

Producer-Consumer: Correct Solution

Process producer

```
.  
.   
P(mutex)  
if count = N  
    then V(mutex); P(mutex_p); P(mutex)  
else  
    P(mutex_p) ;  
count = count + 1  
write(head_ptr)  
head_ptr = (head_ptr + 1) mod N  
V(mutex_c)  
V(mutex)  
.
```

Process consumer

```
.  
.   
P(mutex)  
if count = 0  
    then V(mutex); P(mutex_c); P(mutex)  
else  
    P(mutex_c) ;  
count = count - 1  
read(tail_ptr)  
tail_ptr = (tail_ptr + 1) mod N  
V(mutex_p)  
V(mutex)
```

- Initialize: $count = 0$; $mutex_c \doteq 0$; $mutex_p = N$;
- Assertions $count == mutex_c$; $count + mutex_p = N$

Producer-Consumer: another solution ??

Process producer

```
·  
·  
P(mutex)  
P(mutex_p) ;  
count = count + 1  
write(head_ptr)  
head_ptr = (head_ptr + 1) mod N  
V(mutex_c)  
V(mutex)  
·  
·
```

Process consumer

```
·  
·  
P(mutex)  
P(mutex_c) ;  
count = count - 1  
read(tail_ptr)  
tail_ptr = (tail_ptr + 1) mod N  
V(mutex_p)  
V(mutex)  
·  
·
```

- Initialize: $count = 0$; $mutex_c = 0$; $mutex_p = N$;
- Assertions $count == mutex_c$; $count + mutex_p = N$
- Does not work – DEADLOCK !!

Semaphore: pros and cons

- Pros:
 - no waste of resources due to busy waiting
 - flexible resource management using an initial value > 1
- Cons:
 - processes using semaphores must be aware of each other and coordinate respective use of semaphores
 - insertion of P and V calls is tricky and prone to errors
 - correctness of program using semaphores can be very hard to verify
 - do not scale up well - i.e. impractical for large scale use

Monitors: definition

- Monitors are abstract data types for encapsulating shared resources
- A monitor consists of:
 - shared objects and local variables,
 - a set of procedures
- Basic properties of the monitor
 - procedures are the only operations that can be performed on the resource and on the local variables
 - only one process at a time can be active (i.e. executing a procedure) within a monitor

Semantic of *wait* and *signal*

- A queue is associated with each condition variable
 - *<variable>.queue* returns **true** if queue is not empty
- The *<variable>.wait* call suspends the calling process
 - calling process relinquishes control of the monitor
 - calling process is enqueued on the variable's queue
- The *<variable>.signal* call causes one waiting process to gain control of the monitor
 - it resume execution from where it left (i.e. right after the wait statement)
 - the calling process is enqueued on the *urgent* queue

Producer-Consumer problem

```
circular_pool: monitor
begin
    pool: array 0..N-1 of buffer;
    count, head, tail: int;
    nonempty, nonfull: condition;
```

```
Procedure extract(x)
begin
```

```
    if count = 0 then nonempty.wait;
    x := pool[tail] ;
    tail := tail + 1 mod N;
    count := count - 1;
    nonfull.signal
```

```
end
```

```
Procedure insert(x)
begin
```

```
    if count = N then nonfull.wait;
    pool[head] := x;
    head := head + 1 mod N;
    count := count + 1;
    nonempty.signal
```

```
end
```

```
    count := 0
    head := 0; tail := 0;
end circular_pool
```

Readers-Writers with concurrent reader access

```
procedure startRead
begin
    readers = readers+1;
end
<READ FILE>
```

```
procedure endRead
begin
    readers = readers -1;
    if (readers == 0) then
        writer.signal;
    end
end
```

```
procedure writer
begin
    if (readers >0) then
        writer.wait;
    <WRITE FILE>
end
```

- This solution works, but does not guarantee readers priority
 - hint: who is allowed into the monitor when a writer exits?

Readers-Writers solution with readers' priority

```
procedure startRead;  
begin  
  if busy then OKtoread.wait;  
  readcount := readcount + 1;  
  OKtoread.signal;  
end startRead;
```

```
procedure endRead;  
begin  
  readcount := readcount - 1;  
  if readcount = 0 then OKtowrite.signal;  
end endRead;
```

```
procedure startWrite;  
begin  
  if busy OR readcount ≠ 0  
  then OKtowrite.wait;  
  busy := true;  
end startWrite;
```

```
procedure endWrite;  
begin  
  busy := false;  
  if OKtoread.queue  
  then OKtoread.signal  
  else OKtowrite.signal;  
end endWrite;
```

wait with priority

- An enhanced version of the **wait** operation accepts an optional priority argument:
 - syntax: *<variable>.wait <parameter>*
 - the smaller the value of the parameter, the highest the priority
- When the variable is signaled, the process with highest priority in the queue is activated
 - the base wait implementation used a First-In-First-Out (FIFO) discipline

Example: Smallest job first

```
procedure startPrint;  
begin  
  if NOT printerIsBusy  
    then jobAvailable.wait;  
  printer-file := buffer;  
end startPrint;
```

<print printer-file>

```
procedure endPrint;  
begin  
  printerIsBusy := false;  
  OKtoprint.signal;  
end endPrint;
```

```
procedure enqueueJob(file);  
begin  
  if printerIsBusy  
    then OKtoprint.wait sizeof(file);  
  printerIsBusy := true;  
  buffer := file;  
  jobAvailable.signal  
end;
```

Monitors: pros and cons

- Pros:
 - encapsulation provides automatic serialization
 - flexibility in blocking and unblocking process execution within monitor procedures
- Cons
 - lack of concurrency if monitor encapsulates shared resources
 - possibility of deadlock with nested monitor calls