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.

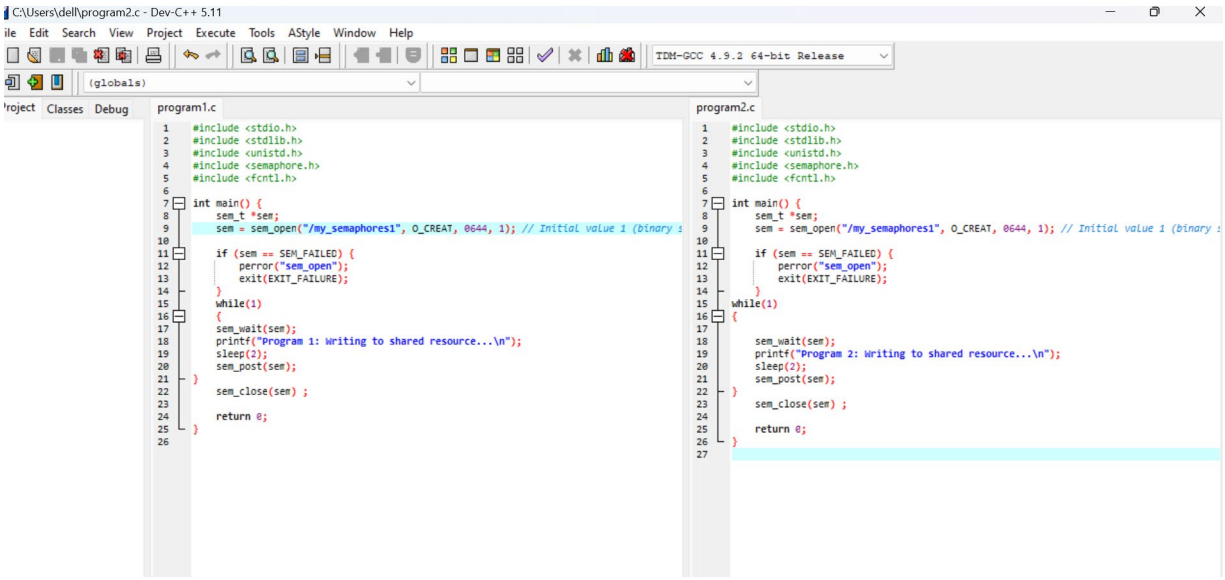
5. sem_unlink

#include <semaphore.h>

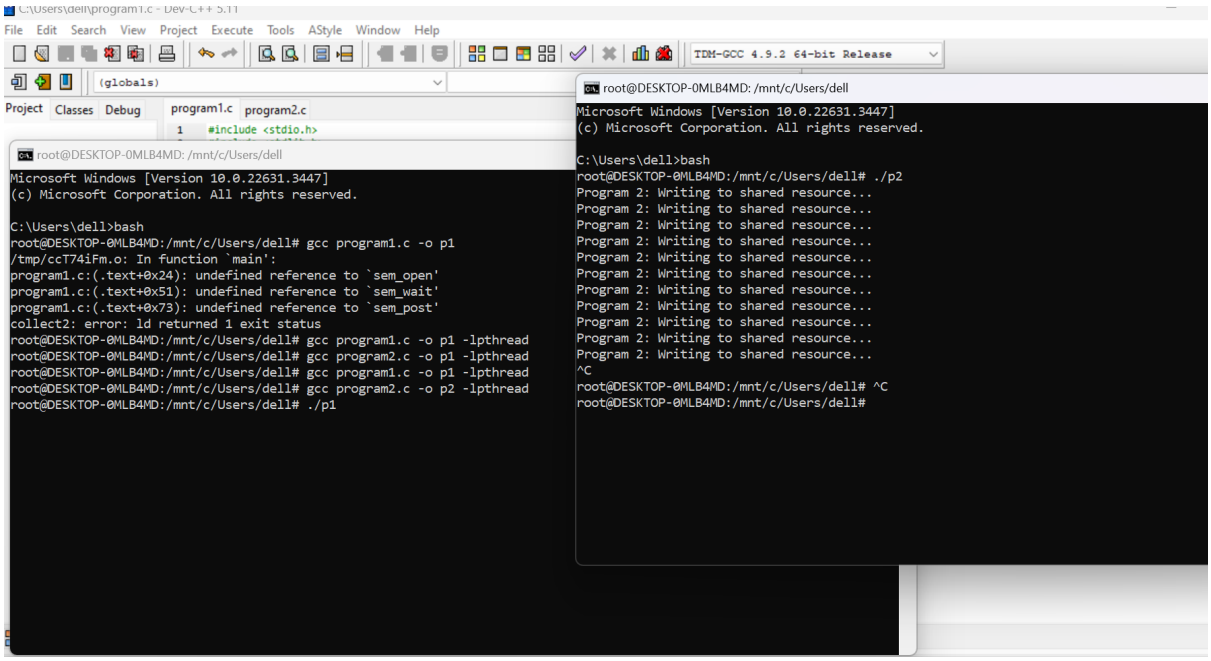
int sem_unlink(const char *name);

- 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.

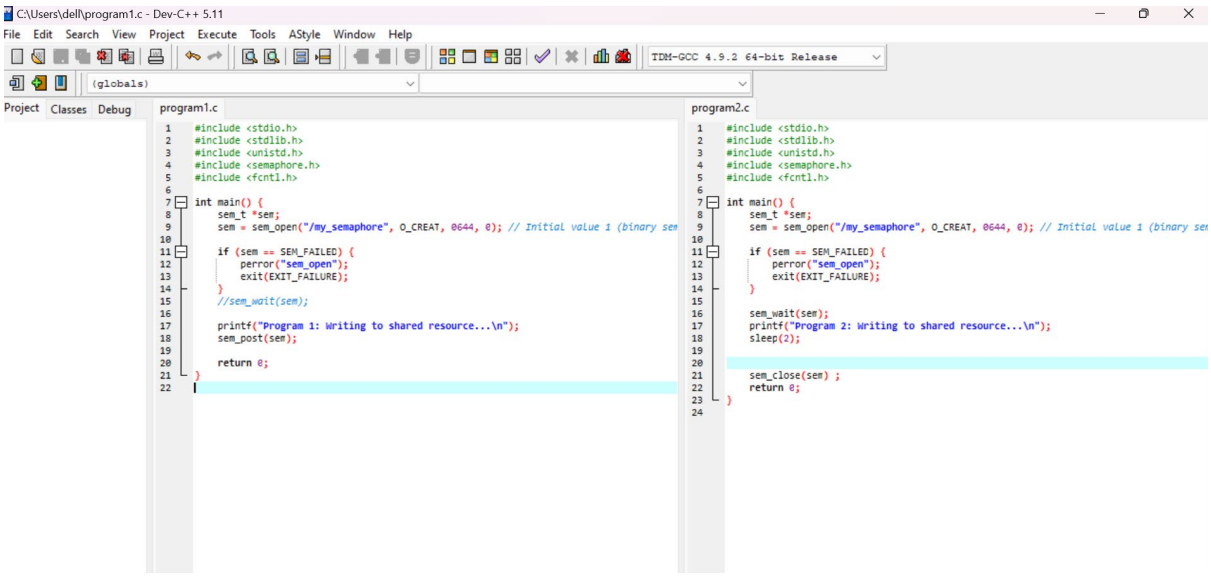
Example 1:



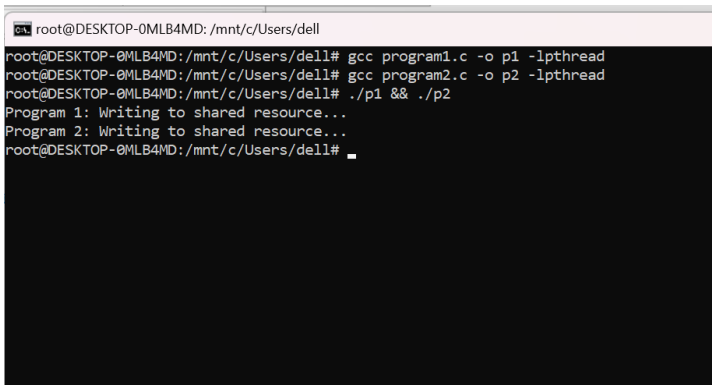
Output:



Example 2:



Output 2:



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.