

Programmable, Finite Impulse Response (FIR) Filter

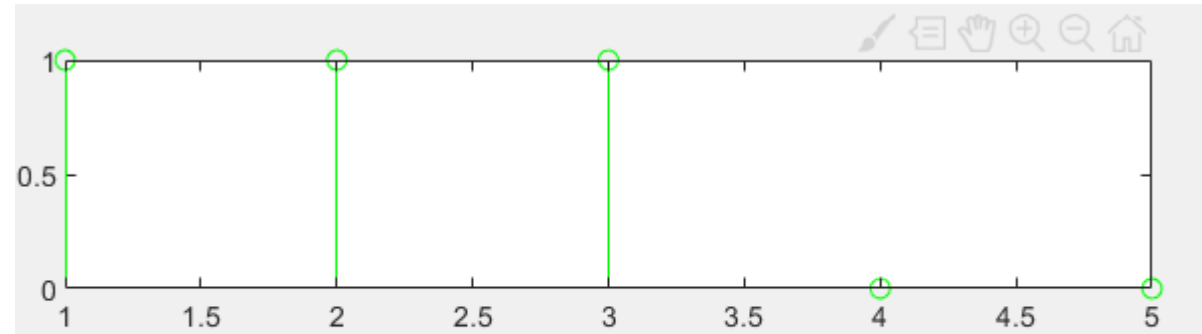
Engineered by Bruno E. Gracia Villalobos

EE 4513

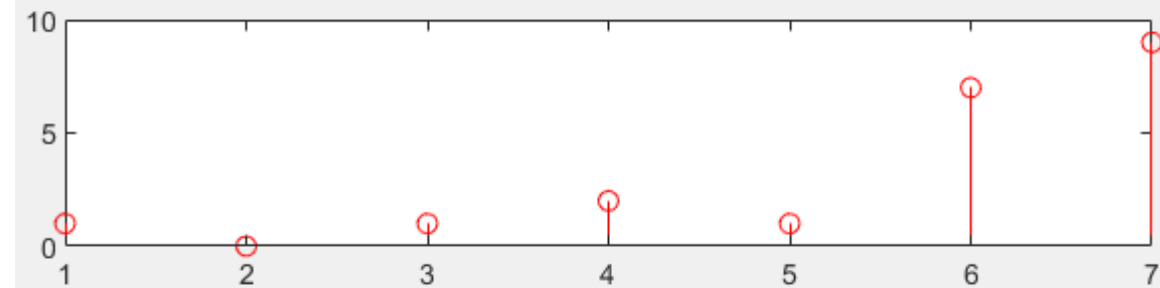
December 2019

WHAT IS A FILTER?

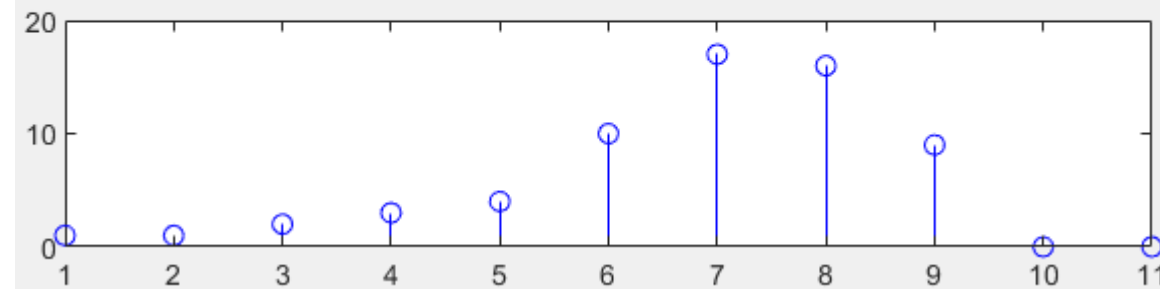
Filter



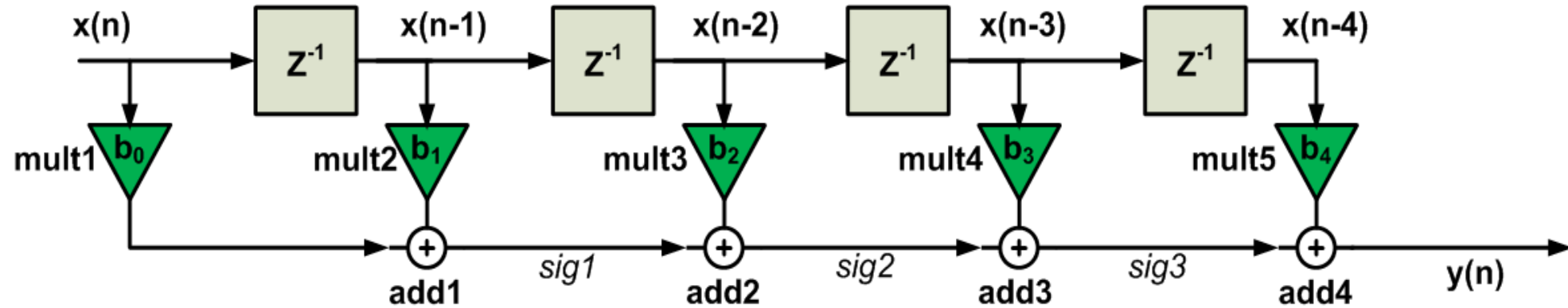
Signal



Output



DIRECT FORM I – 4th ORDER FIR FILTER

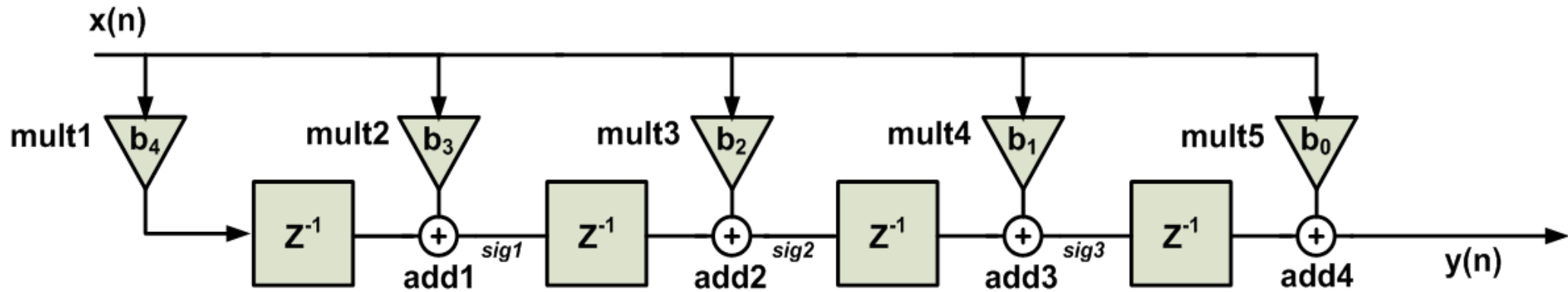


$$y[n] = \sum_{k=0}^M h[k]x[n - k]$$

$$y[n] = b_4 * x[n - 4] + b_3 * x[n - 3] + b_2 * x[n - 2] + b_1 * x[n - 1] + b_0 * x[n]$$

After four clock cycles, $y[n]$ sees $T = T_{mult} + 4T_{add}$

TRANSPOSED, DIRECT FORM I – 4th ORDER



Why?

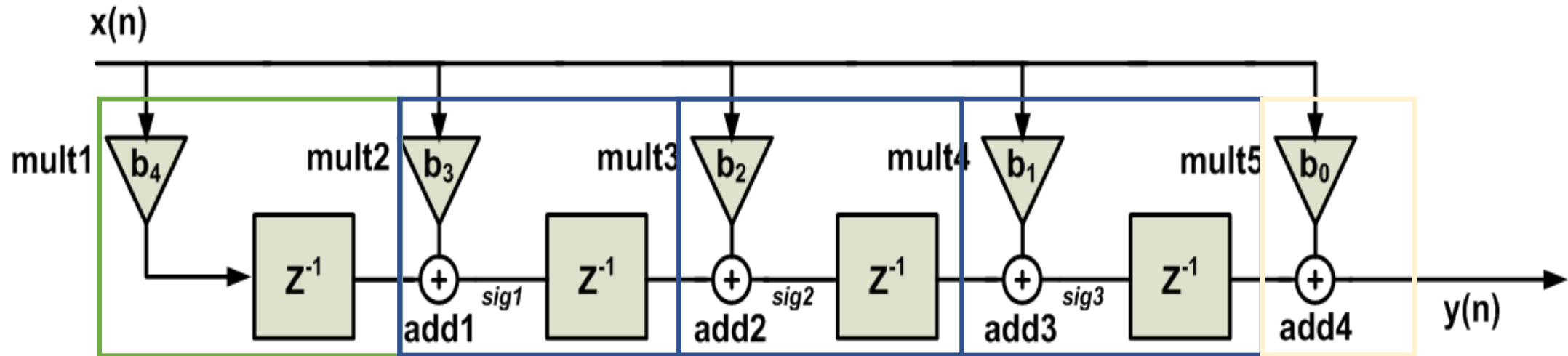
Increase sampling rate... output $y[n]$ "sees" $T = T_{\text{mult}} + T_{\text{add}}$

How?

Reverse all branches without changing functionality.

Switch $x[n]$ & $y[n]$ placement.

PROGRAMMABLE....?



GREEN =

- 1 Multiplier
- 1 Register

BLUE =

- 1 Multiplier
- 1 Adder
- 1 Register

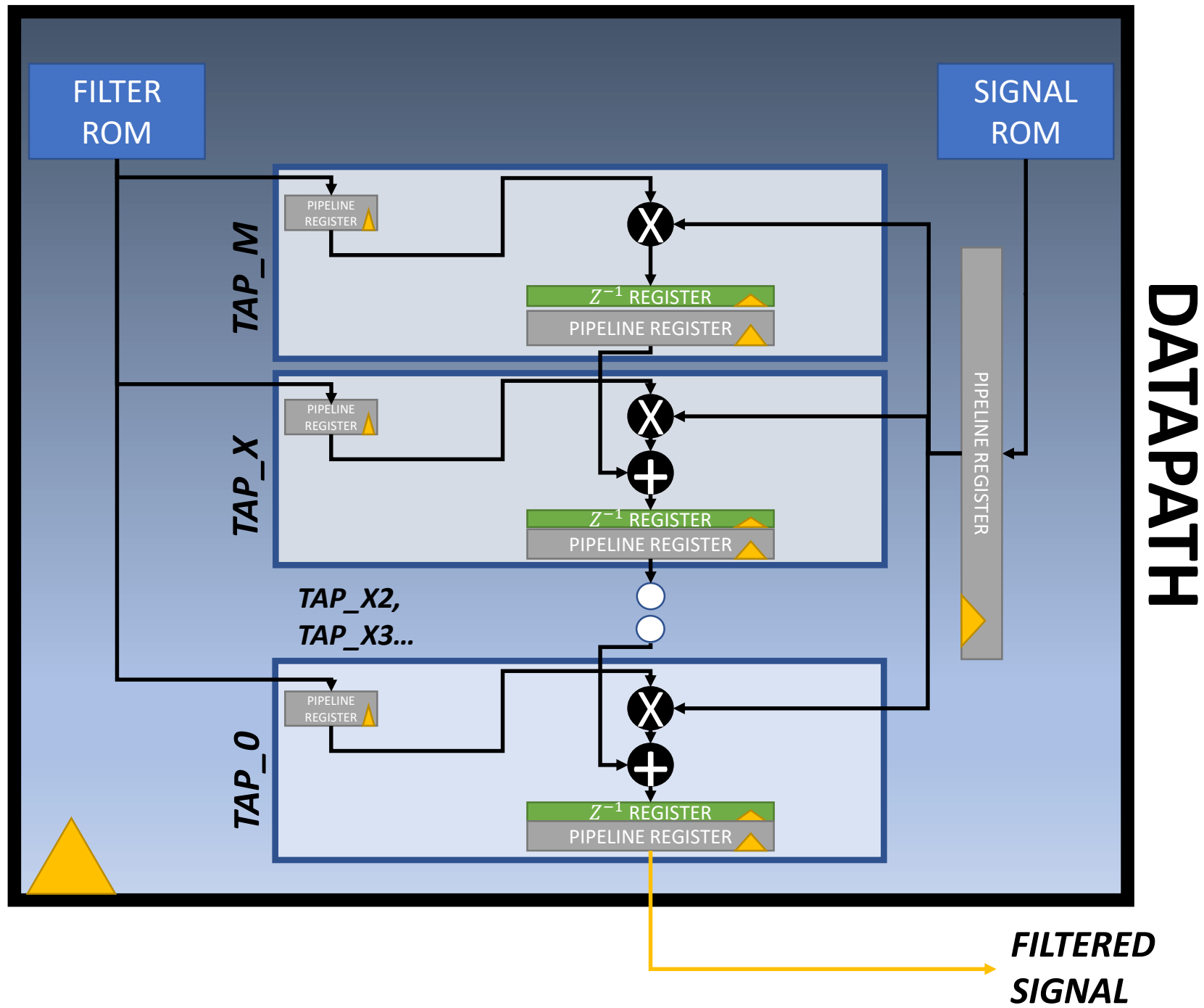
YELLOW =

- 1 Multiplier
- 1 Adder

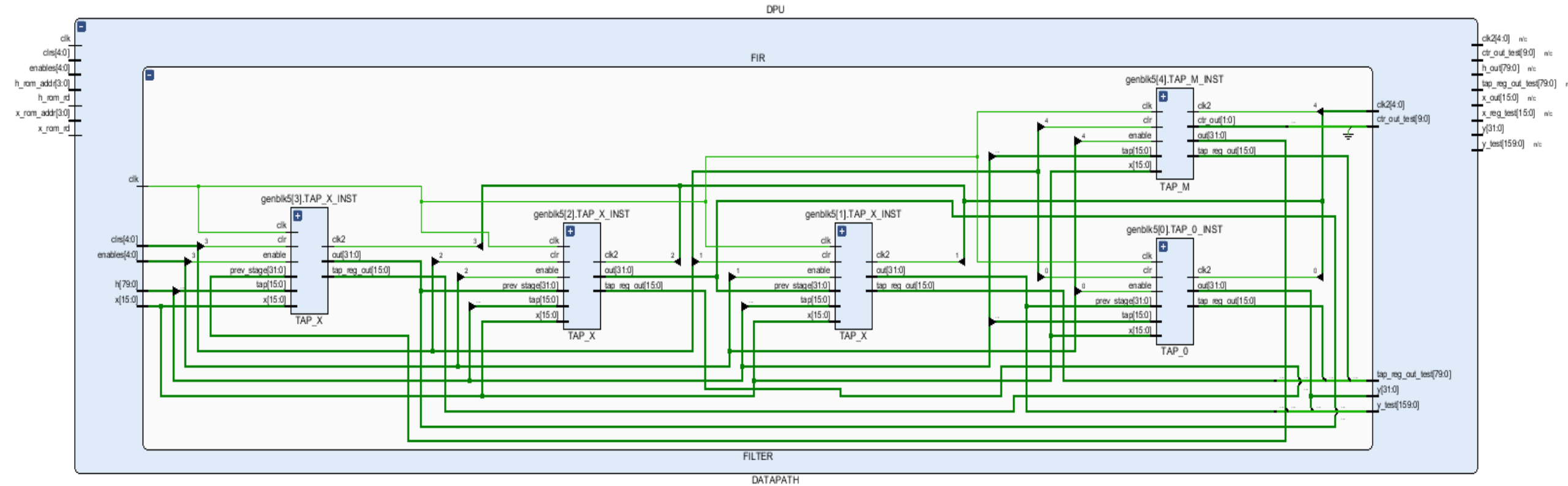
green = 1

yellow = 1

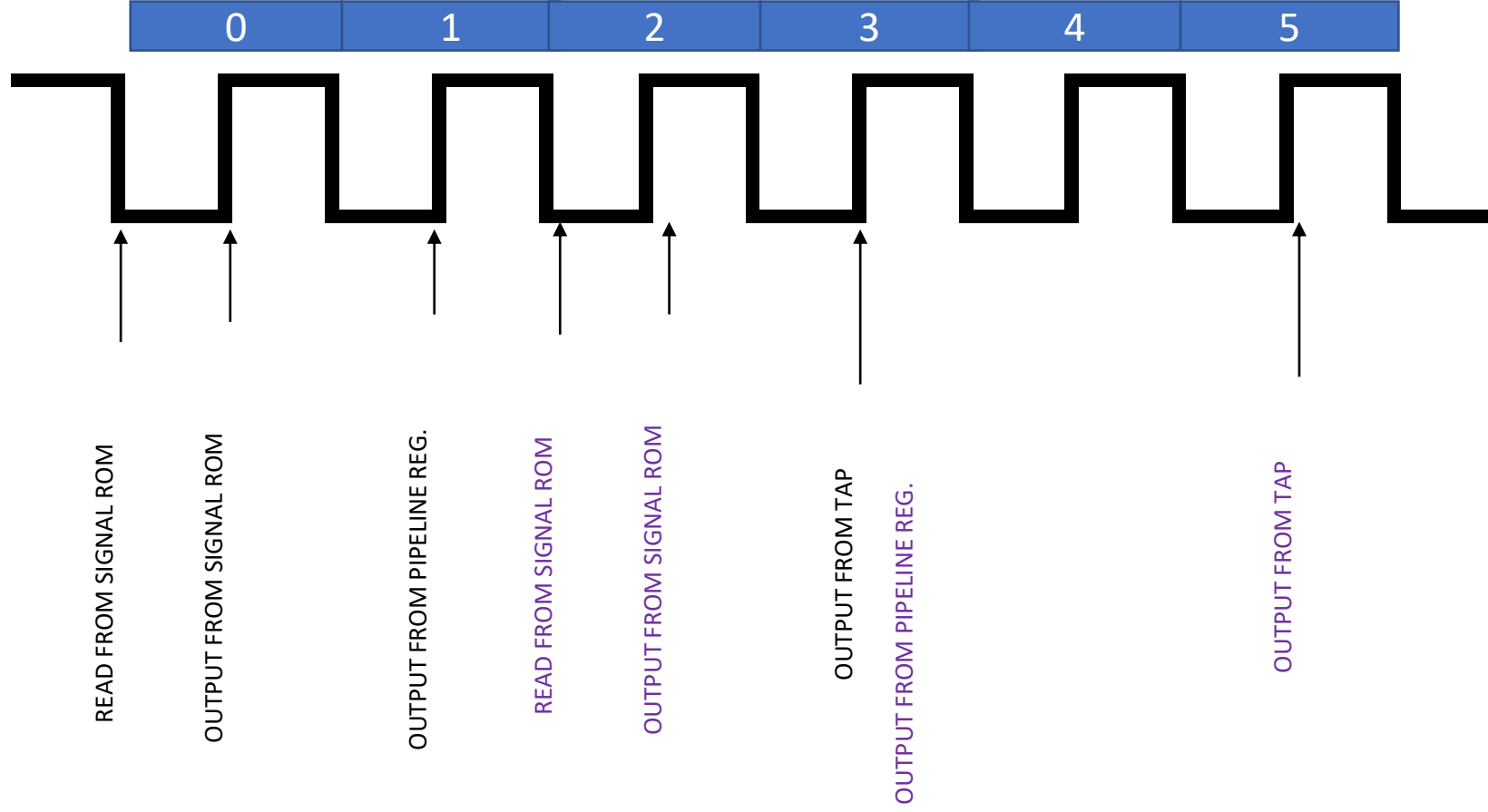
blue = M-1



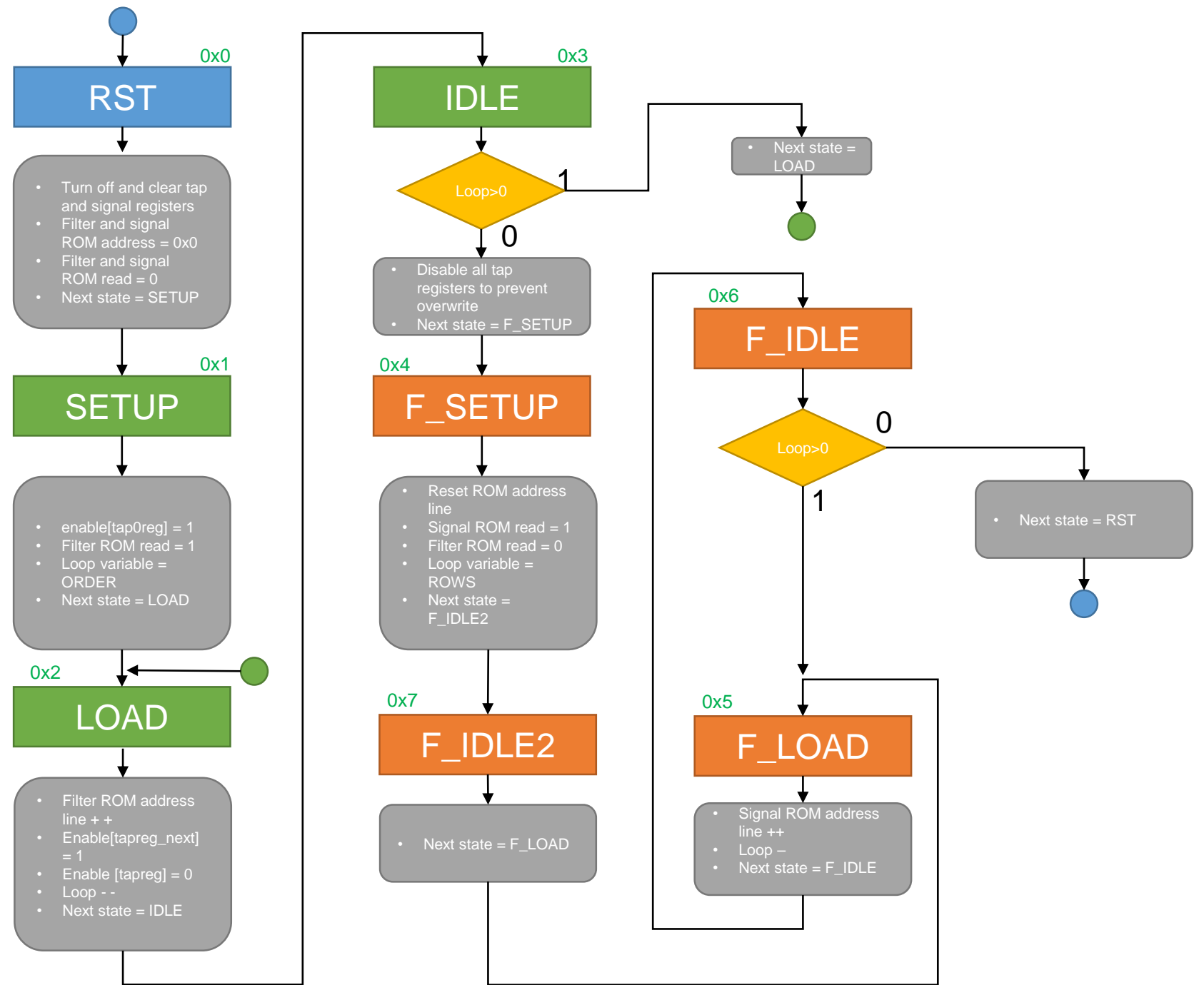
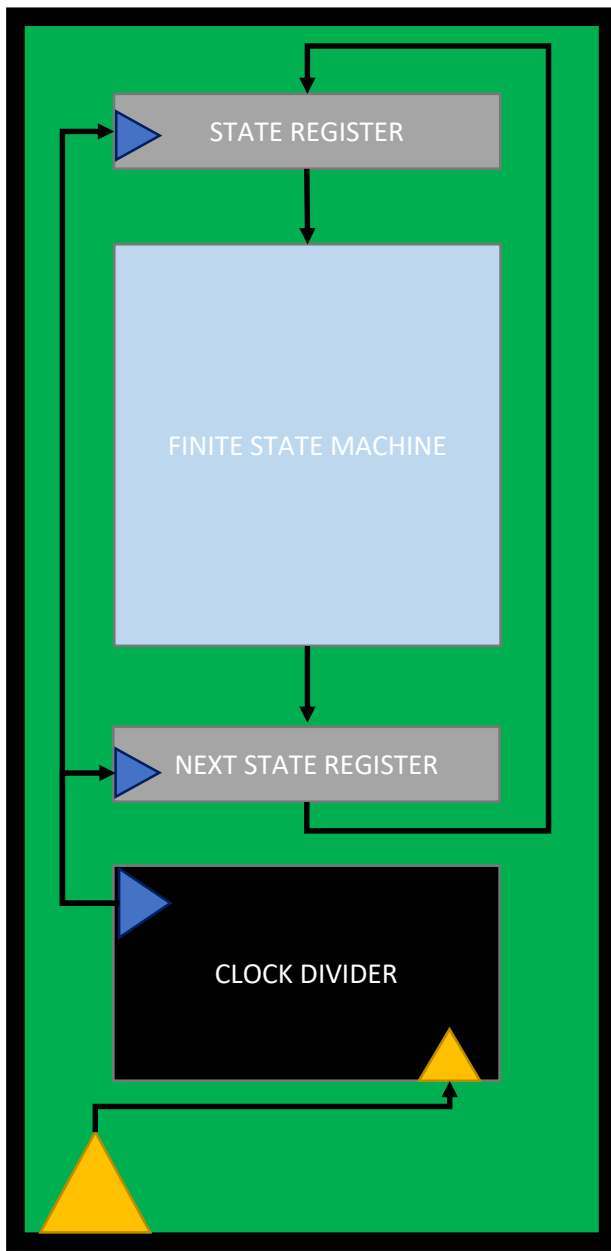
FILTER IN HDL. WHAT IS THE ORDER?



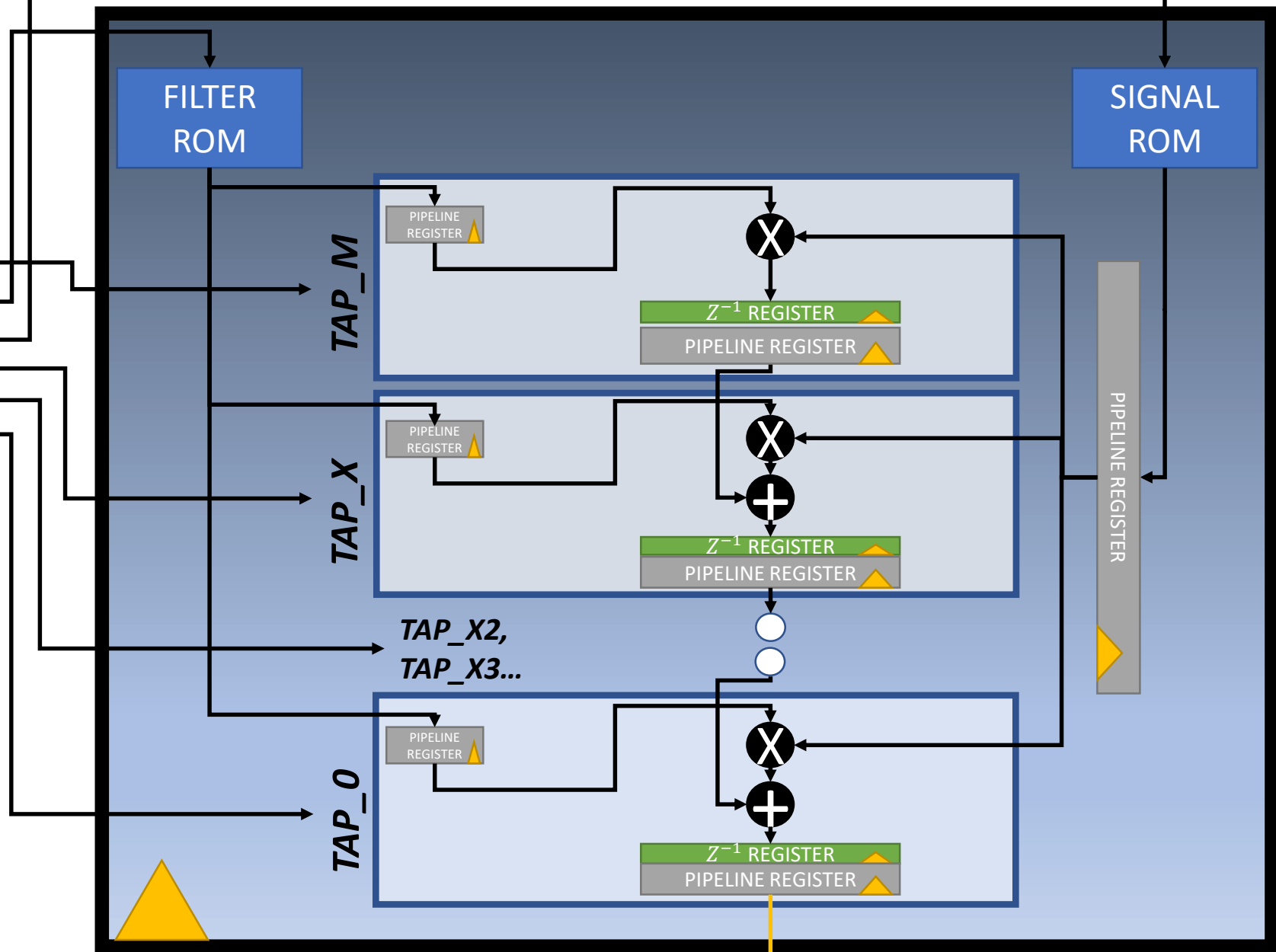
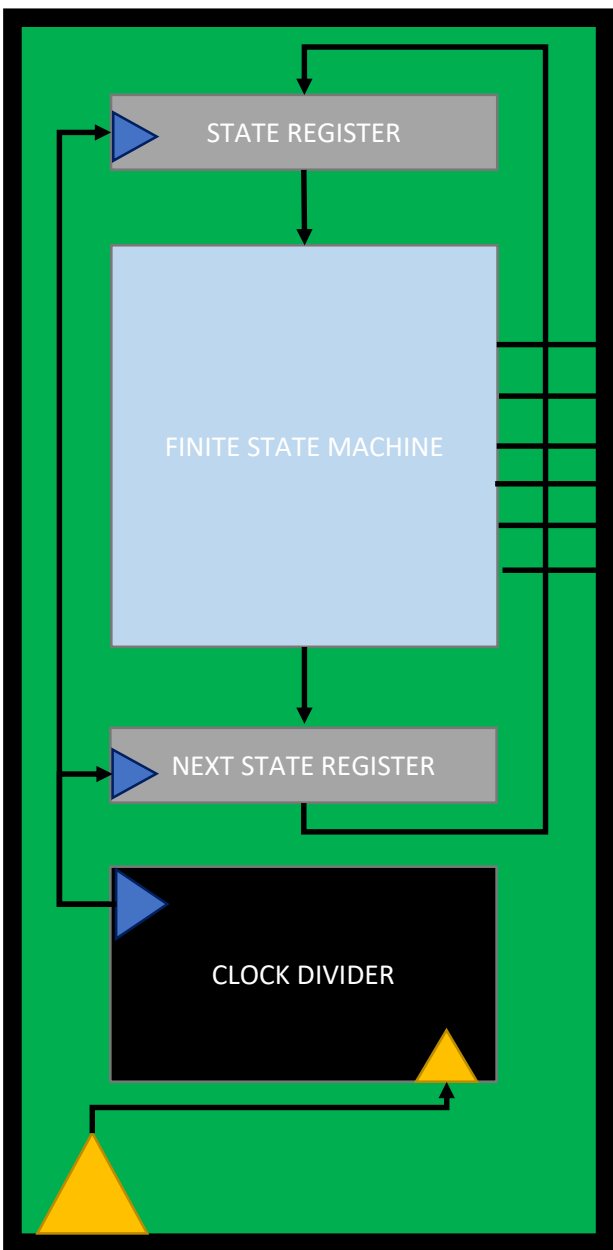
PIPELINE



CONTROLLER



CONTROLLER

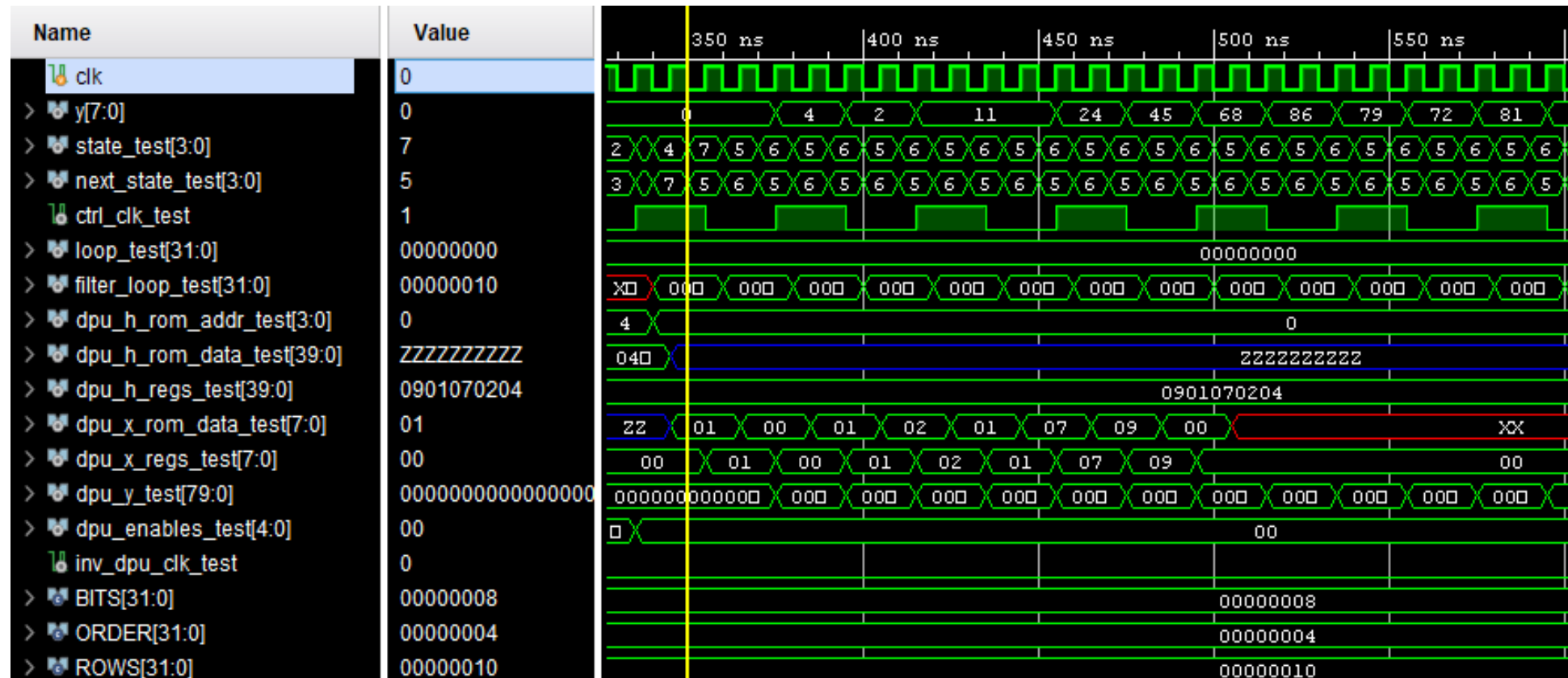


DATAPATH

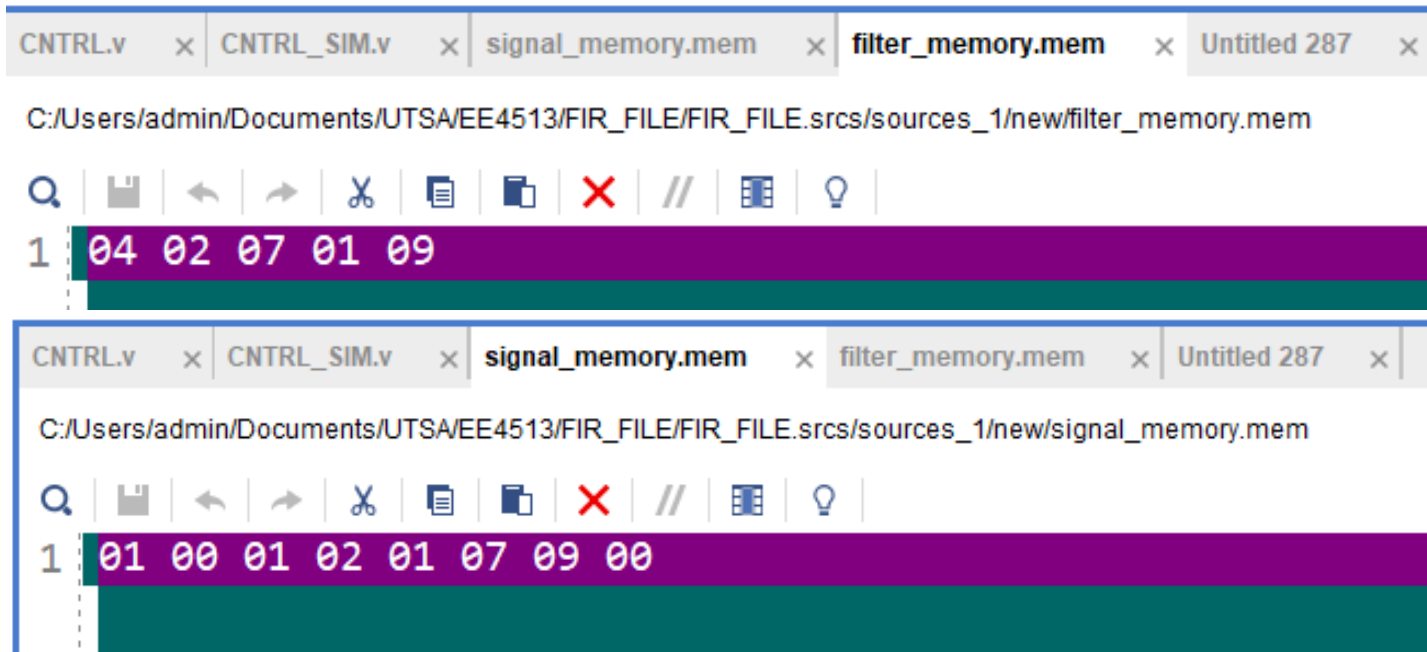
**FILTERED
SIGNAL**

COOL... DOES IT WORK?

h = [4 2 7 1 9]

$$x = [1 \ 0 \ 1 \ 2 \ 1 \ 7 \ 9]$$
$$y = [4 \ 2 \ 11 \ 11 \ 24 \ 45 \ 68 \ 86 \ 79 \ 72 \ 81]$$


WHERE IS THE MEMORY COMING FROM?



The image shows two screenshots of a Verilog IDE. The top screenshot shows the file 'filter_memory.mem' with the following content:

```
1 04 02 07 01 09
```

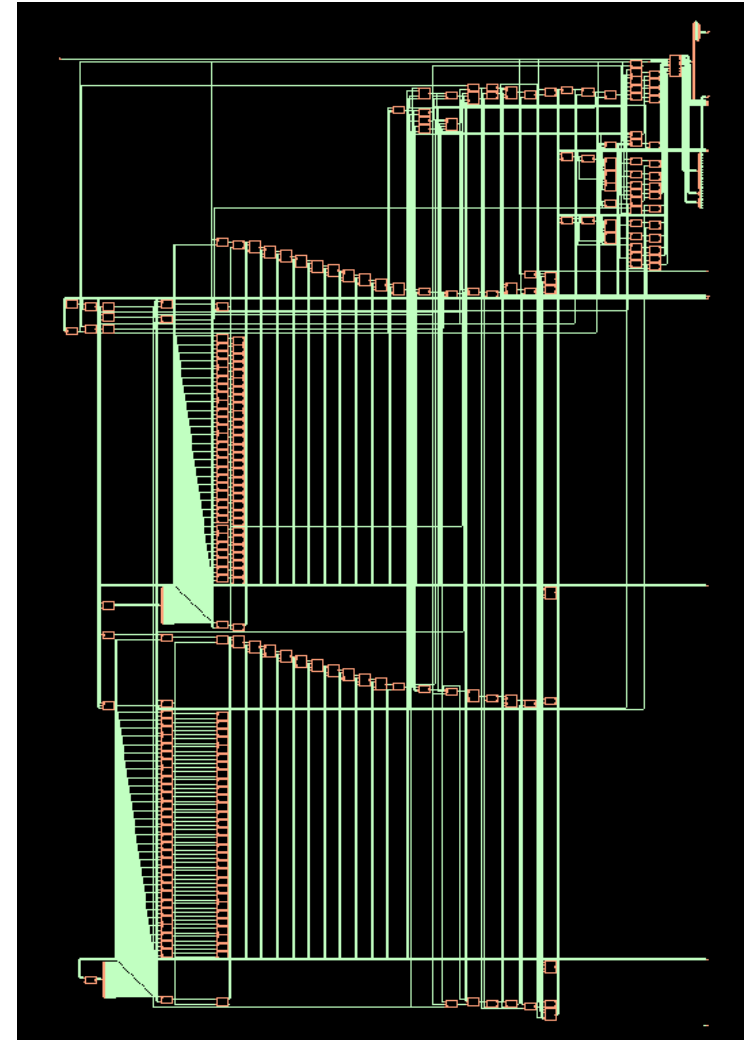
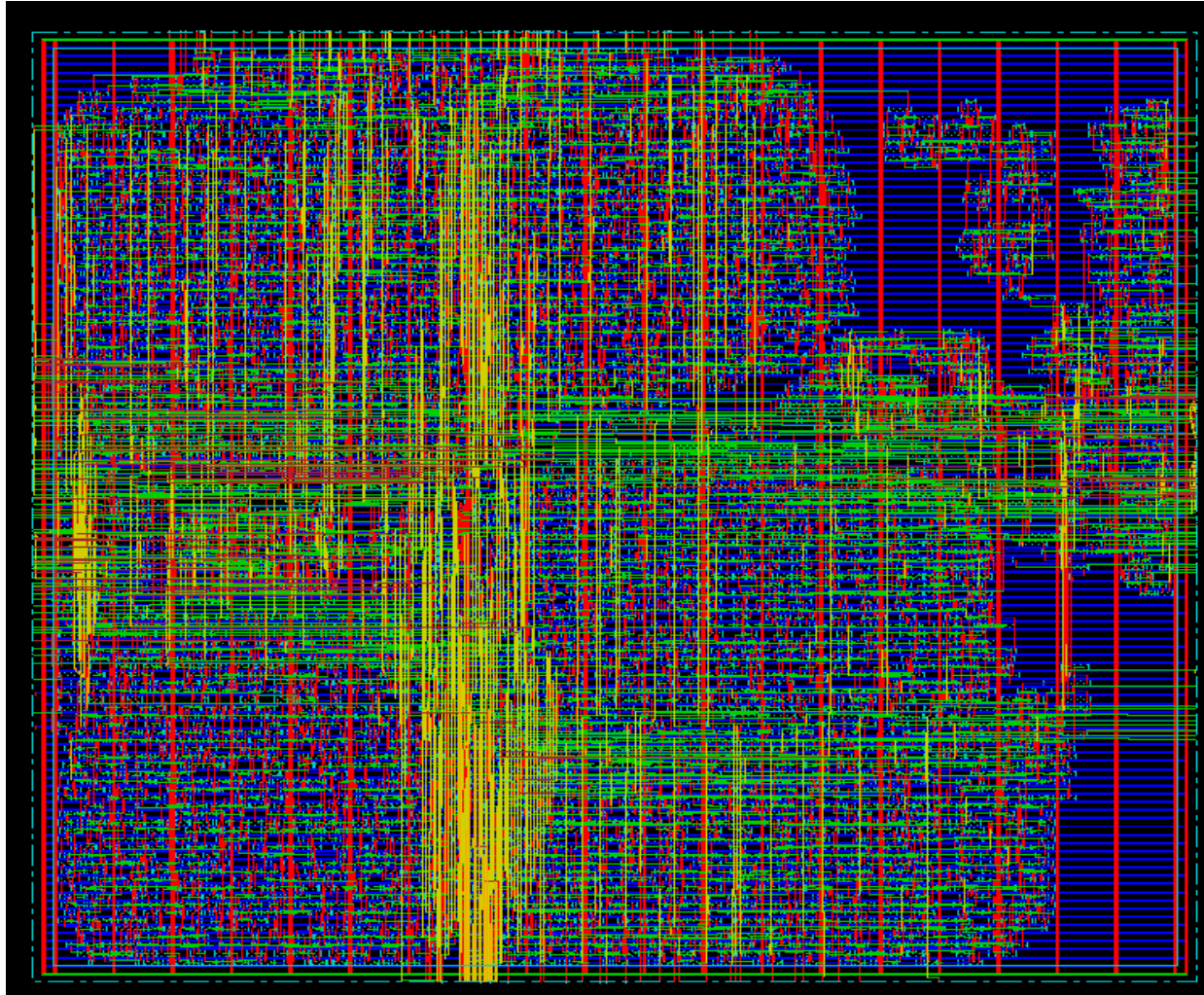
The bottom screenshot shows the file 'signal_memory.mem' with the following content:

```
1 01 00 01 02 01 07 09 00
```

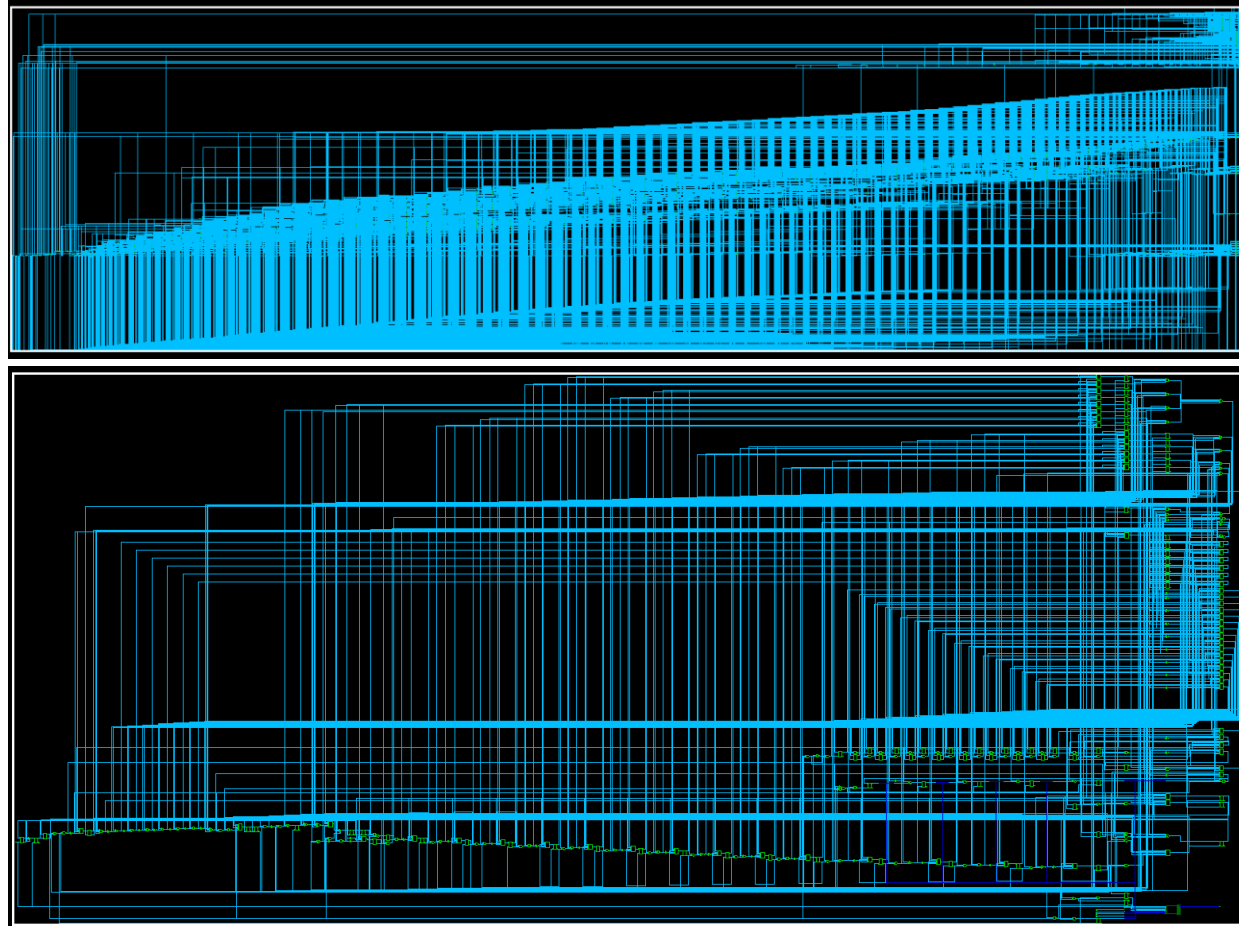
Both screenshots show a toolbar with icons for search, save, undo, redo, cut, copy, paste, delete, comment, and help. The file paths are: C:/Users/admin/Documents/UTSA/EE4513/FIR_FILE/FIR_FILE.srscs/sources_1/new/filter_memory.mem and C:/Users/admin/Documents/UTSA/EE4513/FIR_FILE/FIR_FILE.srscs/sources_1/new/signal_memory.mem.

```
reg [BITS-1:0] rom [0:ROWS-1];  
  
initial begin  
    $readmemh(FILENAME, rom);  
end
```

180NM



45 VS 90 NM



	45NM	90NM
TIMING	0.46f	0.61 f
TOTAL AREA	10948.894428	64264.217708
TOTAL POWER	3.8015e-02 mW	181.5616 uW

THANK YOU ALL

<https://16oh4.com> ... album comes out Dec. 19