Project 1: Bootloader

COS 318

Fall 2014

Project 1 Schedule

- Design Review
  - Tuesday, Sep 23
  - 10-min time slots from 9:30am-2:20pm
- Due date: Sunday, 9/28, 11:59pm

General Suggestions

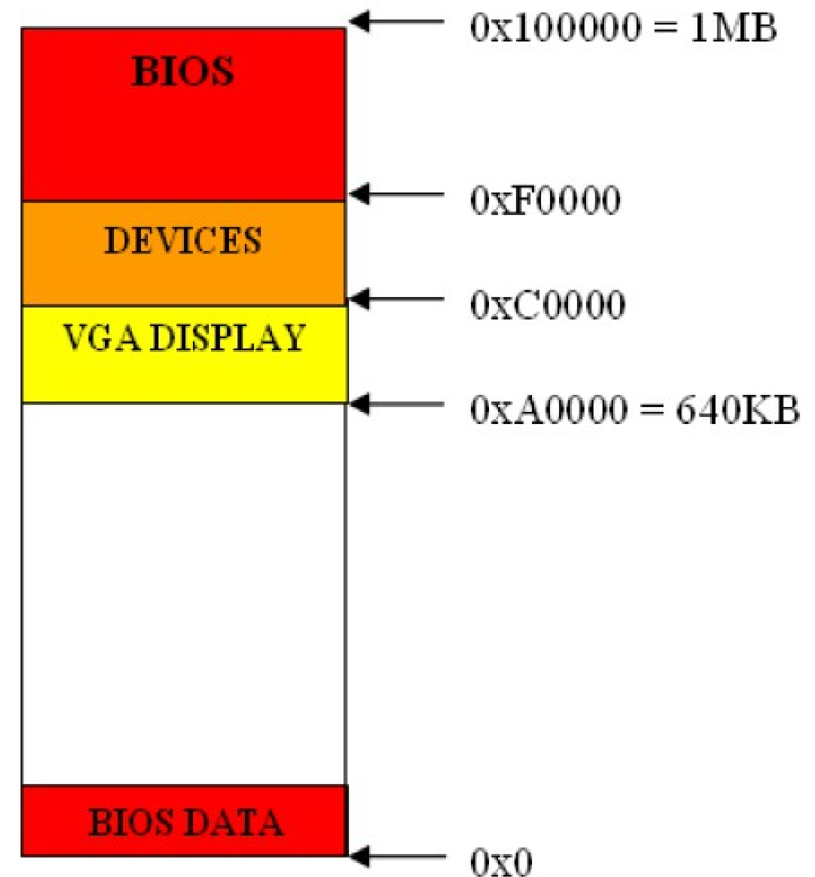
- Read ***assembly_example.s*** in start code pkg
- Get *bootblock.s* working <u>before</u> starting on *createimage.c*
- Read documentation on AT&T syntax x86 Assembly language
- Read provided documentation on ELF format
- Start as early as you can, and get as much done as possible by the design review

Project 1 Overview

- Write a bootloader: ***bootblock.s***
  - How to set up and start running the OS
  - Written in x86 Assembly language (AT&T syntax)
- Implement a tool to create a bootable OS image: ***createimage.c***
  - Bootable image contains bootloader and kernel
  - How are executable files structured?
  - Become familiar with ELF format

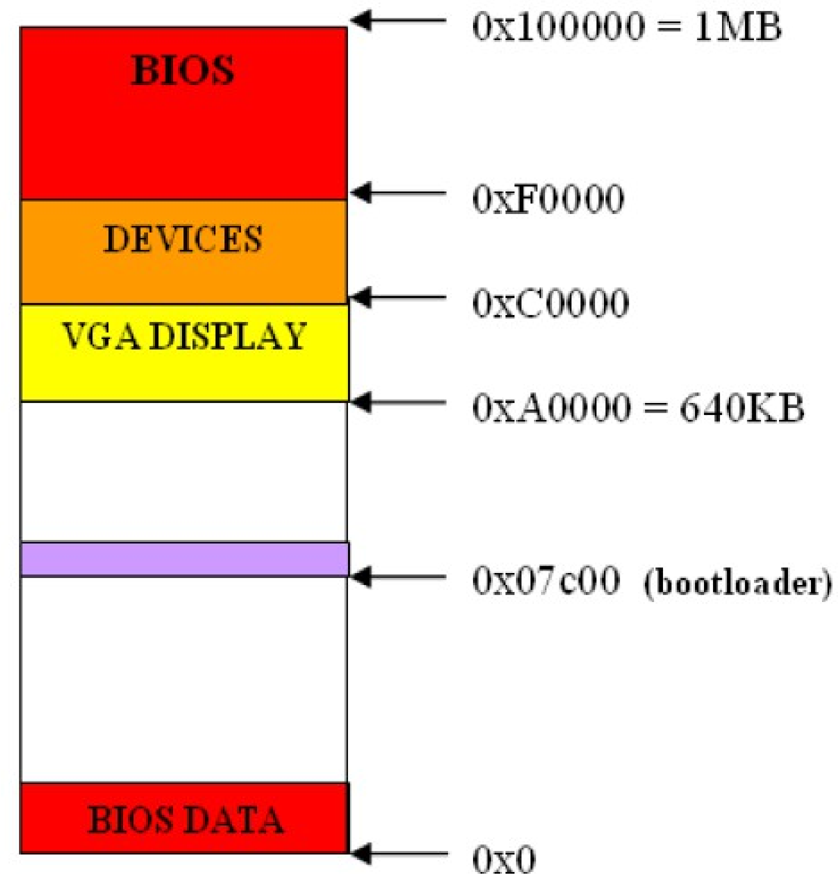
Boot Process

- When powered up, nothing in RAM, so how do we get started?
  - Resort to hardware
  - Load BIOS from ROM
- BIOS:
  - Minimal functionality
  - Initialization of I/O devices
  - Search for bootable devices



Loading the Bootloader

- Found bootable storage volume:
  - HDD, USB, Floppy
  - Load bootloader
- How is this done?
  - Load first sector (512 bytes)
  - Memory location: 0x7c00
  - Switch control to this location to launch the bootloader



The Bootloader

- 3 tasks:
  - Load the kernel into memory
  - Setup the kernel stack
  - Switch control to the kernel

Disk

Bootloader

Kernel

Memory

BIOS

DEVICES

VGA DISPLAY

Kernel STACK

KERNEL

BIOS DATA

0x100000 = 1MB

0xF0000

0xC0000

0xA0000 = 640KB

0x07c00 (bootloader)

0x1000

0x0

Let's Review Assembly

- About numbers, need good bookkeeping
- Move data, perform simple arithmetic
- Need a lot of steps to do useful things
- KEY:
  - Understand memory addresses
  - Know where things are in memory

Memory Addressing

- 1MB of memory
  - Valid address range: 0x00000 - 0xFFFFF
- Real mode segmented model:
  - See full 1MB with 20-bit addresses
  - 16-bit segments and 16-bit offsets
- Addressing format: segment:offset
  - Actual address = 16*segment + offset
  - How would you write the address for the bootloader?

Registers

- 5 types of CPU registers:
  - General purpose: ax, bx, cx, dx (can address high or low-order byte via ah/al etc.)
  - Segment: cs, ds, es, ss
  - Pointer: ip, bp, sp
  - Index: di, si
  - Flags: df, zf (only 9 bits used)
- 32-bit registers have e prefix: e.g. eax

AT&T Syntax

- Prefix register names with % (e.g. %ax)
- Instruction format: instr src, dest
  - e.g. movw %ax, %bx
- Prefix constants, immediate values with $
  - e.g. movw $0x01, %ax
- Suffix instructions with size of data
  - b for byte, w for word (16 bits), l for long (32 bits)
  - Keep the size of your registers in mind!

Important Instructions

- **mov x, y**: moves data into a register
  - e.g. movw %ax, %ds
- Jumps:
  - **jmp imm**: %ip ← imm
    - e.g. jmp $print_char
  - **ljmp imm1, imm2**: %cs ← imm1, %ip ← imm2
    - e.g. ljmp $0x7c0:0x00, $0x00

Important Instructions

- Stack ops:
  - **push x**: %sp--, Mem[%ss:%sp] ← x
  - **pop x**: x ← Mem[%ss:%sp], %sp++
- Function calls:
  - **call <label>**: push %ip, jmp <label>
  - **ret**: pop %ip
  - Be careful not to override register values!

Important Instructions

- Interrupts:
  - **int imm**: invoke a software interrupt
    - int 0x10 (console output)
    - int 0x13 (disk I/O)
    - int 0x16 (keyboard input)
  - Each interrupt offers several functions and parameters
    - Function indicated in %ah
    - Params in other regs

Read from Disk to Memory

- BIOS int 0x13, function 2:
  - Read disk sectors into memory
  - Parameters:
    - %ah = $0x02 (disk read function)
    - %al = # of sectors to read
    - %ch = cylinder number
    - %cl = sector number
    - %dh = head number
    - %dl = drive number (already set)
    - %es:%bx address into which we want to read the data
    - Finally call the interrupt: int $0x13
  - Refer to http://en.wikipedia.org/wiki/Cylinder-head-sector for more info

Assembly Program Structure

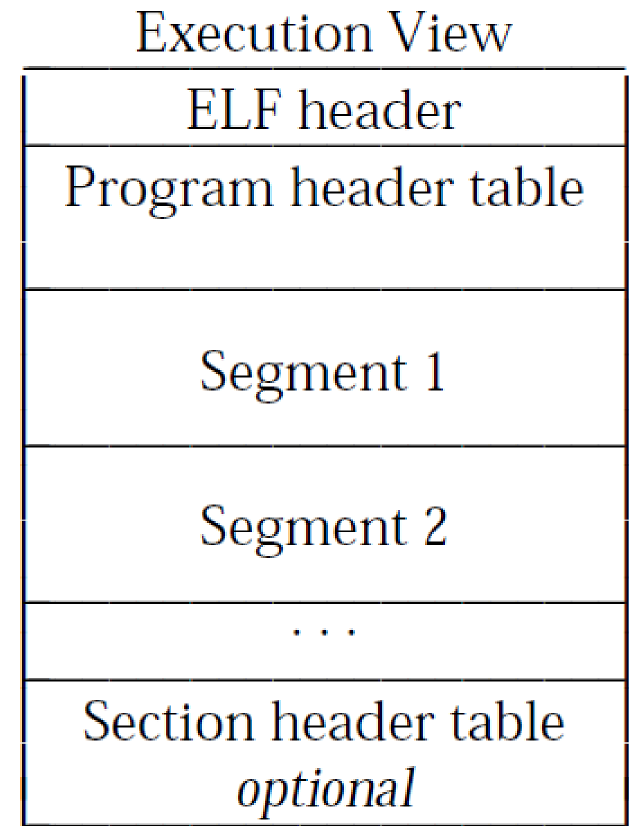
- Assembler directives:
  - Not instructions
  - Segment the program
- .text begins code segment
- .globl defines a list of symbols as global
- .data begins data segment
- .equ defines a constant (like #define)
  - e.g. .equ ZERO, $0x00
- .byte, .word, .asciz reserve space in memory

ELF Format

- Executable and linking format
- Created by assembler and link editor
- Object file: binary representation of programs intended to execute directly on a processor
- Support various processors/architectures:
  - Represent some control data in a machine-independent format

ELF Object File format

- Header (p. 9/10):
  - Beginning of file
  - Roadmap, file organization
- Program header table (p.33):
  - Array, each element describes a segment
  - Tells system how to create the process image
  - Files used to create an executable program must have a Phdr



p. 7 in ELF manual

Warm-up Exercise

- Executable and linking format
- Created by assembler and link editor
- Object file: binary representation of programs intended to execute directly on a processor
- Support various processors/architectures:
  - Represent some control data in a machine-independent format