x86-64 Assembly

CS 2130: Computer Systems and Organization 1
March 9, 2026

Announcements

- Homework 4 due tonight on Gradescope
- Homework 5 available soon, **due Monday at 11:59pm** on Gradescope
- Prof Hott office hour updates!
  - Rice 401 (no longer in 210)
  - Tuesdays 9-10am (earlier!)
  - This week only: No Weds hours, Thurs 10-11am

Rules

Rules to break "big values" into bytes (memory)

1. Break it into bytes
2. Store them adjacently
3. Address of the overall value = smallest address of its bytes
4. Order the bytes
    - If parts are ordered (i.e., array), first goes in smallest address
    - Else, hardware implementation gets to pick (!!)
        - Little-endian
        - Big-endian

Ordering Values

Little-endian

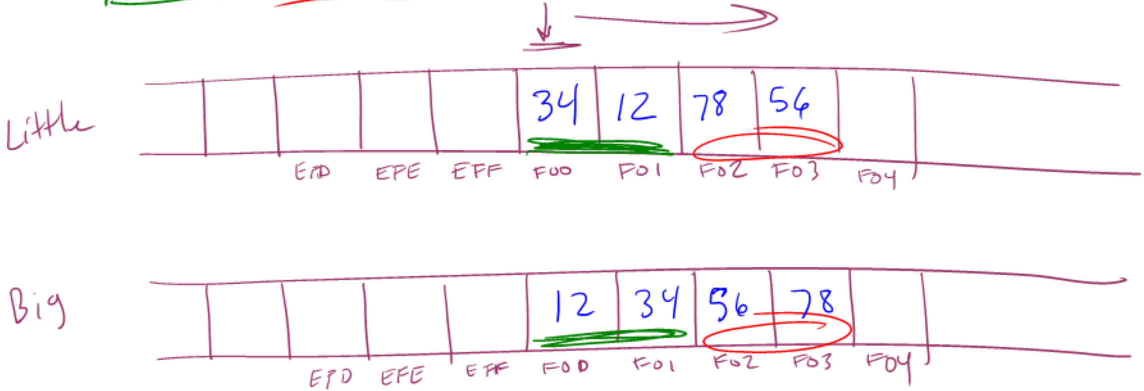
- Store the low order part/byte first
- Most hardware today is little-endian

Big-endian

- Store the high order part/byte first

Example

Store `[0x1234, 0x5678]` at address `0xF00`



Endianness

Why do we study endianness?

- It is **everywhere**
- It is a source of weird bugs
- Ex: It's likely your computer uses:
  - Little-endian from CPU to memory
  - Big-endian from CPU to network
  - File formats are roughly half and half

Moving up!

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!

Assembly

Features of assembly

- Automatic addresses - use **labels** to keep track of addresses
  - Assembler will remember location of labels and use where appropriate
  - Labels will not exist in machine code
- Metadata - data about data
  - Data that helps turn assembly into code the machine can use
- As complicated as machine instructions
  - There are a lot of instructions, and it is one-to-one!

Assembly Languages

There are many assembly languages

- But, they're backed by hardware!
- Two big ones these days: x86-64 and ARM
    - You likely have machines that use one of these
- Others: RISC-V, MIPS, ...

We will focus on **x86-64**

x86-64

x86-64 has a weird and long history

- Expansion of the 8086 series (Intel)
    - 8086, 8286, 8386, 8486, x86
- AMD expanded it with AMD64
- Intel decide to use same build, but called it x86-64
- Backwards compatible with the 8086 series

x86-64

Two dialects - two ways to write the same thing

- Intel - likely using with Windows
  ```
  mov QWORD PTR [rdx+0x227],rax
  ```
- AT&T - likely using with anything else
  ```
  movq %rax,0x227(%rdx)
  ```

We will use AT&T dialect

AT&T x86-84 Assembly

```
instruction source, destination
```

- Instruction followed by `0` or more operands (arguments)
- 4 types of operands:
  - Number (immediate value): `$0x123`
  - Register: `%rax`
  - lea — Address of memory: `(%rax)` or 24 or `labelname`
  - Value at an address in memory: `(%rax)` or 24 or `labelname`

AT&T x86-84 Assembly

```
mylabelname:
```

- Label - remember the address of next thing to use later

```
.something something
```

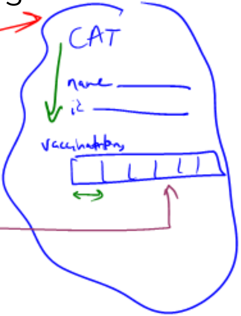
- Metadirective - extra information that is not code
- How the code works with other things (i.e., talk to OS)
- Ex: `.globl main`

```
// we can have comments!
```

Addressing Memory

`2130(%rax, %rsp, 8)`

- Address can have up to 4 parts: 2 numbers, 2 registers
- Combines as: `2130 + %rax + (%rsp * 8)`
- Common usage from this example:
  - `rax` - address of an object in memory
  - `2130` - offset of an array into the object
  - `rsp` - index into the array
  - `8` - size of the values in the array



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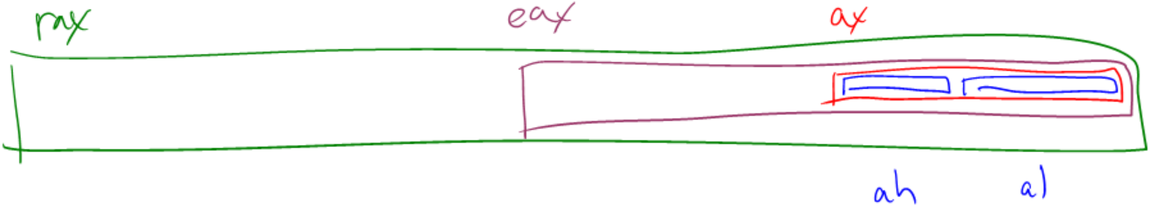
- Don't need all parts: `(%rax)` or `(%rax, 4)` or `4(%rax)`
- This is all one operand (one memory address)

hello.s example

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., +=, &=, …)