Assembly Programing with NASM *(and GAS)*

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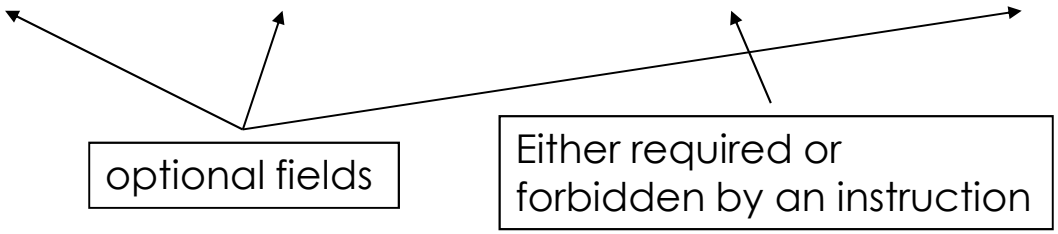
NASM Data Directives

```
    L3      db              110101b         ; byte
▶   L4      db              12h             ; byte
▶   L5      db              17o             ; byte
▶   L6      dd              1A92h           ; double word
▶   L7      resb            1               ; uninitialized byte
▶   L8      db              'A'             ; ascii code = 'A'
▶   L9      db              0,1,2,3         ; 4 bytes
▶   L10     db              'w','o','r','d',0   ; string
▶   L11     db              'word', 0
▶   L12     times 100 db    0               ; 100 bytes of zero
▶   L13     resw            100             ; 100*2(word bytes)
```

Data Types in IA32 (AT&T format)

`short`	Word	`w`	2
`int`	Double word	`l`	4
`long int`	Double word	`l`	4
`long long int`	—	—	4
`char *`	Double word	`l`	4
`float`	Single precision	`s`	4
`double`	Double precision	`l`	8
`long double`	Extended precision	`t`	10/12

Instruction Basics



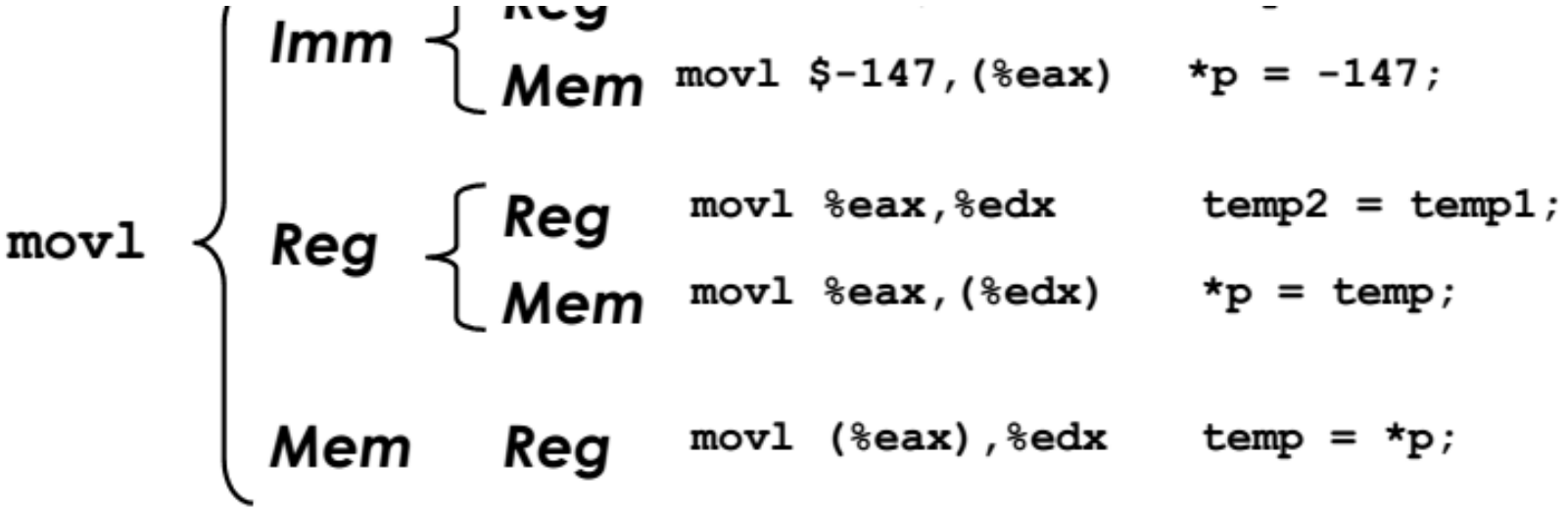
1. **Backslash (\)** uses as the line continuation character: if a line ends with backslash, the next line is considered to be a part of the backslash-ended line.
2. **No restrictions on white space** within a line.
3. A colon after a label is optional.

Example Program

```
3       int t = *xp + y;
4       *xp = t;
5       return t;
6   }
```

```
4       movl    8(%ebp), %edx     Retrieve xp
5       movl    12(%ebp), %eax    Retrieve y
6       addl    (%edx), %eax      Add *xp to get t
7       movl    %eax, (%edx)      Store t at xp
8       popl    %ebp              Restore frame pointer
9       ret                       Return
```

Operand Modes



NASM Data Directives

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    L8      db          'A'             ; ascii code = 'A'
    L9      db          0,1,2,3         ; 4 bytes
    L10     db          'w','o','r','d',0   ; string
    L11     db          'word', 0
    L12     times 100 db    0           ; 100 bytes of zero
    L13     resw        100             ; 100*2(word bytes)
```

Examples

- Mov [L1], ah ; copy ah into byte at L1
- Mov eax, [L6] ; copy double word
- Add eax, [L6] ; eax = eax + double word at L6
- Add [L6], eax ; double word at L6 += eax
- Mov al, [L6] ; copy first byte of double word at L6 into al
- Mov [L6], 1 ; operation size is not specified
- Mov dword [L6], 1 ; store a 1 at L6

Instructions: Setup

- Also used for making subprogram calls, passing parameters and local variables.

- Data can only be added in double word units

- PUSH
  - inserts a double word on the stack by **subtracting 4 from ESP**
  - And then stores the double word at [ESP]

Instructions: Setup

- And then adds 4 to ESP

- CALL
  - Call subprogram
  - Make an unconditional jump to a subprogram
  - And pushes the address of the next instruction on the stack

Instructions: Setup

- And jumps to that address.

- When using this inst.: It is very important that one manage the stack correctly so that **the right number is popped off by the RET**.

Example

```
{
  int t0 = *xp;
  int t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```

```
movl 12(%ebp),%ecx
movl 8(%ebp),%edx
movl (%ecx),%eax
movl (%edx),%ebx
movl %eax,(%edx)
movl %ebx,(%ecx)
```

Body

```
movl -4(%ebp),%ebx
movl %ebp,%esp
popl %ebp
ret
```

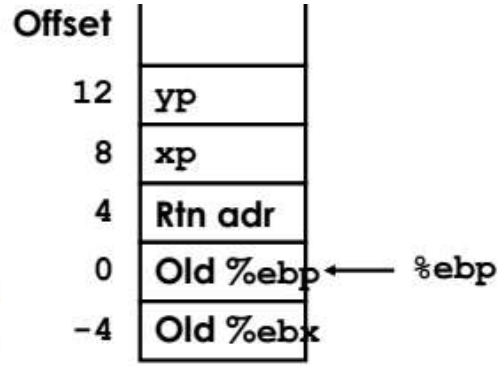
Finish

Example (contd.)

Register	Variable
%ecx	yp
%edx	xp
%eax	t1
%ebx	t0

```
    *xp = t1;
    *yp = t0;
}
```

```
movl 12(%ebp),%ecx   # ecx = yp
movl 8(%ebp),%edx    # edx = xp
movl (%ecx),%eax     # eax = *yp (t1)
movl (%edx),%ebx     # ebx = *xp (t0)
movl %eax,(%edx)     # *xp = eax
movl %ebx,(%ecx)     # *yp = ebx
```



Example (contd.)

%ecx	
%ebx	
%esi	
%edi	
%esp	
%ebp	0x104

```
movl 8(%ebp),%edx    # edx = xp
movl (%ecx),%eax     # eax = *yp (t1)
movl (%edx),%ebx     # ebx = *xp (t0)
movl %eax,(%edx)     # *xp = eax
movl %ebx,(%ecx)     # *yp = ebx
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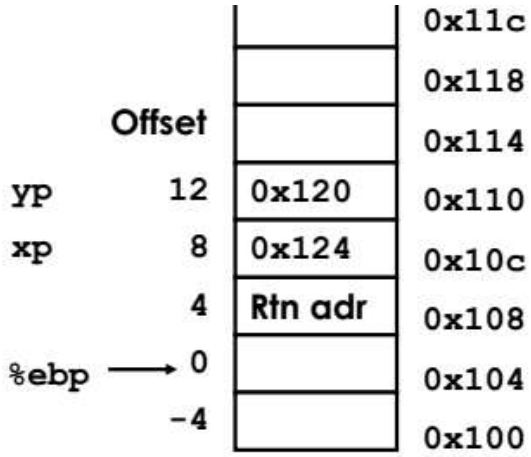

Example (contd.)

%ecx	0x120
%ebx	
%esi	
%edi	
%esp	
%ebp	0x104

```
movl 8(%ebp),%edx     # edx = xp
movl (%ecx),%eax      # eax = *yp (t1)
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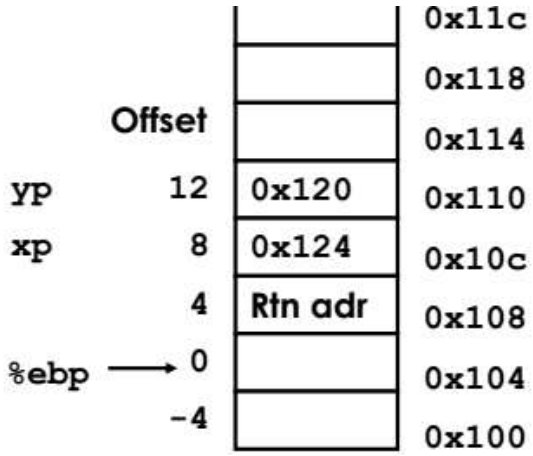
```



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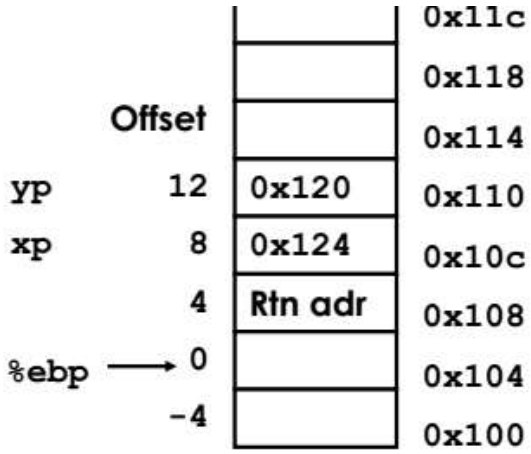

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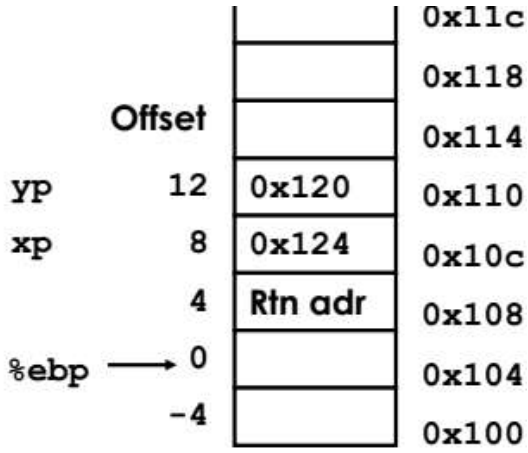
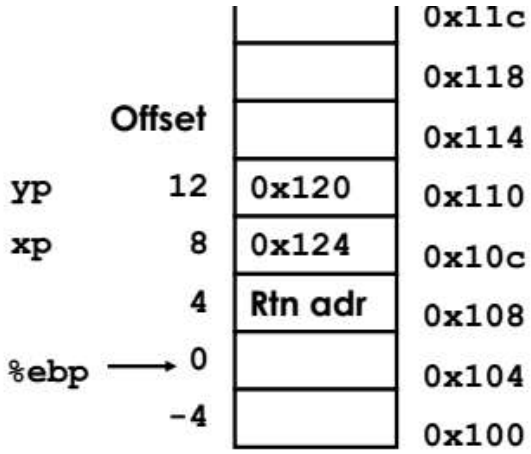
```



Example (contd.)

%ecx	0x120
%ebx	123
%esi	
%edi	
%esp	
%ebp	0x104

```
movl 8(%ebp),%edx     # edx = xp
movl (%ecx),%eax      # eax = *yp (t1)
movl (%edx),%ebx      # ebx = *xp (t0)
movl %eax,(%edx)      # *xp = eax
movl %ebx,(%ecx)      # *yp = ebx
```



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%ebx	123
%esi	
%edi	
%esp	
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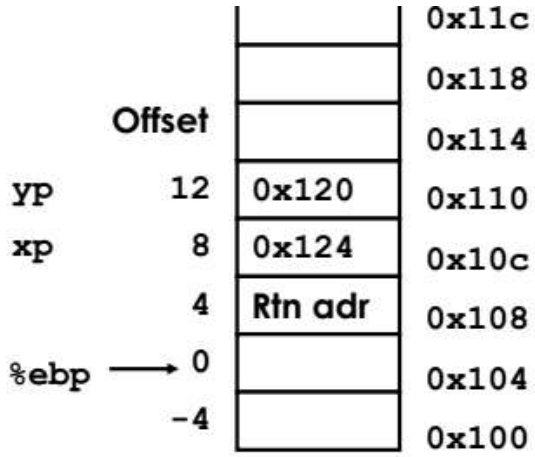

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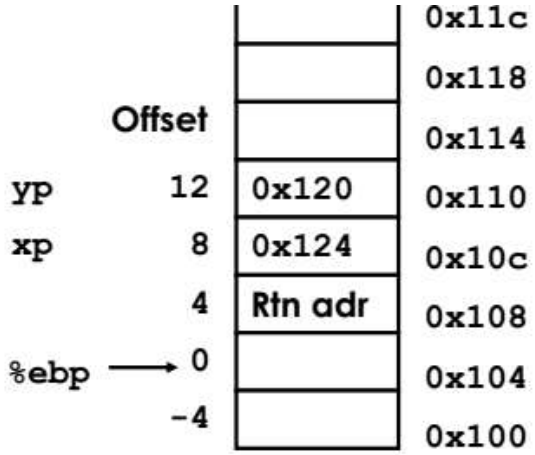


Some Integer Instructions

`addl` *Src,Dest*	*Dest* = *Dest* + *Src*	
`subl` *Src,Dest*	*Dest* = *Dest* – *Src*	
`imull` *Src,Dest*	*Dest* = *Dest* * *Src*	
`sall` *k,Dest*	*Dest* = *Dest* << *k*	Also called `shll`
`sarl` *k,Dest*	*Dest* = *Dest* >> *k*	Arithmetic
`shrl` *k,Dest*	*Dest* = *Dest* >> *k*	Logical

k is an immediate value or contents of %cl

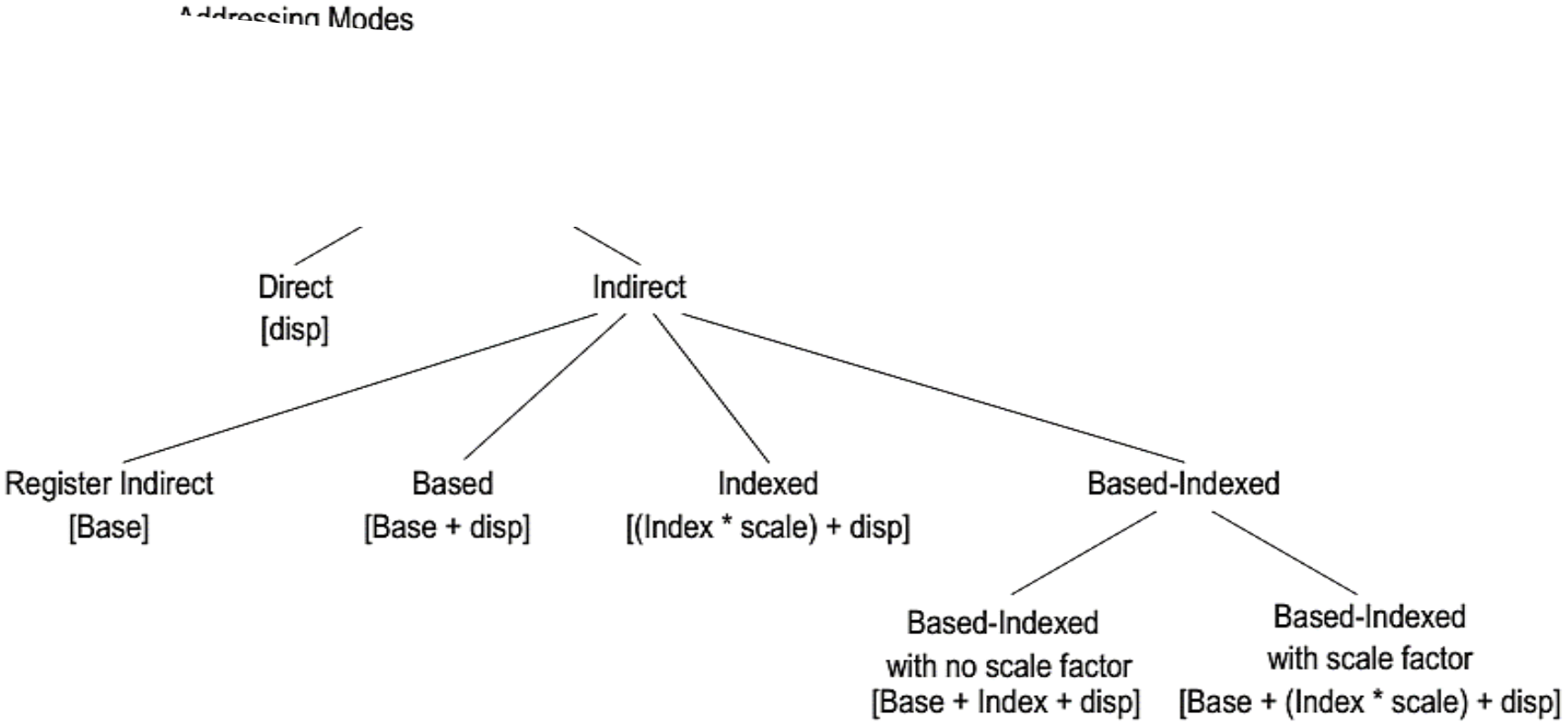
Some Integer Instructions

`xorl`	*Src,Dest*	*Dest* = *Dest* ^ *Src*
`andl`	*Src,Dest*	*Dest* = *Dest* & *Src*
`orl`	*Src,Dest*	*Dest* = *Dest* | *Src*

Some Integer Instructions

`incl` *Dest*	*Dest* = *Dest* + 1
`decl` *Dest*	*Dest* = *Dest* - 1
`negl` *Dest*	*Dest* = -*Dest*
`notl` *Dest*	*Dest* = ~*Dest*

Addressing modes (32-bits)



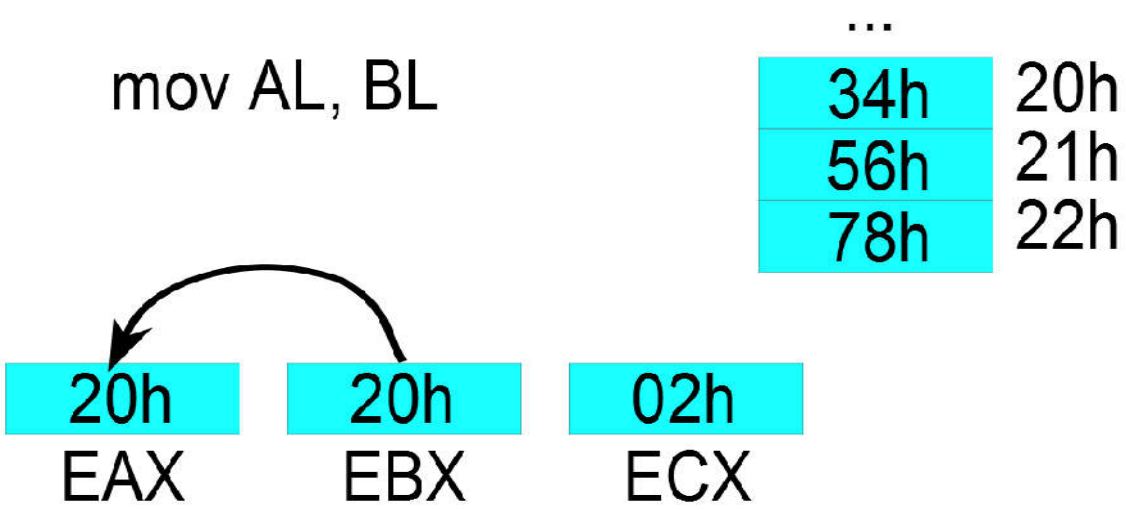
Operands in X86 (NASM)

- Immediate: **MOV EAX, 10h**
  - *Copy* constant to register
- Memory: different addressing modes
  - Typically at most one memory operand
  - Complex address computation supported

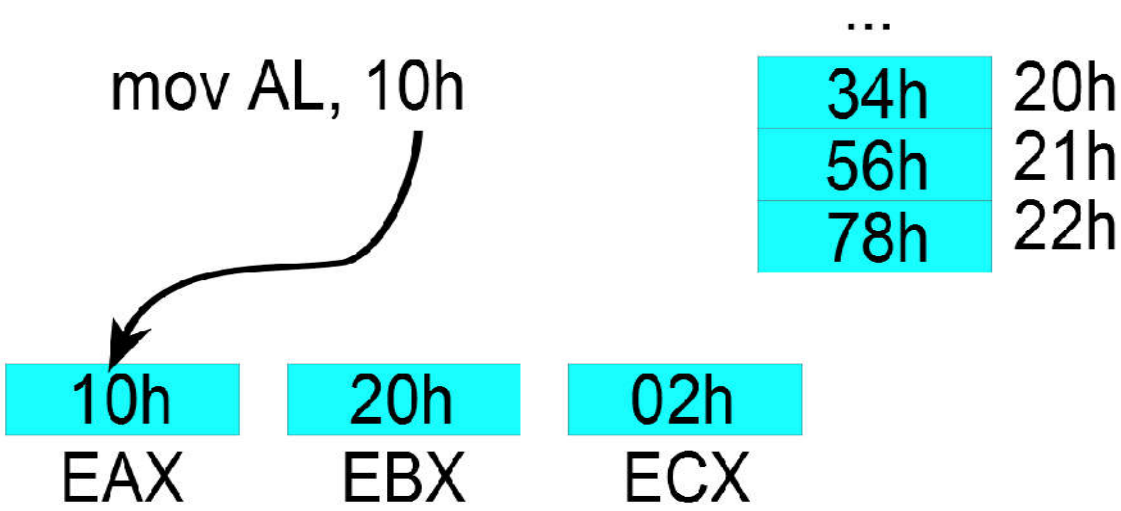
Addressing modes

- Indirect: **MOV EAX, [EBX]**
  - *Copy* value pointed to by register BX
- Indexed: **MOV AL, [EBX + ECX * 4 + 10h]**
  - *Copy* value from array (BX[4 * CX + 0x10])
- Pointers can be associated to type
  - **MOV AL, byte ptr [BX]**

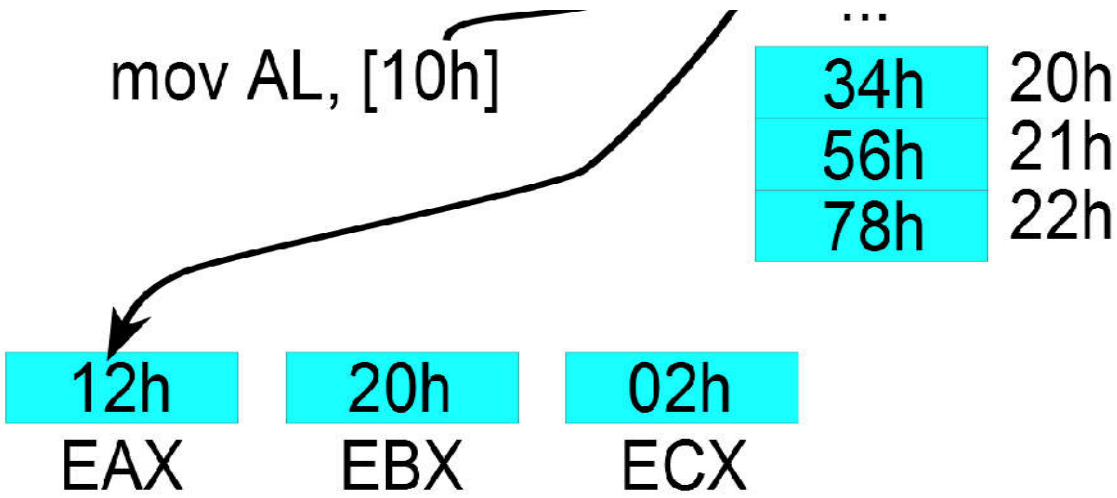
Operands and addressing modes: Register



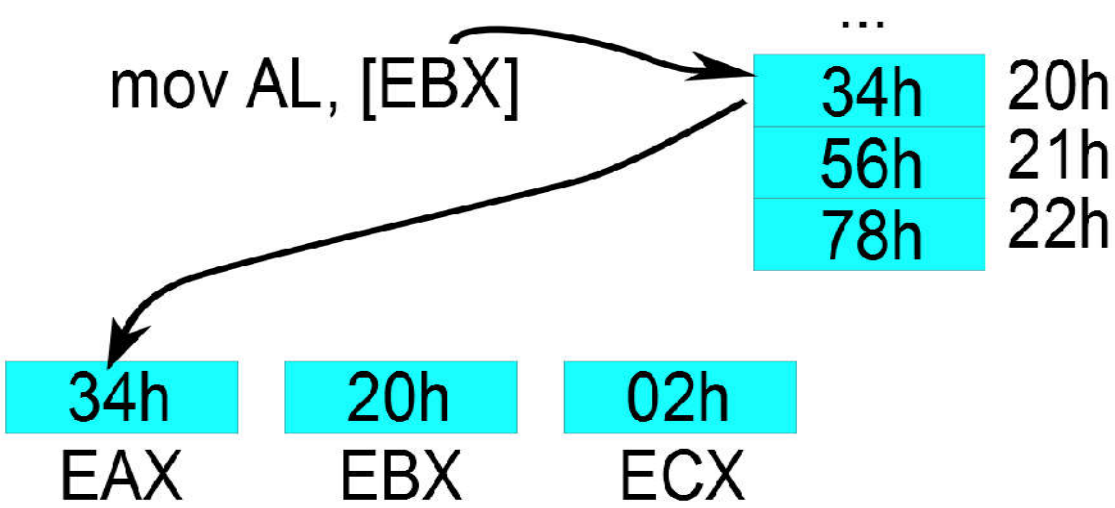
Operands and addressing modes: Immediate



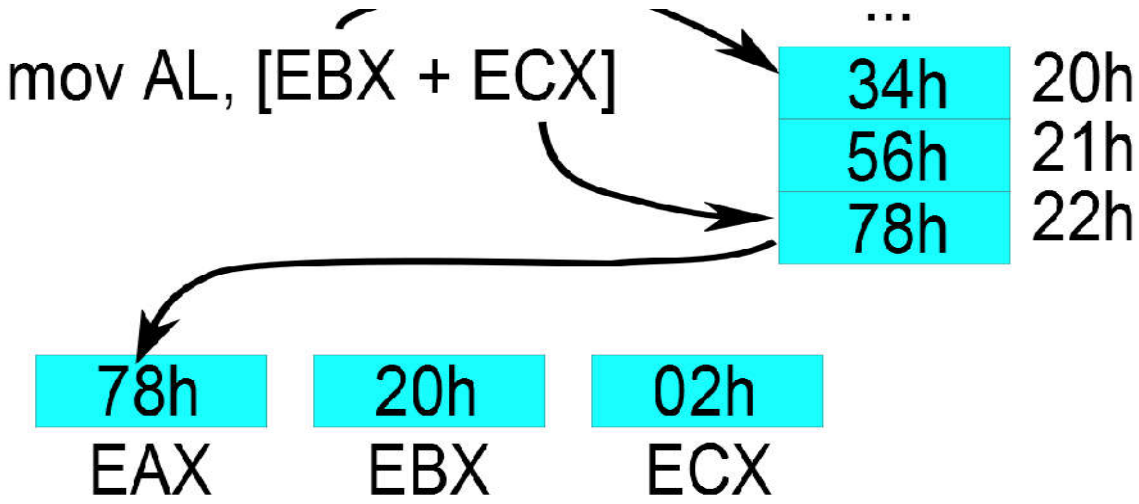
Operands and addressing modes: Direct



Operands and addressing modes: Indirect



Operands and addressing modes: Indexed



Generic 32bit Addressing Mode

SS	EBX	EBX	2	8-bit displacement
DS	ECX	ECX	4	32-bit displacement
ES	EDX	EDX	8	
FS	ESI	ESI		
GS	EDI	EDI		
	EBP	EBP		
	ESP			

Addressing Mode GNU-AS

- Rb: Base register: Any of 8 integer registers
- Ri: Index register: Any, **except for `%esp`**
  - Unlikely you'd use `%ebp`, either
- S: Scale: 1, 2, 4, or 8

GAS - Indexed Addressing Modes

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

Solve the Followings:

0x0(%edx)
(%edx,%ecx)
(%edx,%ecx,4)
0x80(,%edx,2)

- Given:

%edx	0xf000
%ecx	0x100

Another Programing Example

- Print the value
- Add 1 to that
- Print the result

Another Program (1)

```
; set-up phase
        push ebp
        mov ebp, esp

; finish phase
        mov esp, ebp
        pop ebp
        ret
```

Another Program (2)

```
; set-up phase
        push ebp
        mov ebp, esp

; get the command-line data
        mov ebx, DWORD [esp + 12]   ; get argv starting address
        mov ebx, [ebx + 4]          ; get the second argument data

; finish phase
        mov esp, ebp
        pop ebp
        ret
```

Another Program (3)

```
SECTION .text
        extern printf
        global main

main:
; set-up phase
        push ebp
        mov ebp, esp
```

Another Program (3)

```
; print the value
        push ebx                    ; put data on stack for call
        push msg                    ; print the value
        call printf

; finish phase
        add esp, 8                  ; esp back to start
        mov esp, ebp
        pop ebp
        ret
```

Another Program (4)

```
SECTION .text
        extern printf
        extern atoi
        global main

main:
; set-up phase
        push ebp
        mov ebp, esp
```

Another Program (4)

```
; print the value
        push ebx                    ; put data on stack for call
        push msg                    ; print the value
        call printf

; convert to integer
        add esp, 4                  ; stack points to entry edx
        call atoi                   ; call atoi - return in EAX?
```

Another Program (4)

```
; print the result
        push eax                        ; push arg for print
        push msg2                       ; push print message
        call printf

; finish phase
        add esp, 8                      ; esp back to start
        mov esp, ebp
        pop ebp
        ret
```

Another Program (final)

```
SECTION .text
        extern printf
        extern atoi
        global main

main:
; set-up phase
        push ebp
        mov ebp, esp
```

Another Program (final)

```
; print the value
        push ebx                    ; put data on stack for call
        push msg                    ; print the value
        call printf

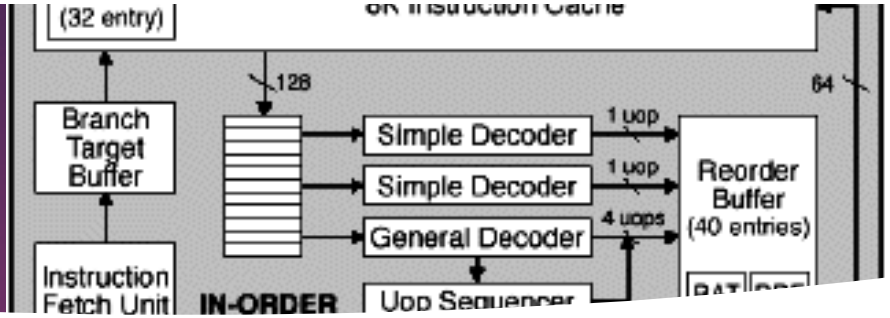
; convert to integer
        add esp, 4                  ; stack points to entry edx
        call atoi                   ; call atoi - return in EAX?
```

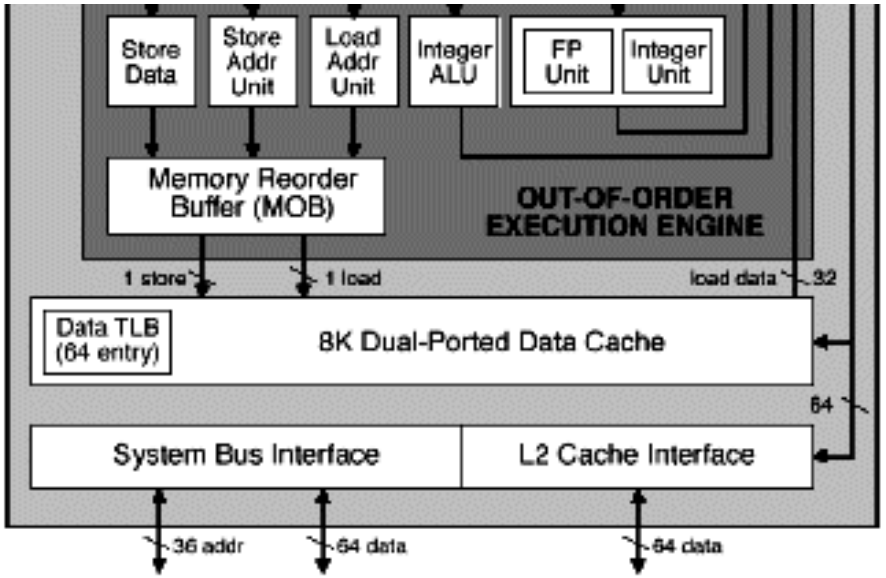
Another Program (final)

```
; print the result
        push eax                        ; push arg for print
        push msg2                       ; push print message
        call printf

; finish phase
        add esp, 8                      ; esp back to start
        mov esp, ebp
        pop ebp
        ret
```

PentiumPro Block Diagram





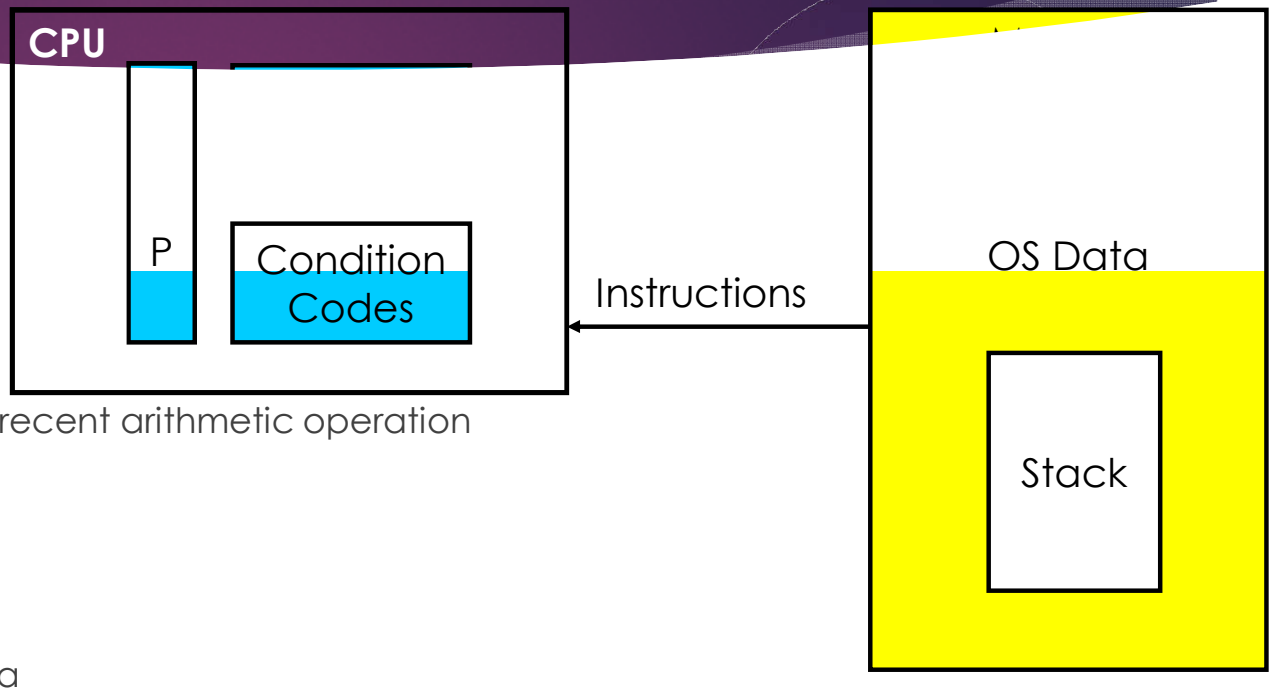
Operations

- Holds
  - Operation 32
  - Two sources, and + 32 + 32
  - Destination + 32 = 128bits **WHY??**
- Executes Uops with **"Out of Order"** engine
  - Uop executed when
    1. Operands are available
    2. Functional unit available

Operations

- Allocates resources
- Consequences
  - Indirect relationship between
    - IA32 code &
    - What actually gets executed
  - Tricky to predict / optimize performance at assembly level

Machine View

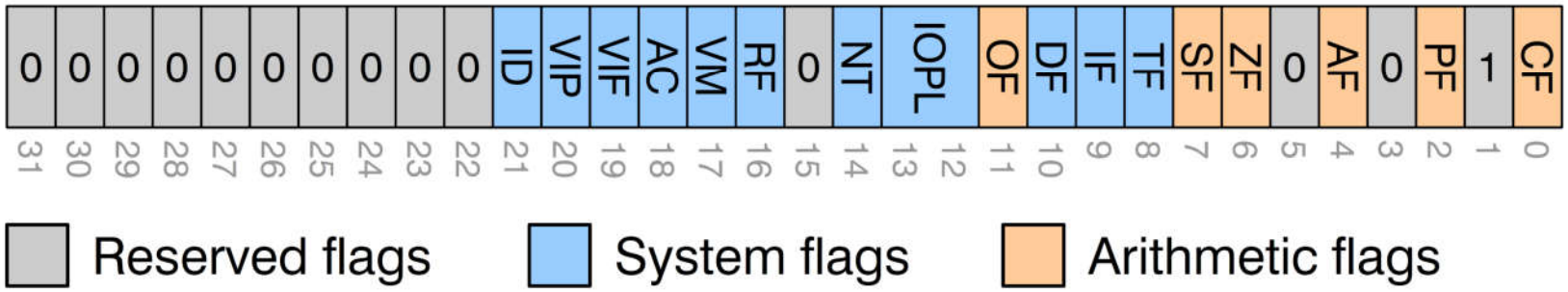


- Heavily used program data
- Condition Codes
  - Store status information about most recent arithmetic operation
  - Used for conditional branching
- Memory
  - Byte addressable array
  - Code, user data, (some) OS data
  - Includes stack used to support procedures

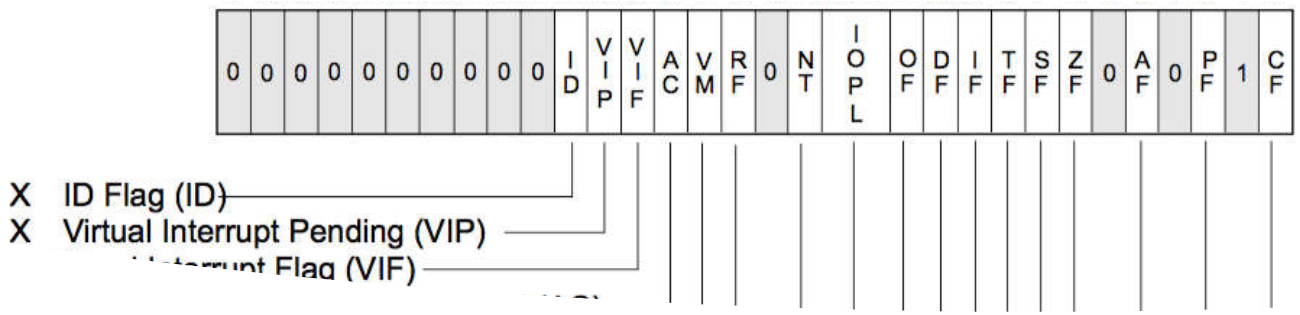
Flow Control Instructions

- Jcc
- CALL
- RET

Revisit EFLAGS



Revisit EFLAGS



S Indicates a Status Flag
C Indicates a Control Flag
X Indicates a System Flag

Reserved bit positions. DO NOT USE.
Always set to values previously read.

JMP: jump

`JMP` *`dest`*

- **Operation (absolute jump)**:

  `EIP` ← *`dest`*

- **Operation (relative jump)**:

  `EIP` ← `EIP` + *`dest`*

-	-	-	-	-	-	-
of	df	sf	zf	af	pf	cf

Unconditional Jumps

- We have two types of jumps,
  - Intersegment
  - Intrasegment
- Address can be in a register, variable or label.

Unconditional Jumps

```
Start:  MOV AX, 0
        INC AX,
        JMP Start
```

Jcc: short jump conditional

`Jcc dest`

- **Operation**:

```
if(cc)
    EIP ← EIP + dest
endif
```

- **Notes:** *cc* is any of the condition codes. *dest* must be within a signed 8-bit range (-128 to 127).

-	-	-	-	-	-	-
of	df	sf	zf	af	pf	cf

Condition Codes

C analog: `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` instruction

Condition Codes

NO	*No Overflow*	`OF=0`
C B NAE	*Carry* *Below* *Not Above nor Equal*	`CF=1`
NC NB AE	*No Carry* *Not Below* *Above or Equal*	`CF=0`

Condition Codes (continued)

E	*Equal*	
NZ NE	*Not Zero* *Not Equal*	`ZF=0`
BE NA	*Below or Equal* *Not Above*	`CF=1 OR ZF=1`
A NBE	*Above* *Not Below nor Equal*	`CF=0 AND ZF=0`

Condition Codes (continued)

NS	*Not Sign*	`SF=0`
P PE	*Parity* *Parity Even*	`PF=1`
NP PO	*Not Parity* *Parity Odd*	`PF=0`

Condition Codes (continued)

NGE	*Not Greater nor Equal*	
GE NL	*Greater or Equal* *Not Less*	SF=OF
LE NG	*Less or Equal* *Not Greater*	ZF=1 OR SF<>OF
G NLE	*Greater* *Not Less nor Equal*	ZF=0 AND SF=OF

Condition Codes (continued)

Conditional Jumps

- Example:

  JZ → jump if zero flag is set.

Conditional Codes

instructions.

Add a value X to eax;
If x < 0
Then
… (body for negative condition)
Else if x = 0
… (body for zero condition)
Else
… (body for positive condition)
End if

Conditional Codes

```
            JNS elseIfZero      ;jump if eax is not negative
            …                   ; code for negative condition
            JMP endCheck
elseifZero:
            JNZ elsePos         ; jump if x is not zero
            …                   ; code for zero condition
            JMP endCheck
elsePos: …                      ; code for positive balance
endCheck:
```

Conditional Codes

```
            …                   ; code for negative condition
            JMP endCheck
elseifZero:
            JNZ elsePos         ; jump if x is not zero
            …                   ; code for zero condition
            JMP endCheck
elsePos:
            …                   ; code for positive balance
endCheck:
```

Then

… (body for negative condition)

Else if x = 0

… (body for zero condition)

Else

… (body for positive condition)

End if

Setting Codes

- like computing ***Src1–Src2*** without setting destination

- **CF** set if carry out from most significant bit
  - Used for unsigned comparisons
- **SF** set if `(a-b) < 0`
- **ZF** set if `a == b`
- **OF** set if two's complement overflow

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

Compare Examples

- CF=OF=SF=0
- ZF=1

- OP1==OP2 signed and unsigned

Compare Examples

- OP1-OP2= 26
- CF=OF=SF=ZF=0

- OP1>OP2 signed and unsigned

Compare Examples

- OP1-OP2= 1F

```
 0001 0101
+0000 1010
 0001 1111 = 1F
```

- SF= OF= ZF= 0s
- Signed operation = op1>op2
- CF= (1 – borrow)
- Unsigned operation =op1 < op2

Compare Examples

cmp value, 03dh

Cmp bh, '$'

Illegal examples

Cmp 1000, total

Compare Programming Ex.

```
Then
   add 1 to xcount;
Else
  add 1 to ycount;
End if;
```

Compare Programming Ex

```
    cmp ebx, 10          ;value < 10
    jnl Elsey
    inc xcount           ;add 1 to xcount
    jmp endVal
Elsey:
    inc ycount           ;add 1 to ycount
endVal:
```

Compare Examples for JNL

- OP1-OP2=80
- **SF=1**
- **OF=1**
- ZF=0
- Signed operation: **op1>=op2**
- Unsigned operation =op1 < op2

```
 0111 1111
+0000 0001
 1000 0000   = 80
```

Instruction: Test

```
test  Src1, Src2
```

- Sets condition codes based on value of: ***Src1 & Src2***
  - Useful to have one of the operands be a mask
- `testl b,a`
  - like computing **`a&b`** without setting destination

Instruction: Test

- AL/AX/EAX (only if **Src2** is immediate)
- Register
- Memory

- ***Src2***
  - Register
  - Immediate

Instruction: Test

- `If (Temp == 0) ZF = 1 else ZF = 0`
- `PF = BitWiseXorNor(Temp[Max-1:0])`
- `CF = 0`
- `OF = 0`
- `AF is undefined`

Set on Condition (setcc reg8)

	Description	Condition	Comment
			SETAE
SETZ	Set if zero	Zero = 1	Same as SETE
SETNZ	Set if not zero	Zero = 0	Same as SETNE
SETS	Set if sign	Sign = 1	-
SETNS	Set if no sign	Sign = 0	-
SETO	Set if overflow	Overflow=1	-
SETNO	Set if no overflow	Overflow=0	-
SETP	Set if parity	Parity = 1	Same as SETPE
SETPE	Set if parity even	Parity = 1	Same as SETP
SETNP	Set if no parity	Parity = 0	Same as SETPO
SETPO	Set if parity odd	Parity = 0	Same as SETNP

Condition Code Example

```
  else
    return y;
}
```

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

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

Body

Finish

Condition Code Example

```
  return y;

Flag:
  return x;
}
```

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

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

Body

Finish

"Do-While" Example

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

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

"Do-While" Example

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
```

Multiplication

operand size	1 byte	2 bytes	4 bytes
other operand	AL	AX	EAX
higher part of result stored in:	AH	DX	EDX
lower part of result stored in:	AL	AX	EAX

- Signed Multi[plication: **imul** arg

Division

divisor size:	1 byte	2 bytes	4 bytes
dividend	AX	DX:AX	EDX:EAX
remainder stored in:	AH	DX	EDX
quotient stored in:	AL	AX	EAX

- Signed: **idiv** arg

Sign extended Register

- Sign-extends EAX into EDX
- Forms the quad-word **EDX:EAX**.
- Since (I)DIV uses EDX:EAX as its input, CDQ must be called after setting EAX if EDX is not manually initialized (as in 64/32 division) before (I)DIV.

Load Effective Address

- Calculates the **address** of the **src** operand and **loads** it into the **dest** operand
- ***Src:*** Immediate / Register / Memory
- ***Dest:*** Register

- No FLAGS are modified by this instruction

Load Effective Address

arithmetic

- SRC can use **General Addressing Mode**
- **[eax + edx*4 -4] (Intel syntax)**
  - **or**
- **-4(%eax, %edx, 4) (GAS syntax)**

Load Effective Address Example

- LEA can be used as follows

```
lea ebx, [ebx*2]      ; Multiply ebx by 2
lea ebx, [ebx*8+ebx]  ; Multiply ebx by 9, which totals ebx*18
```

Jump Table

- We will construct a **array** of the **jump addresses** .
- For each number will jump to the **corresponding entry** in the jump table

Example

```
int main (int argc , char* argv)
{
    jumper (0);
    jumper (1);
    jumper (2);
    return 0;
}
```

jump.s

```
            dd      label_2

str0:       db      "Got the number 0",10,0
str1:       db      "Got the number 1",10,0
str2:       db      "Out of bound",10,0
str3:       db      "num = %d",10,0
section .text
            align   16
            global  jumper
            extern  printf
```

jump.s

```
mov     ebx,dword [ebp+8]
push    ebx
push    str3
call    printf                  ; Print num
add     esp, 8
cmp     ebx,0                   ; Check if num is in bounds
jb      out_of
cmp     ebx ,1
ja      out_of
shl     ebx,2                   ; num = num * 4
jmp     dword [ebx+jt]          ; Jump according to address in table
```

jump.s

```
        call    printf
        add     esp, 4
        jmp     end
label_2:
        push    str1
        call    printf
        add     esp, 4
        jmp     end
        call    printf
        add     esp, 4
        jmp     end
end:
        popa
        pop     ebp
        ret
```

Output

num = 1

Got the number 1

num = 2

Out of bound

jump.s

```
        dd      label_2

str0:   db      "Got the number 0",10,0
str1:   db      "Got the number 1",10,0
str2:   db      "Out of bound",10,0
str3:   db      "num = %d",10,0
section .text
        align   16
        global  jumper
        extern  printf
```

jump.s

```
mov     ebx,dword [ebp+8]
push    ebx
push    str3
call    printf                  ; Print num
add     esp, 8
cmp     ebx,0                   ; Check if num is in bounds
jb      out_of
cmp     ebx ,1
ja      out_of
shl     ebx,2                   ; num = num * 4
jmp     dword [ebx+jt]          ; Jump according to address in table
```

jump.s

```
        call    printf
        add     esp, 4
        jmp     end
label_2:
        push    str1
        call    printf
        add     esp, 4
        jmp     end
        call    printf
        add     esp, 4
        jmp     end
end:
        popa
        pop     ebp
        ret
```

Switch Statement Example (IA32)

```
long switch_eg
   (long x, long y, long z)
{
    long w = 1;
    switch(x) {
      . . .
    }
    return w;
}
```

Setup:

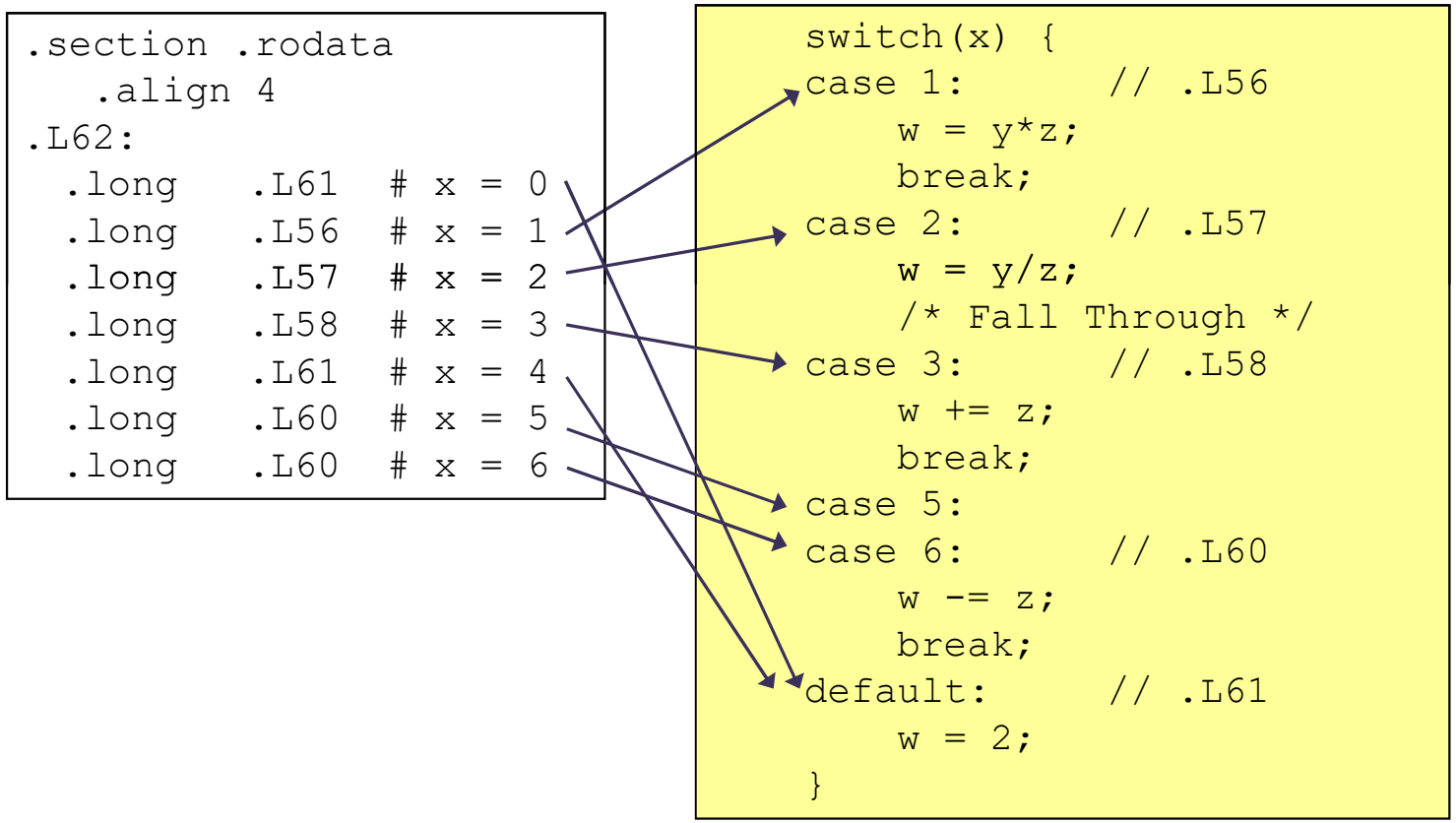
```
switch_eg:
   pushl %ebp              # Setup
   movl  %esp, %ebp        # Setup
   pushl %ebx              # Setup
   movl  $1, %ebx          # w = 1
   movl  8(%ebp), %edx     # edx = x
   movl  16(%ebp), %ecx    # ecx = z
   cmpl  $6, %edx          # x:6
   ja    .L61              # if > goto default
   jmp   *.L62(,%edx,4)    # goto JTab[x]
```

Jump Table

Table Contents

```
.section .rodata
   .align 4
.L62:
  .long    .L61   # x = 0
  .long    .L56   # x = 1
  .long    .L57   # x = 2
  .long    .L58   # x = 3
  .long    .L61   # x = 4
  .long    .L60   # x = 5
  .long    .L60   # x = 6
```

```
switch(x) {
case 1:       // .L56
    w = y*z;
    break;
case 2:       // .L57
    w = y/z;
    /* Fall Through */
case 3:       // .L58
    w += z;
    break;
case 5:
case 6:       // .L60
    w -= z;
    break;
default:      // .L61
    w = 2;
}
```



Code Blocks (Partial)


```
switch(x) {
  . . .
case 2:       // .L57
    w = y/z;
    /* Fall Through */
case 3:       // .L58
    w += z;
    break;
  . . .
default:      // .L61
    w = 2;
}
```

```
.L61:  // Default case
   movl  $2, %ebx     # w = 2
   movl  %ebx, %eax   # Return w
   popl  %ebx
   leave
   ret
.L57:  // Case 2:
   movl  12(%ebp), %eax  # y
   cltd                  # Div prep
   idivl %ecx            # y/z
   movl  %eax, %ebx # w = y/z
# Fall through
.L58:  // Case 3:
   addl  %ecx, %ebx # w+= z
   movl  %ebx, %eax # Return w
   popl  %ebx
   leave
   ret
```

Code Blocks (Rest)

```
    switch(x) {
    case 1:       // .L56
        w = y*z;
        break;
      . . .
    case 5:
    case 6:       // .L60
        w -= z;
        break;
      . . .
    }
```

```
.L60: // Cases 5&6:
   subl  %ecx, %ebx  # w -= z
   movl  %ebx, %eax  # Return w
   popl  %ebx
   leave
   ret
.L56: // Case 1:
   movl  12(%ebp), %ebx # w = y
   imull %ecx, %ebx     # w*= z
   movl  %ebx, %eax  # Return w
   popl  %ebx
   leave
   ret
```