x86-64 Assembly

CS 2130: Computer Systems and Organization 1

March 13, 2023

Announcements

- Homework 5 available, due next Monday at 11pm on Gradescope
- Updated extension policy available on the website
- Results from regrade requests should be available by next week
- No Prof. Hott office hours this week!
- Lab tomorrow: using the lldb debugger

Assembly

General principle of all **assembly languages**

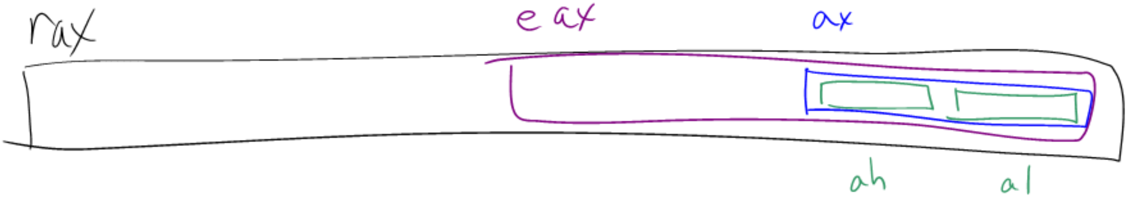
- Code (text, not binary!)
- 1 line of code = 1 machine instruction
- One-to-one reversible mapping between binary and assembly
    - We do not need to remember binary encodings!
    - A program will turn text to binary for us!

AT&T x86-84 Assembly

- `instruction source, destination`
  - Instruction followed by 0 or more operands (arguments)
- `mylabelname:`
  - Label - remember the address of next thing to use later
- `.something something`
  - Metadirective - extra information that is not code
- `// comments!`
- Address Calculations: `2130(%rax, %rsp, 8)`
  - Combines as: `2130 + %rax + (%rsp * 8)`
  - This is all one operand (one memory address)

Registers

`rax` is a 64-bit register



Instructions

Instructions have different versions depending on number of bits to use

- `movq` - 64-bit move
  - `q` = quad word
- `movl` - 32-bit move
  - `l` = long
- There are encodings for shorter things, but we will mostly see 32- and 64-bit

More powerful than our ISA

Instructions can move/operate between memory and register

- `movq %rax, %rcx` - register to register
  - Remember our icode 0
- `movq (%rax), %rcx` - memory to register
  - Remember our icode 3
- `movq %rax, (%rcx)` - register to memory
  - Remember our icode 4
- `movq $21, %rax` - Immediate to register
  - Remember our icode 6 (b=0)

Note: at most one memory address per instruction

Other Instructions

Other instructions work the same way

- `addq %rax, %rcx` — rcx += rax
- `subq (%rbx), %rax` — rax -= M[rbx]
- xor, and, and others work the same way!
- Assembly has virtually no 3-argument instructions
  - All will be modifying something (i.e., `+=`, `&=`, ...)

Load effective address: `leaq 4(%rcx), %rax`

- Performs memory address calculation
- Stores address, not value at the address in memory

Jumps

`jmp foo`

- Unconditional jump to `foo`
- `foo` is a label or memory address
- Need `jmp*` to use register value

Conditional jumps

- `jl`, `jle`, `je`, `jne`, `jg`, `jge`, `ja`, `jb`, `js`, `jo`

Unlike our Toy ISA, these do not compare given register to 0

Jumps

Condition codes - 4 1-bit registers set by every math operation, `cmp`, and `test`

- Result for the operation compared to 0 (if no overflow)
- Example:

```
addq $-5, %rax
// ...code that doesn't set condition codes...
je foo
```

  - Sets condition codes from doing math (subtract 5 from rax)
  - Tells whether result was positive, negative, 0, if there was overflow, ...
  - Then jump if the result of that operation should have been = 0

Jumps: compare and test

`cmpq %rax, %rdx`   %rdx -= %rax

- Compare checks result of `-=` and sets condition codes
- How `rdx - rax` compares with 0
- Be aware of ordering!
  - if `rax` is bigger, sets < flag
  - if `rdx` is bigger, sets > flag

`testq %rax, %rdx`

- Sets the condition codes based on `rdx & rax`
- Less common

Neither save their result, just set condition codes!

Function Calls: Calling Conventions

`callq myfun`

- Push return address, then jump to myfun
- Convention: Store arguments in registers and stack before call
  - First 6 arguments (in order): `rdi`, `rsi`, `rdx`, `rcx`, `r8`, `r9`
  - If more arguments, pushed onto stack (last to first)

`retq`

- Pop return address from stack and jump back
- Convention: store return value in `rax` before calling `retq`

This is similar to our Toy ISA's function calls in homework 4

Debugger

Debugger - step through code!

- Similar experience to our ToyISA simulators
- You will be using `lldb` for lab tomorrow
- Experience seeing results of these instructions step-by-step
- **Please read the x86-64 summary reading before lab!**

example with lldb