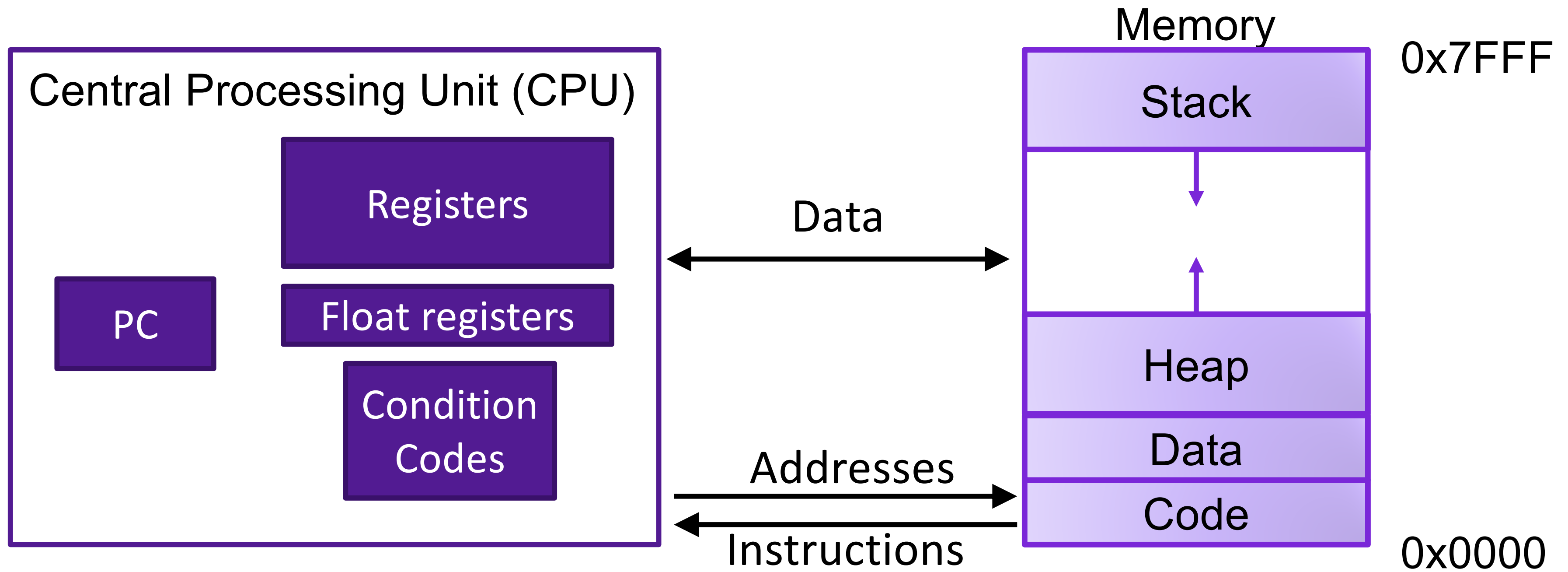
CS 105

Fall 2023

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: 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

Conditional Branching

```
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 4: 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

Register	Use(s)
%rdi	Argument x
%rax	result

Do-while Loops

```
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`	Argument **`x`**
`%rax`	**`result`**

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

?

```
        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
```

```
        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
```

Exercise: Loops

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

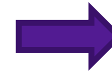
```
loop:
  movq $0, %rax
  movq $0, %rdx
  jmp L1
L0:
  addq %rdx, %rax
  incq %rdx
L1:
  cmp %rdi, %rdx
  jl L0
  ret
```

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

  while(__________){

    ret = _______;
    i   = _______;

  }

  return ret;
}
```

For loops

Register	Use(s)
%rdi	Argument x
%rax	result

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

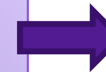


```
Init;
while (Cond) {
    Body;
    Incr;
}
```

Initial test can often be optimized away:

```
  for (j = 0; j < 99; j++)
```

```
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 : 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 = ______;


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

    sum = _______;

  }
  return _______;
}
```

Branches and Jumps

- Processor state (partial)
  - Temporary data (`%rax`, …)
  - Location of runtime stack (`%rsp`)
  - Location of current code control point (`%rip`, …)
  - Status of recent tests (CF, ZF, SF, OF)

Registers

`%rax` (return val)	`%r8`
`%rbx`	`%r9`
`%rcx` (4th arg)	`%r10`
`%rdx` (3rd arg)	`%r11`
`%rsi` (2nd arg)	`%r12`
`%rdi` (1st arg)	`%r13`
`%rsp` (stack ptr)	`%r14`
`%rbp`	`%r15`

`%rip` Instruction pointer

`CF` `ZF` `SF` `OF` Condition codes

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

Example Condition Codes: `compare`

- Instruction `cmp` explicitly sets condition codes

- `cmpq a,b` like computing `b-a` without setting destination
  - ZF set if `(b-a) == 0`
  - PF set if `(b-a)% 2 == 1`
  - SF set if `(b-a) < 0` (as signed)
  - CF set if carry out from most significant bit (used for unsigned comparisons)
  - OF set if two's-complement (signed) overflow

Jumping

- 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
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)