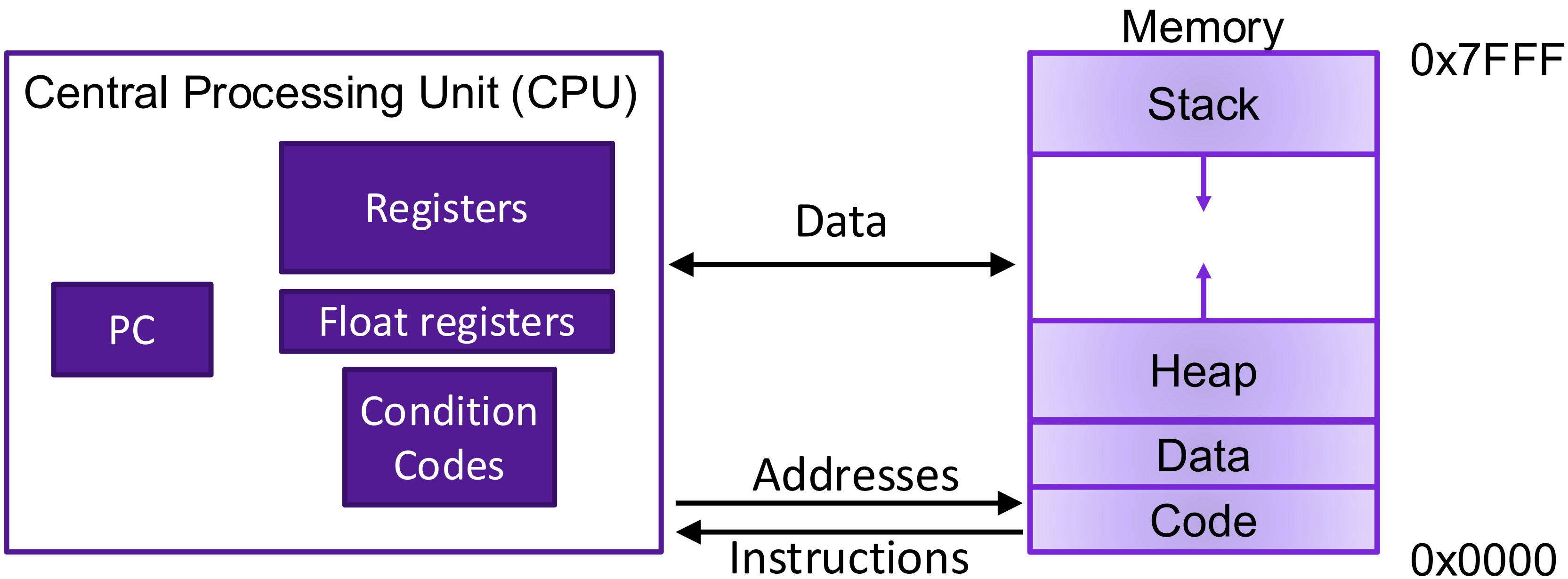
Lecture 6: Control Flow in Assembly

CS 105 Spring 2026

Review: Assembly/Machine Code View



Programmer-Visible State

- PC: Program counter (%rip)
- Register file: 16 Registers
- Float registers
- Condition codes

Memory

- Byte addressable array
- Code and user data
- Stack to support procedures

Review: Assembly Operations

- Transfer data between memory and register
  - Load data from memory into register
  - Store register data into memory
- Perform arithmetic function on register or memory data
- Transfer control
  - Conditional branches
  - Unconditional jumps to/from procedures

Review: Conditional Jumps

- jX instructions
- Jump to different part of code if condition is true

jX	Description
jmp	Unconditional
je	Equal / Zero
jne	Not Equal / Not Zero
jl	Less (Signed)
jle	Less or Equal (Signed)
jg	Greater (Signed)
jge	Greater or Equal (Signed)

- Whether or not we jump depends on how the output of the last operation compares to zero
- Operation includes arithmetic, cmp, test
- Not set by `lea` instruction

Review: Condition Codes

- Single bit registers
  - **ZF** Zero Flag
  - **PF** Parity Flag
  - **SF** Sign Flag (for signed)
  - **OF** Overflow Flag (for signed)
  - CF Carry Flag (for unsigned)
- Implicitly set (as a side effect) by arithmetic operations
- Explicitly set by **`cmp`** and **`test`**
- Not set by **`leaq`** instruction

Review: Conditional Jumps

- Whether or not we jump depends on how the output of the last arithmetic operation compares to zero

```
movq $47, %rax
subq $13, %rax
jg .L2
```

jump

```
movq $47, %rax
subq $13, %rax
je .L2
```

no jump

- Not set by `lea` instruction

- Unless there's an explicit conditional evaluation more recently
  - `cmp a,b` like computing `b-a` without setting destination
  - `test a,b` like computing `a&b` without setting destination

Exercise 1: Conditional Jumps

- Consider each of the following segments of assembly code, and indicate whether or not the jump will occur. In all cases, assume that `%rdi` contains the value 47 and `%rsi` contains the value 13

1. ```
   addq %rdi, %rsi
   je .L0
   ```
2. ```
   subq %rdi, %rsi
   jge .L0
   ```
3. ```
   cmpq %rdi, %rsi
   jl .L0
   ```
4. ```
   testq %rdi, %rdi
   jne .L0
   ```

Implementing Conditional Jumps

- jX instructions
  - Jump to different part of code if condition is true

jX	Condition	Description
jmp	1	Unconditional
je	ZF	Equal / Zero
jne	~ZF	Not Equal / Not Zero
js	SF	Negative
jns	~SF	Nonnegative
jl	(SF^OF)	Less (Signed)
jle	(SF^OF) | ZF	Less or Equal (Signed)
jg	~(SF^OF) & ~ZF	Greater (Signed)
jge	~(SF^OF)	Greater or Equal (Signed)
jb	CF	Below (unsigned)
jbe	CF | ZF	Below or Equal (unsigned)
ja	~ZF & ~CF	Above (unsigned)
jae	~CF	Above or Equal (unsigned)

Conditional Branching

```c
long absdiff(long x, long y){
  long result;

  if (x > y){
    result = x-y;
  } else {
    result = y-x;
  }

  return result;
}
```

```
absdiff:
   cmpq    %rsi, %rdi
   jle     .L4
   movq    %rdi, %rax
   subq    %rsi, %rax
   ret
.L4                # x-y <= 0
   movq    %rsi, %rax
   subq    %rdi, %rax
   ret
```

Register	Use
%rdi	x
%rsi	y
%rax	result

Exercise 2: Conditionals

```
test:
  leaq (%rdi, %rsi), %rax
  addq %rdx, %rax
  cmpq $47, %rax
  jne .L2
  movq %rdi, %rax
  jmp .L4
.L2:
  cmpq $47, %rax
  jle .L3
  movq %rsi, %rax
  jmp .L4
.L3.
  movq %rdx, %rax
.L4:
  rep; ret
```

```
long test(long x, long y, long z){

    long val = __________;

    if (__________);

        __________;

    } else if (__________);

        __________;

    } else {

        __________;
    }

    return val;
}
```

Reg	Use
%rdi	x
%rsi	y
%rdx	z
%rax	result

Loops

- All use conditions and jumps
  - do-while
  - while
  - for

Do-while Loops

Register	Use(s)
%rdi	x
%rax	result

```
long bitcount(unsigned long x){
  long result = 0;
  do {
    result += x & 0x1;
    x >>= 1;
  } while (x != 0);
  return result;
}
```

```
long bitcount(unsigned long x){
  long result = 0;
loop:
  result += x & 0x1;
  x >>= 1;
  if(x != 0) goto loop;
  return result;
}
```

```
   movq    $0, %rax      #  result = 0
.L2:                     #  loop:
   movq    %rdi, %rdx
   andq    $1, %rdx      #  t = x & 0x1
   addq    %rdx, %rax   #  result += t
   shrq    %rdi, $1      #  x >>= 1
   jne     .L2           #  if (x) goto loop
   rep; ret
```

While Loops

Register	Use(s)
%rdi	x
%rax	result

```
long bitcount(unsigned long x){
  long result = 0;
  while (x != 0) {
    result += x & 0x1;
    x >>= 1;
  }
  return result;
}
```

?

```
        movq    $0, %rax
.L1:
        test    %rdi,%rdi
        je      .L2
        movq    %rdi, %rdx
        andq    $1, %rdx
        addq    %rdx, %rax
        shrq    %rdi, $1
        jmp     .L1
.L2:
        rep; ret
```

```
        movq    $0, %rax
        jmp     .L2
.L3:
        movq    %rdi, %rdx
        andq    $1, %rdx
        addq    %rdx, %rax
        shrq    %rdi, $1
.L2:
        testq   %rdi, %rdi
        jne     .L3
        rep; ret
```

Exercise 3: Loops

Reg	Use(s)
%rdi	val
%rdx	i
%rax	ret

```
loop:
  movq $0, %rax
  movq $0, %rdx
  jmp L1
L0:
  addq %rdx, %rax
  incq %rdx
L1:
  cmp %rdi, %rdx
  jl L0
  ret
```

```
long loop(long val){
  long ret = ______;
  long i   = ______;

  while(__________){

    ret = _______;
    i   = _______;

  }

  return ret;
}
```

For loops

Register	Use(s)
%rdi	x
%rax	result

```
for (Init; Cond; Incr){
    Body
}
```

```
Init;
while (Cond) {
    Body;
    Incr;
}
```

Initial test can often be optimized away:
`for (int i = 0; i < 100; i++)`

```
long bitcount(unsigned long x) {
  long result;
  for (result = 0; x!=0; x >>= 1)
    result += x & 0x1;
  return result;
}
```

```
        movq    $0, %rax
.L1:
        test    %rdi,%rdi
        je      .L2
        movq    %rdi, %rdx
        andq    $1, %rdx
        addq    %rdx, %rax
        shrq    %rdi, $1
        testq   %rdi, %rdi
        jmp     .L1
.L2:
        rep ret
```

Exercise 4: Array Loop

Variable	Register
z	%rdi
sum	%rax
i	%rsi

```
array_loop:
  movl    $0, %esi
  xorl    %eax, %eax
  jmp     L2
L1:
  addl    (%rdi,%rsi,4), %eax
  incq    %rsi
L2:
  cmpq    $5, %rsi
  jl     L1
  retq
```

```
int array_loop(int* z) {
  int sum = ______;

  int i;
  for(i = _____ ; i < _____ ; _____){

    sum = _________;

  }
  return _______;
}
```