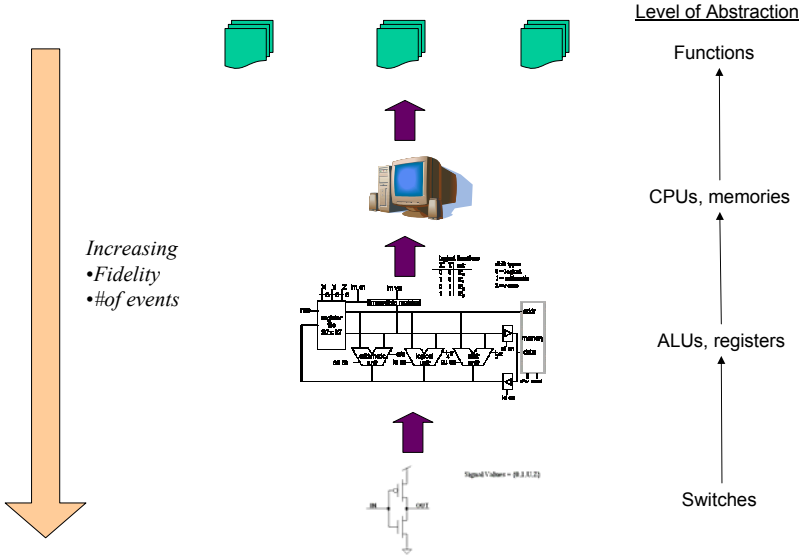
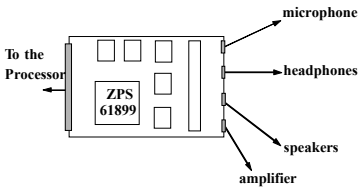
Modeling Digital Systems

Systems Hierarchy



Describing Systems



- From Webster's Dictionary:
  - **System**: "An assemblage of objects united by some form of regular interaction or dependence"
- What aspects of a digital system do we want to describe?
  - Interface
  - Function: behavioral and structural

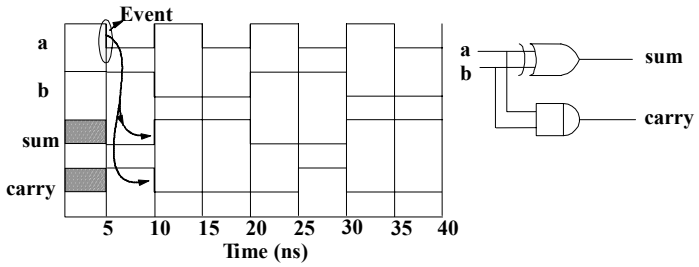
What Elements Should be in a Description?

- Descriptions should be at multiple levels of abstraction
  - The descriptive elements must be common to multiple levels of hierarchy
- The elements should enable meaningful and accurate simulation of hardware described using the elements
  - Elements should have attributes of time as well as function
- The elements should enable the generation of hardware elements that realize a correct physical implementation
  - Existence of a mapping from elements to VLSI devices

What Elements Should be in a Description?

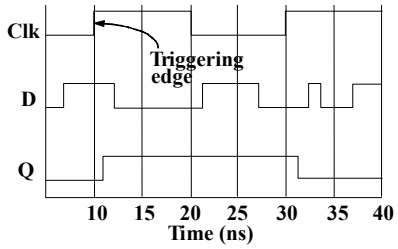
- VHDL was conceived for the description of digital systems
  - From switches to networked systems
- Keep in mind the pragmatic issues of design re-use and portability of descriptions
  - Portability across technology generations
  - Portability across a range of cost/performance points
- Attributes of digital systems serve as the starting point
  - Language features designed to capture the key attributes

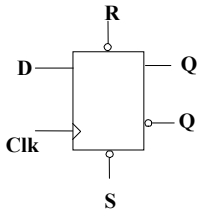
Attributes of Digital Systems



- Digital systems are about *signals* and their *values*
- *Events, propagation delays, concurrency*
  - Signal value changes at specific points in time
- Time ordered sequence of events produces a *waveform*

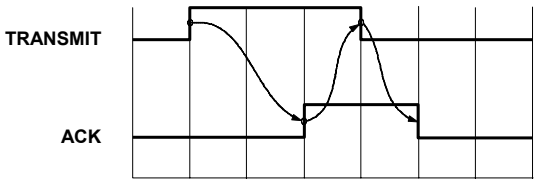
Attributes of Digital Systems: Timing





- Timing: computation of events takes place at specific points in time
- Need to "wait for" an event: in this case the clock
- Timing is an attribute of both synchronous and asynchronous systems

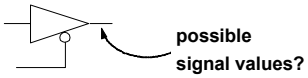
Attributes of Digital Systems: Timing



- Example: Asynchronous communication
- No global clock
- Still need to *wait for* events on specific signals

Attributes of Digital Systems: Signal Values

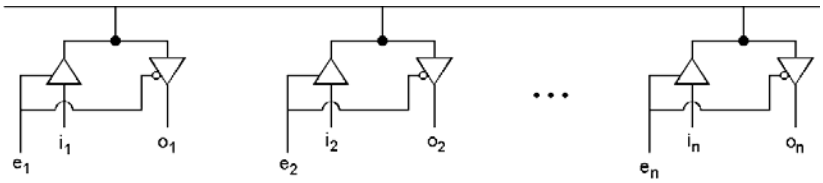
- We associate logical values with the state of a signal



- Signal Values: IEEE 1164 Value System

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

Attributes of Digital Systems: Multiple Drivers



- Shared Signals
  - multiple drivers
- How is the value of the signal determined?
  - arbitration protocols
  - wired logic

Modeling Digital Systems

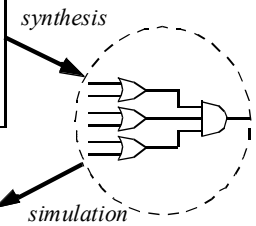
- We seek to describe attributes of digital systems common to multiple levels of abstraction
  - events, propagation delays, concurrency
  - waveforms and timing
  - signal values
  - shared signals
- Hardware description languages must provide constructs for naturally describing these attributes of a specific design
  - simulators use such descriptions for “mimicing” the physical system
  - synthesis compilers use such descriptions for synthesizing manufacturable hardware specifications that conform to this description

Execution Models for VHDL Programs

- Two classes of execution models govern the application of VHDL programs
- For Simulation
  - Discrete event simulation
  - Understanding is invaluable in debugging programs
- For Synthesis
  - Hardware inference
  - The resulting circuit is a function of the building blocks used for implementation
    - Primitives: NAND vs. NOR
    - Cost/performance

Simulation vs. Synthesis

```
entity my_ckt is
port(x, y : in bit;
     z : out bit)
end entity my_ckt;
architecture behavioral of
my_ckt is
begin
-- some code here
--
end architecture behavioral;
```

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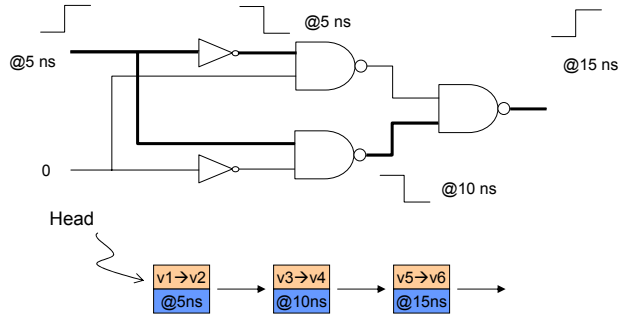
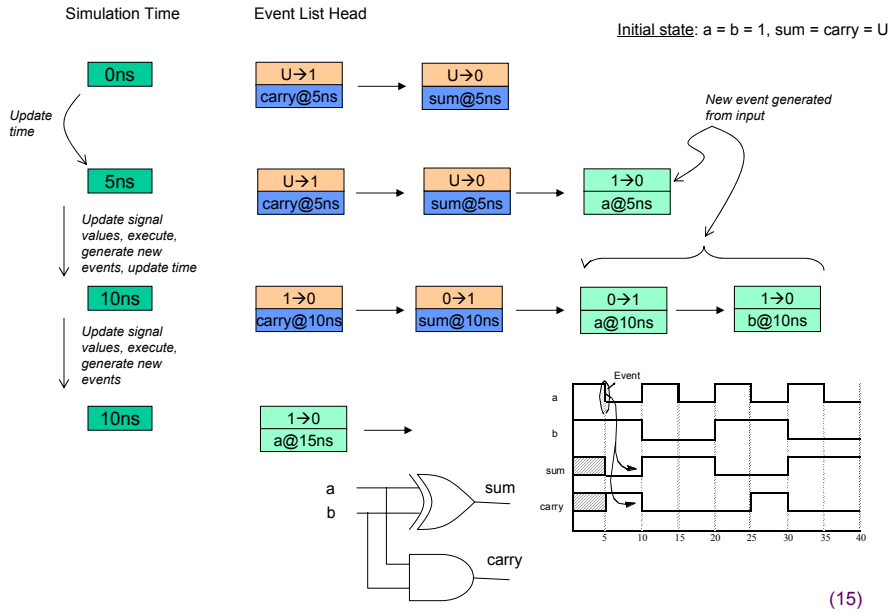
- Simulation and synthesis are complementary processes

Simulation of Digital Systems



- Digital systems are modeled as the generation of events – value transitions – on signals
- Discrete event simulations manage the generation and ordering of events
  - Correct sequencing of event processing
  - Correct sequencing of computations caused by events

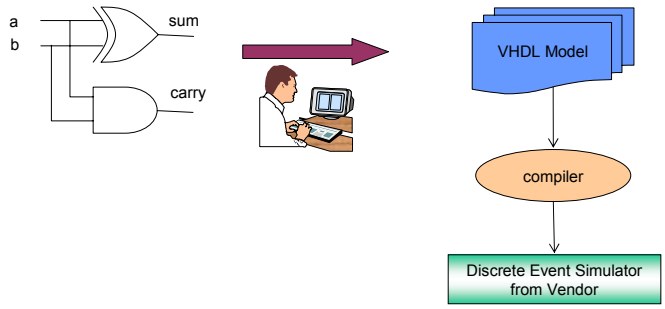
Discrete Event Simulation: Example



Discrete Event Simulation

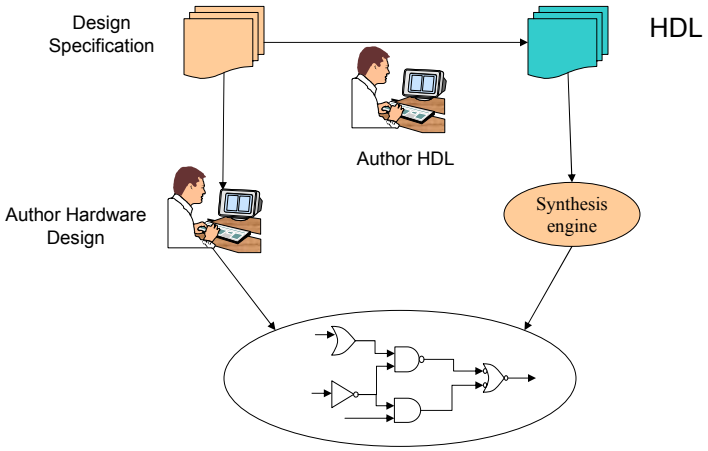
- Management of simulation time: ordering of events
- Two step model of the progression of time
  - Evaluate all affected components at the current time: events on input signals
  - Schedule future events and move to the next time step: the next time at which events take place

Simulation Modeling



- VHDL programs describe the generation of events in digital systems
- Discrete event simulator manages event ordering and progression of time
- Now we can quantitatively understand accuracy vs. time trade-offs
  - Greater detail → more events → greater accuracy
  - Less detail → smaller number of events → faster simulation speed

Synthesis and Hardware Inference



- Both processes can produce very different results!

Summary

- VHDL is used to describe digital systems and hence has language constructs for key attributes
  - Events, propagation delays, and concurrency
  - Timing, and waveforms
  - Signal values and use of multiple drivers for a signal
- VHDL has an underlying discrete event simulation model
  - Model the generation of events on signals
  - Built in mechanisms for managing events and the progression of time
  - Designer simply focuses on writing accurate descriptions