ECE4703 Exam Number 1

Your Name: ______________________________ Your box #: __________

November 7, 2006

Tips:

- Look over all of the questions before starting.
- Budget your time to allow yourself enough time to work on each question.
- Write neatly!
- This exam is worth a total of 100 points.
- Attach your “cheat sheet” to the exam when you hand it in.

problem 1	problem 2	problem 3	problem 4	total exam 1 score
10 points	20 points	30 points	40 points	100 points

1. 10 points. After graduating from WPI, your considerable expertise in real-time DSP lands you a job at a company that produces a popular battery-powered bass guitar effects processor used by many musicians in live performances. This bass guitar processor is currently built with all-analog electronics but your company wants to develop new DSP-based design. Do you recommend going with a fixed-point or floating-point DSP? Does your recommendation have any disadvantages? Explain your answer and discuss the tradeoffs in your approach.

2. 20 points. Suppose that you select an codec (ADC+DAC) for your bass guitar effects processor that has a programmable sampling rate of either 8kHz, 16kHz, 24kHz, 32kHz, 44.1kHz, 48kHz, or 96kHz. *The sampling rate must be the same for both the ADC and the DAC.* Your research reveals that the frequency content of the bass guitar output signal is always below 4.5kHz and that none of the effects produce any frequency content above 13.5kHz. What sampling frequency should you use? Is there any downside to just picking 96kHz? Explain.

3. 30 points total. For the following questions, you are given the following infinite precision FIR filter coefficients.

$$\boldsymbol{h} = \begin{bmatrix} h[0] & h[1] & h[2] \end{bmatrix} = [0.123 \quad 1.5 \quad -3.8]$$

(a) 15 points. Suppose you are required to store these filter coefficients in a $Q-M$ formatted signed 5-bit integer data type. Determine the optimum number of fractional bits (M) to use in your fixed-point representation of the filter coefficients. Show your reasoning.

(b) 15 points. Using your fractional answer from part (a), fill out the following table.

Coefficient Value	Quantized Value (decimal)	Quantized value (binary)	Quantization Error
0.123			
1.5			
-3.8			

4. 40 points total. For the following questions, suppose that you have the following input signal

$$\begin{aligned} x[n] &= 0.9 \times \cos\left(\frac{2\pi n}{10}\right) \text{ for all } n \geq 0 \\ &= 0.9000,\ 0.7281,\ 0.2781,\ -0.2781,\ -0.7281,\ \ldots \end{aligned}$$

and you are filtering this signal with the FIR filter $\boldsymbol{h}$ described in the previous problem. Recall that the filter output is given as

$$y[n] = \sum_{k=0}^{K-1} h[k]x[n-k].$$

(a) 20 points. Suppose $x[n]$ is quantized as a $Q-3$ formatted 4-bit signed integer datatype.

i. Write the quantized values for $x[n]$ (in decimal) for $n = 0, 1, 2, 3, 4$.

ii. Using these quantized values and your Q-formatted 5-bit filter coefficients from the previous problem, compute all of the appropriate intermediate products $u[k] = h[k]x[n-k]$ involved in the computation of $y[4]$ (in decimal).

iii. Using these intermediate products, compute $y[4]$ (in decimal).

(b) 5 points. Under worst-case assumptions, how many total bits are required to store the intermediate results

$$u[k] = h[k]x[n-k]$$

without overflow? How many must be fractional to avoid underflow? Explain.

(c) 5 points. Under worst-case assumptions, how many total bits are required to store the final result

$$y[n] = \sum_{k=0}^{K-1} u[k]$$

without overflow? Explain.

(d) 10 points. Do your results from part (a) agree with those in parts (b) and (c)? In other words, do all of your intermediate results and the final result fit into the Q-formatted integer datatypes predicted by your worst-case analysis? Comment on your results.