Writing Code

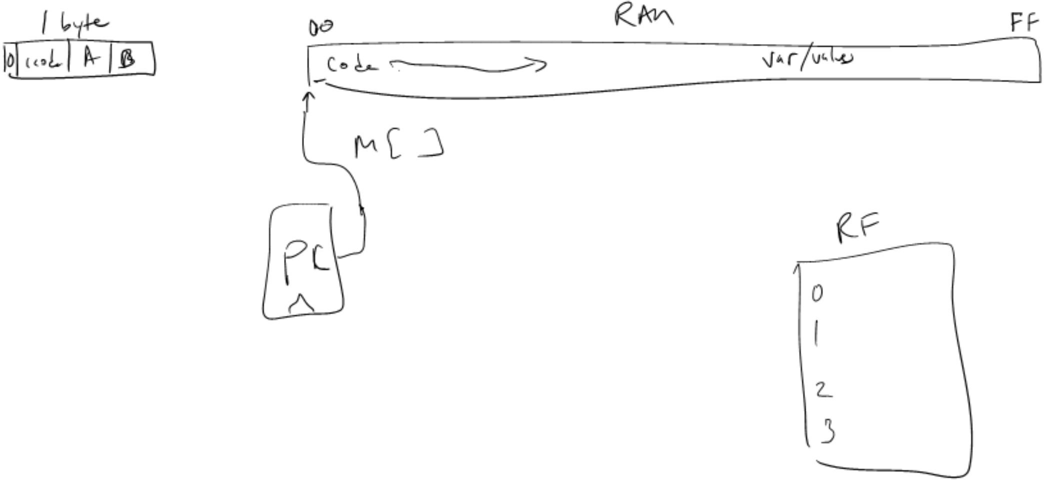
CS 2130: Computer Systems and Organization 1

September 21, 2022

Announcements

- Homework 3 due Monday at 11pm on Gradescope
- Exam 1 next Friday (in class)

Our CS2130 Machine



High-level Instructions

In general, 3 kinds of instructions

- **moves** - move values around without doing “work”
- **math** - broadly doing “work”
- **jumps** - jump to a new place in the code

Moves

Few forms

r0 = r1

- Register to register (icode 0), `x = y`
- Register to/from memory (icodes 3-4), `x = M[b]`, `M[b] = x`

Memory

- **Address**: an index into memory.
  - Addresses are just (large) numbers
  - Usually we will not look at the number and trust it exists and is stored in a register

Moves

Example 3-bit icode

icode	b	action
0		`rA = rB`
3		`rA` = read from memory at address `rB` rA = M[rB]
4		write `rA` to memory at address `rB` M[rB] = rA
5	3	`rA = pc`
6	0	`rA` = read from memory at `pc + 1`
	3	`rA` = read from memory at the address stored at `pc + 1`

Math

Broadly doing work

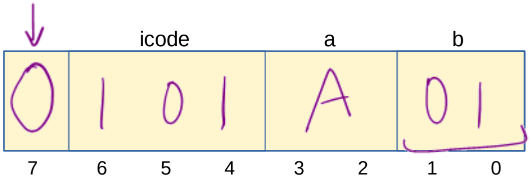
Example 3-bit icode

icode	b	meaning
1		`rA += rB`
2		`rA &= rB`
5	0	`rA = ~rA`
	1	`rA = -rA`
	2	`rA = !rA`
6	1	`rA` += read from memory at `pc + 1`
	2	`rA` &= read from memory at `pc + 1`

Note: We can implement other operations using these things!

icodes 5 and 6

Special property of icodes 5-6: only one register used

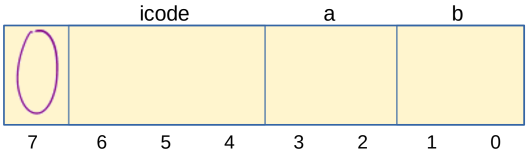


Example 3-bit icode

icode	b	action
5	0	`rA = ~rA`
	1	`rA = -rA`
	2	`rA = !rA`
	3	`rA = pc`

icodes 5 and 6

Special property of 5-6: only one register used



- Side effect: all bytes between 0 and 127 are valid instructions!
- As long as high-order bit is 0
- No syntax errors, any instruction given is valid

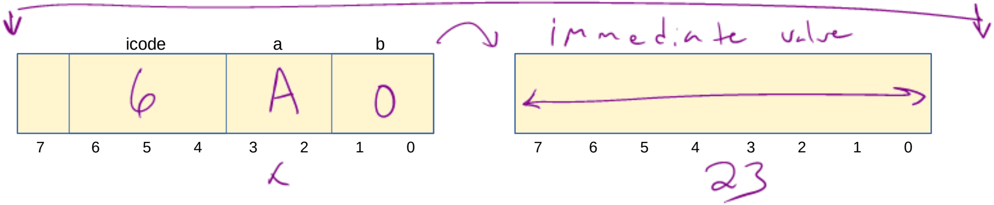
Immediate values

icode 6 provides literals, **immediate** values

x = 23

Example 3-bit icode

icode	b	action
6	0	`rA` = read from memory at `pc + 1`
	1	`rA` += read from memory at `pc + 1`
	2	`rA` &= read from memory at `pc + 1`
	3	`rA` = read from memory at the address stored at `pc + 1`
		For icode 6, increase pc by 2 at end of instruction



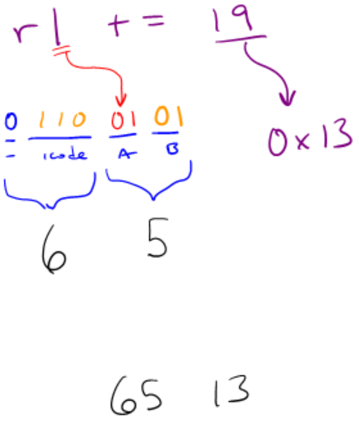
Encoding Instructions

Example 1: `r1 += 19`

Instructions

icode	b	meaning
0		`rA = rB`
1		`rA += rB`
2		`rA &= rB`
3		`rA` = read from memory at address `rB`
4		write `rA` to memory at address `rB`
5	0	`rA = ~rA`
	1	`rA = -rA`
	2	`rA = !rA`
	3	`rA = pc`
6	0	`rA` = read from memory at `pc + 1`
	1	`rA` += read from memory at `pc + 1`
	2	`rA` &= read from memory at `pc + 1`
	3	`rA` = read from memory at the address stored at `pc + 1`
		For icode 6, increase `pc` by 2 at end of instruction

7		Compare `rA` as 8-bit 2's-complement to `0`
		if `rA <= 0` set `pc = rB`
		else increment `pc` as normal



Encoding Instructions

Example 2: `M[0x82] += r3`

Read memory at address `0x82`, add `r3`, write back to memory at same address

Instructions

icode	b	meaning
0		`rA = rB`
1		`rA += rB`
2		`rA &= rB`
3		`rA` = read from memory at address `rB`
4		write `rA` to memory at address `rB`
5	0	`rA = ~rA`
	1	`rA = -rA`
	2	`rA = !rA`
	3	`rA = pc`
6	0	`rA` = read from memory at `pc + 1`
	1	`rA` += read from memory at `pc + 1`
	2	`rA` &= read from memory at `pc + 1`
	3	`rA` = read from memory at the address stored at `pc + 1`
		For icode 6, increase `pc` by 2 at end of instruction
7		Compare `rA` as 8-bit 2's-complement to `0`
		if `rA <= 0` set `pc = rB`
		else increment `pc` as normal

M[x82] += r3

r_0 = 0x82

r_1 = M[r_0]

r_1 += r3

M[r_0) = r_1

0

6 00 00

60 82

3 01 00

34

1 01 11

17

4 01 00

44

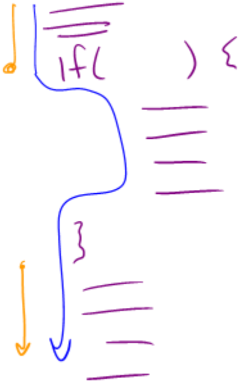
60 82 34 17 44

Jumps

- Moves and math are large portion of our code
- We also need **control constructs**
    - Change what we are going to do next
    - `if`, `while`, `for`, functions, ...
- Jumps provide mechanism to perform these control constructs
- We jump by assigning a new value to the program counter PC

Jumps

For example, consider an `if`



Jumps

Example 3-bit icode

icode	meaning

7	Compare `rA` as 8-bit 2's-complement to `0`
	if `rA <= 0` set `pc = rB`
	else increment `pc` as normal

Instruction icode 7 provides a **conditional** jump

- Real code will also provide an **unconditional** jump, but a conditional jump is sufficient

Writing Code

We can now write any* program!

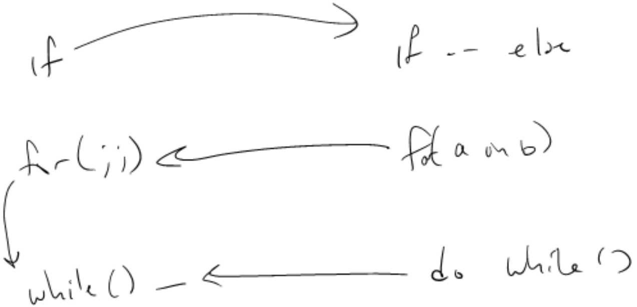
- When you run code, it is being turned into instructions like ours
- Modern computers use a larger pool of instructions than we have (we will get there)

*we do have some limitations, since we can only represent 8-bit values and some operations may be tedious.

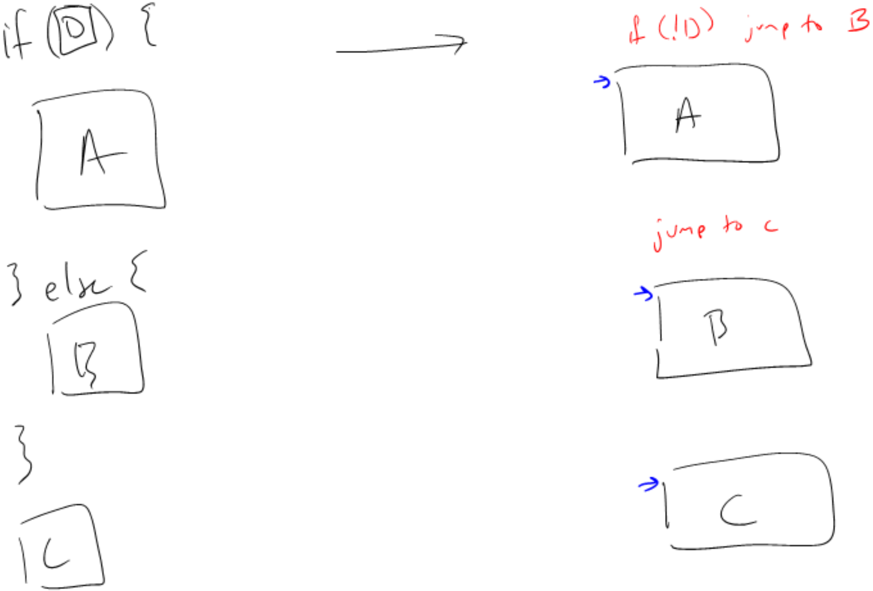
Our code to this machine code

How do we turn our control constructs into jump statements?

```
for(int i=0; i<5; i++){

}

i=0
while(i<5){

    i++
}
```



if/else to jump



while to jump

Function Calls

Encoding Instructions

Example 3: `if r0 < 9 jump to 0x42`

Instructions

icode	b	meaning
0		`rA = rB`
1		`rA += rB`
2		`rA &= rB`
3		`rA` = read from memory at address `rB`
4		write `rA` to memory at address `rB`
5	0	`rA = ~rA`
	1	`rA = -rA`
	2	`rA = !rA`
	3	`rA = pc`
6	0	`rA` = read from memory at `pc + 1`
	1	`rA` += read from memory at `pc + 1`
	2	`rA` &= read from memory at `pc + 1`
	3	`rA` = read from memory at the address stored at `pc + 1`
		For icode 6, increase `pc` by 2 at end of instruction
7		Compare `rA` as 8-bit 2's-complement to `0`
		if `rA <= 0` set `pc = rB`
		else increment `pc` as normal

Questions on Multiply

Encoding Instructions

Example 4: `a <<= b`