

National University of Computer and
Emerging Sciences



Lab Manual 14
Operating Systems Lab

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A semaphore is a synchronization primitive that controls access to shared resources by multiple processes or threads. It maintains a counter and supports two fundamental operations:

- **Wait (P) Operation:** Decrements the semaphore value. If the semaphore value is non-negative, the decrement proceeds, and the process continues. If the semaphore value becomes negative (i.e., no more resources available), the process is blocked until another process increments the semaphore.
- **Signal (V) Operation:** Increments the semaphore value. If any processes were blocked waiting for this semaphore, one of them is allowed to proceed.

POSIX Semaphores

POSIX (Portable Operating System Interface) semaphores are a standardized form of semaphores available on Unix and Linux systems. They provide a way to synchronize processes (including unrelated processes) using named semaphores. POSIX semaphores are part of the POSIX Threads (pthreads) library (**libpthread**).

Key Functions for POSIX Semaphores

1. sem_open

```
#include <semaphore.h>
```

```
sem_t *sem_open(const char *name, int oflag, mode_t mode, unsigned int value);
```

- Opens or creates a named semaphore.
- **name:** Name of the semaphore (must start with a / character).
- **oflag:** Flags indicating the mode of operation (**O_CREAT** for creating if not existing, **O_EXCL** to ensure creation fails if the semaphore already exists).
- **mode:** Permissions for the semaphore if created (**0644** is commonly used).
- **value:** Initial value of the semaphore.

2. sem_wait

```
#include <semaphore.h>
```

```
int sem_wait(sem_t *sem);
```

- Waits (P operation) on the semaphore.
- Decrements the semaphore value.
- Blocks if the semaphore value is zero (no resources available).

3. sem_post

```
#include <semaphore.h>
```

```
int sem_post(sem_t *sem);
```

- Signals (V operation) on the semaphore.
- Increments the semaphore value.

- Unblocks one of the waiting processes (if any).

4. sem_close

```
#include <semaphore.h>
```

```
int sem_close(sem_t *sem);
```

- Closes the named semaphore.
- Releases the associated resources.
- After closing, the semaphore can no longer be used by the process.

5. sem_unlink

```
#include <semaphore.h>
```

```
int sem_unlink(const char *name);
```

- Removes a named semaphore from the system.
- The semaphore can no longer be opened or used after unlinking.
- This is typically done after all processes using the semaphore have finished.

Example 1:

```

program1.c
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <unistd.h>
4 #include <semaphore.h>
5 #include <fcntl.h>
6
7 int main() {
8     sem_t *sem;
9     sem = sem_open("/my_semaphore1", O_CREAT, 0644, 1); // Initial value 1 (binary
10
11     if (sem == SEM_FAILED) {
12         perror("sem_open");
13         exit(EXIT_FAILURE);
14     }
15     while(1)
16     {
17         sem_wait(sem);
18         printf("Program 1: Writing to shared resource...\n");
19         sleep(2);
20         sem_post(sem);
21     }
22     sem_close(sem);
23     return 0;
24 }
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program2.c
1 #include <stdio.h>
2 #include <stdlib.h>
3 #include <unistd.h>
4 #include <semaphore.h>
5 #include <fcntl.h>
6
7 int main() {
8     sem_t *sem;
9     sem = sem_open("/my_semaphore1", O_CREAT, 0644, 1); // Initial value 1 (binary
10
11     if (sem == SEM_FAILED) {
12         perror("sem_open");
13         exit(EXIT_FAILURE);
14     }
15     while(1)
16     {
17         sem_wait(sem);
18         printf("Program 2: Writing to shared resource...\n");
19         sleep(2);
20         sem_post(sem);
21     }
22     sem_close(sem);
23     return 0;
24 }
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```

Output:

The screenshot shows a Windows IDE with two panes. The left pane displays the source code for `program1.c`, which includes `<stdio.h>` and attempts to use `sem_open`, `sem_wait`, and `sem_post`. The right pane shows the terminal output. The first terminal window shows the compilation of `program1.c` with errors: `undefined reference to 'sem_open'`, `undefined reference to 'sem_wait'`, `undefined reference to 'sem_post'`, and `ld returned 1 exit status`. The second terminal window shows the execution of `program1.c` and `program2.c` using `gcc` and `./p1`. The output shows "Program 2: Writing to shared resource..." being printed multiple times.

Example 2:

The screenshot shows a Windows IDE with two panes displaying the source code for `program1.c` and `program2.c`. Both programs include `<stdio.h>`, `<stdlib.h>`, `<unistd.h>`, `<semaphore.h>`, and `<fcntl.h>`. `program1.c` defines a semaphore `sem` and prints "Program 1: Writing to shared resource..." before calling `sem_post(sem)`. `program2.c` defines a semaphore `sem` and prints "Program 2: Writing to shared resource..." after calling `sem_wait(sem)`. Both programs use `sem_close(sem)` and `return 0;` at the end of their `main` functions.

Output 2:

The screenshot shows a terminal window with the following output: `root@DESKTOP-0MLB4MD: /mnt/c/Users/dell# gcc program1.c -o p1 -lpthread`, `root@DESKTOP-0MLB4MD: /mnt/c/Users/dell# gcc program2.c -o p2 -lpthread`, `root@DESKTOP-0MLB4MD: /mnt/c/Users/dell# ./p1 && ./p2`, `Program 1: Writing to shared resource...`, `Program 2: Writing to shared resource...`, and `root@DESKTOP-0MLB4MD: /mnt/c/Users/dell#`. The output demonstrates that both programs can execute their critical sections without interference, as indicated by the sequential printing of their messages.

Question 1: Consider a scenario where three processes (**P1, P2, P3**) need to execute in a specific order while sharing a common resource (file) that requires mutual exclusion. Use semaphores to ensure that the processes execute in the sequence **P1 -> P2 -> P3** and have exclusive access to the shared resource when needed.

- P1 opens a file having all integers and calculate their sum and write it into the same file.
- After that P2 counts the integers and also write it in the same file.
- P3 reads sum and count from this file calculated by P1 and P2 and calculates average and print it on the screen.

Question 2: You are tasked with designing a system where three independent services (S1, S2, S3) process orders in an e-commerce platform. These services must execute in the sequence S1 -> S2 -> S3 to ensure data consistency. Each service uses a shared log file to record its activity, which requires mutual exclusion.

1. **S1 (Order Placement):** S1 receives and writes the order details (order ID and customer information) to the shared log file.
2. **S2 (Payment Processing):** Once the order is recorded, S2 reads the order details from the log, processes the payment, and updates the log with the payment status.
3. **S3 (Order Confirmation):** After the payment is processed, S3 reads the updated log, confirms the order, and writes the confirmation status along with a timestamp into the log.

Task:

Write the pseudocode to synchronize these services using semaphores to ensure:

- **Sequential Execution:** S1 completes before S2, and S2 completes before S3.
- **Mutual Exclusion:** Only one service can write to the shared log at a time.