

EEC420 - Operating Systems

This is an introductory course to operating systems (OS) - we use x86 systems as reference (ARM may be included in the future).

Practical Exercise

General Introduction

The core of an Operating System (OS) is the kernel.

OS Kernel

- system management software
 - provides hardware access to application software (user programs)
- four primary tasks:
 - process/thread management (multitasking)
 - memory management
 - disk management
 - peripheral management (I/O)

Bootstrap Process

Bootstrapping

- common issue for general purpose computers
 - software usually reside in secondary memory
 - how do we load software to primary memory?
- bootstrap process helps load an OS
 - usually in multiple stages
 - first stage as simple as possible
 - small footprint in system address space?
- processors on powerup (or reset)
 - have specific address to start execution
 - e.g. for IA32 0xFFFFF0 (32-bit address)
 - legacy from 8086 0xFFFF0 (20-bit address)
- non-volatile memory placed at that address
 - ROM → EEPROM → NVRAM
 - contains first stage bootstrap code
 - e.g. for IA32 we have BIOS

BIOS (x86) Bootstrap

- BIOS bootloader
 - for cold-boot, perform POST (power-on self-test)
 - iterate boot device list
 - attempt to load first sector (next stage bootstrap)
- load address is at 0x7C00
 - first sector (512 bytes) loaded here
 - must end with boot signature 0x55 0xAA (else HALT)
 - on hard-disks, usually have MBR
 - specifies partitions, so effective code size <512
 - loads first sector of boot partition
 - very limited, but can utilize BIOS functions
- Master Boot Record (MBR) - [📖 Read more @ wikipedia](#)
 - first sector of a partitioned storage
 - classic mbr:
 - 446 bytes executable code
 - 64 bytes partition entries (4 primary partitions)
 - 2 bytes boot signature (0x55 0xAA)
 - modern mbr
 - 218 bytes executable code
 - 2 bytes (always 0x00?)
 - 4 bytes disk timestamp
 - 216 bytes executable code
 - 4 bytes disk signature
 - 2 bytes (always 0x00?)
 - 64 bytes partition entries (4 primary partitions)
 - 2 bytes boot signature (0x55 0xAA)
 - superseded by GUID partition table (GPT) - [📖 Read more @ wikipedia](#)

BIOS (x86) Functions

- invoked using software interrupts
 - as interrupt service (handler) routine
- e.g. int 0x13 is for disk i/o routine
 - register ah used as function select
 - e.g. ah = 0x02 is to read sector from disk
 - register dl should have drive number
 - 0x80 is first hard disk
 - limitations: int 0x13 supports disk size <8GB
- extended bios provide more functions
 - extended disk access

BIOS (x86) Operating Modes

- IA32 processors support dual operating mode
 - Real mode & protected mode
- Real mode
 - legacy 16-bit operating environment from 8086
 - segmented 20-bit address space
 - maximum 1MB address

- an address is made up of *segment* and *offset*
 - *segment* - 16-bit segment selector (cs,ds,ss)
 - *offset* - 16-bit offset within a segment
 - $\text{address} = \text{segment} \ll 4 + \text{offset}$
- segments obviously overlaps by 64k - 16
 - multiple address can refer to same physical address
 - e.g. 0x0000:0x7c00 and 0x07c0:0x0000 refer to same location
- IA32 provides ways to switch operating mode
- Protected mode
 - 32-bit operating mode
 - segmented OR flat memory address
 - provides virtual memory (e.g. paging)

From BIOS to OS

- BIOS boots to real mode
 - newer ones switch to protected mode to get more features
 - subsequent bootstrap code should check or assume in real mode
 - usually loads bootloaders (e.g. LILO for Linux, NTLDR for Windows)
- BIOS functions no longer available in protected mode
 - only works in real mode
 - some OS temporarily drop to real mode to utilize BIOS functions!
 - so, OS in protected mode drives hardware directly (device drivers!)
 - Some OS (Windows) maintains backward compatibility
 - place WinAPI in place of legacy BIOS
 - older DOS programs can still invoke old interrupts services
 - OS (here, most of the time) means bootloaders
 - bootloaders can be part of an OS
 - bootloaders load actual OS kernel

BIOS to UEFI Transition

- BIOS is being replaced by UEFI
 - Unified Extensible Firmware Interface
- UEFI features
 - modular bootloading
 - boot off really large hard disks (>2TB)
 - hardware drivers in early boot
 - useful ones like graphics and networking
 - built-in shell (diagnostic/maintenance)
- utilize GPT instead of MBR?
- requires a special UEFI partition
 - can have multiple firmwares

Hardware (x86) for OS Kernel

- need to separate system (kernel) & application (user) software
- hardware-level privilege

IA32 Privilege Levels

- called protection rings (4)
 - represents privilege levels
 - rings 0 to 3 (0 - highest, 3 - lowest)
 - most only use 2 (0 - kernel, 3 - user)

IA32 Control Registers

- designated crX (e.g. cr0, cr2, cr3)
 - cr0 - enable/disable protected mode
 - cr3 - used for memory paging (virtualization)
 - cr2 - page fault address
- these should only be accessed in ring 0
 - at boot, x86 in real-mode (no privilege levels)
 - modify cr0 - switch to protected mode
 - first code in protected mode is in ring 0
 - setup virtual memory (paging)
 - setup self to run in ring 0, others in ring 3!

IA32 Protected Memory

- memory access in protected mode
 - can access >1MB, use paging
 - needs Global Descriptor Table (GDT)
 - setup memory size and location
 - also defines protection levels (ring)
 - can also setup local descriptor table
 - not used much?
- create 2 main memory segments
 - memory only for ring 0 - kernel space
 - memory allowed for ring 3 (all) - user space
 - each memory space has own code/data segment
 - stack segment defined separately (per process, not system?)

IA32 Task Management

- basic hardware level multitasking support
 - kernels may implement software-level
- defined by Task State Segment (TSS) data structure
 - also contains protection levels

From:

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Last update: **2026/02/08 03:46**

