UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Department of Electrical and Computer Engineering

ECE 310 Digital Signal Processing – Fall 2023

Homework 11

Profs. Do, Snyder, Moustakides **Due: Friday, Nov 10, 2023 on Gradescope**

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1. An analog (continuous-domain) signal $x_c(t) = 5\cos(400\pi t) + 10\sin(500\pi t)$ is to be processed by a digital signal processing (DSP) system in which the sampling frequency is 1 kHz. Suppose that we want to pass the first component of $x_c(t)$ with attenuation of less than 1 dB, but attenuate the second component to at least 50 dB. Sketch the specification of the digital (discrete-domain) filter in such a DSP system, and identify the cutoff frequency ω_c and transition bandwidth $\Delta\omega$ of the desired digital filter.

2. For each of the following scenarios, decide what type of DSP filter (lowpass, highpass, bandpass, or bandstop) you should use to solve the problem and give the cutoff frequency or frequencies of the filter.

   (a) An AM radio receiver uses a continuous-time modulator tuned to 800 kHz to mix a radio signal down to complex baseband, where it is sampled by an ideal (aliasing-free) continuous-to-discrete-time converter at a sample rate of 30 kHz. The user wishes to listen to the station at 800 kHz (0 kHz in complex baseband). AM radio stations have carrier frequencies 10 kHz apart.

   (b) A recording was made with sample rate 400 Hz. There is a strong 60 Hz hum due to electrical equipment in the room that must be removed, but the rest of the recording should be preserved as well as possible. Allow for a transition band of $\pi/10$ in your filter.

3. Draw a block diagram implementation in direct form I and II of the difference equation system described by:

$$y[n] = 3\sum_{k=0}^{3}\left(\frac{1}{3}\right)^k x[n-k] + \sum_{k=1}^{3}\left(\frac{1}{2}\right)^k y[n-k], \quad n = 0, 1, 2, \ldots$$

   Compare the number of multiplications, additions, and registers required in these two implementations, direct form I and II.