Name (Last, First) ______________________________ Student ID number ________________

UNIVERSITY OF CALIFORNIA, BERKELEY

College of Engineering
Electrical Engineering and Computer Sciences Department

EECS 145M: Microcomputer Interfacing Laboratory

Spring Midterm #2 (Closed book- equation sheet provided- calculators OK)
Monday, April 22, 2002

PROBLEM 1 (16 points)

1a (6 points) In a system that periodically samples a waveform, what causes aliasing and how can it be prevented?

1b (12 points) In a system that periodically samples a waveform, what causes spectral leakage? For a periodic waveform, how can it be prevented? For a non-periodic waveform, how can it be prevented?

Name (Last, First) ____________________________

PROBLEM 2 (34 points)

High fidelity audio amplifiers are supposed to be perfectly linear over a wide range of input frequencies and amplitudes. Any nonlinearity distorts the input signal and is called harmonic distortion. To measure the harmonic distortion of a high fidelity audio amplifier, you use a pure harmonic input of exactly 1000 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, using 8 byte double precision numbers.

2a (3 points) How many 8-byte numbers do you input to the fft? How many 8-byte numbers are produced by the fft?

2b (3 points) To what frequencies (in Hz) do the first and second Fourier coefficients (H_0 and H_1) correspond?

2c (4 points) What Fourier coefficient corresponds to the highest frequency that can be reliably sampled and what is that frequency?

2d (6 points) Assuming that the amplifier can amplify the 1000 Hz tone perfectly with no distortion, which Fourier coefficients would be non-zero?

Name (Last, First) _____________________________

2e (6 points) Assuming that the amplifier introduces some distortion that causes the output to be a distorted sinewave described by higher harmonics, where would the kth harmonic appear in the fft output?

2f (6 points) If (1) the audio tone were changed to 1000.25 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.)

2g (6 points) What would the answer to **2f** be if a raised cosine window were used?

Name (Last, First) ____________________________

PROBLEM 3 (50 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 primary 100 kHz tone that leaks into the echo receiver with an amplitude that can be as high as 10 volts peak to peak.
- 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.
- Your system samples at frequency f_s = 409.6 kHz, 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?

3d. (15 points) Design a Butterworth low-pass filter (i.e. determine the order *n* and corner frequency f_c) that has a gain of 0.9 at the maximum signal frequency f_{max} (corresponds to 60 m/s) and a gain < 0.01 at all frequencies that could alias to frequencies < f_{max}.

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

3f. (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.