Toy Instruction Set Architecture

aka Writing Programs for our computer

CS 2130: Computer Systems and Organization 1
February 11, 2026

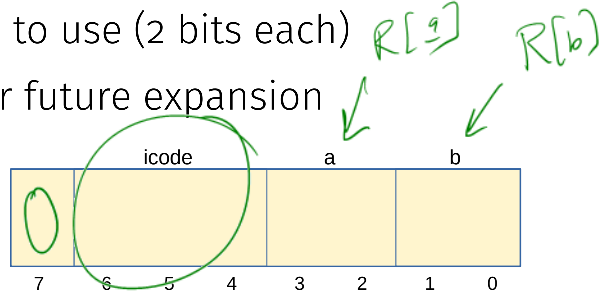
Announcements

- Homework 3 due Monday on Gradescope
- Midterm 1 next Friday (February 20) in class
  - Written, closed notes
  - If you have SDAC, please schedule ASAP

Encoding Instructions

Encoding of Instructions

- 3-bit icode (which operation to perform)
  - Numeric mapping from icode to operation
- Which registers to use (2 bits each)
- Reserved bit for future expansion



Toy ISA Instructions

icode	b	meaning
0		`rA = rB`
1		`rA &= rB`
2		`rA += rB`
3	0	`rA = ~rA`
	1	`rA = !rA`
	2	`rA = -rA`
	3	`rA = pc`
4		`rA` = read from memory at address `rB`
5		write `rA` to memory at address `rB`
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

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

R[a] = R[b]

b = 2 bits

R[b] = 8 bits

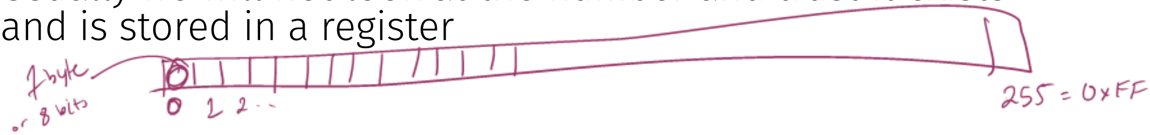
- Register to register (icode 0), `x = y`
- Register to/from memory (icodes 4-5), ~~`x = M[b], M[b] = z`~~

R[a] = M[R[b]]

M[R[b]] = R[a]

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

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

Math

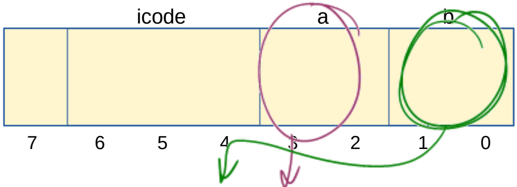
Broadly doing work

icode	b	meaning
1		`rA &= rB`
2		`rA += rB`
3	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 3 and 6

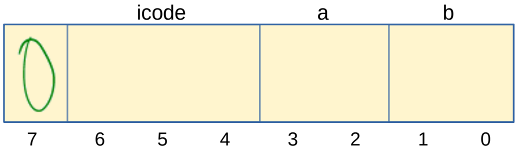
Special property of icodes 3 & 6: only one register used



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

icodes 3 and 6

Special property of 3 & 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

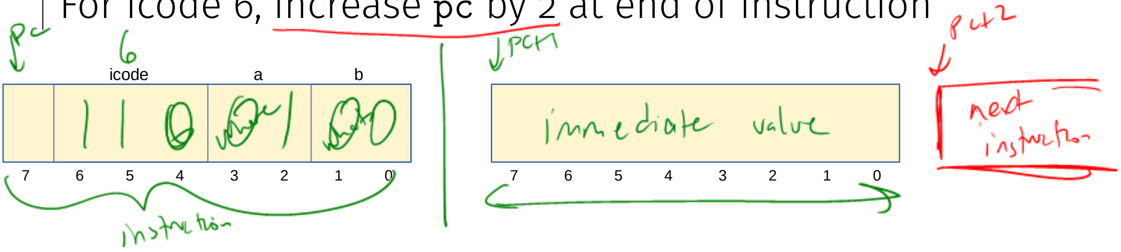
icode 6 provides literals, **immediate** values

x = 25

int y = 3;

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

R[A] = M[M[pc+1]]



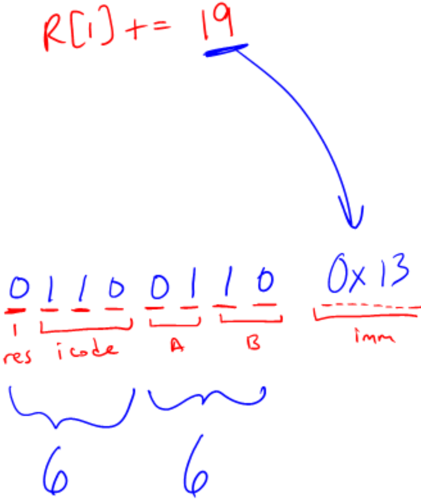
Encoding Instructions

Example 1: `r1 += 19`

Instructions

icode	b	meaning
0		`rA = rB`
1		`rA &= rB`
2		`rA += rB`
3	0	`rA = ~rA`
	1	`rA = !rA`
	2	`rA = -rA`
	3	`rA = pc`
4		`rA` = read from memory at address `rB`
5		write `rA` to memory at address `rB`
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



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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	0	`rA = ~rA`
	1	`rA = !rA`
	2	`rA = -rA`
	3	`rA = pc`
4		`rA` = read from memory at address `rB`
5		write `rA` to memory at address `rB`
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

Writing Code: Homework Hints

1. Write pseudocode that does the desired task

2-3 … deal with control flow

4. Split multi-operation lines into series of single-operation lines
   `x = y-z;` becomes `x = y; x -= z;`

5. Convert operations to those in our instruction set
   `x -= z;` becomes `w = z; w = -w; x += w;`

6. … deal with loops

7. Assign variables to our four registers, ex: `r0=x`, `r1=y`, `r2=z`, `r3=w`
   `r0 = r1; r3 = r2; r3 = -r3; r0 += r3`

10- Write those instructions into triples, then hex