COS 126 Lecture 13: Computer architecture

Levels of abstraction

- raw materials
- transistors
- AND, OR, and NOT gates
- boolean circuits
  - Adder
- sequential circuits
  - registers, counter
  - memory
- control signals
- COMPUTER

physical clock

FETCH–INCREMENT–EXECUTE

Building blocks

Transistor

AND, OR, NOT gates

Adder

Multiplexer (decoder)

Flip-flop

Register

Memory cell

Memory

Counter

CONTROL LINES

Clock

Register Transfer

Wire registers together

- output of one to input of the next
- one wire per bit

To move information

- sequentially turn control lines on, off

Same method moves information

- to and from memory
- to and from arithmetic circuits

Register Selection

Boolean selection circuit

s selects x

t selects y

Register selection

S, then LOAD: contents of X to Z

T, then LOAD: contents of Y to Z

Basic Machine Organization

Memory and registers, interconnected
(not all connections shown)

Two types of wires
- data: connect registers (copy signals)
- control: enable connections

Control

Sequences of control signals "move" information

Ex: 20: 9235 (Load R2 with the word at loc 35)

```
     step  control signal        result
.  0  switch PC--MAR
.  1  LOAD MAR                   PC (20) -> MAR
.  2  main memory R              mem[20] -> MRR
.  3  select MRR-->IR
.  4  LOAD IR                    MRR -> IR
.  5  INCPC
.  6  select IR-->MAR
.  7  LOAD MAR                   IR (35) -> MAR
.  8  main memory R              mem[35] -> MRR
.  9  select MRR-->RWR
. 10  LOAD RWR                   MRR (mem[35]) -> RWR
. 11  select IR0-->RAR
. 12  LOAD RAR                   r0 (2) -> RAR
. 13  reg. memory W              RWR (mem[35]) -> reg[2]
```

Control signal sequence for each instruction
- load, store: main memory, reg. memory
- arithmetic insts: reg. memory, ALU
- jump instructions: PC

MICROPROGRAM: sequence of control signals

Final Step

Q: How can sequence of control signals
be made to happen?
A: Feed counter and op code into decoders

Counter automatically cycles
- each tick raises a control signal
- opcode selects relevant signal
- FETCH-INCREMENT-EXECUTE

Crucial distinctions
- clock: externally generated periodic pulse
- counter: micro control
  - incremented by clock pulse
- PC: just a register
  - incremented by control pulse

Summary

Many details omitted

most important: slim margin for error

Computer constructed by layering abstractions

better implementation at low levels

improves *everything*

Therefore, ongoing search for better switch!

- Babbage
  - mechanical switches
- 1940s
  - relays, vacuum tubes
- 1950s
  - transistor, core memory
- 1960s
  - integrated circuit
- 1970s
  - microprocessor
- 1980s
  - VLSI
- 1990s
  - integrated systems, parallelism

Future?

- new switch technologies
- quantum computing (not switch-based!)
- DNA computing
- [stay tuned!]