15-410
“...What does IRET do, anyway?...”

Exam #1
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Synchronization

Final Exam list posted
- You *must* notify us of conflicts in a timely fashion

P3 milestones (completed, right?)
- Read handout, re-read k-spec
- Chosen 3+ weekly joint hacking sessions
- Set up source control repository
- Rough-draft division of labor, rough pseudo-code/outlines
- Typed *some* code...?

Book report topic chosen?  Great for airplane time...

Summer internship with SCS Facilities?
A Word on the Final Exam

Disclaimer
- Past performance is not a guarantee of future results

The course will change
- Up to now: “basics”
  - What you need for Project 3
- Coming: advanced topics
  - Design issues
  - Things you won't experience via implementation

Examination will change to match
- More design questions
- Some things you won't have implemented
Outline

Question 1
Question 2
Question 3
Question 4
Question 5
Past Misunderstandings

This is a C programming class!

- `sizeof (char) == 1 /* 8 bits */`
- `sizeof (int) == 4 /* 32 bits, mostly true now */`
- You need to really understand pointers

Semantics

- '\0' isn't “just” a 1-byte zero – it's the zero char
- Compare 0, '\0', NULL

Other languages are excellent

- ...but very few are ok for writing OS code
Q1 – Definitions (graded *gently*)

**XCHG**
- instruction, atomically, exchanges

**Kernel Stack**
- stack used by a thread while running kernel code
- “stack” != “memory”, “stack” != “control block”

**Atomic Instruction Sequence**
- Must not be interrupted/interleaved, should be short

**Exception**
- Control transfer to OS, caused by instruction stream

**Yield()**
Q2 – Interrupt Handling

Misconception City!

- static local variable
- What's that ol' IRET do, anyway?
- If an interrupt fires in the forest, and nobody hears it...
- “Assume an infinite stream of interrupts…”
- “printf() is a system call”
- Watch out for sneaky stack growth...
static local variable??

```c
static int ticks_since_boot = 0;
```

**What's that all about?**

- A weird C trivia question, except...
  - Used in C++, and Java too!

**What's the proper scope for `ticks_since_boot`?**

- Used by only one procedure
  - Remember, don't specify data items in your interface!!!
  - Specify methods instead
- Used by only one procedure
  - Don't want it to be global
- But local variables “reset” each time procedure is called!
- Unless they are declared “static”!!!

**Static = procedure-local persistent variable (oh, and ...)**
What's that ol' IRET do, anyway?

IRET should not be mysterious
- You used it in P1, will use it a lot in P3
- Looking things up in intel-*.pdf is a good idea

On interrupt/exception, processor follows a protocol
- Saves some state (“trap frame”), typically on stack
- What’s that “state” for?
  - Exception: explain what “caused” the exception
  - Interrupt & exception: document “where we were at the time”
  - Handler done? Ram it back into the relevant registers!
    » IRET

So...
- IRET pops top of stack into %EIP, %CS, %EFLAGS (...)

- 9 -
Other issues with the bad code

**IRET happens before function clean-up**
- ...leaks “caller's %ebp” each time
- True, but we never run that many times

**Registers might be corrupted before PUSH A**
- *Could* happen...
- ...but not as a result of a *static* local declaration-initialization
If an interrupt fires in the forest...

What do we mean by a “disabled” interrupt?
- Alternate term: “masked”

Why do we “disable interrupts”?
- To protect an atomic instruction sequence...
- ...which should be “short”...
- ...so it's ok for interfering sequences to...
  - ...die?
If an interrupt fires in the forest...

Why do we “disable interrupts”?  
- To protect an atomic instruction sequence...
- ...which should be “short”...
- ...so it's ok for interfering sequences to...
  - ...wait a bit before they can run!

What do we mean by a “disabled” interrupt?  
- Alternate term: “deferred”!
- The interrupt controller will remember it until we re-enable

Why should interrupt handlers be “short”?  
- Not: longer ones are more likely to throw away interrupts!  
  - No length would be safe!
- Because some hardware will get angry if we don't answer...  
  - ...or maybe some user code will.
If an interrupt fires in the forest...

**Impatient Ethernet**
- Interrupts when each packet arrives
- When “ring buffer” overflows, packets will be lost
  - Process them *soon*...

**Impatient Disk**
- Interrupts when sector is ready
- Say “Oh, and give me the next sector too” *soon*...
  - Or it will have rotated past the head.

**Impatient Timer?**
- Reloads and starts counting before you process interrupt
- Inter-interrupt period is, well, 10 milliseconds
- *(1 billion / 1 hundred) instructions*...
- That is a deadline, but it's not really a harsh one.
“Assume an infinite stream of interrupts...”

Each interrupt handler invocation uses stack space

- True

“If we have an infinite stream of interrupts...overflow!”

- True
- True of *any* interrupt handler code
  - .c, .S, asm(), ...

Can this happen?

- Each device issues one interrupt, waits for dismissal
  - `outb(...)` in 15-410 x86 support code
- Finite number of devices on system
- How many trap frames can be on stack?
"printf() is a system call"

Reasoning

- `printf()` is a system call
- System calls are slow
- Interrupt handlers should not be slow

`printf()` isn't magic...

- `printf()` is a *library routine*
- ...which sometimes invokes a system call...
- ...if it's not already in the kernel!

Kernel `printf()` is a library routine...

- ...which calls the console driver!
- It may or may not be "slow"... (scrolling screen isn't zippy)
- ...but it's not *impossibly* slow.
Sneaky Stack Growth

People generally understand

- Function call sequence begins with pushing parameters
- Then there is a call instruction
- What happens after the call?

Several people claimed

- When timer_handler() calls printf() and then outb()...
- ...“all of those parameters are still on the stack at POPA”
Q3: Stack Trace

Many people got this essentially right

**Common “oops”**
- Assuming `mystery(s1, s2)` because it “seems natural”
- Function table shows `mystery(s2, s1)`

**Trouble?**
- Review P0 code
- During P3 you may well need to debug from a hex dump
void main()
{
    printf("Fred!\n");
    exit(99);
}
Q3: Stack Trace

LC0:
  .ascii "Fred!\12\0"

_main:
  pushl %ebp
  movl %esp,%ebp
  pushl $LC0
  call _printf
  addl $4,%esp \⇐ What's that?
  pushl $99
  call _exit
  addl $4,%esp \⇐ There it is again!!
  leave
  ret
Q4: Deadlock

Many people got this mostly right

Key idea

- Four requirements for deadlock
- Four ways to prevent it ("Four Ways to Forgiveness")
- One of them is commonly used (locking order)
  - Now you intuitively understand that

Subtle idea

- You can lock anything as long as each lock() is “in order”
- lock(0); lock(1); lock(33); unlock(33); lock(2);
- Which tool should go at the end?
Q5: Concurrency

“Race condition” / “Thread-safe” still not clear

- Neither one is thread-safe (on either exam)!

Myths

- A: “As long as shared state is changed inside a mutex I'm ok”
- B: “Once cond_wait() returns I'm good to go”
- “Since neither foo() writes to shared state everything is ok”
Myth “A”

"If shared state is changed inside a mutex I'm ok"
- Not if the decision about how to change is outside!

```c
if (queue->start == (queue->end + 1) % QUEUE_LEN)
    return -1;
/* now we mutate NO MATTER WHAT */
mutex_lock(&queue->lock);
queue->buf[queue->end] = data;
queue->end = (queue->end + 1) % QUEUE_LEN;
mutex_unlock(&queue->lock);
```
Myth “B”

"Once cond_wait() returns I'm good to go"

- You're running with the lock, but are you running *first*?

```c
mutex_lock(&stack->lock);
/* If the stack is empty, wait for data */
if (stack->spot == -1)
  cond_wait(&stack->empty, &stack->lock);
data = stack->buf[stack->spot]; /* It can be -1 *again!* */
stack->spot--;
mutex_unlock(stack->lock);
```
Shared Myth

“Since neither foo() writes to shared state foo() is ok”

- What about main()-vs-foo() conflicts?

```c
tid[0] = thr_create(foo, 0); /* foo(0) reads tid[0..1] */
tid[1] = thr_create(foo, 1); /* foo(1) reads tid[0..1] */
```

**main() writes tid[0..1], foo() reads tid[0..1]**

- Nary a mutex in sight...
- Does foo(0) run before or after “tid[0] =”? 
Summary

90% = 67.5  15 students
80% = 60.0  17 students
70% = 52.5  7 students
<70%        6 students