

## Two Versions of Semaphores

- Semaphores from last time (simplified):

<u>wait (s):</u> $s = s - 1$ if ( $s < 0$ ) block the thread that called wait(s) otherwise continue into CS	<u>signal (s):</u> $s = s + 1$ if ( $s \leq 0$ ) wake up one of the waiting threads
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- "Classical" version of semaphores:

<u>wait (s):</u> if ( $s \leq 0$ ) block the thread that called wait(s) $s = s - 1$ continue into CS	<u>signal (s):</u> if (a thread is waiting) wake up one of the waiting threads $s = s + 1$
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- Do both work? What is the difference??

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## Implementing Semaphores

- Implementing semaphores using *busy-waiting*:

<u>wait (s):</u> while ( $s \leq 0$ ) do nothing; $s = s - 1$	<u>signal (s):</u> $s = s + 1$
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- Evaluation:

- ✗ Doesn't support queue of blocked threads waiting on the semaphore
- ✗ Waiting threads wastes time *busy-waiting* (doing nothing useful, wasting CPU time)
- ✗ The code inside wait(s) and signal(s) is a critical section also, and it's not protected

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## Implementing Semaphores (cont.)

- Implementing semaphores (not fully) by *disabling interrupts*:

<u>wait (s):</u> disable interrupts while ( $s \leq 0$ ) do nothing; $s = s - 1$ enable interrupts	<u>signal (s):</u> disable interrupts $s = s + 1$ enable interrupts
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- Evaluation:

- ✗ Doesn't support queue of blocked threads waiting on the semaphore
- ✗ Waiting threads wastes time *busy-waiting* (doing nothing useful, wasting CPU time)
- ✗ Doesn't work on multiprocessors
- ✗ Can interfere with timer, which might be needed by other applications
- ✗ OK for OS to do this, but users aren't allowed to disable interrupts! (Why not?)

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## Implementing Semaphores (cont.)

- Implementing semaphores (not fully) using a *test&set instruction*:

<u>wait (s):</u> while (test&set(lk)!=0) do nothing; $s = s - 1$ lk = 0	<u>signal (s):</u> while (test&set(lk)!=0) do nothing; $s = s + 1$ lk = 0
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- Operation:

- Lock "lk" has an initial value of 0
- If "lk" is free (lk=0), test&set atomically:
  - reads 0, sets value to 1, and returns 0
  - loop test fails, meaning lock is now busy
- If "lk" is busy (lk=1), test&set atomically:
  - reads 1, sets value to 1, and returns 1
  - loop test is true, so loop continues until someone releases the lock

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## Implementing Semaphores (cont.)

- Test&set is an example of an atomic *read-modify-write* (RMW) instruction
  - RMW instructions atomically read a value from memory, modify it, and write the new value to memory
    - Test&set — on most CPUs
    - Exchange — Intel x86 — swaps values between register and memory
    - Compare&swap — Motorola 68xxx — read value, if value matches value in register r1, exchange register r1 and value
- Evaluation:
  - ✓ Can be made to work, even on multiprocessors (although there may be some cache consistency problems)
  - ✗ Doesn't support queue of blocked threads waiting on the semaphore
  - ✗ Waiting threads wastes time *busy-waiting* (doing nothing useful, wasting CPU time)

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## Semaphores in Nachos

- The class Semaphore is defined in **threads/synch.h** and **synch.cc**
  - The classes Lock and Condition are also defined, but their member functions are empty (implementation left as exercise)
- Interesting functions:
  - Semaphores:
    - Semaphore::Semaphore( ) — creates a semaphore with specified name & value
    - Semaphore::P( ) — semaphore wait
    - Semaphore::V( ) — semaphore signal
  - Locks:
    - Lock::Acquire( )
    - Lock::Release( )
  - Condition variables:
    - Condition::Wait( )
    - Condition::Signal( )

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## Semaphores in Nachos

```
void
Semaphore::P()
{
    IntStatus oldLevel = interrupt->
        SetLevel(IntOff); // disable interrupts

    while (value == 0) { // sema not avail
        queue-> // so go to sleep
            Append((void *)currentThread);
        currentThread->Sleep();
    }

    value--; // semaphore available,
            // consume its value

    (void) interrupt-> // re-enable interrupts
        SetLevel(oldLevel);
}
```

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## Semaphores in Nachos (cont.)

```
void
Semaphore::V()
{
    Thread *thread;

    IntStatus oldLevel = interrupt->
        SetLevel(IntOff);

    thread = (Thread *)queue->Remove();
    if (thread != NULL) // make thread ready,
        // consuming the V immediately
        scheduler->ReadyToRun(thread);

    value++;

    (void) interrupt->SetLevel(oldLevel);
}
```

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