CS 134:
Operating Systems
System Calls

CS34

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Overview

Overview
The Processor Status Word
Protection
Types of Protection
Memory Protection
System Calls
Next Assignment

Processor Status Words

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- Interrupt control
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- Condition codes

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MIPS Status

MIPS keeps a STATUS word in control register 12:

- Various cache-control bits
- “Boot flag” for booting from ROM
- Five hardware interrupt enables
- Two software interrupt enables
- Three bit pairs called old/previous/current:
  - Kernel/user mode
  - Global interrupt enable

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How MIPS Interrupts Work

MIPS works like most machines:

- Finish currently executing instructions
- Drain pipeline
- Disable interrupts
- Switch to kernel mode
- Start execution at known location

Minor MIPS detail: in STATUS, old/previous/current is shifted left and current is set to 0 (kernel mode, no interrupts)

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Protection

Processes need to be insulated from each other.

What needs protection?

What do we want from hardware to provide protection?

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Stop here to discuss.

User & Kernel Mode

Two states:

- *User mode*—Processes
- *Kernel mode*—OS code to support processes

The *hardware* usually knows what state we're in. (Why?)

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CPU Protection

If a program hangs, it shouldn't hang the machine

Use a timer interrupt!

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I/O Protection

Protect I/O devices from errant programs

Solution: *I/O Protection*

- Only kernel may interact with I/O hardware
- I/O instructions are privileged
- Interrupt jumps to kernel, sets kernel mode

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Memory Protection

Protecting I/O devices also requires that we protect

- Interrupt vector
- Interrupt service routines (and rest of kernel)
- Operating system data structures

from modification by errant or malicious programs

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Class Exercise

What's the *simplest* solution we could ask from hardware makers to solve problem of ensuring that a program doesn't access outside its own chunk of physical memory?

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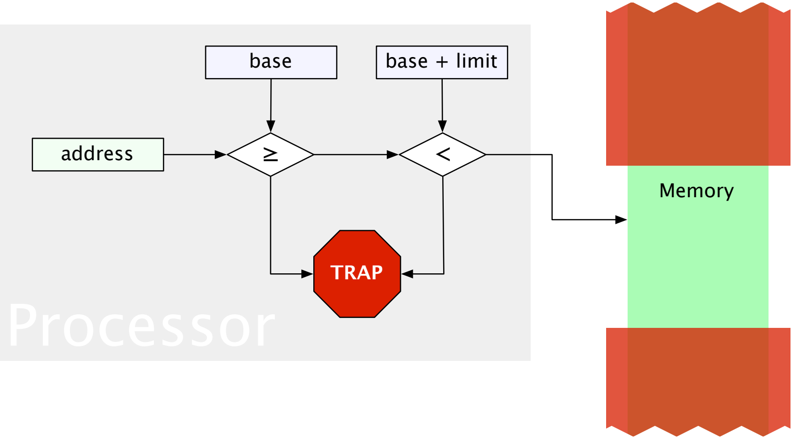
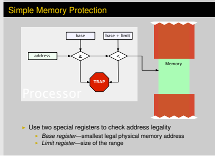
Class Exercise
What's the *simplest* solution we could ask from hardware makers to solve problem of ensuring that a program doesn't access outside its own chunk of physical memory?

Here, we're looking for base/limit registers.

Simple Memory Protection

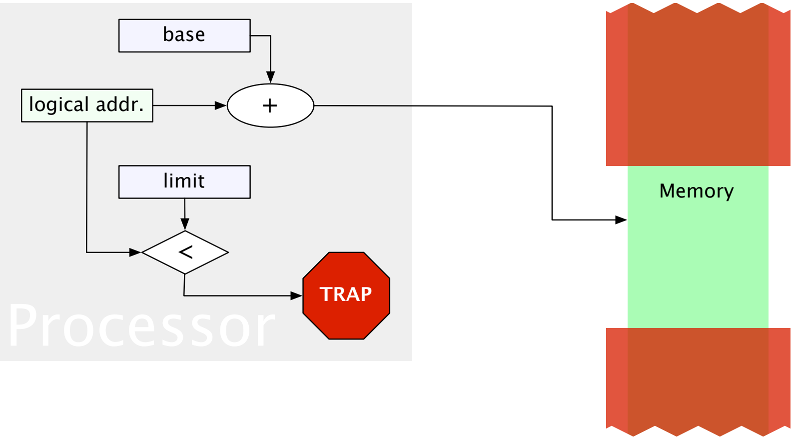


- Use two special registers to check address legality
  - *Base register*—smallest legal physical memory address
  - *Limit register*—size of the range

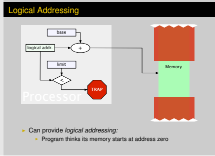


- Memory outside designated range can't be accessed by user-mode code
- In kernel mode, process has unrestricted access to all memory
- Load instructions for base and limit registers are privileged
- Checks can proceed in parallel

Logical Addressing



- Can provide *logical addressing:*
  - Program thinks its memory starts at address zero



Class Question

Given that I/O instructions are privileged. . . and that misusing a modern I/O device can destroy it

> *How does a user-mode program perform I/O?*
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> *(or do anything else it is "forbidden" to do directly)*

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How does a user-mode program perform I/O?
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System Calls

System Call: A method used by a process to request action by the operating system

Implemented as either

- Software interrupt (aka Trap)
- Special `syscall` instruction

Usually works just like hardware interrupt—control passes through interrupt vector to a service routine in the OS, mode bit is set to kernel

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What things do we need to do in the kernel part of a syscall?

System Calls
System Call: A method used by a process to request action by the operating system
Implemented as either
- Software interrupt (aka Trap)
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Class Question
What things do we need to do in the kernel part of a syscall?

The kernel must first save status. Then it needs to figure out which syscall is being made (including verification of legality). Any parameters must be recovered from user space; then the implementing function is called. Finally, results are returned to the user, status is restored, and user mode is resumed.

Most system calls re-enable interrupts during their execution.

MIPS System Call Example

Example code from `libc` on OS/161

```
reboot:
   addiu v0, $0, SYS_reboot /* load syscall no. */
   syscall                  /* make system call */
   beq a3, $0, 1f           /* a3= 0 =>call succeeded */
   nop                      /* delay slot */
   sw v0, errno             /* failure: store errno */
   li v1, -1                /* and force return to -1 */
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   j ra                     /* return */
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X86 System Call Example

Hello World on Linux

```
    .section .rodata
greeting:
    .string "Hello World\n"
    .text
_start:
    mov   $12,%edx        /* write(1, "Hello World\n", 12) */
    mov   $greeting,%ecx
    mov   $1,%ebx
    mov   $4,%eax         /* write is syscall 4 */
    int   $0x80

    xorl  %ebx, %ebx      /* Set exit status and exit */
    mov   $0xfc,%eax
    int   $0x80

    hlt                   /* Just in case... */
```


X86 System Call Example
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Functionality

What functionality should be implemented as system calls?

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Let class brainstorm, them make list on board.

Some POSIX System Calls

Call	Description
`pid = fork()`	Create child process
`pid = waitpid(pid, &statloc, options)`	Wait for child to terminate
`s = execve(name, argv, environp)`	Replace process's image
`exit(status)`	Terminate process
`fd = open(file, how, ...)`	Open file for read/write
`s = close(fd)`	Close open file
`n = read(fd, buffer, nbytes)`	Read data from file into buffer
`n = write(fd, buffer, nbytes)`	Write data from buffer to file
`pos = lseek(fd, offset, whence)`	Move file pointer
`s = stat(name, &buf)`	Get file's status information
`s = mkdir(name, mode)`	Create new directory
`s = rmdir(name)`	Remove empty directory
`s = link(name1, name2)`	Create link to file
`s = unlink(name)`	Remove directory entry
`s = mount(special, name, flag)`	Mount file system
`s = umount(special)`	Unmount file system
`s = chdir(dirname)`	Change working directory
`s = chmod(name, mode)`	Change file's protection bits
`s = kill(pid, signal)`	Send signal to a process
`secs = time(&seconds)`	Get elapsed time since 1/1/70

Beyond System Calls—Library Interfaces

System calls tend to be minimal and low-level

Programmers prefer to use higher-level routines

Class Exercise

What is the key difference between system calls and library calls?

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The Next Assignment

In the next assignment, you must implement

- `open`, `read`, `write`, `lseek`, `close`, `dup2`
- `fork`, `_exit`
- `chdir`, `getcwd`
- `getpid`
- `execv`, `waitpid`

What are the data structures you'll need? Initialization? How/when is data changed or copied?

In general, how should it all work?

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