Assembly Language (Machine Programming) Introduction

- Learning Objectives
  - Explain what assembly language is
  - Define
    - Registers
    - Instruction
    - Operands
  - Produce assembly from C
  - Figure out how the following are expressed in assembly
    - Arithmetic operations
    - Logical operations
  - Figure out how arguments are passed to functions

What is assembly?

- Yet another layer of abstraction!
- When you strip away C, the assembly language is a human readable representation that more closely matches the hardware.
- Typically each assembly instruction corresponds to a machine instruction.
- Assembly doesn't really manipulate variables; it expresses computation in terms of:
  - Registers
  - Memory
  - Instructions

A Note on our Assembly

- We are using Intel x86-64.
  - This means that we are using Intel's 64-bit architecture
- The 3rd edition of the book uses this architecture in most sections, but still has some remnants of the 32-bit architecture in places.
- *The 2nd edition of the book uses Intel's 32-bit architecture.*
- The two are quite similar, but you want to be sure to understand the 64-bit architecture.
- Three ways to see assembly output:
  - cc –S x.c
  - objdump –d x.o
  - In gdb: disas(semble) <address>

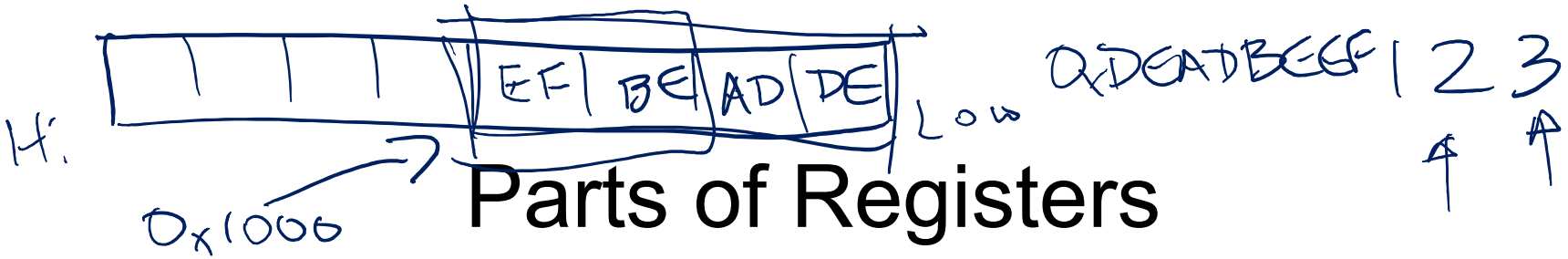
Screen Capture

Example

```
        .file   “f00.c"
        .text
        .globl  f
        .type   f,@function
f:
.LFB0:
        rep ret
.LFE0:
        .size   f, .-f
        .ident  ”GCC: (Ubuntu 4.8.4-2ubuntu1~14.04.3”) 4.8.4”
        .section        .note.GNU-stack,"",@progbits
```

Registers

- Registers are fast memory in the processor.
  - Processors execute many instructions in a single cycle; accessing memory can take 10s or 100s of cycles; placing data in registers allows the processor to execute things more quickly.
  - Most processors have a few tens of registers.
  - The Intel x86-64 has 16 64-bit general purpose registers:
    - %rax, %rbx, %rcx, %rdx, %rbp, %rsi, %rdi, %rsp, %r8-%r15
    - Some conventions for how some of the registers are used.
    - For example:
      - %rbp is the frame pointer
      - %rax is used to return values from procedure calls
      - %rdi, %rsi, %rdx, %rcx, %r8, %r9 are used to pass argument to procedures



Parts of Registers

- In assembly language, we don't really have types like we do in C, but we do operate upon data in different sized units:
  - Double Quad word: 128 bits
  - Quad word: 64 bits (q: 8 bytes)
  - Double word: 32 bits (l: 4 bytes)
  - Word: 16 bits (w: 2 bytes)
  - Byte: 8 bits (b: 1 byte)
- While registers are quad words, we can access smaller items in registers, using different names for the register. Consider %rax:
  - %eax references the low order 32 bits of %rax (a double word)
  - %ax references the low order 16 bits of %rax (a word)
  - %al references the low order 8 bits of %rax (a byte)
  - %ah references bits 8-16 of %rax (also a byte)
  - These conventions apply to %rbx, %rcx, etc.
  - However, for registers %r8 - %r16, we use:
    - %r8d, %r8w, %r8b

Kinds of instructions

- Move data around
- Perform arithmetic operations
- Perform logical operations
- Compare things (sets condition flags)
- Flow control

Screen capture

Checkpoint 1

- Registers are referenced with %
- When we see an `imull` operation like:

```
OP operand1, operand2, operand3
```

  It means

```
operand3 = operand1 * operand2
```

- When we see an `add` operation like:

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- The first argument was in `%edi`.
- The second argument was in `%esi`.
- We returned the result in `%eax`.

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What other operations act like imull and which ones act like add?

What happens if we use longs instead of ints?

What if we have more than 2 arguments?

Screen capture

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Add, sub, and, or, xor all seem to have the same structure.

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Parameters are passed in:

- *%rdi (arg1)*
- *%rsi(arg2)*
- *%rdx(arg3)*
- *%rcx(arg4)*
- *%r8 (arg5)*
- *%r9 (arg6)*
- *… and then on the stack*