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Copy Protection Wars: Analyzing Retro and Modern Schemes

Nate Lawson
Cryptography Research, Inc.

Hackers & Threats II (1450)
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Which copy protection era are you?

Disk drive…?

2006 **1996** **1986**

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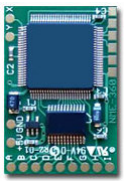
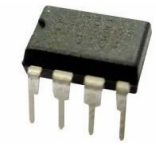
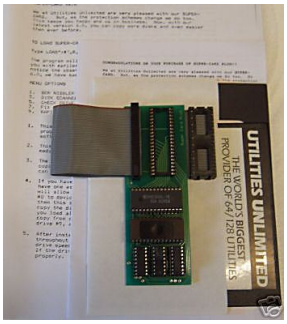
Which copy protection era are you?

Modchip…?







2006
(Xbox360)

1996
(Sony PS1)

1986
(Commodore 1541 floppy)

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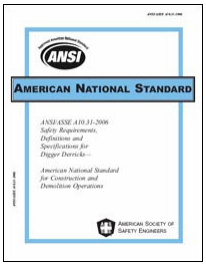
Which copy protection era are you?

ANSI…?



2006

1996

1986

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Which copy protection era are you?

Monitor…?

2006 **1996** **1986**

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Who am I?

- Co-designer of the Blu-ray disc content protection layer (Cryptography Research)
- Designer of ISS RealSecure network intrusion detection system
- FreeBSD committer since 2002
  - Author/maintainer of power management and ACPI kernel code, SCSI and USB
- Contributor to C64 Preservation Project
  - Software for imaging original floppies and replicating copy protection schemes bit-for-bit

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Why does the past matter?

- Approaches are still the same as for C64
  - Killer tracks = LaserLock CD/DVD protection
  - Track-to-track alignment = Xbox1/360 sector skew checks
  - Custom GCR encoding = ECC tricks, weak sectors
- Many modern hackers linked to C64 scene
  - commodore4eva: Xbox360 drive firmware hacks
  - Michael Steil: Xbox1 MIST PCI hack

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Legal support for retro-hacking

- Excluded from DMCA anti-circumvention clause
  - Library of Congress ruling (every 3 years)
- Copyright protection still applies so you must have original media
- Seek legal advice before circumventing any protection
  - I'm not your lawyer!

Exemptions:

2. Computer programs and video games distributed in formats that have become obsolete and that require the original media or hardware as a condition of access, when circumvention is accomplished for the purpose of preservation or archival reproduction of published digital works by a library or archive.

http://www.copyright.gov/1201/docs/2006_statement.html

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Definition: asymmetry

- Asymmetry
  - Property where forward operation is cheaper than reverse
  - Example:

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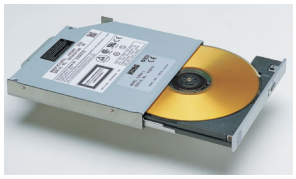
Definition: copy protection

- Copy protection
  - Leveraging asymmetry between production and playback environment to increase *cost* of copying
  - If cost of copying > profit of copying, vendor wins!
    - Note: almost no systems meet this criteria

vs.



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Definition: defender advantage

- Defender advantage
  - As first mover, defender sets the rules of the game
  - But defender must use advantage properly!

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Asymmetry used for copy protection

- Physical media
  - **Meta-data**: production equipment can create patterns on media user equipment cannot
  - **Cost**: pressing discs cheaper than burning recordable media
- Software
  - **Obscurity**: executing code easier than understanding it
  - **Self-checks**: creating integrity checks easier than finding them all
  - **Environment**: real hw/sw have behavior different from patched or emulated hw/sw
- Crypto
  - Encrypting data with a key easier than decrypting without it
    - Caveat: key is always somewhere in hw/sw attacker controls

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Time for a remedial history lesson…

C64 Protection Methods

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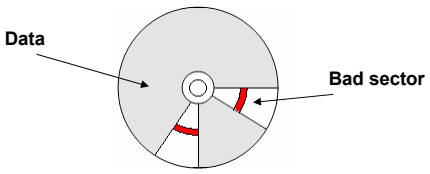
History: sector errors

- Checking sector errors (1983)
  - Asymmetry: firmware in drive cannot create sectors with errors
  - Protection: create bad sectors during mastering and check for them
  - Attack: create custom drive routine to detect and replicate error
- Modern use
  - Multi-session CD with TOC containing errors
  - Sony PS1/Suncomm/CactusShield/key2audio (“sharpie” hack)



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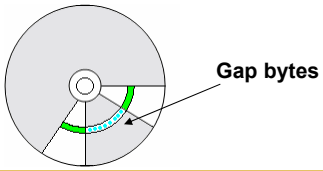
History: gap bytes

- Checking gap bytes (1985)
  - Asymmetry
    - Drive head requires time to switch from reading to writing
    - Drive finds where it is by reading header data
  - Protection: store pattern in gap between sectors and check for it
  - Attack: solder on more drive RAM or parallel cable so entire track can be written at once
- Modern use
  - Store key in sub-channel data that is used to decrypt exe (SafeDisc)



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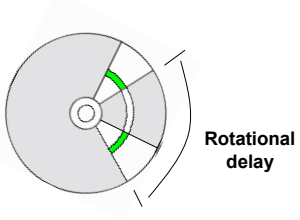
History: track alignment

- Track-to-track alignment (1986)
  - Asymmetry: “soft sector” locator method means overall physical layout unknown
  - Protection: seek from track to track and immediately check first data found
  - Attack
    - Write entire track at once (addl. RAM or parallel cable)
    - Custom drive routine to recreate alignment of original
- Modern use
  - CD Cops PC game protection
  - Xbox1/360 security sector alignment



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Who watches the watcher?

- If you were listening, you said…
  - "All the above schemes can be subverted if code not intact."
- Self-checks, obfuscation, crypto, environment checks…
  - Would be another whole talk
  - Asymmetries
    - Difficult for human to understand arbitrary code
    - Protection can occur anywhere within the code
    - Nearly all methods of observing/modifying code execution cause observable side effects
      - Profound impact on detecting modern virtualization techniques

And now the main event…

C64 vs. Xbox 360

C64 drive interface

- Serial I/O port provides command/response channel
- Parallel I/O port added to tap data directly

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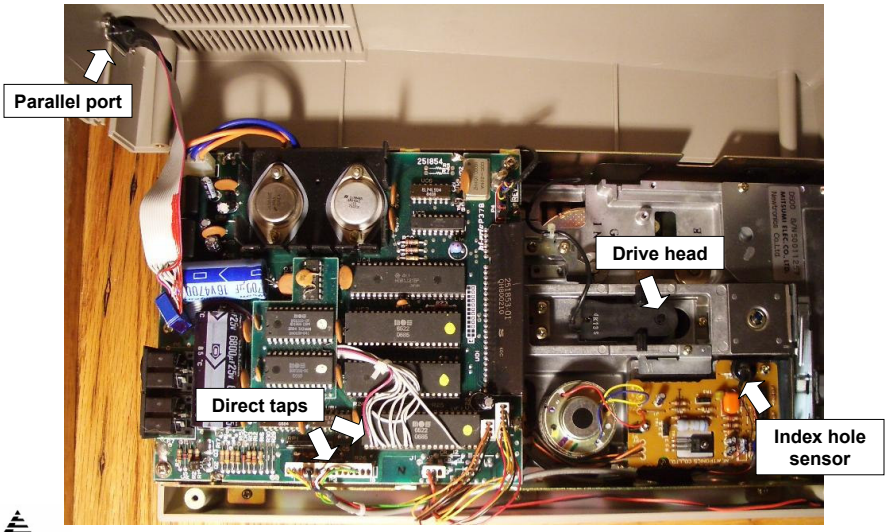
C64 drive interface



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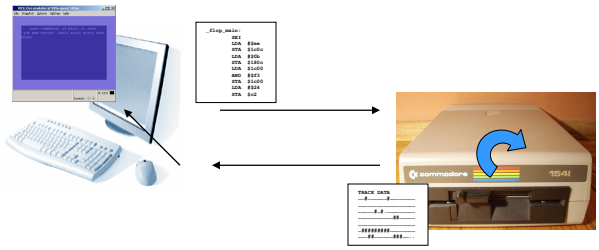
Demo: C64 disk imaging process

- PC writes to drive RAM directly via serial port
- Custom code reads raw track data
- PC scans raw bytes from parallel port
- PC loads disk image into emulator for analysis



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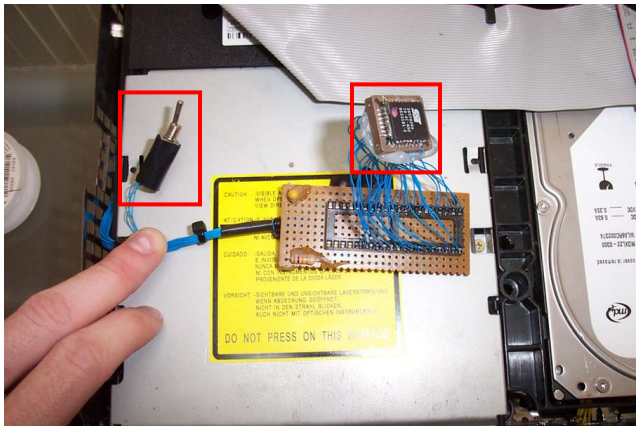
Xbox360 drive hardware hack

- Desolder flash chip and dump/replace using socket
- Disassemble firmware (MN103 microcontroller)



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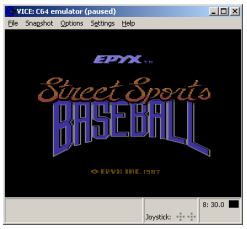
Demo: cracking C64 disk in emulator

- Disk image fails to boot in emulator
- Watch command channel in emulated drive
- Identify protection sequence in drive
  - Vorpal (Epyx): checks gap bytes
- Subvert protection check by patching drive RAM



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Xbox 360 drive software hack

- Unlocking drive (mode B)
  - Send a sequence of ATA commands
  - Ground pin on SATA connector while powering up
- Accessing firmware
  - Read/write a few bytes in drive RAM using cmd 0xE7
  - Upload and execute custom trampoline code
  - Read/write entire drive RAM using custom code

```
// Hitachi read memory command (Kevin East - 7thSon)
cgc.cmd[0] = 0xE7;
cgc.cmd[1] = 0x48;
cgc.cmd[2] = 0x49;
cgc.cmd[3] = 0x54;
cgc.cmd[4] = 0x01;
cgc.cmd[6] = (unsigned char)((addr & 0xFF000000) >> 24);
cgc.cmd[7] = (unsigned char)((addr & 0x00FF0000) >> 16);
cgc.cmd[8] = (unsigned char)((addr & 0x0000FF00) >> 8);
cgc.cmd[9] = (unsigned char)(addr & 0x000000FF);
```

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Xbox 360 Security Analysis

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Xbox 360 status

- Drive totally compromised
  - Fully custom firmware in use
  - Copies run from DVD-R media
- Host completely uncompromised
  - No Linux, user-created games, etc.
  - All crypto keys and kernel code still secret
- Current hacks good enough to support copied games
  - Attacker winning this battle
- Much still unknown about overall security
  - Advantage: defender, but how well will they use this?

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Challenge/response scheme

1. Drive reads security sector from lead-out
2. Drive sends encrypted data to host
3. Host decrypts table
4. Host chooses various challenges and sends to drive
   - Type 0: static value from DRT table
   - Type 1, 3: measurements of length of security sectors
   - Type 5, 7: skew between sector locations on disc
   - Type E0: account of all previous challenges seen
5. Drive calculates response and replies
6. Host checks if response matches value decrypted from table

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Challenge/response attack analysis

- Security sector stored in lead-out
  - Asymmetry: stock firmware won't read this data for the user
  - Attack: read drive memory after it reads lead-out
- C/R table is encrypted
  - Asymmetry: only Xbox has key to decrypt table
  - Attack: none yet, but table can be sent to host without decrypting
- Responses to challenges derived from physical media
  - Asymmetry: real media has strict physical layout, recorded won't
  - Attack: query drive from PC while real media in drive, replay values from patched firmware

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Repairing the hole

- Attackers only have a tenuous hold on drive and no host compromise
- Examining asymmetries gives new defenses
  - Asymmetry: real media analysis will be slightly different each time
    - Defense: check that responses vary appropriately between challenges of the same type
  - Asymmetry: patched firmware can't disable loader methods
    - Defense: use same debug commands to load disc-specific hashing code into drive, check for patched firmware
  - Asymmetry: response table must be somewhere on copied media
    - Defense: look for SS.bin file via host or code loading into drive

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Conclusion

- Asymmetry is a useful concept for analyzing schemes
  - Defender only has to increase cost of attack enough (effort/$) to force attackers to look elsewhere
  - Defender starts with inherent advantage but must use it properly
- A lot can be learned from the past
  - Attacks and defenses still same as 1986!
  - Retro-hacking is fun, cheap, and informative

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Contact Information

For more information, or to discuss how Cryptography Research can help with a security problem:

Nate Lawson
nate@cryptography.com
415.397.0123

www.cryptography.com

We're hiring!

If you are technically strong and want to work on challenging crypto and security problems, please send a resume!