

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 06: Concurrency: Processes & Threads

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

Always check for the latest revision!

REV230 31-May-2020

Operating Systems 2020-1

(A, B, C, D, E) from HOME

Week	Schedule	Topic	OSC10
Week 00	27 Jan - 02 Feb 2020	Overview 1, Virtualization & Scripting	Ch. 1, 2, 18.
Week 01	03 Feb - 09 Feb 2020	Overview 2, Virtualization & Scripting	Ch. 1, 2, 18.
Week 02	10 Feb - 16 Feb 2020	Security, Protection, Privacy, & C-language	Ch. 16, 17
Week 03	17 Feb - 23 Feb 2020	File System & FUSE	Ch. 13, 14, 15
Week 04	24 Feb - 01 Mar 2020	Addressing, Shared Lib, & Pointer	Ch. 9
Week 05	02 Mar - 08 Mar 2020	Virtual Memory	Ch. 10
Reserved	09 Mar - 13 Mar 2020	Q & E	
MidTerm	14 Mar 2020 (13:00-15:30)	MidTerm (UTS)	DONE!
Week 06	05 Apr - 11 Apr 2020	Concurrency: Processes & Threads	Ch. 3, 4
Week 07	12 Apr - 18 Apr 2020	Synchronization & Deadlock	Ch. 6, 7, 8
Week 08	19 Apr - 25 Apr 2020	Scheduling + W06/W07	Ch. 5
Week 09	26 Apr - 02 May 2020	Storage, Firmware, Bootldr, & Systemd	Ch. 11
Week 10	03 May - 09 May 2020	I/O & Programming	Ch. 12
Reserved	10 May - 16 May 2020	Q & A	
Final	08 Jun 2020 13:00	First Part Final (UAS tahap I)	This schedule is subject to change.
Extra	NA	No Extra assignment	

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

- ❑ **Text Book** — Any recent/decent OS book. Eg. (**OSC10**) Silberschatz et. al.: **Operating System Concepts**, 10th Edition, 2018. See also <http://codex.cs.yale.edu/avi/os-book/OS10/>.
- ❑ **Resources**
 - ❑ **Extra Scele from Home** — <https://scele.cs.ui.ac.id/course/view.php?id=822>.
 - ❑ **Extra Scele from Home** —
 - ❑ **All In One** — [BADAQ.cs.ui.ac.id:///extra/](https://badaq.cs.ui.ac.id/extra/) (**FASILKOM only!**).
 - ❑ **Download Slides and Demos from GitHub.com**
<https://github.com/UI-FASILKOM-OS/SistemOperasi/>
 - ❑ **Problems** — <https://rms46.vlsm.org/2/>:
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).
- ❑ **Try Demos**
 - ❑ Your own Ubuntu system.
 - ❑ Ubuntu on VirtualBox, or VMWare, or ...
 - ❑ Windows Subsystem for Linux (**Windows 10 only!**).
 - ❑ SSH to [BADAQ.cs.ui.ac.id](https://badaq.cs.ui.ac.id) (**FASILKOM only!**).

Agenda I

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- 10 01-fork
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- 15 05-fork
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Agenda II

- 17 07-execlp
- 18 08-fork
- 19 09-fork
- 20 10-fork
- 21 11-fork
- 22 12-fork
- 23 13-uas161
- 24 14-uas162
- 25 15-uas171
- 26 16-uas172
- 27 The End

Week 06 Concurrency: Topics¹

- States and state diagrams
- Structures (ready list, process control blocks, and so forth)
- Dispatching and context switching
- The role of interrupts
- Managing atomic access to OS objects
- Implementing synchronization primitives
- Multiprocessor issues (spin-locks, reentrancy)

¹Source: ACM IEEE CS Curricula 2013

Week 06 Concurrency: Learning Outcomes (1)¹

- Describe the need for concurrency within the framework of an operating system. [Familiarity]
- Demonstrate the potential run-time problems arising from the concurrent operation of many separate tasks. [Usage]
- Summarize the range of mechanisms that can be employed at the operating system level to realize concurrent systems and describe the benefits of each. [Familiarity]
- Explain the different states that a task may pass through and the data structures needed to support the management of many tasks. [Familiarity]

¹Source: ACM IEEE CS Curricula 2013

Week 06 Concurrency: Learning Outcomes (2)¹

- Summarize techniques for achieving synchronization in an operating system (e.g., describe how to implement a semaphore using OS primitives). [Familiarity]
- Describe reasons for using interrupts, dispatching, and context switching to support concurrency in an operating system. [Familiarity]
- Create state and transition diagrams for simple problem domains. [Usage]

¹Source: ACM IEEE CS Curricula 2013

Week 06: Concurrency: Processes & Threads

- Reference: (OSC10-ch03 OSC10-ch04 demo-w06)
- Process Concept
 - Program (passive) \leftrightarrow Process (active)
 - Process in Memory: | *Stack* \cdots *Heap* | *Data* | *Text* |
 - Process State: | *running* | *waiting* | *ready* |
 - Process Control Block (PCB)
 - /proc/, Process State, Program Counter, Registers, Management Information.
- Process Creation
 - PID: Process Identifier (uniq)
 - The Parent Process forms a tree of Children Processes
 - `fork()`, new process system call (clone)
 - `exec1p()`, replaces the clone with a new program.
- Process Termination
 - `wait()`, until the child process is terminated.
- PCB (Context) Switch

A PROCESS IN MEMORY



(c) 2017 VauLSMorg

Figure: A Process in (**logical**) Memory

Process State



Figure: A Process State

Process Scheduling

- Scheduling Queue
- Schedulers
 - Long Term (non VM) vs Short Term (CPU)
 - (I/O vs CPU) Bound Processes
- Context Switch
- I/O Queue Scheduling
- Android Systems
 - Dalvik VM Performance Problem: Replaced with ART (Android Runtime).
 - Foreground Processes: with an User Interface (UI) for Videos, Images, Sounds, Texts, etc.
 - Background Processes: with a service with no UI and small memory footprint.

Inter-Process Communication (IPC)

- Independent vs Cooperating Processes.
 - Cooperation: Information Sharing, Computational Speedup, Modularity, Convenience.
- Shared Memory vs Message Passing.
 - Message Passing: Direct vs Indirect Communication
- Client-Server Systems
 - Sockets
 - RPC: Remote Procedure Calls
 - Pipes

- Single vs Multithreaded Process
 - MultiT Benefits: Responsiveness, Resource Sharing, Economy, Scalability
- Multicore Programming
 - Concurrency vs. Parallelism
- Multithreading Models (Kernel vs User Thread)
 - Many to One
 - One to One
 - Many to Many
 - Multilevel Models
- Threading Issues
 - Parallelism on a multi-core system.
- Pthreads

Makefile

```
CC='gcc'
CFLAGS='-std=c99'

P00=00-show-pid
...
P15=15-uas171
P16=16-uas172

EXECS= \
    $(P00) \
    $(P01) \
    ...
    $(P15) \
    $(P16) \

all: $(EXECS)

$(P00): $(P00).c
    $(CC) $(P00).c -o $(P00)

$(P01): $(P01).c
    $(CC) $(P01).c -o $(P01)
...

$(P15): $(P15).c
    $(CC) $(P15).c -o $(P15)

$(P16): $(P16).c
    $(CC) $(P16).c -o $(P16)

clean:
    rm -f $(EXECS)
```

00-show-pid

```
/*
 * (c) 2016-2020 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV07 Tue Mar 24 12:06:10 WIB 2020
 * START Mon Oct 24 09:42:05 WIB 2016
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>

void main(void) {
    printf("  [[[ This is 00-show-pid: PID[%d] PPID[%d] ]]]\n",
          getpid(), getppid());
}

>>>> $ ./00-show-pid

[[[ This is 00-show-pid: PID[5777] PPID[1350] ]]]
```


01-fork

```
>>>> $ cat 01-fork.c ; echo "=====" ; ./01-fork
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
    char *iAM="PARENT";

    printf("PID[%d] PPID[%d] (START:%s)\n", getpid(), getppid(), iAM);
    if (fork() > 0) {
        sleep(1);          /* LOOK THIS ***** */
        printf("PID[%d] PPID[%d] (IFFO:%s)\n", getpid(), getppid(), iAM);
    } else {
        iAM="CHILD";
        printf("PID[%d] PPID[%d] (ELSE:%s)\n", getpid(), getppid(), iAM);
    }
    printf("PID[%d] PPID[%d] (STOP:%s)\n", getpid(), getppid(), iAM);
}

=====
PID[5784] PPID[1350] (START:PARENT)
PID[5785] PPID[5784] (ELSE:CHILD)
PID[5785] PPID[5784] (STOP:CHILD)
PID[5784] PPID[1350] (IFFO:PARENT)
PID[5784] PPID[1350] (STOP:PARENT)
>>>> $
```

02-fork

```
>>>>> $ cat 02-fork.c ; echo "=====" ; ./02-fork
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
    char *iAM="PARENT";

    printf("PID[%d] PPID[%d] (START:%s)\n", getpid(), getppid(), iAM);
    if (fork() > 0) {
        printf("PID[%d] PPID[%d] (IFFO:%s)\n", getpid(), getppid(), iAM);
    } else {
        iAM="CHILD";
        printf("PID[%d] PPID[%d] (ELSE:%s)\n", getpid(), getppid(), iAM);
        sleep(1);      /* LOOK THIS ***** */
    }
    printf("PID[%d] PPID[%d] (STOP:%s)\n", getpid(), getppid(), iAM);
}

=====
PID[5792] PPID[1350] (START:PARENT)
PID[5792] PPID[1350] (IFFO:PARENT)
PID[5792] PPID[1350] (STOP:PARENT)
PID[5793] PPID[5792] (ELSE:CHILD)
>>>>> $ PID[5793] PPID[1] (STOP:CHILD)
>>>>> $
```

03-fork

```
>>>>> $ cat 03-fork.c ; echo "=====" ; ./03-fork
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
    char *iAM="PARENT";

    printf("PID[%d] PPID[%d] (START:%s)\n", getpid(), getppid(), iAM);
    if (fork() > 0) {
        wait(NULL);          /* LOOK THIS ***** */
        printf("PID[%d] PPID[%d] (IFFO:%s)\n", getpid(), getppid(), iAM);
    } else {
        iAM="CHILD";
        printf("PID[%d] PPID[%d] (ELSE:%s)\n", getpid(), getppid(), iAM);
    }
    printf("PID[%d] PPID[%d] (STOP:%s)\n", getpid(), getppid(), iAM);
}

=====
PID[5799] PPID[1350] (START:PARENT)
PID[5800] PPID[5799] (ELSE:CHILD)
PID[5800] PPID[5799] (STOP:CHILD)
PID[5799] PPID[1350] (IFFO:PARENT)
PID[5799] PPID[1350] (STOP:PARENT)
>>>>> $
```

01-fork vs 02-fork vs 03-fork

```
>>>>> $ ./01-fork
PID[5803] PPID[1350] (START:PARENT)
PID[5804] PPID[5803] (ELSE:CHILD)
PID[5804] PPID[5803] (STOP:CHILD)
PID[5803] PPID[1350] (IFF0:PARENT)
PID[5803] PPID[1350] (STOP:PARENT)
>>>>> $ ./02-fork
PID[5805] PPID[1350] (START:PARENT)
PID[5805] PPID[1350] (IFF0:PARENT)
PID[5805] PPID[1350] (STOP:PARENT)
PID[5806] PPID[5805] (ELSE:CHILD)
>>>>> $ PID[5806] PPID[1] (STOP:CHILD)

>>>>> $ ./03-fork
PID[5807] PPID[1350] (START:PARENT)
PID[5808] PPID[5807] (ELSE:CHILD)
PID[5808] PPID[5807] (STOP:CHILD)
PID[5807] PPID[1350] (IFF0:PARENT)
PID[5807] PPID[1350] (STOP:PARENT)
>>>>> $
```

04-sleep

```
#include <stdio.h>
#include <unistd.h>
void main(void) {
    int ii;
    printf("Sleeping 3s with fflush(): ");
    fflush(NULL);
    for (ii=0; ii < 3; ii++) {
        sleep(1);
        printf("x ");
        fflush(NULL);
    }
    printf("\nSleeping with no fflush(): ");
    for (ii=0; ii < 3; ii++) {
        sleep(1);
        printf("x ");
    }
    printf("\n");
}
Sleeping 3s with fflush(): x x x
Sleeping with no fflush(): x x x
```

```

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
    printf("Start:          PID[%d] PPID[%d]\n", getpid(), getppid());
    fflush(NULL);
    if (fork() == 0) {
        /* START BLOCK
        execlp("./00-fork", "00-fork", NULL);
        END BLOCK */
        printf("Child:          ");
    } else {
        wait(NULL);
        printf("Parent:          ");
    }
    printf("          PID[%d] PPID[%d] <<< <<< <<<\n", getpid(), getppid());
}

```

no execlp =====

```

Start:          PID[6040] PPID[1350]
Child:          PID[6041] PPID[6040] <<< <<< <<<
Parent:         PID[6040] PPID[1350] <<< <<< <<<

```

05b-fork

```
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
    printf("Start:          PID[%d] PPID[%d]\n", getpid(), getppid());
    fflush(NULL);
    if (fork() == 0) {
        /* START BLOCK
           END   BLOCK */
        execlp("./00-fork", "00-fork", NULL);
        printf("Child:          ");
    } else {
        wait(NULL);
        printf("Parent:          ");
    }
    printf("          PID[%d] PPID[%d] <<< <<< <<<\n", getpid(), getppid());
}

execlp =====
Start:          PID[6007] PPID[1350]
[[[ This is 00-show-pid: PID[6008] PPID[6007] ]]]
Parent:          PID[6007] PPID[1350] <<< <<< <<<
```

06a-fork

```
#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
/***** main ***/
void main(void) {
    pid_t val1, val2, val3;
    val3 = val2 = val1 = 1000;
    printf("PID==%4d ==== \n", getpid());
    fflush(NULL);
    val1 = fork();
    wait(NULL);
    val2 = fork();
    wait(NULL);
    val3 = fork();
    wait(NULL);
    /* ***** START BLOCK *****
       ***** END** BLOCK *****/
    printf("VAL1=%4d VAL2=%4d VAL3=%4d\n", val1, val2, val3);
}

=====
PID==[13965] ====
VAL1=[01000] VAL2=[01000] VAL3=[01000]
```



```

#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
/***** main ** */
void main(void) {
    pid_t val1, val2, val3;
    val3 = val2 = val1 = 1000;
    printf("PID==%4d ==== \n", getpid());
    fflush(NULL);
    val1 = fork();
    wait(NULL);
/* ***** START BLOCK ***** */
    val2 = fork();
    wait(NULL);
    val3 = fork();
    wait(NULL);
    ***** END** BLOCK */
    printf("VAL1=%4d VAL2=%4d VAL3=%4d\n", val1, val2, val3);
}

=====
PID==[13969] ==== 
VAL1=[00000] VAL2=[01000] VAL3=[01000]
VAL1=[13970] VAL2=[01000] VAL3=[01000]

```

```

#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
/***** main ***/
void main(void) {
    pid_t val1, val2, val3;
    val3 = val2 = val1 = 1000;
    printf("PID==%4d ==== \n", getpid());
    fflush(NULL);
    val1 = fork();
    wait(NULL);
    val2 = fork();
    wait(NULL);
    /* ***** START BLOCK */
    val3 = fork();
    wait(NULL);
    /* ***** END** BLOCK */
    printf("VAL1=%4d VAL2=%4d VAL3=%4d\n", val1, val2, val3);
}

=====
PID==[13971] ==== 
VAL1=[00000] VAL2=[00000] VAL3=[01000]
VAL1=[00000] VAL2=[13973] VAL3=[01000]
VAL1=[13972] VAL2=[00000] VAL3=[01000]
VAL1=[13972] VAL2=[13974] VAL3=[01000]

```

06d-fork

```
#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
/***** main ***/
void main(void) {
    pid_t val1, val2, val3;
    val3 = val2 = val1 = 1000;
    printf("PID==%4d ==== \n", getpid());
    fflush(NULL);
    val1 = fork();
    wait(NULL);
    val2 = fork();
    wait(NULL);
    val3 = fork();
    wait(NULL);
    /* ***** START BLOCK *
       ***** END** BLOCK */
    printf("VAL1=%4d VAL2=%4d VAL3=%4d\n", val1, val2, val3);
}

=====
PID==[13976] ====
VAL1=[00000] VAL2=[00000] VAL3=[00000]
VAL1=[00000] VAL2=[00000] VAL3=[13979]
VAL1=[00000] VAL2=[13978] VAL3=[00000]
VAL1=[00000] VAL2=[13978] VAL3=[13980]
VAL1=[13977] VAL2=[00000] VAL3=[00000]
VAL1=[13977] VAL2=[00000] VAL3=[13982]
VAL1=[13977] VAL2=[13981] VAL3=[00000]
VAL1=[13977] VAL2=[13981] VAL3=[13983]
```

07-execlp

```
>>>> $ cat 07-execlp.c
/* (c) 2019-2020 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV01 Tue Mar 24 16:29:50 WIB 2020
 * START Mon Dec 9 16:28:36 WIB 2019
 */

#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>

void main(int argc, char* argv[]) {
    printf("START %11s PID[%d]\n", argv[0], getpid());
    if(argc == 1) {
        execlp(argv[0], "EXECLP", "WhatEver", NULL);
    } else {
        printf("ELSE %11s PID[%d]\n", argv[1], getpid());
    }
    printf("END %11s PID[%d]\n", argv[0], getpid());
}

$ ./07-execlp
START ./07-execlp PID[14172]
START      EXECLP PID[14172]
ELSE      WhatEver PID[14172]
END      EXECLP PID[14172]
$ ./07-execlp XYZZYPLUGH
START ./07-execlp PID[14174]
ELSE XYZZYPLUGH PID[14174]
END ./07-execlp PID[14174]
$
```

08-fork

```
/* (c) 2005-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Thu Oct 26 12:27:30 WIB 2017
 * START 2005
 */
#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
void main(void) {
    int ii=0;
    if (fork() == 0) ii++;
    wait(NULL);
    if (fork() == 0) ii++;
    wait(NULL);
    if (fork() == 0) ii++;
    wait(NULL);
    printf ("Result = %d \n",ii);
    exit(0);
}
=====
Result = 3
Result = 2
Result = 2
Result = 1
Result = 2
Result = 1
Result = 1
Result = 0
>>>>> $
```

```
/*
 * (c) 2015-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * REV03 Mon Oct 30 11:04:10 WIB 2017
 * REV00 Mon Oct 24 10:43:00 WIB 2016
 * START 2015
 */

#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>

void main(void) {
    int value;

    value=fork();
    wait(NULL);
    printf("I am PID[%4d] -- The fork() return value is: %4d\n", getpid(), value);

    value=fork();
    wait(NULL);
    printf("I am PID[%4d] -- The fork() return value is: %4d\n", getpid(), value);
}

=====
I am PID[6225] -- The fork() return value is:    0)
I am PID[6226] -- The fork() return value is:    0)
I am PID[6225] -- The fork() return value is: 6226)
I am PID[6224] -- The fork() return value is: 6225)
I am PID[6227] -- The fork() return value is:    0)
I am PID[6224] -- The fork() return value is: 6227)
>>>>> $
```

10-fork

```
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Mon Oct 30 20:25:44 WIB 2017
 */

#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>

void procStatus(int level) {
    printf("L%d: PID[%d] (PPID[%d])\n", level, getpid(), getppid());
    fflush(NULL);
}

int addLevelAndFork(int level) {
    if (fork() == 0) level++;
    wait(NULL);
    return level;
}

void main(void) {
    int level = 0;
    procStatus(level);
    level = addLevelAndFork(level);
    procStatus(level);
}

=====
L0: PID[7540] (PPID[1350])
L1: PID[7541] (PPID[7540])
L0: PID[7540] (PPID[1350])
```

11-fork

```
/* (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Mon Oct 30 20:27:24 WIB 2017
 * START Mon Oct 24 09:42:05 WIB 2016
 */

#define LOOP 3
#include <stdio.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>

void procStatus(int level) {
    printf("L%d: PID[%d] (PPID[%d])\n", level, getpid(), getppid());
    fflush(NULL);
}

int addLevelAndFork(int level) {
    if (fork() == 0) level++;
    wait(NULL);
    return level;
}

void main(void) {
    int ii, level = 0;
    procStatus(level);
    for (ii=0;ii<LOOP;ii++) {
        level = addLevelAndFork(level);
        procStatus(level);
    }
}
```


11-fork (2)

```
L0: PID[7548] (PPID[1350])
L1: PID[7549] (PPID[7548])
L2: PID[7550] (PPID[7549])
L3: PID[7551] (PPID[7550])
L2: PID[7550] (PPID[7549])
L1: PID[7549] (PPID[7548])
L2: PID[7552] (PPID[7549])
L1: PID[7549] (PPID[7548])
L0: PID[7548] (PPID[1350])
L1: PID[7553] (PPID[7548])
L2: PID[7554] (PPID[7553])
L1: PID[7553] (PPID[7548])
L0: PID[7548] (PPID[1350])
L1: PID[7555] (PPID[7548])
L0: PID[7548] (PPID[1350])
```

12-fork

```
#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void waitAndPrintPID(void) {
    wait(NULL);
    printf("PID: %d\n", getpid());
    fflush(NULL);
}

void main(int argc, char *argv[]) {
    int rc, status;

    waitAndPrintPID();
    rc = fork();
    waitAndPrintPID();
    if (rc == 0) {
        fork();
        waitAndPrintPID();
        execlp("./00-fork", "00-fork", NULL);
    }
    waitAndPrintPID();
}

=====
PID: 7614
PID: 7615
PID: 7616
[[[ This is 00-fork: PID[7616] PPID[7615] ]]]
PID: 7615
[[[ This is 00-fork: PID[7615] PPID[7614] ]]]
PID: 7614
PID: 7614
>>>>> $
```

```
/*
 * Copyright (C) 2015-2020 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software.

 * REV10 Tue Mar 24 16:38:29 WIB 2020
 * START Xxx Xxx XX XX:XX:XX XXX XXXX
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

void main(void) {
    pid_t  pid1, pid2, pid3;

    pid1 = pid2 = pid3 = getpid();
    printf(" 2016   2015   Lainnya\n=====\\n");
    printf("[%5.5d] [%5.5d] [%5.5d]\\n", pid1, pid2, pid3);
    fork();
    pid1 = getpid();
    wait(NULL);
    pid2 = getpid();
    if(!fork()) {
        pid2 = getpid();
        fork();
    }
    pid3 = getpid();
    wait(NULL);
    printf("[%5.5d] [%5.5d] [%5.5d]\\n", pid1, pid2, pid3);
}
```

```
/*  
# INFO: UTS 2016-1 (midterm)  
*/
```

```
$ ./13-uas161
```

```
2016    2015    Lainnya  
=====
```

[14492]	[14492]	[14492]
[14493]	[14494]	[14495]
[14493]	[14494]	[14494]
[14493]	[14493]	[14493]
[14492]	[14496]	[14497]
[14492]	[14496]	[14496]
[14492]	[14492]	[14492]

```

/* Copyright (C) 2016-2020 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software. This program is distributed in the
 * hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
 * implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
 * REV08 Tue Mar 24 16:40:28 WIB 2020
 * START Sun Dec 04 00:00:00 WIB 2016
 *
 * wait()      = suspends until its child terminates.
 * fflush()    = flushes the user-space buffers.
 * getppid()   = get parent PID
 * ASSUME pid >= 1000 ES pid > ppid **
 */

```

```

#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
#include <sys/wait.h>
#define NN 2

```

```

void main(void) {
    int ii, rPID, rPPID, id1000=getpid();
    for (ii=1; ii<=NN; ii++) {
        fork();
        wait(NULL);
        rPID = getpid()-id1000+1000; /* "relative" */
        rPPID=getppid()-id1000+1000; /* "relative" */
        if (rPPID < 1000 || rPPID > rPID) rPPID=999;
        printf("Loop [%d] - rPID[%d] - rPPID[%4d]\n", ii, rPID, rPPID);
        fflush(NULL);
    }
}

```

```
/*  
# INFO: UTS 2016-2 (midterm)  
*/  
  
$ ./14-uas162  
Loop [1] - rPID[1001] - rPPID[1000]  
Loop [2] - rPID[1002] - rPPID[1001]  
Loop [2] - rPID[1001] - rPPID[1000]  
Loop [1] - rPID[1000] - rPPID[ 999]  
Loop [2] - rPID[1003] - rPPID[1000]  
Loop [2] - rPID[1000] - rPPID[ 999]
```

```

/* Copyright (C) 2005-2020 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software.
 * REV00 Wed May 3 17:07:09 WIB 2017
 * START 2005
 * fflush(NULL): flushes all open output streams
 * fork():      creates a new process by cloning
 * getpid():    get PID (Process ID)
 * wait(NULL):  wait until the child is terminated
 */

```

```

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <stdlib.h>

```

```

void main(void) {
    int firstPID = (int) getpid();
    int RelPID;

    fork();
    wait(NULL);
    fork();
    wait(NULL);
    fork();
    wait(NULL);

    RelPID=(int)getpid()-firstPID+1000;
    printf("RelPID: %d\n", RelPID);
    fflush(NULL);
}

```

```
/*  
# INFO: UTS 2017-1 (midterm)  
*/
```

```
$ ./15-uas171
```

```
RelPID: 1003
```

```
RelPID: 1002
```

```
RelPID: 1004
```

```
RelPID: 1001
```

```
RelPID: 1006
```

```
RelPID: 1005
```

```
RelPID: 1007
```

```
RelPID: 1000
```

```
$
```



```

/*
 * (c) 2017-2020 Rahmat M. Samik-Ibrahim
 * http://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV03 Tue Mar 24 16:42:16 WIB 2020
 * REV02 Mon Dec 11 17:46:01 WIB 2017
 * START Sun Dec 3 18:00:08 WIB 2017
 */

#include <stdio.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>

#define LOOP 3
#define OFFSET 1000

void main(void) {
    int basePID = getpid() - OFFSET;

    for (int ii=0; ii < LOOP; ii++) {
        if(!fork()) {
            printf("PID[%d]-PPID[%d]\n",
                getpid() - basePID,
                getppid() - basePID);
            fflush(NULL);
        }
        wait(NULL);
    }
}

```

```
/*  
# INFO: UTS 2017-2 (midterm)  
*/
```

```
$ ./16-uas172  
PID[1001]-PPID[1000]  
PID[1002]-PPID[1001]  
PID[1003]-PPID[1002]  
PID[1004]-PPID[1001]  
PID[1005]-PPID[1000]  
PID[1006]-PPID[1005]  
PID[1007]-PPID[1000]  
$
```

The End

- ☐ This is the end of the presentation.
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