ESE535: Electronic Design Automation

Day 3: January 26, 2009

Scheduled Operator Sharing

Last Time

- How to construct a dataflow graph from a high-level language
  - From C

Today

- Sharing Resources
- Area-Time Tradeoffs
- Throughput vs. Latency
- VLIW Architectures

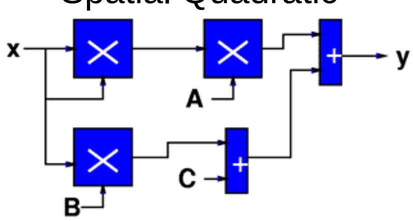
Compute Function

- Compute:

$$y=Ax^2 +Bx +C$$

- Assume
  - D(Mpy) > D(Add)
  - A(Mpy) > A(Add)

Spatial Quadratic



- A(Quad) = 3*A(Mpy) + 2*A(Add)

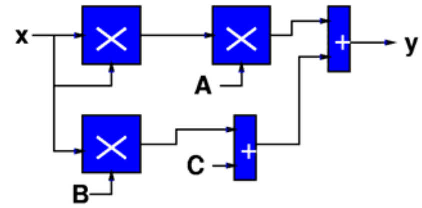
Latency vs. Throughput

- **Latency:** Delay from inputs to output(s)
- **Throughput:** Rate at which can introduce new set of inputs

Washer/Dryer Example

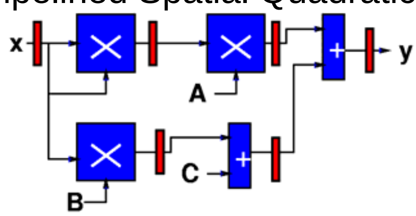
- 1 Washer Takes 30 minutes
- 1 Dryer Takes 45 minutes
- How long to do one load of wash?
  - → Wash latency
- How long to do 5 loads of wash?
- Wash Throughput?

Spatial Quadratic



- D(Quad) = 2*D(Mpy)+D(Add)
- Throughput 1/(2*D(Mpy)+D(Add))
- A(Quad) = 3*A(Mpy) + 2*A(Add)

Pipelined Spatial Quadratic



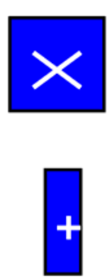
- D(Quad) = 3*D(Mpy)
- Throughput 1/D(Mpy)
- A(Quad) = 3*A(Mpy) + 2*A(Add)+6A(Reg)

Quadratic with Single Multiplier and Adder?

- We've seen reuse to perform the **same** operation
  - pipelining
- We can also reuse a resource in time to perform a different role.
  - Here: x*x, A*(x*x), B*x
  - also: (Bx)+c, (A*x*x)+(Bx+c)

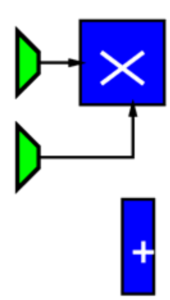
Quadratic Datapath

- Start with one of each operation



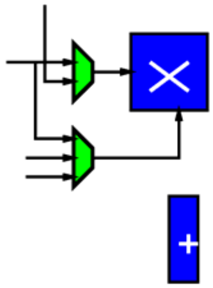
Quadratic Datapath

- Multiplier serves multiple roles
  - x*x
  - A*(x*x)
  - B*x
- Will need to be able to steer data (switch interconnections)



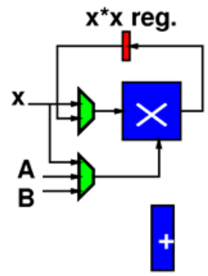
Quadratic Datapath

- Multiplier serves multiple roles
  - x*x
  - A*(x*x)
  - B*x
- x, x*x
- x,A,B



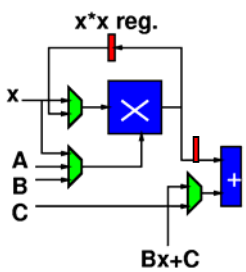
Quadratic Datapath

- Multiplier serves multiple roles
  - x*x
  - A*(x*x)
  - B*x
- x, x*x
- x,A,B

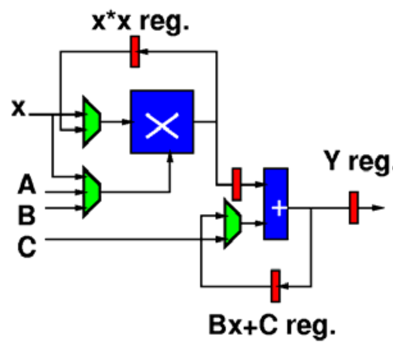


Quadratic Datapath

- Adder serves multiple roles
  - (Bx)+c
  - (A*x*x)+(Bx+c)
- one always mpy output
- C, Bx+C

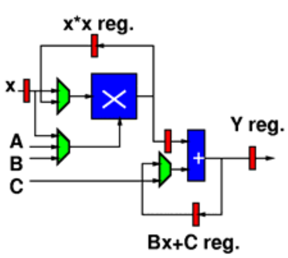


Quadratic Datapath



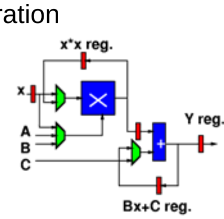
Quadratic Datapath

- Add input register for x



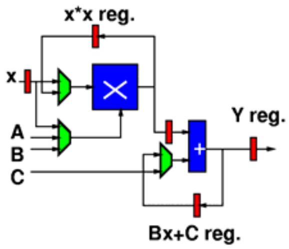
Cycle Impact?

- Add mux delay
- Register setup/hold time, clock skew
- Limited by slowest operation



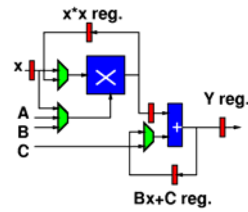
Quadratic Control

- Now, we just need to control the datapath
- What control?
- Control:
  - LD x
  - LD x*x
  - MA Select
  - MB Select
  - AB Select
  - LD Bx+C
  - LD Y



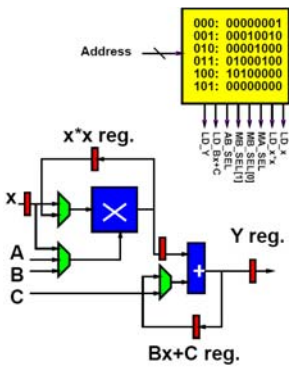
Quadratic Control

1. LD_X
2. MA_SEL=x,MB_SEL[1:0]=x, LD_x*x
3. MA_SEL=x,MB_SEL[1:0]=B
4. AB_SEL=C,MA_SEL=x*x, MB_SEL=A, LD_Bx+C
5. AB_SEL=Bx+C, LD_Y

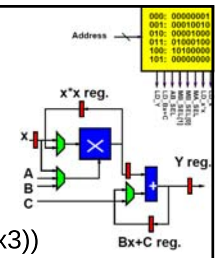


Quadratic Memory Control

1. LD_X
2. MA_SEL=x, MB_SEL[1:0]=x, LD_x*x
3. MA_SEL=x, MB_SEL[1:0]=B
4. AB_SEL=C, MA_SEL=x*x, MB_SEL=A, LD_Bx+C
5. AB_SEL=Bx+C, LD_Y



Quadratic Datapath



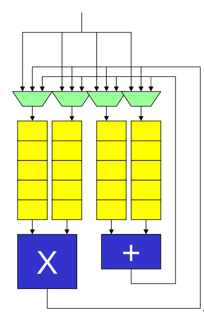
- Latency/Throughput/Area?
- Latency: 5*(D(MPY)+D(mux3))
- Throughput: 1/Latency
- Area: A(Mpy)+A(Add)+5*A(Reg) +2*A(Mux2)+A(Mux3)+A(Imem)

Registers→Memory

- Generally can see many registers
- If # registers >> physical operators
  - Only need to access a few at a time
- Group registers into memory banks

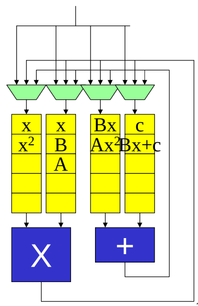
Memory Bank Quadratic

- Store x
- x*x
- B*x
- A*x^2; B*x+c
- (A*x^2)+(B*x+c)



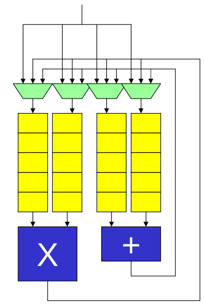
Memory Bank Quadratic

- Store x
- x*x
- B*x
- $A*x^2$; B*x+c
- $(A*x^2)+(B*x+c)$



Cycle Impact?

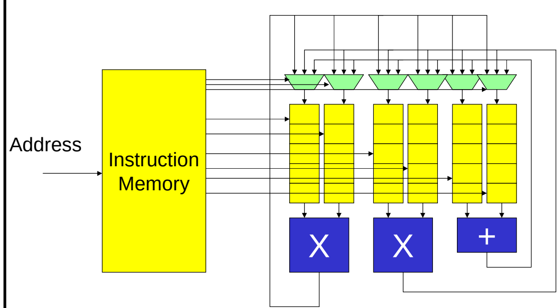
- Add mux delay
- Register setup/hold time, clock skew
- Memory read/write
  - Could pipeline
  - Impact?
    - Latency
    - Througput?
- Limited by slowest operation



VLIW

- Very Long Instruction Word
- Set of operators
  - Parameterize number, distribution
  - Gives rise to Area-Time tradeoff
    - More operators→ less time, more area
    - Fewer operators→ more time, less area
- Memories for intermediate state
- Memory for “long” instructions
- Schedule compute task
- General, potentially more expensive than customized
  - Wiring, memories get expensive
  - Opportunity for further optimizations

VLIW



Summary

- Reuse physical operators in time
- Share operators in different roles
- Allows us to reduce area at expense of increasing time
- Area-Time tradeoff
- Pay some sharing overhead
  - Muxes, memory
- VLIW – general formulation for shared datapaths

Admin

- Reading for Wednesday

Big Ideas:

- Scheduled Operator Sharing