

# CSGE602055 Operating Systems

## CSF2600505 Sistem Operasi

### Week 04: Addressing, Shared Lib, & Pointer

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<https://os.vlsm.org/Slides/os04.pdf>

Always check for the latest revision!

REV338 01-Sep-2021

# OS212<sup>3</sup>): Operating Systems 2021 - 2

| OS A   | OS B                             | OS C                             | OS INT                            |
|--|----------------------------------|----------------------------------|-----------------------------------|
| Every first day of the Week, <b>Quiz#1</b> and <b>Quiz#2</b> : 07:15-08:00 |                                  |                                  |                                   |
| Monday/Thursday<br>13:00 — 14:40   | Monday/Thursday<br>15:00 - 16:40 | Monday/Thursday<br>13:00 — 14:40 | Monday/Wednesday<br>08:00 — 09:40 |

| Week    | Schedule & Deadline <sup>1)</sup> | Topic  | OSC10 <sup>2)</sup> |
|---------|-----------------------------------|--|---------------------|
| Week 00 | 30 Aug - 05 Sep 2021              | Overview 1, Virtualization & Scripting       | Ch. 1, 2, 18.       |
| Week 01 | 06 Sep - 12 Sep 2021              | Overview 2, Virtualization & Scripting       | Ch. 1, 2, 18.       |
| Week 02 | 13 Sep - 19 Sep 2021              | Security, Protection, Privacy, & C-language. | Ch. 16, 17.         |
| Week 03 | 20 Sep - 26 Sep 2021              | File System & FUSE                           | Ch. 13, 14, 15.     |
| Week 04 | 27 Sep - 03 Oct 2021              | Addressing, Shared Lib, & Pointer            | Ch. 9.              |
| Week 05 | 04 Oct - 10 Oct 2021              | Virtual Memory                               | Ch. 10.             |
| Week 06 | 11 Oct - 17 Oct 2021              | Concurrency: Processes & Threads             | Ch. 3, 4.           |
| Week 07 | 01 Nov - 07 Nov 2021              | Synchronization & Deadlock                   | Ch. 6, 7, 8.        |
| Week 08 | 08 Nov - 14 Nov 2021              | Scheduling + W06/W07                         | Ch. 5.              |
| Week 09 | 15 Nov - 21 Nov 2021              | Storage, Firmware, Bootloader, & Systemd     | Ch. 11.             |
| Week 10 | 22 Nov - 28 Nov 2021              | I/O & Programming                            | Ch. 12.             |

<sup>1)</sup> The **DEADLINE** of Week 00 is 05 Sep 2021, whereas the **DEADLINE** of Week 01 is 12 Sep 2021, and so on...

<sup>2)</sup> Silberschatz et. al.: **Operating System Concepts**, 10<sup>th</sup> Edition, 2018.

<sup>3)</sup> This information will be on **EVERY** page two (2) of this course material.

# STARTING POINT — <https://os.vlsm.org/>

- ❑ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10<sup>th</sup> Edition, 2018. See also <https://www.os-book.com/OS10/>.
- ❑ **Resources**
  - ❑ **SCELE OS212** — <https://scele.cs.ui.ac.id/course/view.php?id=3268>.  
The enrollment key is **XXX**.
  - ❑ **Download Slides and Demos from GitHub.com**  
<https://github.com/UI-FASILKOM-OS/SistemOperasi/>:  
[os00.pdf \(W00\)](#), [os01.pdf \(W01\)](#), [os02.pdf \(W02\)](#), [os03.pdf \(W03\)](#),  
[os04.pdf \(W04\)](#), [os05.pdf \(W05\)](#), [os06.pdf \(W06\)](#), [os07.pdf \(W07\)](#),  
[os08.pdf \(W08\)](#), [os09.pdf \(W09\)](#), [os10.pdf \(W10\)](#).
  - ❑ **Problems**  
[195.pdf \(W00\)](#), [196.pdf \(W01\)](#), [197.pdf \(W02\)](#), [198.pdf \(W03\)](#),  
[199.pdf \(W04\)](#), [200.pdf \(W05\)](#), [201.pdf \(W06\)](#), [202.pdf \(W07\)](#),  
[203.pdf \(W08\)](#), [204.pdf \(W09\)](#), [205.pdf \(W10\)](#).
  - ❑ **LFS** — <http://www.linuxfromscratch.org/lfs/view/stable/>
  - ❑ **OSP4DISS** — <https://osp4diss.vlsm.org/>
  - ❑ **DOIT** — <https://doit.vlsm.org/001.html>

# Agenda

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# Agenda (2)

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# Week 04 Addressing: Topics<sup>1</sup>

- Bits, bytes, and words
- Numeric data representation and number bases
- Representation of records and arrays

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<sup>1</sup>Source: ACM IEEE CS Curricula 2013

# Week 04 Addressing: Learning Outcomes<sup>1</sup>

- Explain why everything is data, including instructions, in computers. [Familiarity]
- Explain the reasons for using alternative formats to represent numerical data. [Familiarity]
- Describe the internal representation of non-numeric data, such as characters, strings, records, and arrays. [Familiarity]

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<sup>1</sup>Source: ACM IEEE CS Curricula 2013

# Week 04: Addressing, Shared Lib, & Pointer

- Reference: (OSC10-ch09 demo-w04)
- This will be a difficult week
  - Pray! Pray! We got to pray just to make it today (McH)!
  - Goosfraba: Turn To Page 394 (AM-HP3)!
- Hardware Address Protection
- Binding & Linking
  - Address Binding
  - Address Space: Logical & Physical
  - Dynamic & Static Linking
  - MMU: Memory Management Unit
  - Base and Limit Registers
  - Swapping
  - Mobile Systems Problem: no swap
- Memory Allocation
  - Contiguous Allocation
  - Multiple-variable-partition Allocation
  - First, Best, Worst Fit Allocation Strategy
- Fragmentation: External / Internal / Compaction



# Paging

- Logical/Virtual Address
  - Logical Memory Blocks: Pages
  - Page Number
  - Page Offset
- Page Table
  - Page number index  $\Rightarrow$  frame number
  - PTE: Page Table Entry
  - Page Flags: Valid/ Invalid
  - TLB: Translation Look-aside Buffer (Associative Memory).
  - Two-Level Page-Table Scheme
    - OPT: Outer Page Table (P1)
    - PT: Page Table (P2)
  - Three-Level Page-Table Scheme
  - Hashed Page Tables
  - Inverted Page Table
- Physical Address
  - Physical Memory Blocks: Frames
  - Offset (D)
  - Hierarchical Page Tables

# Addressing (Eg. 16 bits)

| 16 Bits Logical Address Table (HEX) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | Examples   |     |        |             |
|-------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|-----|--------|-------------|
| ADDR                                | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  | bits   | L/B | PTR    | VALUE       |
| 000X                                | A0 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | AA | AB | AC | AD | AE | AF | 8  | —   | [0008] | A8          |
| 001X                                | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | BA | BB | BC | BD | BE | BF | 8  | —   | [0014] | B4          |
| 002X                                | C0 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | CA | CB | CC | CD | CE | CF | 8  | —   | [0015] | B5          |
| 003X                                | D0 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | DA | DB | DC | DD | DE | DF | 16   | LE  | [0014] | B5 B4       |
| 004X                                | 0A |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 16   | BE  | [0014] | B4 B5       |
| ⋮                                   | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | ⋮  | 32   | LE  | [0014] | B7 B6 B5 B4 |
| FFFX                                |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 1 address == 1 byte<br>LE: Little Endian<br>BE: Big Endian |     |        |             |

# Address Translation Scheme

| Address |     | Binary |    |      |    |     |      |     |      |     |  |
|---------|-----|--------|----|------|----|-----|------|-----|------|-----|--|
| DEC     | HEX | OFFSET | PG | OFF  | PG | OFF | PAGE | OFF | PAGE | OFF |  |
| 00      | 00  | 00000  | 0  | 0000 | 00 | 000 | 000  | 00  | 0000 | 0   |  |
| 01      | 01  | 00001  | 0  | 0001 | 00 | 001 | 000  | 01  | 0000 | 1   |  |
| 02      | 02  | 00010  | 0  | 0010 | 00 | 010 | 000  | 10  | 0001 | 0   |  |
| 03      | 03  | 00011  | 0  | 0011 | 00 | 011 | 000  | 11  | 0001 | 1   |  |
| 04      | 04  | 00100  | 0  | 0100 | 00 | 100 | 001  | 00  | 0010 | 0   |  |
| 05      | 05  | 00101  | 0  | 0101 | 00 | 101 | 001  | 01  | 0010 | 1   |  |
| 06      | 06  | 00110  | 0  | 0110 | 00 | 110 | 001  | 10  | 0011 | 0   |  |
| 07      | 07  | 00111  | 0  | 0111 | 00 | 111 | 001  | 11  | 0011 | 1   |  |
| 08      | 08  | 01000  | 0  | 1000 | 01 | 000 | 010  | 00  | 0100 | 0   |  |
| 09      | 09  | 01001  | 0  | 1001 | 01 | 001 | 010  | 01  | 0100 | 1   |  |
| 10      | 0A  | 01010  | 0  | 1010 | 01 | 010 | 010  | 10  | 0101 | 0   |  |
| 11      | 0B  | 01011  | 0  | 1011 | 01 | 011 | 010  | 11  | 0101 | 1   |  |
| 12      | 0C  | 01100  | 0  | 1100 | 01 | 100 | 011  | 00  | 0110 | 0   |  |
| 13      | 0D  | 01101  | 0  | 1101 | 01 | 101 | 011  | 01  | 0110 | 1   |  |
| 14      | 0E  | 01110  | 0  | 1110 | 01 | 110 | 011  | 10  | 0111 | 0   |  |
| 15      | 0F  | 01111  | 0  | 1111 | 01 | 111 | 011  | 11  | 0111 | 1   |  |
| 16      | 10  | 10000  | 1  | 0000 | 10 | 000 | 100  | 00  | 1000 | 0   |  |
| 17      | 11  | 10001  | 1  | 0001 | 10 | 001 | 100  | 01  | 1000 | 1   |  |
| 18      | 12  | 10010  | 1  | 0010 | 10 | 010 | 100  | 10  | 1001 | 0   |  |
| 19      | 13  | 10011  | 1  | 0011 | 10 | 011 | 100  | 11  | 1001 | 1   |  |
| 20      | 14  | 10100  | 1  | 0100 | 10 | 100 | 101  | 00  | 1010 | 0   |  |
| 21      | 15  | 10101  | 1  | 0101 | 10 | 101 | 101  | 01  | 1010 | 1   |  |
| 22      | 16  | 10110  | 1  | 0110 | 10 | 110 | 101  | 10  | 1011 | 0   |  |
| 23      | 17  | 10111  | 1  | 0111 | 10 | 111 | 101  | 11  | 1011 | 1   |  |
| 24      | 18  | 11000  | 1  | 1000 | 11 | 000 | 110  | 00  | 1100 | 0   |  |
| 25      | 19  | 11001  | 1  | 1001 | 11 | 001 | 110  | 01  | 1100 | 1   |  |
| 26      | 1A  | 11010  | 1  | 1010 | 11 | 010 | 110  | 10  | 1101 | 0   |  |
| 27      | 1B  | 11011  | 1  | 1011 | 11 | 011 | 110  | 11  | 1101 | 1   |  |
| 28      | 1C  | 11100  | 1  | 1100 | 11 | 100 | 111  | 00  | 1110 | 0   |  |
| 29      | 1D  | 11101  | 1  | 1101 | 11 | 101 | 111  | 01  | 1110 | 1   |  |
| 30      | 1E  | 11110  | 1  | 1110 | 11 | 110 | 111  | 10  | 1111 | 0   |  |
| 31      | 1F  | 11111  | 1  | 1111 | 11 | 111 | 111  | 11  | 1111 | 1   |  |

# Memory (20 bits)

|       | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 00000 | A0 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | AA | AB | AC | AD | AE | AF |
| 00010 | B0 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | BA | BB | BC | BD | BE | BF |
| 00020 | C0 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | CA | CB | CC | CD | CE | CF |
| 00030 | D0 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | DA | DB | DC | DD | DE | DF |
|       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| FFFF0 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

# Variables and File Formats

- 8 bit Variable (eg. `int ii=10;`)
  - Value ( $10_{10} == 0x\ 0A$ )
  - Logical Address (eg. `0x\ 0040`)
  - Meaning & Context (Variable "ii" is an integer).
  - `[0x\ 0040] == 0x\ 0A`
- Multiple Address Variable ( $> 1$  byte size)
  - Little-Endian (LE)
  - Big-Endian (BE)
  - Bi-Endian
- Executable File Format
  - Ancient Linux/Unix: Assembler Output  $\rightarrow$  `[a.out]`.
  - iOS, MacOS: Mach-Output (Mach-O).
  - Linux: Executable and Linking Format (ELF).
  - Windows: Portable Executable (PE)  $\rightarrow$  `[.acm, .ax, .cpl, .dll, .drv, .efi, .exe, .mui, .ocx, .scr, .sys, .tsp]`.

# Linux Libraries (1)



Figure: Linux Libraries

- Static Libraries (embedded in the program).
  - Self contained
  - StaticLib.a
- Shared Libraries
  - Dynamic Linking (run-time.so).
  - Dynamic Loading (controlled by the program, DL-API).

## Linux Libraries (2)

- `putchar(char)`
- `getpid()`
- `getppid()`
- `sprintf(char*, const char*)`
- `fflush(NULL)`
- MSIZE1 (10k) MSIZE2 (20k) MSIZE3 (50k) MSIZE4 (100k)  
MSIZE5 (1M) MSIZE6 (10M) MSIZE1
- `top`
  - PID (Process Id), PPID (Parent PID), %MEM (Memory), VIRT (Virtual Image KiB), RES (Residen Size KiB), SHR (Shared Memory KiB), SWAP (Swapped Size KiB), CODE (Code Size KiB), DATA (Data+Stack KiB), USED (Res+Swap Size KiB).
  - Save: `~/.toprc`
  - `top -b -n 1 -pYOUR_PID`
- `malloc(size_t)`
- `free(void*)`
- `system(const char*)`

# Makefile

```
CC=gcc
P00=00-global-variables
P01=01-local-variables
...

EXECS= \
    $(P00) \
    $(P01) \
...

DEMOFILES=\
    demo-file1.txt \
    demo-file2.txt \
...

all: $(EXECS)

$(P00): $(P00).c
    $(CC) $(P00).c -o $(P00) -Xlinker -Map=$(P00).map

$(P01): $(P01).c
    $(CC) $(P01).c -o $(P01) -Xlinker -Map=$(P01).map
...

$(P04): $(P04).c
    $(CC) $(P04).c -o $(P04)
...
clean:
    rm -f ${EXECS}
...
demo:
    bash .shsh
```



# 00-global-variables

```
/* Global Variables in Data Segment*/
```

```
char   varchr0='a';
```

```
char   varchr1='b';
```

```
char   varchr2='c';
```

```
char   varchr3='d';
```

```
char   varchr4='e';
```

```
char   varchr5='f';
```

```
char   varchr6='g';
```

```
char   varchr7='h';
```

```
VARIABLE  +++  VALUE  +CHR+  + ADDRESS+
```

```
varchr0 =          0X61 = a    0x00005642d5c38038
```

```
varchr1 =          0X62 = b    0x00005642d5c38039
```

```
varchr2 =          0X63 = c    0x00005642d5c3803a
```

```
varchr3 =          0X64 = d    0x00005642d5c3803b
```

```
varchr4 =          0X65 = e    0x00005642d5c3803c
```

```
varchr5 =          0X66 = f    0x00005642d5c3803d
```

```
varchr6 =          0X67 = g    0x00005642d5c3803e
```

```
varchr7 =          0X68 = h    0x00005642d5c3803f
```

|                     | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8   | 9   | A   | B   | C   | D   | E   | F   |
|---------------------|---|---|---|---|---|---|---|---|-----|-----|-----|-----|-----|-----|-----|-----|
| 0000 5642 D5C3 803X |   |   |   |   |   |   |   |   | 'a' | 'b' | 'c' | 'd' | 'e' | 'f' | 'g' | 'h' |

# Memory Map: 00-global-variables.map

Memory Configuration (00-global-variables.map)

Archive member included to satisfy reference by file (symbol)

Memory Configuration

| Name      | Origin             | Length             | Attributes |
|-----------|--------------------|--------------------|------------|
| *default* | 0x0000000000000000 | 0xffffffffffffffff |            |

Linker script and memory map

== TL;DR ==

|        |                     |       |                 |
|--------|---------------------|-------|-----------------|
| .text  | 0x00000000000001060 | 0x2d1 |                 |
|        | 0x00000000000001145 |       | main            |
| .tdata | 0x00000000000003de8 | 0x0   |                 |
| .data  | 0x00000000000004038 | 0x8   | /tmp/ccEBBZbJ.o |
|        | 0x00000000000004038 |       | varchr0         |
|        | 0x00000000000004039 |       | varchr1         |
|        | 0x0000000000000403a |       | varchr2         |
|        | 0x0000000000000403b |       | varchr3         |
|        | 0x0000000000000403c |       | varchr4         |
|        | 0x0000000000000403d |       | varchr5         |
|        | 0x0000000000000403e |       | varchr6         |
|        | 0x0000000000000403f |       | varchr7         |

OUTPUT(00-global-variables elf64-x86-64)

# 01-local-variables

```
/* Local Variables in Stack Segment */
```

```
char   varchr0='a';
```

```
char   varchr1='b';
```

```
char   varchr2='c';
```

```
char   varchr3='d';
```

```
char   varchr4='e';
```

```
char   varchr5='f';
```

```
char   varchr6='g';
```

```
char   varchr7='h';
```

| VARIABLE | +++ | VALUE | +CHR+ | +++ | ADDRESS            | +++ |
|----------|-----|-------|-------|-----|--------------------|-----|
| varchr0  | =   | 0X61  | = a   |     | 0x00007fff1e3315af |     |
| varchr1  | =   | 0X62  | = b   |     | 0x00007fff1e3315ae |     |
| varchr2  | =   | 0X63  | = c   |     | 0x00007fff1e3315ad |     |
| varchr3  | =   | 0X64  | = d   |     | 0x00007fff1e3315ac |     |
| varchr4  | =   | 0X65  | = e   |     | 0x00007fff1e3315ab |     |
| varchr5  | =   | 0X66  | = f   |     | 0x00007fff1e3315aa |     |
| varchr6  | =   | 0X67  | = g   |     | 0x00007fff1e3315a9 |     |
| varchr7  | =   | 0X68  | = h   |     | 0x00007fff1e3315a8 |     |

|                     | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8   | 9   | A   | B   | C   | D   | E   | F   |
|---------------------|---|---|---|---|---|---|---|---|-----|-----|-----|-----|-----|-----|-----|-----|
| 0000 7FFF 1E33 15AX |   |   |   |   |   |   |   |   | 'h' | 'g' | 'f' | 'e' | 'd' | 'c' | 'b' | 'a' |

## 02-pointers (LE: Little Endian)

```
char   varchr0='a';
char   varchr1='b';
char   varchr2='c';
char   varchr3='d';
char*  ptrchr0=&varchr0;
char*  ptrchr1=&varchr1;
char*  ptrchr2=&varchr2;
char*  ptrchr3=&varchr3;
```

| VARIABLE  | +++                | VALUE | +CHR+ | +ADDRESS +         | +POINTS TO+ |
|-----------|--------------------|-------|-------|--------------------|-------------|
| varchr0 = |                    | 0X61  | = a   | 0x00005650de8b0038 |             |
| varchr1 = |                    | 0X62  | = b   | 0x00005650de8b0039 |             |
| varchr2 = |                    | 0X63  | = c   | 0x00005650de8b003a |             |
| varchr3 = |                    | 0X64  | = d   | 0x00005650de8b003b |             |
| ptrchr0 = | 0x00005650de8b0038 |       |       | 0x00005650de8b0040 | a           |
| ptrchr1 = | 0x00005650de8b0039 |       |       | 0x00005650de8b0048 | b           |
| ptrchr2 = | 0x00005650de8b003a |       |       | 0x00005650de8b0050 | c           |
| ptrchr3 = | 0x00005650de8b003b |       |       | 0x00005650de8b0058 | d           |

|                     | 0                   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8                   | 9   | A   | B   | C  | D  | E  | F  |
|---------------------|---------------------|----|----|----|----|----|----|----|---------------------|-----|-----|-----|----|----|----|----|
| 0000 5650 DE8B 003X |                     |    |    |    |    |    |    |    | 'a'                 | 'b' | 'c' | 'd' |    |    |    |    |
| 0000 5650 DE8B 004X | 0000 5650 DE8B 0038 |    |    |    |    |    |    |    | 0000 5650 DE8B 0039 |     |     |     |    |    |    |    |
| 0000 5650 DE8B 005X | 3A                  | 00 | 8B | DE | 50 | 56 | 00 | 00 | 3B                  | 00  | 8B  | DE  | 56 | 50 | 00 | 00 |

# 03-pointers-of-pointers (LE)

```
=====
/* Global Variables in Data Segment*/
char   varchr0='a';
char   varchr1='b';
char   varchr2='c';
char   varchr3='d';
char*  ptrchr0=&varchr0;
char*  ptrchr1=&varchr1;
char*  ptrchr2=&varchr2;
char*  ptrchr3=&varchr3;
char** ptrptr0=&ptrchr0;
char** ptrptr1=&ptrchr1;
char** ptrptr2=&ptrchr2;
char** ptrptr3=&ptrchr3;
VARIABLE  +++  VALUE +CHR+      +ADDRESS +          +POINTS TO+
varchr0 =      0X61 = a        0x000056200b034038
varchr1 =      0X62 = b        0x000056200b034039
varchr2 =      0X63 = c        0x000056200b03403a
varchr3 =      0X64 = d        0x000056200b03403b
ptrchr0 = 0x000056200b034038 0x000056200b034040      a
ptrchr1 = 0x000056200b034039 0x000056200b034048      b
ptrchr2 = 0x000056200b03403a 0x000056200b034050      c
ptrchr3 = 0x000056200b03403b 0x000056200b034058      d
ptrptr0 = 0x000056200b034040 0x000056200b034060 0x56200b034038
ptrptr1 = 0x000056200b034048 0x000056200b034068 0x56200b034039
ptrptr2 = 0x000056200b034050 0x000056200b034070 0x56200b03403a
ptrptr3 = 0x000056200b034058 0x000056200b034078 0x56200b03403b
=====
```

## 03-pointers-of-pointers (2)

### Little Endian Version A

|                     | 0                   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8                   | 9   | A   | B   | C | D | E | F |
|---------------------|---------------------|---|---|---|---|---|---|---|---------------------|-----|-----|-----|---|---|---|---|
| 0000 5620 0B03 403X |                     |   |   |   |   |   |   |   | 'a'                 | 'b' | 'c' | 'd' |   |   |   |   |
| 0000 5629 0B03 404X | 0000 5620 0B03 4038 |   |   |   |   |   |   |   | 0000 5620 0B03 4039 |     |     |     |   |   |   |   |
| 0000 5629 0B03 405X | 0000 5620 0B03 403A |   |   |   |   |   |   |   | 0000 5620 0B03 403B |     |     |     |   |   |   |   |
| 0000 5629 0B03 406X | 0000 5620 0B03 4040 |   |   |   |   |   |   |   | 0000 5620 0B03 4048 |     |     |     |   |   |   |   |
| 0000 5629 0B03 407X | 0000 5620 0B03 4050 |   |   |   |   |   |   |   | 0000 5620 0B03 4058 |     |     |     |   |   |   |   |

### Little Endian Version B

|                     | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|---------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0000 5620 0B03 403X |    |    |    |    |    |    |    |    | 61 | 62 | 63 | 64 |    |    |    |    |
| 0000 5620 0B03 404X | 38 | 40 | 03 | 0B | 20 | 56 | 00 | 00 | 39 | 40 | 03 | 0B | 20 | 56 | 00 | 00 |
| 0000 5620 0B03 405X | 3A | 40 | 03 | 0B | 20 | 56 | 00 | 00 | 3B | 40 | 03 | 0B | 20 | 56 | 00 | 00 |
| 0000 5620 0B03 406X | 40 | 40 | 03 | 0B | 20 | 56 | 00 | 00 | 48 | 40 | 03 | 0B | 20 | 56 | 00 | 00 |
| 0000 5620 0B03 407X | 50 | 40 | 03 | 0B | 20 | 56 | 00 | 00 | 58 | 40 | 03 | 0B | 20 | 56 | 00 | 00 |

# 04-pointers-of-pointers-of-pointers

```
/* Little Endian/OLD Version      */
/* Global Variables in Data Segment */
char   varchr0='a';
char   varchr1='b';
char   varchr2='c';
char   varchr3='d';
char*  ptrchr0=&varchr0;
char*  ptrchr1=&varchr1;
char*  ptrchr2=&varchr2;
char*  ptrchr3=&varchr3;
char** ptrptr0=&ptrchr0;
char** ptrptr1=&ptrchr1;
char** ptrptr2=&ptrchr2;
char** ptrptr3=&ptrchr3;
char*** ppptr0=&ptrptr0;
```

| VARIABLE | +++ | VALUE    | +CHR+ | +ADDRESS | +        | +POINTS | TO+ |
|----------|-----|----------|-------|----------|----------|---------|-----|
| varchr0  | =   | 0X61     | = a   | 0x601038 |          |         |     |
| varchr1  | =   | 0X62     | = b   | 0x601039 |          |         |     |
| varchr2  | =   | 0X63     | = c   | 0x60103a |          |         |     |
| varchr3  | =   | 0X64     | = d   | 0x60103b |          |         |     |
| ptrchr0  | =   | 0x601038 |       | 0x601040 |          | a       |     |
| ptrchr1  | =   | 0x601039 |       | 0x601048 |          | b       |     |
| ptrchr2  | =   | 0x60103a |       | 0x601050 |          | c       |     |
| ptrchr3  | =   | 0x60103b |       | 0x601058 |          | d       |     |
| ptrptr0  | =   | 0x601040 |       | 0x601060 | 0x601038 |         |     |
| ptrptr1  | =   | 0x601048 |       | 0x601068 | 0x601039 |         |     |
| ptrptr2  | =   | 0x601050 |       | 0x601070 | 0x60103a |         |     |
| ptrptr3  | =   | 0x601058 |       | 0x601078 | 0x60103b |         |     |
| ppptr0   | =   | 0x601060 |       | 0x601080 | 0x601040 |         |     |

## 04-pointers-of-pointers-of-pointers (2)

|        | 0      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8      | 9   | A   | B   | C | D | E | F |
|--------|--------|---|---|---|---|---|---|---|--------|-----|-----|-----|---|---|---|---|
| 60103X |        |   |   |   |   |   |   |   | 'a'    | 'b' | 'c' | 'd' |   |   |   |   |
| 60104X | 601038 |   |   |   |   |   |   |   | 601039 |     |     |     |   |   |   |   |
| 60105X | 60103A |   |   |   |   |   |   |   | 60103B |     |     |     |   |   |   |   |
| 60106X | 601040 |   |   |   |   |   |   |   | 601048 |     |     |     |   |   |   |   |
| 60107X | 601050 |   |   |   |   |   |   |   | 601058 |     |     |     |   |   |   |   |
| 60108X | 601060 |   |   |   |   |   |   |   |        |     |     |     |   |   |   |   |

- `***ppptr0 = **ptrptr0 = *ptrchr = varchr0`
- `ppptr0 = [601080] = 601060`
- `ptrptr0 = [601060] = 601040`
- `ptrchr0 = [601040] = 601038`
- `varchr0 = [601038] = 'a'`

|                     | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|---------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 61 | 62 | 63 | 64 |    |    |    |    |
| 0000 0000 0060 104X | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 39 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 105X | 3A | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 3B | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 106X | 40 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 48 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 107X | 50 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 58 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 108X | 60 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |    |    |    |



## 05-chrptr-vs-intptr (LE)

```
=====
/* Global Variables in Data Segment*/
int    varint0=0x41424344;
char   varchr0='a';
char   varchr1='b';
char   varchr2='c';
char   varchr3='d';

int*    ptrint0=&varint0;
char*   ptrchr0=&varchr0;

ptrint0=(int*) &varchr2;
varint0=*ptrint0;

ptrchr0=(char*) &varint0;
varchr0=*ptrchr0;

ptrchr0++;
varchr0=*ptrchr0;
=====
```

## 05-chrptr-vs-intptr (2)

```
VARIABLE  +++  VALUE +CHR+ +ADDRESS + +POINTS TO+++  
varint0 = 0X41424344 = D      0x601038  
varchr0 =           0X61 = a      0x60103c  
varchr1 =           0X62 = b      0x60103d  
varchr2 =           0X63 = c      0x60103e  
varchr3 =           0X64 = d      0x60103f  
ptrint0 = 0x601038           0x601048 0X41424344  
ptrchr0 = 0x60103c           0x601050      a  
!!! ptrint0=(int*) &varchr1; varint0=*ptrint0; !!!  
VARIABLE  +++  VALUE +CHR+ +ADDRESS + +POINTS TO+++  
ptrint0 = 0x60103d           0x601048 0X65646362  
varint0 = 0X65646362 = b      0x601038
```

|                     | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|---------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 44 | 43 | 42 | 41 | 61 | 62 | 63 | 64 |
| 0000 0000 0060 104X | 65 |    |    |    |    |    |    |    | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 105X | 3C | 10 | 60 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |    |    |    |
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 62 | 63 | 64 | 65 | 61 | 62 | 63 | 64 |
| 0000 0000 0060 104X | 65 |    |    |    |    |    |    |    | 3D | 10 | 60 | 00 | 00 | 00 | 00 | 00 |

## 05-chrptr-vs-intptr (3)

```
!!! ptrchr0=(char*) &varint0; varchr0=*ptrchr0; !!!  
VARIABLE  +++  VALUE +CHR+ +ADDRESS + +POINTS TO+++  
ptrchr0 =    0x601038          0x601050          0X62  
varchr0 =          0X62 = b    0x60103c  
!!!! !!!! ptrchr0++; varchr0=*ptrchr0; !!!! !!!!  
VARIABLE  +++  VALUE +CHR+ +ADDRESS + +POINTS TO+++  
ptrchr0 =    0x601039          0x601050          0X63  
varchr0 =          0X63 = c    0x60103c
```

|                     | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|---------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 44 | 43 | 42 | 41 | 61 | 62 | 63 | 64 |
| 0000 0000 0060 104X | 65 |    |    |    |    |    |    |    | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 105X | 3C | 10 | 60 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |    |    |    |
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 62 | 63 | 64 | 65 | 61 | 62 | 63 | 64 |
| 0000 0000 0060 104X | 65 |    |    |    |    |    |    |    | 3D | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 62 | 63 | 64 | 65 | 62 | 62 | 63 | 64 |
| 0000 0000 0060 105X | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |    |    |    |
| 0000 0000 0060 103X |    |    |    |    |    |    |    |    | 62 | 63 | 64 | 65 | 63 | 62 | 63 | 64 |
| 0000 0000 0060 105X | 39 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |    |    |    |

# 06-pointer-address (LE)

```
unsigned char   varchr0='a';
unsigned char*  ptrchr0=&varchr0;
unsigned char*  ptrcopy=(char *) &ptrchr0;
```

| VARIABLE  | +++            | VALUE | +++ | +CHR+ | +++ | ADDRESS        | +++ | +PTS | TO+ |
|-----------|----------------|-------|-----|-------|-----|----------------|-----|------|-----|
| varchr0 = |                | 0X61  | = a |       |     | 0x7ffe7bb7369f |     |      |     |
| ptrchr0 = | 0x7ffe7bb7369f |       |     |       |     | 0x7ffe7bb73690 |     | 0X61 |     |

```
!!! !!!!! ptrcopy++; ptrcopy++; ptrcopy++; ... !!!!! !!!
ptrcopy = 0x7ffe7bb73690      0x7ffe7bb73688      0X9F
ptrcopy = 0x7ffe7bb73691      0x7ffe7bb73688      0X36
ptrcopy = 0x7ffe7bb73692      0x7ffe7bb73688      0XB7
ptrcopy = 0x7ffe7bb73693      0x7ffe7bb73688      0X7B
ptrcopy = 0x7ffe7bb73694      0x7ffe7bb73688      0XFE
ptrcopy = 0x7ffe7bb73695      0x7ffe7bb73688      0X7F
ptrcopy = 0x7ffe7bb73696      0x7ffe7bb73688      00
ptrcopy = 0x7ffe7bb73697      0x7ffe7bb73688      00
```

## 06-pointer-address (2)

```

!!! !!!!! ptrcopy++; ptrcopy++; ptrcopy++; ... !!!!! !!!
VARIABLE  +++  VALUE  +++  +CHR+  +++  ADDRESS  +++  +PTS  TO+
ptrchr0 = 0x7ffe7bb7369f          0x7ffe7bb73690      0X61
ptrcopy = 0x7ffe7bb73690          0x7ffe7bb73688      0X9F
ptrcopy = 0x7ffe7bb73691          0x7ffe7bb73688      0X36
ptrcopy = 0x7ffe7bb73692          0x7ffe7bb73688      0XB7
ptrcopy = 0x7ffe7bb73693          0x7ffe7bb73688      0X7B
ptrcopy = 0x7ffe7bb73694          0x7ffe7bb73688      0XFE
ptrcopy = 0x7ffe7bb73695          0x7ffe7bb73688      0X7F
ptrcopy = 0x7ffe7bb73696          0x7ffe7bb73688        00
ptrcopy = 0x7ffe7bb73697          0x7ffe7bb73688        00

```

|                     | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|---------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 90 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 369X | 9F | 36 | B7 | 7B | FE | 7F | 00 | 00 |    |    |    |    |    |    |    | 61 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 91 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 92 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 93 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 94 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 95 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 96 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 0000 7FFE 7BB7 368X |    |    |    |    |    |    |    |    | 97 | 36 | B7 | 7B | FE | 7F | 00 | 00 |

## 07-addresses (LE)

```
unsigned int  glInt1 = 0x41;
unsigned int  glInt2 = 0x42;
unsigned int  glInt3 = 0x43;
unsigned int  glInt4 = 0x44;
unsigned int  glInt5 = 0x45;
unsigned int* heapArray[] =
    {&glInt1, &glInt2, &glInt3, &glInt4, &glInt5};
```

| Variable Name | Address  | Size(S)/Value(V) |
|---------------|----------|------------------|
| =====         |          |                  |
| glInt1        | 0x601060 | 0X41 (V)         |
| glInt2        | 0x601064 | 0X42 (V)         |
| glInt3        | 0x601068 | 0X43 (V)         |
| glInt4        | 0x60106c | 0X44 (V)         |
| heapArray---  | 0x601080 | 0X601060 (V)     |
| heapArray[0]  | 0x601080 | 0X601060 (V)     |
| heapArray[1]  | 0x601088 | 0X601064 (V)     |
| heapArray[2]  | 0x601090 | 0X601068 (V)     |
| heapArray[3]  | 0x601098 | 0X60106C (V)     |
| heapArray[4]  | 0x6010a0 | 0X601070 (V)     |

## 07-addresses (2)

```
#define ALLOC0 0x4BD8
#define ALLOC1 0xFF8
#define ALLOC2 0x18
#define ALLOC3 0x19
#define ALLOC4 1
heapArray[0]=malloc(ALLOC0);
heapArray[1]=malloc(ALLOC1);
heapArray[2]=malloc(ALLOC2);
heapArray[3]=malloc(ALLOC3);
heapArray[4]=malloc(ALLOC4);
```

| Variable Name | Address  | Size(S)/Value(V) |
|---------------|----------|------------------|
| =====         |          |                  |
| heapArray---  | 0x601080 | 0X23CF420 (V)    |
| heapArray[0]  | 0x601080 | 0X23CF420 (V)    |
| heapArray[1]  | 0x601088 | 0X23D4000 (V)    |
| heapArray[2]  | 0x601090 | 0X23D5000 (V)    |
| heapArray[3]  | 0x601098 | 0X23D5020 (V)    |
| heapArray[4]  | 0x6010a0 | 0X23D5050 (V)    |

## 07-addresses (3)

```
long printVariable(char* varName, void* varValue, long endAddr) { ... }
long printHeapArray(int mode) { ... }
long demoMalloc(int mode) { ... }
long tripleLoop(int mode) { ... }
void main(void)          { ... }
```

| Variable Name  | Address  | Size(S)/Value(V) |
|----------------|----------|------------------|
| printf         | 0x400480 |                  |
| malloc         | 0x400490 |                  |
| printVariable  | 0x400596 | 0XBE (S)         |
| printHeapArray | 0x400654 | 0XA3 (S)         |
| demoMalloc     | 0x4006f7 | 0X7E (S)         |
| tripleLoop     | 0x400775 | 0XFC (S)         |
| main           | 0x400871 | 0X148 (S)        |



# 07-addresses (3)

#####

## Memory Configuration

|       |                    |   |
|-------|--------------------|---|
|       | 0x0000000000400238 | (SEGMENT-START ("text-segment", 0x400000) + SIZEOF-HEADERS) |
| .plt  | 0x0000000000400460 | 0x40 /usr/lib/gcc/.../x86-64-linux-gnu/crt1.o               |
|       | 0x0000000000400470 | puts@@GLIBC_2.2.5   |
|       | 0x0000000000400480 | printf@@GLIBC_2.2.5   |
|       | 0x0000000000400490 | malloc@@GLIBC_2.2.5   |
| .text | 0x00000000004004a0 | 0x592   |
| .text | 0x0000000000400596 | 0x41d /tmp/ccU78N7D.o                                       |
|       | 0x0000000000400596 | printVariable   |
|       | 0x0000000000400654 | printHeapArray  |
|       | 0x00000000004006f7 | demoMalloc  |
|       | 0x0000000000400775 | tripleLoop  |
|       | 0x0000000000400871 | main  |
| .data | 0x0000000000601060 | 0x48 /tmp/ccU78N7D.o  |
|       | 0x0000000000601060 | glInt1  |
|       | 0x0000000000601064 | glInt2  |
|       | 0x0000000000601068 | glInt3  |
|       | 0x000000000060106c | glInt4  |
|       | 0x0000000000601070 | glInt5  |
|       | 0x0000000000601080 | heapArray   |

#####

# 08-passing-parameters

```
#define NOP()    __asm__ ("nop") /* No Operation inline gcc ASM *** */
#include <stdio.h>
int  varInt1    = 0x01;
int  varInt2    = 0x02;
int* ptrInt1    = &varInt1;
int* ptrInt2    = &varInt2;
void function1(void) {
    NOP();
}
void function2(int iif2) {
    printf("function2:    iif2 = %d\n", ++iif2);
}
void function3(int* iif3) {
    printf("function3:    iif3 = %d\n", ++(*iif3));
}
int  function4(void) {
    NOP();
}
int* function5(void) {
    NOP();
}
void main(void) {
    function1();
    printf("main-1:    *ptrInt1 = %d\n", *ptrInt1);
    function2(*ptrInt1);
    printf("main-2:    *ptrInt1 = %d\n", *ptrInt1);
    printf("main-3:    varInt1 = %d\n",  varInt1);
    function3(&varInt1);
    printf("main-4:    varInt1 = %d\n",  varInt1);
}
```

*// main-1: \*ptrInt1 = 1*  
*// function2: iif2 = 2*  
*// main-2: \*ptrInt1 = 1*  
*// main-3: varInt1 = 1*  
*// function3: iif3 = 2*  
*// main-4: varInt1 = 2*

# 09-struct

```
#include <stdio.h>

typedef struct {
    char* nama;
    int umur;
    int semester;
    char* NIM;
} student;

void printStruct(student* ss) {
    printf("%-10s %11s %3d %2d\n", ss->nama, ss->NIM, ss->umur, ss->semester);
}

student global;
void init(void) {
    global.nama      = "Burhan";
    global.NIM       = "1205000003";
    global.umur      = 10;
    global.semester  = 2;
}

void main(void) {
    student mhs = {"Ali", 12, 1, "1205000001"};
    printStruct(&mhs);
    init();
    printStruct(&global);
}

=====
Ali          1205000001  12  1
Burhan       1205000003  10  2
```

# Week 04: Check List (Deadline: 03 Oct 2021).

- ☐ Week 04 Token: **OS212W04**
- ☐ This page is <https://os.vlsm.org/Slides/check04.pdf>.
- ☐ More details: <https://osp4diss.vlsm.org/W04.html>.
- ☐ Assignment Check List:
  - ① Read OSC-10 (chapter 9)
  - ② Try Demos Week 04 and before.
  - ③ Visit <https://os.vlsm.org/GitHubPages/>. Review **Last Week TOP 10 List** and pick at least 3 out of your 10 next neighbors.
  - ④ Create your **TOP 10 List** of Week 04 (See <https://cbkadal.github.io/os212/W04/>). Do not use lecture material. Please be more creative!
  - ⑤ Update your log (e.g. <https://cbkadal.github.io/os212/TXT/mylog.txt>).
  - ⑥ Download <https://os.vlsm.org/WEEK/WEEK04.tar.bz2.asc>. The passphrase will follow. The result ("WEEK04-TLPI.txt") should be placed into a "W04/" folder and tarballed as "myW04.tar.bz2.asc"
  - ⑦ Update bash script (e.g. <https://cbkadal.github.io/os212/TXT/myscript.sh>).
  - ⑧ Make **SHA256SUM** and sign it (detached, armor) as **SHA256SUM.asc**.

# The End

- ☐ This is the end of the presentation.
- ☒ This is the end of the presentation.
  - This is the end of the presentation.