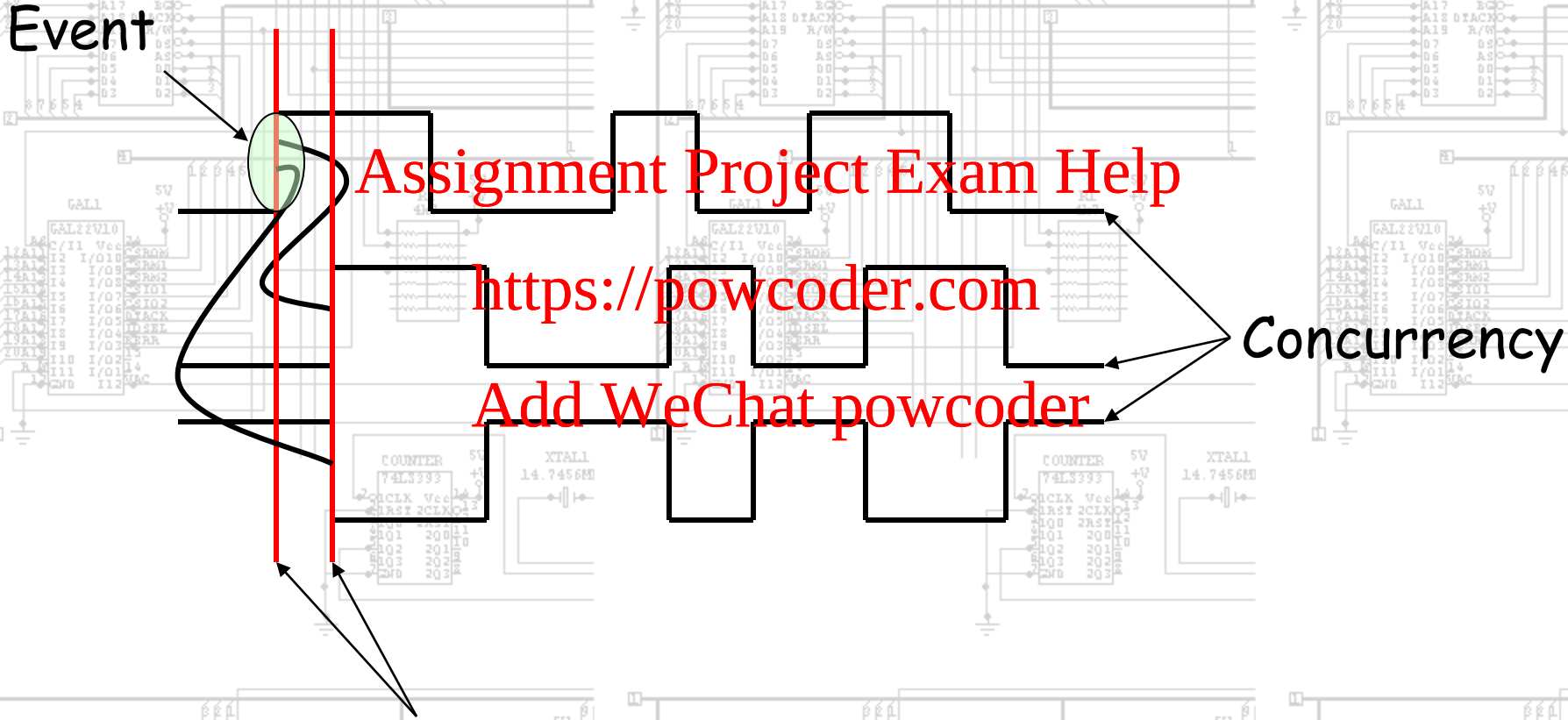
- Synthesis produces a digital circuit that implements the behavior captured in the VHDL description.
- VHDL is also the bases for a simulation.
- Characteristics of digital systems:
  - Structural
  - Behavioral
  - Physical

Event, Propagation Delays and Concurrency



Signals

- May be 0, 1, or Z
- Equivalent to wires in digital circuits
- May be assigned values
- Signals are associated with time values
- Sequences of values determines the waveform
- Signal type depends on the level of abstraction
  - At gate level through wires (or, and, xor…)
  - At module level through integer (ALU…)

Shared Signals

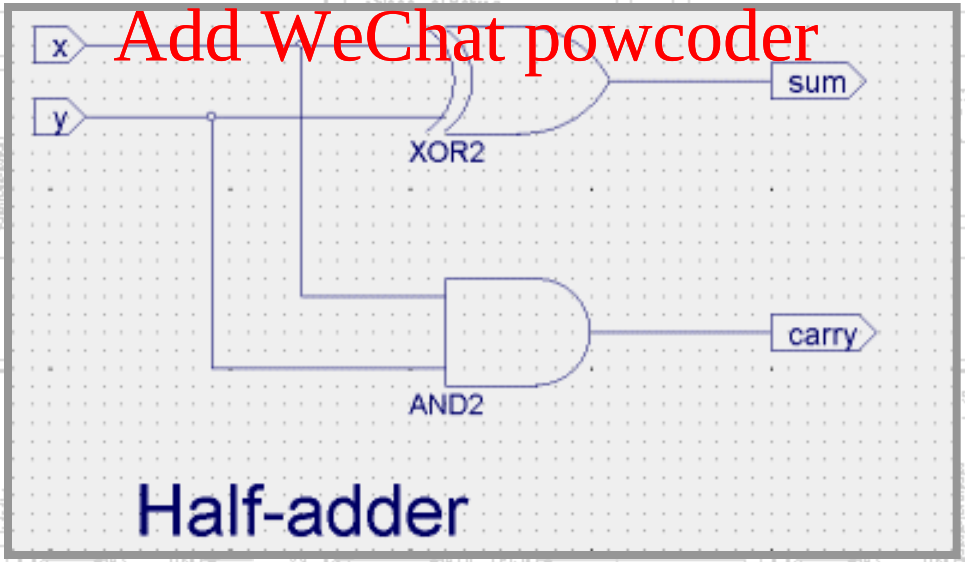
- Hardware description languages must be expressive enough to describe signal that may be driven by one or more sources.
  - Bus

Design Entity

- Design entities could be:
  - Board
  - Chip
  - Gate
  - Transistor
- This design component behavior must be:
  - Described
  - Simulated

Design Entity –Gate Level Example

- Half-Adder
  - Input signals: x, y
  - Output signals: sum, carry



Design Entity - Description

- Input signals
- Output signals
- Behavior
  - Truth table
  - Boolean equation
  - Wires between gates
- Two components in the design-entity description:
  - The interface
  - Internal behavior

Entity Declaration

- Interface to design entities through
  - Entity Declaration:

Blue = keywords

Design Entity Name

Port = input & output

```
entity half_adder is
  Port ( x : in bit;
         y : in bit;
         sum : out bit;
         carry : out bit);
end half_adder;
```

Declaration Details

- **Blue bold** type denotes VHDL reserved keywords (entity, port, …)
- VHDL is not case sensitive
  - Half-adder = HALF_ADDER
- Ports define the input and output of the the design entity
- **Ports are signals** that enable communication between the design entity and other entities.
- Port signals must declare their types.

Port Declaration

- Signal types defined in the VHDL language
- **bit**
  - Represents a single-bit signal
- **bit_vector**
  - Represents a vector of signal of type bit
- Bit and bit_vector are only two out of several other VHDL data types.

IEEE 1164 Signals Values

IEEE 1164 standard defines nine-value signals:

U	Uninitialised
X	Forcing Unknown
0	Forcing 0
1	Forcing 1
Z	High Impedance
W	Weak Unknown
L	Weak 0
H	Weak 1
-	Don't Care

Library IEEE

The following modifications are required to make the previous entity declaration IEEE compliant.


```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
```



```
entity half_adder is
  Port ( x : in std_logic;
         y : in std_logic;
         sum : out std_logic;
         carry : out std_logic);
end half_adder;
```

Signal Mode

- Port declaration distinguishes between:
  - in – input signal
  - out – output signal
  - inout – bidirectional signal

Signal mode

```
entity half_adder is
    Port ( x : in std_logic;
```

4 to 1 Multiplexer

This example uses std_logic_vector(7 downto 0);

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

entity mux is
    Port ( I0 : in std_logic_vector(7 downto 0);
           I1 : in std_logic_vector(7 downto 0);
           I2 : in std_logic_vector(7 downto 0);
           I3 : in std_logic_vector(7 downto 0);
           Sel : in std_logic_vector(1 downto 0);
           Z : out std_logic_vector(7 downto 0));
end mux;
```

Bit vector

std_logic_vector(7 downto 0)

```
entity mux is
    port(i0 : in std_logic_vector(7 downto 0);
```


- This example refers to 8 bits long input vector.
  - bit 7 – most significant bit
  - bit 0 – least significant bit

Entity's Internal Behavior

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

entity half_adder is
    Port ( x : in std_logic;
           y : in std_logic;
           sum : out std_logic;
           carry : out std_logic);
end half_adder;

architecture Behavioral of half_adder is
-- declaration
begin
-- description of behavior
end Behavioral;
```


VHDL describes the internal behavior in the architecture construct.

Architecture

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

entity half_adder is
    Port ( x,y : in std_logic;
           sum,carry : out std_logic);
end half_adder;

architecture concurrent_behavior of half_adder is
begin
sum <= (x xor y) after 5 ns;
carry <= (x and y) after 5 ns;
end concurrent_behavior;
```