

# CSCI 340 Operating Systems Project

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I compiled the program by stating '`gcc filename.c -o filename -lpthread`' followed by '`./filename`'. I found many resources on how to link the pthread library with the program, but I preferred this solution as it was the shortest. I have written the commands for each part below their headers.

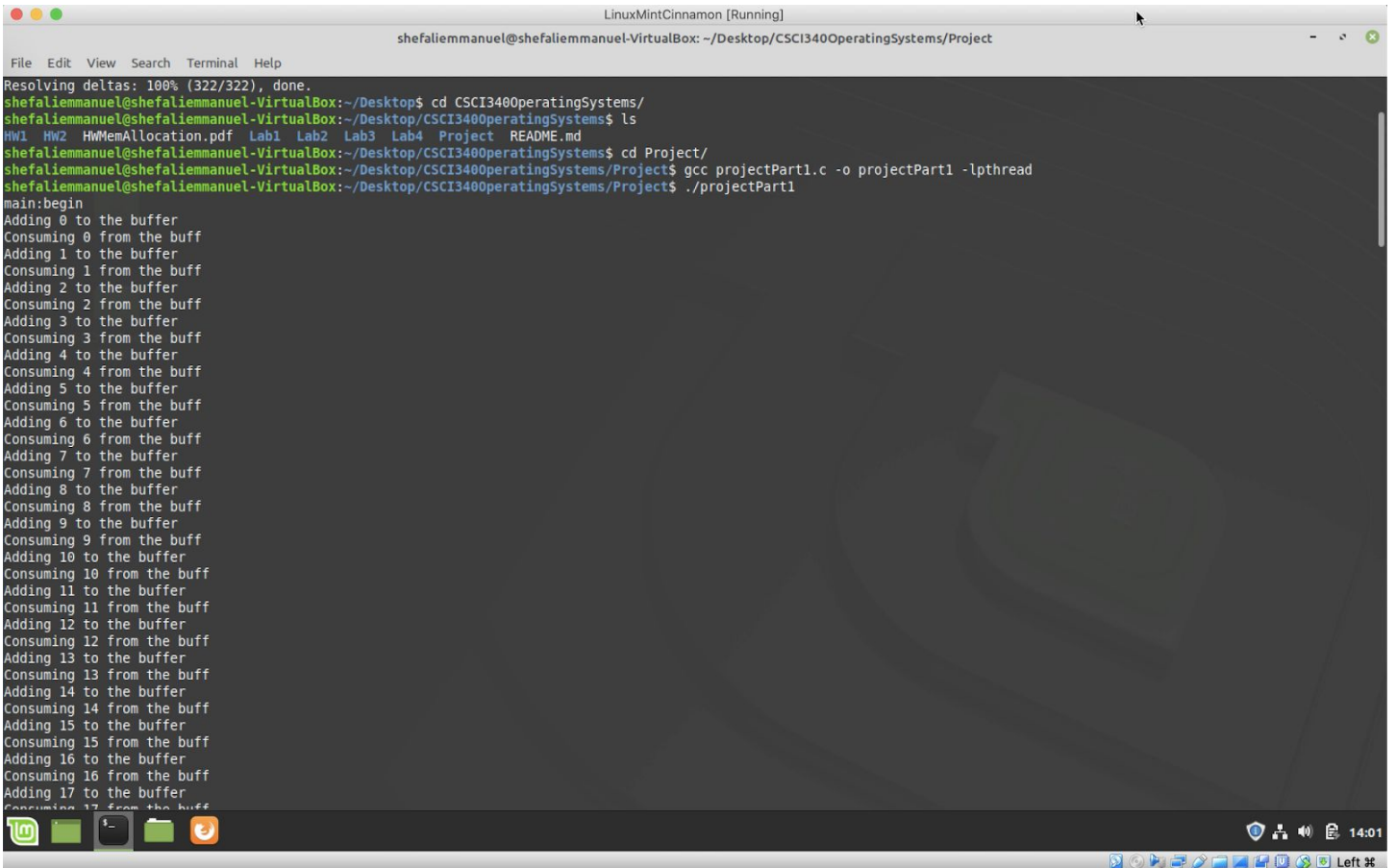
Here is a link to my main reference:

<https://www.includehelp.com/c-programming-questions/compiling-program-with-pthread-library-linux.aspx>

I also referenced various parts of the book and github.

## Part 1:

```
gcc projectPart1.c -o projectPart1 -lpthread
./projectPart1
```

A screenshot of a Linux terminal window titled "LinuxMintCinnamon [Running]". The window shows the user "shefaliemmanuel" at the prompt "shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340OperatingSystems/Project". The terminal output shows the user navigating to the "Project" directory, compiling "projectPart1.c" with "gcc" and "-lpthread", and then running the resulting "projectPart1" binary. The program's output consists of a series of "Adding" and "Consuming" messages for values 0 through 17, indicating a busy-wait loop. The terminal window has a menu bar with "File", "Edit", "View", "Search", "Terminal", and "Help". The bottom of the window shows a taskbar with various application icons and a system tray with a clock showing "14:01".

```
File Edit View Search Terminal Help
Resolving deltas: 100% (322/322), done.
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop$ cd CSCI340OperatingSystems/
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI340OperatingSystems$ ls
HW1 HW2 HWMemAllocation.pdf Lab1 Lab2 Lab3 Lab4 Project README.md
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI340OperatingSystems$ cd Project/
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI340OperatingSystems/Project$ gcc projectPart1.c -o projectPart1 -lpthread
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI340OperatingSystems/Project$ ./projectPart1
main:begin
Adding 0 to the buffer
Consuming 0 from the buff
Adding 1 to the buffer
Consuming 1 from the buff
Adding 2 to the buffer
Consuming 2 from the buff
Adding 3 to the buffer
Consuming 3 from the buff
Adding 4 to the buffer
Consuming 4 from the buff
Adding 5 to the buffer
Consuming 5 from the buff
Adding 6 to the buffer
Consuming 6 from the buff
Adding 7 to the buffer
Consuming 7 from the buff
Adding 8 to the buffer
Consuming 8 from the buff
Adding 9 to the buffer
Consuming 9 from the buff
Adding 10 to the buffer
Consuming 10 from the buff
Adding 11 to the buffer
Consuming 11 from the buff
Adding 12 to the buffer
Consuming 12 from the buff
Adding 13 to the buffer
Consuming 13 from the buff
Adding 14 to the buffer
Consuming 14 from the buff
Adding 15 to the buffer
Consuming 15 from the buff
Adding 16 to the buffer
Consuming 16 from the buff
Adding 17 to the buffer
Consuming 17 from the buff
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 16 to the buffer
Consuming 16 from the buff
Adding 17 to the buffer
Consuming 17 from the buff
Adding 18 to the buffer
Consuming 18 from the buff
Adding 19 to the buffer
Consuming 19 from the buff
Adding 20 to the buffer
Consuming 20 from the buff
Adding 21 to the buffer
Consuming 21 from the buff
Adding 22 to the buffer
Consuming 22 from the buff
Adding 23 to the buffer
Consuming 23 from the buff
Adding 24 to the buffer
Consuming 24 from the buff
Adding 25 to the buffer
Consuming 25 from the buff
Adding 26 to the buffer
Consuming 26 from the buff
Adding 27 to the buffer
Consuming 27 from the buff
Adding 28 to the buffer
Consuming 28 from the buff
Adding 29 to the buffer
Consuming 29 from the buff
Adding 30 to the buffer
Consuming 30 from the buff
Adding 31 to the buffer
Consuming 31 from the buff
Adding 32 to the buffer
Consuming 32 from the buff
Adding 33 to the buffer
Consuming 33 from the buff
Adding 34 to the buffer
Consuming 34 from the buff
Adding 35 to the buffer
Consuming 35 from the buff
Adding 36 to the buffer
Consuming 36 from the buff
Adding 37 to the buffer
Consuming 37 from the buff
Consuming 37 from the buff
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 36 to the buffer
Consuming 36 from the buff
Adding 37 to the buffer
Consuming 37 from the buff
Adding 38 to the buffer
Consuming 38 from the buff
Adding 39 to the buffer
Consuming 39 from the buff
Adding 40 to the buffer
Consuming 40 from the buff
Adding 41 to the buffer
Consuming 41 from the buff
Adding 42 to the buffer
Consuming 42 from the buff
Adding 43 to the buffer
Consuming 43 from the buff
Adding 44 to the buffer
Consuming 44 from the buff
Adding 45 to the buffer
Consuming 45 from the buff
Adding 46 to the buffer
Consuming 46 from the buff
Adding 47 to the buffer
Consuming 47 from the buff
Adding 48 to the buffer
Consuming 48 from the buff
Adding 49 to the buffer
Consuming 49 from the buff
Adding 50 to the buffer
Consuming 50 from the buff
Adding 51 to the buffer
Consuming 51 from the buff
Adding 52 to the buffer
Consuming 52 from the buff
Adding 53 to the buffer
Consuming 53 from the buff
Adding 54 to the buffer
Consuming 54 from the buff
Adding 55 to the buffer
Consuming 55 from the buff
Adding 56 to the buffer
Consuming 56 from the buff
Adding 57 to the buffer
Consuming 57 from the buff
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 56 to the buffer
Consuming 56 from the buff
Adding 57 to the buffer
Consuming 57 from the buff
Adding 58 to the buffer
Consuming 58 from the buff
Adding 59 to the buffer
Consuming 59 from the buff
Adding 60 to the buffer
Consuming 60 from the buff
Adding 61 to the buffer
Consuming 61 from the buff
Adding 62 to the buffer
Consuming 62 from the buff
Adding 63 to the buffer
Consuming 63 from the buff
Adding 64 to the buffer
Consuming 64 from the buff
Adding 65 to the buffer
Consuming 65 from the buff
Adding 66 to the buffer
Consuming 66 from the buff
Adding 67 to the buffer
Consuming 67 from the buff
Adding 68 to the buffer
Consuming 68 from the buff
Adding 69 to the buffer
Consuming 69 from the buff
Adding 70 to the buffer
Consuming 70 from the buff
Adding 71 to the buffer
Consuming 71 from the buff
Adding 72 to the buffer
Consuming 72 from the buff
Adding 73 to the buffer
Consuming 73 from the buff
Adding 74 to the buffer
Consuming 74 from the buff
Adding 75 to the buffer
Consuming 75 from the buff
Adding 76 to the buffer
Consuming 76 from the buff
Adding 77 to the buffer
Consuming 77 from the buff
Consuming 77 from the buff

14:01
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Consuming 73 from the buff
Adding 74 to the buffer
Consuming 74 from the buff
Adding 75 to the buffer
Consuming 75 from the buff
Adding 76 to the buffer
Consuming 76 from the buff
Adding 77 to the buffer
Consuming 77 from the buff
Adding 78 to the buffer
Consuming 78 from the buff
Adding 79 to the buffer
Consuming 79 from the buff
Adding 80 to the buffer
Consuming 80 from the buff
Adding 81 to the buffer
Consuming 81 from the buff
Adding 82 to the buffer
Consuming 82 from the buff
Adding 83 to the buffer
Consuming 83 from the buff
Adding 84 to the buffer
Consuming 84 from the buff
Adding 85 to the buffer
Consuming 85 from the buff
Adding 86 to the buffer
Consuming 86 from the buff
Adding 87 to the buffer
Consuming 87 from the buff
Adding 88 to the buffer
Consuming 88 from the buff
Adding 89 to the buffer
Consuming 89 from the buff
Adding 90 to the buffer
Consuming 90 from the buff
Adding 91 to the buffer
Consuming 91 from the buff
Adding 92 to the buffer
Consuming 92 from the buff
Adding 93 to the buffer
Consuming 93 from the buff
Adding 94 to the buffer
Consuming 94 from the buff
Consuming 95 from the buff

14:01
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 81 to the buffer
Consuming 81 from the buff
Adding 82 to the buffer
Consuming 82 from the buff
Adding 83 to the buffer
Consuming 83 from the buff
Adding 84 to the buffer
Consuming 84 from the buff
Adding 85 to the buffer
Consuming 85 from the buff
Adding 86 to the buffer
Consuming 86 from the buff
Adding 87 to the buffer
Consuming 87 from the buff
Adding 88 to the buffer
Consuming 88 from the buff
Adding 89 to the buffer
Consuming 89 from the buff
Adding 90 to the buffer
Consuming 90 from the buff
Adding 91 to the buffer
Consuming 91 from the buff
Adding 92 to the buffer
Consuming 92 from the buff
Adding 93 to the buffer
Consuming 93 from the buff
Adding 94 to the buffer
Consuming 94 from the buff
Adding 95 to the buffer
Consuming 95 from the buff
Adding 96 to the buffer
Consuming 96 from the buff
Adding 97 to the buffer
Consuming 97 from the buff
Adding 98 to the buffer
Consuming 98 from the buff
Adding 99 to the buffer
Consuming 99 from the buff
main:end
Produced Item Total: 100
Consumed Item Total: 100
Destory everything
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/Desktop/CSCI340operatingSystems/Project$
```

## Part 2:

```
gcc projectPart2.c -o projectPart2 -lpthread  
./projectPart2
```

Code that was changed from part 1:

```
void *consumer(void *arg)
{
    sem_wait(&mutex);
    sem_wait(&full);
    int tmp = get();
    sem_post(&empty);
    sem_post(&mutex);
    printf("Consuming %d from the buff\n", tmp);
}

void *producer(void *arg)
{
    sem_wait(&mutex);
    sem_wait(&empty);
    put(counter);
    sem_post(&full);
    sem_post(&mutex);
    printf("Adding %d to the buffer\n", counter);
    counter++;
}
```



## Screenshots:

```
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ gcc projectPart2.c -o projectPart2 -lpthread
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ ./projectPart2
```

```
main:begin
Adding 0 to the buffer
Consuming 0 from the buff
Adding 1 to the buffer
Consuming 1 from the buff
Adding 2 to the buffer
Consuming 2 from the buff
Adding 3 to the buffer
Consuming 3 from the buff
Adding 4 to the buffer
Consuming 4 from the buff
Adding 5 to the buffer
Consuming 5 from the buff
█
```



```
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ ./projectPart2
```

```
main:begin
Consuming 0 from the buff
Adding 0 to the buffer
Adding 1 to the buffer
Consuming 1 from the buff
^C
```

```
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ ./projectPart2
```

```
main:begin
Adding 0 to the buffer
Consuming 0 from the buff
```



```
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ ./projectPart2
```

```
main:begin
Adding 0 to the buffer
Consuming 0 from the buff
Adding 1 to the buffer
Consuming 1 from the buff
Adding 2 to the buffer
Consuming 2 from the buff
Adding 3 to the buffer
Consuming 3 from the buff
█
```



```
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ ./projectPart2
main:begin
^C
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/Desktop/CSCI3400peratingSystems/Project$ ./projectPart2
main:begin
Adding 0 to the buffer
Consuming 0 from the buff
Adding 1 to the buffer
Consuming 1 from the buff
Adding 2 to the buffer
Consuming 2 from the buff
Adding 3 to the buffer
Consuming 3 from the buff
Adding 4 to the buffer
Consuming 4 from the buff
Adding 5 to the buffer
Consuming 5 from the buff
Adding 6 to the buffer
Consuming 6 from the buff
Adding 7 to the buffer
Consuming 7 from the buff
Adding 8 to the buffer
Consuming 8 from the buff
Adding 9 to the buffer
Consuming 9 from the buff
Adding 10 to the buffer
Consuming 10 from the buff
Adding 11 to the buffer
Consuming 11 from the buff
```

After running the program multiple times, it was clear to me that the output was not the same. This version 2 of the project is indeterministic. This version will produce a deadlock. A producer can accept a mutex, but then get blocked when all buffer slots are being utilized. Since it is holding the mutex, the consumer can not rid itself of the buffer. I did not expect the program to reach a different breaking point upon each execution. Sometimes it would not even start the first thread creation... other times it would create multiple!



## Part 3:

```
gcc projectPart3.c -o projectPart3 -lpthread
./projectPart3
```

Code that was changed from part 1:

```
void *consumer(void *arg)
{
    for (int s = 0; s < MAX_BUFFER_SIZE; s++)
    {
        sem_wait(&full);
        //sem_wait(&mutex);
        int tmp = get();
        //sem_post(&mutex);
        sem_post(&empty);
        printf("Consuming %d from the buff\n", tmp);
    }
}

void *producer(void *arg)
{
    for (int s = 0; s < MAX_BUFFER_SIZE; s++)
    {
        sem_wait(&empty);
        //sem_wait(&mutex);
        put(counter);
        //sem_post(&mutex);
        sem_post(&full);
        printf("Adding %d to the buffer\n", counter);
        counter++;
    }
}

int main(int argc, char *argv[])
{
    pthread_t p1, p2, p3;    initialize the new producer added
    int rc;

    //initialize semaphore that will guarantee mutual exclusive access to the shared counter
    sem_init(&mutex, 0, 1); //at most 1 may access guarded resources
    sem_init(&full, 0, 0);
    sem_init(&empty, 0, MAX_BUFFER_SIZE);

    printf("main:begin\n");
    pthread_create(&p1, NULL, producer, "A");
    pthread_create(&p2, NULL, producer, "B");
    pthread_create(&p3, NULL, consumer, "C");
    pthread_join(p1, NULL);
    pthread_join(p2, NULL);
    pthread_join(p3, NULL);

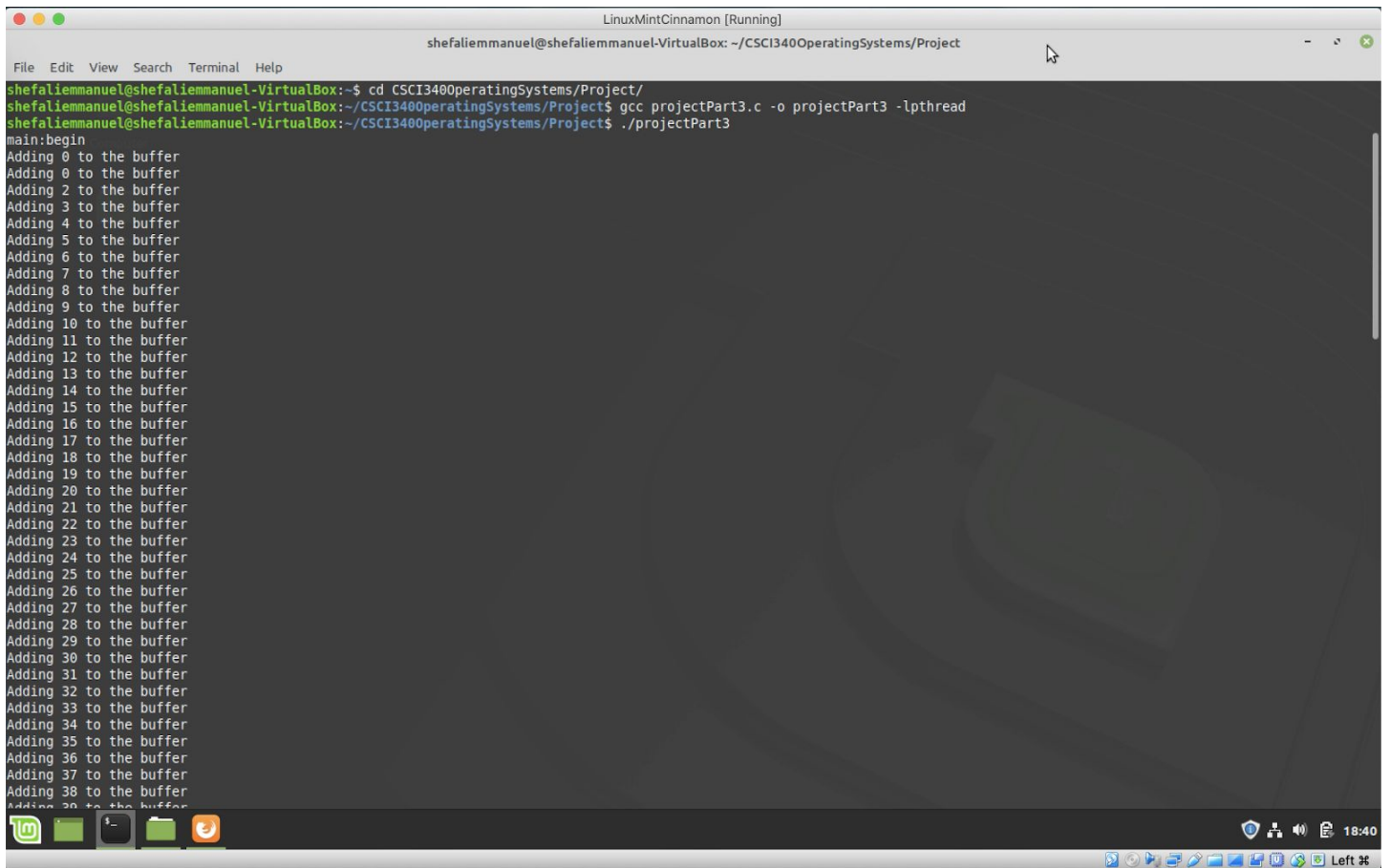
    printf("main:end\n");
    printf("Produced Item Total: %d\n", fillIndex);
    printf("Consumed Item Total: %d\n", useIndex);

    printf("Destroy everything\n");
    sem_destroy(&mutex);
    sem_destroy(&full);
    sem_destroy(&empty);

    return 0;
}
```

Create & Join new producer

## Screenshots:



The screenshot shows a terminal window titled "LinuxMintCinnamon [Running]" with the user "shefaliemmanuel" and the path "~/CSCI340OperatingSystems/Project". The terminal displays the following commands and output:

```
shefaliemmanuel@shefaliemmanuel-VirtualBox:~$ cd CSCI340OperatingSystems/Project/
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/CSCI340OperatingSystems/Project$ gcc projectPart3.c -o projectPart3 -lpthread
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/CSCI340OperatingSystems/Project$ ./projectPart3
main:begin
Adding 0 to the buffer
Adding 0 to the buffer
Adding 2 to the buffer
Adding 3 to the buffer
Adding 4 to the buffer
Adding 5 to the buffer
Adding 6 to the buffer
Adding 7 to the buffer
Adding 8 to the buffer
Adding 9 to the buffer
Adding 10 to the buffer
Adding 11 to the buffer
Adding 12 to the buffer
Adding 13 to the buffer
Adding 14 to the buffer
Adding 15 to the buffer
Adding 16 to the buffer
Adding 17 to the buffer
Adding 18 to the buffer
Adding 19 to the buffer
Adding 20 to the buffer
Adding 21 to the buffer
Adding 22 to the buffer
Adding 23 to the buffer
Adding 24 to the buffer
Adding 25 to the buffer
Adding 26 to the buffer
Adding 27 to the buffer
Adding 28 to the buffer
Adding 29 to the buffer
Adding 30 to the buffer
Adding 31 to the buffer
Adding 32 to the buffer
Adding 33 to the buffer
Adding 34 to the buffer
Adding 35 to the buffer
Adding 36 to the buffer
Adding 37 to the buffer
Adding 38 to the buffer
Adding 39 to the buffer
```

The terminal window has a menu bar with "File", "Edit", "View", "Search", "Terminal", and "Help". The bottom of the window shows a taskbar with various application icons and a system tray with a clock showing "18:40".

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 36 to the buffer
Adding 37 to the buffer
Adding 38 to the buffer
Adding 39 to the buffer
Adding 40 to the buffer
Adding 41 to the buffer
Adding 42 to the buffer
Adding 43 to the buffer
Adding 44 to the buffer
Adding 45 to the buffer
Adding 46 to the buffer
Adding 47 to the buffer
Adding 48 to the buffer
Adding 49 to the buffer
Adding 50 to the buffer
Adding 51 to the buffer
Adding 52 to the buffer
Adding 53 to the buffer
Adding 54 to the buffer
Adding 55 to the buffer
Adding 56 to the buffer
Adding 57 to the buffer
Adding 58 to the buffer
Adding 59 to the buffer
Adding 60 to the buffer
Adding 61 to the buffer
Adding 62 to the buffer
Adding 63 to the buffer
Adding 64 to the buffer
Adding 65 to the buffer
Adding 66 to the buffer
Adding 67 to the buffer
Adding 68 to the buffer
Adding 69 to the buffer
Adding 70 to the buffer
Adding 71 to the buffer
Adding 72 to the buffer
Adding 73 to the buffer
Adding 74 to the buffer
Adding 75 to the buffer
Adding 76 to the buffer
Adding 77 to the buffer
Adding 78 to the buffer
Adding 79 to the buffer
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 71 to the buffer
Adding 72 to the buffer
Adding 73 to the buffer
Adding 74 to the buffer
Adding 75 to the buffer
Adding 76 to the buffer
Adding 77 to the buffer
Adding 78 to the buffer
Adding 79 to the buffer
Adding 80 to the buffer
Adding 81 to the buffer
Adding 82 to the buffer
Adding 83 to the buffer
Adding 84 to the buffer
Adding 85 to the buffer
Adding 86 to the buffer
Adding 87 to the buffer
Adding 88 to the buffer
Adding 89 to the buffer
Adding 90 to the buffer
Adding 91 to the buffer
Adding 92 to the buffer
Adding 93 to the buffer
Adding 94 to the buffer
Adding 95 to the buffer
Adding 96 to the buffer
Adding 97 to the buffer
Adding 98 to the buffer
Adding 99 to the buffer
Consuming 0 from the buff
Consuming 0 from the buff
Consuming 1 from the buff
Consuming 2 from the buff
Consuming 3 from the buff
Consuming 4 from the buff
Consuming 5 from the buff
Consuming 6 from the buff
Consuming 7 from the buff
Consuming 8 from the buff
Consuming 9 from the buff
Consuming 10 from the buff
Consuming 11 from the buff
Consuming 12 from the buff
Consuming 13 from the buff
```

```
LinuxMintCinnamon [Running]
shefaliemmanuel@shefaliemmanuel-VirtualBox: ~/CSCI340OperatingSystems/Project

File Edit View Search Terminal Help

Adding 90 to the buffer
Adding 91 to the buffer
Adding 92 to the buffer
Adding 93 to the buffer
Adding 94 to the buffer
Adding 95 to the buffer
Adding 96 to the buffer
Adding 97 to the buffer
Adding 98 to the buffer
Adding 99 to the buffer
Consuming 0 from the buff
Consuming 0 from the buff
Consuming 1 from the buff
Consuming 2 from the buff
Consuming 3 from the buff
Consuming 4 from the buff
Consuming 5 from the buff
Consuming 6 from the buff
Consuming 7 from the buff
Consuming 8 from the buff
Consuming 9 from the buff
Consuming 10 from the buff
Consuming 11 from the buff
Consuming 12 from the buff
Consuming 13 from the buff
Consuming 14 from the buff
Consuming 15 from the buff
Adding 1 to the buffer
Adding 101 to the buffer
Adding 102 to the buffer
Adding 103 to the buffer
Adding 104 to the buffer
Adding 105 to the buffer
Adding 106 to the buffer
Adding 107 to the buffer
Adding 108 to the buffer
Adding 109 to the buffer
Adding 110 to the buffer
Adding 111 to the buffer
Adding 112 to the buffer
Consuming 16 from the buff
The futex facility returned an unexpected error code.Aborted (core dumped)
shefaliemmanuel@shefaliemmanuel-VirtualBox:~/CSCI340OperatingSystems/Project$
```

These results are indeterministic due to a race condition that is going on. I created 2 procedures followed by a consumer. In the race condition mentioned above, the first procedure runs to its fullest extent. Next the consumer gets allocated some memory which is quickly taken away by the start of the second producer who starts promptly after the consumer has run for a little bit. Each time I ran this executable, the consumer ends at a different number.