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 17, 2000

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

Problem 1 (20 points)

In this course we studied several types of A/D converters:
Tracking Successive Approximation Dual Slope or Integrating Flash

1a. (5 points) Which is the best A/D converter for very high rates (> 100 MHz) at moderate resolution (10 bits)?

1b. (5 points) Which is the best A/D converter for high resolution (16 bits) at moderate rates (<500 kHz)?

1c. (5 points) Which has the best differential linearity and an accuracy that does not depend on the accuracy of internal resistors?

1d. (5 points) Which requires a sample-and-hold amplifier for full accuracy at its maximum conversion rate?

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PROBLEM 2 (35 points) An arbitrary waveform $h(t)$ is periodic with period P and contains only frequencies $f < f_{max}$.

2a. (10 points) $h(t)$ is sampled at a frequency $f_s > 2\ f_{max}$ for a time $S = 4P$.
$M = f_s\ S$ is a power of 2
The sampled values h_k, $k = 0$ to $M - 1$ are transformed using the FFT.
Which Fourier amplitudes H_n would you expect to be non-zero?

2b. (5 points) If a sinewave of frequency $f = (7/8)f_s$ is added to $h(t)$ before sampling, which Fourier amplitudes would change?

2c. (10 points) If $h(t)$ is sampled at a frequency $f_s > 2\ f_{max}$ for a time $S = 3.5P$, and $M = f_s\ S$ is a power of 2, which Fourier amplitudes H_n would you expect to be non-zero?

2d. (10 points) If $h(t)$ is sampled as in 2c above and multiplied by a Hanning window before the FFT, which Fourier amplitudes H_n would you expect to be non-zero?

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PROBLEM 3 (45 points)

You have been asked to help design a Doppler ultrasound system for measuring the speed of approaching vehicles on a highway. The system sends a continuous tone of 100 kHz sound waves in a well-defined direction and there is a receiver alongside that receives the Doppler-shifted echo. Your part in the project is to design the sampling and signal processing hardware and software, starting from the echo receiver.

- The Doppler-shifted frequency is given by $f' = f / [1 - v/c]$, where v is the speed of the approaching vehicle and c is the speed of sound in air (assume 300 m/s).
- To simplify and speed your calculations, use the approximation $f' \approx f [1 + v/c]$.
- Assume that the echo receiver signal is the sum of 0.1 volt p-p echo and an unavoidable 10 volt peak-to-peak (p-p) primary 100 kHz tone that leaks into the echo receiver.
- The echo circuit has wide-band amplification with white noise, so you decide to use an low-pass 8-pole Butterworth anti-aliasing filter that effectively accepts frequencies below f_1 and rejects frequencies above $2 f_1$, where f_1 is a frequency of your choosing.
- Your system samples at frequency f_s, takes M samples (where M is a power of 2), performs the FFT, and must be able to determine the speed of an approaching vehicle between 3 m/s and 60 m/s to an accuracy of ±0.3 m/s.

3a. (5 points) What are the echo frequencies for vehicle speeds of 3 m/s, 30 m/s (67 mph), 30.3 m/s, and 60 m/s (134 mph)?

3b. (5 points) How long must your sampling window be to clearly distinguish 30 m/s from 30.3 m/s?

3c. (5 points) How can you reduce the spectral leakage from the 10 volt p-p 100 kHz primary onto the 0.1 v p-p echo frequency?

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3d. (5 points) Considering the maximum signal frequency (corresponds to 60 m/s) and the white noise in the echo receiver circuit, what value of f_1 does your low pass filter require?

3e. (5 points) Considering the value of f_1 from part 3d above, and that the filter rejects frequencies above $2f_1$, what is the minimum sampling frequency that prevents the aliasing of white noise between f_1 and $2f_1$ into frequencies below f_1?

3f. (5 points) How many samples will you take for each measurement of vehicle speed?

3g. (15 points) Sketch all FFT magnitudes vs. frequency index for a vehicle speed of 30 m/s. You will need to use a vertical axis labeled in powers of ten. Provide an additional label for the horizontal axis in Hz. Assume that the white noise is 10% of the Fourier magnitude of the echo signal.