Cairo University – Faculty of Engineering
Computer Department

VLSI Project – Phase 2

Group 4

Team 13 - CNN Module

Team Members:

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Finite State Machine states:

Cond1: only in the first time. At CNN start, we load number of layers to process and assume it is not more than three Layers and set the image pointer and the new image pointer (pointer to where write the image).

Cond2: Load the layer data (as shown in Phase 1 delivery) including number of filters,in depth, out depth, filter size,etc….

Cond3: load new rows if needed to process.

Cond4: load filter if needed

Cond5: calculate the result of convolution and pooling.

Cond6: add the new pixel result to the row to be stored later in the RAM.

Cond7_sub: save the new row in the RAM when it's done.

Cond8: reset any signal needed to to start over and decide which state the program will return to.

Project file tree:

Control unit (Control_unit.vhd): this file contains the whole logic and FSM states implementation. The file uses the following entities:

a. Counter.vhd: contains an 8-bit counter used in state_counter (which controls the states of the FSM), filters_covered_counter, rows_covered_counter
b. Counter_ptrs: contains a custom 16-bit counter.
c. Counter_filters.vhd: contains a custom counter used to track the filters address and layers data addresses.
d. Xor_1bit_out.vhd: in order to avoid using "PROCESS" a lot; this file contain an entity that returns '1' when the two inputs are equal and '0' otherwise.
e. Window_selection_logic.vhd: select the window to process from the row currently held in the registers.
f. bias _selection_logic.vhd: selects the correct bias for convolution .
g. Add_new_row_logic.vhd: adds the CNN result to new_row to be stored later.
h. Swap_algorithm.vhd: swap image pointer to the new value every layer.
i. Mux_5x1.vhd
j. Mux_3x1.vhd
k. Tristate.vhd: contains a regular tri-state buffer.
l. CNN_pyramid: this module is responsible for making the calculations including multiplication, addition and any operations in the convolution/pooling process.

Modules(Entities) description:

1. CNN_pyramid:

Input	Output
CLK	Result (the operation output)
Conv/Pool (type of operation)	
Five (1 bit state the window size 5 or 3)	
Bias (zero in case of pooling)	
Filter (if exists)	
Window of pixels	

2. Window_selection_logic: in case window size is 3x3, the last two rows in the window and the most significant two pixels are set to zero.

Input	Output
CLK	The window to process in the next stage of the FSM
Window_en (enable the operation)	
Five rows of the image	
Size of the window	
Window of pixels	

3. xor_1bit_out:

Input	Output
Variable 1	F (1 if they are equal else 0)
Variable 2	

4. bias_selection_logic:

Input	Output
CLK	Bias (the bias to use in the calculations with this filter)
bias_en (enable every time we use new filter)	
Biases (200 bit long signal contain the layer biases values)	

5. add_new_row_logic:

Input	Output
CLK	new_row (with the result added to it)
Enable(allow to write the result in the row)	
Reset(clear the row)	
Result (the value to store)	
Row_is_done (signal indicate is row is full and ready to be stored)	
out_size(to know when the row is done)	

6. Mux_3x1:

Input	Output
SEL1 (1 bit)	F (selected input)
SEL 2 (1 bit)	
A (selection input)	
B (selection input)	
C (selection input)	

7. Mux_5x1:

Input	Output
SEL	F (selected input)
filter_size	
A (selection input)	
B (selection input)	
C (selection input)	
D (selection input)	
E (selection input)	

8. Swap_algorithm: to optimize ram size we set only two addresses to use in the CNN module. We first use address1 and write in address2, and then, in the following layer, we use andress2 and write in address1, and so on.

Input	Output
Enable	New_image pointer (the start address of the image)
Image pointer 1 address	
Image pointer 2 address	
Current image pointer address	
New image pointer address	

9. Remaining modules are just counters used in controlling the flow of the system including:

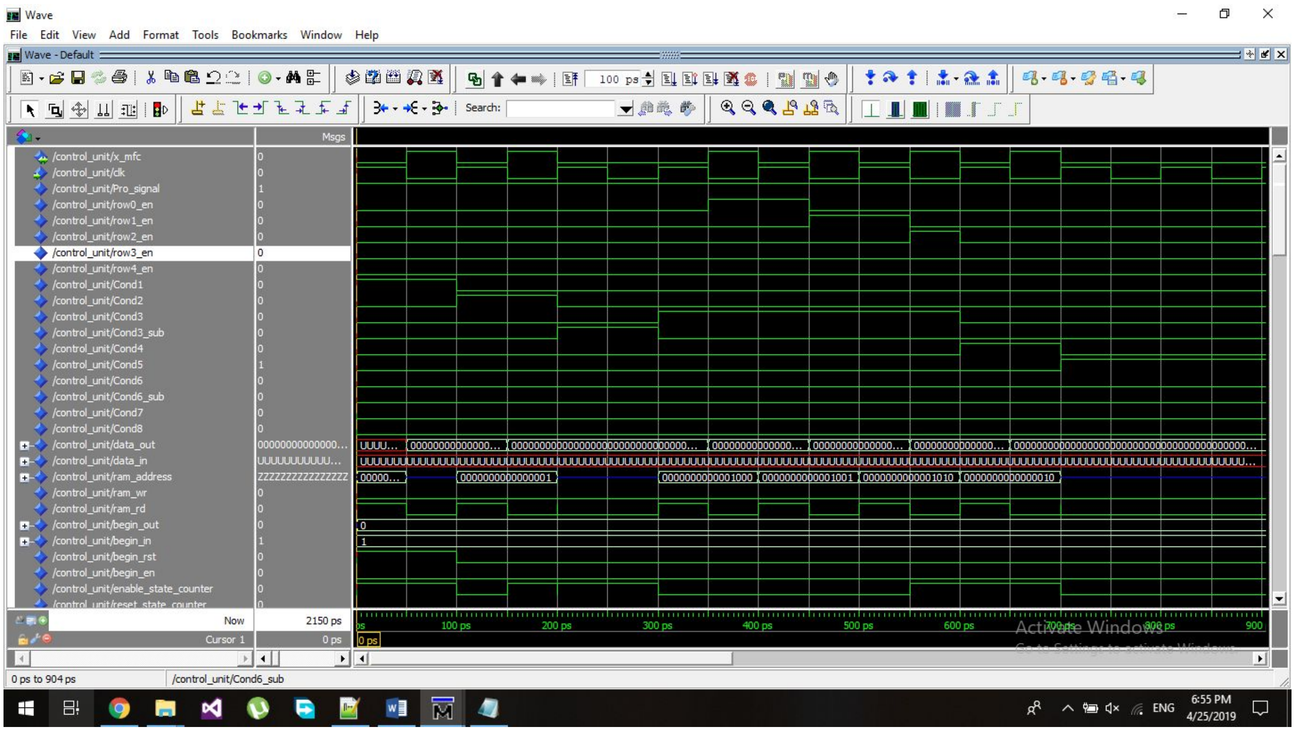
a. Counter
b. Counter_ptrs
c. Counter_filters
d. State_counter

10. We use 42 modules in total, but only these modules are ours. The rest is booth multiplication logic which is ***done by the FC team*** and duplicate common files like adders between the two teams.

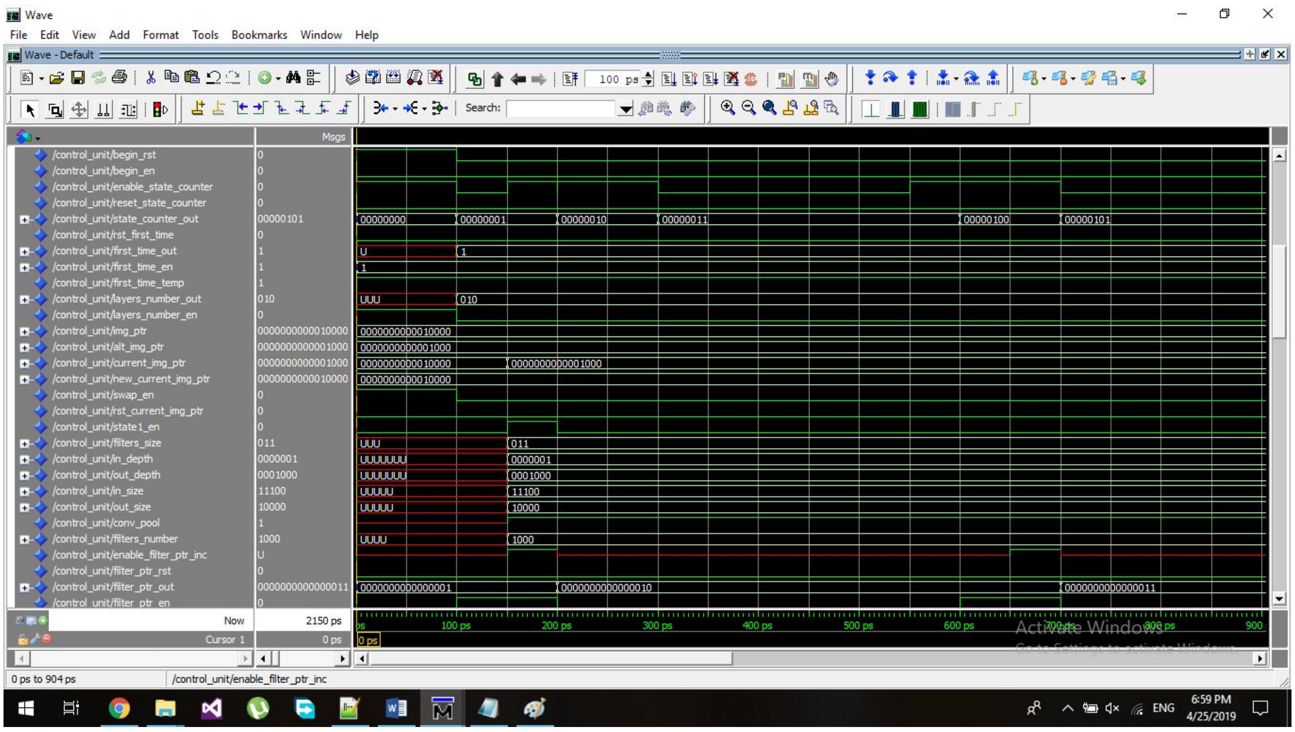
IO description:

CLK	GLOBAL
Pro_signal	Signal to start (from the previous module)
RST	Reset the system signal (Global)
FC_start	Signal for FC module to start

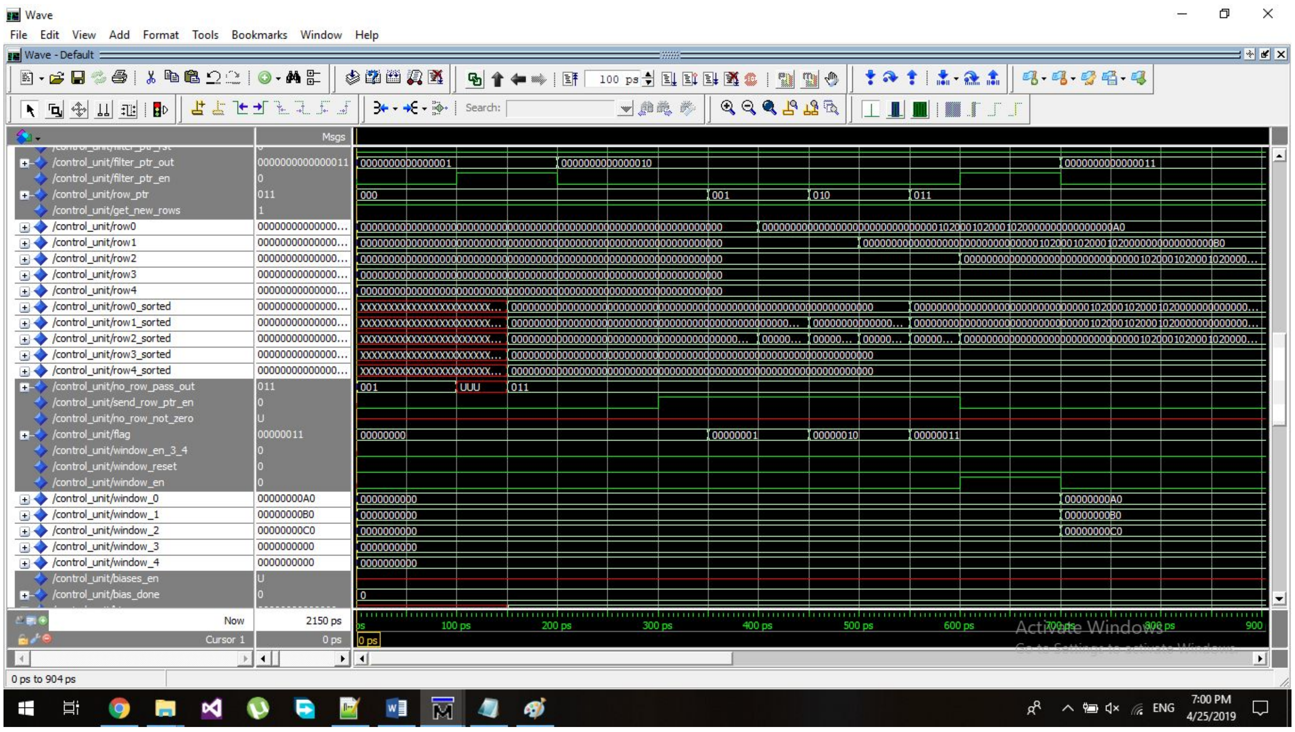
Time Diagram (of control unit): this is the diagram of the Control unit but it is too big.so, we attached the do file that generate it under the name “cu_do.txt”



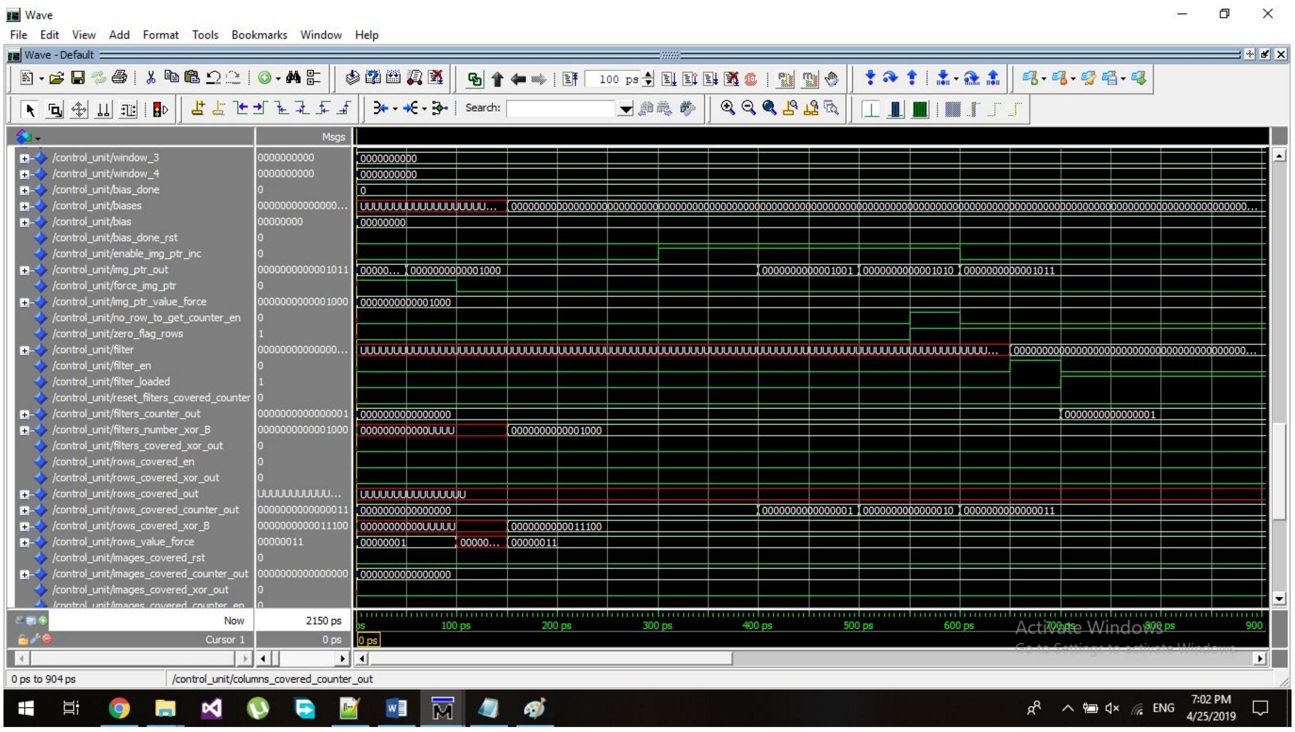
```
/control_unit/x_mfc                 0
/control_unit/clk                   0
/control_unit/Pro_signal            1
/control_unit/row0_en               0
/control_unit/row1_en               0
/control_unit/row2_en               0
/control_unit/row3_en               0
/control_unit/row4_en               0
/control_unit/Cond1                 0
/control_unit/Cond2                 0
/control_unit/Cond3                 0
/control_unit/Cond3_sub             0
/control_unit/Cond4                 0
/control_unit/Cond5                 1
/control_unit/Cond6                 0
/control_unit/Cond6_sub             0
/control_unit/Cond7                 0
/control_unit/Cond8                 0
/control_unit/data_out              00000000000000...
/control_unit/data_in               UUUUUUUUUUU...
/control_unit/ram_address           ZZZZZZZZZZZZZZZZ
/control_unit/ram_wr                0
/control_unit/ram_rd                0
/control_unit/begin_out             0
/control_unit/begin_in              1
/control_unit/begin_rst             0
/control_unit/begin_en              0
/control_unit/enable_state_counter  0
/control_unit/reset_state_counter   0
Now       2150 ps
Cursor 1  0 ps
0 ps to 904 ps    /control_unit/Cond6_sub
```



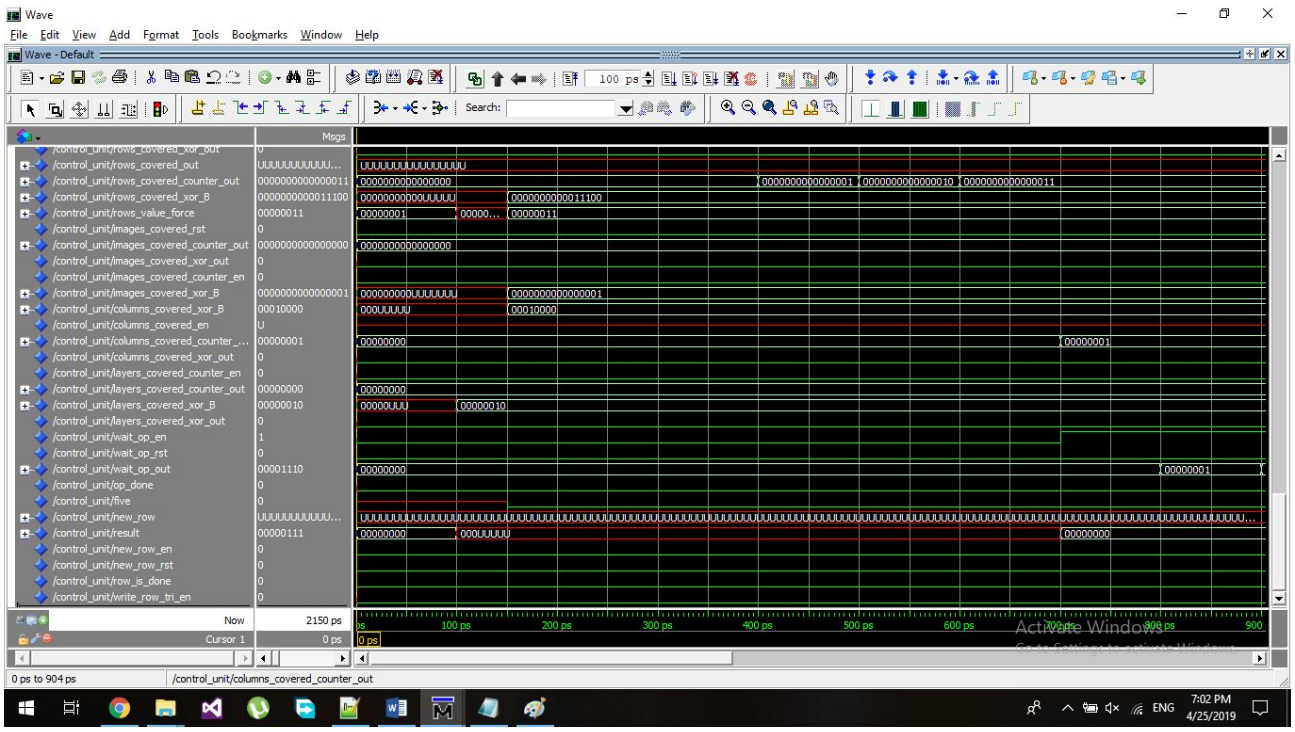
```
/control_unit/begin_rst             0
/control_unit/begin_en              0
/control_unit/enable_state_counter  0
/control_unit/reset_state_counter   0
/control_unit/state_counter_out     00000101
/control_unit/rst_first_time        0
/control_unit/first_time_out        1
/control_unit/first_time_en         1
/control_unit/first_time_temp       1
/control_unit/layers_number_out     010
/control_unit/layers_number_en      0
/control_unit/img_ptr               0000000000010000
/control_unit/alt_img_ptr           0000000000001000
/control_unit/current_img_ptr       0000000000001000
/control_unit/new_current_img_ptr   0000000000010000
/control_unit/swap_en               0
/control_unit/rst_current_img_ptr   0
/control_unit/state1_en             0
/control_unit/filters_size          011
/control_unit/in_depth              0000001
/control_unit/out_depth             0001000
/control_unit/in_size               11100
/control_unit/out_size              10000
/control_unit/conv_pool             1
/control_unit/filters_number        1000
/control_unit/enable_filter_ptr_inc U
/control_unit/filter_ptr_rst        0
/control_unit/filter_ptr_out        0000000000000011
/control_unit/filter_ptr_en         0
Now       2150 ps
Cursor 1  0 ps
0 ps to 904 ps    /control_unit/enable_filter_ptr_inc
```



```
/control_unit/filter_ptr_out                 0000000000000011
/control_unit/filter_ptr_en                  0
/control_unit/row_ptr                        011
/control_unit/get_new_rows                   1
/control_unit/row0                           00000000000000...
/control_unit/row1                           00000000000000...
/control_unit/row2                           00000000000000...
/control_unit/row3                           00000000000000...
/control_unit/row4                           00000000000000...
/control_unit/row0_sorted                    00000000000000...
/control_unit/row1_sorted                    00000000000000...
/control_unit/row2_sorted                    00000000000000...
/control_unit/row3_sorted                    00000000000000...
/control_unit/row4_sorted                    00000000000000...
/control_unit/no_row_pass_out                011
/control_unit/send_row_ptr_en                0
/control_unit/no_row_not_zero                U
/control_unit/flag                           00000011
/control_unit/window_en_3_4                  0
/control_unit/window_reset                   0
/control_unit/window_en                      0
/control_unit/window_0                       00000000A0
/control_unit/window_1                       00000000B0
/control_unit/window_2                       00000000C0
/control_unit/window_3                       0000000000
/control_unit/window_4                       0000000000
/control_unit/biases_en                      U
/control_unit/bias_done                      0
Now                                          2150 ps
Cursor 1                                     0 ps
0 ps to 904 ps
```



```
/control_unit/window_3                       0000000000
/control_unit/window_4                       0000000000
/control_unit/bias_done                      0
/control_unit/biases                         00000000000000...
/control_unit/bias                           00000000
/control_unit/bias_done_rst                  0
/control_unit/enable_img_ptr_inc             0
/control_unit/img_ptr_out                    0000000000001011
/control_unit/force_img_ptr                  0
/control_unit/img_ptr_value_force            0000000000001000
/control_unit/no_row_to_get_counter_en       0
/control_unit/zero_flag_rows                 1
/control_unit/filter                         00000000000000...
/control_unit/filter_en                      0
/control_unit/filter_loaded                  1
/control_unit/reset_filters_covered_counter  0
/control_unit/filters_counter_out            0000000000000001
/control_unit/filters_number_xor_B           0000000000001000
/control_unit/filters_covered_xor_out        0
/control_unit/rows_covered_en                0
/control_unit/rows_covered_xor_out           0
/control_unit/rows_covered_out               UUUUUUUUUUU...
/control_unit/rows_covered_counter_out       0000000000000011
/control_unit/rows_covered_xor_B             0000000000011100
/control_unit/rows_value_force               00000011
/control_unit/images_covered_rst             0
/control_unit/images_covered_counter_out     0000000000000000
/control_unit/images_covered_xor_out         0
Now                                          2150 ps
Cursor 1                                     0 ps
0 ps to 904 ps     /control_unit/columns_covered_counter_out
```



```
/control_unit/rows_covered_xor_out          0
/control_unit/rows_covered_out              UUUUUUUUUUUU...
/control_unit/rows_covered_counter_out      0000000000000011
/control_unit/rows_covered_xor_B            0000000000011100
/control_unit/rows_value_force              00000011
/control_unit/images_covered_rst            0
/control_unit/images_covered_counter_out    0000000000000000
/control_unit/images_covered_xor_out        0
/control_unit/images_covered_counter_en     0
/control_unit/images_covered_xor_B          0000000000000001
/control_unit/columns_covered_xor_B         00010000
/control_unit/columns_covered_en            U
/control_unit/columns_covered_counter_...   00000001
/control_unit/columns_covered_xor_out       0
/control_unit/layers_covered_counter_en     0
/control_unit/layers_covered_counter_out    00000000
/control_unit/layers_covered_xor_B          00000010
/control_unit/layers_covered_xor_out        0
/control_unit/wait_op_en                    1
/control_unit/wait_op_rst                   0
/control_unit/wait_op_out                   00001110
/control_unit/op_done                       0
/control_unit/five                          0
/control_unit/new_row                       UUUUUUUUUUUU...
/control_unit/result                        00000111
/control_unit/new_row_en                    0
/control_unit/new_row_rst                   0
/control_unit/row_is_done                   0
/control_unit/write_row_tri_en              0
Now                                         2150 ps
Cursor 1                                    0 ps
0 ps to 904 ps    /control_unit/columns_covered_counter_out
```

Design flow reports:

We still have problems in the control unit synthesized file, the output file is missing a lot of things and it's not working and we're still fixing it. The following numbers reflect this. But all the other modules have synthesized successfully.

data required time	20.00
data arrival time / slack	10.99 / 9.01
Number of gates	11242
Clock Cycle Duration	20ns