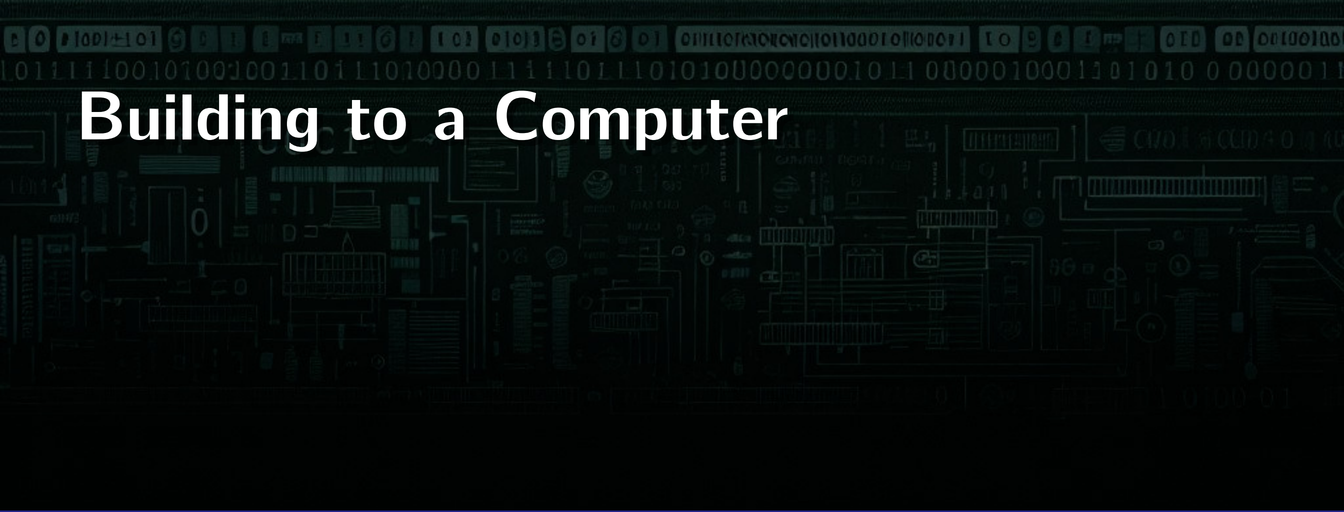
# Building to a Computer



CS 2130: Computer Systems and Organization 1
September 17, 2025

# Announcements

- Homework 2 due Monday
- Office hours most days!

# 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:

# 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`

# Equals

Equals: =

- Attach with a wire (i.e., connect things)
- Ex: `z = x * y`
- What about the following?

```
x = 1
x = 0
```

# Equals

Equals: =

- Attach with a wire (i.e., connect things)
- Ex: `z = x * y`
- What about the following?
  ```
  x = 1
  x = 0
  ```
- **Single assignment**: each variable can only be assigned a value once

# Subtraction

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

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

# Comparisons

Each of our comparisons in code are straightforward to build:

- == - xor then nor bits of output

# Comparisons

Each of our comparisons in code are straightforward to build:

- == - xor then nor bits of output
- != - same as == without not of output

# Comparisons

Each of our comparisons in code are straightforward to build:

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

# Comparisons

Each of our comparisons in code are straightforward to build:

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

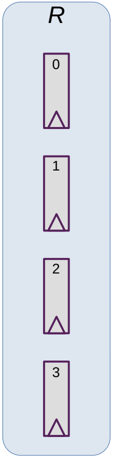
# Indexing

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

# Reading

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

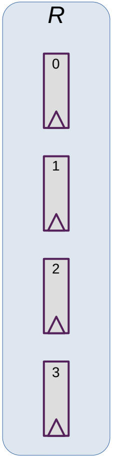


# Aside: 4-input Mux

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

# 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 $\approx$ KiB

- 6 gates each, $\approx$ 24 transistors
- Efficient, fast
- Expensive!
- Ex: local variables

*These do not persist between power cycles*

# Memory and Storage

Memory $\approx$ 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

# Our story so far

- Information modeled by voltage through wires (1 vs 0)
- Transistors
- Gates: & | ~ ^
- Multi-bit values: representing integers, floating point numbers
- Multi-bit operations using circuits
- Storing results using registers, clocks
- Memory

# Code

How do we run code? What do we need?

Consider the following code:

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

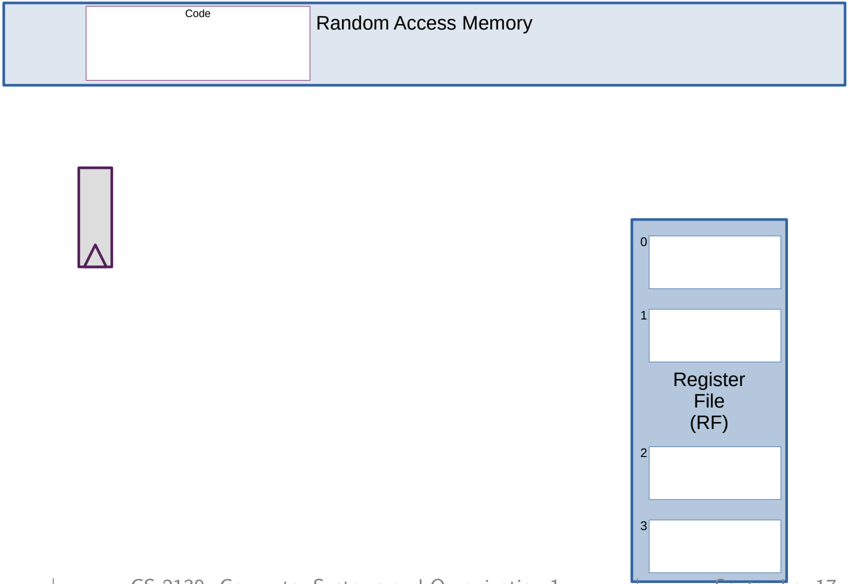
What is the value of *x* after line 10?

# 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)** - where we are in our code
  - Single register - byte number in memory for next instruction

# Building a Computer

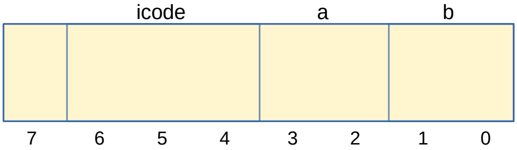


# Encoding Instructions

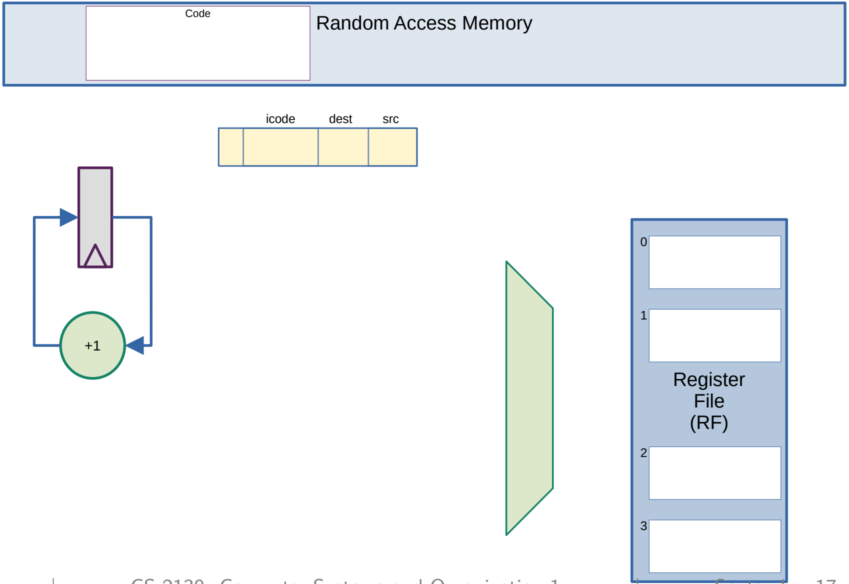
Encoding of Instructions (**icode** or **opcode**)

- Numeric mapping from icode to operation

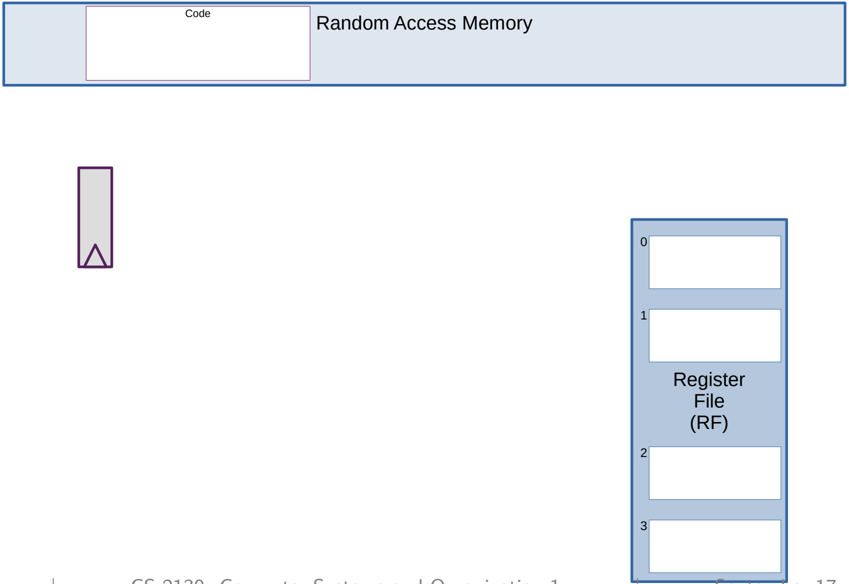
| icode | meaning |
|---|---|
| 0 | `rA = rB` |
| 1 | `rA &= rB` |
| 2 | `rA += rB` |
| ... | ... |



# Building a Computer



# Building a Computer


Code
Random Access Memory
0
1
Register
File
(RF)
2
3