CSCI-UA.0201

Computer Systems Organization

Machine Level – Assembly (x86-64) basics

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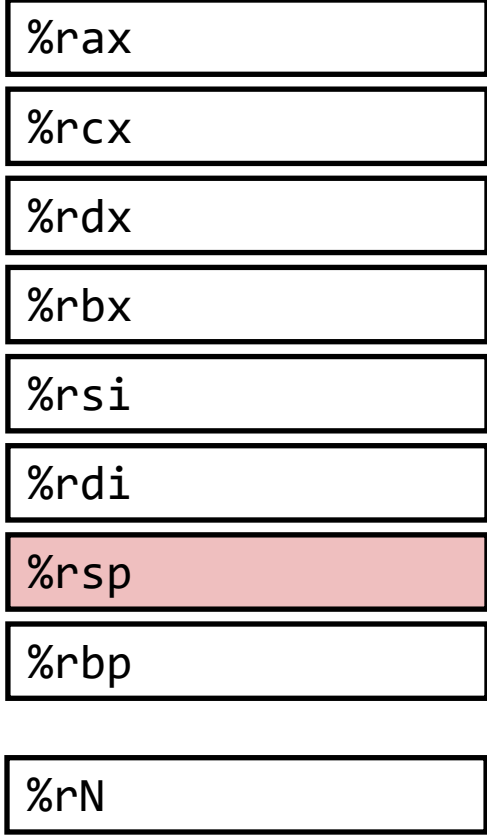
Moving Data

Moving Data

- Moving Data

  movq ***Source, Dest***

- Operand Types
  - ***Immediate:*** Constant integer data
    - Example: **$0x400, $-533**
    - Like C constant, but prefixed with **'$'**
  - ***Register:*** One of 16 integer registers
    - Example: **%rax, %r13**
    - But **%rsp** reserved for special use
    - Others have special uses for particular instructions (later on that)
  - ***Memory:*** 8 consecutive bytes of memory at address given by register
    - Simplest example: **(%rax)**
    - We will see various other "address modes" later.



movq Operand Combinations

	Source	Dest	Src,Dest	C Analog
movq	*Imm*	*Reg*	`movq $0x4,%rax`	`temp = 0x4;`
		Mem	`movq $-147,(%rax)`	`*p = -147;`
	Reg	*Reg*	`movq %rax,%rdx`	`temp2 = temp1;`
		Mem	`movq %rax,(%rdx)`	`*p = temp;`
	Mem	*Reg*	`movq (%rax),%rdx`	`temp = *p;`

No memory-to-memory instruction

movq

C Declaration	Intel Data Type	Assembly code suffix	Size (bytes)
Char	Byte	b	1
Short	Word	w	2
Int	Double Word	l	4
Long	Quad Word	q	8
Pointer	Quad Word	q	8

Simple Memory Addressing Modes

- Normal: (R) → Mem[Reg[R]]
  - Register R specifies memory address to read from/write to

```
movq (%rcx),%rax
```

- Displacement : D(R) → Mem[Reg[R]+D]
  - Register R specifies start of memory region
  - Constant displacement D specifies offset in bytes

```
movq 8(%rbp),%rdx
```

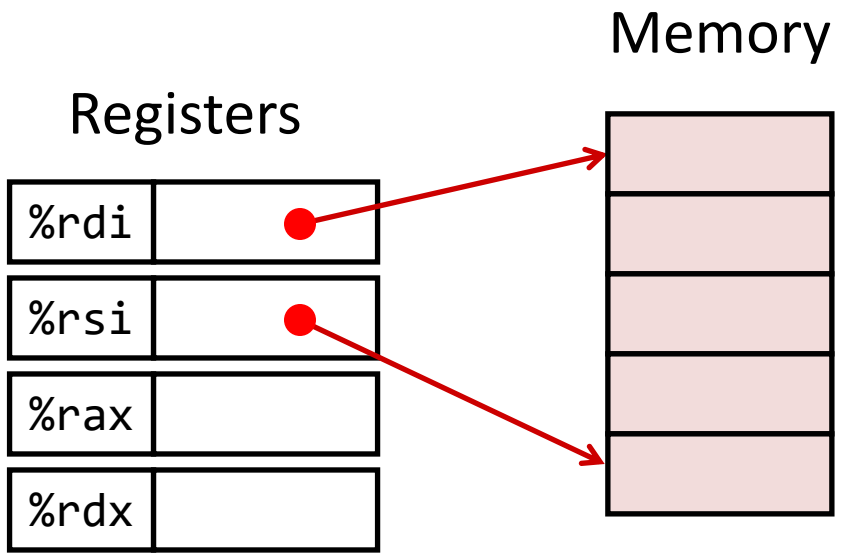
Example of Simple Addressing Modes

```
void swap (long *xp, long *yp)
{
  long t0 = *xp;
  long t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```

```
swap:
    … some setup code
    movq    (%rdi), %rax
    movq    (%rsi), %rdx
    movq    %rdx, (%rdi)
    movq    %rax, (%rsi)
    … wrap-up code
    ret
```

Understanding swap()

```
void swap(long *xp, long *yp)
{
  long t0 = *xp;
  long t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```



Register	Value
%rdi	xp
%rsi	yp
%rax	t0
%rdx	t1

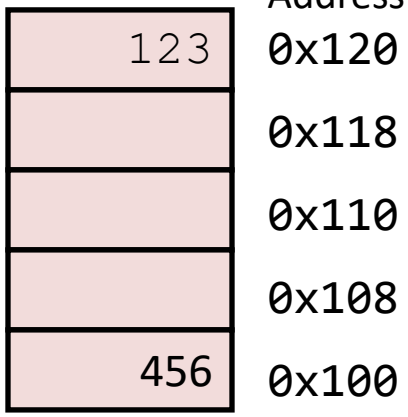
```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```

Understanding swap()

Registers

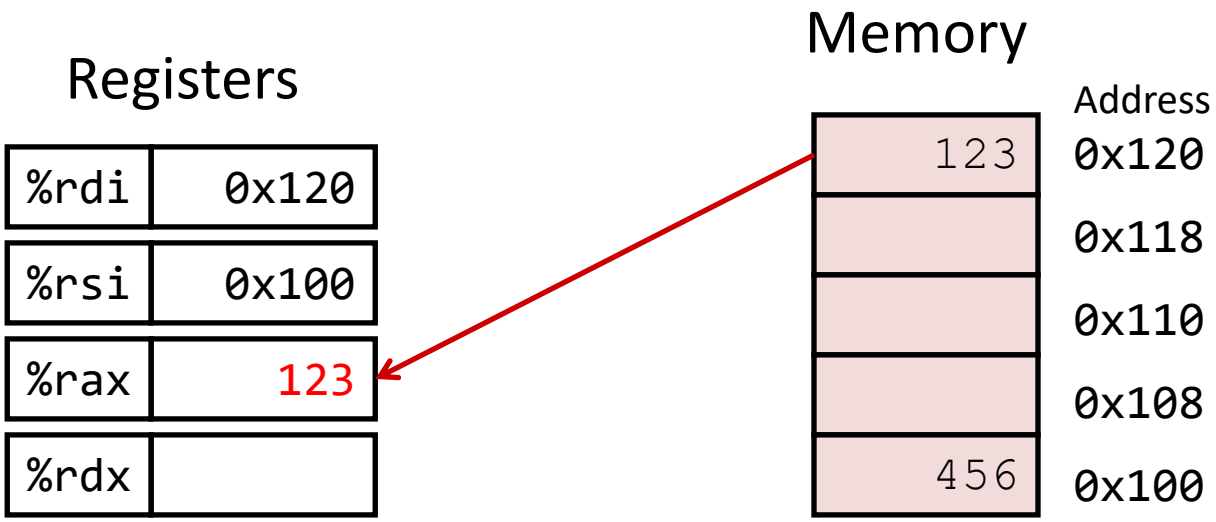
%rdi	0x120
%rsi	0x100
%rax	
%rdx	

Memory



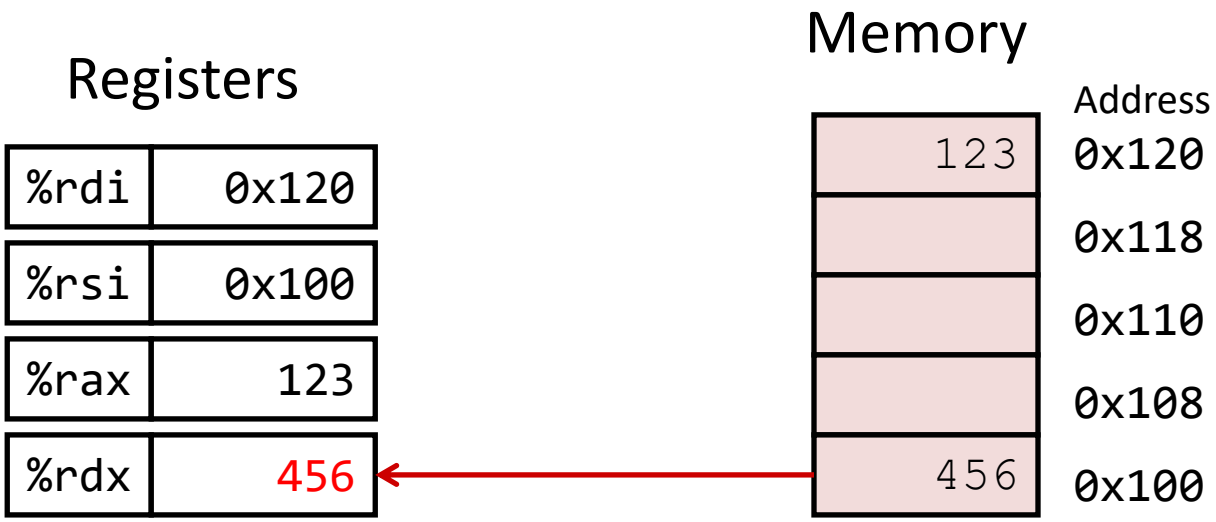

```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```

Understanding swap()



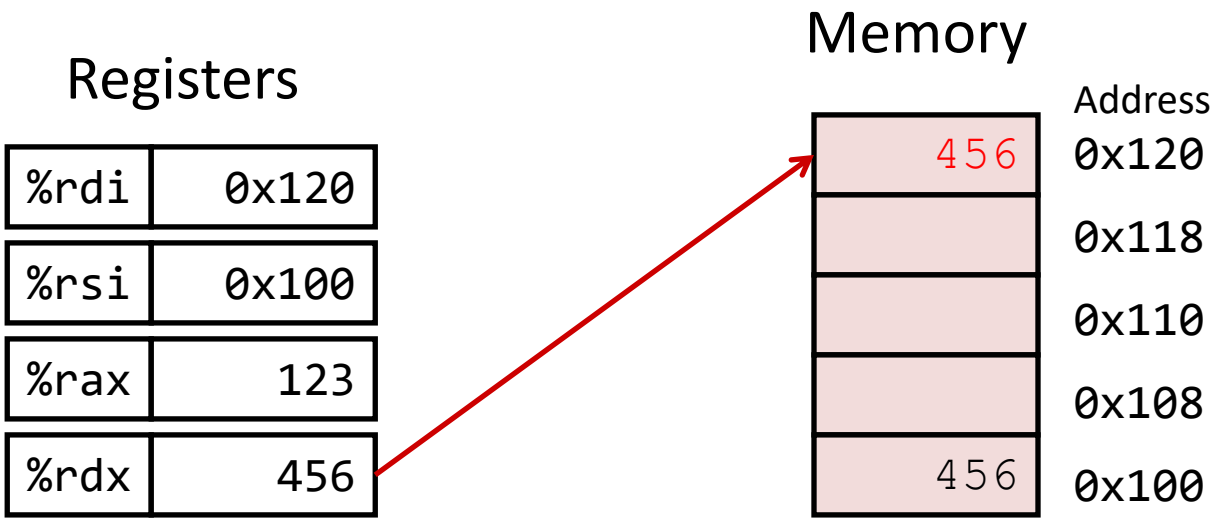

```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```

Understanding swap()



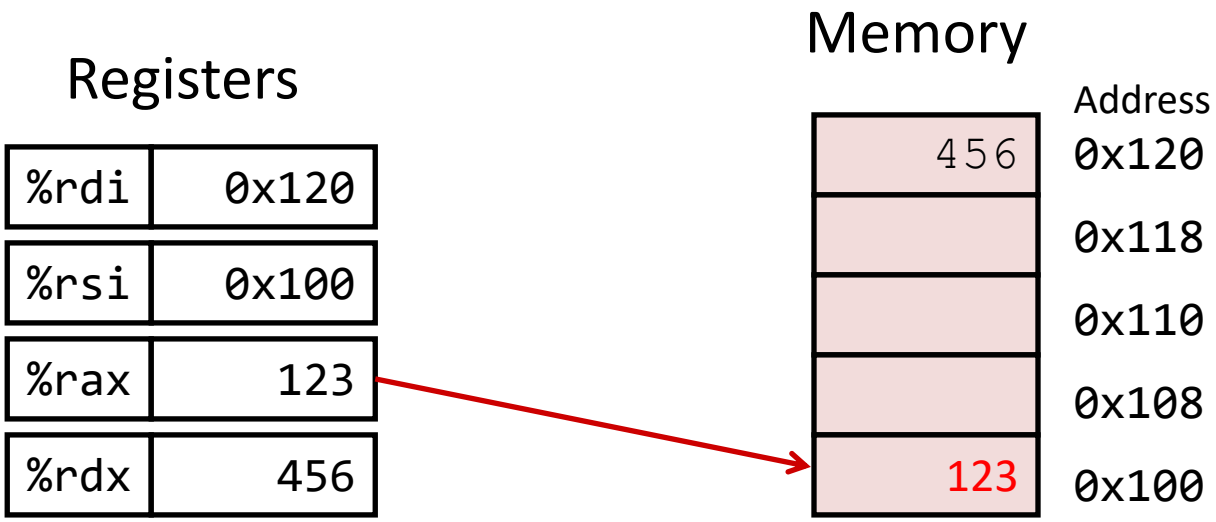

```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```

Understanding swap()




```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```

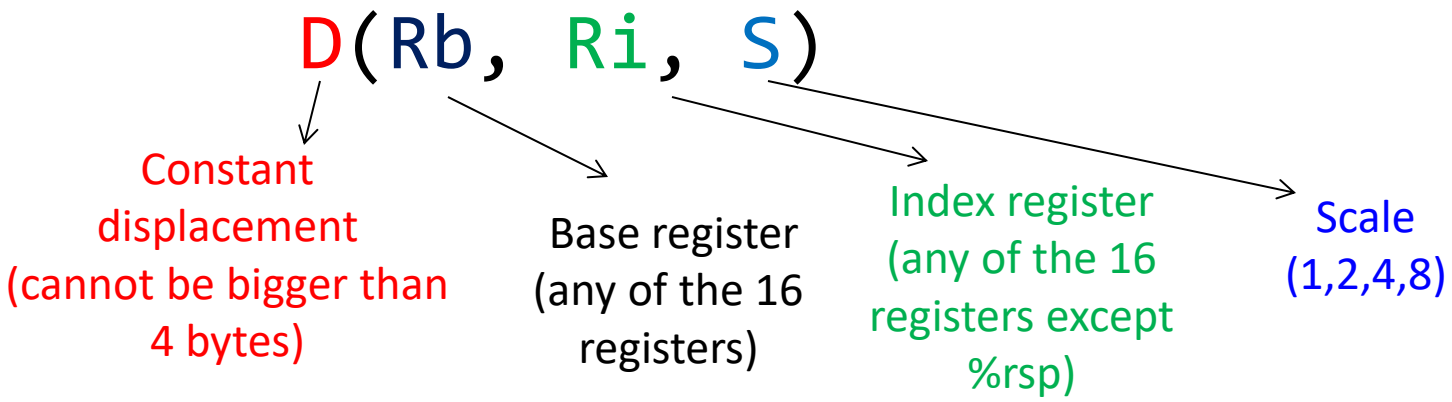
Understanding swap()




```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```

General Memory Addressing Modes

- Most General Form




```
Mem[Reg[Rb] + S*Reg[Ri] + D]
```

- Special Cases

```
(Rb,Ri)       Mem[Reg[Rb] + Reg[Ri]]
D(Rb,Ri)      Mem[Reg[Rb] + Reg[Ri] + D]
(Rb,Ri,S)     Mem[Reg[Rb] + S*Reg[Ri]]
```

Address Computation Examples

%rdx	0xf000
%rcx	0x0100

Expression	Address Computation	Address
0x8(%rdx)	0xf000 + 0x8	0xf008
(%rdx,%rcx)	0xf000 + 0x100	0xf100
(%rdx,%rcx,4)	0xf000 + 4*0x100	0xf400
0x80(,%rdx,2)	2*0xf000 + 0x80	0x1e080

Address Computation Instruction

- `leaq` ***Src***, ***Dst***
  - *Src* is address mode expression
  - Set *Dst* to address calculated for src
- Uses
  - Computing addresses without a memory access
    - E.g., translation of **`p = &x[i];`**
  - Computing arithmetic expressions of the form `x + k*y`
    - k = 1, 2, 4, or 8
- Example

```
long m12(long x)
{
  return x*12;
}
```

Converted to ASM by compiler:

```
leaq (%rdi,%rdi,2), %rax     # t = x+x*2
salq $2, %rax                # return t<<2
```

Summary

- History of Intel processors and architectures
  - Evolutionary design leads to many quirks and artifacts
- C, assembly, machine code
  - Compiler must transform statements, expressions, procedures into low-level instruction sequences
- Assembly Basics: Registers, operands, move
  - The x86 move instructions cover wide range of data movement forms

Arithmetic & Logic Operations

Some Arithmetic Operations

- Two Operand Instructions, examples:

Format	***Computation***		
`addq`	*Src,Dest*	Dest = Dest + Src	
`subq`	*Src,Dest*	Dest = Dest – Src	
`imulq`	*Src,Dest*	Dest = Dest * Src	
`salq`	*Src,Dest*	Dest = Dest << Src	⟵ ***Also called*** `shlq`
`sarq`	*Src,Dest*	Dest = Dest >> Src	⟵ ***Arithmetic***
`shrq`	*Src,Dest*	Dest = Dest >> Src	⟵ ***Logical***
`xorq`	*Src,Dest*	Dest = Dest ^ Src	
`andq`	*Src,Dest*	Dest = Dest & Src	
`orq`	*Src,Dest*	Dest = Dest | Src	

- Watch out for argument order!
- No distinction between signed and unsigned int (why?)

Some Arithmetic Operations

- One Operand Instructions

`incq`	*Dest*	*Dest = Dest + 1*
`decq`	*Dest*	*Dest = Dest – 1*
`negq`	*Dest*	*Dest = – Dest*
`notq`	*Dest*	*Dest = ~Dest*

- See book and other references for more instructions

Arithmetic Expression Example

```
long arith
(long x, long y, long z)
{
  long t1 = x+y;
  long t2 = z+t1;
  long t3 = x+4;
  long t4 = y * 48;
  long t5 = t3 + t4;
  long rval = t2 * t5;
  return rval;
}
```

```
arith:
  leaq    (%rdi,%rsi), %rax
  addq    %rdx, %rax
  leaq    (%rsi,%rsi,2), %rdx
  salq    $4, %rdx
  leaq    4(%rdi,%rdx), %rcx
  imulq   %rcx, %rax
  ret
```

Understanding Arithmetic Expression Example

```
long arith
(long x, long y, long z)
{
  long t1 = x+y;
  long t2 = z+t1;
  long t3 = x+4;
  long t4 = y * 48;
  long t5 = t3 + t4;
  long rval = t2 * t5;
  return rval;
}
```

```
arith:
  leaq    (%rdi,%rsi), %rax
  addq    %rdx, %rax
  leaq    (%rsi,%rsi,2), %rdx
  salq    $4, %rdx
  leaq    4(%rdi,%rdx), %rcx
  imulq   %rcx, %rax
  ret
```

Register	Use(s)
%rdi	Argument **x**
%rsi	Argument **y**
%rdx	Argument **z**
%rax	**t1, t2, rval**
%rdx	**t4**
%rcx	**t5**

Understanding Arithmetic Expression Example

```
long arith
(long x, long y, long z)
{
  long t1 = x+y;
  long t2 = z+t1;
  long t3 = x+4;
  long t4 = y * 48;
  long t5 = t3 + t4;
  long rval = t2 * t5;
  return rval;
}
```

```
arith:
   leaq    (%rdi,%rsi), %rax
   addq    %rdx, %rax
   leaq    (%rsi,%rsi,2), %rdx
   salq    $4, %rdx
   leaq    4(%rdi,%rdx), %rcx
   imulq   %rcx, %rax
   ret
```

- Instructions in different order from C code
- Some expressions require multiple instructions
- Some instructions cover multiple expressions