Session 2
Assembly Language Introduction

Security Summer School
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Outline

- Instruction Set Architecture
- Hello (Assembly) World
- Assembly Basics
- Data Transfer
- Control Flow
- Arithmetic/Logic
- Function Calls
- System Calls
- Compiler Patterns
- Resources

Instruction Set Architecture

- Microprocessor Operations:
  - logical
  - arithmetic
  - control
  - input/output (I/O)
- Structure of an x86 instruction:

```
NASM syntax: add dword [0xdeadbeef], 42
       hex:  8    3     0    5     e    f    b    e    a    d    d    e     2    a
    binary: [1000 0011][0000 0101][1110 1111 1011 1110 1010 1101 1101 1110][0010 1010]
            |          |          |                                        \- immediate: 42
            |          |          \- memory address: 0xdeadbeef (note the endianness)
            |          \- opcode modifiers:
            |               2 bits = addressing mode
            |               3 bits = register/opcode modifier
            |               3 bits = r/m field
            \- opcode: add sign-extended 8-bits immediate to register, or 32-bits memory addr
```

Hello (Assembly) World

- Compiling the Hello World C code

```
gcc -m32 -O0 hello.c -o hello
```

- Dumping the object

```
objdump -M intel -d hello
```

- Compiling the Assembly code

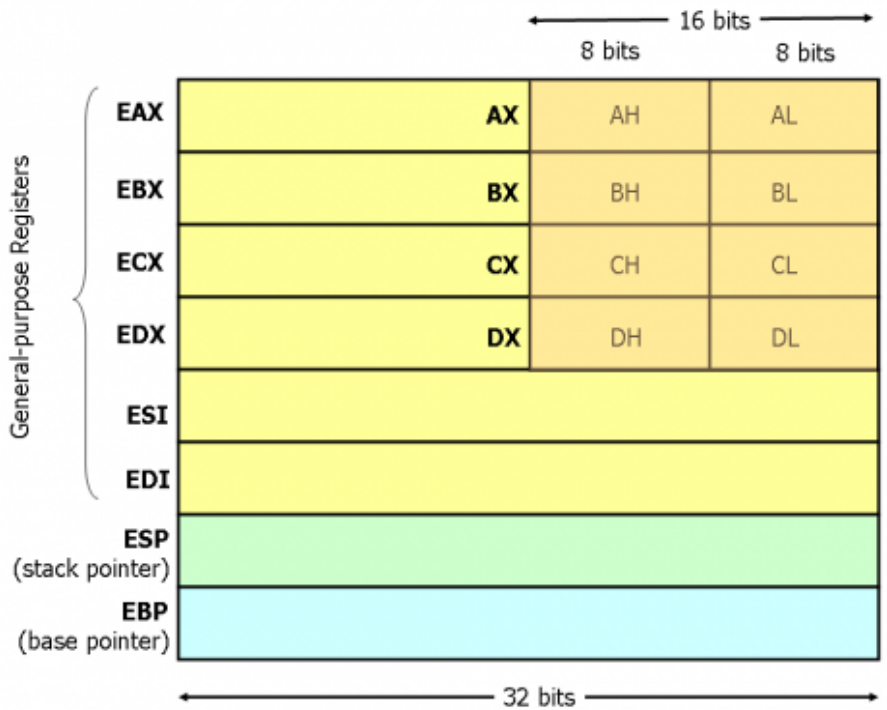
```
nasm -f elf32 hello.asm
```

- Linking the Assembly object

```
ld -s -lc -m elf_i386 -dynamic-linker \
   /lib/ld-linux.so.2 -e main hello.o -o hello_min
```

Assembly Basics

- CPU Operation Modes:
  - protected mode
  - real mode
  - virtual 8086 mode
  - long mode
- x86 Registers:



Assembly Basics - Register Usage

- eax: accumulator, used in arithmetic operations
- ebx: base pointer in memory operations (e.g., arrays)
- ecx: loop counters
- edx: also used in arithmetic operations
- esi: source addresses in memory operations
- edi: destination addreses in memory operations
- ebp: frame base pointer
- esp: stack pointer

Assembly Basics - Addressing Modes

- Addressing Formula:

$$\begin{Bmatrix} CS: \\ DS: \\ SS: \\ ES: \\ FS: \\ GS: \end{Bmatrix} \left[\begin{Bmatrix} EAX \\ EBX \\ ECX \\ EDX \\ ESP \\ EBP \\ ESI \\ EDI \end{Bmatrix} \right] + \left[\begin{Bmatrix} EAX \\ EBX \\ ECX \\ EDX \\ EBP \\ ESI \\ EDI \end{Bmatrix} * \begin{Bmatrix} 1 \\ 2 \\ 4 \\ 8 \end{Bmatrix} \right] + [\text{displacement}]$$

- Addressing Modes:

```
; direct (displacement)
mov eax, [0xcafebab3]

; register indirect (base)
mov eax, [esi]

; based (base + displacement)
mov eax, [ebp-8]

; indexed (index*scale + displacement)
mov eax, [ebx*4 + 0xdeadbeef]

; based-indexed w/o scale (base + index + displacement)
mov eax, [edx + ebx + 12]

; based-indexed w/ scale (base + index*scale + displacement)
mov eax, [edx + ebx*4 + 42]
```

Data Transfer

- mov ⟨dest⟩, ⟨src⟩: move
- xchg ⟨dest⟩, ⟨src⟩: exchange (swap)
- movzx ⟨dest⟩, ⟨src⟩: move with zero extend
- movsx ⟨dest⟩, ⟨src⟩: move with sign extend
- movsb: move byte from location pointed to by esi to edi
- movsw: similar, move word (2 bytes)
- lea ⟨dest⟩, ⟨src⟩: load effective address (calculate address of ⟨src⟩ and load it to ⟨dest⟩)

Control Flow

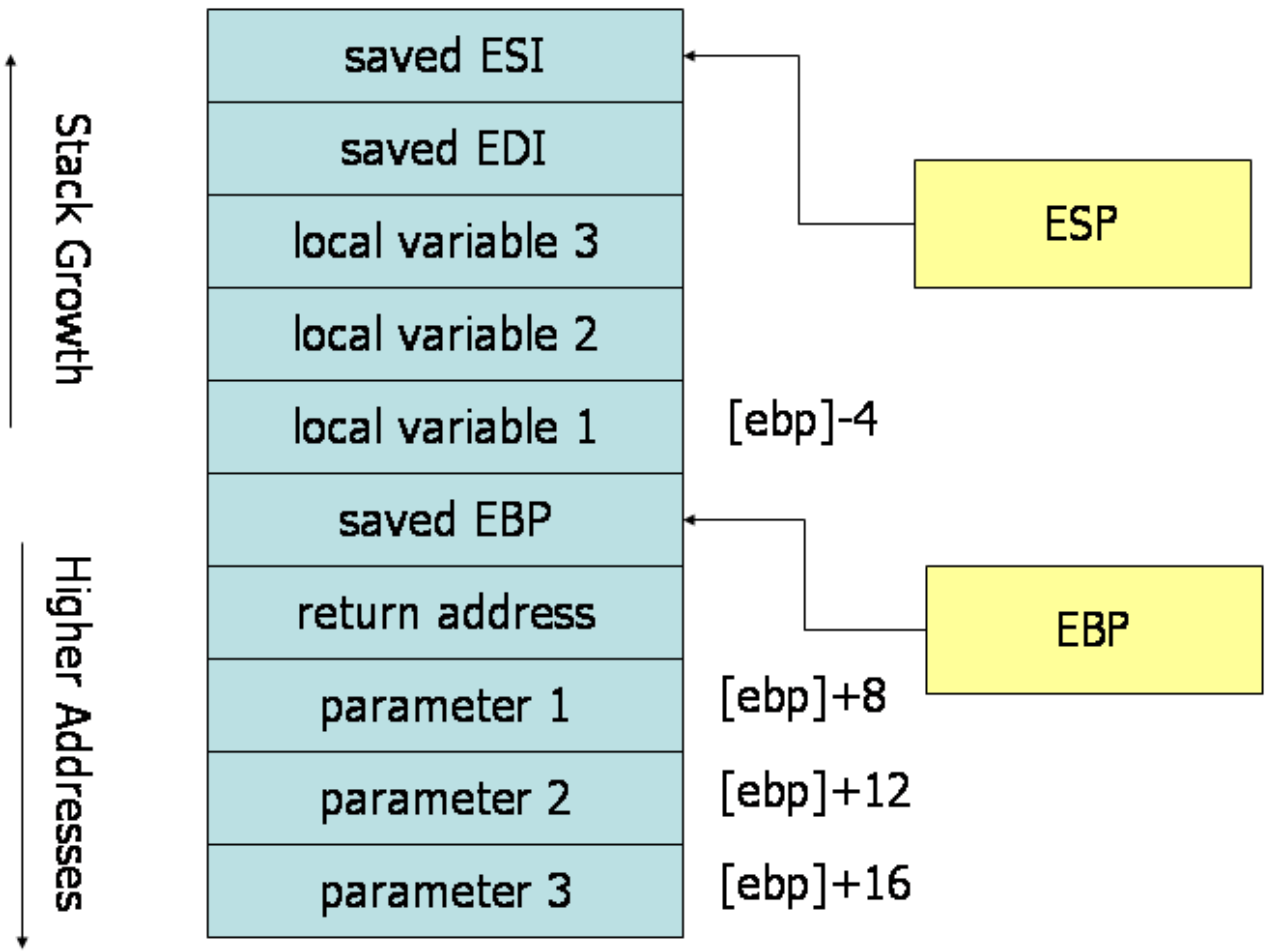
- Control Instructions:
  - jmp ⟨addr⟩: loads ⟨addr⟩ into eip
  - call ⟨addr⟩: pushes current eip on stack, and loads ⟨addr⟩ into eip
  - ret ⟨val⟩: loads head of stack into eip, and pops ⟨val⟩ bytes off the stack
  - loop ⟨addr⟩: decrements ecx, and jumps to ⟨addr⟩ if ecx != 0
- Conditional Jump Flags:
  - ZF (zero flag): previous arithmetic operation resulted in zero
  - SF (sign flag): previous result's most significant bit
  - CF (carry flag): previous result requires a carry
  - OF (everflow flag): previous result overflows the maximum value that fits a register

Arithmetic/Logic

- Arithmetic Instructions:
  - add ⟨dest⟩, ⟨src⟩: addition
  - sub ⟨dest⟩, ⟨src⟩: subtraction
  - mul ⟨arg⟩: multiplication with corresponding byte-wise eax (i.e., ⟨arg⟩ = "dh" ? dh * ah)
  - imul ⟨arg⟩: signed multiplication
  - imul ⟨dest⟩, ⟨src⟩: signed multiplication (dest = dest * src)
  - imul ⟨dest⟩, ⟨src⟩, ⟨aux⟩: signed multiplication (dest = src * aux)
  - div ⟨arg⟩: division
  - idiv ⟨arg⟩: signed division
  - neg ⟨arg⟩: 2's complement negation
- Shifts and Rotations:
  - shr, shl (logical shift right/left)
  - sar, sal (arithmetic shift right/left)
  - shld, shrd (double-shift)
  - ror, rol (rotate)
  - rcr, rcl (rotate with carry)
- Logical Instructions:
  - and, or, xor, not

Function Calls

- Calling conventions:
  - cdecl, stdcall, fastcall, thiscall
- Call Stack:



System Calls

- Syscalls are the interface that allows user applications to request services from the OS kernel
- The mechanism is invoked by triggering an interrupt (int 0x80)
- The conventions for invoking a syscall on Linux are:
  - eax contains the syscall ID
  - parameters are passed in ebx, ecx, edx, esi, edi, ebp (in this order)
  - the syscall is responsible of saving and restoring all registers

Compiler Patterns

- function prologue
- function epilogue
- for loop
- while loop
- nested fors with break and continue

Resources

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