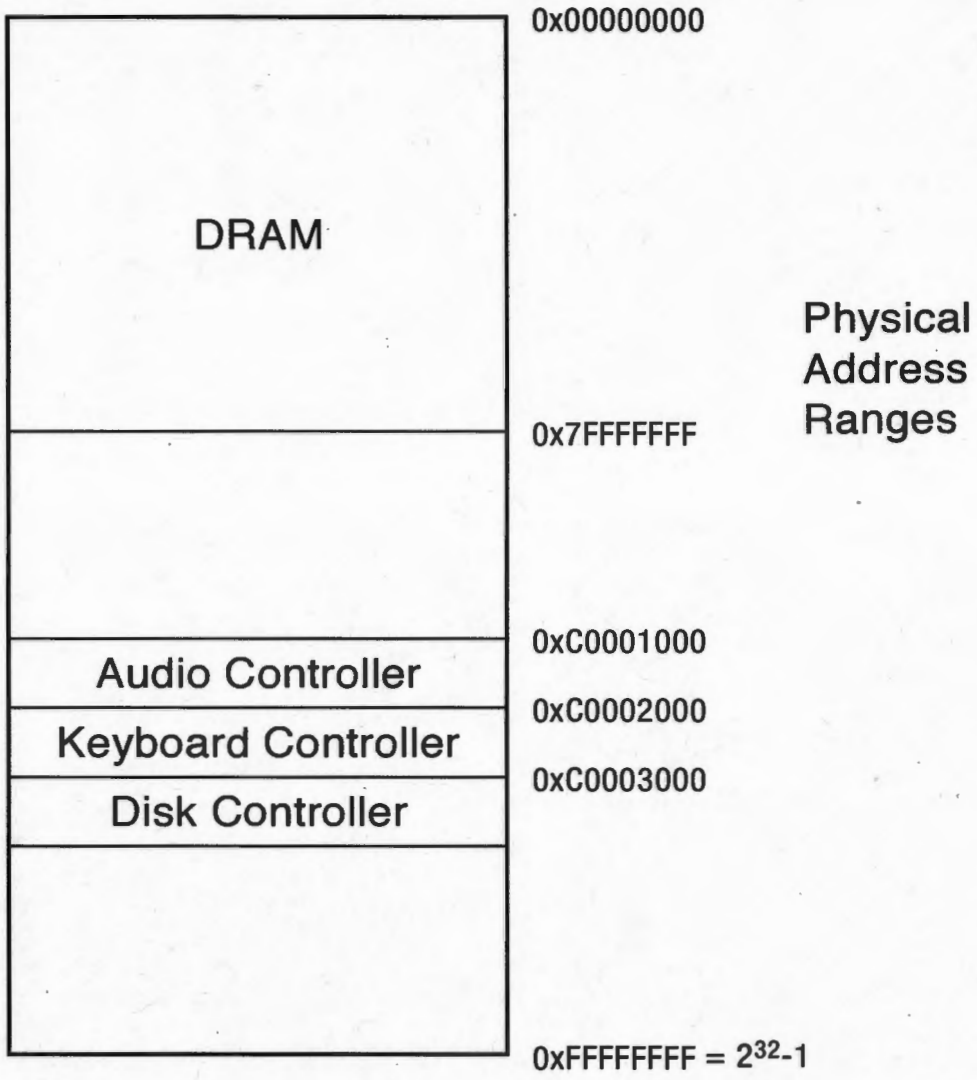
The Kernel Abstraction

CSE 006

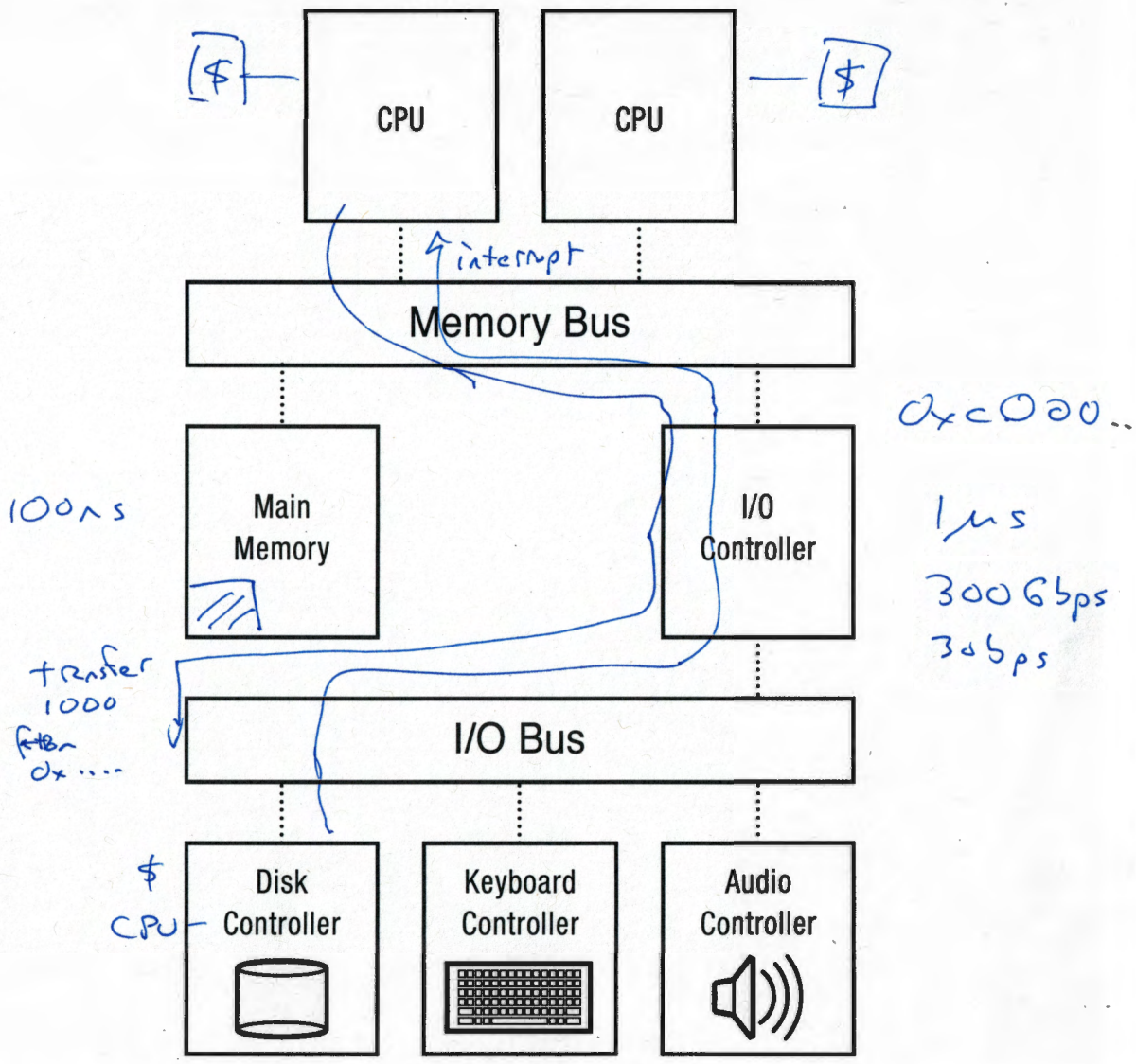
12:30 TODAY

Physical Address Layout



Device I/O

- Polling vs. interrupts
- Programmed I/O vs. DMA
- One operation at a time vs. queue of operations



Question

- What (hardware, software) do you need to be able to run an untrustworthy application?

Memory range limit

System calls limit

which user/apps have which permissions

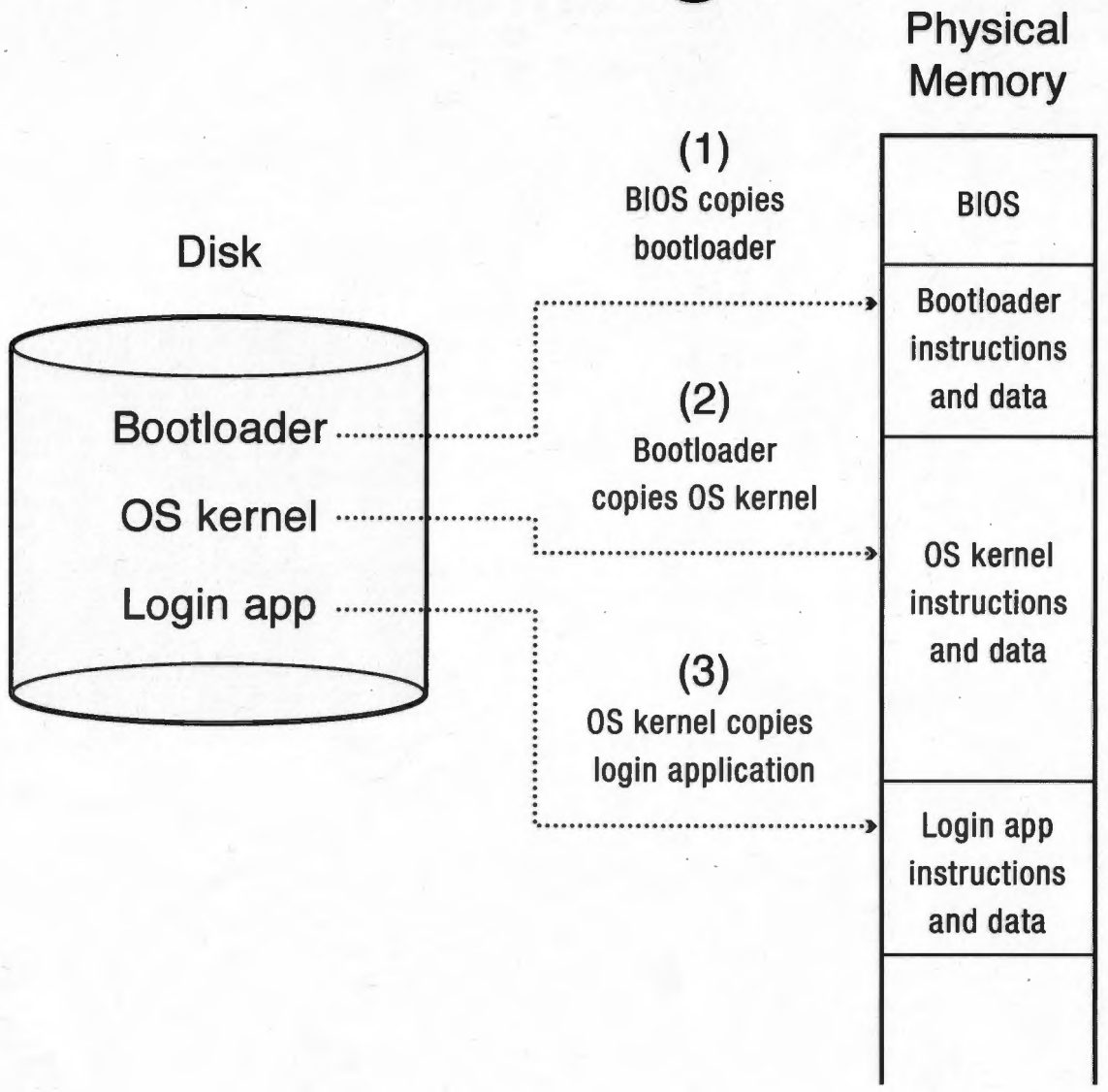
halt app - timer interrupt

limit apps to change permissions

Main Points

- Process concept
  - A process is the OS abstraction for executing a program with limited privileges
- Dual-mode operation: user vs. kernel
  - Kernel-mode: execute with complete privileges
  - User-mode: execute with fewer privileges
- Safe control transfer
  - How do we switch from one mode to the other?

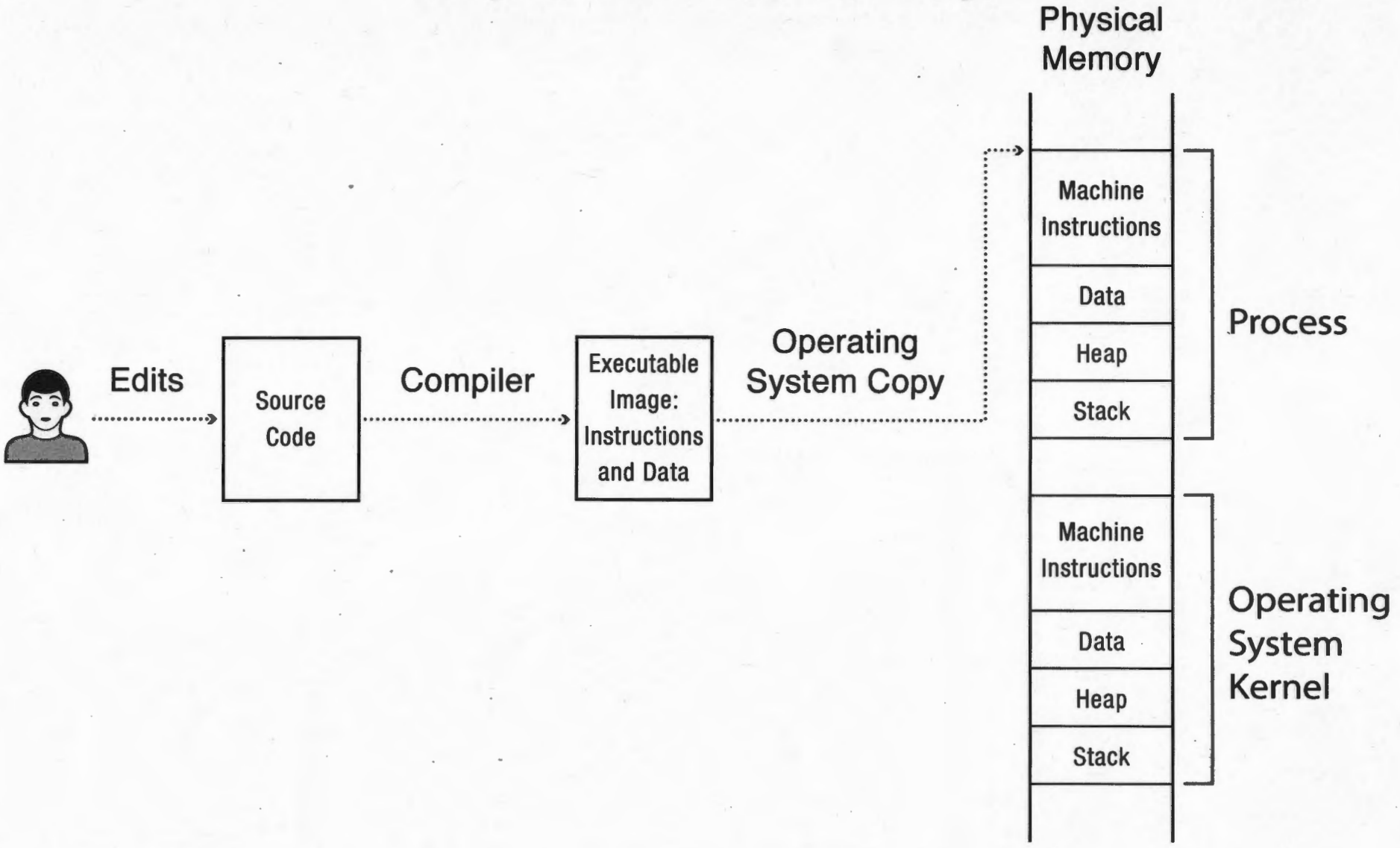
Booting


Physical Memory
(1)
BIOS copies bootloader
Disk
BIOS
Bootloader instructions and data
Bootloader
OS kernel
Login app
(2)
Bootloader copies OS kernel
OS kernel instructions and data
(3)
OS kernel copies login application
Login app instructions and data

Challenge: Protection

- How do we execute code with restricted privileges?
  - Either because the code is buggy or if it might be malicious
- Some examples:
  - A script running in a web browser
  - A program you just downloaded off the Internet
  - A program you just wrote that you haven't tested yet

Physical Memory



Process Abstraction

- Process: an *instance* of a program, running with limited rights
  - Thread: a sequence of instructions within a process
    - Potentially many threads per process (for now 1:1)
  - Address space: set of rights of a process
    - Memory that the process can access
    - Other permissions the process has (e.g., which system calls it can make, what files it can access)

Thought Experiment

- How can we implement execution with limited privilege?
  - Execute each program instruction in a simulator
  - If the instruction is permitted, do the instruction
  - Otherwise, stop the process
  - Basic model in Javascript and other interpreted languages
- How do we go faster?
  - Run the unprivileged code directly on the CPU!

Dual-Mode Operation

- Kernel mode
  - Execution with the full privileges of the hardware
  - Read/write to any memory, access any I/O device, read/write any disk sector, send/read any packet
- User mode
  - Limited privileges
  - Only those granted by the operating system kernel
- On the x86, mode stored in EFLAGS register
- On the MIPS, mode in the status register

0x0 add r1, r2, r3

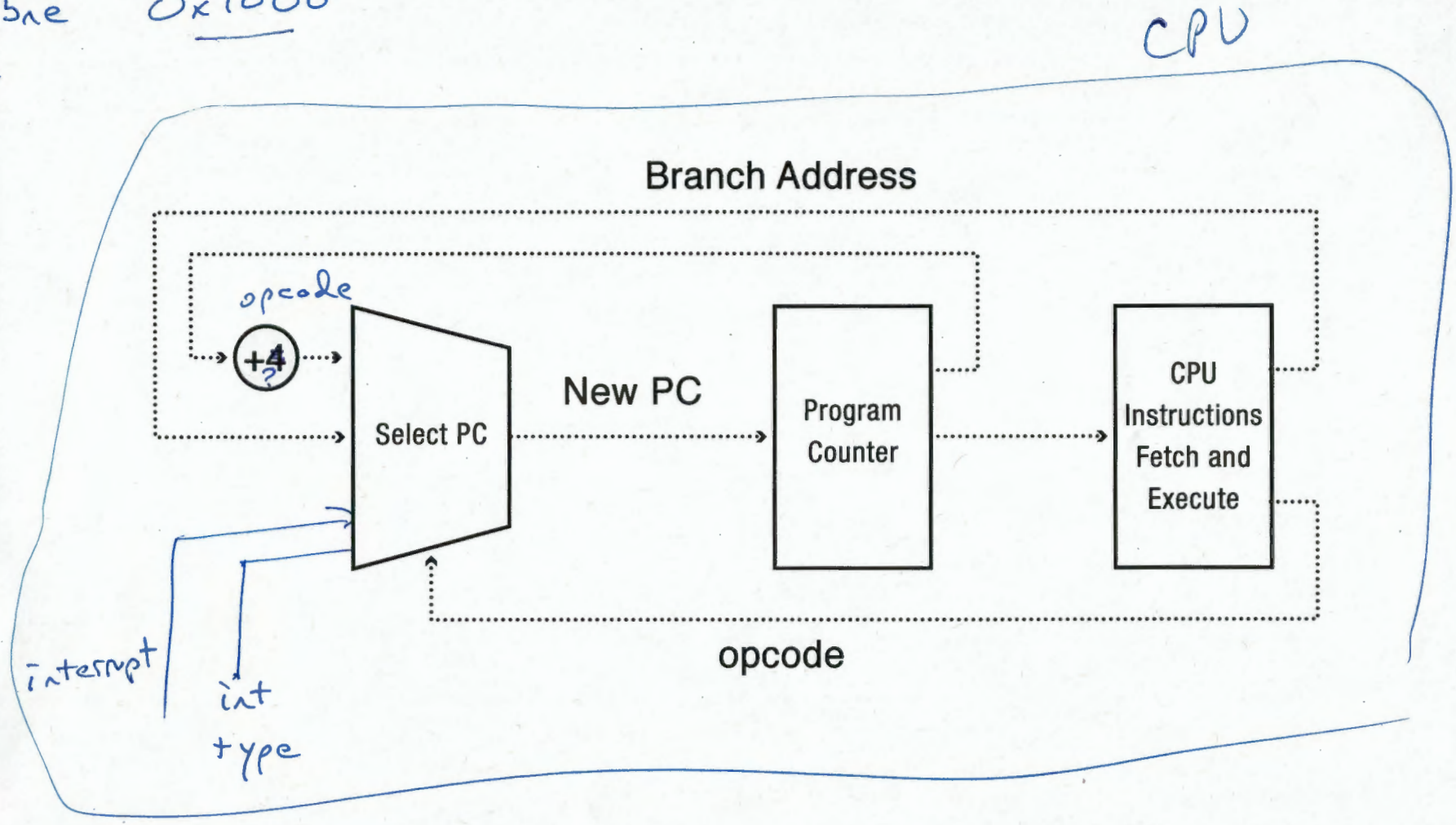
0x4 adds %eax, %ebx, %eax

~~jmp 0x1000~~

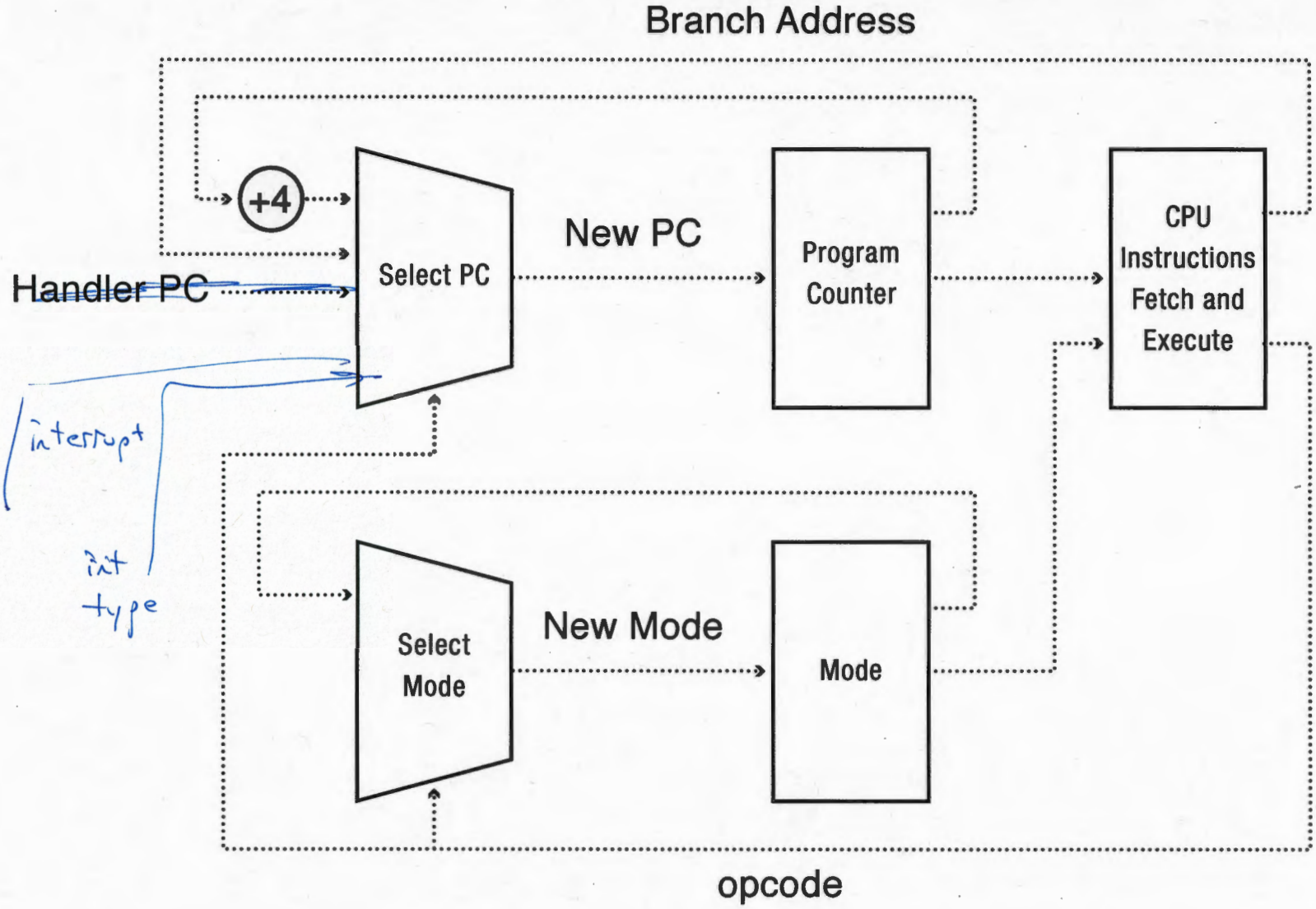
0x6 bne 0x1000

0x12

A Model of a CPU



A CPU with Dual-Mode Operation



Hardware Support for Dual-Mode Operation

- Privileged instructions
  - Available to kernel
  - Not available to user code
- Limits on memory accesses
  - To prevent user code from overwriting the kernel
- Timer
  - To regain control from a user program in a loop
- Safe way to switch from user mode to kernel mode, and vice versa

Question

- For a "Hello world" program, the kernel must copy the string from the user program memory into the screen memory.
- Why not allow the application to write directly to the screen's buffer memory?

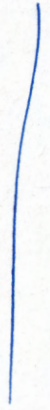
Privileged instructions

- Examples?

change eflags

change page table ~~pt~~

~~set~~ iret



- What should happen if a user program attempts to execute a privileged instruction?

kill it

error flag

exception –