

CSE620, HDL Project

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Overview

All the code is [HERE] on my github repository. Every file on the repository contains the following:

```
ram_dual_port/  
-- Makefile  
-- ram_dual_port_test_bench.vhd  
-- ram_dual_port.vhd  
-- results.txt  
-- sim.png  
-- sim.vcd  
-- test_vectors.txt  
-- work-obj93.cf
```

- Makefile: compile and run scripts
- test_vector.txt: a file to input values.
- results.txt: results of the test bench.
- xxx_test_bench.vhd: test bench code.
- sim.png simulation screenshot.
- sim.vcd simulation data.

1-Bit Latch

Test Strategy

D	Clk	q	qbar	comment
1	1	1	0	problem reacting to change in D
1	0	1	0	The latch does not hold D
0	1	0	1	Deasserting D (do latch depend on clk?)
1	0	0	1	output is not changing at the clock

Test Output

Time is now: 15 ns, D=1, clk=1, Actual q=1, Actual nq=0 Test PASSED
Time is now: 30 ns, D=1, clk=0, Actual q=1, Actual nq=0 Test PASSED
Time is now: 45 ns, D=0, clk=1, Actual q=0, Actual nq=1 Test PASSED
Time is now: 60 ns, D=1, clk=0, Actual q=0, Actual nq=1 Test PASSED

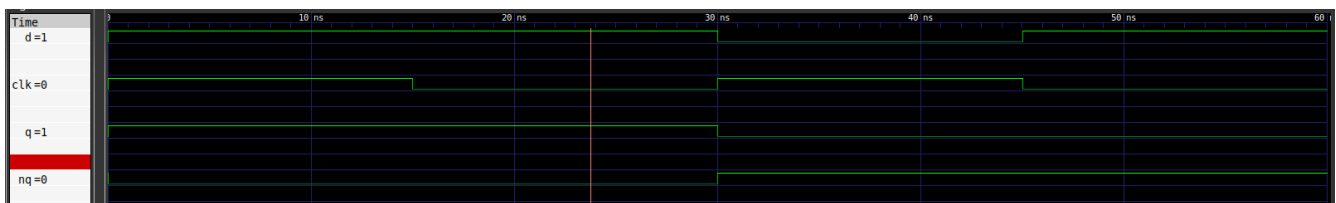


Figure 1: 1-bit Latch

Address Decoder 2

Test Strategy

address	decode	comment
7	10	Corner case for first case.
15	01	Corner case for second case (changing both bits).

address	decode	comment
17	01	does save the output(out side the range behaviour).
20	11	problem reacting to change in D.

Test Output

Time is now: 15 ns, address=7, decode=10, Actual decode=10 Test PASSED
Time is now: 30 ns, address=15, decode=01, Actual decode=01 Test PASSED
Time is now: 45 ns, address=17, decode=01, Actual decode=01 Test PASSED
Time is now: 60 ns, address=20, decode=11, Actual decode=11 Test PASSED

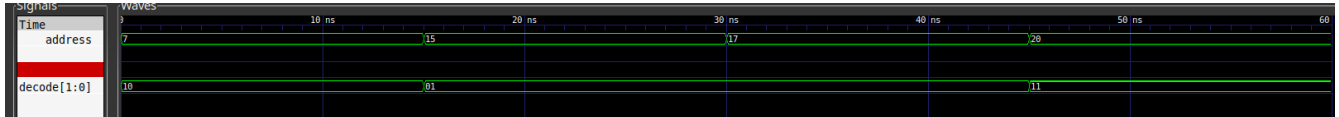


Figure 2: Address Decoder_2

Mux

Test Strategy

abcd	s	z	comment
0001	11	1	Not selecting the last input.
0001	00	0	stuck at 1 output.
1000	00	1	not selecting first input.
0010	10	1	Not selecting third input.
1000	01	0	stuck at 1 fault.
1100	01	1	Not selecting second input.

Test Output

Time is now: 15 ns, a,b,c,d=0001, s=11, z=1, Actual z=1 Test PASSED
Time is now: 30 ns, a,b,c,d=0001, s=00, z=0, Actual z=0 Test PASSED
Time is now: 45 ns, a,b,c,d=1000, s=00, z=1, Actual z=1 Test PASSED
Time is now: 60 ns, a,b,c,d=0010, s=10, z=1, Actual z=1 Test PASSED
Time is now: 75 ns, a,b,c,d=1000, s=01, z=0, Actual z=0 Test PASSED
Time is now: 90 ns, a,b,c,d=1100, s=01, z=1, Actual z=1 Test PASSED

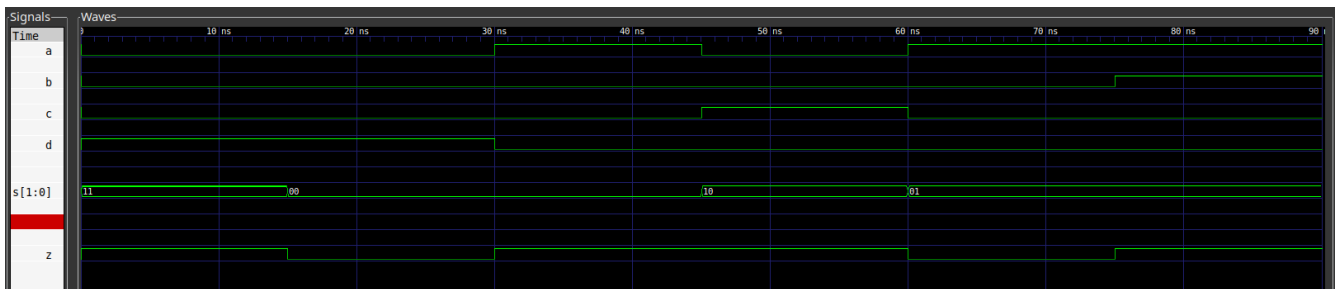


Figure 3: Mux simulation

ALU

Test Strategy

op	a	b	c	comment
01	1100	1101	1111	all ones test.
01	0011	1100	0111	maximum range(positive) of c.
01	1111	0111	1000	maximum range (negative)of c.
01	0011	0011	0000	getting zero output.
00	1100	1101	1001	random test.
00	0011	1100	1111	all ones test of c.
00	1111	1001	1000	maximum range (negative)of c.
00	0011	0100	0111	maximum range(positive) of c.
00	0011	1101	0000	getting zero output.
10	0011	1111	1101	not changing op.
10	0111	0001	0111	max range(positive).
10	1100	0010	1000	max range(negative).
10	1101	1110	0110	not considering sign.
11	1101	1110	0000	not considering sign.
11	0111	0001	0111	max range(positive).
11	1000	0001	1000	max range(negative).
11	0111	1101	1110	random example.

Test output

time is now: 15 ns, op=sub, a=1100, b=1101, c=-1, actual c=1111 test passed
time is now: 30 ns, op=sub, a=0011, b=1100, c=7, actual c=0111 test passed
time is now: 45 ns, op=sub, a=1111, b=0111, c=-8, actual c=1000 test passed
time is now: 60 ns, op=sub, a=0011, b=0011, c=0, actual c=0000 test passed
time is now: 75 ns, op=add, a=1100, b=1101, c=-7, actual c=1001 test passed
time is now: 90 ns, op=add, a=0011, b=1100, c=-1, actual c=1111 test passed
time is now: 105 ns, op=add, a=1111, b=1001, c=-8, actual c=1000 test passed
time is now: 120 ns, op=add, a=0011, b=0100, c=7, actual c=0111 test passed
time is now: 135 ns, op=add, a=0011, b=1101, c=0, actual c=0000 test passed
time is now: 150 ns, op=mul, a=0011, b=1111, c=-3, actual c=1101 test passed
time is now: 165 ns, op=mul, a=0111, b=0001, c=7, actual c=0111 test passed
time is now: 180 ns, op=mul, a=1100, b=0010, c=-8, actual c=1000 test passed
time is now: 195 ns, op=mul, a=1101, b=1110, c=6, actual c=0110 test passed
time is now: 210 ns, op=div, a=1101, b=1110, c=1, actual c=0000 failed,
error messages: not considering sign.
time is now: 225 ns, op=div, a=0111, b=0001, c=7, actual c=0111 test passed
time is now: 240 ns, op=div, a=1000, b=0001, c=-8, actual c=1000 test passed
time is now: 255 ns, op=div, a=0111, b=1101, c=-2, actual c=1110 test passed



Figure 4: ALU

RAM single port

Test strategy

rw	enable	address	datain	dataout	comment
1	1	0000	1100	0000	memory is not storing input.
0	1	0000	1100	1100	memory is not storing input.
1	1	1000	0101	1100	stuck at the previous output.
0	1	1000	0101	0101	stuck at the previous output.
0	1	0000	1100	1100	loses the stored data.
0	0	1000	0101	0101	Enable is now working.
1	1	1111	1101	1100	corner cases (last address).
0	1	1111	1101	1101	corner cases (last address).
1	1	1100	1000	1000	corner cases (middle address).
0	1	1100	1000	1000	corner cases (middle address).
0	1	0000	1100	1100	Not storing previous data.
1	1	1000	1111	1111	Not accepting new data.
0	1	1000	1111	1111	Not accepting new data.

Test Output

Time is now: 30 ns, rw=1, enable=1, address=0000, write_data_in=1100, read_data_out=0000, memory data=1100
Time is now: 45 ns, rw=0, enable=1, address=0000, write_data_in=1100, read_data_out=1100, memory data=1100 Test PASSED
Time is now: 60 ns, rw=1, enable=1, address=1000, write_data_in=0101, read_data_out=1100, memory data=0101
Time is now: 75 ns, rw=0, enable=1, address=1000, write_data_in=0101, read_data_out=0101, memory data=0101 Test PASSED
Time is now: 90 ns, rw=0, enable=1, address=0000, write_data_in=1100, read_data_out=1100, memory data=1100 Test PASSED
Time is now: 105 ns, rw=0, enable=0, address=1000, write_data_in=0101, read_data_out=0101, memory data=ZZZZ Test PASSED
Time is now: 120 ns, rw=1, enable=1, address=1111, write_data_in=1101, read_data_out=1100, memory data=1101
Time is now: 135 ns, rw=0, enable=1, address=1111, write_data_in=1101, read_data_out=1101, memory data=1101 Test PASSED
Time is now: 150 ns, rw=1, enable=1, address=1100, write_data_in=1000, read_data_out=1000, memory data=1000
Time is now: 165 ns, rw=0, enable=1, address=1100, write_data_in=1000, read_data_out=1000, memory data=1000 Test PASSED
Time is now: 180 ns, rw=0, enable=1, address=0000, write_data_in=1100, read_data_out=1100, memory data=1100 Test PASSED
Time is now: 195 ns, rw=1, enable=1, address=1000, write_data_in=1111, read_data_out=1111, memory data=1111
Time is now: 210 ns, rw=0, enable=1, address=1000, write_data_in=1111, read_data_out=1111, memory data=1111 Test PASSED

Ram Dual Port

Test Strategy

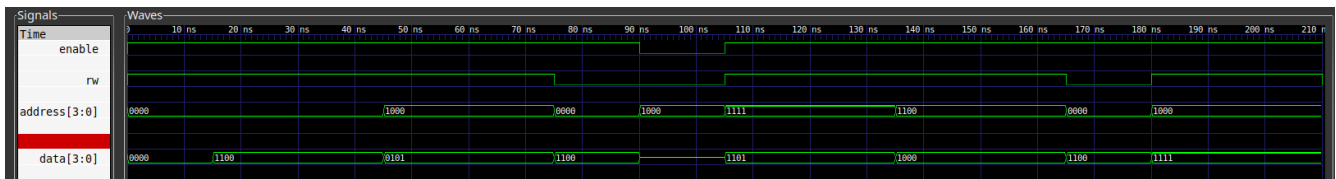


Figure 5: RAM single port

r	w	address_in	address_out	data_in	data_out	
1	1	0000	0000	1100	1100	Reading and writing at the same time.
1	1	1101	1101	0101	0101	Reading and writing at the same time.
1	0	1101	1101	1111	0101	writing when ever address is valid.
1	1	1001	1101	1111	0101	writing and reading in different locations.
1	0	1001	1001	1111	1111	Reading the previous location.
1	1	0000	1101	1000	0101	Not accepting multiple writes to the same location.
1	0	0000	0000	1000	1000	Not accepting multiple writes to the same location.
0	0	0000	0000	1101	1000	read and write stuck at 0.
1	0	0000	0000	1000	1000	read and write stuck at 0.

Test Output

Time is now: 30 ns, r=1, w=1, address_in=0000, address_out=0000, data_in=1100, data_out=1100 Test PASSED
Time is now: 45 ns, r=1, w=1, address_in=1101, address_out=1101, data_in=0101, data_out=0101 Test PASSED
Time is now: 60 ns, r=1, w=0, address_in=1101, address_out=1101, data_in=1111, data_out=0101 Test PASSED
Time is now: 75 ns, r=1, w=1, address_in=1001, address_out=1101, data_in=1111, data_out=0101 Test PASSED
Time is now: 90 ns, r=1, w=0, address_in=1001, address_out=1001, data_in=1111, data_out=1111 Test PASSED
Time is now: 105 ns, r=1, w=1, address_in=0000, address_out=1101, data_in=1000, data_out=0101 Test PASSED
Time is now: 120 ns, r=1, w=0, address_in=0000, address_out=0000, data_in=1000, data_out=1000 Test PASSED
Time is now: 135 ns, r=0, w=0, address_in=0000, address_out=0000, data_in=1101, data_out=1000 Test PASSED
Time is now: 150 ns, r=1, w=0, address_in=0000, address_out=0000, data_in=1000, data_out=1000 Test PASSED

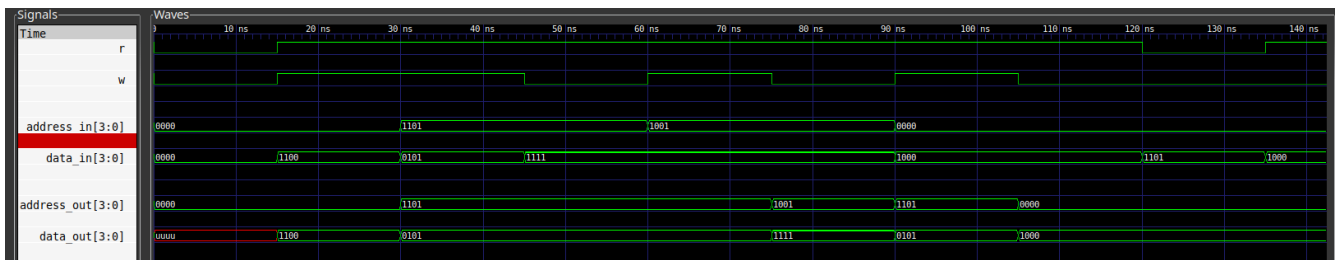


Figure 6: RAM dual port

ROM

Test strategy

enable	address	data	comment
1	000	000000	initial value.
1	111	110001	data stuck at 0

Test Output

Time is now: 30 ns, enable=1, address=000, Actual data=000000, data=000000 Test PASSED
 Time is now: 45 ns, enable=1, address=111, Actual data=110001, data=110001 Test PASSED
 Time is now: 60 ns, enable=1, address=010, Actual data=000100, data=000100 Test PASSED
 Time is now: 75 ns, enable=1, address=110, Actual data=100100, data=100100 Test PASSED
 Time is now: 90 ns, enable=0, address=110, Actual data=100100, data=ZZZZZZ Test PASSED
 Time is now: 105 ns, enable=1, address=101, Actual data=011001, data=011001 Test PASSED



Figure 7: ROM

Shift Register

Test strategy

clk	clr	l_in	r_in	s0	s1	d	q	comment
1	1	0	0	1	1	1111	1111	stuck at 0 output.
0	1	0	0	1	0	1111	1111	stuck at 1 output.
1	1	0	0	1	0	1111	1110	stuck at 1 output.
0	1	0	0	1	0	1111	1110	Not shifting left.
1	1	0	0	1	0	1111	1100	Not shifting left.
0	1	0	1	1	0	1111	1100	r_in stuck at 0.
1	1	0	1	1	0	1111	1001	r_in stuck at 0.
0	1	0	1	0	1	1111	1001	stuck at shifting left state.
1	1	0	1	0	1	1111	0100	stuck at shifting left state.
0	1	1	1	0	1	1111	0100	l_in stuck at 0.
1	1	1	1	0	1	1111	1010	l_in stuck at 0.
1	0	1	1	0	1	1111	0000	Not clearing the output.
0	1	1	1	0	1	1111	0000	random test after clear.
1	1	1	1	0	1	1111	1000	random test after clear.

Test output

Time is now: 30 ns, clk=1, clr=1, l_in=0, r_in=0, s0=1, s1=1, d=1111, Actual q=1111, q=1111 Test PASSED
 Time is now: 45 ns, clk=0, clr=1, l_in=0, r_in=0, s0=1, s1=0, d=1111, Actual q=1111, q=1111 Test PASSED
 Time is now: 60 ns, clk=1, clr=1, l_in=0, r_in=0, s0=1, s1=0, d=1111, Actual q=1110, q=1110 Test PASSED
 Time is now: 75 ns, clk=0, clr=1, l_in=0, r_in=0, s0=1, s1=0, d=1111, Actual q=1110, q=1110 Test PASSED
 Time is now: 90 ns, clk=1, clr=1, l_in=0, r_in=0, s0=1, s1=0, d=1111, Actual q=1100, q=1100 Test PASSED
 Time is now: 105 ns, clk=0, clr=1, l_in=0, r_in=1, s0=1, s1=0, d=1111, Actual q=1100, q=1100 Test PASSED
 Time is now: 120 ns, clk=1, clr=1, l_in=0, r_in=1, s0=1, s1=0, d=1111, Actual q=1001, q=1001 Test PASSED
 Time is now: 135 ns, clk=0, clr=1, l_in=0, r_in=1, s0=0, s1=1, d=1111, Actual q=1001,

q=1001 Test PASSED
Time is now: 150 ns, clk=1, clr=1, l_in=0, r_in=1, s0=0, s1=1, d=1111, Actual q=0100,
q=0100 Test PASSED
Time is now: 165 ns, clk=0, clr=1, l_in=1, r_in=1, s0=0, s1=1, d=1111, Actual q=0100,
q=0100 Test PASSED
Time is now: 180 ns, clk=1, clr=1, l_in=1, r_in=1, s0=0, s1=1, d=1111, Actual q=1010,
q=1010 Test PASSED
Time is now: 195 ns, clk=1, clr=0, l_in=1, r_in=1, s0=0, s1=1, d=1111, Actual q=0000,
q=0000 Test PASSED
Time is now: 210 ns, clk=0, clr=1, l_in=1, r_in=1, s0=0, s1=1, d=1111, Actual q=0000,
q=0000 Test PASSED
Time is now: 225 ns, clk=1, clr=1, l_in=1, r_in=1, s0=0, s1=1, d=1111, Actual q=1000,
q=1000 Test PASSED



Figure 8: Shift Register

Priority Encoder

Test strategy

sel	z	comment
1000	000	stuck at 1 output.
0010	010	not responding for input.
0001	011	corner case.
0100	001	corner case.

Test Output

Time is now: 30 ns, sel=1000, Actual z=000, z=000 Test PASSED
Time is now: 45 ns, sel=0010, Actual z=010, z=010 Test PASSED
Time is now: 60 ns, sel=0001, Actual z=011, z=011 Test PASSED
Time is now: 75 ns, sel=0100, Actual z=001, z=001 Test PASSED

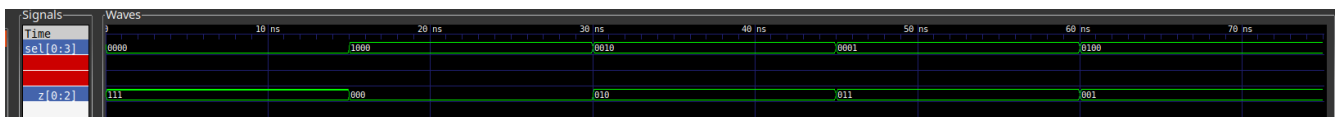


Figure 9: Priority Encoder

FSM Mealy 2p

Test strategy

clk	reset	x	y	comment
0	0	1	1	to odd state.
1	0	1	0	to odd state.
0	0	0	1	staying at odd.
1	0	0	1	staying at odd.
0	0	1	0	going to even.
1	0	1	1	going to even.
0	0	0	0	staying in even.
1	0	0	0	staying in even.

Test output

```
Time is now: 30 ns, reset=0, clk=0, x=1, Actual y=1, y=1 Test PASSED
Time is now: 45 ns, reset=0, clk=1, x=1, Actual y=0, y=0 Test PASSED
Time is now: 60 ns, reset=0, clk=0, x=0, Actual y=1, y=1 Test PASSED
Time is now: 75 ns, reset=0, clk=1, x=0, Actual y=1, y=1 Test PASSED
Time is now: 90 ns, reset=0, clk=0, x=1, Actual y=0, y=0 Test PASSED
Time is now: 105 ns, reset=0, clk=1, x=1, Actual y=1, y=1 Test PASSED
Time is now: 120 ns, reset=0, clk=0, x=0, Actual y=0, y=0 Test PASSED
Time is now: 135 ns, reset=0, clk=1, x=0, Actual y=0, y=0 Test PASSED
```

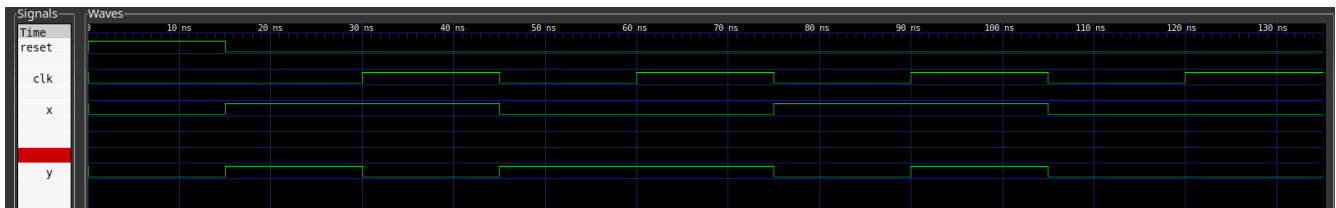


Figure 10: Finite State Machine

Tools

- [GHDL]: Free and open-source analyzer, compiler, simulator and (experimental) synthesizer for VHDL
- [gtkwave]: An open source simulation viewer.
- Makefile: script automation tool fro development.
- [github]: source control platform.
- [spacemacs]: coding text editor.
- [pandoc]: A file converter and styling. I wrote the report in Markdown language ant it generates the styles for the report automatic.

Resource

- [print string to file]