

EE5630 Digital Signal Processing

HW#6

Lecturer: Yi-Wen Liu

Due Sunday April 19, 2020

1. **(10%)** In Lecture 14 around 19:20, Oppenheim said “it is not a particularly good method in terms of the basic guidelines we set down.” Please explain what this means.
2. **(10%)** In Lecture 14 around 22:20, there is an iterative definition of  $\Delta^{(k)}[y(n)]$  in terms of  $\Delta^{(k-1)}y(n)$ . Let  $\Delta^{(3)}[y(n)] = a_0y(n) + a_1y(n+1) + a_2y(n+2) + a_3y(n+3)$ . Find out explicitly what the coefficients  $a_0 \dots a_3$  are.
3. **(20%)** Briefly summarize what is the advantage vs. disadvantage of impulse invariance IIR filter design compared to bilinear transform filter design.
4. **(60%)** In Video 15-16, even though general principles for bilinear transform-based filter design are discussed extensively, the final form of the filter is not shown in terms of a difference equation. Here, I ask you to complete it by going through the following steps.
  - (a) [10 pts] Find an explicit expression of  $H_a(s)$  given the order  $N=6$  and the cut-off frequency  $\Omega_c = 0.76622$  that should meet the digital filter specifications.
  - (b) [20 pts] By choosing  $T = 1$  and hence substituting  $s(z) = 2(1 - z^{-1})/(1 + z^{-1})$ , find out explicitly an expression for  $H(z) = H_a(s(z)) = B(z)/A(z)$ , where  $B(z)$  and  $A(z)$  are polynomials of  $z^{-1}$ . How many poles and zeros does  $H(z)$  have?
  - (c) [20 pts] Suppose that the system is causal, write down the corresponding constant-coefficient linear difference equation. Please compute and show the coefficients explicitly.
  - (d) [10 pts] Suppose we have a floating-point processor to use. For computing every sample of output, how many floating-point multiplications are required?
  - (e) *Bonus 5 pts:* For those of you that are familiar with analog circuit design, please describe how can this 6<sup>th</sup>-order Butterworth filter be implemented in analog, e.g., how many transistors should be used and what design techniques might be involved? (Note: Prof. Liu is not familiar and would thus be curious.)