Datapath Components
Adders
- Adds two N-bit binary numbers
  - 2-bit adder: adds two 2-bit numbers, outputs 3-bit result
  - e.g., 01 + 11 = 100  (1 + 3 = 4)
- Can design using combinational logic design process, but doesn’t work well for reasonable-size N
  - Why not?

Digital Design
Chapter 4:
Datapath Components
http://www.ddvahid.com

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Why not use standard combinational design process
- Truth table too big
  - 2-bit adder’s truth table shown
    - Has 2^{2+2} = 16 rows
  - 8-bit adder: 2^{8+8} = 65,536 rows
  - 16-bit adder: 2^{16+16} = ~4 billion rows
  - 32-bit adder: ...
- Big truth table with numerous 1s/0s yields big logic
  - Plot shows number of transistors for N-bit adders, using state-of-the-art automated combinational design tool

How many of transistors are needed for a 16-bit adder?
Datapath Components
Alternative Method: Imitate Adding by Hand

- Alternative Adder Design Method
  - Mimic how people do addition by hand
  - One column at a time
    - Compute sum, add carry to next column

1   1   1   1
+   0   1   1
0   1   1   1

A: 1 1 1 1
B: 0 1 1 0

Step 1: Capture the function
Step 2: Convert to equations
Step 3: Create the circuit

Datapath Components
Half-Adder

- Half-adder: Adds 2 bits, generates sum and carry
- Design using combinational design process from Ch 2

Step 1: Capture the function
Step 2: Convert to equations
Step 3: Create the circuit

Datapath Components
Full-Adder

- Full-adder: Adds 3 bits, generates sum and carry
- Design using combinational design process from Ch 2

Step 1: Capture the function
Step 2: Convert to equations
Step 3: Create the circuit
Carry-Ripple Adder

Datapath Components

- Using half-adder and full-adders, we can build an adder that adds like we would by hand.
- Called a carry-ripple adder.

- 4-bit adder shown: Adds two 4-bit numbers, generates 5-bit output.
  - 5-bit output can be considered 4-bit “sum” plus 1-bit “carry out.”
  - Can easily build any size adder.

- Carry-ripple adder

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Carry-Ripple Adder’s Behavior

- Using full-adder instead of half-adder for first bit, we can include a “carry in” bit in the addition.

- Will be useful later when we connect smaller adders to form bigger adders.

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Correct answer appears after 4 FA delays.
Datapath Components

Cascading Adders

 Incrementer

- Counter design used incrementer
- Incrementer design
  - Could use carry-ripple adder with B input set to 00...001
  - But when adding 00...001 to another number, the leading 0’s obviously don’t need to be considered → so just two bits being added per column
  - Use half-adders (adds two bits) rather than full-adders (adds three bits)