CSE 451: Operating Systems

Section 4

Project 2 Intro; Threads

Project 1

- Congratulations, you're all kernel hackers now!

Project 2: user-level threads

- Part A: due Monday, November 1
  - Implement part of a user thread library
  - Add synchronization primitives
  - Solve a synchronization problem
- Part B: due Wednesday, November 17
  - Implement a multithreaded web server
  - Add preemption
  - Get some results and write a (small) report

Project 2 notes

- Start EARLY!
  - It's looooooong
  - Read the assignment carefully
  - Read it again
  - Understand the skeleton code
- Use the same groups as for project 1

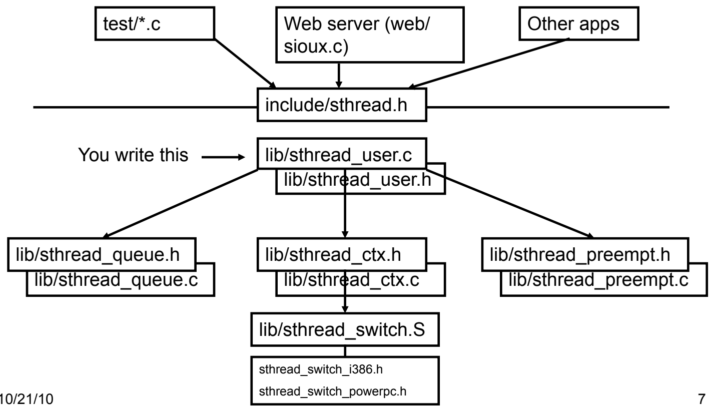
Project 2 tips

* Understand what the provided code does for you
* Division of work
  * Part 3 can be completed without parts 1 and 2
* More tools
  * ddd

Simplethreads

* We give you:
  * Skeleton functions for thread interface
  * Machine-specific code (x86 and PPC)
    * Support for creating new stacks
    * Support for saving regs/switching stacks
  * A queue data structure
  * Very simple test programs
    * You should write more, and include them in the turnin
  * A single-threaded web server

Simplethreads code structure



Pthreads

* Pthreads (POSIX threads) is a preemptive, kernel-level thread library
* Simplethreads is similar to Pthreads
* Project 2: compare your implementation against Pthreads
  * ./configure --with-pthreads

Thread operations

- What functions do we need?

Simplethreads API

```
void sthread_init()
```
- Initialize the whole system

```
sthread_t sthread_create(func start_func,
   void *arg)
```
- Create a new thread and make it runnable

```
void sthread_yield()
```
- Give up the CPU

```
void sthread_exit(void *ret)
```
- Exit current thread

```
void* sthread_join(sthread_t t)
```
- Wait for specified thread to exit

Simplethreads internals

- Structure of the TCB:

```
struct _sthread {
   sthread_ctx_t *saved_ctx;
   /**
    * Add your fields to the thread
    * data structure here.
    */
};
```

Sample multithreaded program

- (this slide and next)

```
void *thread_start(void *arg) {
   printf("in thread_start, arg = %p\n",
       arg);
   return 0;
}

...
```

Sample multithreaded program

```
int main(int argc, char **argv) {
   sthread_init();
   for(i = 0; i < 3; i++) {
      if (sthread_create(thread_start,
                         (void *)i) == NULL) {
         printf("sthread_create failed\n");
         exit(1);
      }
   }
   sthread_yield();
   printf("back in main\n");
   return 0;
}
```

Managing contexts

∗(Provided for you in project 2)

∗Thread *context* = thread stack + stack pointer

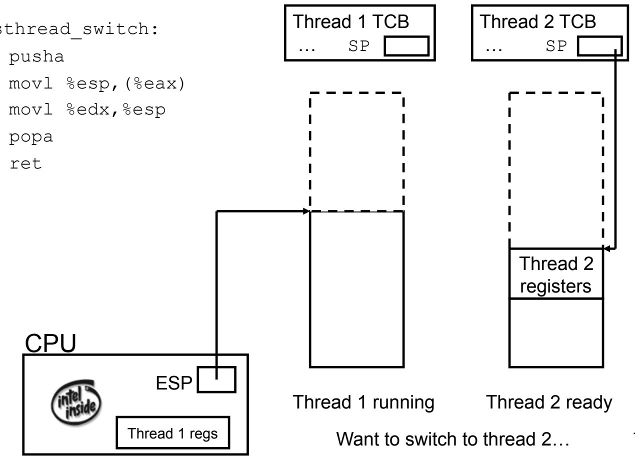
`sthread_new_ctx(func_to_run)`
- ∗ creates a new thread context that can be switched to

`sthread_free_ctx(some_old_ctx)`
- ∗ Deletes the supplied context

`sthread_switch(oldctx, newctx)`
- ∗ Puts current context into oldctx
- ∗ Takes newctx and makes it current

How sthread_switch works

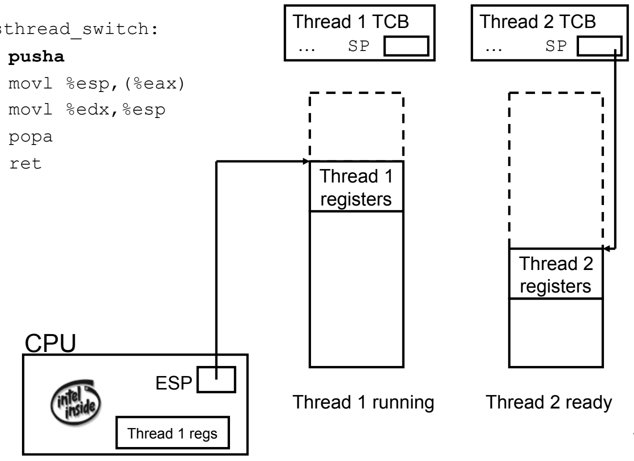
```
Xsthread_switch:
  pusha
  movl %esp,(%eax)
  movl %edx,%esp
  popa
  ret
```

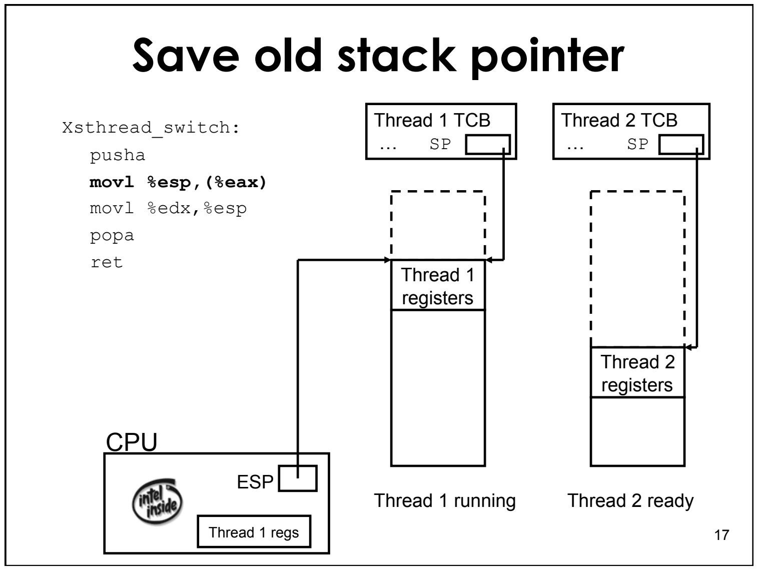


Want to switch to thread 2…

Push old context

```
Xsthread_switch:
  pusha
  movl %esp,(%eax)
  movl %edx,%esp
  popa
  ret
```





Save old stack pointer

```
Xsthread_switch:
  pusha
  movl %esp,(%eax)
  movl %edx,%esp
  popa
  ret
```

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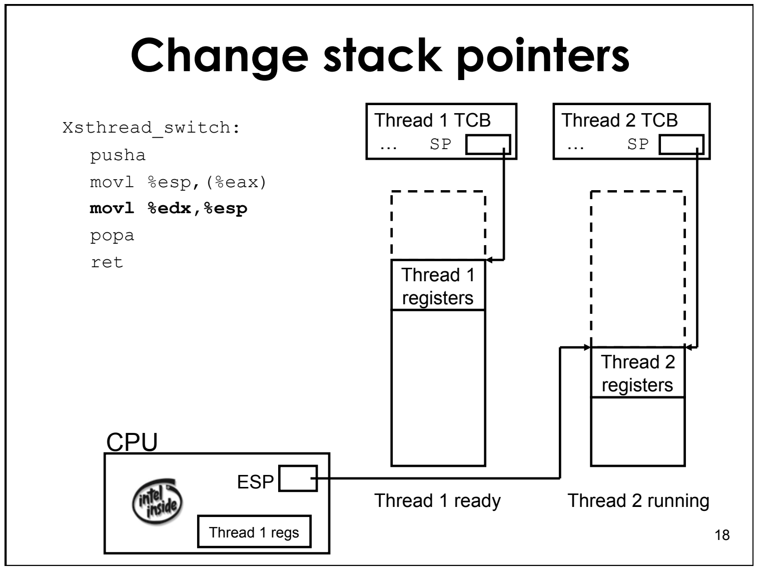

Change stack pointers

```
Xsthread_switch:
  pusha
  movl %esp,(%eax)
  movl %edx,%esp
  popa
  ret
```

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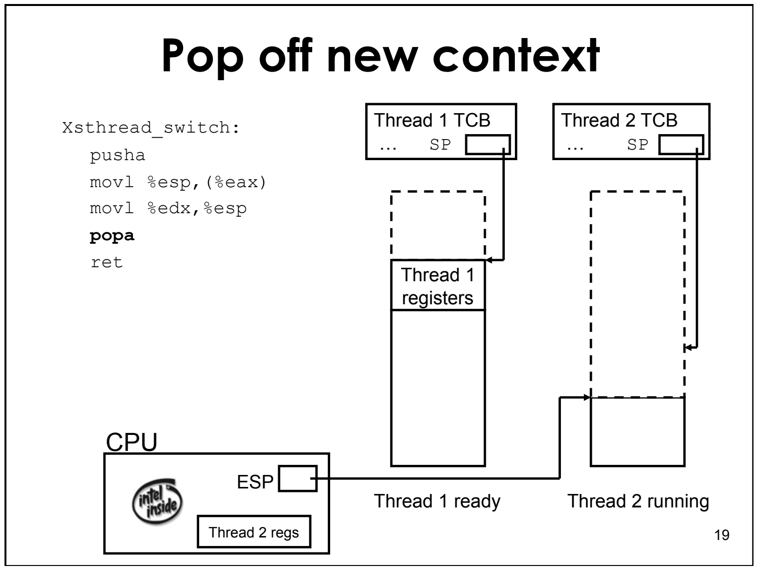

Pop off new context

```
Xsthread_switch:
  pusha
  movl %esp,(%eax)
  movl %edx,%esp
  popa
  ret
```

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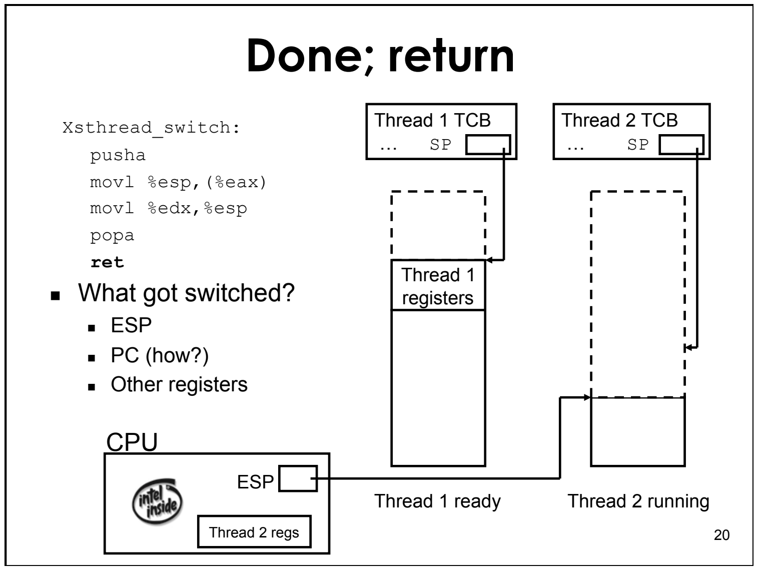

Done; return

```
Xsthread_switch:
  pusha
  movl %esp,(%eax)
  movl %edx,%esp
  popa
  ret
```

- What got switched?
  - ESP
  - PC (how?)
  - Other registers

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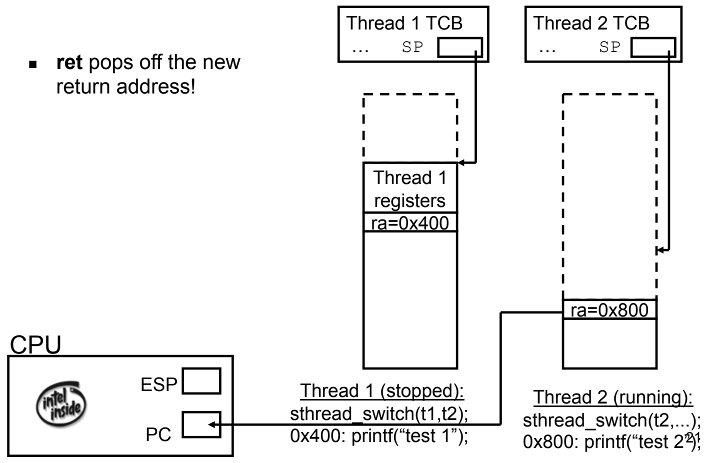
Adjusting the PC

- **ret** pops off the new return address!



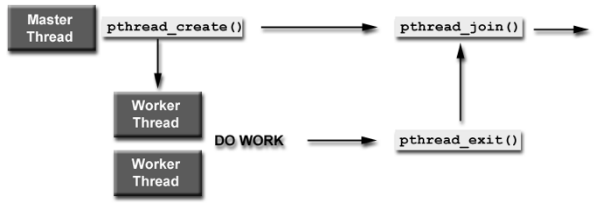
Thread joining

∗With Pthreads (and Sthreads):

∗Master thread calls join on worker thread

∗Join blocks until worker thread exits.

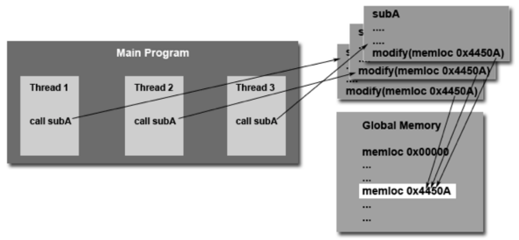
∗Join returns the return value of the worker thread.



The need for synchronization

∗Thread safety:

∗An application's ability to execute multiple threads simultaneously without "clobbering" shared data or creating "race" conditions



Synchronization primitives: mutexes

```
sthread_mutex_t sthread_mutex_init()
void sthread_mutex_free(sthread_mutex_t lock)

void sthread_mutex_lock(sthread_mutex_t lock)
```

∗ When returns, thread is guaranteed to acquire lock

```
void sthread_mutex_unlock(
   sthread_mutex_t lock)
```

Synchronization primitives: condition variables

```
sthread_cond_t sthread_cond_init()
void sthread_cond_free(sthread_cond_t cond)

void sthread_cond_signal(sthread_cond_t cond)
```

- ∗ Wake-up one waiting thread, if any

```
void sthread_cond_broadcast(
   sthread_cond_t cond)
```

- ∗ Wake-up all waiting threads, if any

```
void sthread_cond_wait(sthread_cond_t cond,
   sthread_mutex_t lock)
```

- ∗ Wait for given condition variable
- ∗ Returning thread is guaranteed to hold the lock

Things to think about

- ∗ How do you create a thread?
  - ∗ How do you pass arguments to the thread's start function?
    - ∗ Function pointer passed to sthread_new_ctx() doesn't take any arguments
- ∗ How do you deal with the initial (main) thread?
- ∗ How do you block a thread?

Things to think about

- ∗ When and how do you reclaim resources for a terminated thread?
  - ∗ Can a thread free its stack itself?
- ∗ Where does sthread_switch return?
- ∗ Who and when should call sthread_switch?
- ∗ What should be in struct _sthread_mutex, struct _sthread_cond?