Thread and Synchronization

Synchronization Mechanisms (Module 21)

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Kernel Semaphores

- **struct semaphore: count, wait queue, and number of sleepers**

  *void sem_init(struct semaphore *sem, int val);*

  // Initialize a semaphore's counter sem->count to given value

  *inline void down(struct semaphore *sem);*

  //try to lock the critical section by decreasing sem->count

  *inline void up(struct semaphore *sem); // release the semaphore*

- **blocked thread can be in TASK_UNINTERRUPTIBLE or TASK_INTERRUPTIBLE (by timer or signal)**
- **Special case – mutexes (binary semaphores)**

  *void init_MUTEX (struct semaphore *sem)*
  *void init_MUTEX_LOCKED(struct semaphore *sem)*

- **Read/Write semaphores**

Spin lock vs Semaphore

- **Only a spin lock can be used in interrupt context,**
- **Only a semaphore can be held while a task sleeps.**

Requirement	Recommended Lock
Low overhead locking	Spin lock
Short lock hold time	Spin lock
Long lock hold time	Semaphore
Need to lock from interrupt context	Spin lock
Need to sleep while holding lock	Semaphore

- **Other mechanisms:**
  - Completion: synchronization among multiprocessors
  - The global kernel lock (a.k.a big kernel lock, or BKL)
    - *Lock_kernel(), unlock_kernel()*
  - RCU – read-copy update, for mostly-read access

Blocking Mechanism in Linux Kernel

- **ISR can wake up a block kernel thread**
  - which is waiting for the arrival of an event
- **Wait queue**
- **Wait_for_completion_timeout**
  - specify “completion” condition, timeout period, and action at timeout
  - “complete” to wake up thread in wait queue
  - wake-one or wake-many

```
struct semaphore {
        raw_spinlock_t          lock;
        unsigned int            count;
        struct list_head        wait_list;
};
```

```
struct completion {
        unsigned int done;
        wait_queue_head_t  wait;
};
```

```
struct __wait_queue_head {
        spinlock_t              lock;
        struct list_head        task_list;
};
```

Wait_for_Completion Example

- **In i2c-designware-core.c**
- **Threads call *i2c_dw_xfer* will do**
  - *INIT_COMPLETION(dev->cmd_complete);*
  - *i2c_dw_xfer_init(dev);*
  - *ret = wait_for_completion_interruptible_timeout(&dev->cmd_complete, HZ);*
- **In *i2c_dw_xfer_init*, interrupt get enabled**
- **In *i2c_dw_isr*, when xfer is done**
  - *complete(&dev->cmd_complete);*

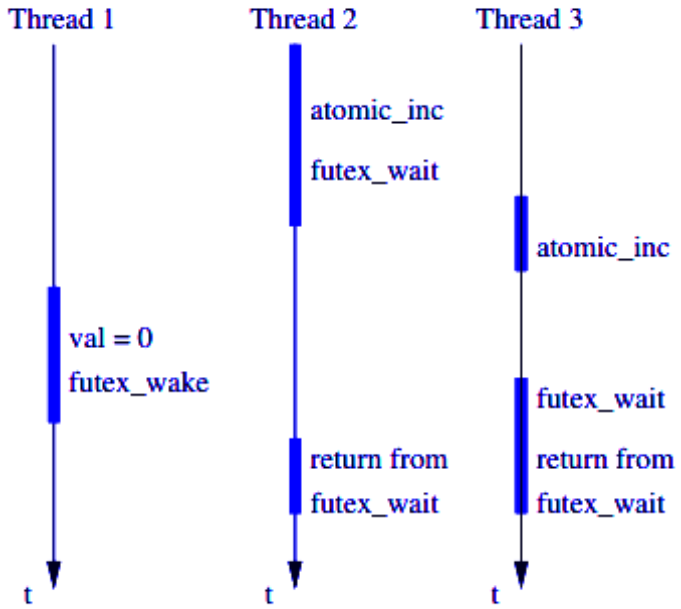
Mutex in Linux

- **Two states: locked and unlocked.**
  - if locked, wait until it is unlocked
  - only the thread that locked the mutex may unlock it
- **Various implementations for performance/function tradeoffs**
  - Speed or correctness (deadlock detection)
  - lock the same mutex multiple times
  - priority-based and priority inversion
  - forget to unlock or terminate unexpectedly
- **Available types**
  - normal
  - fast
  - error checking
  - recursive: owner can lock multiple times (couting)
  - robust: return an error code when crashes while holding a lock
  - RT: priority inheritance

Pthread Futex

- **Lightweight and scalable**
- **In the noncontended case can be acquired/released from userspace without having to enter the kernel.**
  - lock is a user-space address, e.g. a 32-bit lock variable field.
  - “uncontended” and “waiter-pending”
  - kernel provides futex queue, and sys_futex system call
  - invoke sys_futex only when there is a need to use futex queue
  - need atomic operations in user space
  - race condition: atomic update of *ulock* and system call are not atomic

```
typedef struct ulock_t {
        long status;
} ulock_t;
```



Reader/Writer -- ISR and Buffering

- **Input: single producer (ISR) and single consumer (thread)**
- **If a read is initialed by the thread**
  - calls "*read*" with a buffer of *n* bytes
  - initiate IO operation, enable interrupt
  - ISR reads input and store in the buffer.
  - If done, signal the completion
- **Blocking or nonblocking**
  - in thread context (e.g. vxWorks) – semaphore, lock
  - in kernel context (Linux) – wait queue
- **Guarded access**
  - Lock (mutex) and interrupt lock (disable)