Hardware and Booting

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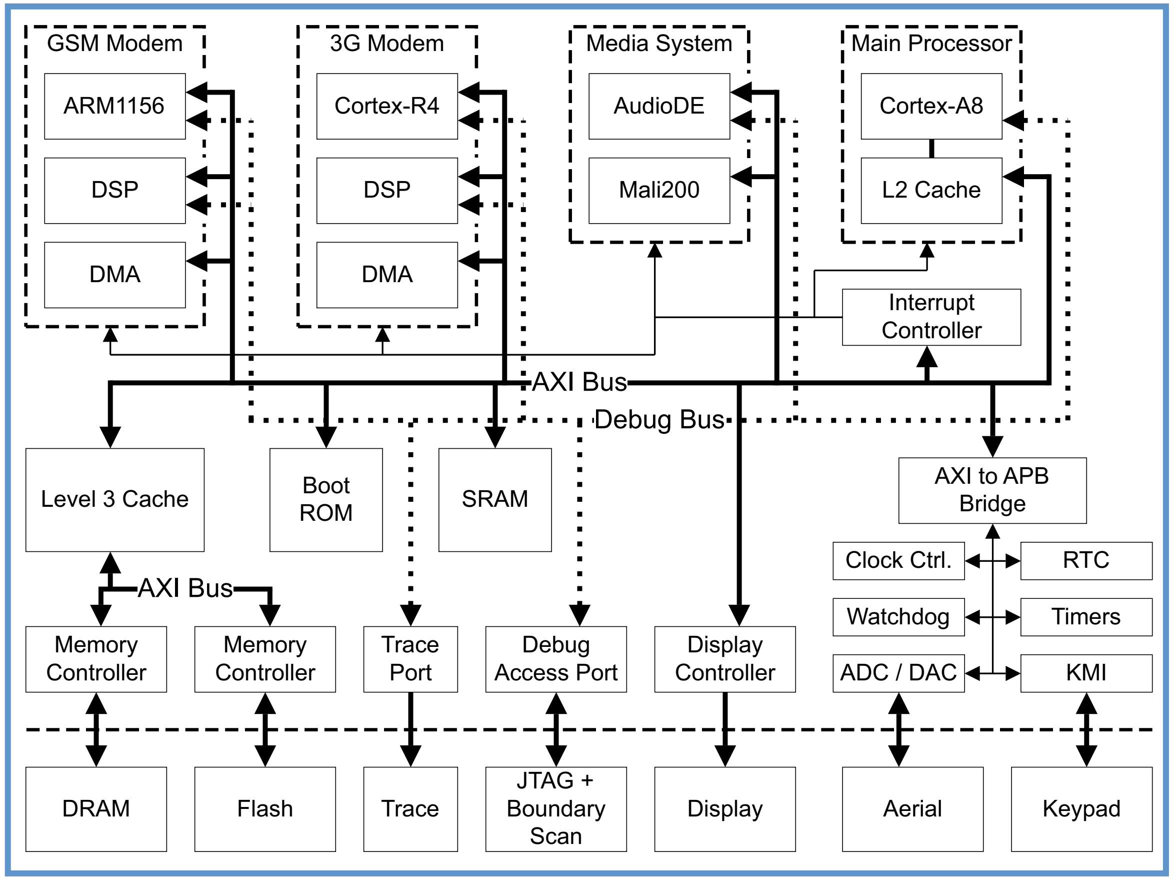
IIT Madras

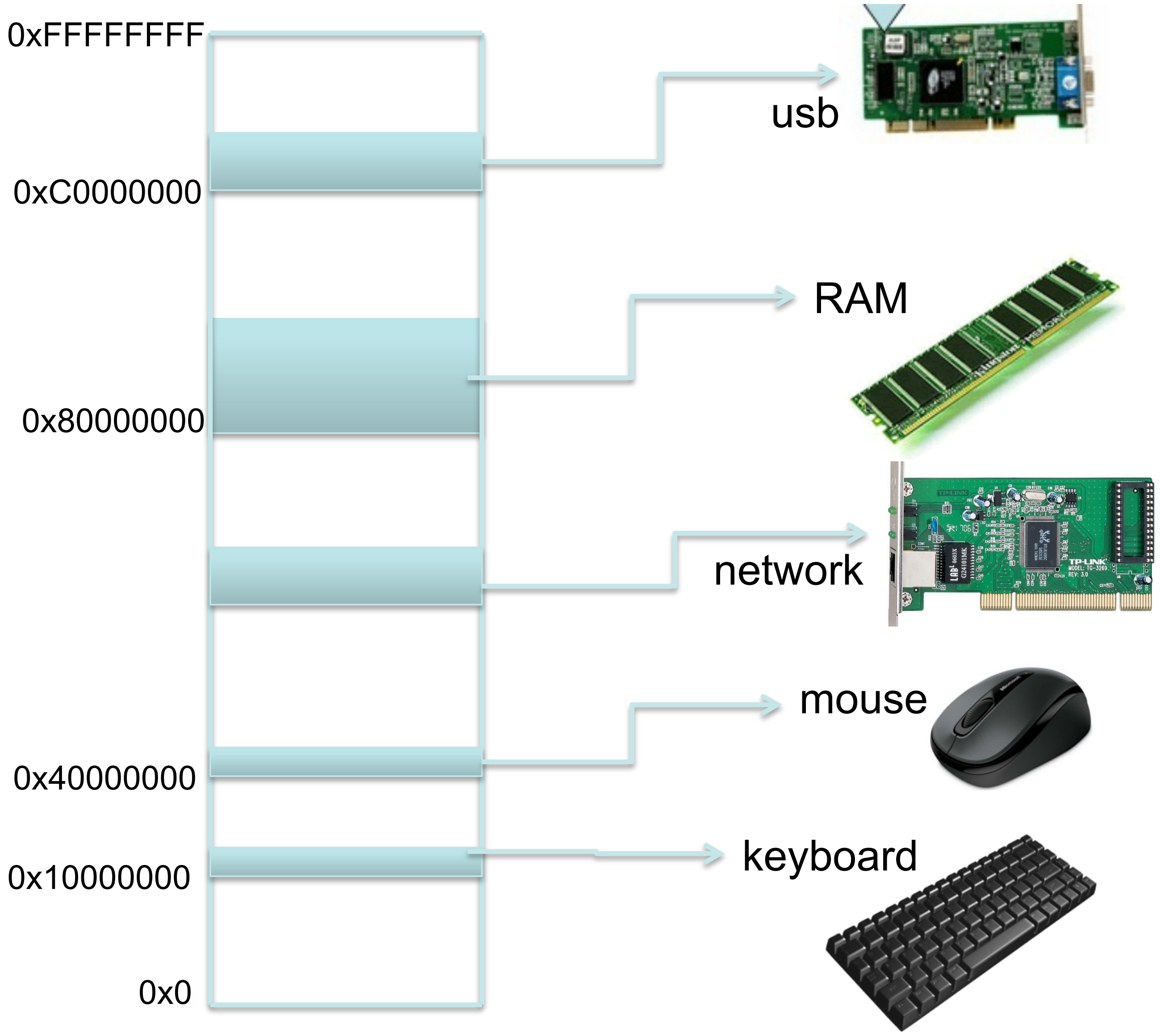
System Organization



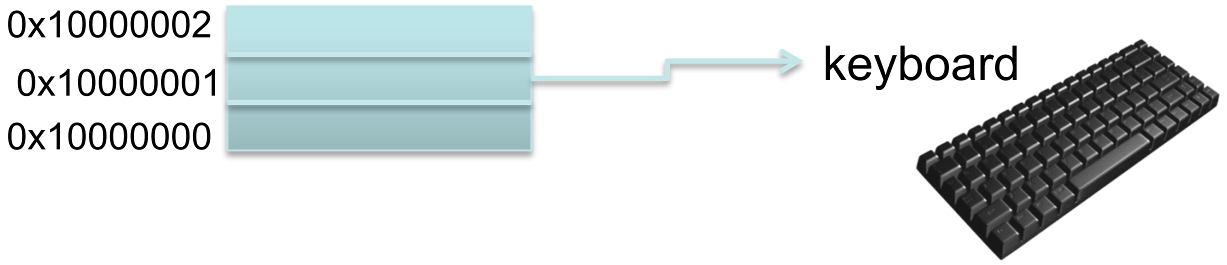
Address Types

- Memory Addresses
- Memory Mapped IO Addresses

Memory Maps


0xFFFFFFFF
0xC0000000
0x80000000
0x40000000
0x10000000
0x0
usb
RAM
network
mouse
keyboard

Accessing keyboards



2 input ports and 1 output port

Pointer to the keyboard:

```
char *keyboard_ptr = (char *) 0x10000000;
```

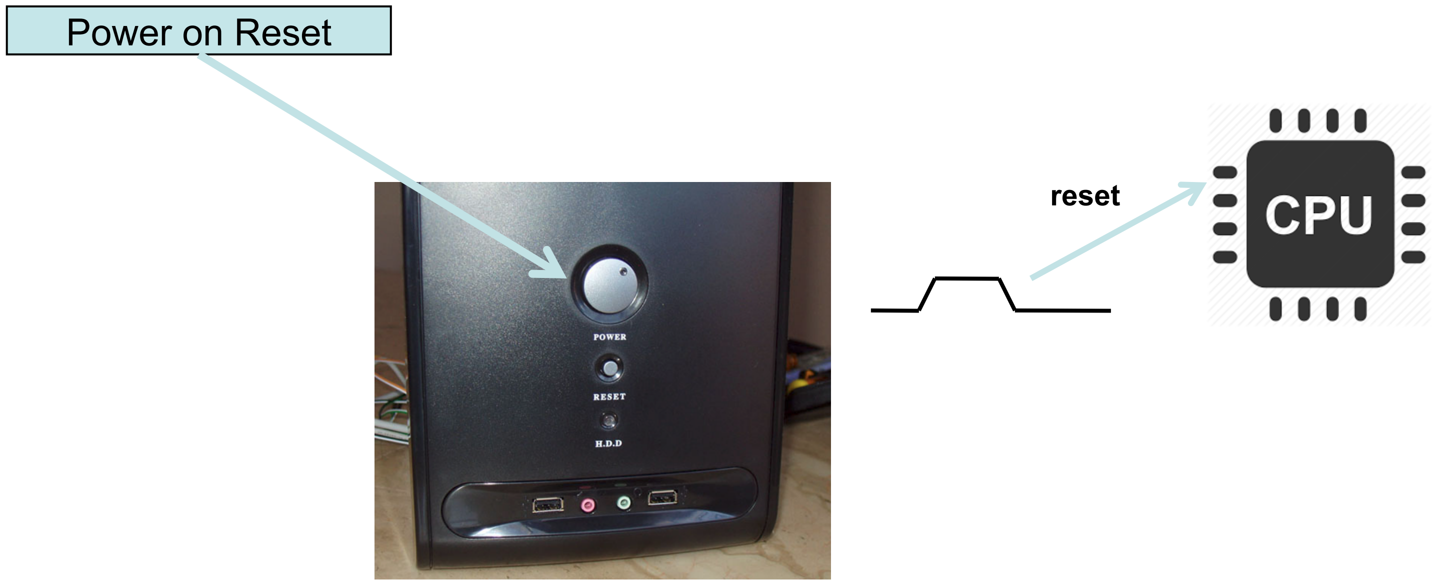
Read from keyboard

```
char x = *(keyboard_ptr + 1);
```

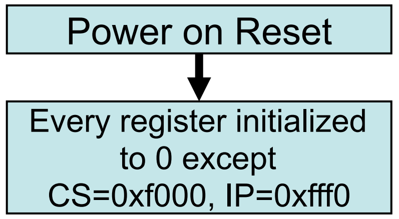
Write to keyboard

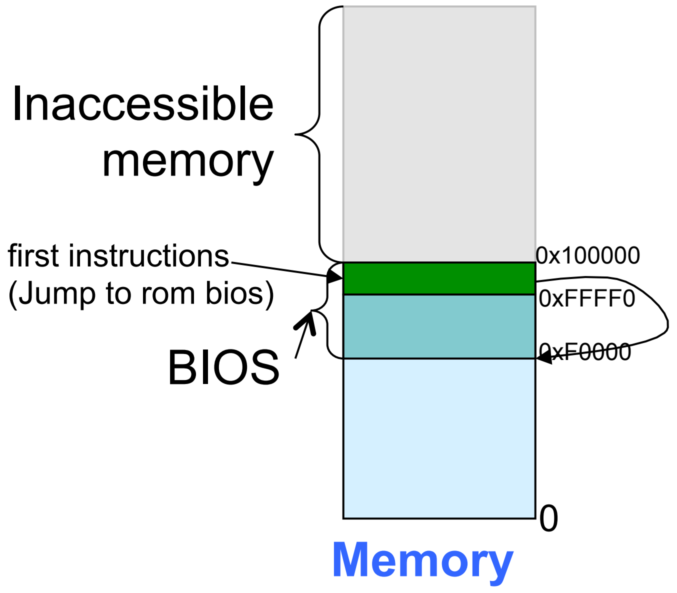
```
*(keyboard) = y;
```

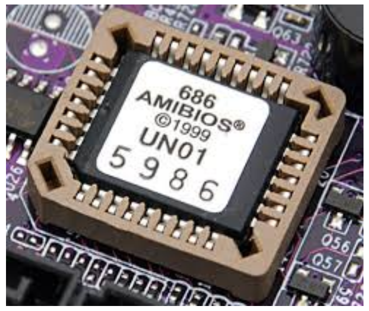
Powering Up



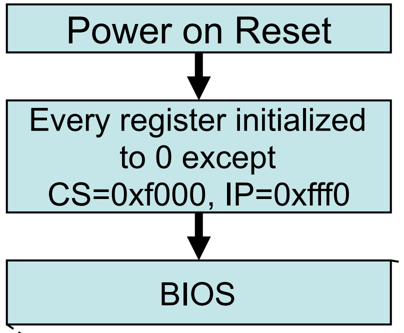
Powering up : Reset



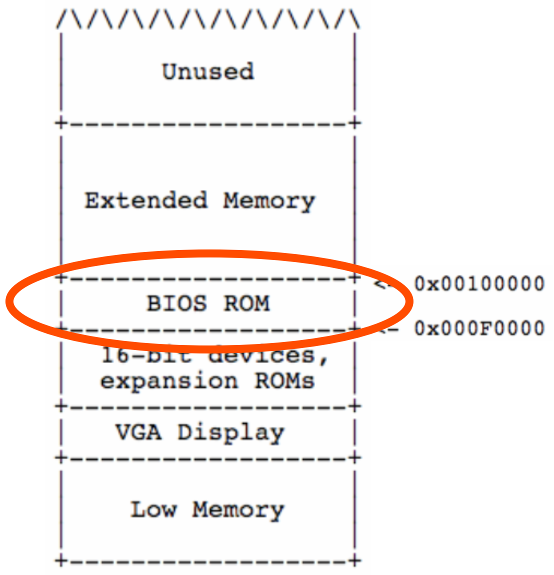


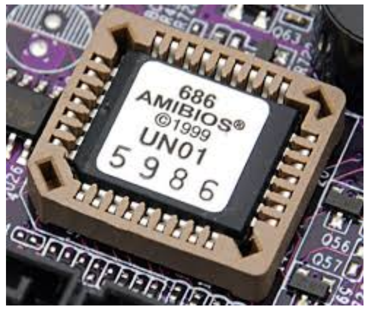


Powering up : BIOS

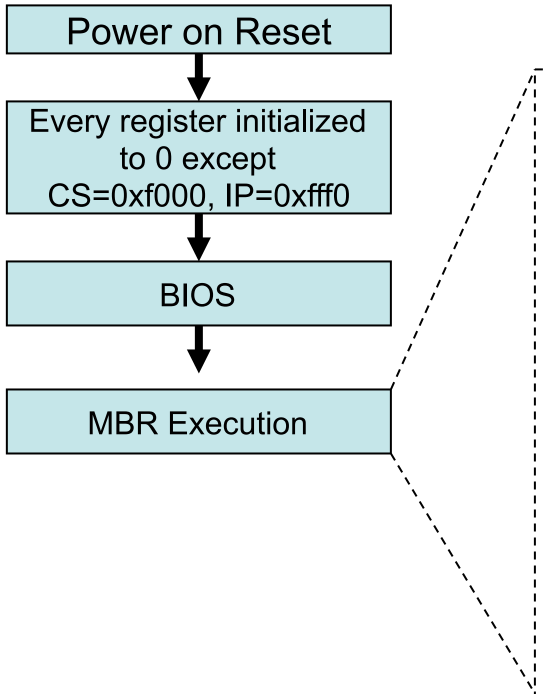


- Present in a small chip connected to the processor
  - Flash/EPROM/E^2PROM
- Does the following
  - Power on self test
  - Initialize video card and other devices
  - Display BIOS screen
  - Perform brief memory test
  - Set DRAM memory parameters
  - Configure Plug & Play devices
  - Assign resources (DMA channels & IRQs)
  - Identify the boot device
    - Read sector 0 from boot device into memory location **0x7c00**
    - Jumps to 0x7c00



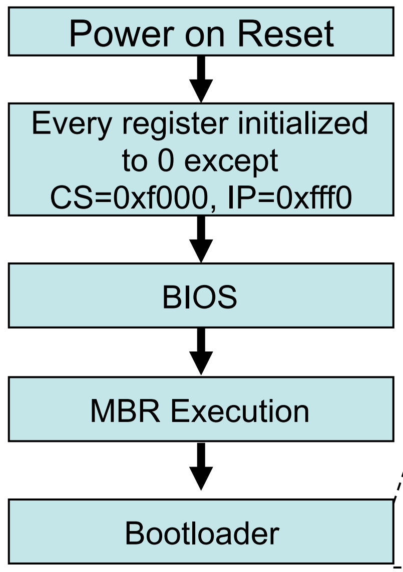


Powering up : MBR



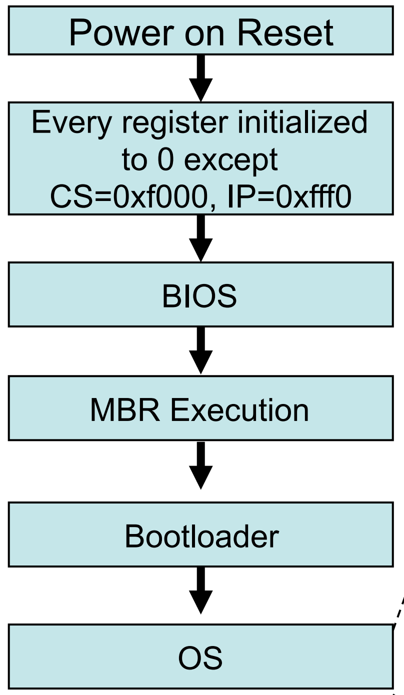
- Sector 0 in the disk called Master Boot Record (MBR)
- Contains code that boots the OS or another boot loader
- Copied from disk to RAM by BIOS and then begins to execute
- Size 512 bytes
  - 446 bytes bootable code
  - 64 bytes disk partition information (16 bytes per partition)
  - 2 bytes signature
- Typically, MBR code looks through partition table and loads the bootloader (such as Linux or Windows)
- or, it may directly load the OS

Powering Up : bootloader



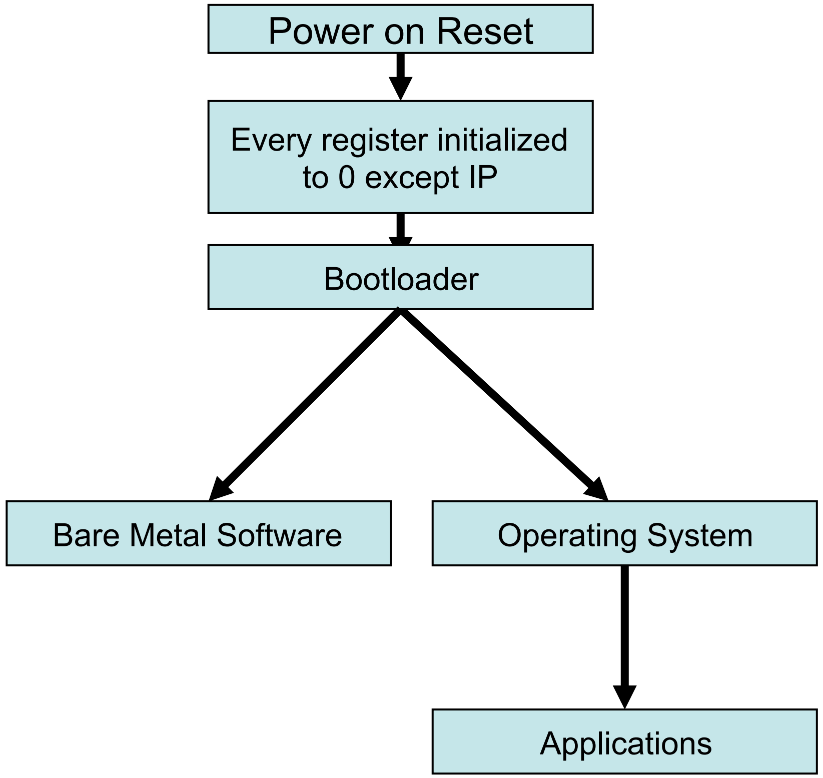
- Loads the operating system
  - May also allow the user to select which OS to load (eg. Windows or Linux)
- Other jobs done
  - Disable interrupts :
    - Don't want to bother with interrupts at this stage
    - Interrupts re-enabled by xv6 when ready
  - Setup GDT
  - Switch modes (eg. Machine mode to Supervisor mode)

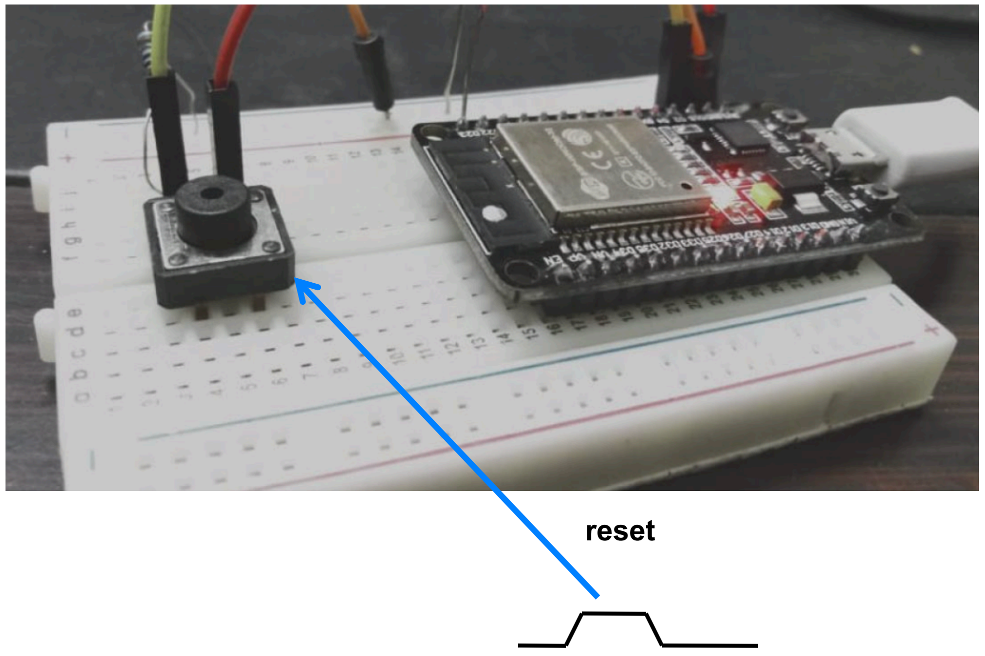
Powering Up : OS



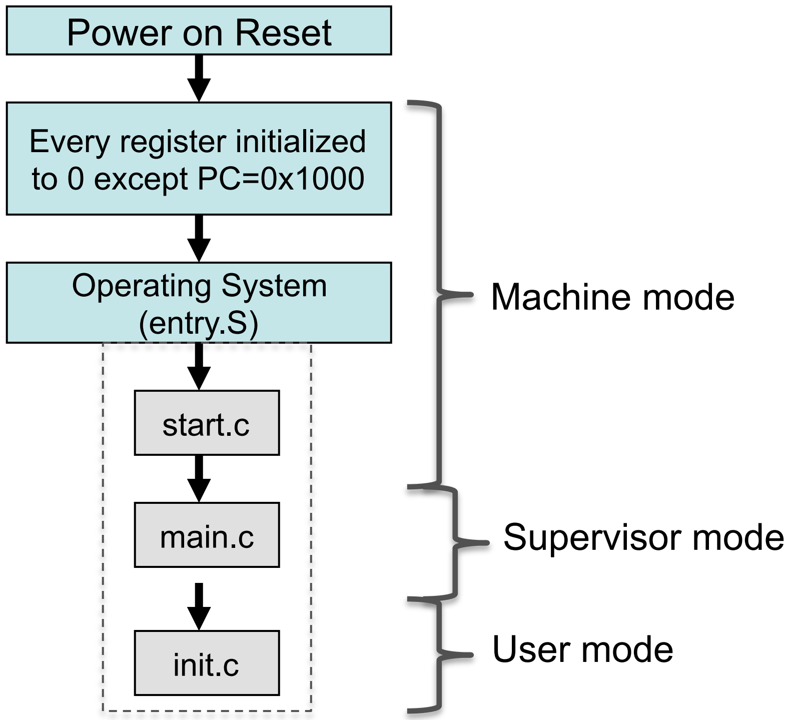
- Set up virtual memory
- Initialize interrupt vectors
- Initilize
  - timers,
  - monitors,
  - hard disks,
  - consoles,
  - filesystems,
- Initialized other processors (if any)
- Startup user process

Powering up an Embedded Device

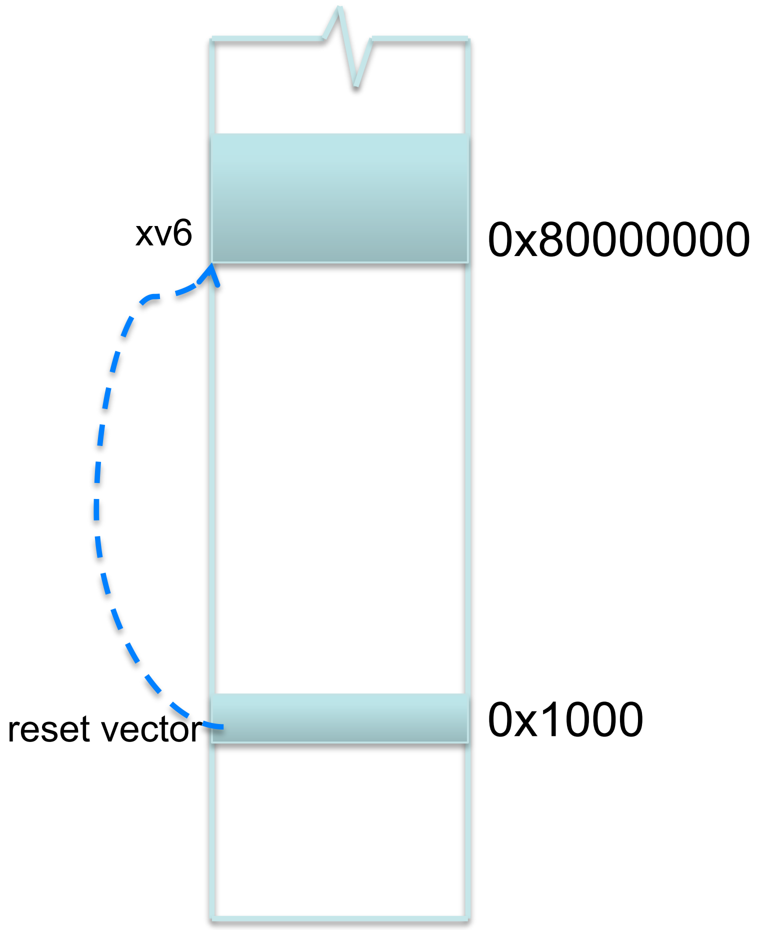




Powering up xv6 on qemu



Power on Reset
Every register initialized to 0 except PC=0x1000
Operating System (entry.S)
start.c
main.c
init.c
Machine mode
Supervisor mode
User mode



Memory map

Linker Descriptor

kernel.ld

```
OUTPUT_ARCH( "riscv" )
ENTRY( _entry )

SECTIONS
{
  /*
   * ensure that entry.S / _entry is at 0x80000000,
   * where qemu's -kernel jumps.
   */
  . = 0x80000000;
  .text :
  {
    *(.text)
    . = ALIGN(0x1000);
    *(trampsec)
  }

  . = ALIGN(0x1000);
  PROVIDE(etext = .);

  /*
   * make sure end is after data and bss.
   */
  .data : {
    *(.data)
  }
  .bss : {
    *(.bss)
    *(.sbss*)
     PROVIDE(end = .);
  }
}
```

First function to be executed (before main)

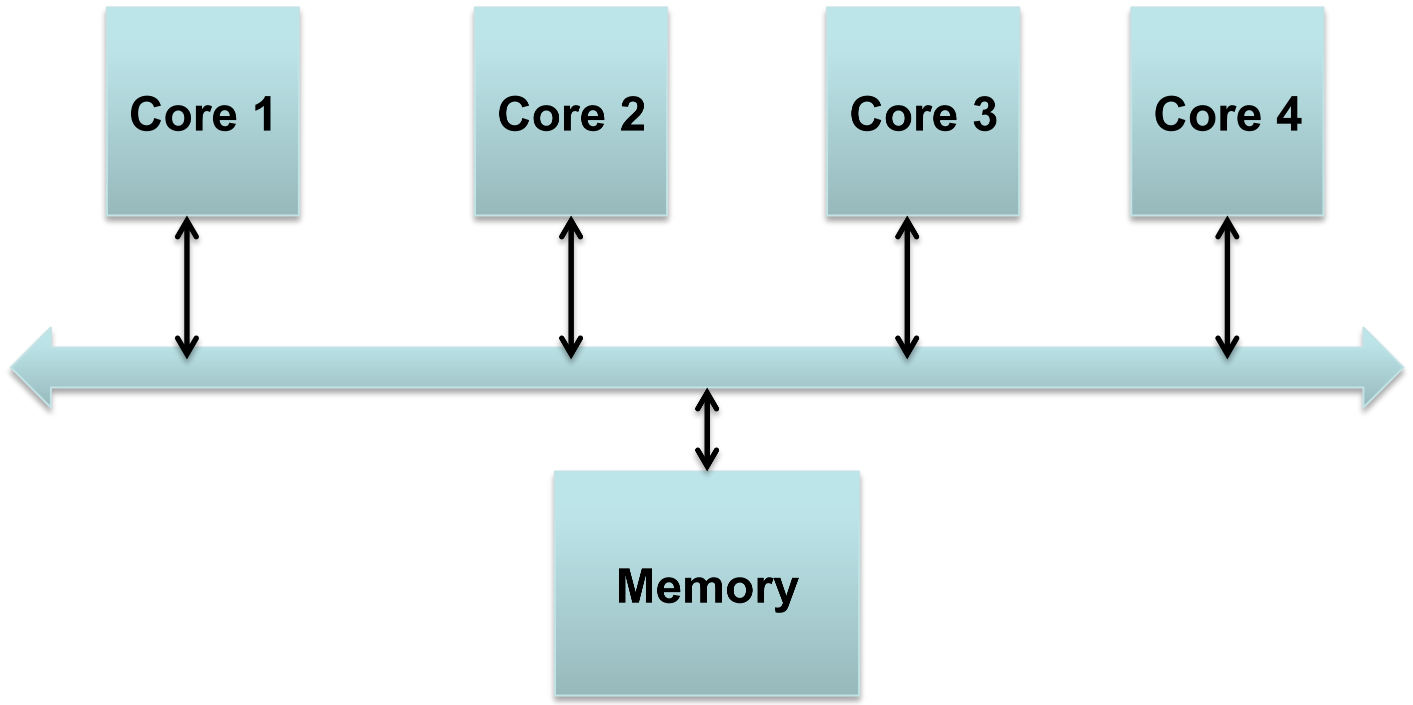
Kernel code to be placed in 0x80000000

An indicator of the end of kernel code

After the kernel code, place data and then bss

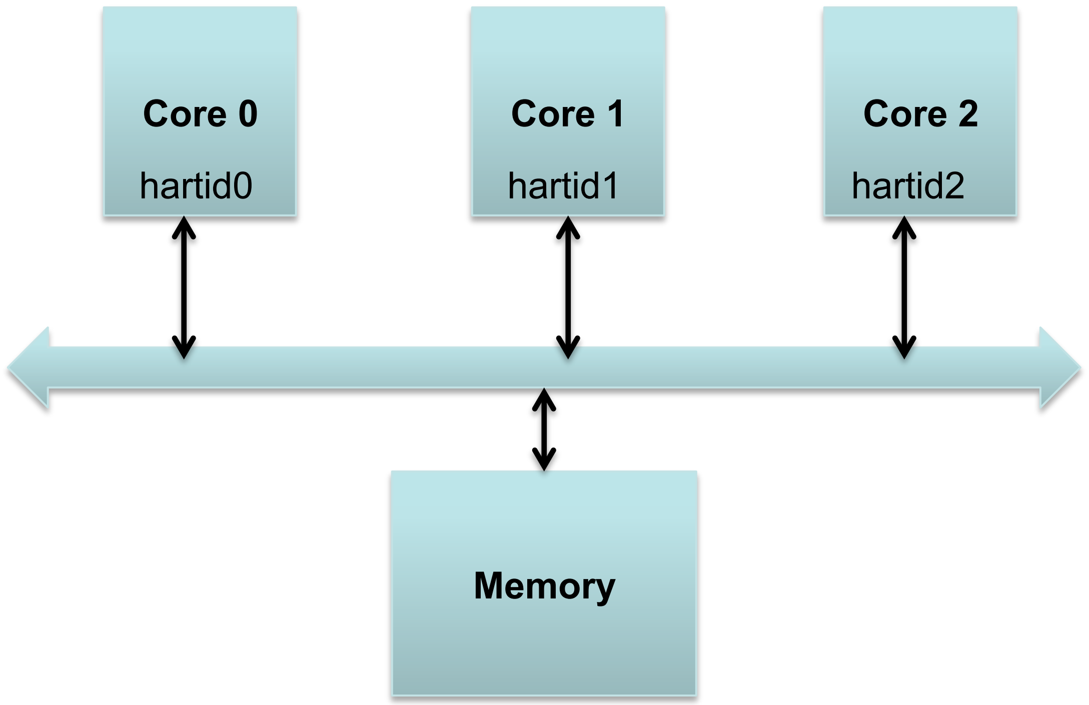
An indicator of the end of kernel

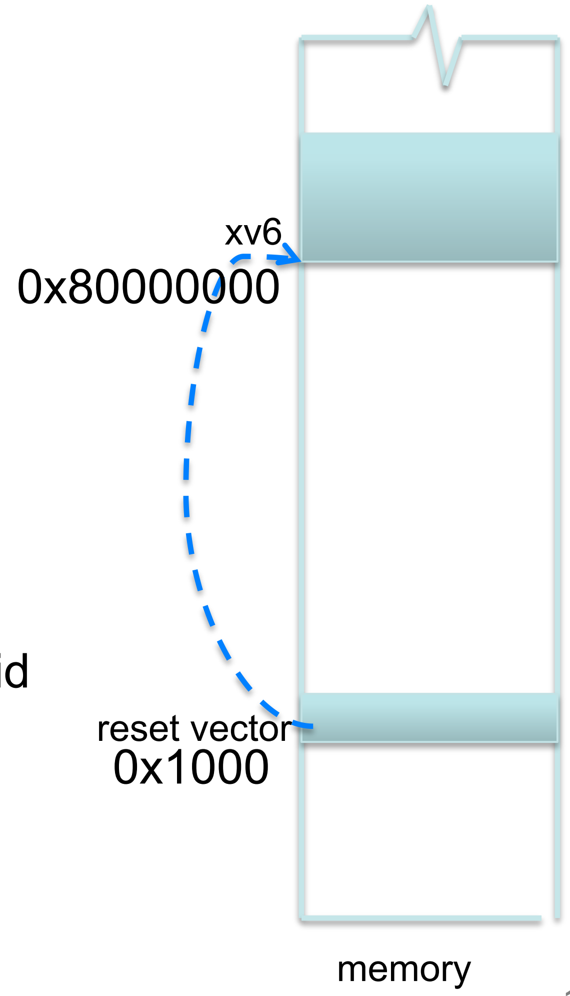
Powering Up : xv6 on qemu



- Memory Symmetry
  - All processors in the system share the same memory space
  - Advantage : Common operating system code
- I/O Symmetry
  - All processors share the same I/O subsystem
  - Every processor can receive interrupt from any I/O device

Powering Up : xv6 on qemu





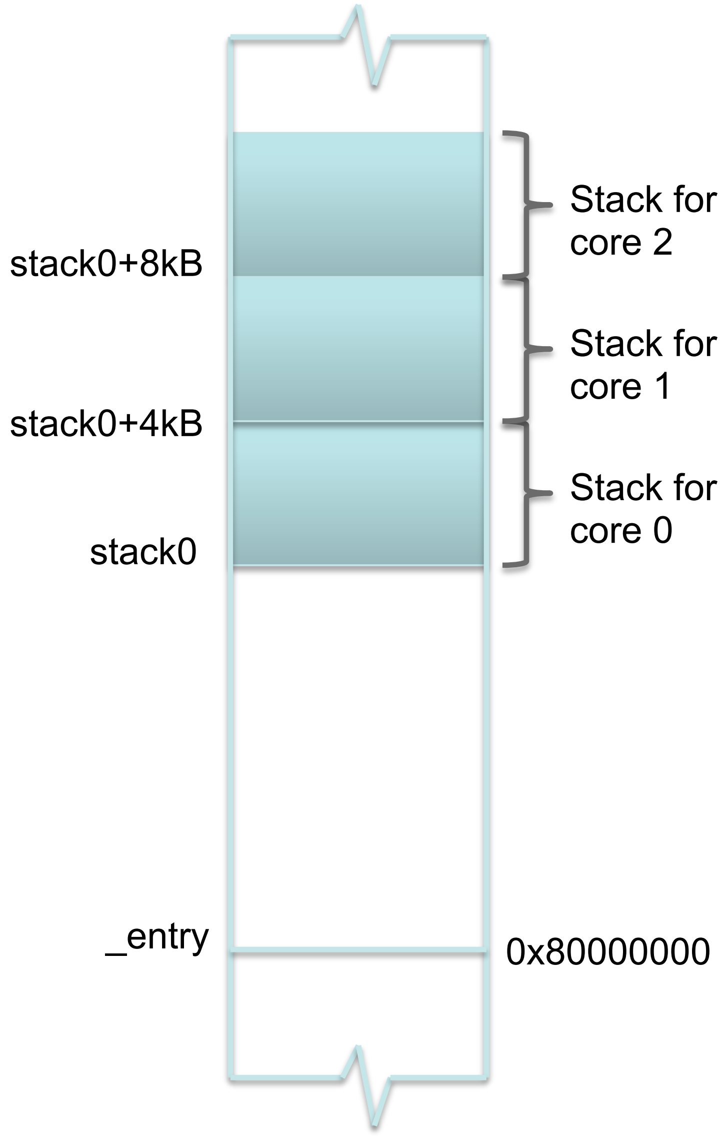
`csrr a1, mhartid` ; instruction that reads the hartid

All cores start the same way with IP=0x1000, and then jumping to 0x80000000

xv6-boot

entry.S

```
.section .data
.globl stack0
.section .text
.globl start
.section .text
.globl _entry
_entry:
        # set up a stack for C.
        # stack0 is declared in start.c,
        # with a 4096-byte stack per CPU.
        # sp = stack0 + (hartid * 4096)
        la sp, stack0
        li a0, 1024*4
        csrr a1, mhartid
        addi a1, a1, 1
        mul a0, a0, a1
        add sp, sp, a0
        # jump to start() in start.c
        call start
junk:
        j junk
```



xv6-boot

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        csrr a1, mhartid
        addi a1, a1, 1
        mul a0, a0, a1
        add sp, sp, a0
        # jump to start() in start.c
        call start
junk:
        j junk
```

define label for stack0 (something like extern)
actual stack0 defined in start.c

_entry → will reside at 0x80000000

set sp to stack0 and a0 to 4KB

read the hartid for the processor core using
the corresponding CSR

set sp appropriately for the core
why increment a1?

call the C code (present in start.c)

Unreachable code

start.c

xv6-boot

```
// entry.S jumps here in machine mode on stack0.
void
start()
{
  // set M Previous Privilege mode to Supervisor, for mret.
  unsigned long x = r_mstatus();
  x &= ~MSTATUS_MPP_MASK;
  x |= MSTATUS_MPP_S;
  w_mstatus(x);

  // set M Exception Program Counter to main, for mret.
  // requires gcc -mcmodel=medany
  w_mepc((uint64)main);

  // disable paging for now.
  w_satp(0);

  // delegate all interrupts and exceptions to supervisor mode.
  w_medeleg(0xffff);
  w_mideleg(0xffff);

  // ask for clock interrupts.
  timerinit();

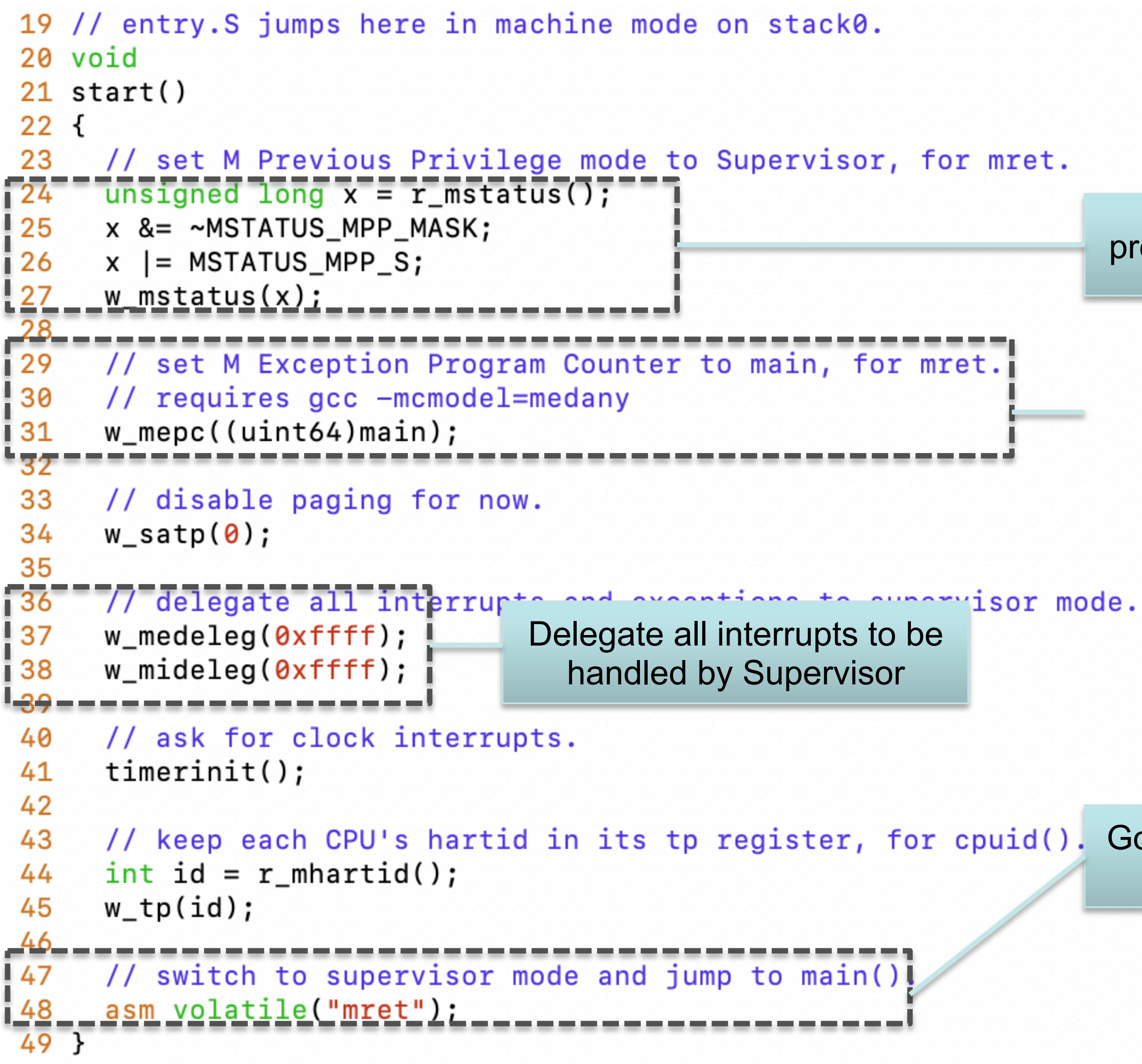
  // keep each CPU's hartid in its tp register, for cpuid().
  int id = r_mhartid();
  w_tp(id);

  // switch to supervisor mode and jump to main().
  asm volatile("mret");
}
```

Moves from machine mode to supervisor mode.

start.c

xv6-boot



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  int id = r_mhartid();
  w_tp(id);

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  asm volatile("mret");
}
```
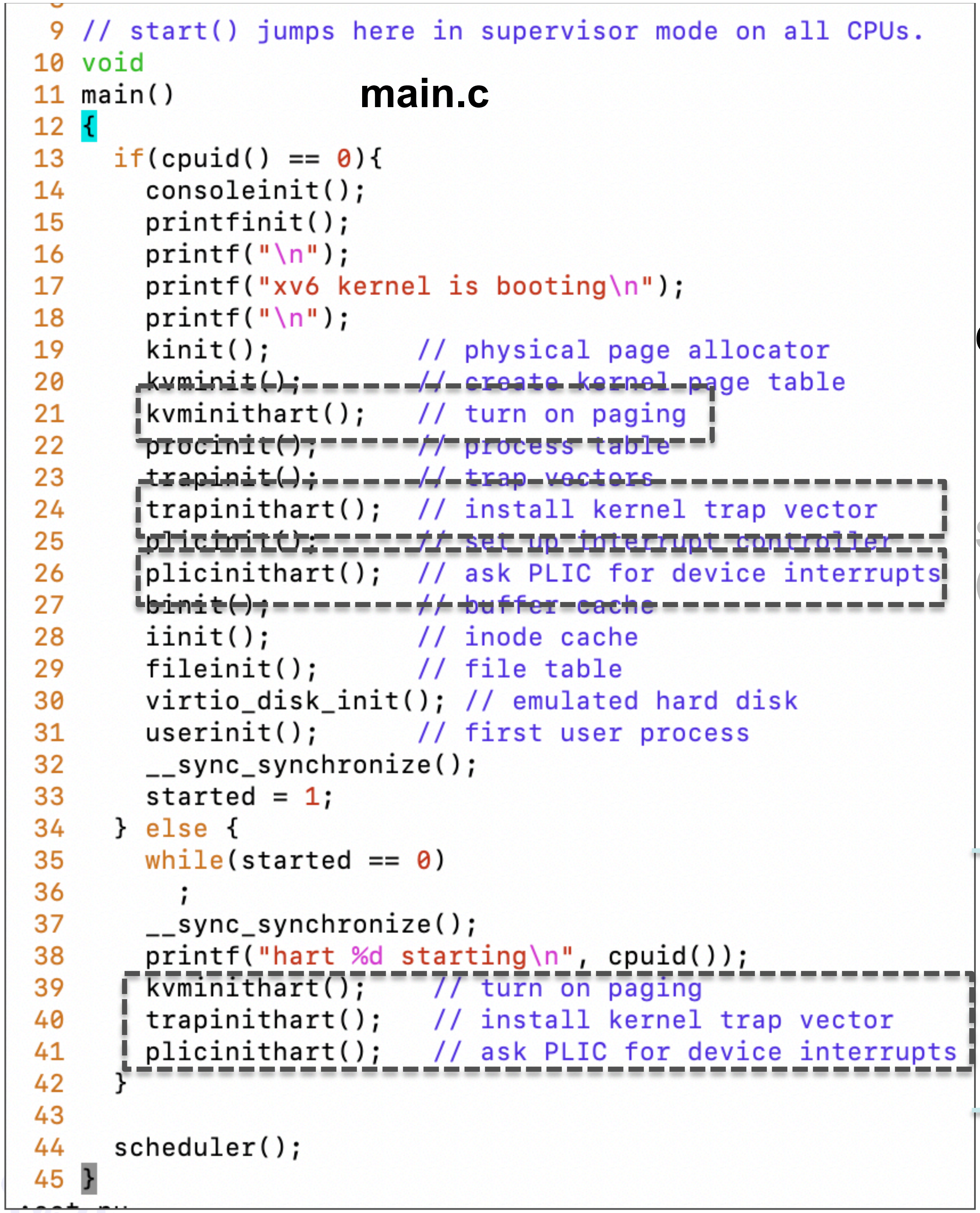

previous mode = supervisor

Delegate all interrupts to be handled by Supervisor

Goto “previous mode” at the address “previous PC”

xv6-boot



```c
// start() jumps here in supervisor mode on all CPUs.
void
main()
{
  if(cpuid() == 0){
    consoleinit();
    printfinit();
    printf("\n");
    printf("xv6 kernel is booting\n");
    printf("\n");
    kinit();         // physical page allocator
    kvminit();       // create kernel page table
    kvminithart();   // turn on paging
    procinit();      // process table
    trapinit();      // trap vectors
    trapinithart();  // install kernel trap vector
    plicinit();      // set up interrupt controller
    plicinithart();  // ask PLIC for device interrupts
    binit();         // buffer cache
    iinit();         // inode cache
    fileinit();      // file table
    virtio_disk_init(); // emulated hard disk
    userinit();      // first user process
    __sync_synchronize();
    started = 1;
  } else {
    while(started == 0)
      ;
    __sync_synchronize();
    printf("hart %d starting\n", cpuid());
    kvminithart();    // turn on paging
    trapinithart();   // install kernel trap vector
    plicinithart();   // ask PLIC for device interrupts
  }

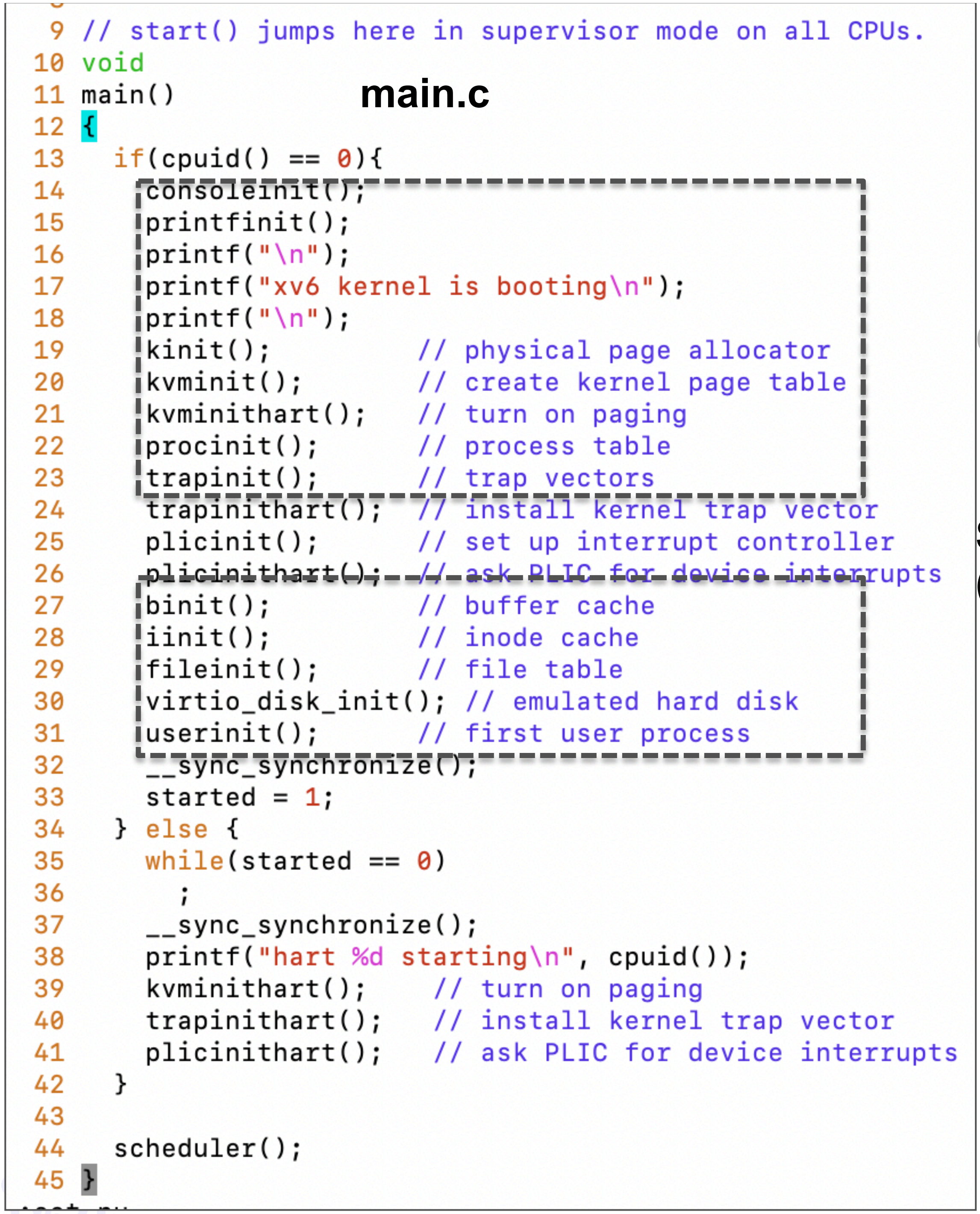
  scheduler();
}
```

Core specific initialization (done by all cores)

System specific initialization (done only by core 0)

Executed by all cores except core0 after started=1

xv6-boot


main.c

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    started = 1;
  } else {
    while(started == 0)
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    __sync_synchronize();
    printf("hart %d starting\n", cpuid());
    kvminithart();    // turn on paging
    trapinithart();   // install kernel trap vector
    plicinithart();   // ask PLIC for device interrupts
  }

  scheduler();
}
```

Core specific initialization
(done by all cores)

System specific initialization
(done only by core 0)