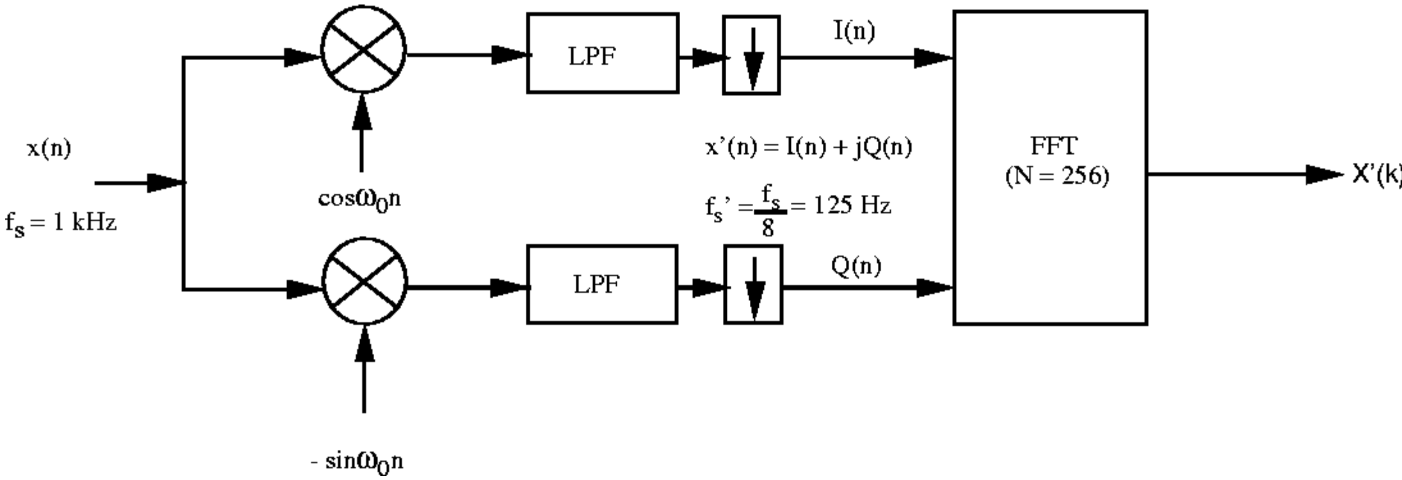
End-Term Project

Note: You should treat this project as a take-home exam. Thus, you should neither give nor receive assistance on completing the project. Include in an appendix your Matlab code.

The following complex basebanding and FFT architecture is to be implemented in software:



LPF specifications: 64-coefficient, linear phase, FIR
passband cutoff frequency = 40 Hz (analog)
stopband cutoff frequency = 85 Hz (analog)
passband/stopband weighting ratio = 50

I. Data Set

A. Generate a 4096-point data file containing samples of the following signal:

$$x(t) = \sum_{l=1}^{3} s_l(t) \text{ where: } s_l(t) = A_l \cos\left(2\pi f_l\, t + \phi_l\right)$$

l	A_l	f_l	ϕ_l
1	100	160	0
2	10	237	0
3	1	240	0

Note: fs = 1 kHz (sampling rate)

B. Plot x(n) (n = 0, ..., 255) (amplitude). Take a N = 256 FFT of that portion of the data set using a KB window ($\alpha = 2.5$ or $\beta = 7.85$). Plot $|X(k)|$ (dB) and identify the locations of $\pm f_1$, $\pm f_2$, and $\pm f_3$. What is the bin width (analog) of the FFT? In what bins do f_1, f_2, and f_3 reside (for bins numbered –N/2, …, 0, …, N/2-1)? Speculate on whether or not a rectangularly windowed FFT would have indicated distinct spectral peaks corresponding f_2 and f_3.

II. Decimation Filter Design

A. Using an equiripple FIR filter design algorithm, design the decimation filter.

B. Plot h(n) (amplitude). Take a N = 1024 FFT of h(n) (rectangular window). Plot |H(k)| (dB). Note that the sidelobe level should be –40 dB. Plot an expanded version of |H(k)| (dB) in the region $0 \le |f| \le 40$ Hz (analog) to illustrate the passband ripples.

III. Complex Basebanding and Desampling

A. Consider a center frequency f_0 = 250 Hz (analog). Implement the complex multiplication $e^{-j\omega_0 n} x(n)$. Take a N = 256 FFT of the new complex sequence for n = 0,..., 255 using a KB window ($\alpha = 2.5$ or $\beta = 7.85$). Plot | FFT| (dB) and identify the locations of $\pm f_1$, $\pm f_2$, and $\pm f_3$. Note: $\omega_0 = 2\pi(f_0 / f_s)$

B. Pass the new 4096-point complex sequence through the LPF (i.e. implement the filtering operation in the time domain). Take a N = 256 FFT of the filtered complex sequence for n = 256,..., 511 using a KB window ($\alpha = 2.5$ or $\beta = 7.85$). Plot | FFT| (dB) and identify the locations of $\pm f_1$, $\pm f_2$, and $\pm f_3$.

C. Desample the complex filtered sequence by a factor of 8 (i.e. $f_S' = \frac{f_S}{8} = 125\,Hz$) yielding the 512-point sequence x' (n).

IV. High Resolution Spectral Analysis

A. Take a N = 256 FFT of x' (n) for n = 256, ..., 511 using a KB window ($\alpha = 2.5$ or $\beta = 7.85$). Plot $|X'(k)|$ (dB) and identify the spectral components present (i.e. $+f_1$, $+f_2$, $+f_3$, $-f_1$, $-f_2$, and $-f_3$). What is the bin width (analog) of the FFT?

B. Make recommendations regarding a second iteration in the design of the LPF. All specifications are to remain as originally given with the exception of the passband/stopband weighting ratio. Support your recommendations with plots as generated in II and IVA. Discuss both stopband attenuation and passband ripples.

Notes

(1) Work through the entire problem on paper *first*. Include as an appendix.

(2) All | FFT| plots must include both negative (to the left) and positive (to the right) frequencies. Rather than use the frequency index k as the horizontal axis variable, use normalized frequency f (-0.5 to 0.5 cycles/sample) or f reflected back in terms of analog frequency (Hz) (multiplying by f_s or f_s' as appropriate).