

CSGE602055 Operating Systems

CSF2600505 Sistem Operasi

Week 07: Synchronization

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

Always check for the latest revision!

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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 - 19 Jun 2020	Final (UAS)	This schedule is subject to change.
Extra	TBA	Extra assignment confirmation	

- ❑ **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**
 - ❑ **All In One** — 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 (**FASILKOM only!**).

Agenda

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Week 07 Synchronization & Deadlock: Topics¹

- Shared Memory and Critical Section
- Consistency, and its role in programming language guarantees for data-race-free programs
- Message passing: PtPo vs Multicast, Blocking vs non-blocking, buffering.

¹Source: ACM IEEE CS Curricula 2013

Week 07 Synchronization & Deadlock: Learning Outcomes¹

- Use mutual exclusion to avoid a given race condition. [Usage]
- Give an example of an ordering of accesses among concurrent activities (e.g., program with a data race) that is not sequentially consistent. [Familiarity]
- Use semaphores to block threads [Usage]

¹Source: ACM IEEE CS Curricula 2013

Week 07: Synchronization

- Reference: (OSC10-ch06 OSC10-ch07 OSC10-ch08 demo-w07)
- **Cooperating Process = ??? Race Condition = ???**
- **The SYNC Game**
 - Three (3) participants: A_1 (left), B (middle), and A_2 (right).
 - Each participant: His/her weekly **MEMO** + a ballpoint/pencil.
 - **This is not a RACING contest!**
 - Objective: Count, how many "I/O" lines per participant per time.
 - Communication Protocol: CSMA/CD (=listen before talk).
 - Each participant: **EXECUTE** this following (**NO need to hurry!**).
 - A_1 writes "1000" to his/her memo.
 - A_2 writes "2000" to his/her memo.
 - **REPEAT:**
 - Random Delay (1-2 seconds).
 - A_{1or2} notify B: A_{1or2} number.
 - B writes that number to his/her memo.
 - A_{1or2} requests B's number.
 - A_1 add one (+1) and writes the number to his/her memo.
 - A_2 sub one (-1) and writes the number to his/her memo.
- Q: What is the last value/number of each participant?

The Critical Section Problem

- Requirements with nonzero speed assumption:
 - Mutual Exclusion
 - Progress
 - Bounded Waiting
- Peterson's Solution
- Semaphores
- Classical Problems
 - Bounded-Buffer Problem
 - Readers and Writers Problem
 - Dining-Philosophers Problem
- Resource and Allocation Graph



Figure: Request and Holding

Peterson's Solution

Process 0

flag[0]=

turn=

```
do {  
    flag[0] = true  
    turn = 1  
    while (flag[1] && turn == 1)  
        (do nothing);  
    [CRITICAL SECTION];  
    flag[0] = false  
    [REMAINDER SECTION];  
} while(true);
```

Process 1

flag[1]=

```
do {  
    flag[1] = true  
    turn = 0  
    while (flag[0] && turn == 0)  
        (do nothing);  
    [CRITICAL SECTION];  
    flag[1] = false  
    [REMAINDER SECTION];  
} while(true);
```

Semaphore

- Dijkstra's Seinpalen (1963): Probeer (Try) en Verhoog (+1)
- Semaphore: Wait(W) and Signal(S)
- Linux System Calls: `sem_init()`, `sem_wait()`, and `sem_post()`

```
# Semaphore (Seinpalen)
```

```
# Wait (Probeer)
```

```
wait(S) {  
    while (S <= 0)  
        ; // busy wait  
    S--;  
}
```

```
# Signal (Verhoog)
```

```
signal(S) {  
    S++;  
}
```

Deadlock and Starvation

- Deadlock Characterization
 - Mutual exclusion
 - Hold and wait
 - No preemption
 - Circular wait
- Banker's Algorithm
- Deadlock Prevention
- Deadlock Avoidance
- How do Operating Systems handle Deadlocks?

IGNORE THE PROBLEM!

Pretending that deadlocks never occur
Just **RESET/REBOOT** it
This is how they **DO IT!**

99-myutils.h (01)

```
/* (c) 2011-2018 Rahmat M. Samik-Ibrahim -- This is free software  
 * Feel free to copy and/or modify and/or distribute it,  
 * provided this notice, and the copyright notice, are preserved.  
 * REV04 Wed Aug 29 18:47:14 WIB 2018 */
```

```
#include <semaphore.h>  
#define MAX_THREAD 256  
#define MAX_globalID 5  
#define BUFFER_SIZE 5  
#define TRUE 1  
#define FALSE 0
```

```
extern sem_t mutex, db, empty, full, globalIDmutex;  
typedef struct {  
    int buffer[BUFFER_SIZE];  
    int in;  
    int out;  
    int count;  
} bbuf_t;
```

99-myutils.h (02)

```
void daftar_trit    (void* trit);           // mempersiapkan "trit"
void jalankan_trit (void);                 // menjalankan dan menunggu hasil
                                              // dari "daftar_trit"
void beberes_trit   (char* pesan);         // beberes menutup "jalankan_trit"

void rehat_acak     (long max_mdetik);     //istirohat acak "0-max_mdetik"(ms)

void init_globalID  (void);                // globalID
int  getADDglobalID (int id);              // globalID[id]++

void init_buffer    (void);                // init buffer
void enter_buffer   (int entry);           // enter an integer item
int  remove_buffer  (void);                // remove the item

void init_rw        (void);                // init readers writers
int  startRead      (void);                // start reading
int  endRead        (void);                // end reading
void startWrite     (void);                // start writing
void endWrite       (void);                // end writing
```

99-myutils.c (01)

```
/*  
 * (c) 2011-2020 Rahmat M. Samik-Ibrahim -- This is free software  
 * Feel free to copy and/or modify and/or distribute it,  
 * provided this notice, and the copyright notice, are preserved.  
 * REV04 Wed Mar 25 08:58:08 WIB 2020  
 * REV03 Wed Aug 29 18:46:36 WIB 2018  
 * REV02 Tue Nov 7 20:15:16 WIB 2017  
 * REV01 Wed Nov 2 11:49:55 WIB 2016  
 * START Xxx Mar 30 02:13:01 UTC 2011  
 */  
  
#include <pthread.h>  
#include <stdio.h>  
#include <stdlib.h>  
#include <time.h>  
#include "99-myutils.h"  
  
sem_t      mutex, db, empty, full, globalIDmutex;
```


99-myutils.c (02)

```
/* TRIT *****/
int      jumlah_trit = 0;
void*    trits   [MAX_THREAD];
pthread_t trit_id[MAX_THREAD];
void daftar_trit(void *trit) {
    if(jumlah_trit >= MAX_THREAD) {
        printf("\n ERROR MAX daftar_trit %d\n",jumlah_trit);
        exit(1);
    }
    trits[jumlah_trit++] = trit;
}
void jalankan_trit(void){
    int ii;
    for (ii=0;ii<jumlah_trit;ii++) {
        if(pthread_create(&trit_id[ii], NULL, trits[ii], NULL)) {
            printf("\n ERROR pthread_creat: %d\n",ii);
            exit(1);
        }
    }
    for (ii=0;ii<jumlah_trit;ii++){
        if(pthread_join(trit_id[ii], NULL)) {
            printf("\n ERROR pthread_join: %d\n",ii);
            exit(1);
        }
    }
}
void beberes_trit(char* pesan) {
    if (pesan != NULL)
        printf("%s\n",pesan);
    pthread_exit(NULL);
}
```

99-myutils.c (03)

```
/* REHAT *****/
int  pertamax    = TRUE;

void rehat_acak(long max_mdetik) {
    struct timespec tim;
    long          ndetik;

    if (pertamax) {
        pertamax = FALSE;
        srandom((unsigned int) time (NULL));
    }
    ndetik      = random() % max_mdetik;
    tim.tv_sec   = ndetik   / 1000L;
    tim.tv_nsec  = ndetik   % 1000L * 1000000L;
    nanosleep(&tim, NULL);
}
```

```
/* globalID **** */

int globalID[MAX_globalID];

void init_globalID (void) {
    sem_init (&globalIDmutex, 0, 1);
    for (int ii=0; ii<MAX_globalID; ii++) {
        globalID[ii]=0;
    }
}

int getADDglobalID (int id) {
    sem_wait (&globalIDmutex);
    int ii=globalID[id]++;
    sem_post (&globalIDmutex);
    return ii;
}
```

```
/* BOUNDED BUFFER *****/
```

```
bbuf_t buf;
```

```
void init_buffer(void) {  
    buf.in    = 0;  
    buf.out   = 0;  
    buf.count = 0;  
    sem_init  (&mutex, 0, 1);  
    sem_init  (&empty, 0, BUFFER_SIZE);  
    sem_init  (&full,  0, 0);  
}
```

99-myutils.c (06)

```
void enter_buffer(int entry) {
    sem_wait(&empty);
    sem_wait(&mutex);
    buf.count++;
    buf.buffer[buf.in] = entry;
    buf.in = (buf.in+1) % BUFFER_SIZE;
    sem_post(&mutex);
    sem_post(&full);
}

int remove_buffer(void) {
    int item;
    sem_wait(&full);
    sem_wait(&mutex);
    buf.count--;
    item = buf.buffer[buf.out];
    buf.out = (buf.out+1) % BUFFER_SIZE;
    sem_post(&mutex);
    sem_post(&empty);
    return item;
}
```

```
/* READERS WRITERS *****/
int readerCount;

void init_rw(void) {
    readerCount = 0;
    sem_init    (&mutex, 0, 1);
    sem_init    (&db,    0, 1);
}

int startRead(void) {
    sem_wait(&mutex);
    if (++readerCount == 1 )
        sem_wait(&db);
    sem_post(&mutex);
    return readerCount;
}
```

```
int endRead(void) {
    sem_wait(&mutex);
    if (--readerCount == 0 )
        sem_post(&db);
    sem_post(&mutex);
    return readerCount;
}

void startWrite(void) {
    sem_wait(&db);
}

void endWrite(void) {
    sem_post(&db);
}
```

00-thread (01)

```
/*  
 * Copyright (C) 2015-2020 Rahmat M. Samik-Ibrahim  
 * http://rahmatm.samik-ibrahim.vlsm.org/  
 * REV11 Tue Mar 24 17:03:47 WIB 2020  
 * START Xxx Sep 30 XX:XX:XX UTC 2015  
 */  
  
#include <stdio.h>  
#include <stdlib.h>  
#include <unistd.h>  
#include <sys/types.h>  
#include "99-myutils.h"  
  
volatile int loop = 6; // display 6 times  
volatile int share = 0; // start share=0
```


00-thread (02)

```
void flushsleep(int ii) {  
    fflush(NULL);  
    sleep (ii );  
}
```

// THREAD#1: start share=1000 --> share++

```
void* thread1 (void* a) {  
    printf("THREAD#1-PID[%5.5d]\n", getpid());  
    flushsleep(1);  
    rehat_acak(100);  
    share = 1000;  
    while (loop > 0) {  
        rehat_acak(100);  
        share++;  
    }  
}
```

```
// THREAD#2: start share=2000 --> share--
void* thread2 (void* a) {
    printf("THREAD#2-PID[%5.5d]\n", getpid());
    flushsleep(1);
    rehat_acak(100);
    share = 2000;
    while (loop > 0) {
        rehat_acak(100);
        share--;
    }
}
```

00-thread (04)

```
// THREAD#3: display "share" every 1 second
void* thread3 (void* a) {
    printf("THREAD#3-PID[%5.5d]\n", getpid());
    while (loop-- > 0) {
        printf("---SHARE----+%5.5d+\n", share);
        flushsleep(1);
    }
}

// MAIN: start share=0
void main(void) {
    printf("---MAIN--PID[%5.5d]\n", getpid());
    daftar_trit    (thread1);
    daftar_trit    (thread2);
    daftar_trit    (thread3);
    jalankan_trit  ();
    beberes_trit   ("----- Done.");
}
```

00-thread (05)

```
$ ./00-thread
---MAIN--PID[05568]
THREAD#1-PID[05568]
THREAD#2-PID[05568]
THREAD#3-PID[05568]
---SHARE-----+00000+
---SHARE-----+00000+
---SHARE-----+02001+
---SHARE-----+02001+
---SHARE-----+02000+
---SHARE-----+01995+
----- Done.
```

```
$ ./00-thread
---MAIN--PID[05576]
THREAD#1-PID[05576]
THREAD#2-PID[05576]
THREAD#3-PID[05576]
---SHARE-----+00000+
---SHARE-----+00000+
---SHARE-----+01001+
---SHARE-----+01006+
---SHARE-----+01006+
---SHARE-----+01005+
----- Done.
```

01-thread (01)

```
>>>> $ cat 01-thread.c
```

```
/*  
 * (c) 2015-2017 Rahmat M. Samik-Ibrahim  
 * https://rahmatm.samik-ibrahim.vlsm.org/  
 * This is free software.  
 * REV02 Wed Nov 1 16:48:40 WIB 2017  
 * REV01 Wed Nov 2 11:49:39 WIB 2016  
 * START Xxx Sep 30 XX:XX:XX UTC 2015  
 */
```

```
#include <stdio.h>  
#include <stdlib.h>  
#include <semaphore.h>  
#include "99-myutils.h"
```

```
sem_t generik;  
sem_t generik2;
```

01-thread (02)

```
void* thread1 (void* a) {
    sem_wait    (&generik);
    printf("THREAD1: I am second!\n");
    sem_post    (&generik2);
}
```

```
void* thread2 (void* a) {
    printf("THREAD2: I am first!\n");
    sem_post    (&generik);
}
```

```
void* thread3 (void* a) {
    sem_wait    (&generik2);
    printf("THREAD3: I am last!\n");
}
```

```
void main(void) {
    sem_init    (&generik,  0, 0);
    sem_init    (&generik2, 0, 0);
    daftar_trit (thread1);
    daftar_trit (thread2);
    daftar_trit (thread3);
    jalankan_trit ();
    beberes_trit ("Bye Bye Main...");
}
```

```
>>>>> $ 01-thread
THREAD2: I am first!
THREAD1: I am second!
THREAD3: I am last!
Bye Bye Main...
```

02-prodkon (01)

```
/*
 * Copyright (C) 2011-2020 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.
 * REV06 Tue Mar 24 17:11:58 WIB 2020
 * REV05 Wed Aug 29 18:35:33 WIB 2018
 * REV04 Tue Apr 17 09:31:37 WIB 2018
 * START Xxx Mar 30 02:13:01 UTC 2011
 */

#include <stdio.h>
#include <stdlib.h>
#include "99-myutils.h"

#define P_REHAT 1000
#define K_REHAT 3000
int produk = 0;

void* Produsen (void* a) {
    printf("Produsen siap...\n");
    while (TRUE) {
        printf("P: REHAT *****\n");
        rehat_acak(P_REHAT);
        printf("P: PRODUKSI %d\n", produk);
        enter_buffer (produk++);
    }
}
```

02-prodkon (02)

```
void* Konsumen (void* a) {
    printf ("                Konsumen siap...\n");
    while (TRUE) {
        printf("                K: REHAT *****\n");
        rehat_acak(K_REHAT);
        printf("                K: KONSUMSI %d\n", remove_buffer());
    }
}

int main(int argc, char * argv[])
{
    init_buffer();
    daftar_trit(Produsen);
    daftar_trit(Konsumen);
    jalankan_trit();
    beberes_trit("Selese...");
}

#####
>>>> $ ./02-prodkon
Produsen siap...
P: REHAT *****

                Konsumen siap...
                K: REHAT *****

P: PRODUKSI 0
P: REHAT *****

                K: KONSUMSI 0
                K: REHAT *****

P: PRODUKSI 1
P: REHAT *****
P: PRODUKSI 2
P: REHAT *****

                K: KONSUMSI 1
                K: REHAT *****
```


03-readwrite (01)

```
>>>> $ cat 03-readwrite.c

/*
 * (c) 2011-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Wed Nov 1 16:53:38 WIB 2017
 * REV01 Wed Nov 2 13:49:55 WIB 2016
 * REV00 Xxx Sep 30 XX:XX:XX UTC 2015
 * START Xxx Mar 30 02:13:01 UTC 2011
 */

#include <stdio.h>
#include <stdlib.h>
#include <semaphore.h>
#include "99-myutils.h"

extern sem_t    mutex, db, empty, full, rmutex, wmutex;

#define R_REHAT 4000
#define R_READ  4000
#define R_JUMLAH 4

#define W_REHAT 2000
#define W_WRITE 2000
#define W_JUMLAH 3

int reader_ID = 0;
int writer_ID = 0;
```

03-readwrite (02)

```
void* Reader (void* a) {
    int  my_ID;

    sem_wait (&rmutex);
    my_ID  = reader_ID++;
    sem_post (&rmutex);

    printf ("                READER %d: SIAP  *****\n", my_ID);
    while (TRUE) {
        printf ("                READER %d: REHAT  *****\n", my_ID);
        rehat_acak(R_REHAT);
        printf ("                READER %d: MAU  MEMBACA\n", my_ID);
        printf ("                **** JUMLAH PEMBACA %d\n", startRead());
        printf ("                READER %d:=SEDANG==BACA\n", my_ID);
        rehat_acak(R_READ);
        printf ("                READER %d: SELESAI BACA\n", my_ID);
        printf ("                **** SISA PEMBACA %d\n", endRead());
    }
}
```

03-readwrite (03)

```
void* Writer (void* a) {
    int my_ID;

    sem_wait (&wmutex);
    my_ID = writer_ID++;
    sem_post (&wmutex);

    printf ("WRITER %d: SIAP *****\n", my_ID);
    while (TRUE) {
        printf("WRITER %d: REHAT *****\n", my_ID);
        rehat_acak(W_REHAT);
        printf("WRITER %d: MAU  MENULIS\n", my_ID);
        startWrite();
        printf("WRITER %d:=SEDANG==NULIS\n", my_ID);
        rehat_acak(W_WRITE);
        endWrite();
        printf("WRITER %d: SELESAI NULIS\n", my_ID);
    }
}

int main(int argc, char * argv[])
{
    int ii;
    init_rw();
    for (ii = 0 ; ii < R_JUMLAH; ii++)
        daftar_trit(Reader);
    for (ii = 0 ; ii < W_JUMLAH; ii++)
        daftar_trit(Writer);
    jalankan_trit();
    beberes_trit("Selese...");
}
```

03-readwrite (04)

```
>>>> $ 03-readwrite

READER 1: SIAP *****
READER 1: REHAT *****
READER 0: SIAP *****
READER 0: REHAT *****

WRITER 1: SIAP *****
WRITER 1: REHAT *****

READER 3: SIAP *****
READER 3: REHAT *****
READER 2: SIAP *****
READER 2: REHAT *****

WRITER 2: SIAP *****
WRITER 2: REHAT *****
WRITER 0: SIAP *****
WRITER 0: REHAT *****
WRITER 2: MAU    MENULIS
WRITER 2:=SEDANG==NULIS

READER 3: MAU    MEMBACA
READER 1: MAU    MEMBACA

WRITER 2: SELESAI NULIS
WRITER 2: REHAT *****

***** JUMLAH PEMBACA 2
READER 1:=SEDANG==BACA
***** JUMLAH PEMBACA 1
READER 3:=SEDANG==BACA

WRITER 1: MAU    MENULIS

READER 1: SELESAI BACA
***** SISA PEMBACA 1
READER 1: REHAT *****

WRITER 0: MAU    MENULIS

READER 3: SELESAI BACA
```

04-readwrite (01)

```
/* Copyright (C) 2011-2020 Rahmat M. Samik-Ibrahim  
 * http://rahmatm.samik-ibrahim.vlsm.org/  
 * This program is free script/software.  
 * REV08 Tue Mar 24 17:41:12 WIB 2020  
 * START Xxx Mar 30 02:13:01 UTC 2011  
 */
```

```
#include <stdio.h>  
#include <stdlib.h>  
#include "99-myutils.h"
```

```
sem_t          sync_er, sync_re, sync_ew, sync_we;
```

```
#define R_REHAT 1500  
#define R_READ  1500  
#define R_JUMLAH 2
```

```
#define W_REHAT 1500  
#define W_WRITE 1500  
#define W_JUMLAH 2
```

04-readwrite (02)

```
#define aReader 0
#define aWriter 1

void* Extra (void* a) {
    int ii;
    while (TRUE) {
        for (ii=0; ii<W_JUMLAH; ii++)
            sem_wait (&sync_we);
        for (ii=0; ii<R_JUMLAH; ii++)
            sem_post (&sync_er);
        for (ii=0; ii<R_JUMLAH; ii++)
            sem_wait (&sync_re);
        for (ii=0; ii<W_JUMLAH; ii++)
            sem_post (&sync_ew);
    }
}
```

04-readwrite (03)

```
void* Reader (void* a) {
    int  my_ID;
    sem_wait (&rmutex);
    my_ID = reader_ID++;
    sem_post (&rmutex);

    printf ("                READER %d: SIAP  *****\n", my_ID);
    while (TRUE) {
        sem_wait (&sync_er);
        printf("                READER %d: REHAT  *****\n", my_ID);
        rehat_acak(R_REHAT);
        printf("                READER %d: MAU  MEMBACA\n", my_ID);
        printf("                **** JUMLAH PEMBACA %d\n", startRead());
        printf("                READER %d:=SEDANG==BACA\n", my_ID);
        rehat_acak(R_READ);
        printf("                READER %d: SELESAI BACA\n", my_ID);
        printf("                ***** SISA PEMBACA %d\n", endRead());
        sem_post (&sync_re);
    }
}
```

04-readwrite (04)

```
void* Writer (void* a) {
    int  my_ID;
    sem_wait (&wmutex);
    my_ID = writer_ID++;
    sem_post (&wmutex);

    printf ("WRITER %d: SIAP  *****\n", my_ID);
    while (TRUE) {
        printf("WRITER %d: REHAT  *****\n", my_ID);
        rehat_acak(W_REHAT);
        printf("WRITER %d: MAU    MENULIS\n", my_ID);
        startWrite();
        printf("WRITER %d:=SEDANG==NULIS\n", my_ID);
        rehat_acak(W_WRITE);
        endWrite();
        printf("WRITER %d: SELESAI NULIS\n", my_ID);
        sem_post (&sync_we);
        sem_wait (&sync_ew);
    }
}
```


04-readwrite (05)

```
int main(int argc, char * argv[])
{
    int ii;
    init_rw();
    sem_init (&sync_er, 0, 0);
    sem_init (&sync_re, 0, 0);
    sem_init (&sync_ew, 0, 0);
    sem_init (&sync_we, 0, 0);
    daftar_trit(Extra);
    for (ii = 0 ; ii < R_JUMLAH; ii++)
        daftar_trit(Reader);
    for (ii = 0 ; ii < W_JUMLAH; ii++)
        daftar_trit(Writer);
    jalankan_trit();
    beberes_trit("Selese...");
}
```

04-readwrite (06)

```
>>>> $ 04-readwrite

READER 1: SIAP *****
READER 0: SIAP *****

WRITER 0: SIAP *****
WRITER 0: REHAT *****
WRITER 1: SIAP *****
WRITER 1: REHAT *****
WRITER 1: MAU MENULIS
WRITER 1:=SEDANG==NULIS
WRITER 0: MAU MENULIS
WRITER 0:=SEDANG==NULIS
WRITER 1: SELESAI NULIS
WRITER 0: SELESAI NULIS

READER 1: REHAT *****
READER 0: REHAT *****
READER 1: MAU MEMBACA
***** JUMLAH PEMBACA 1
READER 1:=SEDANG==BACA
READER 1: SELESAI BACA
***** SISA PEMBACA 0
READER 0: MAU MEMBACA
***** JUMLAH PEMBACA 1
READER 0:=SEDANG==BACA
READER 0: SELESAI BACA
***** SISA PEMBACA 0

WRITER 1: REHAT *****
WRITER 0: REHAT *****
WRITER 0: MAU MENULIS
WRITER 0:=SEDANG==NULIS
```

05-alu (01)

```
>>>> $ cat 05-alu.c
/* (c) 2013-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Wed Nov 1 17:16:35 WIB 2017
 * REV01 Wed Nov 2 13:50:33 WIB 2016
 * START Xxx Xxx XX XX:XX:XX UTC 2013
 */

#include <stdio.h>
#include <stdlib.h>
#include <semaphore.h>
#include "99-myutils.h"

#define      NThreads 4

sem_t      mutex,   switch1, switch2;
int        addvar1, addvar2, addresult;
int        subvar1, subvar2, subresult;
int        mulvar1, mulvar2, mulresult;
int        divvar1, divvar2, divresult;

void* add (void* a) {
    sem_post (&switch1);
    sem_wait (&switch2);

    sem_wait (&mutex);
    printf("Add starts \n");
    addresult = addvar1 + addvar2;
    sem_post (&mutex);
    sem_post (&switch1);
}
```

05-alu (02)

```
void* subtract (void* a) {
    sem_post (&switch1);
    sem_wait (&switch2);

    sem_wait (&mutex);
    printf("Subtract starts \n");
    subresult = subvar1 - subvar2;
    sem_post (&mutex);
    sem_post (&switch1);
}

void* multiply (void* a) {
    sem_post (&switch1);
    sem_wait (&switch2);
    sem_wait (&mutex);
    printf("Multiply starts \n");
    mulresult = mulvar1 * mulvar2;
    sem_post (&mutex);
    sem_post (&switch1);
}

void* divide (void* a) {
    printf("Divide starts \n");
    sem_post (&switch1);
    sem_wait (&switch2);
    sem_wait (&mutex);
    divresult = divvar1 / divvar2;
    sem_post (&mutex);
    sem_post (&switch1);
}
```

05-alu (03)

```
void* manager (void* a) {
    printf("Manager starts \n");

    for (int ii=0; ii< NThreads;ii++)
        sem_wait (&switch1);
    sem_wait (&mutex);
    addvar1 = 5;
    addvar2 = 2;
    subvar1 = 7;
    subvar2 = 2;
    mulvar1 = 2;
    mulvar2 = 3;
    divvar1 = 4;
    divvar2 = 2;
    sem_post (&mutex);

    for (int ii=0; ii< NThreads;ii++)
        sem_post (&switch2);
    for (int ii=0; ii< NThreads;ii++)
        sem_wait (&switch1);
    printf("Result: %d + %d = %d\n", addvar1, addvar2, addresult);
    printf("Result: %d - %d = %d\n", subvar1, subvar2, subresult);
    printf("Result: %d * %d = %d\n", mulvar1, mulvar2, mulresult);
    printf("Result: %d / %d = %d\n", divvar1, divvar2, divresult);
}
```

05-alu (04)

```
void main(void) {
    sem_init      (&mutex,   0, 1);
    sem_init      (&switch1, 0, 0);
    sem_init      (&switch2, 0, 0);
    daftar_trit   (manager);
    daftar_trit   (add);
    daftar_trit   (subtract);
    daftar_trit   (multiply);
    daftar_trit   (divide);
    jalankan_trit ();
    beberes_trit  ("Done...");
}
```

```
>>>> $ 05-alu
Manager starts
Divide starts
Add starts
Subtract starts
Multiply starts
Result: 5 + 2 = 7
Result: 7 - 2 = 5
Result: 2 * 3 = 6
Result: 4 / 2 = 2
Done...
>>>> $
```

06-balap (01)

```
/* Copyright (C) 2012-2020 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.
 * REV06 Tue Mar 24 19:07:30 WIB 2020
 * REV05 Mon Feb 11 15:44:22 WIB 2019
 * START Xxx Mar 30 02:13:01 UTC 2012
 */

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include "99-myutils.h"

#define lamaRehat 250
#define jmlPembalap 12
sem_t start1, start2, mutex1, mutex2;

void* bandar (void* a) {
    for (int ii=0; ii<jmlPembalap; ii++)
        sem_wait (&start1);
    printf ("Bandar Siap!\n");
    fflush(NULL);
    for (int ii=0; ii<jmlPembalap; ii++)
        sem_post (&start2);
}

int idmaster = 1;
int juara   = 1;
int menang  = TRUE;
```

06-balap (02)

```
void* pembalap (void* a) {
    sem_wait (&mutex);
    int id = idmaster++;
    sem_post (&mutex);
    printf ("Pembalap %2.2d Siap!\n",id);
    sem_post (&start1);
    sem_wait (&start2);
    rehat_acak(lamaRehat);
    sem_wait (&mutex1);
    rehat_acak(lamaRehat);
    sem_wait (&mutex2);
    if (menang==TRUE) printf("HORE, pemain");
    else printf("Aduh, pemain");
    printf(" %2.2d juara %2.2d!\n",id,juara++);
    menang = FALSE;
    rehat_acak(lamaRehat);
    sem_post (&mutex2);
    rehat_acak(lamaRehat);
    sem_post (&mutex1);
}

void main(void) {
    sem_init (&mutex, 0, 1);
    sem_init (&mutex1, 0, 1);
    sem_init (&mutex2, 0, 1);
    sem_init (&start1, 0, 0);
    sem_init (&start2, 0, 0);
    daftar_trit (bandar);
    for (int ii=0; ii<jmlPembalap; ii++)
        daftar_trit (pembalap);
    jalankan_trit ();
    beberes_trit ("Selese...");
}
```


06-balap (03)

```
$ ./06-balap
Pembalap 01 Siap!
Pembalap 04 Siap!
Pembalap 03 Siap!
Pembalap 06 Siap!
Pembalap 02 Siap!
Pembalap 05 Siap!
Pembalap 07 Siap!
Pembalap 08 Siap!
Pembalap 09 Siap!
Pembalap 10 Siap!
Pembalap 11 Siap!
Pembalap 12 Siap!
Bandar Siap!
HORE, pemain 12 juara 01!
Aduh, pemain 02 juara 02!
Aduh, pemain 09 juara 03!
Aduh, pemain 08 juara 04!
Aduh, pemain 11 juara 05!
Aduh, pemain 04 juara 06!
Aduh, pemain 03 juara 07!
Aduh, pemain 06 juara 08!
Aduh, pemain 05 juara 09!
Aduh, pemain 10 juara 10!
Aduh, pemain 07 juara 11!
Aduh, pemain 01 juara 12!
Selese...
$
```

07-sudokuSV (01)

```
>>>> $ cat 07-sudokuSV.c
/*
 * (c) 2015 M. Anwar Ma'sum and R.M. Samik-Ibrahim
 * (c) 2016-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * SSV: Sudoku Solution Validator
 * REV02 Wed Nov 1 18:04:38 WIB 2017
 * REV01 Wed Nov 2 11:20:30 WIB 2016
 */
#include <stdio.h>
#include <pthread.h>
#include <semaphore.h>
#include "99-myutils.h"
#define V_THREADS 27

int idSequence = 0;
sem_t mutex, sync;
char result[3][9];
int sudoku[9][9] = { /* Check this 9x9 matrix */
    {5,3,4, 7,6,8, 9,1,2},
    {6,7,2, 1,9,5, 3,4,8},
    {1,9,8, 3,4,2, 5,6,7},

    {8,5,9, 6,7,1, 4,2,3},
    {4,2,6, 8,5,3, 7,9,1},
    {7,1,3, 9,2,4, 8,5,6},

    {9,6,1, 5,3,7, 2,8,4},
    {2,8,7, 4,1,9, 6,3,5},
    {3,4,5, 2,8,6, 1,7,9}
};
```

07-sudokuSV (02)

```
char validate(int iINIT,int iEND,int jINIT,int jEND) {
    int ii, jj;
    char flag[9];

    for (ii = 0; ii < 9; ii++) flag[ii] = 'F';
    for (ii = iINIT; ii < iEND; ii++) {
        for (jj = jINIT; jj < jEND; jj++) {
            if (flag[sudoku[ii][jj]-1] == 'F')
                flag[sudoku[ii][jj]-1] = 'T';
            else
                return 'F';
        }
    }
    return 'T';
}

void *reporter (void *p) {
    int ii,jj;
    for (ii = 0; ii < V_THREADS; ii++)
        sem_wait(&sync);
    for (ii = 0; ii < 3; ii++) {
        if (ii == 0) printf ("ROW Validators: ");
        else if (ii == 1) printf ("COL Validators: ");
        else printf ("BOX Validators: ");
        for (jj = 0; jj < 9; jj++)
            printf("%c ", result[ii][jj]);
        printf("\n");
    }
}
```

07-sudokuSV (03)

```
void *sudokuValidator (void *param) {
    int my_ID, tmp0, tmp1;
    char check;

    sem_wait(&mutex);
    my_ID = idSequence++;
    sem_post(&mutex);

    if (my_ID < 9) {
        check = validate (my_ID, my_ID+1, 0, 9);
    } else if (my_ID < 18) {
        check = validate (0,9,my_ID%9,my_ID%9+1);
    } else {
        tmp0 = ((my_ID%9)/3)*3;
        tmp1 = ((my_ID%9)%3)*3;
        check = validate (tmp0,tmp0+3,tmp1,tmp1+3);
    }

    sem_wait(&mutex);
    result[(my_ID/9)][(my_ID%9)] = check;
    sem_post(&mutex);
    sem_post(&sync);
}
```

07-sudokuSV (04)

```
void main(void *v) {
    int ii, jj;
    printf("SSV: Sudoku Solution Validator\n\n");
    for (ii=0; ii<9; ii++) {
        for (jj=0; jj<9; jj++) {
            printf("%d ", sudoku[ii][jj]);
            if ((jj%3) == 2)
                printf(" ");
        }
        printf ("\n");
        if ((ii%3) == 2)
            printf("\n");
    }
    sem_init(&mutex,0,1);
    sem_init(&sync, 0,0);
    daftar_trit(reporter);
    for (ii = 0; ii < V_THREADS; ii++)
        daftar_trit(sudokuValidator);
    jalankan_trit();
    beberes_trit("Done...");
}
```

07-sudokuSV (05)

SSV: Sudoku Solution Validator

```
5 3 4 7 6 8 9 1 2
6 7 2 1 9 5 3 4 8
1 9 8 3 4 2 5 6 7
```

```
8 5 9 6 7 1 4 2 3
4 2 6 8 5 3 7 9 1
7 1 3 9 2 4 8 5 6
```

```
9 6 1 5 3 7 2 8 4
2 8 7 4 1 9 6 3 5
3 4 5 2 8 6 1 7 9
```

```
ROW Validators: T T T T T T T T T
COL Validators: T T T T T T T T T
BOX Validators: T T T T T T T T T
```

```
5 3 4 7 6 8 9 1 2
6 9 2 1 9 5 3 4 8
1 9 8 3 4 2 5 6 7
```

```
8 5 9 6 7 1 4 2 3
4 2 6 8 5 3 7 9 1
7 1 3 9 2 4 8 5 6
```

```
9 6 1 5 3 7 2 8 4
2 8 7 4 1 9 6 3 5
3 4 5 2 8 6 1 7 9
```

```
ROW Validators: T F T T T T T T T
COL Validators: T F T T T T T T T
BOX Validators: F T T T T T T T T
```

08-mainDadu (01)

```
>>>> $ cat 08-mainDadu.c
/*
 * (c) 2012-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV02 Wed Nov  1 18:16:14 WIB 2017
 * REV01 Wed Nov  2 11:20:30 WIB 2016
 * REV00 Xxx Sep 30 XX:XX:XX UTC 2015
 * START Xxx Mar 30 02:13:01 UTC 2012
 */

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <semaphore.h>
#include "99-myutils.h"

#define P_REHAT  400
#define K_REHAT 2000
#define WINpoint 12

sem_t mutex1;

int  idmaster=0;
int  winner=0;
```

08-mainDadu (02)

```
void* Dice (void* a) {
    int dadu;
    printf("The Dice is ready...\n");
    while (TRUE) {
        rehat_acak(P_REHAT);
        dadu=(random() % 6) + 1;
        printf("Dice value %d\n", dadu);
        enter_buffer (dadu);
        if (winner !=0) {
            enter_buffer (dadu);
            enter_buffer (dadu);
            enter_buffer (dadu);
            enter_buffer (dadu);
            enter_buffer (dadu);
            enter_buffer (dadu);
            break;
        }
    }
}
```


08-mainDadu (03)

```
void* Player (void* a) {
    int id, prev=0, total=0;
    sem_wait (&mutex1);
    id=idmaster++;
    sem_post (&mutex1);
    printf ("                Player %d is ready...\n",id);
    while (total < WINpoint) {
        rehat_acak(K_REHAT);
        prev = total;
        total += remove_buffer();
        if (winner !=0) break;
        printf("                Player %d's points: %2d [plus %d] \n",
            id, total, total-prev);
    }
    if (winner != 1)
        printf("                Player %d WINS!!!! (%d)\n", id, total);
    winner = 1;
    printf("                Player %d EXIT\n", id);
}
```

08-mainDadu (04)

```
int main(int argc, char * argv[]) {
    printf("The first player -- with more than %d points -- wins **** ****\n", WINpoint);
    sleep(1);
    sem_init (&mutex1, 0, 1);
    init_buffer();
    daftar_trit(Dice);
    daftar_trit(Player);
    daftar_trit(Player);
    daftar_trit(Player);
    daftar_trit(Player);
    daftar_trit(Player);
    jalankan_trit();
    beberes_trit("Done...");
}
```

08-mainDadu (05)

The first player -- with more than 12 points -- wins **** ****

The Dice is ready...

Player 0 is ready...

Player 2 is ready...

Player 3 is ready...

Player 4 is ready...

Player 1 is ready...

Dice value 3

Player 3's points: 3 [plus 3]

Dice value 5

Dice value 2

Player 4's points: 5 [plus 5]

Dice value 5

Dice value 2

Dice value 6

Player 3's points: 5 [plus 2]

Player 0's points: 5 [plus 5]

Player 0's points: 7 [plus 2]

Player 1's points: 6 [plus 6]

Dice value 5

Player 2's points: 5 [plus 5]

Dice value 2

Player 4's points: 7 [plus 2]

Dice value 5

Player 0's points: 12 [plus 5]

Player 0 WINS!!!! (12)

Player 0 EXIT

Dice value 5

Player 3 EXIT

Player 4 EXIT

Player 1 EXIT

Player 2 EXIT

Done

09-rpsls (01)

```
/*  
 * (c) 2014-2017 Rahmat M. Samik-Ibrahim  
 * https://rahmatm.samik-ibrahim.vlsm.org/  
 * This is free software.  
 * REV02 Wed Nov 1 18:21:02 WIB 2017  
 * REV01 Wed Nov 2 11:20:30 WIB 2016  
 * REV00 Xxx Sep 30 XX:XX:XX UTC 2015  
 * START Xxx Oct 19 XX:XX:XX UTC 2014  
 */
```

```
// *Rock*Paper*Scissors*Lizard*Spock*
```

```
// Invented by Sam Kass and Karen Bryla  
// Rock crushes Scissors  
// Rock crushes Lizard  
// Paper covers Rock  
// Paper disproves Spock  
// Scissors cut Paper  
// Scissors decapitate Lizard  
// Lizard eats Paper  
// Lizard poisons Spock  
// Spock vaporizes Rock  
// Spock smashes Scissors
```

```
#include <semaphore.h>  
#include <stdio.h>  
#include <stdlib.h>  
#include <time.h>  
#include <unistd.h>  
#include "99-myutils.h"
```

09-rpsls (02)

```
#define nPlayers 2
#define nWeapons 5
int    playerSEQ=1;
int    myWeapon[nPlayers+1];
sem_t  mutex, sync1, sync2;

// (0=Rock) (1=Paper) (2=Scissors) (3=Lizard) (4=Spock)
char *weaponName[nWeapons]= {
    "Rock", "Paper", "Scissors",
    "Lizard", "Spock"
};

// '-' = draw 'v' = win 'x' = lose
char weaponTable[nWeapons][nWeapons] = {
    {'-', 'x', 'v', 'v', 'x'},
    {'v', '-', 'x', 'x', 'v'},
    {'x', 'v', '-', 'v', 'x'},
    {'x', 'v', 'x', '-', 'v'},
    {'v', 'x', 'v', 'x', '-'}
};

void waitPlayers() {
    for (int ii=0; ii < nPlayers; ii++)
        sem_wait(&sync1);
}

void postPlayers() {
    for (int ii=0; ii < nPlayers; ii++)
        sem_post(&sync2);
}
```

09-rpsh (03)

```
void* playerThread (void* a) {
    int    playerID;
    sem_wait (&mutex);
    playerID=playerSEQ++;
    sem_post (&mutex);
    printf("Player[%d]: READY\n",playerID);
    sem_post (&sync1);
    sem_wait (&sync2);
    myWeapon[playerID] = rand() % nWeapons;
    printf("Player[%d]: %s\n",
        playerID, weaponName[myWeapon[playerID]]);
    sem_post (&sync1);
}

void* refereeThread (void* a) {
    waitPlayers();
    printf("Referee:  ALL READY!\n");
    postPlayers();
    waitPlayers();
    char result =
        weaponTable[myWeapon[1]][myWeapon[2]];
    if (result == '-')
        printf("Referee:  DRAW!\n");
    else if (result == 'v')
        printf("Referee:  Player[1] WINS!\n");
    else
        printf("Referee:  Player[2] WINS!\n");
}
```

09-rpsls (04)

```
void main() {
    // randomize with a time seed
    srand(time(NULL));
    sleep(1);
    // init semaphore mutex = 1 syncx = 0
    sem_init (&mutex, 0, 1);
    sem_init (&sync1, 0, 0);
    sem_init (&sync2, 0, 0);
    // register and execute threads
    daftar_trit (refereeThread);
    for (int ii=0; ii<nPlayers; ii++)
        daftar_trit (playerThread);
    jalankan_trit ();
    beberes_trit ("Goodbye...");
}

>>>> $ 09-rpsls
Player[1]: READY
Player[2]: READY
Referee:  ALL READY!
Player[1]: Rock
Player[2]: Lizard
Referee:  Player[1] WINS!
Goodbye...
>>>> $ 09-rpsls
Player[1]: READY
Player[2]: READY
Referee:  ALL READY!
Player[2]: Paper
Player[1]: Spock
Referee:  Player[2] WINS!
Goodbye...
>>>> $
```

10-kiriklanan (01)

```
>>>> $ cat 10-kiriklanan.c
/*
 * (c) 2011-2017 Rahmat M. Samik-Ibrahim
 * This is free software. Feel free to copy and/or
 * modify and/or distribute it, provided this
 * notice, and the copyright notice, are preserved.
 * REV02 Wed Nov 1 19:46:42 WIB 2017
 * REV01 Wed May 17 17:02:37 WIB 2017
 * START Wed May 3 12:58:28 WIB 2017
 *
 * sem_init(), sem_wait(), sem_post(): semaphore
 * sleep(X): sleep X seconds
 * daftar_trit(T): register thread T
 * jalankan_trit(): start all registered threads.
 * beberes_trit(): exit all threads above. */

#define jmlKIRI    5
#define jmlKANAN   3
#define SLEEP      2000
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include "99-myutils.h"

sem_t    syncModKiri, syncModKanan;
sem_t    syncKiriMod, syncKananMod;

#define aCetak 0
#define aKanan 1
#define aKiri  2
```


10-kiriklanan (02)

```
void cetak(char* posisi, int id) {
    printf("%2.2d %s(%2.2d)\n", getADDglobalID(aCetak), posisi, id);
}

void* Moderator (void* a) {
    int ii;
    while (TRUE) {
        for (ii=0; ii<jmlKIRI; ii++)
            sem_wait (&syncKiriMod);
        for (ii=0; ii<jmlKANAN; ii++) {
            sem_post (&syncModKanan);
            rehat_acak(SLEEP);
        }
        for (ii=0; ii<jmlKANAN; ii++)
            sem_wait (&syncKananMod);
        for (ii=0; ii<jmlKIRI; ii++) {
            sem_post (&syncModKiri);
            rehat_acak(SLEEP);
        }
    }
}

void* Kanan (void* a) {
    int id = getADDglobalID(aKanan);
    while (TRUE) {
        sem_wait (&syncModKanan);
        cetak("--++Kanan", id);
        sem_post (&syncKananMod);
    }
}
```

10-kirikanan (03)

```
void* Kiri (void* a) {
    int id = getADDglobalID(aKiri);
    while (TRUE) {
        cetak("Kiri-+-+--", id);
        fflush(NULL);
        sem_post (&syncKiriMod);
        sem_wait (&syncModKiri);
    }
}

int main(int argc, char * argv[]) {
    int ii;

    init_globalID();
    sem_init (&syncModKiri, 0, 0);
    sem_init (&syncModKanan, 0, 0);
    sem_init (&syncKiriMod, 0, 0);
    sem_init (&syncKananMod, 0, 0);

    for (ii = 0 ; ii < jmlKANAN; ii++)
        daftar_trit(Kanan);
    for (ii = 0 ; ii < jmlKIRI; ii++)
        daftar_trit(Kiri);
    daftar_trit(Moderator);

    jalankan_trit();
    beberes_trit("Selese...");
}
```

10-kiriklanan (04)

00 Kiri-+-+- (00)
03 Kiri-+-+- (03)
02 Kiri-+-+- (02)
04 Kiri-+-+- (04)
01 Kiri-+-+- (01)
05 -+-+-+Kanan(00)
06 -+-+-+Kanan(01)
07 -+-+-+Kanan(02)
08 Kiri-+-+- (00)
09 Kiri-+-+- (02)
10 Kiri-+-+- (03)
11 Kiri-+-+- (04)
12 Kiri-+-+- (01)
13 -+-+-+Kanan(00)
14 -+-+-+Kanan(01)
15 -+-+-+Kanan(02)
16 Kiri-+-+- (00)
17 Kiri-+-+- (02)
18 Kiri-+-+- (03)
19 Kiri-+-+- (04)
20 Kiri-+-+- (01)
21 -+-+-+Kanan(00)
22 -+-+-+Kanan(01)
23 -+-+-+Kanan(02)
24 Kiri-+-+- (00)
25 Kiri-+-+- (02)
26 Kiri-+-+- (03)
27 Kiri-+-+- (04)
28 Kiri-+-+- (01)
29 -+-+-+Kanan(00)
30 -+-+-+Kanan(01)

11-thread (01)

```
>>>> $ cat 11-thread.c
```

```
/*
 * (c) 2015-2017 Rahmat M. Samik-Ibrahim
 * https://rahmatm.samik-ibrahim.vlsm.org/
 * This is free software.
 * REV05 Wed Nov 1 19:51:21 WIB 2017
 * REV04 Tue Dec 13 15:19:04 WIB 2016
 * START Wed Sep 30 00:00:00 UTC 2015
 */

#include <stdio.h>
#include <stdlib.h>
#include "99-myutils.h"
#define nSem 7

sem_t sem[nSem];

void* thread1 (void* a) {
    sem_wait (&sem[1]);
    printf("T1X\n");
    sem_post (&sem[4]);
}

void* thread2 (void* a) {
    sem_wait (&sem[2]);
    printf("T2X\n");
    sem_post (&sem[5]);
    sem_post (&sem[1]);
}
```

11-thread (02)

```
void* thread3 (void* a) {
    printf("T3X\n");
    sem_post (&sem[6]);
    sem_post (&sem[2]);
}
void* thread4 (void* a) {
    sem_wait (&sem[4]);
    printf("T44\n");
    sem_wait (&sem[5]);
    printf("T45\n");
    sem_wait (&sem[6]);
    printf("T46\n");
}
void main(void) {
    printf("MAIN\n");
    for (int ii=1;ii<nSem;ii++)
        sem_init(&sem[ii], 0, 0);
    daftar_trit (thread1);
    daftar_trit (thread2);
    daftar_trit (thread3);
    daftar_trit (thread4);
    jalankan_trit ();
    beberes_trit ("TREXIT");
}
MAIN
T3X
T2X
T1X
T44
T45
T46
TREXIT
```

12-multi-thread (01)

```
/*  
 * Copyright (C) 2017-2020 Rahmat M. Samik-Ibrahim  
 * http://rahmatm.samik-ibrahim.vlsm.org/  
 * This program is free script/software.  
 * REV02 Wed Mar 25 09:45:51 WIB 2020  
 * REV01 Wed Aug 29 18:33:51 WIB 2018  
 * START Mon Nov 27 10:19:59 WIB 2017  
 */
```

```
#include <stdio.h>  
#include <stdlib.h>  
#include <unistd.h>  
#include "99-myutils.h"  
#define NTHREAD      8  
#define RECDEEP      8  
#define LOOP1    100  
#define LOOP2    100  
#define LOOP3    100
```

12-multi-thread (02)

```
volatile unsigned share=0;
unsigned multiloop(int recursive) {
    sleep(1);
    unsigned dummy = share;
    for (int ii; ii<LOOP1; ii++) {
        for (int jj; jj<LOOP2; jj++) {
            for (int kk; kk<LOOP3; kk++) {
                dummy++;
            }
        }
    }
    share = dummy;
    if (recursive-- < 0)
        return share;
    else
        return multiloop(recursive);
}
```

12-multi-thread (03)

```
void* thread (void* a) {  
    printf("Start Thread %8.8X ...\n", share);  
    share=multiloop(RECDEEP);  
    printf("Stop Thread %8.8X ...\n", share);  
}
```

```
void main(void) {  
    printf("This is MAIN\n");  
    for (int ii=0;ii<NTHREAD;ii++)  
        daftar_trit (thread);  
    jalankan_trit ();  
    beberes_trit ("TREXIT!");  
}
```


12-multi-thread (04)

This is MAIN

Start Thread 00000000 ...

Start Thread 00000000 ...

Start Thread 00000000 ...

Start Thread 00000000 ...

Start Thread 00000000 ...

Start Thread 00000000 ...

Start Thread 00000000 ...

Start Thread 00000000 ...

Stop Thread 0000170C ...

Stop Thread 00001900 ...

Stop Thread 00001770 ...

Stop Thread 00001964 ...

Stop Thread 00001838 ...

Stop Thread 0000189C ...

Stop Thread 00001770 ...

Stop Thread 000017D4 ...

TREXIT!

13-mini-sudoku-4x4 (01)

```
/* Copyright (C) 2017-2020 Rahmat M. Samik-Ibrahim  
 * http://rahmatm.samik-ibrahim.vlsm.org/  
 * This program is free script/software.  
 * REV10 Sat Apr 11 13:34:55 WIB 2020  
 * START Mon Dec 4 18:52:57 WIB 2017 */
```

```
#include <stdio.h>  
#include <stdlib.h>  
#include <unistd.h>  
#include "99-myutils.h"  
#define WaitSudoku 3  
#define SSIZE      4  
#define TOTALSIZE  SSIZE * SSIZE
```

```
int      globalExit=FALSE;  
sem_t    mutexing;  
sem_t    syncing1;  
sem_t    syncing2;
```

13-mini-sudoku-4x4 (02)

```
// cellSudoku[row][column][0]    = value
// cellSudoku[row][column][1-4] = guesses
// if (value != 0) all guesses = 0
//                               (no more guesses)
int cellSudoku[][SSIZE+1][SSIZE+1]={
    {},{{}}, {0,1,2,3,4}, {0,1,2,3,4},
        {0,1,2,3,4}, {0,1,2,3,4}},
    {{}}, {0,1,2,3,4}, {0,1,2,3,4},
        {0,1,2,3,4}, {0,1,2,3,4}},
    {{}}, {0,1,2,3,4}, {0,1,2,3,4},
        {0,1,2,3,4}, {0,1,2,3,4}},
    {{}}, {0,1,2,3,4}, {0,1,2,3,4},
        {0,1,2,3,4}, {0,1,2,3,4}}
};
```

13-mini-sudoku-4x4 (03)

```
// Print Cells
void printCells(char* state) {
    printf ("\nSudoku Cells: %s\n", state);
    for (    int jj=1; jj<SSIZE+1; jj++) {
        for (int kk=1; kk<SSIZE+1; kk++) {
            int cell=cellSudoku[jj][kk][0];
            if (cell == 0 || cell == 5)
                printf ("[ ]");
            else      printf ("[%d]", cell);
            if (kk == SSIZE) printf ("\n");
        }
    }
    fflush(NULL);
}
```

13-mini-sudoku-4x4 (04)

```
// Filling the CELLS
void
fillCell(int rowCell,int colCell,int valCell)
{
    sem_wait (&mutexing);
    // Filling "valCell" into
    // cellSudoku[rowCell, colCell];
    cellSudoku[rowCell][colCell][0] = valCell;
    // This is Cell is "taken".
    // Eliminate all guesses!
    for (int ii=1; ii<SSIZE+1; ii++) {
        cellSudoku[rowCell][colCell][ii] = 0;
    }
    // Deleting "valCell"
    // from all "columns guess"
    for (int ii=1; ii<SSIZE+1; ii++) {
        cellSudoku[rowCell][ii][valCell] = 0;
    }
    // Delete "valCell" from all "rows guess".
    for (int ii=1; ii<SSIZE+1; ii++) {
        cellSudoku[ii][colCell][valCell] = 0;
    }
    // Delete "valCell" from all "boxes guess".
    rowCell = 1 + 2*((rowCell - 1)/2);
    colCell = 1 + 2*((colCell - 1)/2);
    for (int ii=rowCell; ii<rowCell+2; ii++) {
        for (int jj=colCell; jj<colCell+2; jj++){
            cellSudoku[ii][jj][valCell] = 0;
        }
    }
    sem_post (&mutexing);
}
```

13-mini-sudoku-4x4 (05)

```
// From Standard Input into Cell using  
// fillCell -- SCAN INPUT: scanf()  
// is the oposite of printf()  
void inputCell(void) {  
    for (int ii=0; ii < TOTALSIZE; ii++) {  
        int tmpCell=0;  
        scanf("%d", &tmpCell);  
        int rowCell = ii/4 + 1;  
        int colCell = ii%4 + 1;  
        if (tmpCell != 0) {  
            fillCell(rowCell,colCell,tmpCell);  
        }  
    }  
}
```

13-mini-sudoku-4x4 (06)

```
// CellWatcher
int cwID = 0;
void* cellWatcher (void* a) {
    sem_wait (&syncing1);
    sem_wait (&mutexing);
    int rowCell = cwID/4 + 1;
    int colCell = cwID%4 + 1;
    cwID++;
    sem_post (&mutexing);
    int localExit=FALSE;
    while (!localExit && !globalExit) {
        int tmpCell=0, nZero=0;
        for (int ii=1; ii<SSIZE+1; ii++) {
            if (cellSudoku[rowCell][colCell][ii]==0)
                nZero++;
            else
                tmpCell=ii;
        }
        if (nZero==3)
            fillCell(rowCell, colCell, tmpCell);
        localExit =
            cellSudoku[rowCell][colCell][0]!=0;
    }
    fflush(NULL);
    sem_post (&syncing2);
}
```

13-mini-sudoku-4x4 (07)

```
// Timeout after "WaitSudoku"
void* managerSudoku (void* a) {
    sleep(WaitSudoku);
    for (int ii=0; ii<TOTALSIZE; ii++) {
        int rowCell = ii/4 + 1;
        int colCell = ii%4 + 1;
        if(cellSudoku[rowCell][colCell][0]==0){
            cellSudoku[rowCell][colCell][0]= 5;
        }
        sem_post (&syncing2);
    }
    globalExit = TRUE;
}
```


13-mini-sudoku-4x4 (08)

```
// Display Sudoku
void* displaySudoku (void* a) {
    printCells("INITIAL");
    for(int jj=0;jj<TOTALSIZE;jj++)
        sem_post(&syncing1);
    for(int jj=0;jj<TOTALSIZE;jj++)
        sem_wait(&syncing2);
    printCells("RESULT");
}

// This is MAIN
void main(void) {
    printf ("MAIN:\nRUN: ./13-sudoku-mini-4x4 < 13-1-data-sudoku.txt");
    printf ("      \n OR: Enter the value of the 16 cells (4x4)\n");
    sem_init (&mutexing, 0, 1);
    sem_init (&syncing1, 0, 0);
    sem_init (&syncing2, 0, 0);
    inputCell();
    for (int ii=0; ii<TOTALSIZE; ii++) {
        daftar_trit(cellWatcher);
    }
    daftar_trit (displaySudoku);
    daftar_trit (managerSudoku);
    jalankan_trit ();
    beberes_trit (" \nTRIT: EXIT");
}
```

13-mini-sudoku-4x4 (09)

```
PROMPT> cat 13-1-data-sudoku.txt
```

```
0 0  0 3
```

```
0 1  4 0
```

```
0 2  3 0
```

```
1 0  0 0
```

```
PROMPT> ./13-mini-sudoku-4x4 < 13-1-data-sudoku.txt
```

```
MAIN: START
```

```
Sudoku Cells: INITIAL
```

```
[ ][ ][ ][3]
```

```
[ ][1][4][ ]
```

```
[ ][2][3][ ]
```

```
[1][ ][ ][ ]
```

```
Sudoku Cells: RESULT
```

```
[2][4][1][3]
```

```
[3][1][4][2]
```

```
[4][2][3][1]
```

```
[1][3][2][4]
```

```
TRIT: EXIT
```

```
PROMPT>
```

W08:10-create-file (01)

```
/* Copyright (C) 2018 Rahmat M. Samik-Ibrahim http://rahmatm.samik-ibrahim.vlsm.org/
 * This program is free script/software.
 * REV01 Thu Nov 15 09:51:28 WIB 2018
 * START Wed Nov 14 20:30:05 WIB 2018 */

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <unistd.h>

typedef struct {
    char  mystring[16];
    int   myint;
    char  ends[2];
} myshare;

#define MYFLAGS  O_CREAT|O_RDWR
char*   sfile="demo-file.bin";

void main(void) {
    printf("Create shared file \"%s\"\n", sfile);
    int ssize=sizeof(myshare);
    myshare* mymap=malloc(ssize);
    strcpy((char*) mymap, "AAAAAAAAAABBBBBBZZZZ\n");
    int fd=open(sfile,MYFLAGS,S_IRWXU);
    write(fd,mymap,ssize);
    close(fd);
    printf("Please check file \"%s\"\n", sfile);
}
```

W08:10-create-file (02)

```
$ cat demo-file.bin
Ah, This is Mr. Y. Yoda!
DUDE, THIS MAY NOT A TEXT FILE!
Ah, This is Mr. Y. Yoda!
```

```
$ ./10-create-file
Create shared file "demo-file.bin"
Please check file "demo-file.bin"
```

```
$ cat demo-file.bin
AAAAAAAAAABBBBBBZZZZ
```

```
DUDE, THIS MAY NOT A TEXT FILE!
Ah, This is Mr. Y. Yoda!
```

```
$ hexdump -c demo-file.bin
00000000  A  A  A  A  A  A  A  A  A  A  B  B  B  B  B  B
00000010  Z  Z  Z  Z  \n \0 \0 \0 \n D  U  D  E  ,  T
00000020  H  I  S      M  A  Y      N  O  T      A      T  E
00000030  X  T      F  I  L  E  !  \n A  h  ,      T  h  i
00000040  s      i  s      M  r  .      Y  .      Y  o  d  a
00000050  !  \n  \n
00000053
$
```

W08:11-create-mmap (01)

```
/* Copyright (C) 2018 Rahmat M. Samik-Ibrahim  
 * http://rahmatm.samik-ibrahim.vlsm.org/  
 * This program is free script/software.  
 * REV01 Thu Nov 15 11:16:22 WIB 2018  
 * START Wed Nov 14 20:30:05 WIB 2018  
 */
```

```
#include <stdio.h>  
#include <stdlib.h>  
#include <fcntl.h>  
#include <unistd.h>  
#include <sys/types.h>  
#include <sys/stat.h>  
#include <sys/mman.h>  
#define MYFLAGS      O_RDWR  
#define MYPROTECTION PROT_READ|PROT_WRITE  
#define MYVISIBILITY MAP_SHARED  
char*  sfile="demo-file.bin";
```

W08:11-create-mmap (02)

```
typedef struct {
    char mystring[16];
    int  myint;
    char ends[2];
} myshare;

void main(void) {
    struct stat fsize;
    int  ssize=sizeof(myshare);
    int  fd=open(sfile,MYFLAGS,S_IRWXU);

    printf("Create mmap()\n");
    fstat(fd, &fsize);
    if (fsize.st_size < ssize) {
        printf("Does %s exist? Size >= %d?\n", sfile, ssize);
        exit(1);
    }
    myshare* mmap=mmap(NULL, ssize, MYPROTECTION, MYVISIBILITY, fd, 0);
    if (mmap == MAP_FAILED) {
        printf("mmap(): FAILED\n");
        exit(1);
    }
    mmap->mystring[0]='X';
    mmap->mystring[1]='Y';
    mmap->mystring[2]='Z';
    mmap->mystring[3]=' ';
    mmap->myint=0x61626364;
    close(fd);
    printf("Please check file \"%s\"\n", sfile);
}
```

W08:11-create-mmap (03)

```
$ cat demo-file.bin  
AAAAAAAAAABBBBBBZZZZ
```

```
DUDE, THIS MAY NOT A TEXT FILE!  
Ah, This is Mr. Y. Yoda!
```

```
$ ./11-create-mmap  
Create mmap()  
Please check file "demo-file.bin"
```

```
$ cat demo-file.bin  
XYZ AAAAAABBBBBBdcba
```

```
DUDE, THIS MAY NOT A TEXT FILE!  
Ah, This is Mr. Y. Yoda!
```

```
$ hexdump -c demo-file.bin  
00000000 X Y Z A A A A A B B B B B B  
00000010 d c b a \n \0 \0 \0 \n D U D E , T  
00000020 H I S M A Y N O T A T E  
00000030 X T F I L E ! \n A h , T h i  
00000040 s i s M r . Y . Y o d a  
00000050 ! \n \n  
00000053  
$
```

```
/*
 * Copyright (C) 2015-2018 CC BY-SA 3.0 adapted from
 * https://stackoverflow.com/questions/32205396/
 *   share-posix-semaphore-among-multiple-processes
 * Copyright (C) 2018 Rahmat M. Samik-Ibrahim (slightly modified)
 * This is Free Software
 * REV03 Wed Aug 29 20:39:16 WIB 2018
 * REV02 Wed Apr 18 22:02:52 WIB 2018
 */

#define SEM_NAME "/semaphore-demo-rms46"

/* ATTN:
   Replace the "rms46" part in SEM_NAME with your userid!
   "Dead semaphores" are lingering in folder "/dev/shm/".
   If you are the owner, you can delete "dead semaphores" manually.
 * ***** */
```



```
#include <stdio.h>
#include <stdlib.h>
#include <fcntl.h>
#include <unistd.h>
#include <semaphore.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <sys/wait.h>

#define SEM_PERMS (S_IRUSR | S_IWUSR | S_IRGRP | S_IWGRP)
#define INITIAL_VALUE 0

#define CHILD_PROGRAM "./21-child"
#define CHILDREN      2
```

W08:20-parent (03)

```
int main(void) {
    size_t ii;
    pid_t  pids[CHILDREN], mypid=getpid();

    /* We initialize the semaphore counter to 1 (INITIAL_VALUE) */
    sem_t *semaphore = sem_open(SEM_NAME, O_CREAT | O_EXCL, SEM_PERMS, INITIAL_VALUE);

    if (semaphore == SEM_FAILED) {
        perror("sem_open(3) error");
        sem_unlink(SEM_NAME);
        exit(EXIT_FAILURE);
    }
    for (ii = 0; ii < sizeof(pids)/sizeof(pids[0]); ii++) {
        if ((pids[ii] = fork()) < 0) {
            perror("fork(2) failed");
            exit(EXIT_FAILURE);
        } else if (pids[ii] == 0) {
            if (execl(CHILD_PROGRAM, CHILD_PROGRAM, NULL) < 0) {
                perror("execl(2) failed");
                exit(EXIT_FAILURE);
            }
        }
        printf("Parent PID[%d] creates child PID[%d]\n", mypid, pids[ii]);
    }
    printf("Parent PID[%d] signals [%s]\n", mypid, SEM_NAME);
    sem_post(semaphore);
    for (ii = 0; ii < sizeof(pids)/sizeof(pids[0]); ii++)
        wait(NULL);
    if (sem_unlink(SEM_NAME) < 0) perror("sem_unlink(3) failed");
    printf("Parent PID[%d] says Good Bye!\n", mypid);
    return 0;
}
```

```
/*  
 * TESTED ON WSL Windows 10:  
 *  
 $ ./20-parent  
 Parent PID[185] creates child PID[186]  
 Parent PID[185] creates child PID[187]  
 Parent PID[185] signals [/semaphore-demo-rms46]  
 Child PID[186] is UP!  
 Child PID[187] is UP!  
 Child PID[187] is inside the Critical Section  
 Child PID[187] is outside the Critical Section  
 Child PID[186] is inside the Critical Section  
 Child PID[186] is outside the Critical Section  
 Child PID[186] is inside the Critical Section  
 Child PID[186] is outside the Critical Section  
 Child PID[187] is inside the Critical Section  
 Child PID[187] is outside the Critical Section  
 Parent PID[185] says Good Bye!  
 $  
 */
```

W08:21-child (01)

```
/*
 * TAKE NOTE (RMS)
 * "21-child" is executed by "20-parent".
 *
 * Copyright (C) 2015-2018 CC BY-SA 3.0 adapted from
 * https://stackoverflow.com/questions/32205396/share-posix-semaphore-among-multiple-processes
 * Copyright (C) 2018 Rahmat M. Samik-Ibrahim (slightly modified)
 * This is Free Software
 * REV04 Wed Aug 29 20:38:59 WIB 2018
 * REV03 Mon Apr 23 17:01:28 WIB 2018
 * START Xxx Xxx XX XX:XX:XX WIB 2015
 */

#define ITTERS 2
#define SEM_NAME "/semaphore-demo-rms46"

/* ATTN:
   Replace the "rms46" part in SEM_NAME with your userid!
   "Dead semaphores" are lingering in folder "/dev/shm/".
   If you are the owner, you can delete "dead semaphores" manually.
 * ***** */

#include <stdio.h>
#include <stdlib.h>
#include <fcntl.h>
#include <semaphore.h>
#include <unistd.h>
#include <time.h>
#include <sys/stat.h>
#include <sys/types.h>

#define DELAY 10000000
```

W08:21-child (02)

```
int main(void) {
    pid_t mypid = getpid();
    sem_t *semaphore = sem_open(SEM_NAME, O_RDWR);

    if (semaphore == SEM_FAILED) {
        perror("sem_open(3) failed");
        exit(EXIT_FAILURE);
    }
    printf("Child PID[%d] is UP!\n", mypid);
    for (int ii = 0; ii < ITERS; ii++) {
        sleep(1);
        sem_wait(semaphore);
        printf("Child PID[%d] is inside the Critcl Sectn\n", mypid);
        sem_post(semaphore);
        printf("Child PID[%d] is outside the Critcl Sectn\n", mypid);
    }
    if (sem_close(semaphore) < 0)
        perror("sem_close(3) failed");
    return 0;
}
```

```
/*  
 * Copyright (C) 2013-2019 CC BY-SA 3.0 adapted from  
 * https://stackoverflow.com/questions/5656530/  
 * how-to-use-shared-memory-with-linux-in-c  
 * Copyright (C) 2018 Rahmat M. Samik-Ibrahim (slightly modified)  
 * This is Free Software  
 * REV03 Wed Feb 27 19:12:02 WIB 2019  
 * REV02 Wed Aug 29 20:39:39 WIB 2018  
 * START Xxx Xxx XX XX:XX:XX WIB 2015  
 */
```

```
#include <stdio.h>  
#include <string.h>  
#include <unistd.h>  
#include <stdlib.h>  
#include <sys/mman.h>
```

W08:22-hello-goodbye (02)

```
// parent process will write this message
char parent_message[] = "You say Hello";
char child_message[] = "And I say Goodbye"; // child process

int main(void) {
    int protection = PROT_READ | PROT_WRITE;
    int visibility = MAP_ANONYMOUS | MAP_SHARED;
    char* shmem = mmap(NULL, 128, protection, visibility, 0, 0);
    memcpy(shmem, parent_message, sizeof(parent_message));
    int pid = fork();
    if (pid == 0) {
        printf("Child read: %s\n", shmem);
        memcpy(shmem, child_message, sizeof(child_message));
        printf("Child wrote: %s\n", shmem);
    } else {
        printf("Parent read: %s\n", shmem);
        sleep(1);
        printf("After 1s, parent read: %s\n", shmem);
    }
}
```

```
/*  
 * TAKE NOTE (RMS)  
 * This program has been TESTED ON WSL Windows 10:  
 *
```

```
$ ./22-hello-goodbye  
Parent read: You say Hello  
Child read:  You say Hello  
Child wrote: And I say Goodbye  
After 1s, parent read: And I say Goodbye  
$
```

```
*/
```


W08:23-kirim-ambil (01)

```
/*
Copyright (C) 2013-2018 CC BY-SA 3.0
adapted from https://stackoverflow.com/questions/5656530/how-to-use-shared-memory-with-linux-in-c

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* REV08 Wed Aug 29 20:42:05 WIB 2018
* REV07 Wed Apr 25 09:28:14 WIB 2018
* START Xxx Xxx XX XX:XX:XX WIB 2013
*/

// DO NOT USE THE SAME SEMAPHORE NAME!!!!
// Replace "demo" with your own SSD name.
#define SEM_SYN_KRAM      "/syn-KRAM-demo"
#define SEM_SYN_AMKR      "/syn-AMKR-demo"
#define SEM_Mutex         "/sm_mutex-demo"

#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <semaphore.h>
#include <sys/mman.h>
#include <sys/types.h>
#include <sys/wait.h>
```

W08:23-kirim-ambil (02)

```
// Shared Memory: R/W with no name.
#define PROT      (PROT_READ | PROT_WRITE)
#define VISIBLE   (MAP_ANON   | MAP_SHARED)
#define KIRIM 0
#define AMBIL 1
#define LOOP 2

typedef struct {
    int    produk;
    int    turn;
    int    loop;
} buffer;

// KRAM: Kirim-Ambil; AMKR: Ambil-Kirim
sem_t*    sync_KRAM;
sem_t*    sync_AMKR;
sem_t*    sem_mutex;

// WARNING: NO ERROR CHECK! //////////
void persiapan(buffer* buf) {
    buf->loop    = 0;
    buf->produk  = 0;
    buf->turn    = AMBIL;
    sync_KRAM    = sem_open(SEM_SYN_KRAM,
                            O_CREAT, 0600, 0);
    sync_AMKR    = sem_open(SEM_SYN_AMKR,
                            O_CREAT, 0600, 0);
    sem_mutex    = sem_open(SEM_MUTEX,
                            O_CREAT, 0600, 1);
    printf("PR KIRIMAN AWAL: %d\n",
          buf->produk);
}
```

W08:23-kirim-ambil (03)

```
void kirim (buffer* buf) {
    printf("KR KIRIM PID[%d]\n",getpid());
    sem_post(sync_KRAM);
    sem_wait(sync_AMKR);
    int krLoop = 0;
    while (buf->turn != KIRIM)
        ;
    while (buf->loop < LOOP) {
        krLoop++;
        sem_wait(sem_mutex);
        if (buf->turn == KIRIM) {
            buf->turn = AMBIL;
            printf("KR %d\n",++(buf->produk));
        }
        sem_post(sem_mutex);
    }
    wait(NULL);
    printf("KR LOOPS = %d\n", krLoop);
}
```

```
void ambil (buffer* buf) {
    sem_wait(sync_KRAM);
    sem_post(sync_AMKR);
    printf("AM AMBIL PID[%d]\n",getpid());
    int amLoop = 0;
    while (buf->loop < LOOP+1) {
        amLoop++;
        sem_wait(sem_mutex);
        if(buf->turn == AMBIL) {
            buf->turn = KIRIM;
            printf("AM %d\n", buf->produk);
            buf->loop++;
        }
        sem_post(sem_mutex);
    }
    printf("AM LOOPS = %d\n", amLoop);
}
```

```
// WARNING: NO ERROR CHECK! //////////////////////////////////
void main(void) {
    printf("STARTING PID[%d]\n", getpid());
    buffer* shrbuf = mmap(NULL,
                           sizeof(buffer), PROT,
                           VISIBLE, 0, 0);
    persiapan(shrbuf);
    if (fork()) kirim (shrbuf); //Parent
    else          ambil (shrbuf); //Child
    sem_unlink(SEM_SYN_KRAM);
    sem_unlink(SEM_SYN_AMKR);
    sem_unlink(SEM_MUTEX);
    printf("STOP PID[%d]\n", getpid());
}
```

W08:23-kirim-ambil (06)

```
/*  
 * TAKE NOTE (RMS)  
 * This program has been TESTED ON WSL Windows 10:  
 $ ./23-kirim-ambil  
 STARTING PID[241]  
 PR KIRIMAN AWAL: 0  
 KR KIRIM PID[241]  
 AM AMBIL PID[242]  
 AM 0  
 KR 1  
 AM 1  
 KR 2  
 AM 2  
 AM LOOPS = 66  
 STOP PID[242]  
 KR LOOPS = 32  
 STOP PID[241]  
 $  
 */
```

/*

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** REV05 Wed Mar 25 12:09:31 WIB 2020*

** REV04 Mon Oct 28 21:00:19 WIB 2019*

** REV03 Wed Aug 29 20:42:26 WIB 2018*

** START Wed Apr 18 19:50:01 WIB 2018*

INFO: UAS 2018-1 (final term)

INFO: To run: ./50-181

**/*

UAS W08:50-181 (02)

```
// DO NOT USE THE SAME SEMAPHORE NAME!!!!
```

```
// Replace "demo" with your own SSO name.
```

```
#define SEM_COUNT1      "/count-1-demo"  
#define SEM_COUNT2      "/count-2-demo"  
#define SEM_Mutex       "/mutex-demo"  
#define SEM_SYNC        "/sync-demo"
```

```
#include <fcntl.h>  
#include <stdio.h>  
#include <stdlib.h>  
#include <unistd.h>  
#include <semaphore.h>  
#include <sys/mman.h>  
#include <sys/types.h>  
#include <sys/wait.h>
```

```
// Shared Memory: R/W with no name.
```

```
#define PROT      (PROT_READ | PROT_WRITE)  
#define VISIBLE (MAP_ANON | MAP_SHARED)
```

```
#define LOOP      2  
#define BUFSIZE 1
```

```
sem_t*  ctr_prod;  
sem_t*  ctr_cons;  
sem_t*  mutex;  
sem_t*  ssync;  
int*    product;
```



```
// WARNING: NO ERROR CHECK! //////////////////////////////////
```

```
void flushprintf(char* str,int ii) {
    printf("%s [%d]\n", str, ii);
    fflush(NULL);
}

void init(void) {
    product  = mmap(NULL, sizeof(int),
                    PROT, 0, 0);
    *product = 0;
    ctr_prod = sem_open(SEM_COUNT1,
                        O_CREAT, 0600, BUFSIZE);
    ctr_cons = sem_open(SEM_COUNT2,
                        O_CREAT, 0600, 0);
    mutex    = sem_open(SEM_MUTEX,
                        O_CREAT, 0600, 1);
    ssync     = sem_open(SEM_SYNC,
                        O_CREAT, 0600, 0);
}
```

```

void producer (void) {
    sem_wait(ssync);
    flushprintf("PRODUCER  PID",getpid());
    for (int loop = 0; loop < LOOP; loop++) {
        sem_wait(ctr_prod);
        sem_wait(mutex);
        flushprintf("PRODUCT  ",++(*product));
        sem_post(mutex);
        sem_post(ctr_cons);
    }
    wait(NULL);
}

```

```
void consumer (void) {  
    flushprintf("CONSUMER  PID",getpid());  
    sem_post(ssync);  
    for (int loop = 0; loop < LOOP; loop++) {  
        sem_wait(ctr_cons);  
        sem_wait(mutex);  
        flushprintf("CONSUME  ", *product);  
        sem_post(mutex);  
        sem_post(ctr_prod);  
    }  
}
```

```
// WARNING: NO ERROR CHECK! //////////////////////////////////  
void main(void) {  
    flushprintf("STARTING  PID", getpid());  
    init();  
    if (fork()) producer (); //Parent  
    else          consumer (); //Child  
    sem_unlink(SEM_COUNT1);  
    sem_unlink(SEM_COUNT2);  
    sem_unlink(SEM_SYNC);  
    sem_unlink(SEM_Mutex);  
    flushprintf("STOP HERE PID", getpid());  
}
```

/*

** TAKE NOTE (RMS)*

** This program has been TESTED ON WSL Windows 10.*

\$./50-181

STARTING PID [252]

CONSUMER PID [253]

PRODUCER PID [252]

PRODUCT [1]

CONSUME [1]

PRODUCT [2]

CONSUME [2]

STOP HERE PID [253]

STOP HERE PID [252]

\$

UAS W08:51-182 (01)

```
/*
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* REV06 Wed Mar 25 12:10:59 WIB 2020
* REV05 Mon Oct 28 20:57:52 WIB 2019
* REV03 Mon Dec 10 18:53:06 WIB 2018
* START Wed Nov 14 20:30:05 WIB 2018

# INFO: UAS 2018-2 (final term)
# INFO:          To run:      ./51-182

*/

#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <semaphore.h>
#include <unistd.h>
#include <sys/mman.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <sys/wait.h>

#define MYFLAGS      O_CREAT | O_RDWR
#define MYPROTECT PROT_READ | PROT_WRITE
#define MYVISIBILITY      MAP_SHARED
#define SFILE        "demo-file.bin"
```

```
typedef struct {
    sem_t   sync[3];
    int     share;
    int     loop;
    pid_t   relative;
} myshare;

myshare* mymap;

void flushprintf(char* tag1, char* tag2){
    printf("%s[%s] loop%d relative(%d)\n",
        tag1, tag2, mymap->loop,
        getpid() + mymap->relative);
    fflush(NULL);
}
```

UAS W08:51-182 (03)

```
#define MAIN "51:182 "  
#define ADD1 "52:182a"  
#define SUB1 "53:182b"  
  
void main(void) {  
    int fd    =open(SFILE,MYFLAGS,S_IRWXU);  
    int ssize=sizeof(myshare);  
    truncate(SFILE, ssize);  
    mmap=mmap(NULL, ssize, MYPROTECT, MYVISIBILITY, fd, 0);  
    mmap->share    = 0;  
    mmap->loop      = 6;  
    mmap->relative  = 1000 - getpid();  
    sem_init (&(mmap->sync[0]), 1, 0);  
    sem_init (&(mmap->sync[1]), 1, 0);  
    sem_init (&(mmap->sync[2]), 1, 0);  
    flushprintf(MAIN, "EXEC");  
    if (!fork()) execlp("./52-182a", ADD1, NULL);  
    if (!fork()) execlp("./53-182b", SUB1, NULL);  
    do {  
        sleep(1);  
        flushprintf(MAIN, "LOOP");  
    } while (--mmap->loop);  
    flushprintf(MAIN, "WAIT");  
    sem_wait (&(mmap->sync[0]));  
    sem_wait (&(mmap->sync[0]));  
    if      (mmap->share > 1500) flushprintf("SHARE +/-", "2000");  
    else if (mmap->share > 500)  flushprintf("SHARE +/-", "1000");  
    else                               flushprintf("SHARE +/-", "0");  
    wait(NULL); wait(NULL);  
    flushprintf(MAIN, "EXIT");  
    close(fd);  
}
```


\$./50-181

STARTING PID [8535]

CONSUMER PID [8536]

PRODUCER PID [8535]

PRODUCT [1]

CONSUME [1]

PRODUCT [2]

CONSUME [2]

STOP HERE PID [8536]

STOP HERE PID [8535]

\$

UAS W08:52-182a (01)

```
/*
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* REV06 Wed Mar 25 12:10:46 WIB 2020
* REV05 Tue May 7 20:54:40 WIB 2019
* REV04 Tue Dec 11 10:32:07 WIB 2018
* START Wed Nov 14 20:30:05 WIB 2018

# INFO: UAS 2018-2 (final term)
# INFO: Run from: ./51-182

*/

#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <semaphore.h>
#include <unistd.h>
#include <sys/mman.h>
#include <sys/types.h>
#include <sys/stat.h>

#define MYFLAGS O_CREAT | O_RDWR
#define MYPROTECT PROT_READ | PROT_WRITE
#define MYVISIBILITY MAP_SHARED
#define SFILE "demo-file.bin"
```

```
typedef struct {  
    sem_t   sync[3];  
    int     share;  
    int     loop;  
    pid_t   relative;  
} myshare;  
  
myshare* mymap;  
  
void flushprintf(char* tag1, char* tag2){  
    printf("%s[%s] loop%d relative(%d)\n",  
        tag1, tag2, mymap->loop,  
        getpid() + mymap->relative);  
    fflush(NULL);  
}
```

```
void main(int argc, char* argv[]) {
    int fd =open(SFILE,MYFLAGS,S_IRWXU);
    int ssize=sizeof(myshare);
    mymap=mmap(NULL, ssize, MYPROTECT, MYVISIBILITY, fd, 0);
    sem_post (&(mymap->sync[2]));
    sem_wait (&(mymap->sync[1]));
    sem_wait (&(mymap->sync[1]));
    mymap->share=1000;
    flushprintf(argv[0], "PASS");
    while (mymap->loop) {
        for(int ii=0; ii<1000000; ii++)    ;
        mymap->share++;
    }
    sem_post (&(mymap->sync[2]));
    sem_wait (&(mymap->sync[1]));
    flushprintf(argv[0], "EXIT");
    sem_post (&(mymap->sync[2]));
    sem_post (&(mymap->sync[0]));
    close(fd);
}
```

UAS W08:53-182b (01)

```
/*
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* REV06 Wed Mar 25 12:12:59 WIB 2020
* REV05 Tue May 7 20:55:29 WIB 2019
* REV04 Tue Dec 11 10:32:43 WIB 2018
* START Wed Nov 14 20:30:05 WIB 2018

# INFO: UAS 2018-2 (final term)
# INFO: Run from: ./51-182

*/

#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <semaphore.h>
#include <unistd.h>
#include <sys/mman.h>
#include <sys/types.h>
#include <sys/stat.h>

#define MYFLAGS O_CREAT | O_RDWR
#define MYPROTECT PROT_READ | PROT_WRITE
#define MYVISIBILITY MAP_SHARED
#define SFILE "demo-file.bin"
```

```
typedef struct {  
    sem_t  sync[3];  
    int     share;  
    int     loop;  
    pid_t   relative;  
} myshare;  
  
myshare* mymap;  
  
void flushprintf(char* tag1, char* tag2){  
    printf("%s[%s] loop%d relative(%d)\n",  
        tag1, tag2, mymap->loop,  
        getpid() + mymap->relative);  
    fflush(NULL);  
}
```

```
void main(int argc, char* argv[]) {
    int fd =open(SFILE,MYFLAGS,S_IRWXU);
    int ssize=sizeof(myshare);
    mymap=mmap(NULL, ssize, MYPROTECT, MYVISIBILITY, fd, 0);
    sem_post (&(mymap->sync[1]));
    sem_wait (&(mymap->sync[2]));
    mymap->share=2000;
    flushprintf(argv[0], "PASS");
    sem_post (&(mymap->sync[1]));
    while (mymap->loop) {
        for(int ii=0; ii<1000000; ii++) ;
        mymap->share--;
    }
    sem_post (&(mymap->sync[1]));
    sem_wait (&(mymap->sync[2]));
    sem_wait (&(mymap->sync[2]));
    flushprintf(argv[0], "EXIT");
    sem_post (&(mymap->sync[0]));
    close(fd);
}
```

UAS W08:54-191 (01)

```
/*
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REVO2 Wed Mar 25 11:56:58 WIB 2020
REVO1 Mon Oct 28 21:11:13 WIB 2019
START Wed May 08 09:06:00 WIB 2019

# INFO: UAS 2019-1 (final term)
# INFO:                To run:    ./54-191

WARNING: NO ERROR CHECK! ////////////
exit(STATUS)    == exit with STATUS
memcpy(*d,*s,n) == copy n from s to d
mmap()          == creates a new memory map
usleep(DELAY1MS) == sleep 1 MS

*/

#define TURNS    15
#define LAP      25
#define DELAY1MS 901
#define DELAY    DELAY1MS*20

// =====
typedef struct {
    char motoGP[35];
    int  countLap;
} drivers;
```


UAS W08:54-191 (02)

```
drivers D[]={  
    {"(93) M Marquez      - Honda  ", 0}  
    ,{"(42) A Rins        - Suzuki ", 0}  
    ,{"(04) A Dovizioso   - Ducati ", 0}  
    ,{"(46) V Rossi       - Yamaha  ", 0}  
    ,{"(09) D Petrucci    - Ducati  ", 0}  
    ,{"(12) M Vinales     - Yamaha  ", 0}  
    ,{"(43) J Miller      - Ducati  ", 0}  
    ,{"(30) T Nakagami    - Honda   ", 0}  
    ,{"(35) C Crutchlow   - Honda   ", 0}  
    ,{"(21) F Morbidelli  - Yamaha  ", 0}  
    ,{"(44) P Espargaro   - KTM    ", 0}  
    ,{"(41) A Espargaro   - Aprilia", 0}  
    ,{"(21) F Quartararo - Yamaha  ", 0}  
    ,{"(99) J Lorenzo     - Honda   ", 0}  
    ,{"(63) F Bagnaia    - Ducati  ", 0}  
    ,{"(36) J Mir         - Suzuki  ", 0}  
    ,{"(88) M Oliveira    - KTM    ", 0}  
    ,{"(05) J Zarco       - KTM    ", 0}  
    ,{"(06) S Bradl      - Honda   ", 0}  
    ,{"(29) A Iannone     - Aprilia", 0}  
    ,{"(53) T Rabat       - Ducati  ", 0}  
    ,{"(17) K Abraham     - Ducati  ", 0}  
    ,{"(55) H Syahrin    - KTM    ", 0}  
    ,{"(38) B Smith      - Aprilia", 0}  
};
```

```
#include <semaphore.h>  
#include <stdio.h>  
#include <stdlib.h>  
#include <string.h>  
#include <sys/mman.h>
```

UAS W08:54-191 (03)

```
#include <sys/types.h>
#include <sys/wait.h>
#include <unistd.h>
#define SIZEofD (int) sizeof(D)
#define SIZEofD0 (int) sizeof(D[0])
#define NDRIVERS SIZEofD/SIZEofD0
typedef struct {
    sem_t    mutex;
    sem_t    turns[TURNS];
    pid_t    relPID;
    volatile int rTime;
    drivers  D[NDRIVERS];
} shareMem;
#define MSIZE (int) sizeof(shareMem)
#define MAXSEM 2
#define MUTEX 1
#define PROTECT PROT_READ | PROT_WRITE
#define VISIBLE MAP_SHARED|MAP_ANONYMOUS

shareMem* mymap;
// =====
void init(void) {
    printf("[1000] INIT:  %d %d %d %d\n", SIZEofD, SIZEofD0, NDRIVERS, MSIZE);
    mymap=mmap(NULL, MSIZE, PROTECT, VISIBLE, 0, 0);
    for (int ii=0; ii<TURNS; ii++)
        sem_init (&(mymap->turns[ii]), 1, MAXSEM);
    sem_init (&(mymap->mutex),1,MUTEX);
    mymap->rTime=0;
    mymap->relPID=getpid() - 1000;
    memcpy(mymap->D, D, sizeof(D));
    printf("[1000] INIT:  END\n");
}
```

```
void motoGP(int number) {
    pid_t relPID=getpid()-mymap->relPID;
    while(mymap->D[number].countLap<LAP){
        for (int ii=0; ii<TURNS; ii++) {
            usleep(DELAY);
            sem_wait (&(mymap->turns[ii]));
            sem_post (&(mymap->turns[ii]));
        }
        mymap->rTime++;
        mymap->D[number].countLap++;
    }
    sem_wait (&(mymap->mutex));
    printf("[%d] %s Lap %2d rTime %3d\n",
        relPID, mymap->D[number].motoGP,
        mymap->D[number].countLap,
        mymap->rTime++);
    fflush(NULL);
    sem_post (&(mymap->mutex));
    exit (0);
}

void main(void) {
    init();
    printf("[1000] motoGP:START\n");
    for (int ii=0; ii<NDRIVERS; ii++) {
        if(!fork()) motoGP(ii);
        usleep(DELAY1MS);
    }
    printf("[1000] motoGP:RACING\n");
    for (int ii=0; ii<NDRIVERS; ii++) wait(NULL);
    printf("[1000] motoGP:FINISH\n");
    exit (0);
}
```

UAS W08:54-191 (05)

\$./54-191

[1000] INIT: 960 40 24 1480

[1000] INIT: END

[1000] motoGP:START

[1000] motoGP:RACING

[1002] (42) A Rins - Suzuki Lap 25 rTime 576

[1001] (93) M Marquez - Honda Lap 25 rTime 578

[1003] (04) A Dovizioso - Ducati Lap 25 rTime 580

[1007] (43) J Miller - Ducati Lap 25 rTime 582

[1005] (09) D Petrucci - Ducati Lap 25 rTime 584

[1006] (12) M Vinales - Yamaha Lap 25 rTime 586

[1008] (30) T Nakagami - Honda Lap 25 rTime 588

[1010] (21) F Morbidelli - Yamaha Lap 25 rTime 590

[1011] (44) P Espargaro - KTM Lap 25 rTime 592

[1012] (41) A Espargaro - Aprilia Lap 25 rTime 594

[1014] (99) J Lorenzo - Honda Lap 25 rTime 596

[1013] (21) F Quartararo - Yamaha Lap 25 rTime 599

[1015] (63) F Bagnaia - Ducati Lap 25 rTime 600

[1016] (36) J Mir - Suzuki Lap 25 rTime 602

[1017] (88) M Oliveira - KTM Lap 25 rTime 604

[1018] (05) J Zarco - KTM Lap 25 rTime 606

[1004] (46) V Rossi - Yamaha Lap 25 rTime 608

[1009] (35) C Crutchlow - Honda Lap 25 rTime 610

[1020] (29) A Iannone - Aprilia Lap 25 rTime 612

[1019] (06) S Bradl - Honda Lap 25 rTime 614

[1021] (53) T Rabat - Ducati Lap 25 rTime 616

[1022] (17) K Abraham - Ducati Lap 25 rTime 618

[1023] (55) H Syahrin - KTM Lap 25 rTime 620

[1024] (38) B Smith - Aprilia Lap 25 rTime 622

[1000] motoGP:FINISH

\$

UAS W08:55-192a (01)

```
/*
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implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

* REV02 Wed Mar 25 12:13:38 WIB 2020
* REV01 XXX Dec 15 15:05:00 WIB 2019
* START XXX Dec 09 16:28:00 WIB 2019

# INFO: UAS 2019-2 (final term)
# INFO:                To run:    ./55-192a

*/

#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <semaphore.h>
#include <unistd.h>
#include <sys/mman.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <sys/wait.h>

#define MYFLAGS      O_CREAT | O_RDWR
#define MYPROTECT PROT_READ | PROT_WRITE
#define MYVISIBILITY      MAP_SHARED
#define SFILE        "demo-file.bin"
```

```
typedef struct {
    sem_t  sync1;
    sem_t  sync2;
    pid_t  relative;
} myshare;

myshare* mymap;

void flushprintf(char* tag){
    printf("PIDr[%d] %s\n",
        getpid() + mymap->relative, tag);
    fflush(NULL);
}

void main(void) {
    int fd    =open(SFILE,MYFLAGS,S_IRWXU);
    int ssize=sizeof(myshare);
    truncate(SFILE, ssize);
    mymap=mmap(NULL, ssize, MYPROTECT,
        MYVISIBILITY, fd, 0);
    mymap->relative = 1000 - getpid();
    sem_init (&(mymap->sync1), 1, 0);
    sem_init (&(mymap->sync2), 1, 0);
    flushprintf("START");
    if (!fork())
        execlp("./56-192b", "./56-192b", NULL);
    wait(NULL);
    flushprintf("EXIT");
}
```

UAS W08:56-192b (01)

```
/*
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* REV02 Wed Mar 25 12:16:00 WIB 2020
* REV01 XXX Dec 15 15:05:00 WIB 2019
* START XXX Dec 09 16:28:00 WIB 2019

# INFO: UAS 2019-2 (final term)
# INFO: Run from: ./54-192a

*/

#include <fcntl.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <semaphore.h>
#include <unistd.h>
#include <sys/mman.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <sys/wait.h>

#define MYFLAGS      O_CREAT | O_RDWR
#define MYPROTECT    PROT_READ | PROT_WRITE
#define MYVISIBILITY  MAP_SHARED
#define SFILE        "demo-file.bin"
```

UAS W08:56-192b (02)

```
typedef struct {
    sem_t  sync1;
    sem_t  sync2;
    pid_t  relative;
} myshare;

myshare* mymap;

void flushprintf(char* tag){
    printf("PIDr[%d] %s\n", getpid() + mymap->relative, tag);
    fflush(NULL);
}

void main(int argc, char* argv[]) {
    int fd    =open(SFILE,MYFLAGS,S_IRWXU);
    int ssize=sizeof(myshare);
    mymap=mmap(NULL, ssize, MYPROTECT, MYVISIBILITY, fd, 0);
    flushprintf("START");
    if(argc == 1) {
        if (!fork()) {
            sem_post (&(mymap->sync1));
            sem_wait (&(mymap->sync2));
            flushprintf("FORK CHILD");
        } else {
            sem_wait (&(mymap->sync1));
            flushprintf("FORK PARENT");
            sem_post (&(mymap->sync2));
        }
        execlp(argv[0], argv[0], "XYZZY", NULL);
    }
    wait(NULL);
    flushprintf("EXIT");
}
```


UAS W08:55-192a – W08:56-192b

```
$ ./55-192a
PIDr[1000] START
PIDr[1001] START
PIDr[1001] FORK PARENT
PIDr[1002] FORK CHILD
PIDr[1002] START
PIDr[1002] EXIT
PIDr[1001] START
PIDr[1001] EXIT
PIDr[1000] EXIT
$ ./56-192b
PIDr[1004] START
PIDr[1004] FORK PARENT
PIDr[1005] FORK CHILD
PIDr[1004] START
PIDr[1005] START
PIDr[1005] EXIT
PIDr[1004] EXIT
$
```

The End

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