Advanced Integrated Circuit Design Homework 2

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I. Question 1

If we have a system below, where $H(z) = \sum_{i=0}^{7} h_i z^i$ and the block diagram is shown in Fig. 1.

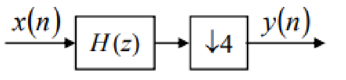


Fig. 1. Block diagram of question 1

A. Plot the RTL design of "direct implementation" based on Direct-form I structure.

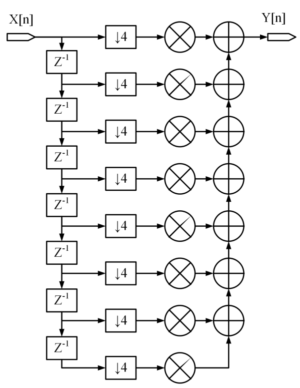


Fig. 2. Direct-Form I

B. Plot its equivalent RTL design based on "polyphase" structure.

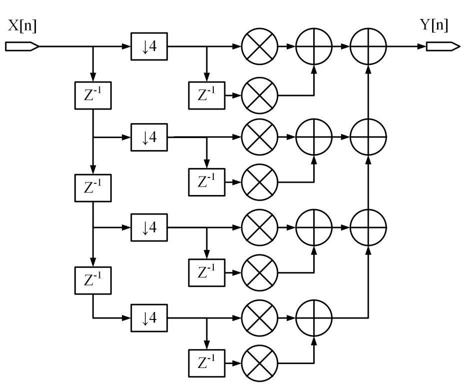


Fig. 3. Polyphase

C. Compare these two RTL designs in terms of

1) Total complexity (number of adders/ multipliers/ registers, etc.). : Both configuration using 7 registers, 8 multipliers and 7 adders. Therefore, they have same complexity in hardware units and we view those up-samplers and down-samplers as black boxes.

2) Running clock rate of each adder/multiplier. Suppose that input clock rate of x(n) is 1G sample/sec.: All of the adders and multipliers in both configuration are operated at lower frequency, namely, 0.25 GHz.

3) General comments on these two designs: Fig. 4. shows that the critical path of Direct-Form I configuration will go through 3 more adders than polyphase configuration. Therefore, we can reduce the minimum clock cycle by using polyphase configuration.

II. Question 2

Design a Raised-Cosine Filter based on Matlab program specified in https://www.mathworks.com/help/signal/ref/rcosdesign.html?requested-Domain=www.mathworks.com

A. Create a normal raised-cosine filter with rolloff 0.25. Specify that this filter span 4 symbols with 3 samples per symbol, as shown on the Fig. 5

B. Plot the frequency response of this raised-cosine filter. What is the value of its excess bandwidth α

As shown in Fig. 6, the excess bandwidth α is 0.25.

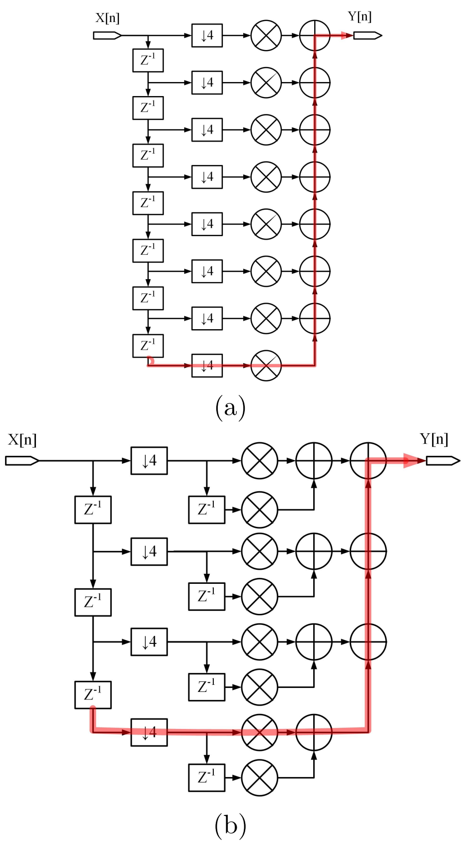


Fig. 4. Critical path of (a) Direct-Form I configuration and (b) polyphase configuration.

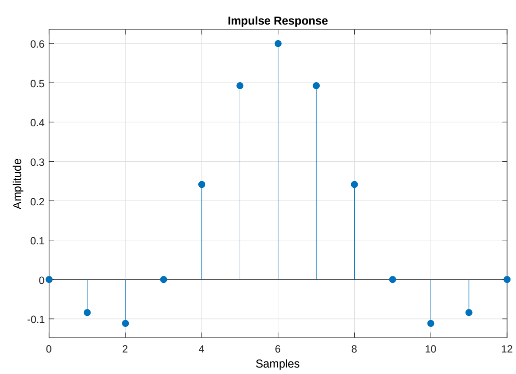


Fig. 5. Impulse response of raised-cosine filter.

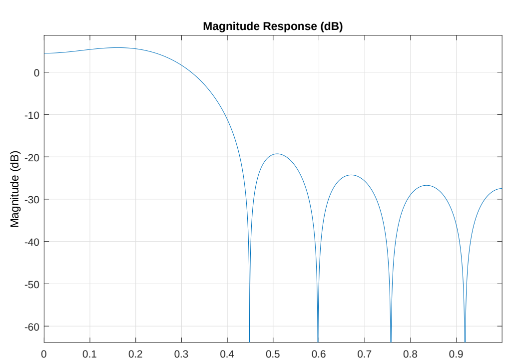


Fig. 6. Magnitude of raised-cosine filter.

III. Question 3

A. Validate the RTL design of short-length FIR filter with $M = 3$ on Lec4.21. Is it correct? Or the design on Lec4.21 needs modification? If so, please check the slide on Lec4.21 and re-design it.

Fig. 7. shows the revised RTL design and the modification is shown in red color.

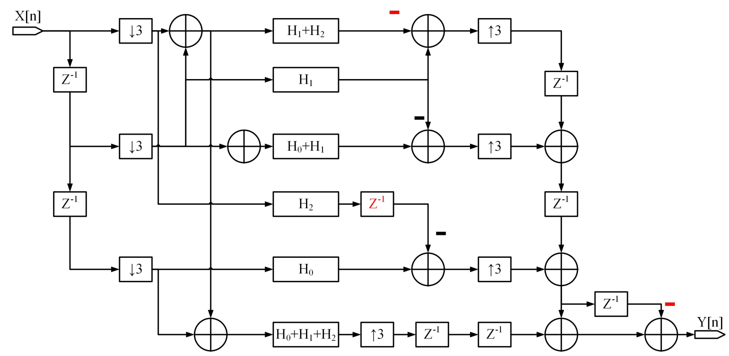


Fig. 7. RTL of short-length filter with $M = 3$.

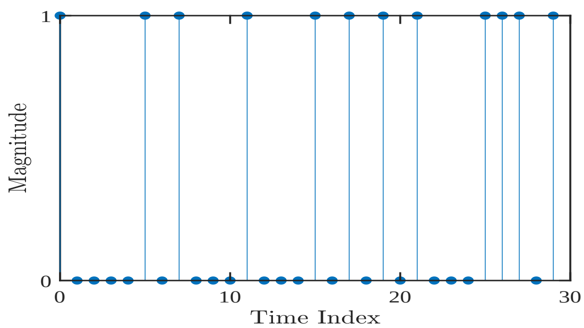
B. Verify the RTL design of short-length FIR filter with $M = 3$ on Lec4.21, by using a filter design with coefficients of the above Raised-cosine filter. That is, run a Matlab program to verify the RTL design on Lec.4.21, by comparing its filtering results with a normal M=1 (direct implementation) FIR filter. Show the first 30 filtering results of your Matlab program of both M=3 and M=1 filters.

Fig. 8. shows the simulation results of randomly generated signals, filtered result of direct implementation and short-length filter with $M = 3$.

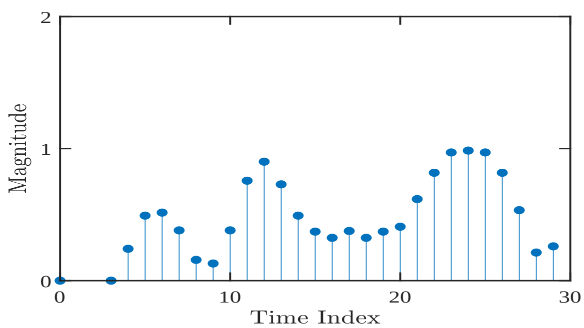
C. Derive the "transpose architecture" of the correct Lec4.21. Then, rerun the Matlab. Show the first 30 filtering results of your Matlab program of both M=3 (transposed form) and M=1 (direct implementation) filters.

Fig. 9. shows the RTL of transpose short-length filter with $M = 3$.

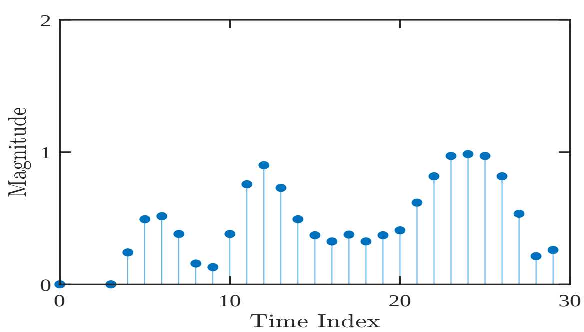
Fig. 10. shows the simulation results of randomly generated signals, filtered result of direct implementation and transpose short-length filter with $M = 3$.



(a)



(b)



(c)

Fig. 8. (a) Randomly generated signal, (b) filtered result of direct implementation and (c) filtered result of short-length filter with $M = 3$.

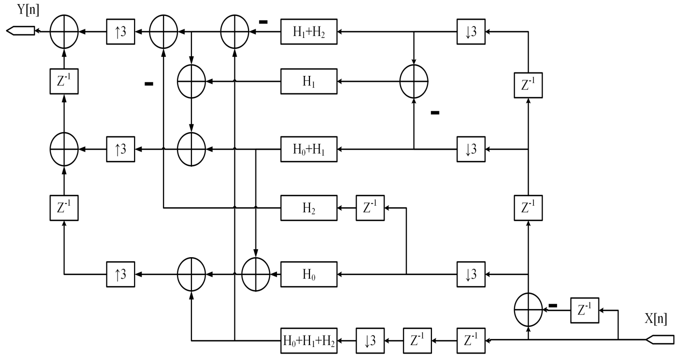
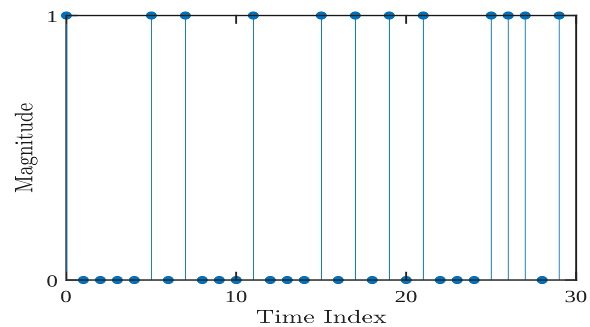
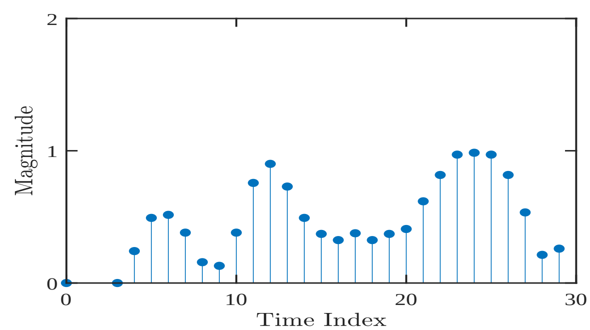


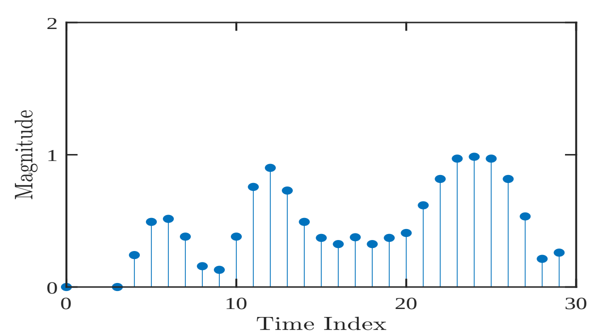
Fig. 9. RTL of transpose short-length filter with $M = 3$.



(a)



(b)



(c)

Fig. 10. (a) Randomly generated signal, (b) filtered result of direct implementation and (c) filtered result of transpose short-length filter with $M = 3$.