Name (Last, First) ____________________________ Student ID number _________________

UNIVERSITY OF CALIFORNIA

College of Engineering
Electrical Engineering and Computer Sciences Department

EECS 145M: Microcomputer Interfacing Laboratory

Spring Midterm #2 (Closed book- equation sheet provided- calculators OK)
Full credit can only be given if you show your work.
Wednesday, April 12, 2006

PROBLEM 1 (54 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:

1.1 (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)

1.2 (3 points) For what frequency range does the anti-aliasing filter have gain <0.01?

1.3 (2 points) How long does it take to acquire the samples?

1.4 (3 points) To what frequencies do the FFT coefficients H_0 and H_1 correspond?

1.5 (4 points) What is the FFT coefficient with the highest frequency index and to what frequency does it correspond?

1.6 (4 points) What is the FFT coefficient that corresponds to the highest frequency and what is that frequency?

1.7 (6 points) You sample a 4,000 Hz ***sinewave*** with the system and take the FFT. What FFT coefficients should be non-zero?

1.8 (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)

1.9 (6 points) You sample a 4,002 Hz ***sinewave*** with the system and take the FFT. What FFT coefficients should be non-zero?

1.10 (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?

1.11 (8 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?

1.12 (3 points) How would you change the system to reduce the closeness in problem 1.10 by a factor of two?

PROBLEM 2 (46 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 a 0.1 volt p-p echo from the vehicle plus a 100 kHz 10V p-p echo from stationary objects.
- The echo circuit has wide-band amplification with white noise, so you decide to use a low-pass Butterworth anti-aliasing filter that you need to design.
- You do not use a windowing function (like the raised cosine)
- Your system 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.

2.1 (5 points) What are the echo frequencies for vehicle speeds of 3 m/s, 30 m/s (67 mph), and 60 m/s (134 mph)?

2.2 (5 points) What is the minimum length of time that you need to sample to sample to clearly detect a change in speed of 0.3 m/s?

2.3 (5 points) Even though you do not use a windowing function, how could you reduce the spectral leakage from the ≈10 volt p-p 100 kHz primary onto the 0.1 v p-p echo frequency?

2.4 (5 points) Design an n = 8 order Butterworth low-pass filter (i.e. determine the corner frequency f_c) that has a gain of 0.9 at the maximum signal frequency f_1 (vehicle speed 60 m/s)

2.5 (6 points) If the gain $G_2 < 0.01$ at all frequencies $f > f_2$ that could alias to frequencies $< f_1$, what are f_2 and the minimum sampling frequency f_s?

2.6 (5 points) What is the minimum number of samples that you will need to take for each measurement of vehicle speed?

2.7 (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 at each frequency the white noise is 10% of the Fourier magnitude of the echo signal. (Do not worry if the number of samples is not a power of two).