Assembly II: Control Flow

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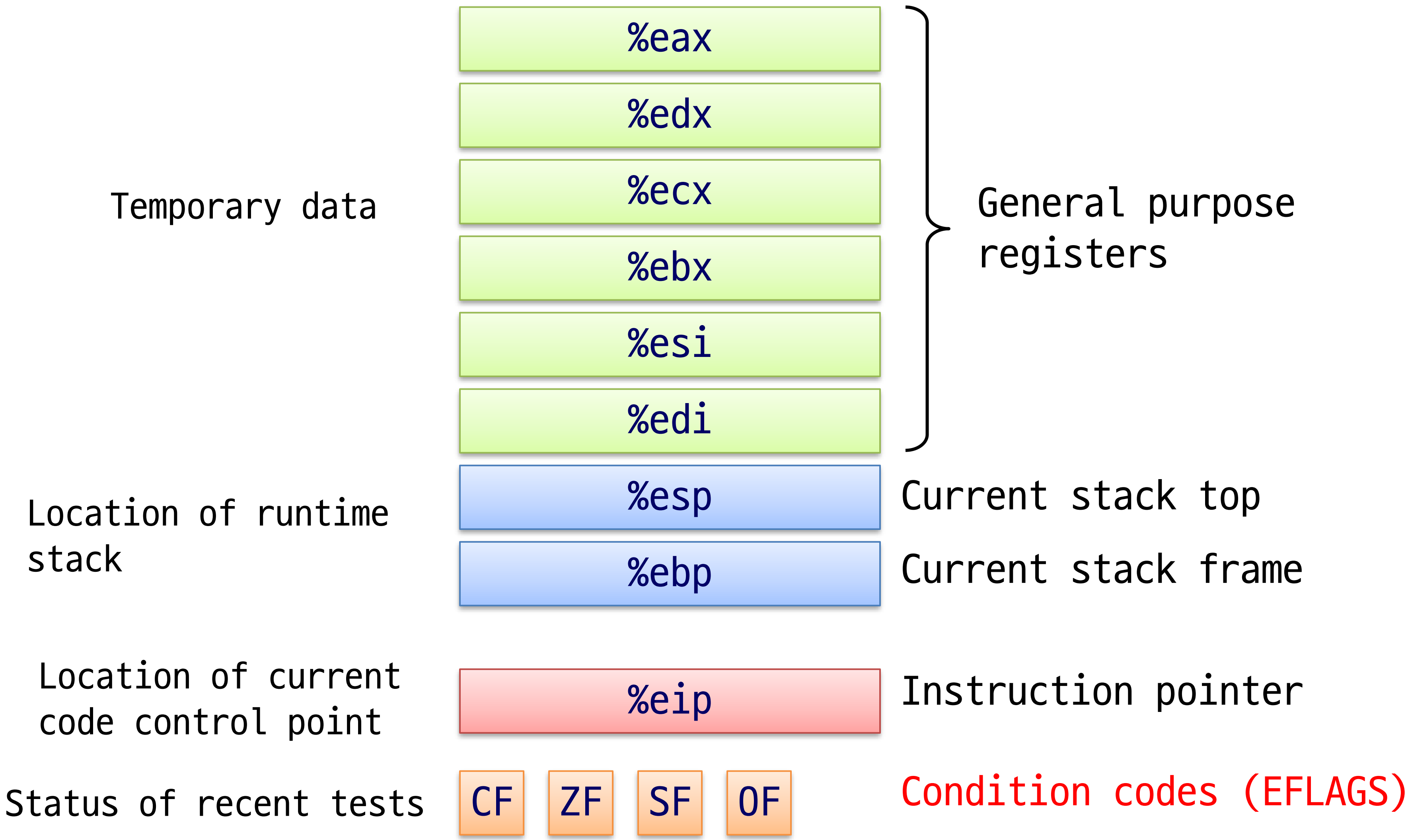
Control Flow of Program Code

```
if (a == 0) {
        do_something();
}
else {
        do_else();
}
// switch ()
```

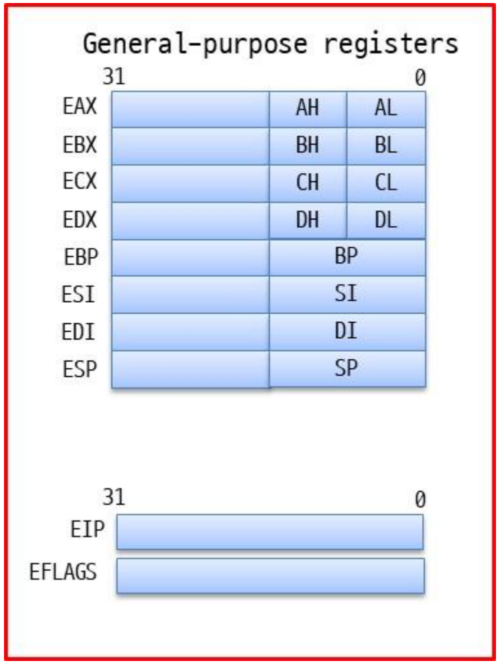
```
while (a > b) {
        do_somthing();
}
// for () // do ... while
```

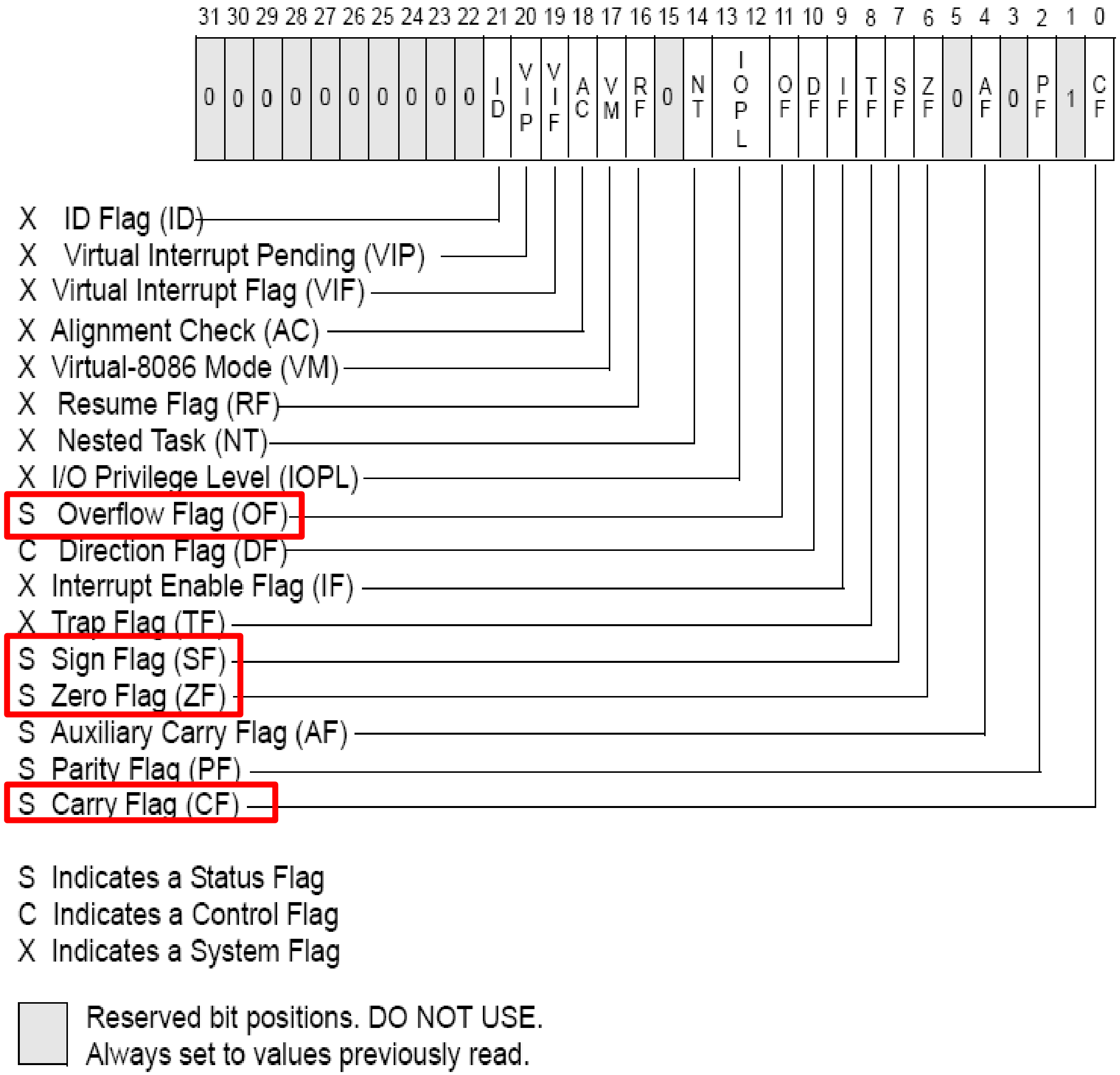
```
sub1() {
        do_something...
}
main () {
        do_a;
        sub1();
        do_b;
}
// function? or not?
```

IA-32 Processor State



EFLAGS Register





Setting Condition Codes (1)

Single bit registers

- CF (Carry), SF (Sign), ZF (Zero), OF (Overflow)

Implicitly set by arithmetic operations

- Example: **addl Src, Dest** (t = a + b)
- CF set if carry out from most significant bit
  - Used to detect unsigned overflow
- ZF set if **t == 0**
- SF set if **t < 0**
- OF set if two's complement overflow
  - **(a>0 && b>0 && t<0) || (a<0 && b<0 && t>=0)**

Not set by **leal**, **incl**, or **decl** instruction

Setting Condition Codes (2)

Explicitly setting by compare instruction

- Example: **cmpl b, a**
- Computes **(a – b)** without saving the result (arithmetic)
- CF set if carry out from most significant bit
  - Used for unsigned comparisons
- ZF set if **a == b**
- SF set if **(a – b) < 0**
- OF set if two's complement overflow

  (a>0 && b<0 && (a-b)<0) || (a<0 && b>0 && (a-b)>0)

Setting Condition Codes (3)

Explicitly setting by test instruction

- Example: **testl b, a**
- Sets condition codes based on value of a and b
  - Useful to have one of the operands be a mask
- Computes **a & b** without setting destination (logical)
- ZF set when **a & b == 0**
- SF set when **a & b < 0**
- CF and OF are cleared to 0

Jumping

```
cmpl    %eax, %edx
je      L9
```

jX instructions

- Jump to different part of code depending on condition codes
- Jump instruction changes the value of PC(EIP)

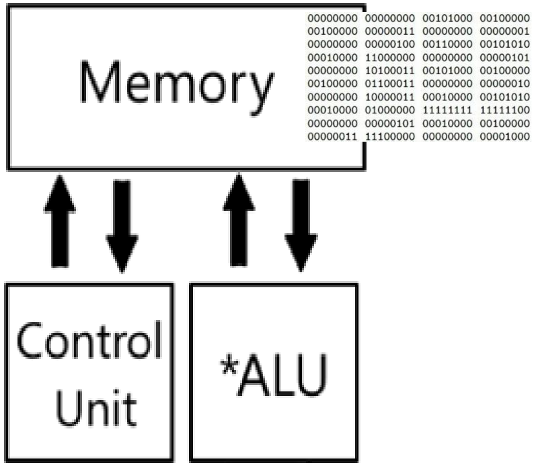
jX	Condition	Description
jmp	1	Unconditional
je	ZF	Equal / Zero
jne	~ZF	Not Equal / Not Zero
js	SF	Negative
jns	~SF	Nonnegative
jg	~(SF ^ OF) & ~ZF	Greater (Signed >)
jge	~(SF ^ OF)	Greater or Equal (Signed >=)
jl	(SF ^ OF)	Less (Signed <)
jle	(SF ^ OF) ¦ ZF	Less or Equal (Signed <=)
ja	~CF & ~ZF	Above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

Jumping

```
...
...
...
if (a == 0) {
        do_something();
}
else {
        do_else();
}
...
...
...
```

a.exe

00000000	00000000	00101000	00100000
00100000	00000011	00000000	00000001
00000000	00000100	00110000	00101010
00010000	11000000	00000000	00000101
00000000	10100011	00101000	00100000
00100000	01100011	00000000	00000010
00000000	10000011	00010000	00101010
00010000	01000000	11111111	11111100
00000000	00000101	00010000	00100000
00000011	11100000	00000000	00001000



Reading Condition Codes (1)

setX instructions

- Set single byte based on combinations of condition codes

setX	Condition	Description
sete R_8	R_8 <- ZF	Equal / Zero
setne R_8	R_8 <- ~ZF	Not Equal / Not Zero
sets R_8	R_8 <- SF	Negative
setns R_8	R_8 <- ~SF	Nonnegative
setg R_8	R_8 <- ~(SF ^ OF) & ~ZF	Greater (Signed >)
setge R_8	R_8 <- ~(SF ^ OF)	Greater or Equal (Signed >=)
setl R_8	R_8 <- (SF ^ OF)	Less (Signed <)
setle R_8	R_8 <- (SF ^ OF) ¦ ZF	Less or Equal (Signed <=)
seta R_8	R_8 <- ~CF & ~ZF	Above (Unsigned >)
setae R_8	R_8 <- ~CF	Above or Equal (Unsigned >=)
setb R_8	R_8 <- CF	Below (Unsigned <)
setbe R_8	R_8 <- CF ¦ ZF	Below or Equal (Unsigned <=)

Reading Condition Codes (2)

setX instructions

```
int gt (int x, int y){
   return x > y;
}
```

```
movl 12(%ebp),%eax        # %eax = y
cmpl %eax,8(%ebp)         # Compare x : y
setg %al                  # al = x > y
movzbl %al,%eax           # Zero rest of %eax
```

%eax	%ah	%al
%edx	%dh	%dl
%ecx	%ch	%cl
%ebx	%bh	%bl
%esi		
%edi		
%esp		
%ebp		

- One of 8 addressable byte registers

  %ah, %al, %bh, %bl,

  %ch, %cl, %dh, %dl
- Does not alter remaining 3 bytes
- Typically use **movzbl** to finish job (for backward compatibility)

Conditional Branch (1)

```c
int max(int x, int y)
{
  if (x > y)
    return x;
  else
    return y;
}
```

```
_max:
        pushl %ebp
        movl %esp,%ebp

        movl 8(%ebp),%edx
        movl 12(%ebp),%eax
        cmpl %eax,%edx
        jle L9
        movl %edx,%eax
L9:

        movl %ebp,%esp
        popl %ebp
        ret
```

Set Up

Body

Finish

Conditional Branch (2)

```
int max(int x, int y)
{
  if (x > y)
    return x;
  else
    return y;
}
```

```
int goto_max(int x, int y)
{
  int rval = y;
  int ok = (x <= y);
  if (ok)
    goto done;
  rval = x;
done:
  return rval;
}
```

- C allows "goto" as means of transferring control
  - Closer to machine-level programming style
- Generally considered bad coding style

```
    movl 8(%ebp),%edx      # edx = x
    movl 12(%ebp),%eax     # eax = y
    cmpl %eax,%edx         # x : y
    jle L9                 # if <= goto L9
    movl %edx,%eax         # eax = x
L9:                        # Done:
```

Skipped when x <= y

%edx is less than or equal with %eax

When a function ends, the value of %eax is the return value

Conditional Branch (3)

```
int positive(int x)
{
  if (x > 0)
    rval = 1;
  else
    rval = 0;
  return rval;
}
```

Conditional Branch (3)

```
int positive(int x)
{
  if (x > 0)
    rval = 1;
  else
    rval = 0;
  return rval;
}
```

```
      movl 8(%ebp), %edx       # edx = x
      cmpl $0, %edx            # x : 0
      jle L9                   # if <= goto L9
      movl $1, %eax            # rval = 1
   L9:
      movl $0, %eax            # rval = 0
```

%edx is less than or equal with $0

Conditional Branch (4)

```
int positive(int x)
{
  int rval;
  if (x > 0)
    rval = 1;
  else
    rval = 0;
  return rval;
}
```

```
int positive(int x)
{
  int rval = 0;
  if (x <= 0)
    goto L9;
  rval = 1;
L9:
  return rval;
}
```

```
    movl 8(%ebp), %edx      # edx = x
    movl $0, %eax           # rval = 0
    cmpl $0, %edx           # x : 0
    jle L9                  # if <= goto L9
    movl $1, %eax           # rval =1
L9:
```

%edx is less than or equal with $0

Ex.

What does this code mean?

```
_func:
   pushl %ebp                  # setup
   movl %esp,%ebp              # setup

   movl 8(%ebp),%edx
   movl 12(%ebp),%eax
   cmpl %eax, %edx
   jg L9
   je L10
   movl %edx,%eax
L10:
   movl $0,%eax
L9:

   movl %ebp,%esp              # finish
   popl %ebp                   # finish
   ret                         # finish
```

```
int func (int x, int y)
{
```

Looping statements

```
int total () {
  int sum = 0, x = 1;
  do {
    sum = sum + x;
    x = x + 1;
  } while (x <= 10);
  return sum;
}
```

```
int total () {
  int sum = 0, x = 1;
  while (x <= 10) {
    sum = sum + x;
    x = x + 1;
  }
  return sum;
}
```

```
int total () {
  int sum = 0, int x;
  for ( x = 1; x <= 10; x++) {
    sum = sum + x;
  }
  return sum;
}
```

```
int total () {
  int sum = 0, x = 1;
loop:
  sum = sum + x;
  x = x + 1;
  if (x <= 10)
    goto loop;
  return sum;
}
```

"Do-While" Loop (1)

C Code

```
int fact_do (int x)
{
  int result = 1;
  do {
    result *= x;
    x = x - 1;
  } while (x > 1);
  return result;
}
```

Goto Version

```
int fact_goto (int x)
{
  int result = 1;
loop:
  result *= x;
  x = x - 1;
  if (x > 1)
    goto loop;
  return result;
}
```

- Use backward branch to continue looping
- Only take branch when "while" condition holds

"Do-While" Loop (2)

Goto Version

```
int fact_goto (int x)
{
  int result = 1;
loop:
  result *= x;
  x = x - 1;
  if (x > 1)
    goto loop;
  return result;
}
```

Registers

%edx	x
%eax	result

Assembly

```
_fact_goto:
   pushl %ebp            # Setup
   movl %esp,%ebp        # Setup

   movl $1,%eax          # eax = 1
   movl 8(%ebp),%edx     # edx = x
L11:
   imull %edx,%eax       # result *= x
   decl %edx             # x--
   cmpl $1,%edx          # Compare x : 1
   jg L11                # if > goto loop

   movl %ebp,%esp        # Finish
   popl %ebp             # Finish
   ret                   # Finish
```

"Do-While" Loop (3)

General "Do-While" translation

C Code

```
do
  Body
while (Test);
```

Goto Version

```
loop:
  Body
  if (Test)
    goto loop
```

- Body can be any C statement
  - Typically compound statement:

```
{
  Statement_1;
  Statement_2;
    …
  Statement_n;
}
```

- Test is expression returning integer

  = 0 interpreted as false
  ≠ 0 interpreted as true

"While" Loop (1)

C Code

```
int fact_while (int x)
{
  int result = 1;
  while (x > 1) {
    result *= x;
    x = x - 1;
  };
  return result;
}
```

First Goto Version

```
int fact_while_goto (int x)
{
  int result = 1;
loop:
  if (!(x > 1))
    goto done;
  result *= x;
  x = x - 1;
  goto loop;
done:
  return result;
}
```

- Is this code equivalent to the do-while version?
- Must jump out of loop if test fails

"While" Loop (2)

First Goto Version

```
int fact_while_goto (int x)
{
  int result = 1;
loop:
  if (!(x > 1))
    goto done;
  result *= x;
  x = x - 1;
  goto loop;
done:
  return result;
}
```

Second Goto Version

```
int fact_while_goto2 (int x)
{
  int result = 1;
  if (!(x > 1))
    goto done;
loop:
  result *= x;
  x = x - 1;
  if (x > 1)
    goto loop;
done:
  return result;
}
```

- Historically used by GCC
- Uses same inner loop as do-while version
- Guards loop entry with extra test

"While" Loop (3)

General "While" translation

C Code

```
while (Test)
  Body
```

Do-While Version

```
  if (!Test)
    goto done;
  do
    Body
  while(Test);
done:
```

Goto Version

```
  if (!Test)
    goto done;
loop:
  Body
  if (Test)
    goto loop;
done:
```

C Code

```
do
  Body
while (Test);
```

Goto

```
loop:
  Body
  if (Test)
    goto loop
```

"While" Loop (4)

Second Goto Version

```c
int fact_while_goto2
(int x)
{
  int result = 1;
  if (!(x > 1))
    goto done;
loop:
  result *= x;
  x = x - 1;
  if (x > 1)
    goto loop;
done:
  return result;
}
```

Assembly

```
_fact_while_goto2:
   pushl %ebp             # Setup
   movl %esp,%ebp         # Setup

   movl $1,%eax           # eax = 1
   movl 8(%ebp),%edx      # edx = x
   cmpl $1,%edx           # x : 1
   jle L9                 # (!(x > 1))
L11:
   imull %edx,%eax        # result *= x
   decl %edx              # x--
   cmpl $1,%edx           # Compare x : 1
   jg L11                 # if > goto loop
L9:

   movl %ebp,%esp         # Finish
   popl %ebp              # Finish
   ret                    # Finish
```

"Do-While" Loop vs. "While" Loop

Goto Version

```
int fact_goto (int x)
{
  int result = 1;
loop:
  result *= x;
  x = x - 1;
  if (x > 1)
    goto loop;
  return result;
}
```

Second Goto Version

```
int fact_while_goto2
(int x)
{
  int result = 1;
  if (!(x > 1))
    goto done;
loop:
  result *= x;
  x = x - 1;
  if (x > 1)
    goto loop;
done:
  return result;
}
```

"Do-While" Loop vs. "While" Loop

Assembly

```
_fact_goto:
   pushl %ebp           # Setup
   movl %esp,%ebp       # Setup

   movl $1,%eax         # eax = 1
   movl 8(%ebp),%edx    # edx = x
L11:
   imull %edx,%eax      # result *= x
   decl %edx            # x--
   cmpl $1,%edx         # Compare x : 1
   jg L11               # if > goto loop

   movl %ebp,%esp       # Finish
   popl %ebp            # Finish
   ret                  # Finish
```

Assembly

```
_fact_while_goto2:
   pushl %ebp           # Setup
   movl %esp,%ebp       # Setup

   movl $1,%eax         # eax = 1
   movl 8(%ebp),%edx    # edx = x
   cmpl $1,%edx         # x : 1
   jle L9               # (!(x > 1))
L11:
   imull %edx,%eax      # result *= x
   decl %edx            # x--
   cmpl $1,%edx         # Compare x : 1
   jg L11               # if > goto loop
L9:

   movl %ebp,%esp       # Finish
   popl %ebp            # Finish
   ret                  # Finish
```

"For" Loop (1)

```
/* Compute x raised to nonnegative power p */
int ipwr_for(int x, unsigned p) {
  int result;
  for (result = 1; p != 0; p = p >> 1) {
    if (p & 0x1)
      result *= x;
    x = x * x;
  }
  return result;
}
```

Algorithm

- Exploit property that $p = p_0 + 2p_1 + 4p_2 + 8p_3 + \ldots 2^{n-1}p_{n-1}$
- Gives: $x^p = z_0 \cdot z_1{}^2 \cdot (z_2{}^2)^2 \cdot ((z_3{}^2)^2)^2 \cdot \ldots \cdot (\ldots((z_{n-1}{}^2)^2)\ldots)^2$
  - $z_i = 1$ when $p_i = 0$
  - $z_i = x$ when $p_i = 1$
- Complexity $O(\log p)$

Example

$3^{10} = 3^2 * 3^8$

$= 3^2 * ((3^2)^2)^2$

"For" Loop (2)

```
int result;
for (result = 1; p != 0; p = p >> 1)
{
  if (p & 0x1)
    result *= x;
  x = x * x;
}
```

General Form

```
for (Init; Test; Update )

    Body
```

Init

```
result = 1
```

Test

```
p != 0
```

Body

```
{
  if (p & 0x1)
    result *= x;
  x = x * x;
}
```

Update

```
p = p >> 1
```

"For" Loop (3)

For Version

```
for (Init; Test; Update )

    Body
```

While Version

```
Init;
while (Test ) {
    Body
    Update ;
}
```

Do-While Version

```
  Init;
  if (!Test)
    goto done;
  do {
    Body
    Update ;
  } while (Test)
done:
```

Goto Version

```
  Init;
  if (!Test)
    goto done;
loop:
  Body
  Update ;
  if (Test)
    goto loop;
done:
```

"For" Loop (4)

Goto Version

```
  Init;
  if (!Test)
    goto done;
loop:
  Body
  Update ;
  if (Test)
    goto loop;
done:
```

→

```
  result = 1;
  if (p == 0)
    goto done;
loop:
  if (p & 0x1)
    result *= x;
  x = x * x;
  p = p >> 1;
  if (p != 0)
    goto loop;
done:
```

Init

```
result = 1
```

! Test

```
p == 0
```

Body

```
{
  if (p & 0x1)
    result *= x;
  x = x * x;
}
```

Update

```
p = p >> 1
```

Test

```
p != 0
```

"For" Loop (5)

je	ZF
jne	~ZF

```
int ipwr_for(int x,
unsigned p) {

  int result = 1;
  if (p == 0)
    goto done;
loop:
  if (p & 0x1)
    result *= x;
  x = x * x;
  p = p >> 1;
  if (p != 0)
    goto loop;
done:
  return result;

}
```

```
_ipwr_for:
    pushl %ebp                  # Setup
    movl %esp,%ebp              # Setup

    movl 8(%ebp), %ecx          # %ecx = x
    movl 12(%ebp), %edx         # %edx = p
    movl $1, %eax               # result = 1
    cmpl $0, %edx               # (p == 0)
    je L2
L5:
    testb $1, %dl               # (p & 0x1)
    je L4                       # (p & 0x1) == 0
    imull %ecx, %eax            # result = result * x
L4:
    imull %ecx, %ecx            # x = x * x
    shrl $1, %edx               # p = p >> 1
    jne L5                      # p != 0
L2:

    movl %ebp,%esp              # Finish
    popl %ebp                   # Finish
    ret                         # Finish
```

switch vs. if-then-else

```
char change (int x) {
  if (x==0)
    return '+';
  else if (x==1)
    return '-';
  else if (x==2)
    return '*';
  else if (x==3)
    return '/';
}
```

```
char change (int x) {
  switch (x) {
    case 0 :  return '+';
    case 1 :  return '*';
    case 2 :  return '-';
    case 3 :  return '/';
  }
}
```

Bug in example code ?

"Switch" Statement (1)

Implementation options

1. Series of conditionals
   - Good if few cases
   - Slow if many
2. Jump table
   - Lookup branch target
   - Avoids conditionals
   - Possible when cases are small integer constants

- GCC
  - Picks one based on case structure

```
typedef enum {
   ADD, MULT, MINUS, DIV,
   MOD, BAD
}  op_type;

char unparse_symbol
(op_type op) {
  switch (op) {
  case ADD :  return '+';
  case MULT:  return '*';
  case MINUS: return '-';
  case DIV:   return '/';
  case MOD:   return '%';
  case BAD:   return '?';
  }
}
```

"Switch" Statement (2)

Jump table structure

Switch Form

```
switch(op) {
  case val_0:
    Block 0
  case val_1:
    Block 1
    • • •
  case val_n-1:
    Block n–1
}
```

Jump Table

jtab:

Targ0
Targ1
Targ2
• • •
Targ*n*–1

Jump Targets

Targ0: Code Block 0

Targ1: Code Block 1

• • •

Targ*n*–1: Code Block *n*–1

Approx. Translation

```
target = JTab[op];
goto *target;
```

"Switch" Statement (3)

Branching Possibilities

```
typedef enum {
   ADD, MULT, MINUS, DIV, MOD, BAD
}  op_type;

char unparse_symbol(op_type op)
{
  switch (op) {
    • • •
  }
}
```

Enumerated Values

ADD	0
MULT	1
MINUS	2
DIV	3
MOD	4
BAD	5

```
unparse_symbol:
   pushl %ebp              # Setup
   movl %esp,%ebp          # Setup

   movl 8(%ebp),%eax       # eax = op
   cmpl $5,%eax            # Compare op : 5
   ja .L49                 # If > goto done
   jmp *.L57(,%eax,4)      # goto Table[op]
```

"Switch" Statement (4)

```
unparse_symbol:
    pushl %ebp              # Setup
    movl %esp,%ebp          # Setup

    movl 8(%ebp),%eax       # eax = op
    cmpl $5,%eax            # Compare op : 5
    ja .L49                 # If > goto done
    jmp *.L57(,%eax,4)      # goto Table[op]
```

Symbolic labels

- Labels of form .LXX translated into addresses by assembler

Table structure

- Each target requires 4 bytes, Base address at **.L57**

Jumping

- **jmp .L49**
  - Jump target is denoted by label **.L49**
- **jmp *.L57(,%eax,4)**
  - Start of jump table denoted by label **.L57**
  - Register **%eax** holds **op**
  - Must scale by factor of 4 to get offset into table
  - Fetch target from effective address **.L57 + op * 4**

"Switch" Statement (5)

```
jmp *.L57(,%eax,4)
```

Table Contents

```
.section .rodata
   .align 4
.L57:
  .long .L51   #Op = 0
  .long .L52   #Op = 1
  .long .L53   #Op = 2
  .long .L54   #Op = 3
  .long .L55   #Op = 4
  .long .L56   #Op = 5
```

Enumerated Values

```
ADD      0
MULT     1
MINUS    2
DIV      3
MOD      4
BAD      5
```

Targets & Completion

```
.L51:
      movl $43, %eax   # '+'
      jmp .L49
.L52:
      movl $42, %eax   # '*'
      jmp .L49
.L53:
      movl $45, %eax   # '-'
      jmp .L49
.L54:
      movl $47, %eax   # '/'
      jmp .L49
.L55:
      movl $37, %eax   # '%'
      jmp .L49
.L56:
      movl $63, %eax   # '?'
      # Fall Through to .L49
```

"Switch" Statement (6)

Switch statement completion

```
.L49:                        # Done:
     movl %ebp,%esp          # Finish
     popl %ebp               # Finish
     ret                     # Finish
```

- What value returned when op is invalid?
  - Register %eax set to op at beginning of procedure
  - This becomes the return value

Advantage of jump table

- Can do k-way branch in O(1) operations

"Switch" Statement (7)

```
unparse_symbol:
    pushl %ebp           # Setup
    movl %esp,%ebp       # Setup

    movl 8(%ebp),%eax    # eax = op
    cmpl $5,%eax         # Compare op : 5
    ja .L49              # If > goto done
    jmp *.L57(,%eax,4)   # goto Table[op]

.section .rodata
   .align 4
.L57:
  .long .L51     #Op = 0
  .long .L52     #Op = 1
  .long .L53     #Op = 2
  .long .L54     #Op = 3
  .long .L55     #Op = 4
  .long .L56     #Op = 5
```

```
.L51:
     movl $43, %eax      # '+'
     jmp .L49
.L52:
     movl $42, %eax      # '*'
     jmp .L49
.L53:
     movl $45, %eax      # '-'
     jmp .L49
.L54:
     movl $47, %eax      # '/'
     jmp .L49
.L55:
     movl $37, %eax      # '%'
     jmp .L49
.L56:
     movl $63, %eax      # '?'
     # Fall Through to .L49

.L49:                   # Done:
     movl %ebp,%esp     # Finish
     popl %ebp          # Finish
     ret                # Finish
```

"Switch" Statement (8)

Sparse switch example

- Not practical to use jump table
  - Would require 1000 jump table entries
- Obvious translation into if-then-else would have max. of 10 tests

```
/* Return x/111 if x is
   multiple of 111 && <= 999.
   Return -1 otherwise */
int div111(int x) {
  switch(x) {
  case   0: return 0;
  case 111: return 1;
  case 222: return 2;
  case 333: return 3;
  case 444: return 4;
  case 555: return 5;
  case 666: return 6;
  case 777: return 7;
  case 888: return 8;
  case 999: return 9;
  default: return -1;
  }
}
```

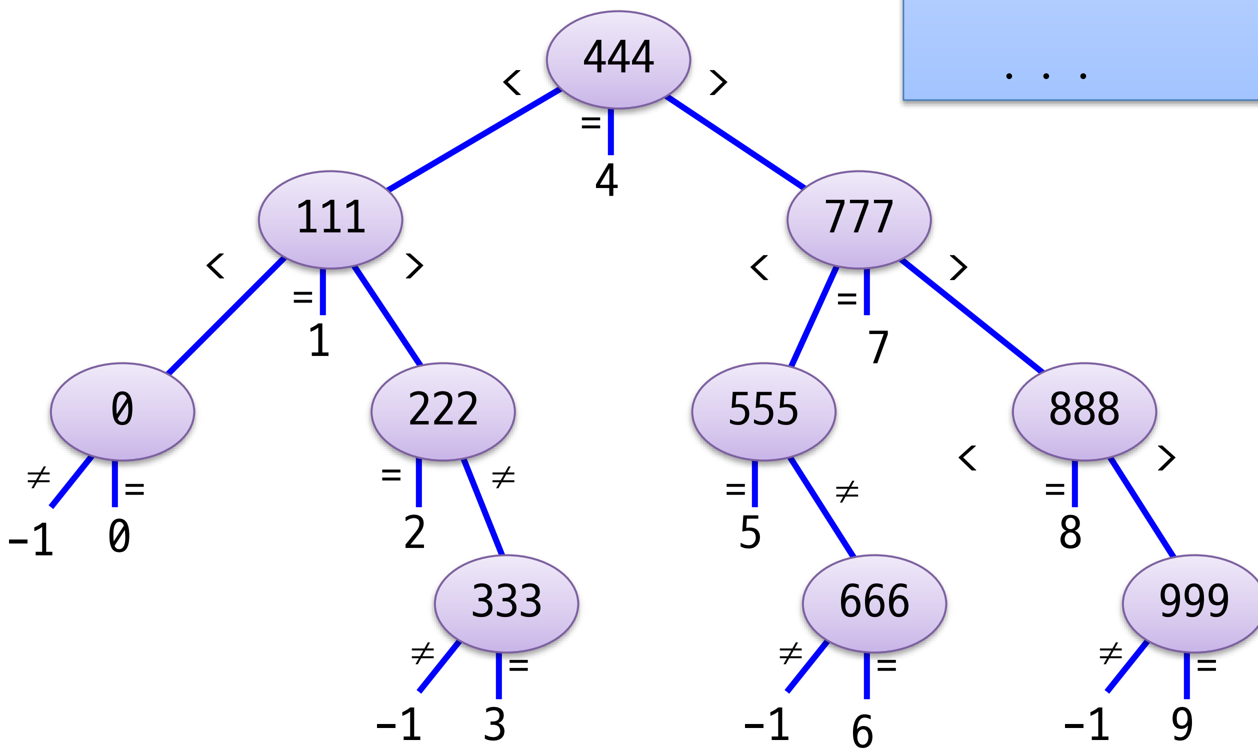
"Switch" Statement (9)

Sparse switch code structure

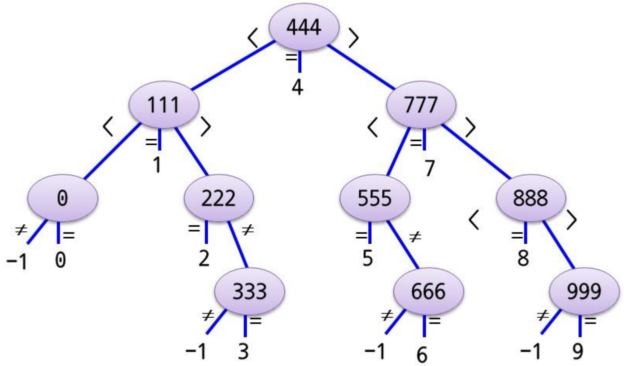
- Organizes cases as binary tree
- Logarithmic performance

```
movl 8(%ebp),%eax      # get x
cmpl $444,%eax         # x:444
je L8
jg L16
cmpl $111,%eax         # x:111
je L5
jg L17
testl %eax,%eax        # x:0
je L4
jmp L14

. . .
```



"Switch" Statement (10)



- Compares x to possible case values
- Jumps different places depending on outcomes

```
    movl 8(%ebp),%eax      # get x
    cmpl $444,%eax         # x:444
    je L8
    jg L16
    cmpl $111,%eax         # x:111
    je L5
    jg L17
    testl %eax,%eax        # x:0
    je L4
    jmp L14

    . . .
```

```
    . . .
L5:
    movl $1,%eax
    jmp L19
L6:
    movl $2,%eax
    jmp L19
L7:
    movl $3,%eax
    jmp L19
L8:
    movl $4,%eax
    jmp L19
    . . .
```

- We can finish it in max. 4 comparisons

Summary

C Control

- if-then-else
- do-while
- while, for
- switch

Assembler control

- Jump
- Conditional jump
- Indirect jump

Compiler

- Must generate assembly code to implement more complex control

Summary

Standard techniques

- All loops converted to do-while form and goto style
- Large switch statements use jump tables

Conditions in CISC

- CISC machines generally have condition code registers

Conditions in RISC

- Use general registers to store condition information
- Special comparison instructions
- E.g., on Alpha: cmple $16, 1, $1
  - Sets register $1 to 1 when $16 <= 1

Ex.

What does this code mean?

```
_func:
   pushl %ebp              # Setup
   movl %esp,%ebp          # Setup

   movl $0,%eax
   movl 8(%ebp),%edx

L11:
   addl %edx,%eax
   incl %edx
   cmpl $10,%edx
   jg L11

   movl %ebp,%esp          # Finish
   popl %ebp               # Finish
   ret                     # Finish
```

```
int func (int x)
{
```