SUBJECT : Testing And Verification(2ECDE59)

TVDC PROJECT

TITLE OF PROJECT : Test Bench of Single Port RAM

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❖ Introduction:

RAM modules are used to temporarily store information in a computer system. A random-access memory (RAM) having a single input and one output port, as implemented by a Single Port RAM block. Only one port on a single-port RAM module is available for data input or output. There is just one en input and one we input. Data can be written to RAM when both en and we are high, and RAM can be read when en is high but we is low. Below is a block diagram of a RAM unit, along with the corresponding Verilog code.
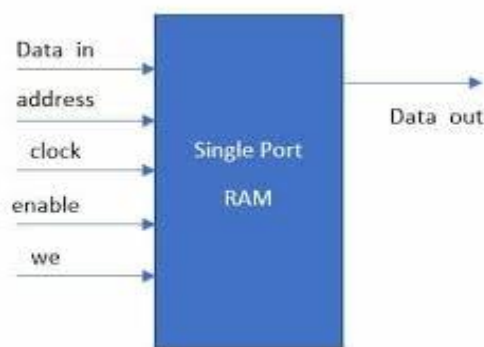
Single Port RAM

● There has one output port and three input ports for addressing, data, and writing enabled (WE). Single Port RAM uses words with the same number of bits, width, and binary digit position to store data.

● The FPGA's Ultra RAM, distributed memory, or block memory may all be used to create a single-port RAM. There is only one address for each data word, and that address must be an unsigned integer between zero and the RAM depth minus one. Although it is impossible to read beyond the end of the memory in the simulation, this may be achievable in hardware with a block memory implementation (with unexpected outcomes). Given that the single-port

- Distributed memory, also known as block RAM, allows the starting contents of RAM to be set using block parameters. When the write enable signal's value is 1, the data input is written to the address input's memory location. The Boolean data type is required for the write enable signal. What's produced by a write operation is dependent on the kind of memory technology used.

- Changing the output port's behaviour when in write mode. The value at the address line's position is sent to the output port when the WE is 0.
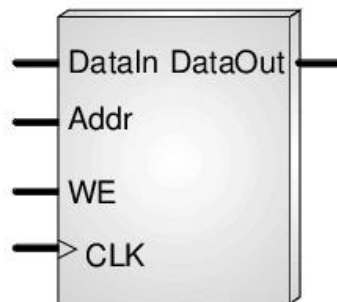
❖ Single Port RAM Types

- Single-port random-access memories (RAMs) are frequently used as cache memory, data buffers, and registers in digital systems. It is crucial to verify single port RAMs to ensure they perform as expected inside the larger system. Single-port random-access memories come in a number of flavours, including synchronous and asynchronous RAMs, ROMs, and RAMs. These RAMs may be verified in a number of ways, including:

  1. Functional Verification: This involves testing the functionality of the RAM by providing input data and verifying that the output data matches the expected results. This can be done using simulation or emulation techniques.

  2. Timing Verification: This involves checking the timing constraints of the RAM by verifying that the data is read and written to the RAM within the specified time limits. This can be done using static timing analysis (STA) tools or by simulating the timing constraints.

  3. Power Verification: This involves verifying the power consumption of the RAM and ensuring that it meets the power budget for the system. This can be done using power analysis tools or by simulating the power consumption of the RAM.

  4. Compliance Verification: This involves verifying that the RAM complies with the relevant industry standards and specifications. This can be done using compliance checkers or by running compliance tests. Overall, verification of single port RAMs is a critical part of the digital design process and requires a combination of various verification techniques to ensure that the RAM functions correctly and meets the requirements of the system.

❖ Single Port RAMs can be categorized into two main types:

1. Single Port RAM Synchronous
2. Single Port RAM Asynchronous

single-port RAM
asynchronous

single-port RAM
synchronous

➢ Asynchronous Single Port RAM:

- Asynchronous Single Port RAM operates independently of a system clock and is often used in low-power, low-speed applications. In an asynchronous RAM, the read and write operations are initiated by the input signals and the data is available on the output port after a specified access time.

- The output data is usually held stable until the next access cycle. Asynchronous RAMs are relatively simple to design and require less power than synchronous RAMs, but they suffer from limitations in terms of speed and maximum operating frequency.

➢ Synchronous Single Port RAM:

- Synchronous Single Port RAM, on the other hand, operates with a system clock and is often used in high-speed applications that require fast access times. In a synchronous RAM, the read and write operations are synchronized with the system clock, which allows for more efficient and faster access to the memory.

- The read and write operations are triggered by the rising or falling edge of the clock signal, and the output data is available on the output port after a specified number of clock cycles. Synchronous RAMs are more complex to design and require a clock signal to operate, but they offer higher performance, larger capacity, and higher maximum operating frequency than asynchronous RAMs.

- In terms of verification, both asynchronous and synchronous RAMs require different techniques to ensure their proper operation. Asynchronous RAMs are verified using functional simulations and asynchronous timing analysis, while synchronous RAMs require functional simulations, timing analysis, and clock domain crossing verification to ensure that the data is properly synchronized across different clock domains.

❖ Code

```
module single_port_ram(data_in , ram_address,write_enable,clk,data_out);
input [7:0]data_in;
input [5:0] ram_address;
input write_enable;
input clk;
output [7:0]data_out;

reg [7:0] ram_memory[31:0]; // a 32 byte ( 32*8 bit)  RAM
reg [5:0] address_register;

always @(posedge clk)
begin
if (write_enable)  // write operation
  ram_memory[ram_address] <= data_in;
else
  address_register <= ram_address;
end

assign data_out = ram_memory[address_register];

endmodule
```

❖ Test Bnech

```verilog
module single_port_ram_testbench;
reg [7:0]data_in;
reg [5:0] ram_address;
reg write_enable;
reg clk;
wire [7:0]data_out;

single_port_ram  ram1(data_in , ram_address,write_enable,clk,data_out);

initial begin // clock initialization
clk =1'b1;
forever #10 clk=~clk;
end

initial
begin
// writing data into the memory
write_enable =1'b1;

#20;
ram_address=5'd0;
data_in = 8'h10;
#20;

ram_address=5'd2;
data_in = 8'h11;
#20;

ram_address=5'd7;
data_in = 8'haf;
#20;

//reading data from the memory
write_enable = 1'b0;

ram_address=5'd0;
#20;

ram_address=5'd2;
#20;

ram_address=5'd7;
#20;

$finish;
end
endmodule
```
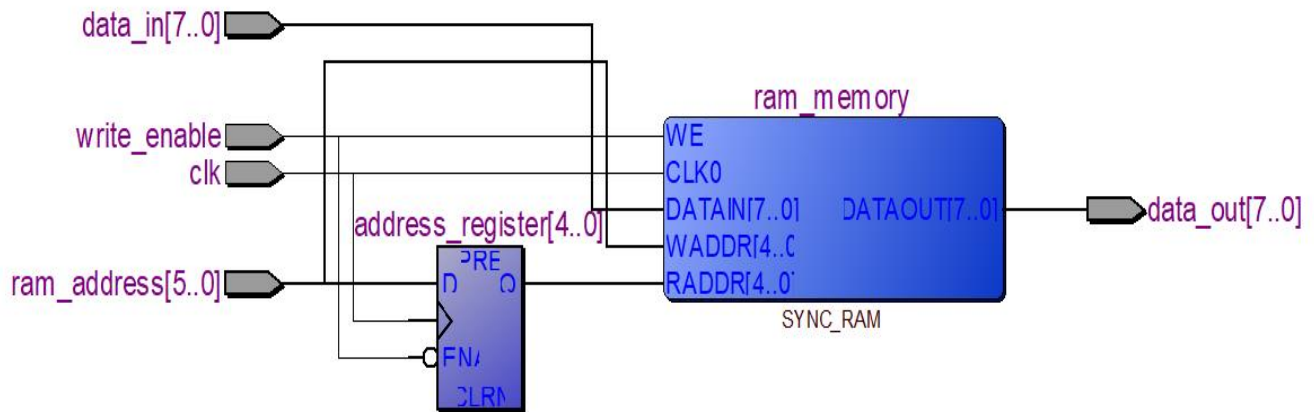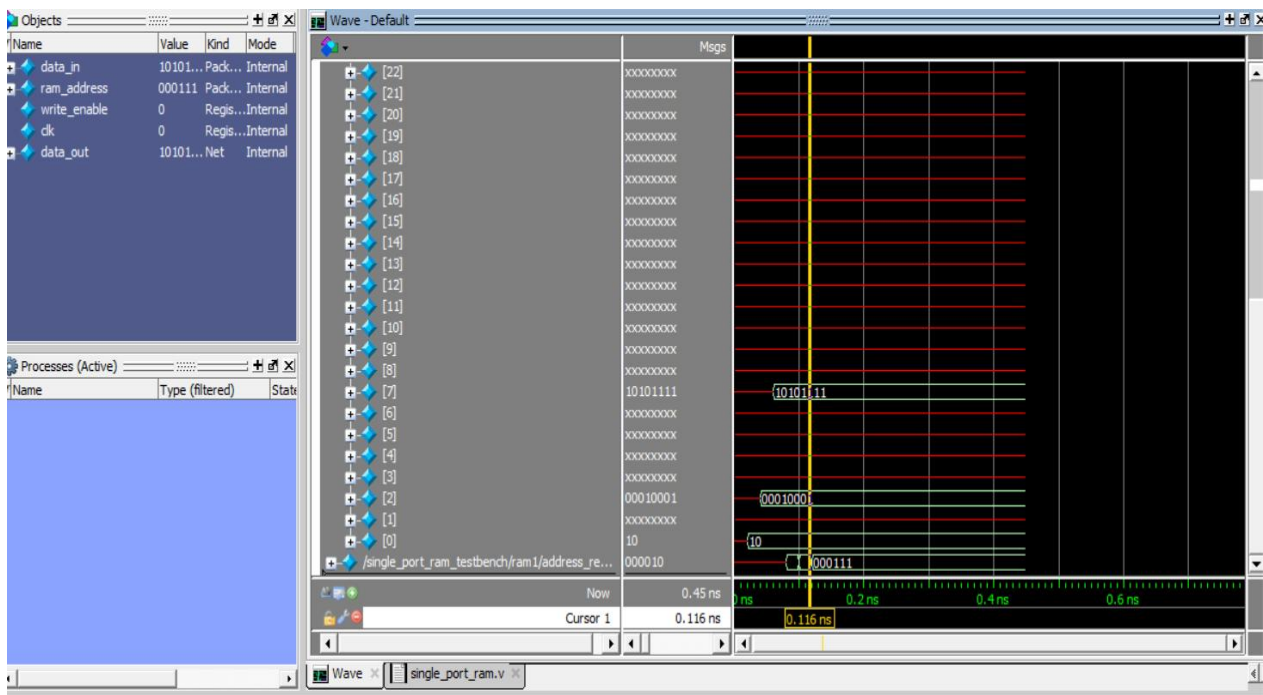
❖ RTL Schematic:

❖ Output:

write_enable on

write_enable off

❖ **Advantages:**

● Simplicity: Single-port RAM is less complex compared to other types of RAM such as dual-port RAM. It requires fewer input and output pins, which can reduce the cost and complexity of the system.
● Cost-effective: Single-port RAM is typically less expensive than dual-port RAM because it has fewer features and is less complex.
● Easy to use: Single-port RAM is easy to use because it requires only one clock signal and one set of address and data lines. This makes it easy to integrate into a system and operate.
● Low power consumption: Single-port RAM requires less power to operate compared to dual-port RAM because it has fewer features and requires fewer pins.

❖ **Disadvantages:**

● Limited access: Single-port RAM can only access one memory location at a time. This can result in a delay when trying to access multiple memory locations simultaneously.

● Limited bandwidth: Single-port RAM has limited bandwidth because it can only transfer data in one direction at a time.
● Limited concurrency: Single-port RAM can only handle one read or write operation at a time. This can limit the concurrency of the system.
● Limited functionality: Single-port RAM has limited functionality compared to other types of RAM such as dual-port RAM or synchronous RAM. It cannot perform complex operations such as simultaneous reads and writes.

Overall, single-port RAM is a good option for simple systems that require basic memory functionality. However, if the system requires more advanced memory features or higher performance, dual-port RAM or other types of RAM may be a better choice.

❖ **Application of single port RAM**

● Embedded systems: Single-port RAM is commonly used in embedded systems, such as micro controllers and digital signal processors (DSPs). These systems require small memory footprints and lower power consumption, making single-port RAM an ideal choice.
● Graphics processing: Single-port RAM can be used in graphics processing units (GPUs) to store texture maps and frame buffers. The memory is accessed by the GPU for processing and rendering images in real-time.

- Networking equipment: Single-port RAM is commonly used in networking equipment such as routers, switches, and modems to store routing tables, packet headers, and other data. It provides quick access to data and supports fast packet processing.
- Industrial automation: Single-port RAM is used in industrial automation systems to store and retrieve data such as sensor readings, process data, and control signals. This helps to increase the efficiency and accuracy of the manufacturing process.
- Medical devices: Single-port RAM is used in various medical devices such as ultrasound machines, patient monitors, and medical imaging equipment. It is used to store and process data such as images, waveforms, and patient information.
- Automotive electronics: Single-port RAM is used in automotive electronics such as engine management systems, navigation systems, and infotainment systems. It is used to store and retrieve data such as maps, audio files, and vehicle parameters.Overall, single-port RAM is a versatile memory technology that is used in various applications where low power consumption, small memory footprint, and fast access times are important.

❖ Conclusion:

Single-port RAM (Random Access Memory) is a widely used memory technology that offers advantages and disadvantages depending on the specific application. It is a simple, cost-effective, and easy-to-use memory technology that requires fewer pins, making it suitable for small memory footprints and lower power consumption. Single-port RAM is commonly used in embedded systems, graphics processing, networking equipment, industrial automation, medical devices, and automotive electronics. However, it has limited access, bandwidth, concurrency, and functionality compared to other types of RAM, such as dual-port RAM and synchronous RAM. The choice of using single-port RAM depends on the specific requirements of the application, and in some cases, more advanced memory technologies may be necessary to achieve the desired performance.