ECE4703 Exam Number 2

Your Name: ______________________________ Your box #: __________

November 28, 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	total exam 2 score
15 points	35 points	50 points	100 points

1. 15 points. After graduating from WPI, your considerable DSP experience lands you a job at a company that produces an inexpensive toy that has a very simple fixed-point DSP on board. The main function of the DSP is to lowpass filter incoming sounds from the toy's onboard microphone and ADC. The design engineers decided to go with an 8th order IIR filter with a "direct form II" realization due to the limited memory and computational resources available on the DSP.

   The toy was in hot demand for the 2005 holiday shopping season and your company had to rush the development and testing to meet demand. After shipping more than a million of these toys around the world, customer complaints began to pour in and distributers began returning all of their stock. Nobody at your company could figure out why the toys were not working as expected. Using your knowledge from ECE4703, you discovered late one night that the IIR filter in the DSP was actually unstable due to the fact that the fixed-point coefficient quantization moved two of the poles outside of the unit circle.

   After firing the original design engineers, your boss (who is not an engineer) tells you that it looks like the company will have to replace the low-cost DSP in these toys with either a higher-cost high-precision fixed-point DSP or maybe even a floating point DSP in order to make the IIR filter stable. All of the returned toys will have to be retrofitted due to this engineering disaster!

   Is your boss right? Can you suggest any alternative plans that could potentially avoid the expensive prospect of having to retrofit the low-cost fixed point DSPs used in the original design?

2. 35 points total. Suppose you are given a linear time invariant IIR filter with the transfer function

$$\begin{aligned} H(z) &= \frac{Y(z)}{X(z)} \\ &= \frac{0.5(1-0.3z^{-1})^2(1+2.2z^{-1})^2}{(1-(0.7+0.7j)z^{-1})(1-(0.7-0.7j)z^{-1})(1-0.9jz^{-1})(1+0.9jz^{-1})} \\ &= \frac{0.5+1.9z^{-1}+1.145z^{-2}-1.254z^{-3}+0.2178z^{-4}}{1-1.4z^{-1}+1.79z^{-2}-1.134z^{-3}+0.7938z^{-4}} \end{aligned}$$

Note that $j=\sqrt{-1}$.

(a) 10 points. Is $H(z)$ stable? Why or why not?

Continued...

(b) 25 points. Draw a "Direct Form II – Second Order Sections" realization of $H(z)$ assuming infinite precision filter coefficients (each second order section should have *real-valued* coefficients). Draw neatly and label everything accurately for full credit.

3. 30 points. Suppose you write a program to compute the inverse of an $N \times N$ matrix in real-time. After profiling the code for various values of N, you determine that the number of cycles to compute the matrix inverse follows the trend

$$\text{cycles} = 125 + \frac{3N^3}{4}$$

If your sampling rate is $f_s = 8000$Hz and all processing is performed on a frame-by-frame basis, how large can N be before your program will no longer run in real-time? Explain your answer.

4. 50 points total. Suppose your DSP is running the assembly code given on the last page of this exam (taken from the Kehtarnavaz examples).

   (a) 10 pts. Draw a box around the instruction(s) in the second fetch packet. Label it FP2.

   (b) 10 pts. Draw a box around the instruction(s) in the sixth execute packet. Label it EP6.

   (c) 10 points. Suppose the SHR instruction on line 15 is currently in pipeline stage E1. Put a pound sign (#) next to the instruction(s) currently in pipeline stage DP.

   (d) 10 points. Including the 5 NOP cycles at the end of the listing, how many cycles does this code require to execute?

   (e) 10 points. Suppose the first LDW instruction results in A5=1, the second LDW instruction results in A5=2, and the third LDW instruction results in A5=3. Similarly, suppose the first LDH instruction results in B5=11, the second LDH instruction results in B5=12, and the third LDH instruction results in B5=13 (all values are decimal). Compute the results of the first and second MPY instructions. Explain your answer.

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; ************************************************************************
; *     This code is written by N. Kehtarnavaz and N. Kim as part of the
; *     textbook "Real-Time Digital Signal Processing Based on TMS320C6000".
; ************************************************************************

        .global _iir            ; Simple iir filter implementation
        .sect   ".iir"

_iir:
                ZERO    .S1     A10             ; BSUM
        ||      ZERO    .S2     B10             ; ASUM
        ||      LDW     .D1     *A4++,A5        ; Load input sample (A5=1)
        ||      LDH     .D2     *B4++,B5        ; Load b coefficient (B5=11)
                LDW     .D1     *A4++,A5        ; Load input sample (A5=2)
        ||      LDH     .D2     *B4++,B5        ; Load b coefficient (B5=12)
                LDW     .D1     *A4++,A5        ; Load input sample (A5=3)
        ||      LDH     .D2     *B4++,B5        ; Load b coefficient (B5=13)
                LDW     .D1     *++A6,A7        ; Load output sample
        ||      LDH     .D2     *++B6,B7        ; Load a coefficient
                LDW     .D1     *++A6,A7        ; Load output sample
        ||      LDH     .D2     *++B6,B7        ; Load a coefficient
                MPY     .M1x    A5, B5, A8      ; b * input
                MPY     .M1x    A5, B5, A8      ; b * input
                SHR     .S1     A8, 15, A9      ; Shift right
        ||      MPY     .M1x    A5, B5, A8      ; b * input
                SHR     .S1     A8, 15, A9      ; Shift right
        ||      ADD     .L1     A9, A10, A10    ; Add
        ||      MPY     .M2x    A7, B7, B8      ; a * output
                SHR     .S1     A8, 15, A9      ; Shift right
        ||      ADD     .L1     A9, A10, A10    ; Add
        ||      MPY     .M2x    A7, B7, B8      ; a * output
                ADD     .L1     A9, A10, A10    ; Add
        ||      SHR     .S2     B8, 15, B9      ; Shift right
                SHR     .S2     B8, 15, B9      ; Shift right
        ||      ADD     .L2     B9, B10, B10    ; Add
                ADD     .L2     B9, B10, B10    ; Add
                SUB     .L1     A10, B10, A4    ; BSUM - ASUM
                B       .S2     B3
                NOP     5
```