

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 04: Addressing, Shared Lib, & Pointer

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<https://os.vlsm.org/>

Always check for the latest revision!

REV167 18-Oct-2018

Operating Systems 2018-2 (Room 3114)

R/M (Tu/Th 13-15) | I (Tu/Th 15-17)

| Week | Schedule | Topic | OSC10 |
|----------|----------------------|---|-------------------------------------|
| Week 00 | 04 Sep - 12 Sep 2018 | Overview 1, Virtualization & Scripting | Ch. 1, 2, 18. |
| Week 01 | 13 Sep - 19 Sep 2018 | Overview 2, Virtualization & Scripting | Ch. 1, 2, 18. |
| Week 02 | 20 Sep - 26 Sep 2018 | Security, Protection, Privacy, & C-language | Ch. 16, 17 |
| Week 03 | 27 Sep - 03 Oct 2018 | File System & FUSE | Ch. 13, 14, 15 |
| Week 04 | 04 Oct - 10 Oct 2018 | Addressing, Shared Lib, & Pointer | Ch. 9 |
| Week 05 | 11 Oct - 17 Oct 2018 | Virtual Memory | Ch. 10 |
| Reserved | 18 Oct - 19 Oct 2018 | | |
| Mid-Term | 24 Oct 2018 | MidTerm (UTS): 09:00 - 11:30 | |
| Week 06 | 30 Oct - 05 Nov 2018 | Concurrency: Processes & Threads | Ch. 3, 4 |
| Week 07 | 06 Nov - 12 Nov 2018 | Synchronization & Deadlock | Ch. 6, 7, 8 |
| Week 08 | 13 Nov - 21 Nov 2018 | Scheduling | Ch. 5 |
| Week 09 | 22 Nov - 28 Nov 2018 | Disks, BIOS, Loader, & Systemd | Ch. 11 |
| Week 10 | 29 Nov - 05 Dec 2018 | I/O & Programming | Ch. 12 |
| Reserved | 06 Dec - 14 Dec 2018 | | |
| Final | 15 Dec - 22 Dec 2018 | Final (UAS): TBA | This schedule is subject to change. |
| Extra | 12 Jan 2019 | Extra assignment | |

The Weekly Check List

- ☐ **Resources:** <https://os.vlsm.org/>
 - ☐ **(THIS) Slides** — <https://github.com/UI-FASILKOM-OS/SistemOperasi/tree/master/pdf/>
 - ☐ **Demos** — <https://github.com/UI-FASILKOM-OS/SistemOperasi/tree/master/demos/>
 - ☐ **Extra** — BADAK.cs.ui.ac.id:///extra/
 - ☐ **Problems** — rms46.vlsm.org/2/195.pdf, [196.pdf](http://rms46.vlsm.org/2/196.pdf), ..., [205.pdf](http://rms46.vlsm.org/2/205.pdf)
- ☐ **Text Book:** any recent/decent OS book. Eg. **(OSC10)** Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018.
- ☐ Encode your **QRC** with size upto 7cm x 7cm (ca. 400x400 pixels):
"OS182 CLASS ID SSO-ACCOUNT Your-Full-Name"
- ☐ For **Week 00**, send your **embedded QRC before the 2nd lecture**
<mailto:operatingsystems@vlsm.org>
With Subject: OS182 CLASS ID SSO-ACCOUNT Your-Full-Name
- ☐ Write your Memo (with QRC) **every week**.
- ☐ Login to badak.cs.ui.ac.id via kawung.cs.ui.ac.id for at least **10 minutes** every week. Copy the weekly demo files to your own home directory.
Eg. (Week00): `cp -r /extra/Week00/W00-demos/ W00-demos/`

Agenda

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- 5 Week 04: Addressing, Shared Lib, & Pointer
- 6 Paging
- 7 Addressing
- 8 Translation
- 9 Memory
- 10 Variables and File Formats
- 11 Linux Libraries (1)
- 12 Linux Libraries (2)

Agenda (2)

- 13 Makefile
- 14 00-global-variables
- 15 Memory Map
- 16 01-local-variables
- 17 02-pointers
- 18 03-pointers-of-pointers
- 19 04-pointers-of-pointers-of-pointers
- 20 05-chrptr-vs-intptr
- 21 06-pointer-address
- 22 07-addresses
- 23 08-passing-parameters
- 24 09-struct
- 25 The End

Week 04 Addressing: Topics¹

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

¹Source: ACM IEEE CS Curricula 2013

Week 04 Addressing: Learning Outcomes¹

- 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]

¹Source: 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 LE: Little Endian 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      0x601038
```

```
varchr1 =          0X62 = b      0x601039
```

```
varchr2 =          0X63 = c      0x60103a
```

```
varchr3 =          0X64 = d      0x60103b
```

```
varchr4 =          0X65 = e      0x60103c
```

```
varchr5 =          0X66 = f      0x60103d
```

```
varchr6 =          0X67 = g      0x60103e
```

```
varchr7 =          0X68 = h      0x60103f
```

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|--------|---|---|---|---|---|---|---|---|-----|-----|-----|-----|-----|-----|-----|-----|
| 60103X | | | | | | | | | 'a' | 'b' | 'c' | 'd' | 'e' | 'f' | 'g' | 'h' |

Memory Map

Memory Configuration (00-global-char.map)

| Name | Origin | Length | Attributes |
|-----------|--------------------|--------------------|-----------------------------|
| *default* | 0x0000000000000000 | 0xffffffffffffffff | PLT=Procedure Linkage Table |
| .plt | 0x0000000000400420 | 0x30 | /usr/lib/.../crt1.o |
| | 0x0000000000400430 | | puts@@GLIBC\2.2.5 |
| | 0x0000000000400440 | | printf@@GLIBC\2.2.5 |
| .text | 0x0000000000400450 | 0x282 | |
| .data | 0x0000000000601028 | 0x18 | |
| .data | 0x0000000000601038 | 0x8 | /tmp/cc0DQ6w0.o |
| | 0x0000000000601038 | | varchr0 |
| | 0x0000000000601039 | | varchr1 |
| | ... | | ... |
| | 0x000000000060103e | | varchr6 |
| | 0x000000000060103f | | varchr7 |
| .bss | 0x0000000000601040 | 0x8 | |

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      0x7ffcc188b51f
```

```
varchr1 =          0X62 = b      0x7ffcc188b51e
```

```
varchr2 =          0X63 = c      0x7ffcc188b51d
```

```
varchr3 =          0X64 = d      0x7ffcc188b51c
```

```
varchr4 =          0X65 = e      0x7ffcc188b51b
```

```
varchr5 =          0X66 = f      0x7ffcc188b51a
```

```
varchr6 =          0X67 = g      0x7ffcc188b519
```

```
varchr7 =          0X68 = h      0x7ffcc188b518
```

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|-------------------|---|---|---|---|---|---|---|---|-----|-----|-----|-----|-----|-----|-----|-----|
| 00007ffc-c188b51X | | | | | | | | | '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 | 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 |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|-------------------|-------------------|----|----|----|----|----|----|----|-------------------|-----|-----|-----|----|----|----|----|
| 00000000-0060103X | | | | | | | | | 'a' | 'b' | 'c' | 'd' | | | | |
| 00000000-0060104X | 00000000-00601038 | | | | | | | | 00000000-00601039 | | | | | | | |
| 00000000-0060105X | 3A | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 3B | 10 | 60 | 00 | 00 | 00 | 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      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
=====
```

03-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 | | | | | | | |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|-------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 00000000-0060103X | | | | | | | | | 61 | 62 | 63 | 64 | | | | |
| 00000000-0060104X | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 39 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060105X | 3A | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 3B | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060106X | 40 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 48 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060107X | 50 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 58 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |

04-pointers-of-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;  
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 |
|-------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 00000000-0060103X | | | | | | | | | 61 | 62 | 63 | 64 | | | | |
| 00000000-0060104X | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 39 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060105X | 3A | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 3B | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060106X | 40 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 48 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060107X | 50 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | 58 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060108X | 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 |
|-------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 00000000-0060103X | | | | | | | | | 44 | 43 | 42 | 41 | 61 | 62 | 63 | 64 |
| 00000000-0060104X | 65 | | | | | | | | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060105X | 3C | 10 | 60 | 00 | 00 | 00 | 00 | 00 | | | | | | | | |

| | | | | | | | | | | | | | | | | |
|-------------------|----|--|--|--|--|--|--|--|----|----|----|----|----|----|----|----|
| 00000000-0060103X | | | | | | | | | 62 | 63 | 64 | 65 | 61 | 62 | 63 | 64 |
| 00000000-0060104X | 65 | | | | | | | | 3D | 10 | 60 | 00 | 00 | 00 | 00 | 00 |

05-chrptr-vs-intptr (2)

```
!!! 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 |
|-------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 00000000-0060103X | | | | | | | | | 44 | 43 | 42 | 41 | 61 | 62 | 63 | 64 |
| 00000000-0060104X | 65 | | | | | | | | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060105X | 3C | 10 | 60 | 00 | 00 | 00 | 00 | 00 | | | | | | | | |
| 00000000-0060103X | | | | | | | | | 62 | 63 | 64 | 65 | 61 | 62 | 63 | 64 |
| 00000000-0060104X | 65 | | | | | | | | 3D | 10 | 60 | 00 | 00 | 00 | 00 | 00 |
| 00000000-0060103X | | | | | | | | | 62 | 63 | 64 | 65 | 62 | 62 | 63 | 64 |
| 00000000-0060105X | 38 | 10 | 60 | 00 | 00 | 00 | 00 | 00 | | | | | | | | |
| 00000000-0060103X | | | | | | | | | 62 | 63 | 64 | 65 | 63 | 62 | 63 | 64 |
| 00000000-0060105X | 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 |
|-------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 00007FFE-7BB7368X | | | | | | | | | 90 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7369X | 9F | 36 | B7 | 7B | FE | 7F | 00 | 00 | | | | | | | | 61 |
| 00007FFE-7BB7368X | | | | | | | | | 91 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7368X | | | | | | | | | 92 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7368X | | | | | | | | | 93 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7368X | | | | | | | | | 94 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7368X | | | | | | | | | 95 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7368X | | | | | | | | | 96 | 36 | B7 | 7B | FE | 7F | 00 | 00 |
| 00007FFE-7BB7368X | | | | | | | | | 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
```

The End

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