Chapter 4

Datapath Components and tradeoffs
Chapters 4.1 - 4.8

Datapath components

- Datapath components are larger building blocks commonly used inside a CPU.
- The sequential datapath components include:
  - Registers with parallel load
  - Shift Registers
  - Rotate Registers
  - Multi-function Registers

Parallel Load Register

- Adds an additional signal called LOAD
- Selects between the current state or the data in.
- Uses a 2-to-1 Mux to select.

Shift Register

- Has a serial in and serial out signal.
- The amount of shift depends on the number of flip-flops.

Rotate Register

- Specialized Shift register where the output is feed back into the input.
- Need a way to initialize the register or select an external input.

Multi-function register

- A register with multiple inputs and operations.
- Controlled by select lines.
- Two select lines uses 4-to-1 Muxes.

Datapath components

- The combinational datapath components include:
  - Adders (subtractors)
  - Comparators
  - Multipliers
  - Arithmetic Logic Units (ALU)
  - Shifters

Adders

- Consider adding two 32-bit numbers. How many input signals? How many output signals?
- We need a better way to design a large adder. Consider adding two numbers column by column
- Design a circuit for a column addition.

Adders

- A Half Adder adds two inputs, A and B. It has two outputs, S and Cout.
- A Full Adder adds three inputs, A, B, and Cin. It has two outputs, S and Cout.
- Use the design process to design each circuit.

Adders

- Design a 4-bit adder using Full Adders.
- Consider how long it takes to add two 4-bit numbers. Use a propagation delay of 1 nS for an inverter, 2 nS for an OR gate and 3 nS for an AND gate.
- Calculate the maximum delay from any input to any output.
- What is the propagation delay of a 32-bit adder using 4-bit adder components?

Comparators

- Design a circuit that compares two 4-bit numbers for equality (Identity comparator).
- Design a Magnitude Comparator circuit using a carry-ripple style. Outputs A>B, A==B, and A<B signals.

Multiplication

- An MxN multiplier will have M + N output bits.
- Design a 4x4-bit multiplier

Subtraction

- How to represent a negative number
  - Signed magnitude
  - Complements
    - 1's complement
    - 2's complement

Subtraction

- Design a 4-bit Adder/Subtraction circuit
- Overflow detection.

ALU

- Arithmetic Logic Unit operations
  - Bitwise logic operartions
    - AND
    - OR
    - NOT
    - XOR
  - Add
  - Subtract
  - Other operations

Shifting

- N-bit shifter
- Shift left
- Shift right
- Arithmetic shift
- Circular shift (rotate)

Barrel Shifter

- 8-bit barrel shifter

Counters

- Counters increment (or decrement) the binary value by 1 each clock cycle.
- Use the design procedure to design a 4-bit counter.
- Counters have an extra output signal to indicate the count has reached its terminal count.
- Counters may have a Count Enable input signal.

Modulo Counter

- Design a 4-bit counter that counts to 9 and starts over at 0.

Ripple Counter

- A counter that can divide a clock frequency by 2, 4, 8, etc.

Register Files

- An array of registers.
- A register is selected using decoders and Muxes.
- May use Three State Buffers instead of a Mux.
- Acts like an array of memory