Low level attacks
Assembly (part 1)

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What is assembly language?

- The CPU manages arithmetical, logical, and control activities
- The CPU follows machine language instructions
- Machine language instructions are strings in $\{0, 1\}^*$
- Assembly is almost one-to-one to machine language

Why studying an assembly language?

To understand the following:

- How programs interface with OS, processor, and BIOS
- How data is represented in memory and other external devices
- How the processor accesses and executes instruction
- How instructions access and process data
- How a program accesses external devices

Setup

Download and install NASM

`http://www.nasm.us/`

Example

Try hello.asm

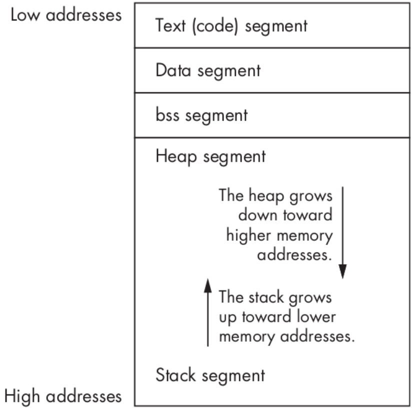
- Assemble: `nasm -f elf hello.asm`
- Link: `ld -m elf_i386 -o hello hello.o`
- Run: `./hello`

Basic syntax

Three sections:

- `section .text`
  - Actual code to be executed
  - Entry point declared by `global _start`
- `section .data`
  - Global initialized variables
- `section .bss`
  - Global unitialized variables

Memory segments


Low addresses
Text (code) segment
Data segment
bss segment
Heap segment
The heap grows down toward higher memory addresses.
The stack grows up toward lower memory addresses.
Stack segment
High addresses

- Text: assembly code
- Data: global initialized variables
- BSS: global unitialized variables
- Heap: dynamically allocated memory
- Stack: local (and temporary) memory

Statements (1)

Three types:

- Executable instructions or instructions
  - Consist of an operation code and up to 3 arguments
  - Each instruction generates one machine language instruction
- Assembler directives or pseudo-ops
  - Used by the assembler
  - Do not generate machine language instructions
- Macros
  - Text substitution

Statements (2)

Syntax

```
[label] mnemonic [operands] [;comment]
```

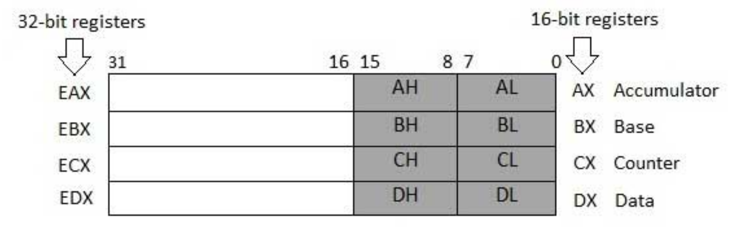
Examples of assembly language statements

- Increment the value of variable count
  ```
  inc count
  ```
- Move value 0 into variable count
  ```
  mov count, 0
  ```
- Add the value stored in register ebx to the value stored in register eax
  ```
  add eax, ebx
  ```

Registers of an x86 processor

- General registers
  - Data registers
  - Pointer registers
  - Index registers
- Control registers
- Segment registers

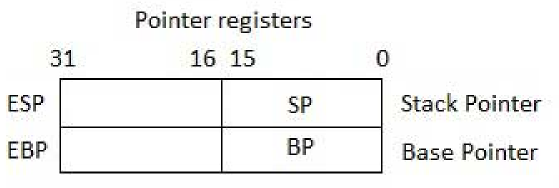
Data registers



- Four 32-bit data registers
- Used for arithmetic, logical and other operations
- Can be also used as 16-bit or 8-bit data registers

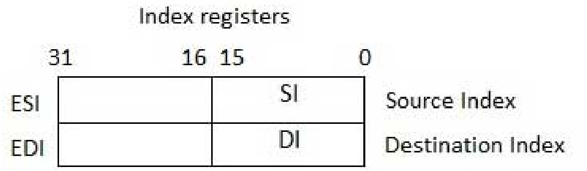
AX, BX, CX, DX use bits 0-15

Pointer registers



- Three 32-bit pointer registers
  - ESP: address of current top stack element
  - EBP: address of the stack frame
- Can be also used as 16-bit pointer registers

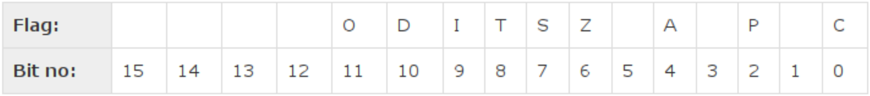
Index registers



- Two 32-bit index registers
- Used for addressing memory
- Can be also used as 16-bit pointer registers

Control registers

- EIP: 32-bit instruction pointer register
  - Address of the next instruction to be executed
  - Can be also used as 16-bit IP register



Flag:					O	D	I	T	S	Z		A		P		C
Bit no:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

- EFLAGS: 32-bit flags register
  - Overflow Flag (OF): 1 if the last arith. op. overflowed
  - Direction Flag (DF): left-to-right (0) or right-to-left (1) processing of strings
  - Interrupt Flag (IF): ignore (0) or process (1) external interrupts
  - Trap Flag (TF): 1 for single-step execution (to debug)
  - Sign Flag (SF): 0 if the last arith. op. gave a positive result
  - Zero Flag (ZF): 1 if the last arith. op. gave 0
  - Auxiliary Carry Flag (AF): the carry from bit 3 to bit 4 in the last arith. op.
  - Parity Flag (PF): parity bit of the last arith. op.
  - Carry Flag (CF): the carry of the high-order bit in the last arith. op.

Segment registers

Registers pointing to starting addresses of memory segments

- Code Segment (CS)
- Data Segment (DS)
- Stack Segment (SS)
- Extra Segments (ES, FS, GS)

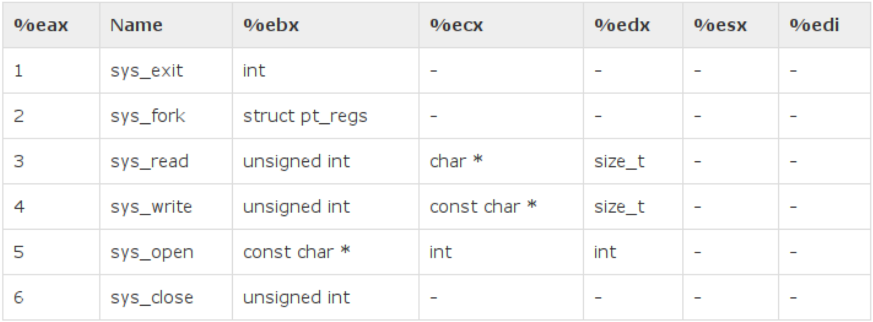
Example

Try `9starts.asm`, focusing on the use of registers.

Linux system calls (1)

- Put the system call number in the EAX register
- Store arguments in EBX, ECX, EDX, ESI, EDI, EBP
    - If there are more than 6 arguments, store the address of the first argument in EBX
- Trigger the interrupt 0x80
- The result is returned in EAX

Linux system calls (2)



%eax	Name	%ebx	%ecx	%edx	%esx	%edi
1	sys_exit	int	-	-	-	-
2	sys_fork	struct pt_regs	-	-	-	-
3	sys_read	unsigned int	char *	size_t	-	-
4	sys_write	unsigned int	const char *	size_t	-	-
5	sys_open	const char *	int	int	-	-
6	sys_close	unsigned int	-	-	-	-

All system calls are listed in...

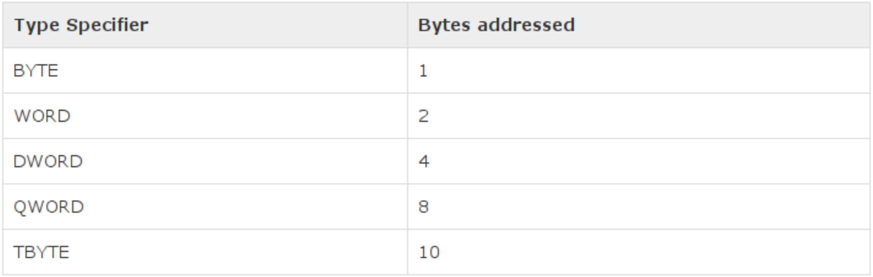
`/usr/include/asm/unistd.h`

Example

Try `read_number.asm`, focusing on the system calls.

Addressing modes (1)

- Instructions may have up to 3 operands
- First operand is generally the destination
- Several addressing modes
  - Register addressing: use of register values
  - Immediate addressing: use of constants (with type specifier)
  - Memory addressing: e.g., use of square brakets



Type Specifier	Bytes addressed
BYTE	1
WORD	2
DWORD	4
QWORD	8
TBYTE	10

Addressing modes (2)

`mov destination, source`

- `mov register, register`
- `mov register, immediate`
- `mov register, memory`
- `mov memory, register`
- `mov memory, immediate`

Example

Try `mov.asm`, focusing on the different forms of the `mov` instruction.

Variables

- Use D* to declare initialized global variables
- Use RES* to reserve space for unitialized global variables
- * is one of the following:
  - B: byte
  - W: word
  - D: double word
  - Q: quadword
  - T: ten bytes
- `times` can be used to repeat several times the same initialization
  - e.g., `starts times 9 db '*'`
    allocates 9 bytes with value '*********'

Constants

- `constant_name equ expression`
  Cannot be redefined
- `%assign constant_name expression`
  Can be redefined
- `%define constant_name string`
  Can be redefined

Example

Try `constants.asm`, focusing the definition of constants.

Arithmetic instructions (1)

- `inc destination`
- `dec destination`
- `add destination, source`
- `sub destination, source`

At least one operand must be different from memory address

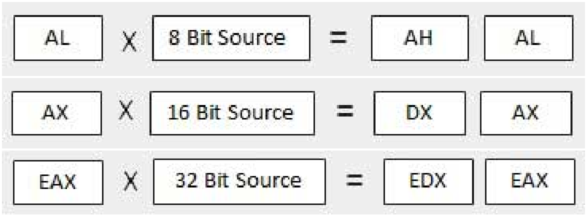
Example

Try `arith1.asm`

Arithmetic instructions (2)

- `mul multiplier` (unsigned integers, or natural numbers)
- `imul multiplier` (signed integers, or integers)

Some operands are implicit depending on the size of the multiplier

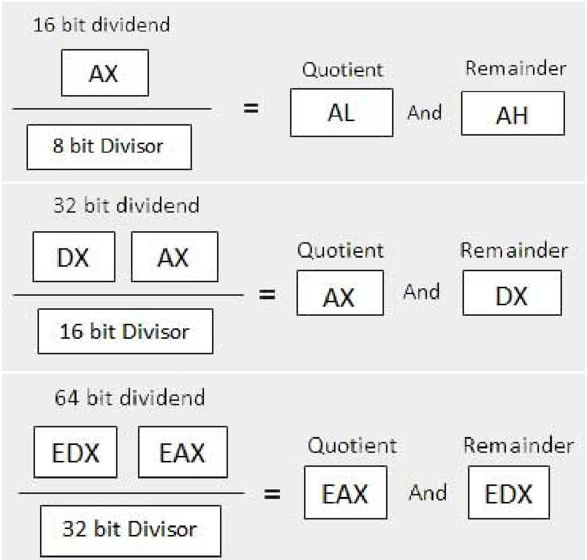


Example

Try `arith2.asm`

Arithmetic instructions

- `div divisor` (unsigned integers, or natural numbers)
- `idiv divisor` (signed integers, or integers)



Logical instructions

Bitwise logical operations, storing the result in `operand1`:

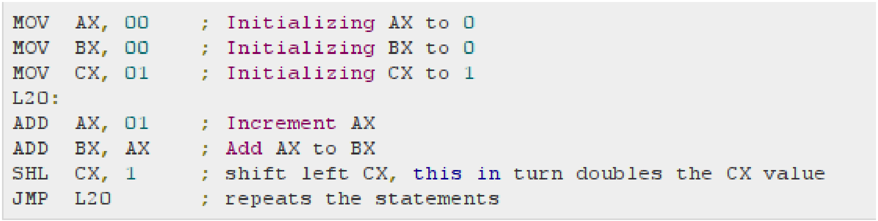
- `and operand1, operand2`
- `or operand1, operand2`
- `xor operand1, operand2`
- `not operand1`

Bitwise AND, just setting flags (e.g., ZF is set to 1 if the AND is 0)

- `test operand1, operand2`

Unconditional jump

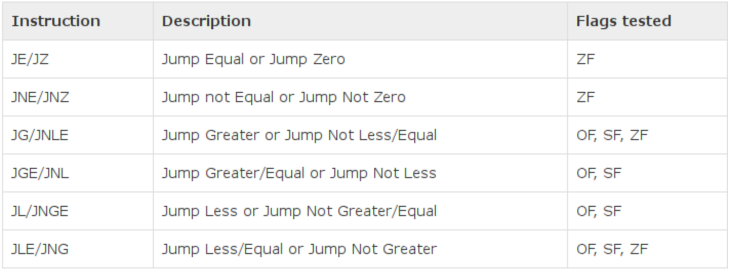
- `jmp label`
  Set IP to the address of the given label



```
MOV  AX, 00    ; Initializing AX to 0
MOV  BX, 00    ; Initializing BX to 0
MOV  CX, 01    ; Initializing CX to 1
L20:
ADD  AX, 01    ; Increment AX
ADD  BX, AX    ; Add AX to BX
SHL  CX, 1     ; shift left CX, this in turn doubles the CX value
JMP  L20       ; repeats the statements
```

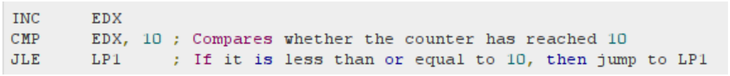
Conditional jump

- `j<condition> label`



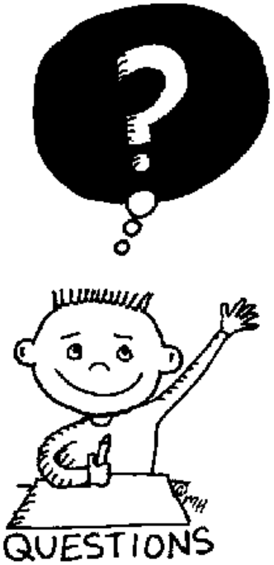
Instruction	Description	Flags tested
JE/JZ	Jump Equal or Jump Zero	ZF
JNE/JNZ	Jump not Equal or Jump Not Zero	ZF
JG/JNLE	Jump Greater or Jump Not Less/Equal	OF, SF, ZF
JGE/JNL	Jump Greater/Equal or Jump Not Less	OF, SF
JL/JNGE	Jump Less or Jump Not Greater/Equal	OF, SF
JLE/JNG	Jump Less/Equal or Jump Not Greater	OF, SF, ZF

- Often preceded by `cmp operand1, operand2`
- It is like `sub`, but `operand1` is not changed
- Only flags are affected



```
INC     EDX
CMP     EDX, 10 ; Compares whether the counter has reached 10
JLE     LP1     ; If it is less than or equal to 10, then jump to LP1
```

Example: Try `jumps.asm`



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