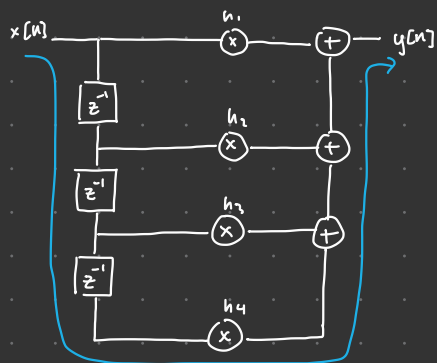


of mult will be most important for mark, then lengths

Mar 4

Filter Structures

- direct form



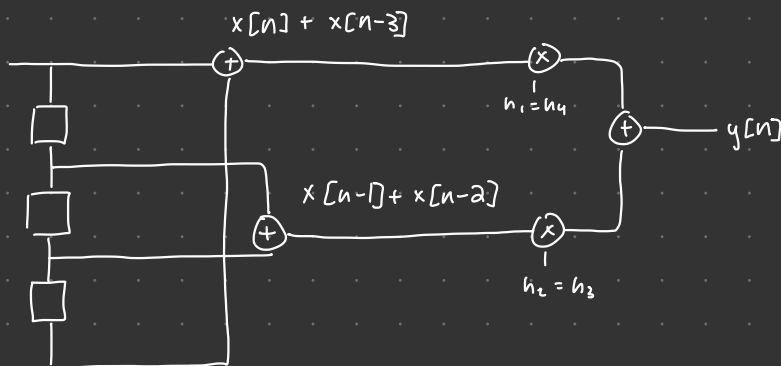
- 4 mults

- 3 adds

CP: 1 mult, 3 adds

- symmetry based structure

- used when coeffs have symmetry



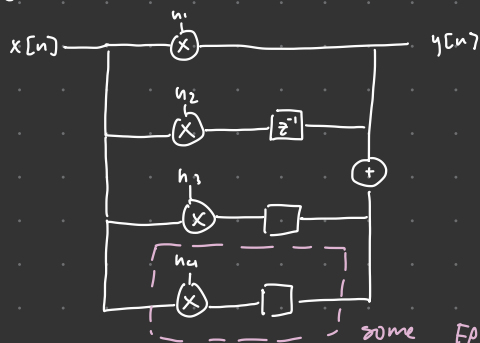
2 mults

3 adds

- tree structure



- systolic [FPGA - centric]



some FPGAs have a 'DSP block'

so this design could use 3 DSP blocks

same hardware cost, just maps nicely

polyphase structure

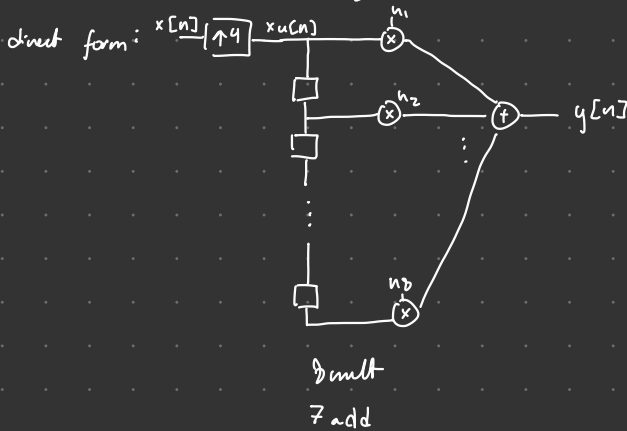
- can't be used all the time
- use when there is up/down sampling right before the filter



↳ can build this block or the other one; build the upsample and filter in tandem

ex1 consider an 8-tap filter

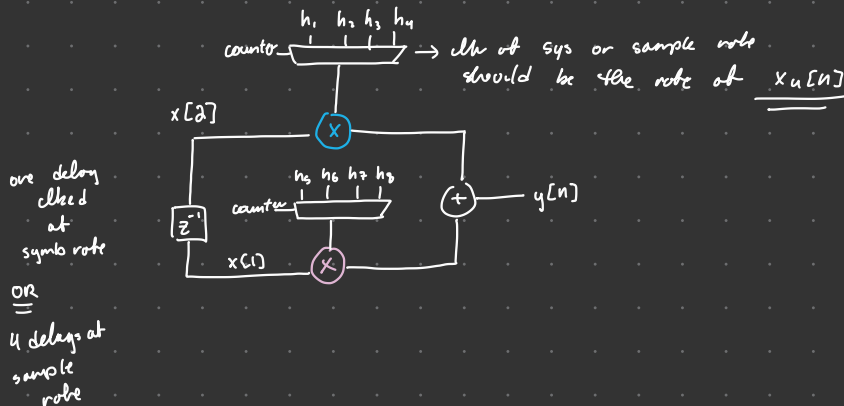
$$h = [h_1, h_2, \dots, h_8]$$



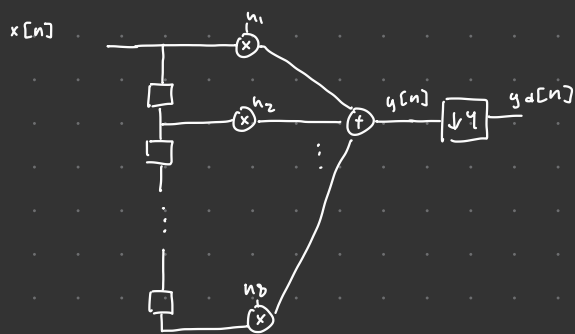
| m | $x[n]$ | $x_u[n]$ | $y[n] = x_u[n] * h[n]$ |
|---|--------|----------|------------------------|
| 1 | $x[1]$ | $x[1]$ | $x[1] h_1$ |
| 2 | | 0 | $x[1] h_2$ |
| 3 | | 0 | $x[1] h_3$ |
| 4 | | 0 | $x[1] h_4$ |
| 5 | $x[2]$ | $x[2]$ | $x[2] h_1 + x[1] h_5$ |
| 6 | | 0 | $x[2] h_2 + x[1] h_6$ |
| 7 | | 0 | $x[2] h_3 + x[1] h_7$ |
| 8 | | 0 | $x[2] h_4 + x[1] h_8$ |
| 9 | $x[3]$ | $x[3]$ | $x[3] h_1 + x[2] h_5$ |

↳ but a factor of 4 inefficiency because of the upsampling
the convolution only requires 2 mults at once
↳ $8/4 = 2$ mults only

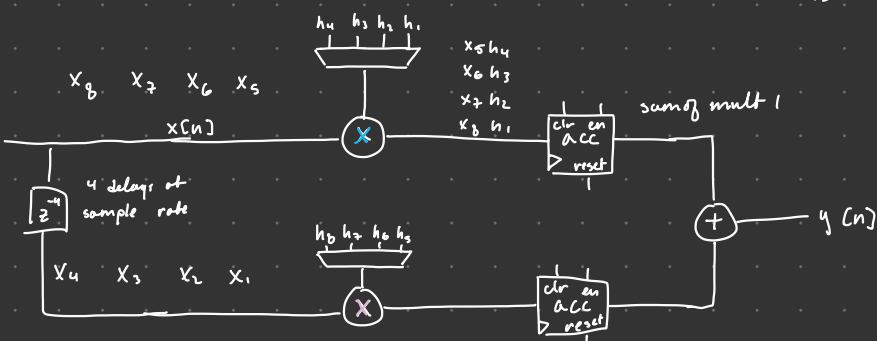
notice how each 4 samples are doubled



polyphase for down sampling:



- downsampling takes only every M samples so we are throwing away 3 each time
- direct form is wasteful



can think of combining the symmetry structure and the polyphase structure

| m | $x[n]$ | $y[n] = x[n] * h[n]$ | $y_d[n]$ |
|-----|----------|---|----------|
| 1 | $x[1]$ | $x[1] h_1$ | |
| 2 | $x[2]$ | $x_2 h_1 + x_1 h_2$ | |
| 3 | $x[3]$ | $x_3 h_1 + x_2 h_2 + x_1 h_3$ | |
| 4 | \vdots | \vdots | |
| 5 | $x[5]$ | $x_4 h_1 + x_3 h_2 + x_2 h_3 + x_1 h_4$ | |
| 6 | \vdots | \vdots | |
| 7 | \vdots | \vdots | |
| 8 | $x[8]$ | $x_8 h_1 + x_7 h_2 + x_6 h_3 + x_5 h_4 + x_4 h_5 + x_3 h_6 + x_2 h_7 + x_1 h_8$ | |
| 9 | $x[9]$ | $x_9 h_1 + \dots$ | |
| 10 | $x[10]$ | $x_{10} h_1 + \dots$ | |
| 11 | $x[11]$ | $x_{11} h_1 + \dots$ | |
| 12 | $x[12]$ | $x_{12} h_1 + \dots$ | |
| 13 | $x[13]$ | $x_{13} h_1 + \dots$ | |

same value held →