Announcement

- Midterm will be Oct. 21 (Tuesday)
- Midterm review will be Oct. 16

VHDL in Action

Chapter 4
Signal Drivers
and Delay Models

Last time

- Started talking about signal drivers
  - For every signal assigned a value within a process, a signal driver is created for that process within the simulator.
- Resolution functions
  - Handle multiple processes assigning values to the same signal

Delay Models

- Inertial Delay
- Transport Delay

Effect of Short Pulses on Real Gates

What do you expect the output to be?

Inertial Delay

- Signal propagation will take place if and only if an input persists at a given level for a specified amount of time (that time given in the after clause)
- \( Z \leq X \) after 10 ns;
  - changes in X will affect Z only if they stay at the new level for 10 ns or more
  - models a real circuit, as voltages cannot change instantaneously
Transport Delay

- Signal propagation will take place regardless of the duration of input signal values
- \( Z \leftarrow \text{transport} \ X \text{ after} 10 \text{ ns}; \)
  - changes in \( X \) will always affect \( Z \)
  - useful at higher levels of abstraction since the transport delay would not accurately model the hardware

**Inertial vs. Transport Delay**

- \( X_{\text{Inertial}} \leftarrow Y \text{ after} 3 \text{ ns}; \) \( \ldots \) \( \text{-- inertial delay} \)
- \( X_{\text{Transport}} \leftarrow \text{transport} \ Y \text{ after} 3 \text{ ns}; \) \( \ldots \) \( \text{-- transport delay} \)

**Transactions and Waveforms (1)**

- **Transaction**
  - A pair consisting of a value and time. The value part represents a future value of the driver; the time part represents the time at which the value part becomes the current value of the driver.
- **Waveform**
  - A series of transactions. Each transaction represents a future value of the driver of the signal. The transactions in a waveform are ordered with respect to time.

**Inertial Delay (VHDL ’93)**

- Can also specify the pulse rejection limit separately from the propagation delay...
  - Pulse rejection limit must be less than the propagation delay.
- Example:
  \[
  b \leftarrow \text{reject} \ 7 \text{ ns inertial} \ a \text{ after} 20 \text{ ns};
  \]

**Drivers and Processes**

- Each process that assigns a value to a signal creates a separate waveform driver for the signal.
- A resolution function resolves conflicts among the various drivers for the signal.

**Vectors, Arrays, Records**

- Each component of a composite data type has its own independent signal driver.
- In particular, each bit of a \text{Bit\_Vector} has its own separate signal driver.
Events on Bit_Vectors

- signal S: Bit_Vector (7 downto 0);
- If S'event then ...
- If S(3)'event then ...
- If S(3 downto 0)'event then ...

Signal Drivers

- Each signal driver consists of a waveform of (time,value) pairs.
- Current value of a driver
  - There is exactly one transaction in the driver whose time value is less than or equal to the current simulation time.
  - The signal value of the above transaction is the current value of the driver.

Signal Drivers

- Process A
  - M <= H;
- Process B
  - M <= E;

Signal Value Changing Due to Time Advance

- State of driver Ma at simulation time 8 ns. CV of signal is '0'.

Updating the Current Value of a Signal Driver Due to Simulation Time Advance

- There is exactly one transaction whose time component is not greater than the current simulation time.
- The current value of the driver is the value component of this transaction.
- If, as a result of simulation time advance, the current simulation time becomes equal to the time component of the next transaction, then the first transaction is deleted from the projected output waveform and the next transaction becomes the current value of the driver.

Waveform Updating Due to Executing a Signal Assignment Statement

- A1. All old transactions that are projected to occur at or after the time at which the earliest new transaction is projected to occur are deleted from the projected output waveform.
- A2. The new transactions are then appended to the projected output waveform in the order of their projected occurrence.
Additional Waveform Updating for Inertial Delay

- B1. All of the new transactions are marked.
- B2. An old transaction is marked if it immediately precedes a marked transaction and its value component is the same as that of the marked transaction.
- B3. The transaction that determines the current value of the driver is marked.
- B4. All unmarked transactions (all of which are old transactions) are deleted from the projected output waveform.

Example of Waveform Updating

State of Signal Driver at Simulation Time 5 ns.

<table>
<thead>
<tr>
<th>Time (ns)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>0</td>
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<tr>
<td>30</td>
<td>1</td>
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<tr>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

Compare the following signal assignment statements if they are executed at simulation time 5 ns.

S<= transport '1' after 23 ns; '0' after 42 ns; '1' after 50 ns;
S<= transport '1' after 23 ns; '0' after 42 ns; '1' after 50 ns;

Are These Equivalent Processes?

architecture A1 of entity B is
signal A: Bit := '0';
P1: process
A <= '1' after 10 ns;
A <= '0' after 20 ns;
wait;
end process;
end A1;

architecture A2 of entity B is
signal A: Bit := '0';
P2: process
A <= '1' after 10 ns, '0' after 20 ns;
wait;
end process;
end A2;

Another Architecture

architecture A3 of entity B is
signal A: Bit := '0';
P3: process
A <= transport '1' after 10 ns;
A <= transport '0' after 20 ns;
wait;
end process;
end A3;

Yet Another Architecture

architecture A4 of B is
signal A: Bit;
begin
A <= '1' after 10 ns;
A <= '0' after 20 ns;
end A4;

Short Pulses

architecture SHORT of ENTITY is
signal A, B, S_INERTIAL, S_TRANSPORT: Bit;
begin
S1: A <= '0', '1' after 1 ns, '0' after 5 ns;
S2: B <= '0';
S3: S_INERTIAL <= A or B after 10 ns;
S4: S_TRANSPORT <= transport A or B after 10 ns;
end SHORT;
Signal Drivers in Procedures

- A procedure maintains a dynamic signal driver for each formal signal parameter of mode OUT or INOUT.
- The calling process maintains a signal driver for each actual signal that is associated with a formal signal parameter.

Signal Drivers in Procedures (cont.)

- Attributes of the actual signal are NOT copied to the formal signal.
- An assignment to the driver of the formal signal is equivalent to an assignment to the driver of the actual signal and takes effect when the assignment is made.

Summary

- Delay Models
  - Inertial—Short pulses filtered out
  - Transport—Passes all pulses
- Waveform Updating Algorithms

- Next time: Macro/micro time