.** in units of 1 LSB of the A/D?

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PROBLEM 2 (50 points)

You have designed and built a computer system to sample waveforms and perform the FFT.

It has the following characteristics:

- Sampling frequency = 2^{18} Hz = 262,144 Hz
- Number of samples = 2^{16} = 65,536
- Low-pass Butterworth anti-aliasing filter of order 8 and f_c = 100,000 Hz
- Hanning (raised cosine) window

Answer the following questions:

2.a (3 points) For what frequency range does the anti-aliasing filter have gain >0.99?
(*Hint:* Use the Butterworth gain table on the equation sheet)

2.b (3 points) For what frequency range does the anti-aliasing filter have gain <0.01?

2.c (2 points) How long does it take to acquire the samples?

2.d (2 points) To what frequencies do the FFT coefficients H_0 and H_1 correspond?

2.e (4 points) What is the FFT coefficient with the highest index and to what frequency does it correspond?

2.f (4 points) What is the FFT coefficient that corresponds to the highest frequency and what is that frequency?

2.g (6 points) You sample a 4,000 Hz ***sinewave*** with the system and take the FFT. What FFT coefficients should be non-zero?

2.h (6 points) You sample a 4,000 Hz symmetric ***square*** wave with the system and take the FFT. What FFT coefficients should be non-zero? (symmetric means 50% high, 50% low)

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2.i (6 points) You sample a 4,002 Hz ***sinewave*** with the system and take the FFT. What FFT coefficients should be non-zero?

2.j (6 points) You sample two sinewave signals, one with a frequency of 4,000 Hz and another at a nearby frequency and 10 times smaller in magnitude. How closely can the frequency of the second signal approach 4,000 Hz and still be resolved in the FFT coefficients as a separate peak?

2.k (6 points) You sample a sinewave of frequency 2^{18} – 84,000 Hz = 178,144 Hz and take the FFT. What FFT coefficients should be non-zero? How does the magnitude of the largest FFT coefficient compare with that you would get if you sampled an 84,000 Hz sinewave?

2.l (2 points) How would you change the system to reduce the answer to the previous question by a factor of two?