

Exercises

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1 3.1

Write an entity declaration for a memory circuit whose input and output ports are shown below. Use only the `std_logic` or `std_logic_vector` data types.

- `addr`: 12-bit address input
- `wra`: 1-bit write-enable control signal
- `oen`: 1-bit output-enable control signal
- `bit`: bidirectional data bus

1.1 Answer

```
1 library ieee;
2 use ieee.std_logic_1164.all;
3
4 entity MemoryCircuit is
5 port (
6     addr: in std_logic_vector(11 downto 0);
7     wra : in std_logic;
8     oen : in std_logic;
9     bit : inout std_logic_vector(11 downto 0)
10 );
```

2 3.5

Assume that `a` is a 10-bit signal with the `std_logic_vector(9 downto 0)` data type. List the 10 bits assigned to the `a` signal.

- (a) `a <= (others=>'1');`
- (b) `a <= (1|3|5|7|9=>'1', others=>'0');`
- (c) `a <= (9|7|2=>'1', 6=>'0', 0=>'1', 1|5|8=>'0', 3|4=>'0');`

2.1 Answer

- (a) "1111111111"
- (b) "0101010101"
- (c) "1010000101"

3 3.6

Assume that `a` and `y` are 8-bit signals with the `std_logic_vector(7 downto 0)` data type. If the signals are interpreted as unsigned numbers, the following assignment statement performs `a / 8`. Explain.

```
1 y <= "000" & a(7 downto 3);
```

3.1 Answer

Shifting the binary numbers does multiplication or division by 2 depending on the direction of the shift operation. • Left: $number \times 2$ • right: $\frac{number}{2}$

In the question, we've got division so we must do a right shift, but how many shifts are needed? $\log_2 8 = 3$. So we have to do the right shift 3 times.

In shifting the unsigned numbers, we don't care about the last digit because it is not the *sign* of the number, so we insert zero for each shift.

In the question, we have concatenated 3 zeros with the rest of the number (5 digits that are still present and not thrown away).

4 3.7

Assume the same `a` and `y` signals in Problem 3.6. We want to perform `a mod 8` and assign the result to `y`. Rewrite the previous signal assignment statement using only the `&` operator.

4.1 Answer

Taking `number mod 2n` is equivalent to stripping off all but the `n` lowest-order (right-most) bits of `number`.

For example

number	number % 4
00000001	00000001
00000010	00000010
00000011	00000011
00000100	00000000
00000101	00000001
00000110	00000010

In order to do it only with concatenation in VHDL, we have to keep 3 bits ($\log_2 8 = 3$) and make the rest bits to be zero.

```
1 y <= "00000" & a(2 downto 0)
```

5 3.8

Assume that the following double-quoted strings are with the `std_logic_vector` data type. Determine whether the relational operation is syntactically correct. If yes, what is the result (i.e., `true` or `false`)?

- (a) `"0110" > "1001"`
- (b) `"0110" > "0001001"`
- (c) `2#1010# > "1010"`
- (d) `1010 > "1010"`

5.1 Answer

- (a) false
- (b) false
- (c) type mismatch
- (d) type mismatch

6 3.11

Determine whether the following signal assignment is syntactically correct. If not, use the proper conversion function and type casting to correct the problem.

```
1 library ieee;
2 use ieee.std_logic_1164.all;
3 use ieee.numeric_std.all;
4 ...
5 signal s1, s2, s3, s4, s5, s6, s7: std_logic_vector(3 downto
    0);
6 signal u1, u2, u3, u4, u5, u6, u7: unsigned(3 downto 0);
7 signal sg: signed(3 downto 0);
8 ...
9 u1 <= 2#0001#;
10 u2 <= u3 and u4;
11 u5 <= s1 + 1;
12 u6 <= u3 + u4 + 3;
13 u7 <= (others=>'1');
14 s2 <= s3 + s4 - 1;
15 s5 <= (others=>'1');
16 s6 <= u3 and u4;
17 sg <= u3 - 1;
18 s7 <= not sg;
```

6.1 Answer

- u1 <= 2#0001# → u1 is unsigned but 2#0001# is integer.
Correct: to_unsigned(2#0001#, 4)

- $u2 \leq u3 \text{ and } u4 \rightarrow \text{Correct}$
- $u5 \leq s1 + 1 \rightarrow \text{std_logic_vector does not support +}$
Correct: $u5 \leq \text{unsigned}(s1) + 1$
- $u6 \leq u3 + u4 + 3 \rightarrow \text{Correct}$
- $u7 \leq (\text{others} \Rightarrow '1') \rightarrow \text{Correct}$
- $s2 \leq s3 + s4 - 1 \rightarrow \text{std_logic_vector does not support +}$
Correct: $s2 \leq \text{std_logic_vector}(\text{unsigned}(s3) + \text{unsigned}(s4) - 1)$
- $s5 \leq (\text{others} \Rightarrow '1') \rightarrow \text{Correct}$
- $s6 \leq u3 \text{ and } u4 \rightarrow \text{unsigned type does not support and}$
Correct: $s6 \leq \text{std_logic_vector}(u3) \text{ and } \text{std_logic_vector}(u4)$
- $sg \leq u3 - 1 \rightarrow \text{unsigned does not support minus operator AND the result should be signed}$
Correct: $sg \leq \text{signed}(u3) - 1$
- $s7 \leq \text{not } sg \rightarrow \text{singed does not support not operator}$
Correct: $s7 \leq \text{not } \text{std_logic_vector}(sg)$

7 3.12

For the following VHDL segment, correct the type mismatch with proper conversion function(s).

```

1 library ieee;
2 use ieee.std_logic_1164.all;
3 use ieee.numeric_std.all;
4 ...
5 signal src, dest: std_logic_vector(15 downto 0);
6 signal amount: std_logic_vector(3 downto 0);
7 ...
8 dest <= shift_left(src, amount);

```

7.1 Answer

```
1 dest <= std_logic_vector(  
2     shift_left(unsigned(src),  
3     to_integer(unsigned(amount))  
4 )  
5 )
```

8 3.13

For the following VHDL segment, correct the type mismatch with proper conversion function(s).

```
1 library ieee;  
2 use ieee.std_logic_1164.all;  
3 use ieee.numeric_std.all;  
4 ...  
5 signal src, dest: std_logic_vector(15 downto 0);  
6 signal amount: std_logic_vector(3 downto 0);  
7 ...  
8 dest <= src sll amount;
```

8.1 Answer

9 3.14

For the following VHDL segment, correct the type mismatch with proper conversion function(s).

```
1 library ieee;  
2 use ieee.std_logic_1164.all;  
3 use ieee.std_logic_arith.all;  
4 use ieee.numeric_std.all;  
5 ...  
6 signal src, dest: std_logic_vector(15 downto 0);  
7 signal amount: std_logic_vector(3 downto 0);  
8 ...  
9 dest <= src sll amount;
```
