Building Computers: Fetch-Decode-Execute

CS 2130: Computer Systems and Organization 1

September 16, 2022

Announcements

- Homework 2 due on Gradescope, 11pm Monday
- Quiz 3 available at 5pm, due Monday at 8am
  - 24-hours to complete once opened
  - Do **not** submit until you are finished (you should save!)

Code to Build Circuits from Gates

Write code to build circuits from gates

- Gates we *already* know: `&`, `|`, `^`, `~`
- Operations we can build from gates: `+`, `-`
- Others we can build: `*`, `/`, `%`
- Ternary operator: `?` `:`

Equals

Equals: `=`

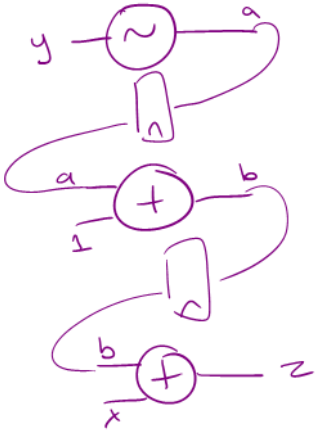
- Attach with a wire (i.e., connect things)
- Ex: `z = x * y`
- **Single assignment**: each variable can only be assigned a value once

Comparison operators

- `==` - xor then nor bits of output
- `!=` - same as `==` without not of output
- `<` - consider `x < 0`
- `>`, `<=`, `=>` are similar

Subtraction

```
a = ~y
b = a + 1
z = x + b
```



Indexing

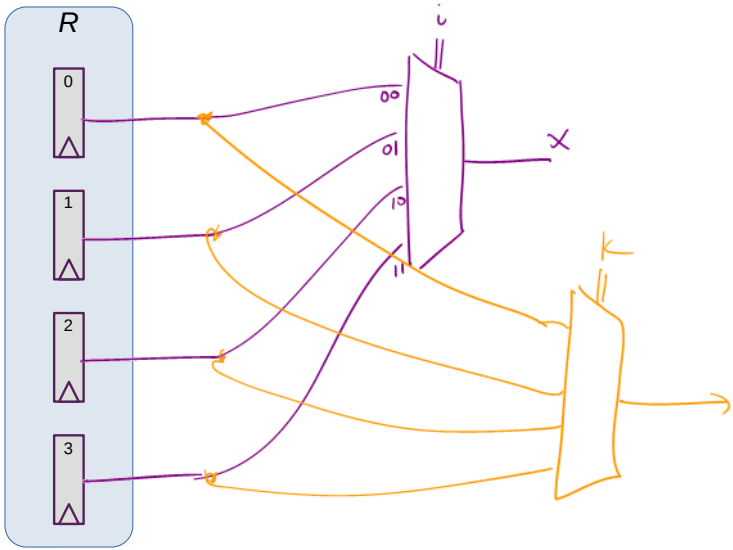
Indexing with square brackets: `[ ]`

- **Register bank** (or **register file**) - an array of registers
  - Can programmatically pick one based on index
  - I.e., can determine which register while running
- Two important operations:
  `x = R[i]` - Read from a register
  `R[j] = y` - Write to a register

R[z]

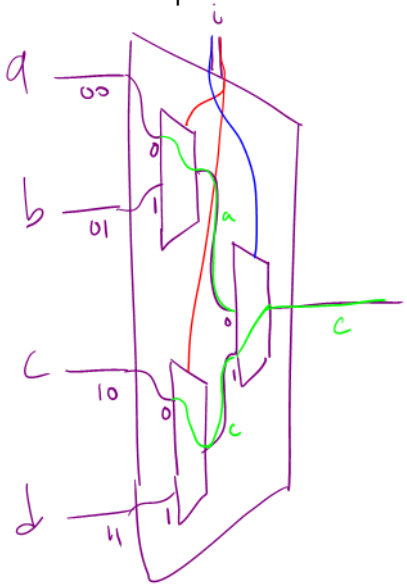
Reading

`x = R[i]` - connect output of registers to *x* based on index *i*



Aside: 4-input Mux

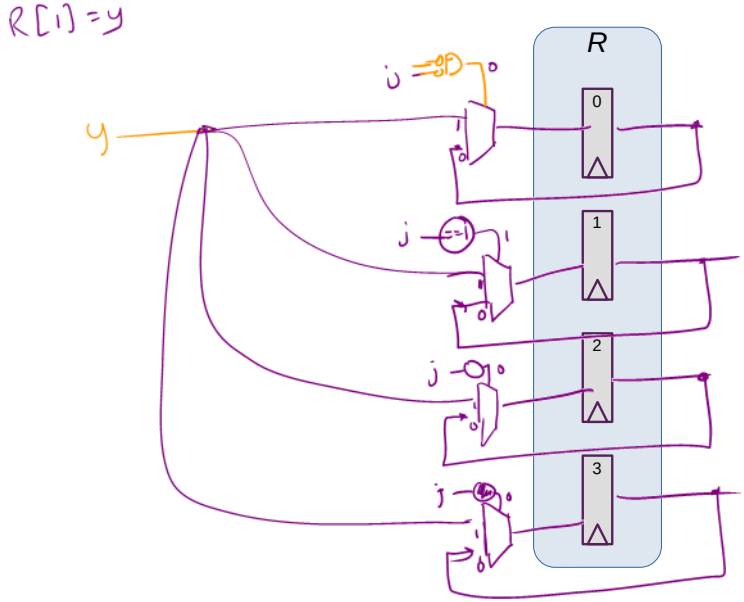
How do we build a 4-input mux? How many wires should *i* be?



$i = 10$

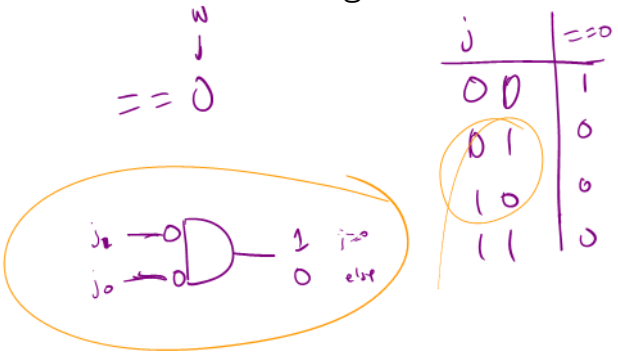
Writing

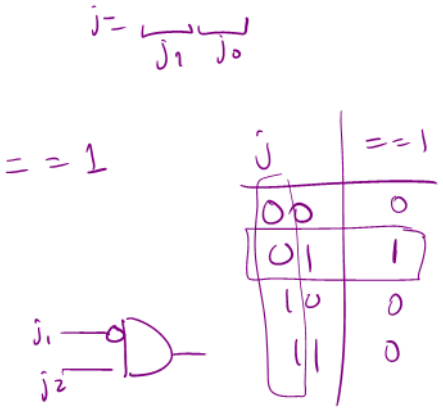
`R[j] = y` - connect *y* to input of registers based on index *j*



Aside: Creating ==0 gates

How do we build gates that check for $j == w$?





Need one more thing to build computers

Memory and Storage

Registers ≈ KiB

- 6 gates each, ≈ 24 transistors
- Efficient, fast
- Expensive!
- Ex: local variables

Memory NVRAM ≈ GiB

- Two main types: SRAM, DRAM
- DRAM: 1 transistor, 1 capacitor per bit
- DRAM is cheaper, simpler to build
- Ex: data structures, local variables

These do not persist between power cycles

Memory and Storage

Disk ≈ GiB-TiB

- Two main types: flash (solid state), magnetic disk
- Magnetic drive
  - Platter with physical arm above and below
  - Cheap to build
  - Very slow! Physically move arm while disk spins

- Ex: files

Data on disk does persist between power cycles

Putting it all together

Code

How do we run code? What do we need?

Example Code

```
…
8:   x = 16
9:   y = x
10:  x += y
…
```

What is the value of *x* after line 10?

Bookkeeping

What do we need to keep track of?

- **Code** - the program we are running
  - RAM (Random Access Memory)
- **State** - things that may change value (i.e., variables)
  - Register file - can read and write values each cycle
- **Program Counter (PC)** - were we are in our code
  - Single register - byte number in memory for next instruction

Building a Computer

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