Pipelining

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See: P&H Chapter 4.5
Alice

Bob

They don’t always get along...
The Bicycle
N pieces, each built following same sequence:

Saw → Drill → Glue → Paint
Alice owns the room
Bob can enter when Alice is finished
Repeat for remaining tasks
No possibility for conflicts
Can we do better?

Latency: $\frac{1}{4}$ hrs / task
Throughput: \task / $\frac{1}{4}$ hrs
Concurrency: \
Partition room into *stages of a pipeline*

One person owns a stage at a time
4 stages
4 people working simultaneously
Everyone moves right in lockstep
Pipelined Performance

Latency: 4 hrs/task
Throughput: 1 task/hr
Concurrency: 4 workers
Unequal Pipeline Stages

Latency: 5
Throughput: 1 task/min
Concurrency:
Latency: $4 \times 90 = 6$ hrs / test
Throughput: $1$ task / 90 min
Concurrency: $4$
Latency: 3 hrs / task
Throughput: 1 task / 90 min
Concurrency: 2 stages
Splitting Pipeline Stages

 Latency: 9.0 min/task
 Throughput: 1 task/15 min
 Concurrency: 4
Q: What if glue step of task 3 depends on output of task 1?

Latency:
Throughput:
Concurrency:
Principle:
Latencies can be masked by parallel execution

Pipelining:
• Identify *pipeline stages*
• Isolate stages from each other
• Resolve pipeline *hazards*
A Processor

- memory
- PC
- new pc
- inst
- +4
- offset
- target
- imm
- extend
- control
- equal?
- cmp
- alu
- addr
- do
- dm
- mem
- out
- control
- new pc
- offset
- target
- imm
- extend
- alu
- equal?
- cmp
- control
- new pc
Five stage “RISC” load-store architecture

1. Instruction fetch (IF)
   - get instruction from memory, increment PC

2. Instruction Decode (ID)
   - translate opcode into control signals and read registers

3. Execute (EX)
   - perform ALU operation, compute jump/branch targets

4. Memory (MEM)
   - access memory if needed

5. Writeback (WB)
   - update register file

Slides thanks to Sally McKee & Kavita Bala
Break instructions across multiple clock cycles (five, in this case)

Design a separate stage for the execution performed during each clock cycle

Add pipeline registers to isolate signals between different stages