



Machine-Level Programming IV: Procedures – passing data

These slides adapted from materials provided by the textbook authors.

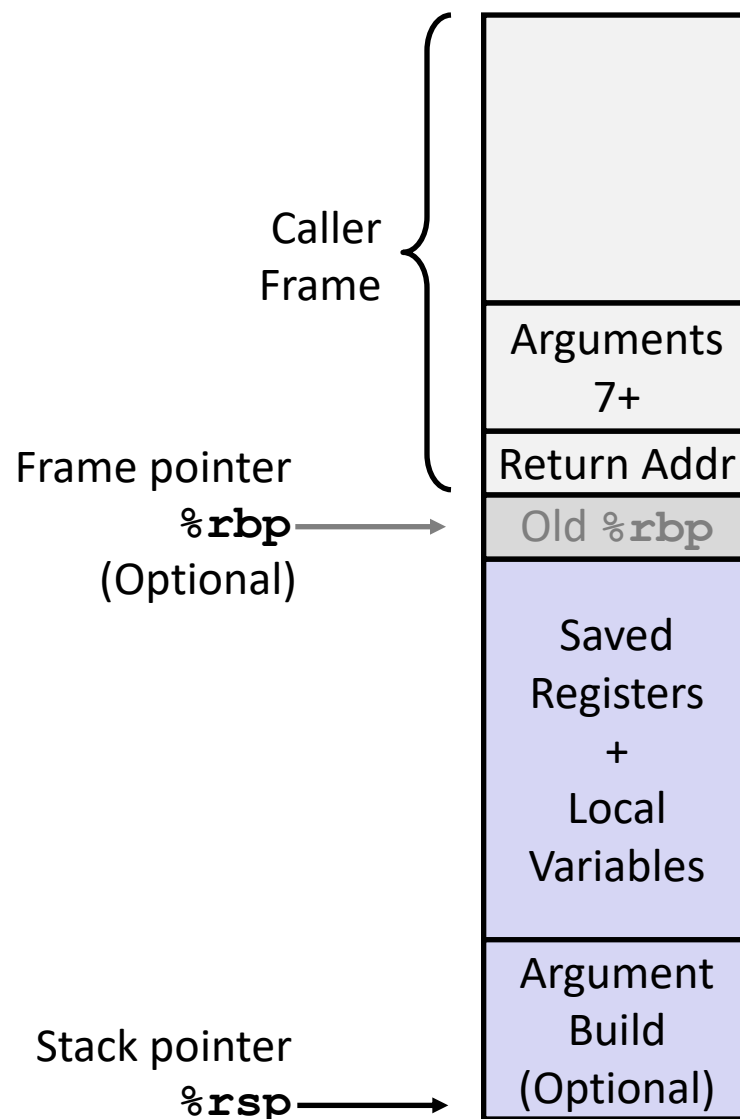
x86-64/Linux Stack Frame

■ Current Stack Frame (“Top” to Bottom)

- “Argument build:”
Parameters for function about to call
- Local variables
If can’t keep in registers
- Saved register context
- Old frame pointer (optional)

■ Caller Stack Frame

- Return address
 - Pushed by **call** instruction
- Arguments for this call



Example: `incr`

```
long incr(long *p, long val) {  
    long x = *p;  
    long y = x + val;  
    *p = y;  
    return x;  
}
```

```
incr:  
    movq    (%rdi), %rax  
    addq    %rax, %rsi  
    movq    %rsi, (%rdi)  
    ret
```

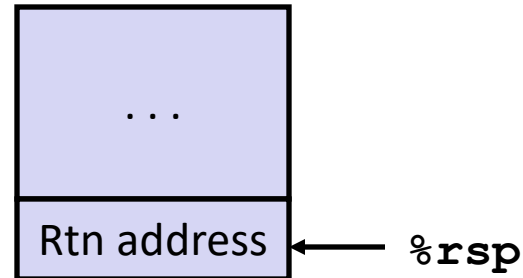
Register	Use(s)
%rdi	Argument <code>p</code>
%rsi	Argument <code>val, y</code>
%rax	<code>x</code> , Return value

Example: Calling `incr` #1

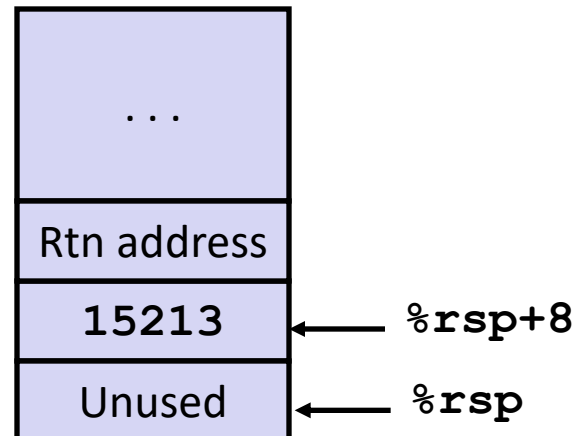
```
long call_incr() {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return v1+v2;  
}
```

```
call_incr:  
    subq    $16, %rsp  
    movq    $15213, 8(%rsp)  
    movl    $3000, %esi  
    leaq    8(%rsp), %rdi  
    call    incr  
    addq    8(%rsp), %rax  
    addq    $16, %rsp  
    ret
```

Initial Stack Structure



Resulting Stack Structure

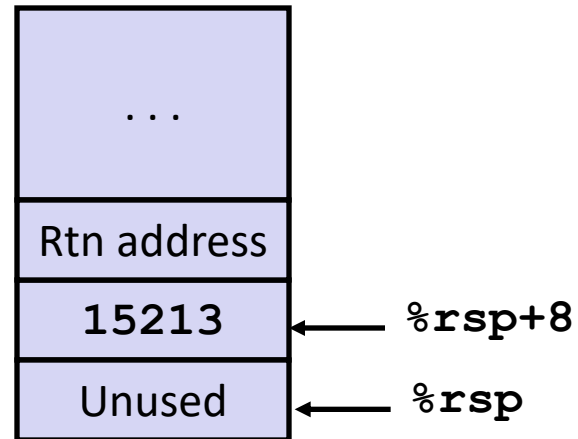


Example: Calling `incr` #2

```
long call_incr() {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return v1+v2;  
}
```

```
call_incr:  
    subq    $16, %rsp  
    movq    $15213, 8(%rsp)  
    movl    $3000, %esi  
    leaq    8(%rsp), %rdi  
    call    incr  
    addq    8(%rsp), %rax  
    addq    $16, %rsp  
    ret
```

Stack Structure



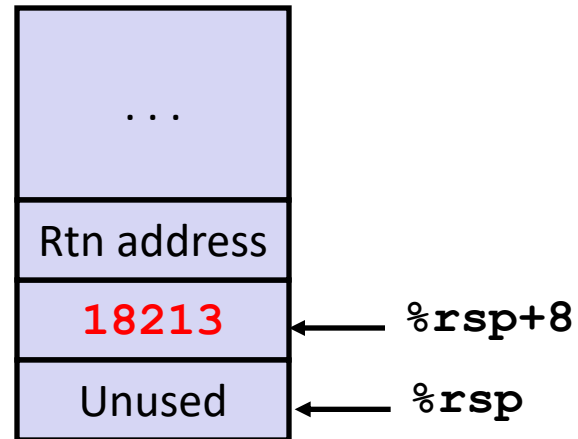
Register	Use(s)
<code>%rdi</code>	<code>&v1</code>
<code>%rsi</code>	3000

Example: Calling `incr` #3

```
long call_incr() {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return v1+v2;  
}
```

```
call_incr:  
    subq    $16, %rsp  
    movq    $15213, 8(%rsp)  
    movl    $3000, %esi  
    leaq    8(%rsp), %rdi  
    call    incr  
    addq    8(%rsp), %rax  
    addq    $16, %rsp  
    ret
```

Stack Structure



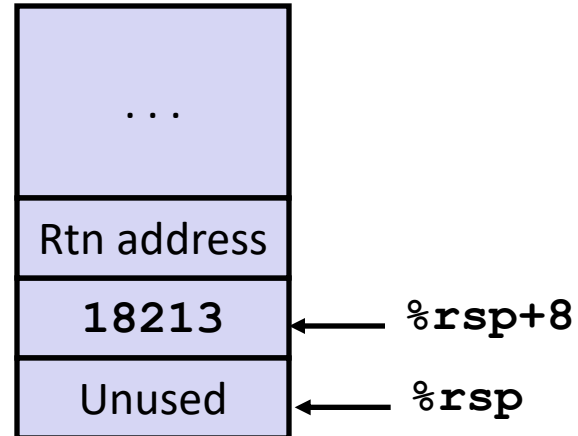
Register	Use(s)
%rdi	&v1
%rsi	3000

Example: Calling `incr` #4

```
long call_incr() {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return v1+v2;  
}
```

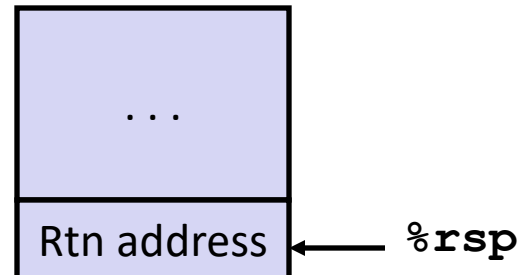
```
call_incr:  
    subq    $16, %rsp  
    movq    $15213, 8(%rsp)  
    movl    $3000, %esi  
    leaq    8(%rsp), %rdi  
    call    incr  
    addq    8(%rsp), %rax  
    addq    $16, %rsp  
    ret
```

Stack Structure



Register	Use(s)
<code>%rax</code>	Return value

Updated Stack Structure

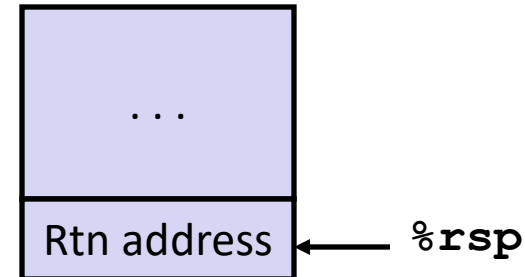


Example: Calling `incr` #5

```
long call_incr() {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return v1+v2;  
}
```

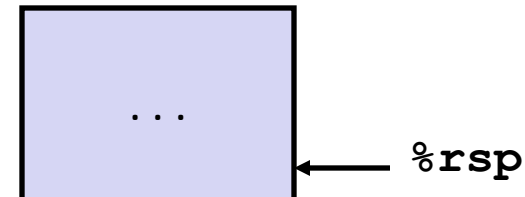
```
call_incr:  
    subq    $16, %rsp  
    movq    $15213, 8(%rsp)  
    movl    $3000, %esi  
    leaq    8(%rsp), %rdi  
    call    incr  
    addq    8(%rsp), %rax  
    addq    $16, %rsp  
    ret
```

Updated Stack Structure



Register	Use(s)
<code>%rax</code>	Return value

Final Stack Structure



Register Saving Conventions

- When procedure `yoo` calls `who`:
 - `yoo` is the **caller**
 - `who` is the **callee**
- Can register be used for temporary storage?

```
yoo:
    . . .
    movq $15213, %rdx
    call who
    addq %rdx, %rax
    . . .
    ret
```

```
who:
    . . .
    subq $18213, %rdx
    . . .
    ret
```

- Contents of register `%rdx` overwritten by `who`
- This could be trouble → something should be done!
 - Need some coordination

Register Saving Conventions

- When procedure **yoo** calls **who**:
 - **yoo** is the **caller**
 - **who** is the **callee**
- Can register be used for temporary storage?
- Conventions
 - “**Caller Saved**”
 - Caller saves temporary values in its frame before the call
 - “**Callee Saved**”
 - Callee saves temporary values in its frame before using
 - Callee restores them before returning to caller

x86-64 Linux Register Usage #1

■ **%rax**

- Return value
- Also caller-saved
- Can be modified by procedure

■ **%rdi, ..., %r9**

- Arguments
- Also caller-saved
- Can be modified by procedure

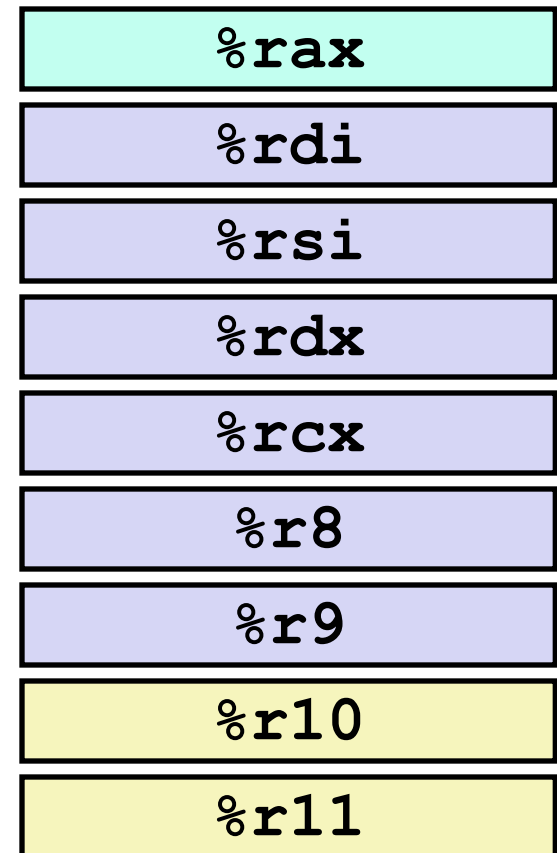
■ **%r10, %r11**

- Caller-saved
- Can be modified by procedure

Return value

Arguments

Caller-saved
temporaries



x86-64 Linux Register Usage

#2

■ **%rbx, %r12, %r13, %r14**

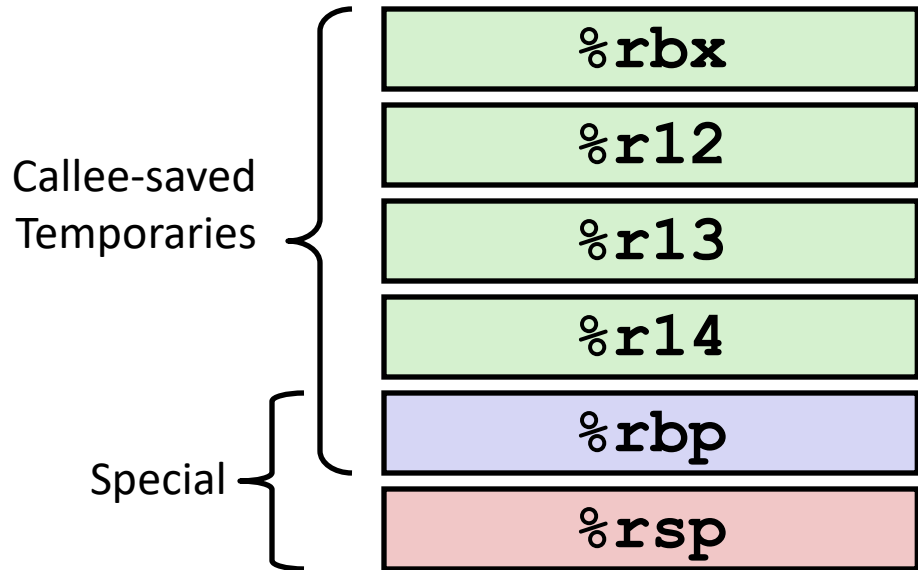
- Callee-saved
- Callee must save & restore

■ **%rbp**

- Callee-saved
- Callee must save & restore
- May be used as frame pointer
- Can mix & match

■ **%rsp**

- Special form of callee save
- Restored to original value upon exit from procedure

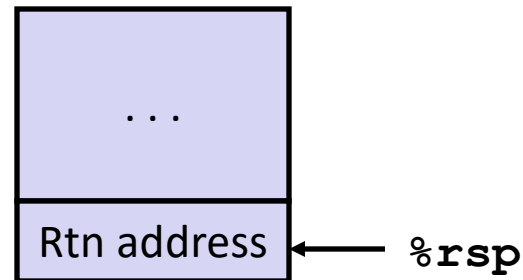


Callee-Saved Example #1

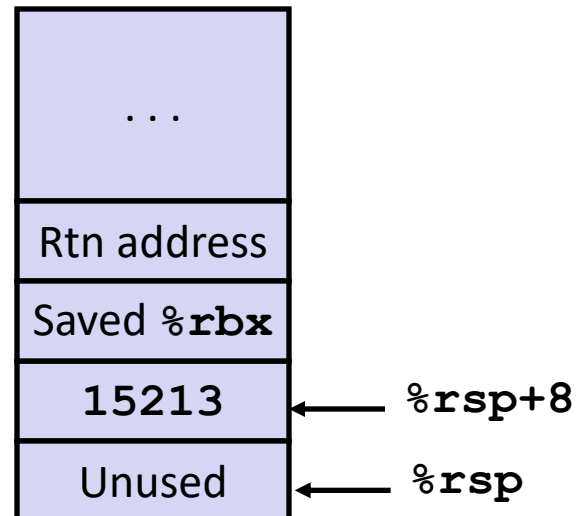
```
long call_incr2(long x) {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return x+v2;  
}
```

```
call_incr2:  
    pushq    %rbx  
    subq     $16, %rsp  
    movq     %rdi, %rbx  
    movq     $15213, 8(%rsp)  
    movl     $3000, %esi  
    leaq     8(%rsp), %rdi  
    call     incr  
    addq     %rbx, %rax  
    addq     $16, %rsp  
    popq     %rbx  
    ret
```

Initial Stack Structure



Resulting Stack Structure

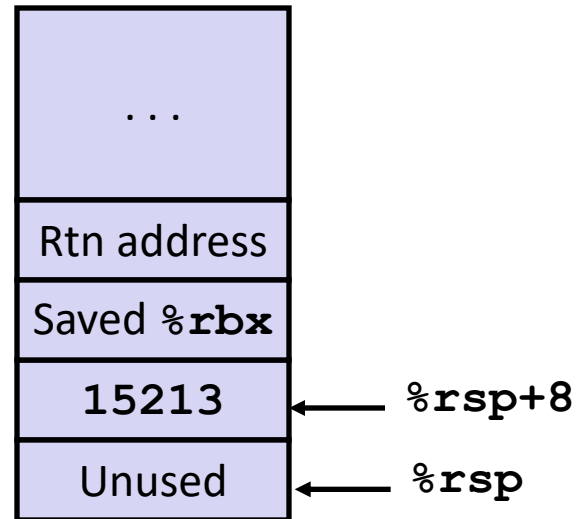


Callee-Saved Example #2

```
long call_incr2(long x) {  
    long v1 = 15213;  
    long v2 = incr(&v1, 3000);  
    return x+v2;  
}
```

```
call_incr2:  
    pushq    %rbx  
    subq     $16, %rsp  
    movq     %rdi, %rbx  
    movq     $15213, 8(%rsp)  
    movl     $3000, %esi  
    leaq     8(%rsp), %rdi  
    call     incr  
    addq     %rbx, %rax  
    addq     $16, %rsp  
    popq     %rbx  
    ret
```

Resulting Stack Structure



Pre-return Stack Structure

