

Operating Systems Design

2. Booting

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What runs first?

- Boot loader
 - A program that loads a bigger program (e.g., the OS)

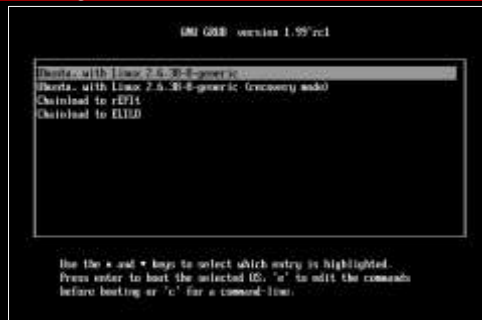
Booting



Load selector: Card, Tape, Drum

<http://www.computer-history.info/Page4.dir/pages/IBM.701.dir/images/IBM701.jpg>

Booting



Multi-stage boot loader (chain loading)

- **First stage boot loader**
 - Often primitive enough that an operator could enter the code via front panel switches ... or it could sit in the first block of a disk
- **Second stage loader**
 - More sophisticated and included error checking
- **Second stage loader may give the user a choice:**
 - Different operating systems
 - Boot a test program
 - Enable diagnostic modes (e.g., safe boot) in the OS

Transfer of control

- When the boot loader finishes loading the OS, it transfers control to it
- The OS will initialize itself and load device drivers as needed

Intel/AMD PC Startup

- CPU reset at startup
- Start execution at `0xffffffff0`
 - Jump instruction to BIOS code in non-volatile memory
 - Near the top of 32-bit addressable memory map
 - **Reset vector**: jump to firmware initialization code
 - Processor starts in Real Mode
 - 20-bit address space (top 12 address lines held high)
 - Direct access to I/O, interrupts, and memory

BIOS

- BIOS = Basic Input/Output System
- Found in Intel-based 16- and 32-bit PCs
- Code resident in ROM or non-volatile flash memory
- Background: CP/M (MS-DOS was almost a clone)
 - Console Command Processor (CCP)
 - Basic Disk Operating System (BDOS)
 - Basic Input/Output System (BIOS): *all the device interfaces*

PC Startup

- BIOS executes:
 - Power-on self-test (POST)
 - Detect video card's BIOS – execute video initialization
 - Detect other device BIOS – initialize
 - Display start-up screen
 - Brief memory test
 - Set memory, drive parameters
 - Configure Plug & Play devices: PCIe, USB, SATA, SPI
 - Assign resources (DMA channels & IRQs)
 - Identify boot device:
 - Load block 0 (Master Boot Record) to `0x7c00` and jump there

Booting Windows (XP/2003/2000/NT)

- The BIOS does *not* know file systems but can read disk blocks
- MBR = Master Boot Record = Block 0 of disk (512 bytes)
 - Small boot loader (chain loader, ≤ 440 bytes)
 - Disk signature (4 bytes)
 - Disk partition table (16 bytes per partition * 4)
- BIOS firmware loads and executes the contents of the MBR
- MBR code scans through partition table and loads the Volume Boot Record (VBR) for that partition
 - Identifies partition type & size
 - Contains Instruction Program Loader that executes startup code
 - IPL reads additional sectors to load NTLDR

Booting other systems on a PC

- Example: GRUB (Grand Unified Boot Loader)
- MBR contains GRUB Stage 1
 - Or another boot loader that may boot GRUB Stage 1 from the Volume Boot Record
- Stage 1 loads Stage 2
 - Present user with choice of operating systems to boot
 - Optionally specify boot parameters
 - Load selected kernel and run the kernel
 - For Windows (which is not Multiboot compliant),
 - Run MBR code or Windows boot menu
 - Multiboot specification:
 - Free Software Foundation spec on loading multiple kernels using a single boot loader

PCs and (U)EFI

- ~2005: Unified Extensible Firmware Interface (UEFI)
- Typically used for 32- and 64-bit architectures
 - Including Macs, which also have BIOS support for Windows
- Goal:
 - Create a successor to the BIOS
 - no restrictions on running in 16-bit 8086 mode with 20-bit addressing

UEFI Includes

- Preserved from BIOS:
 - Power management (Advanced Configuration & Power Interface, ACPI)
 - System management components from the BIOS
- Support for larger disks
 - BIOS only supported 4 partitions per disk, each up to 2.2 TB per partition
 - EFI supports max partition size of 9.4 ZB (9.4×10^{21} bytes)
- Pre-boot execution environment with direct access to all memory
- Device drivers, including the ability to interpret architecture-independent EFI Byte Code (EBC)
- Boot manager: lets you select and load an OS
 - No need for a dedicated boot loader
 - Stick your files in the EFI boot partition and EFI can load them
- Extensible: extensions can be loaded into non-volatile memory

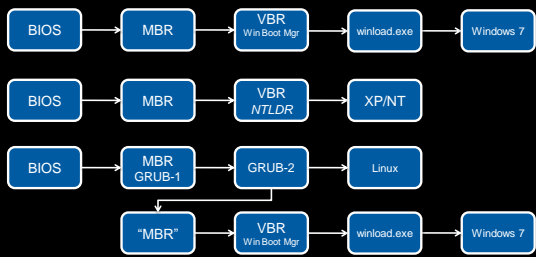
EFI Booting

- No need for MBR code (*ignore block 0*)
- Read GUID Partition Table (GPT)
 - Describes layout of the partition table on a disk (blocks 1-33)
- EFI understands the FAT file system
 - Apple's EFI knows HFS+ in addition
- Read programs stored as *files* in the EFI System Partition:
 - Windows 7, Vista, Windows 2008 (64-bit Microsoft systems):
 - Windows Boot Manager (BOOTMGR) is in the EFI partition
 - NT (IA-64): IA64ldr
 - Linux: elilo.efi (ELILO = EFI Linux Boot Loader)
 - OS X: boot.efi

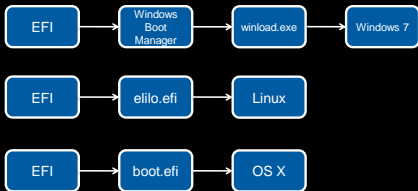
Non-Intel Systems

- Power on: execute boot ROM code (typically NOR Flash)
 - Often embedded in the CPU ASIC
- Boot ROM code detects boot media
 - Loads first stage boot loader (sometimes to internal RAM)
 - Initialize RAM
 - Execute boot loader
- Second stage boot loader loads kernel into RAM
 - For Linux, typically GRUB for larger systems
 - uBoot for embedded systems
 - Set up network support, memory protection, security options

Summary



Summary



The End