EPITECH.
PARIS GRADUATE SCHOOL OF DIGITAL INNOVATION

Kickoff

Assembly

B4 - x86_64 Assembler

B-ASM-400

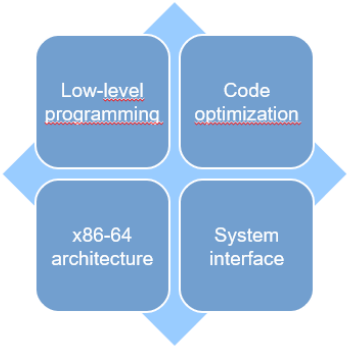
Assembly: what for?

- Better understanding of microprocessor capabilities
- More efficient code writing
- Still used for embedded/kernel programming
- Reverse engineering, debugging

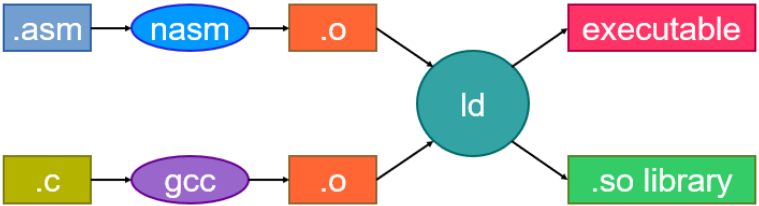
IT Culture

- Turing machine
- Von Neumann architecture
- CISC vs RISC
- Superscalar designs
- Pipelines

Skills to be Acquired

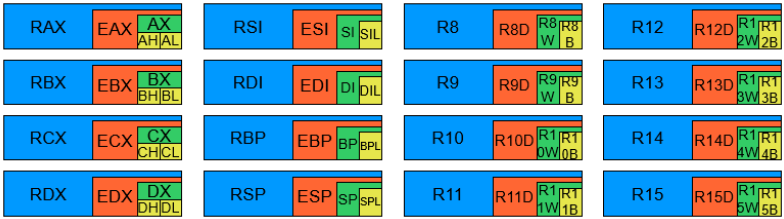


Toolchain



General-Purpose Registers

16 registers (some with specific roles)
64-bit (blue), 32-bit (orange), 16-bit (green) or 8-bit (yellow)



General-Purpose Registers: Specific Roles

RSP: stack pointer (important; used implicitly by PUSH, POP, CALL, RET, ENTER, LEAVE…)

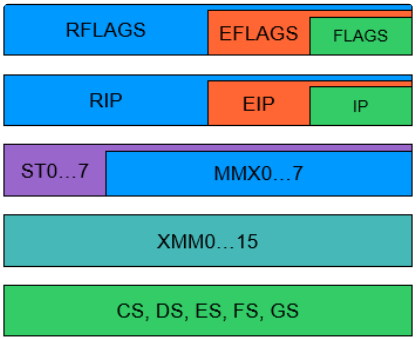
RBP: frame pointer (optional; used implicitly by ENTER & LEAVE)

RCX: counter for loop and string instructions

RSI: source pointer for string instructions

RDI: destination pointer for string instructions

Other Registers



RFLAGS: for conditional jumps

RIP: current instruction pointer

ST0…7 (80-bit): legacy floating-point numbers

MMX0…7 (64-bit) & **XMM0…15** (128-bit): vector instructions

Segment registers & numerous other registers: for operating system instructions

Flags

- Set by most instructions; CMP & TEST most appropriate
- Tested by conditional jump instructions Jxx

CF: unsigned carry (integer overflow)
OF: signed overflow
ZF: zero (result is null)
SF: sign (result is negative, leftmost bit = 1)
PF: parity (rightmost bit = 0)

Function Calling Convention

- Specified by the System V AMD64 Application Binary Interface (ABI)
- 6 first integer/pointer parameters in RDI, RSI, RDX, RCX, R8 & R9
- 8 first floating-point number (FPN) parameters in XMM0…7
- Remaining parameters in the stack
- VarArgs (printf…): number of FPN parameters in AL
- RBP, RBX, R12, R13, R14 & R15: must be preserved by callee
- Other registers may be altered at will
- Return value in RAX (integer/pointer) or XMM0 (FPN)

System Call

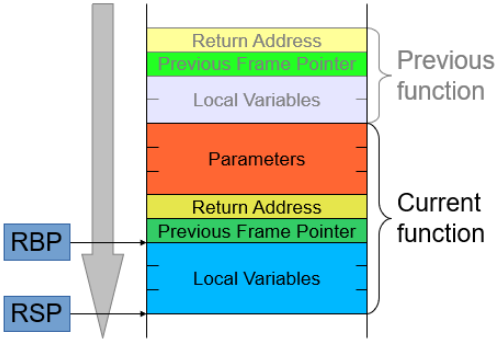
- Same registers used, except R10 instead of RCX for 4th parameter
- Integer and pointers only, no floating-point parameter
- System call number in RAX
- RCX & R11 may be overwritten
- Specific instruction: SYSCALL
- Return value in RAX, on error RAX = -errno (between -4095 and -1)
- List: /usr/include/asm/unistd_64.h

Memory - Static Sections

Code: .text
Read-only data: .rodata
Read/write data: .data
Unitialized data: .bss

cf. nm/objdump

Memory - Stack



Grows downwards.
Contains the function local state.

RSP
top of stack

RBP
frame pointer (beginning of local variables)
for convenience only

Memory - Stack Frame Setup

- Optional
- RSP varies (pushes and pops), but RBP fixed
- Easier to access local variables: RBP - constant
- Function prologue: PUSH RBP + MOV RBP, RSP
- Function epilogue: MOV RSP, RBP + POP RBP
- Alternatives: ENTER & LEAVE

Instructions - Assembly Directives

- Comment: **; this is a comment**
- Set architecture: **BITS 64**
- Change section: **SECTION .name**
- Set symbol: **label:**
- Export symbol: **GLOBAL symbol**
- Import symbol: **EXTERN symbol**
- Put bytes (static data): **vDB / RESB**

Instructions - Syntax

INSTR SRC/DEST or **INSTR SRC/DEST, SRC**

- Source (SRC): immediate value, register or memory
- Destination (DEST): register or memory

Both arguments cannot be memory.
Type determined from other parameter if available or specified explicitly using a prefix (BYTE, WORD, DWORD, QWORD).

Example: **ADD RAX, RDX** <=> **RAX = RAX + RDX**

Memory Access

[immediate + register + register * coefficient]

- immediate: immediate value (explicit constant)
- register: general-purpose register
- coefficient: 1 (default), 2, 4 or 8

All are optional.
Type is determined from other parameter if available or can be specified explicitly using a prefix (BYTE, WORD, DWORD, QWORD).

Example 1: **MOV RDX, [RBX + RCX * 4]**
Example 2: **MOV BYTE [RDI + 1337], 42**

Main Instructions

- **Data movement**: MOV, XCHG, PUSH, POP
- **Type conversion**: CBW, CWDE, CDQE
- **Arithmetic**: NEG, INC, DEC, ADD, SUB, IMUL, MUL, IDIV, DIV
- **Bitwise**: NOT, AND, OR, XOR
- **Bitshifts**: SHL, SHR, SAL, SAR, ROL, ROR
- **Resultless** (flags only, for conditional jumps): CMP, TEST

Branching

- **Unconditional jump**: JMP
- **Conditional jump** (depends on RFLAGS): JA, JAE, JB, JBE, JC, JE, JG, JGE, JL, JLE, JNA, JNAE, JNB, JNBE, JNC, JNE, JNG, JNGE, JNL, JNLE, JNO, JNP, JNS, JNZ, JO, JP, JPE, JPO, JS, JZ (cheers!)
- **Function call**: CALL ('PUSH RIP' + JMP)
- **Function return**: RET ('POP RIP')
- **System function call** (kernel interface): SYSCALL

Instructions - Miscellaneous

- No-operation: NOP (actually: XCHG RAX, RAX), used to fill up space
- Instructions with carry
- String instructions (with REP prefix)
- LEA: immediate + register + register × coefficient, all at once
- Supplemental instruction sets: MMX, SSE, AVX, AES-NI…
- and many rarely-used, legacy and system instructions

Resources

- Intel Architectures Software Developer Manuals, Volumes 1 & 2
- NASM documentation
- Internet

Commented Example - beginning

```
BITS 64                                 ; 64-bit mode
SECTION .text                           ; Code section
GLOBAL  main                            ; Export 'main'
EXTERN  printf                          ; Import 'printf'

main:
        PUSH    RBP                     ; Prologue:
        MOV     RBP, RSP                ; Stack frame setup
        MOV     RDI, str                ; First parameter
        CALL    printf                  ; Function call: printf(str)
        ;; WARNING: won't work! (cf. calling conventions)
```

Commented Example - end

```
        MOV     RAX, 60                 ; exit() syscall number
        XOR     RDI, RDI                ; RDI = 0 (first parameter)
        SYSCALL                         ; System call: exit(0)
        LEAVE                           ; Epilogue
        RET                             ; Return

SECTION .rodata                         ; Read-only data
str:    DB 'Hello, World!', 0Ah, 0      ; Format string for printf()
```

Any questions

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