Detecting Hardware Keyloggers

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Who?

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What?

- Hardware Keylogger
  - PS/2
  - USB

- Hardware Keyloggers are undetectable by Software

  „Visual inspection is the primary means of detecting hardware keyloggers, since there are no known methods of detecting them through software. “, en.wikipedia.org, 26.09.10

- Talk: Detection of Hardware Keyloggers with Software ;)

Why?

- Less research on this topic
  - Few information
  - No practical way to detect HKL
- Because HKL are a threat
  - 2005 (GB): Sumitomo Bank
    - Attackers tried to steal 423 million USD
    - Multiple HKL were installed
  - How about your company?
- Solution to identify HKL in large enterprises
  - Visual inspection is impractical
  - Only possible via software

Hardware Keylogger

- Hardware Keylogger
  - **USB**
  - **PS/2**
  - Keyboard Module
  - Mini- / PCI card

- Installed between PC and Keyboard
  - Records key strokes

- Captured data are retrieved
  - Software
  - Keyboard
    - Ghost typing
    - Flash drive
  - Wi-Fi-Access
    - Email
    - TCP connect
  - Bluetooth

Hardware Keylogger

- Features
  - Up to 2 GB flash memory
  - Encryption
  - Password protection
  - Timestamping
  - Time use charts
  - Search functions
  - Upgradeable firmware

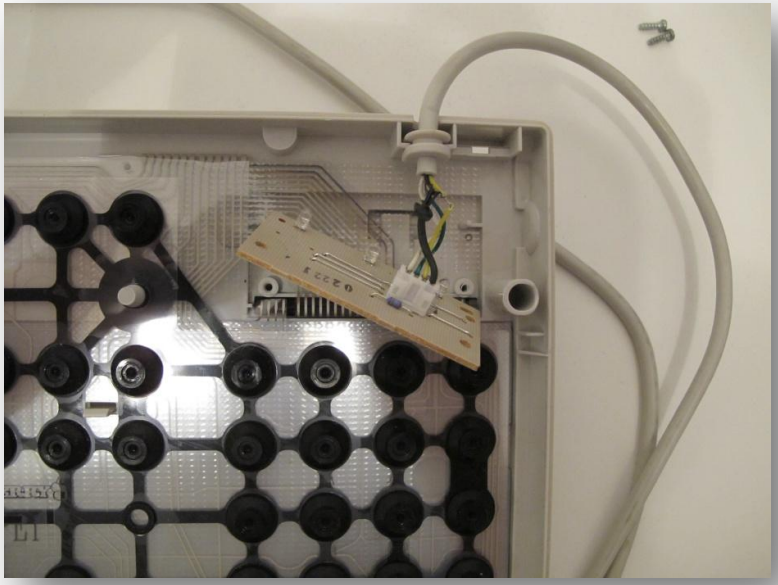
- Pricing
  - PS/2: 32.00 USD
  - USB: 58.00 USD

Hardware Keylogger – The companies

- Big ones
  - KeyDemon, KeeLog, … (PL)
  - KeyCarbon (US)
- Most companies rebrand KeyDemon
  - KeyCobra
  - KeyLlama (once own products)
  - …
- Also „famous“ (older products)
  - KEYKatcher (US)
  - KeyGhost (NZ)
  - KeyShark (DE)
- The others
  - WirelessKeylogger (UK)
  - Exotic Stuff (mostly CN)
  - Some Open Source Keylogger

PS/2 – How does it work

- Keyboard
  - Wire matrix
  - Microcontroller
  - Sends scancode (make/break)
- PC
  - Keyboard Controller (KBC)
    - 0x60: I/O-Buffer
    - 0x64: Status



PS/2 – How does it work

- Communication KBC <-> Keyboard
  - Obvious
    - Scancodes
  - Not that obvious ;)
    - Set LEDs
    - Choose scancode
    - Set repeate rate
    - Keyboard self-test / reset
    - Ping
    - …

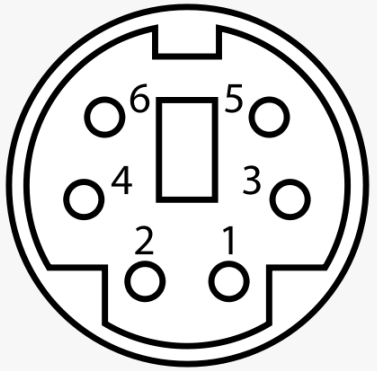
Example (Ping)

```
KBC sends "ping" (0xEE) via 0x60
KB sends "pong" (0xEE) to 0x60
```

PS/2 – How does it work

- PS/2 is a serial interface

- Communication
  - DATA
  - CLK
  - Bidirectional
  - Keyboard defines clock (30 – 50 ns)



1. DATA
2. -
3. GND
4. VCC
5. CLCK
6. -

- Data frames
  - KB (11 bit): startbit, D0-D7 [data], odd parity, stopbit
  - KBC (12 bit): startbit, D0-D7 [data], odd parity, stopbit, ACK (KB)

PS/2 – How does it work

- PS/2 is a serial interface

- Communication
  - DATA
  - CLK
  - Bidirectional
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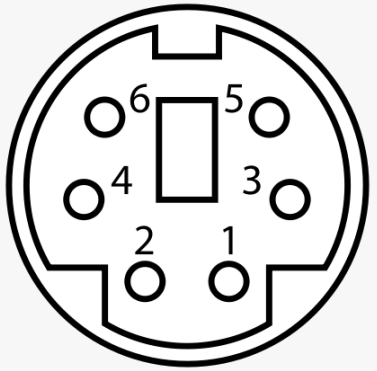

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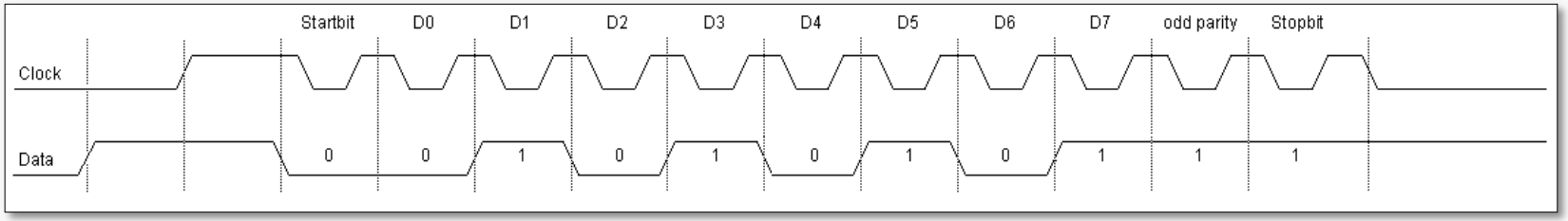


Detecting PS/2 Hardware Keylogger

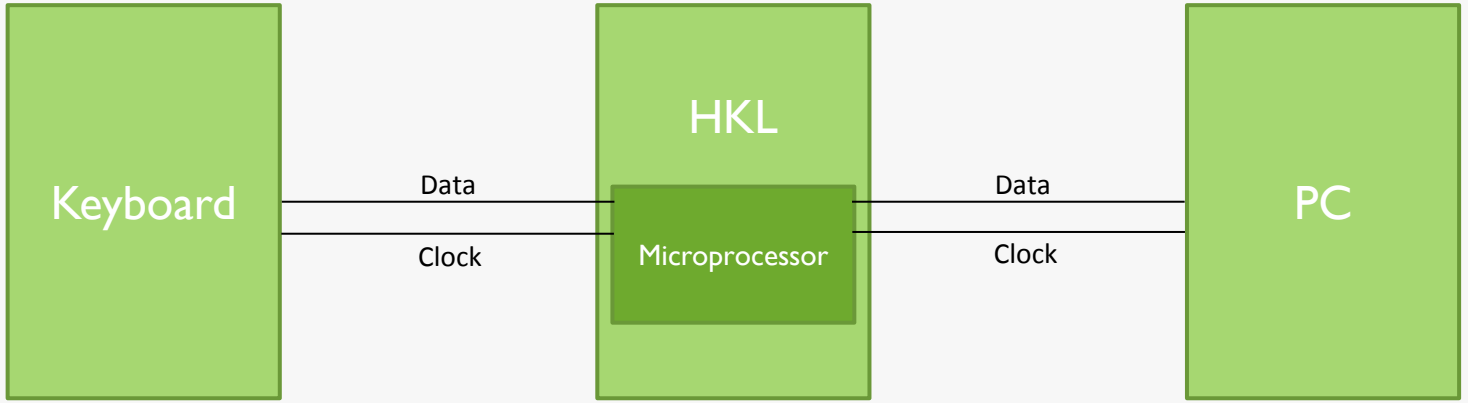
- Current measurement
  - Additional electronic components
  - = Additional power consumption ;)
    - KeyDemon = 65 mA
    - KeyKatcher = 54 mA
  - More current is drawn
  - Cannot be measured by software

Detecting PS/2 Hardware Keylogger

- Keylogger are password protected
  - Entered via Keyboard
  - Ghost typing
  - Shipped with default password
  - Password restore is complex
- Brute Force password
  - Via software
  - Check ghost typing

Detecting PS/2 Hardware Keylogger

- Problem
  - Tested HKL don‘t tap the data line
  - HKL are placed „inline“



  - HKL knows the data flow
  - KBC can‘t send fake keystrokes

Detecting PS/2 Hardware Keylogger

- However
  - Some KB commands (0x60) lead to fake key presses
  - Maybe keyboard response is interpreted…
- Brute Force password
  - Translation Table (KB command -> key press)
  - Brute Force attack via Software
- Practical?
  - Limited amount of chars (~10)
  - Not all passwords can be Brute Forced
  - Works for: KeyGhost, KEYKatcher (some)

Detecting PS/2 Hardware Keylogger

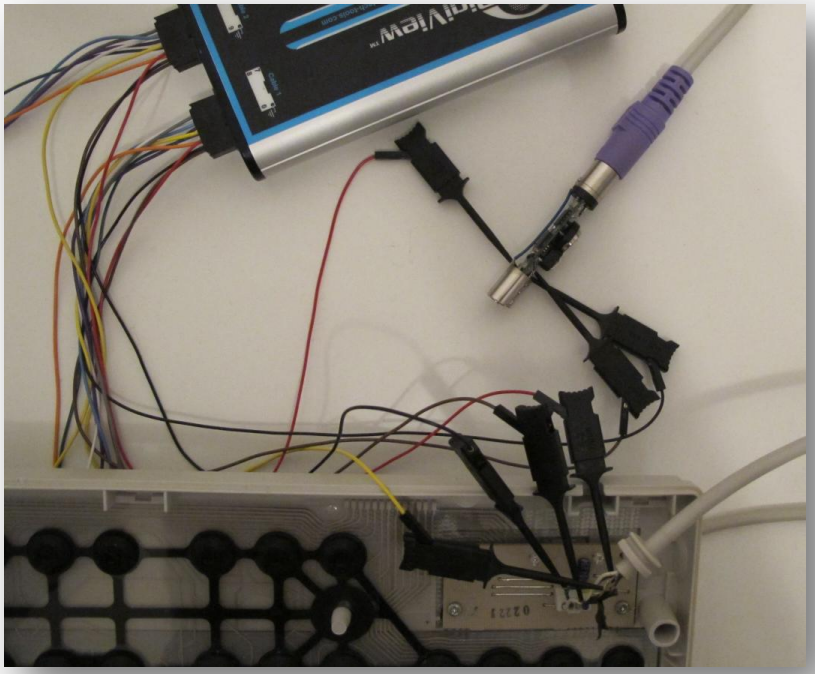
Demo

Detecting PS/2 Hardware Keylogger

- Changes on the line
  - HKL are placed „inline“
- HKL might change signals on the line
  - Different signals (data)
  - Own clock (30-50 ns)
  - Slight dislocation of data/clock signal
  - Maybe more… ;)

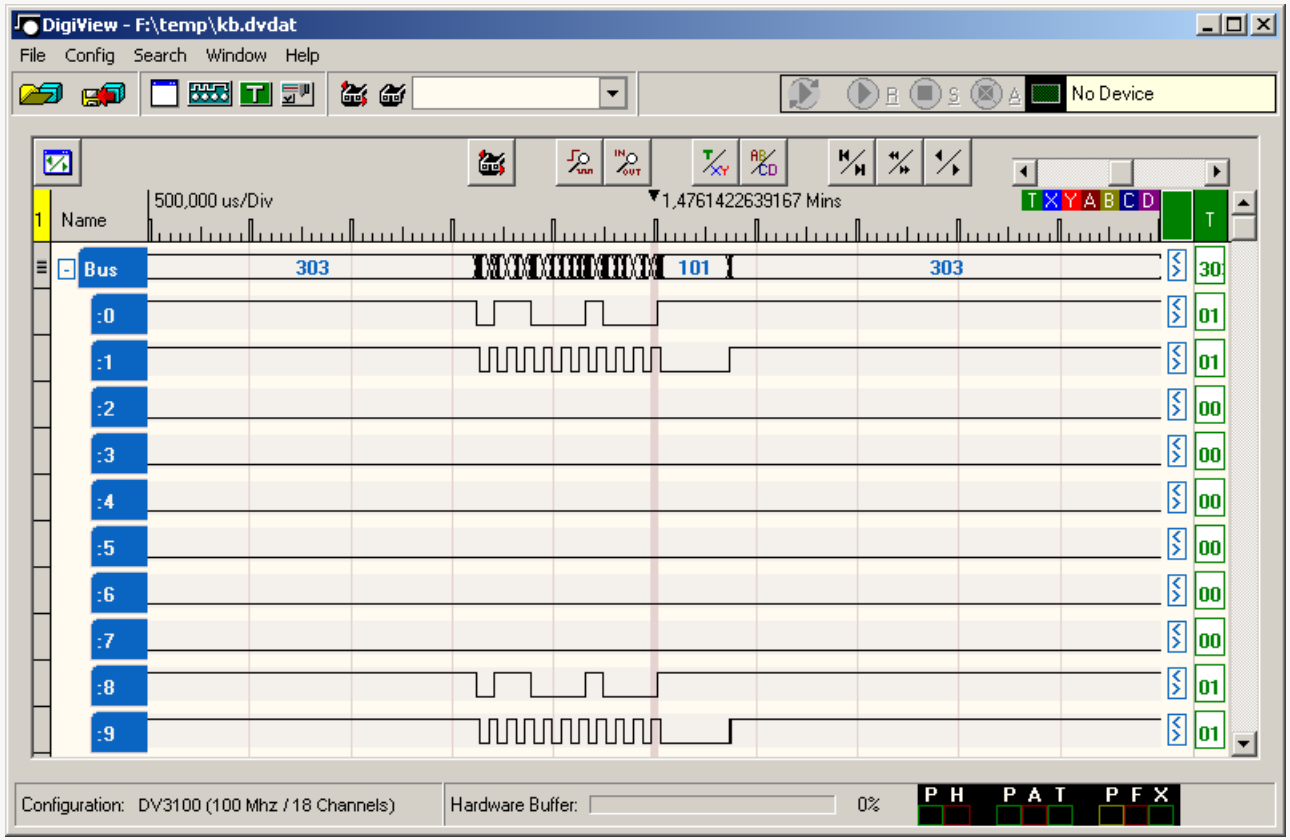
Detecting PS/2 Hardware Keylogger

- Analyze the data flow
  - Tap signal at the keyboard
  - Tap signal after the keylogger



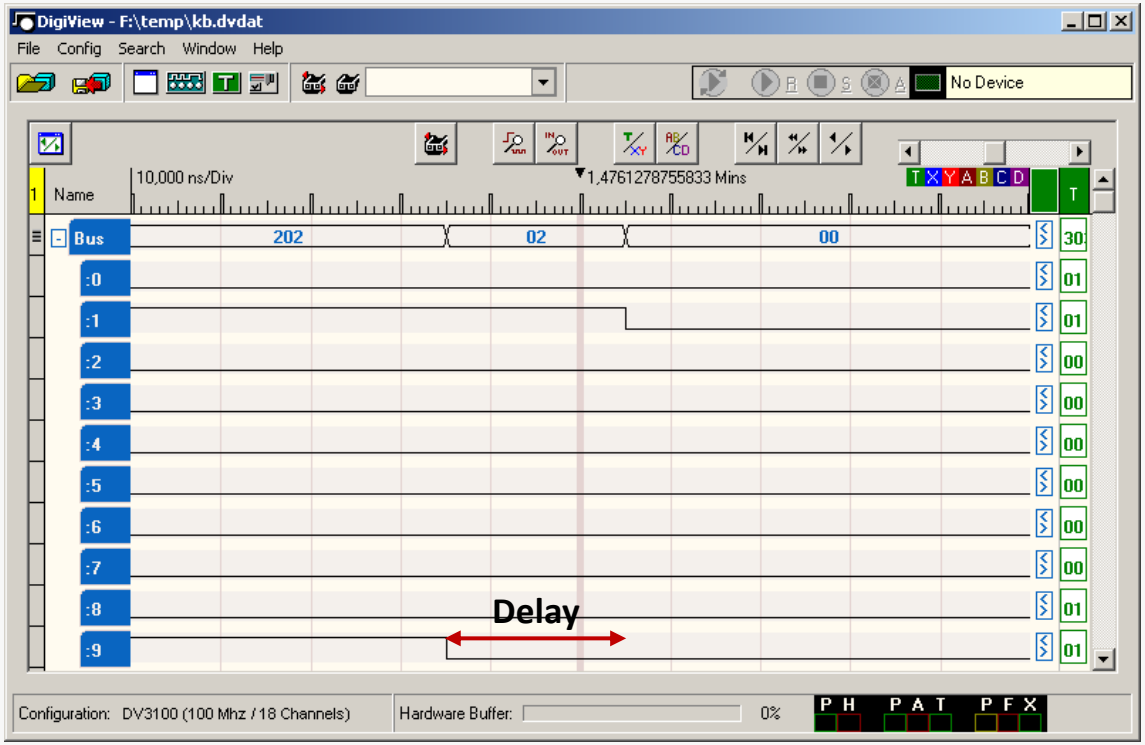
Detecting PS/2 Hardware Keylogger

- Result:



Detecting PS/2 Hardware Keylogger

- Clock is set to low
  - Delay of the HKL

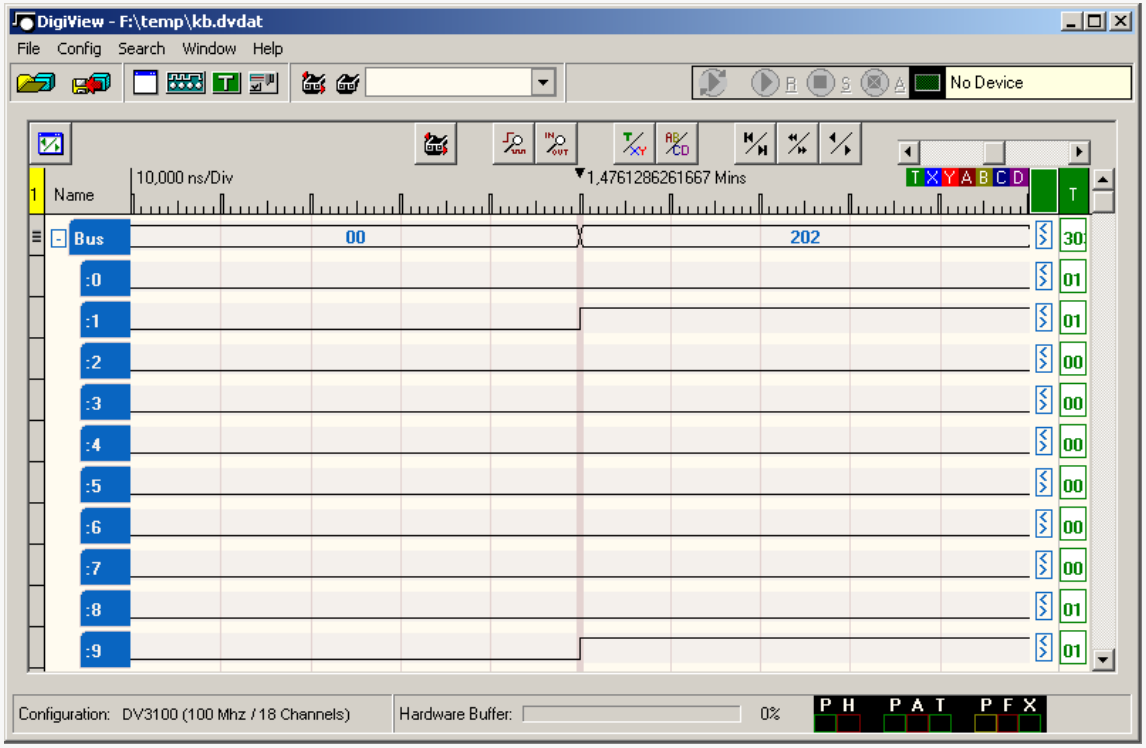


Keylogger

Keyboard

Detecting PS/2 Hardware Keylogger

- Clock is set to high
  - Same timing

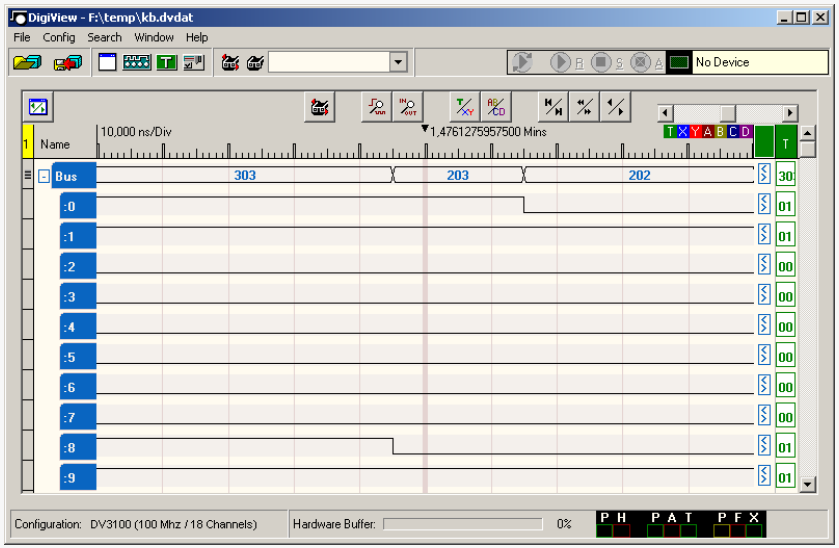


Detecting PS/2 Hardware Keylogger

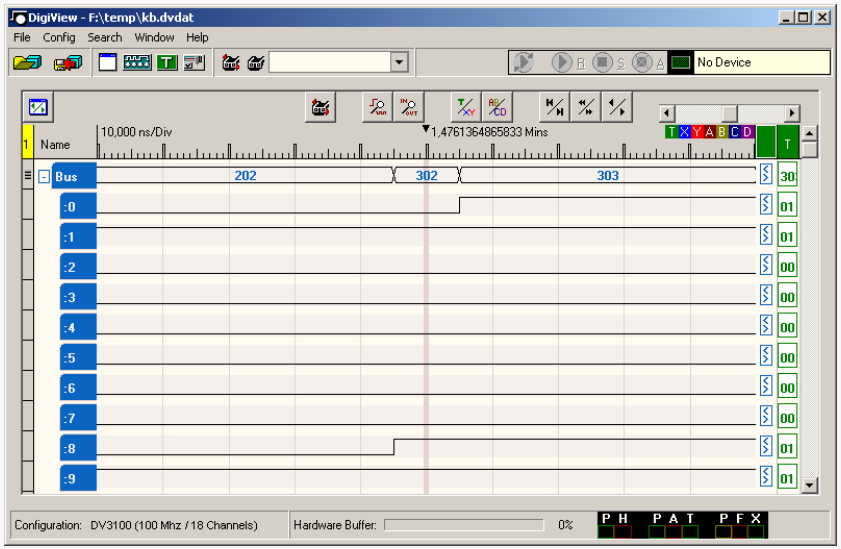
- Clock cycles are shorter for HKL
  - Probably HKL generates own clock signal
  - Can be detected on the wire
  - No possibility to detect via software
  - Exact clock state cannot be retrieved by KBC
- But the clock signal starts later…
  - Remember when clock was pulled low
  - HKL might cause a delay on the wire

Detecting PS/2 Hardware Keylogger

- Time Measurement
  - Tested HKL were placed „inline“
  - Microprocessor has to analyze the signal and pass it on
  - This additional logic increase signal propagation time



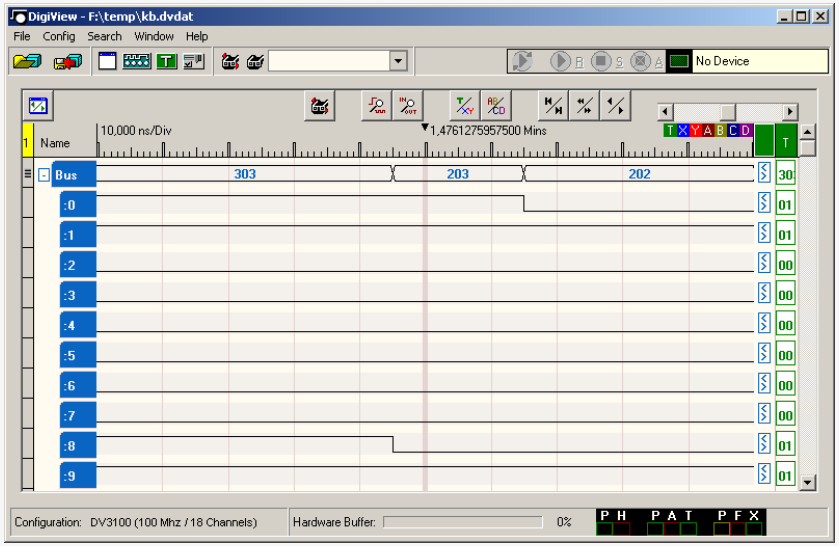
Data signal (begin)

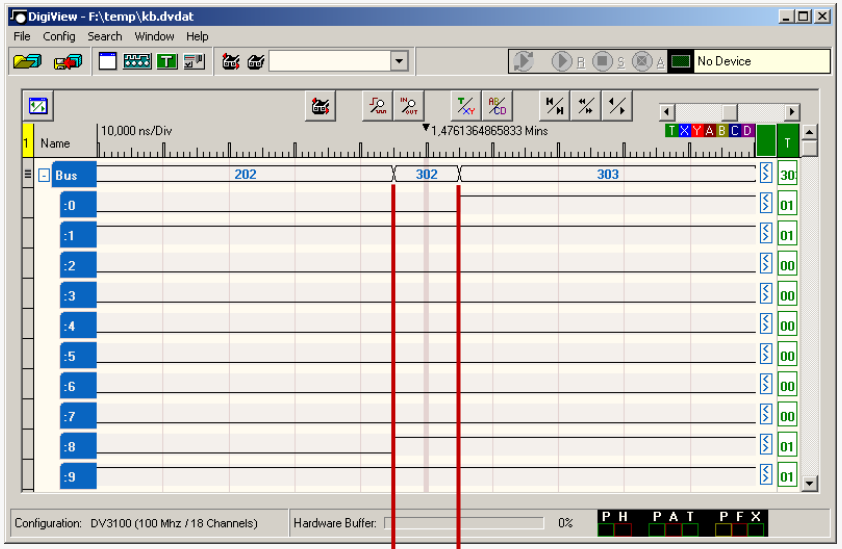


Data signal (end)

Detecting PS/2 Hardware Keylogger

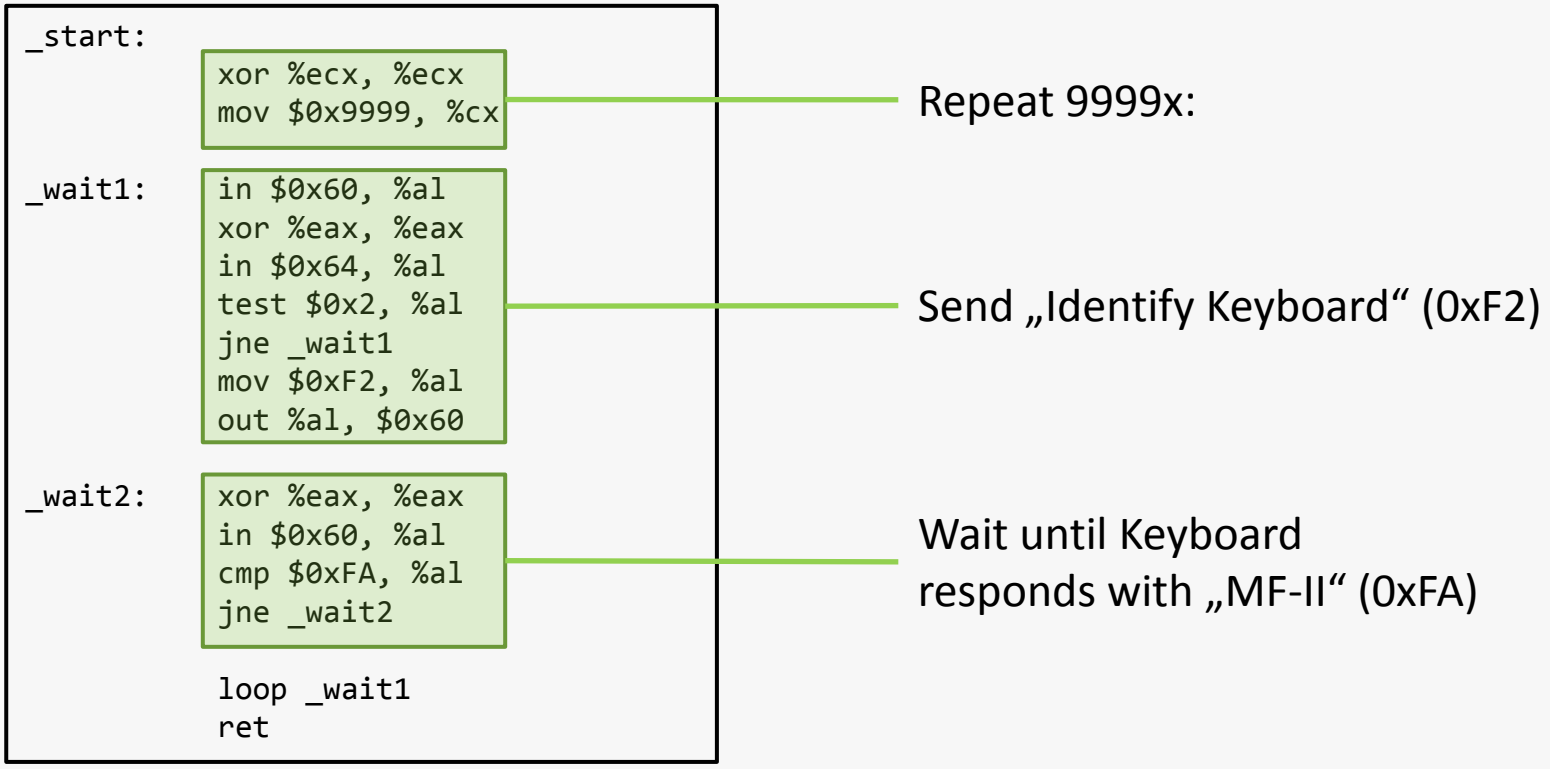
- Time Measurement
  - Tested HKL were placed „inline“
  - Microprocessor has to analyze the signal and pass it on
  - This additional logic increase signal propagation time





Detecting PS/2 Hardware Keylogger

- Basic idea
  - Send command to KB, wait for response and measure run time
  - Like a „ping“



Detecting PS/2 Hardware Keylogger

- Delay introduced by the HKL is very (!) small
  - Previous code can‘t be used in „normal OS state“
    - scheduler, interrupts, …
    - Measurement isn‘t exact enough
  - Code must run exclusively
    - Get the most accurate measurement

Detecting PS/2 Hardware Keylogger

- Solution
  - Loadable Kernel Module
  - Get CPU exclusively
    - Deactivate interrupts for processor
    - Disable kernel preemption
    - SMP locking
  - Run ASM code („ping“)
  - Measure runtime of the code
    - Interrupts are disabled
    - Read processors time stamp counter (rdtsc)
    - Counter is increased every clock cycle
    - Use the number of clock cycles
  - Restore everything and write result to kernel message buffer

Detecting PS/2 Hardware Keylogger

- Time Measurement
  - Results

Setup	Clock cycles
Keyboard	338 1 03523280
KeyGhost	338 5 62656160
KeyKatcher Mini	338 6 25304965
KeyKatcher Magnum	338 4 21058298

  - „Inline“ HKL can be detected using Time Measurement
    - Measure without HKL
    - Define Baseline (e.g 338200000000)
    - Measure again
    - Win ;)

Defeat PS/2 Hardware Keylogger

- Fill Keylogger memory via software
  - Some stop logging
  - Some overwrite memory at the beginning
  - Keystrokes are overwritten / not recorded
- Keyboard commands
  - Some commands lead to fake keypress (see Brute Force)
  - Send those repeatedly
  - ~100 logged keys in 10s
  - 109 minutes to fill 64kB
- Keyboard command „0xFE“
  - Resend
  - Keyboard responds by resending the last-sent byte
  - ~ 4 logged keys in 10 s
- Practical?
  - Most PS/2 HKL have a few KBytes memory
  - Nevertheless takes too much time
  - Works for: KeyGhost, KEYKatcher (some)

Defeat PS/2 Hardware Keylogger

- Stop HKL from sniffing keystrokes
- Keyboard sends scancodes
  - Make / Break codes
  - Defined in scan code set
  - Scan codes set can be choosen via KB command „0xF0“
- 3 scancode sets
  - 1: XT keyboards
  - **2: MF2 keyboard**
  - 3: AT keyboads
- Tested Keyloggers support scancode set 2 and 3
- Choose scancode set 1…
  - Keylogger doesn‘t log correctly
  - Logs can‘t be used
  - New mapping scancode <-> keycode is necessary for OS
    - hdev
    - HAL
    - setkeycode

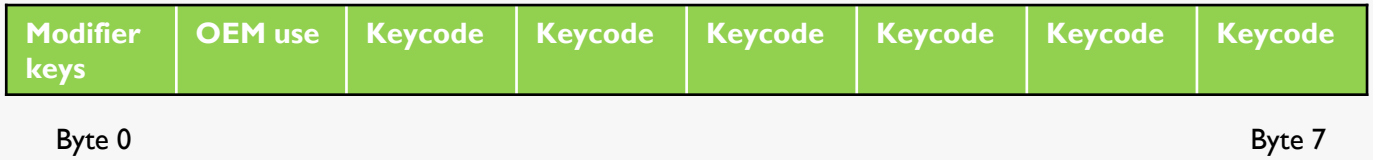
USB – How does it work

- Host controller + Hubs + devices build tree structure
- Device has various endpoints
  - Buffer in / out
  - Configuration via endpoint 0
  - Low Speed devices (Keyboard): endpoint 0 + 2 endpoints with 8 Bytes
- Only host controller manages communication with devices
  - Polls buffer (device configuration)
  - Writes buffer
- Data are transferred as packets
- Data transfer types
  - Isochronous transfer (guaranteed data rate, no error correction)
  - **Interrupt transfer (small amount of data, retransmission)**
  - Bulk transfer (big amount of data, retransmission)
  - **Control transfer (device configuration, ACKed in both directions)**

USB – How does it work

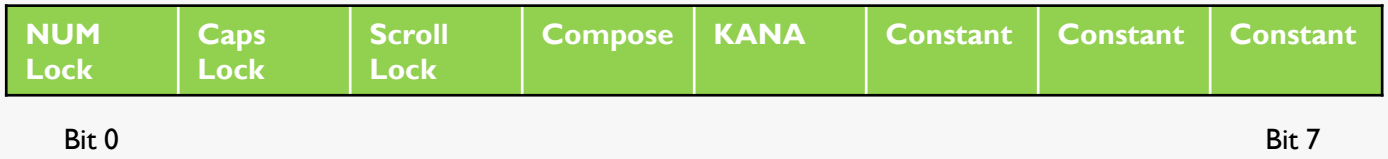
- Different device classes
  - Plug and Play
  - Relevant: HID class
  - Defines communication

- KB sends 8 Byte input report
  - Interrupt Transfer
  - Periodically polled by host
  - Contains pressed keys
  - No make / break codes
  - Packet:



USB – How does it work

- PC sends 1 Byte output report
  - USB Control Transfer
  - Control LEDs
  - Packet:



- No addtional KB commands
  - Transfer handeld via USB
  - Typematic rate, etc. configured on PC

Detecting USB Hardware Keylogger

- Current Measurement
  - Like PS/2
  - More current is drawn
  - Cannot be measured by software
    - Device configuration contains current
    - However no accurate information available

Detecting USB Hardware Keylogger

- Brute Force KL password
  - KeyCarbon: software to retrieve keystrokes

Detecting USB Hardware Keylogger

- Brute Force KL password
  - KeyCarbon: software to retrieve keystrokes
  - Software needs to communicate with KL…
  - USB sniffer:

Type	Seq	Time	Request	Request Details	Raw Data	I/O
START	0001	0:16:31.281				
URB	0002	0:16:44.656	Class Interface	Set Report (Output l…	04	out
URB	0003	0:16:44.656	Class Interface	Set Report (Output l…	04	out
URB	0004-0003	0:16:44.671	Control Transfer	Set Report (Output l…		out
URB	0005-0002	0:16:44.671	Control Transfer	Set Report (Output l…		out
URB	0006	0:16:44.812	Class Interface	Set Report (Output l…	05	out
URB	0007	0:16:44.812	Class Interface	Set Report (Output l…	05	out
URB	0008-0007	0:16:44.812	Control Transfer	Set Report (Output l…		out
URB	0009-0006	0:16:44.812	Control Transfer	Set Report (Output l…		out
URB	0010	0:16:44.812	Class Interface	Set Report (Output l…	03	out
URB	0011	0:16:44.812	Class Interface	Set Report (Output l…	03	out
URB	0012-0011	0:16:44.828	Control Transfer	Set Report (Output l…		out
URB	0013-0010	0:16:44.828	Control Transfer	Set Report (Output l…		out
URB	0014	0:16:44.968	Class Interface	Set Report (Output l…	07	out
URB	0015	0:16:44.968	Class Interface	Set Report (Output l…	07	out
URB	0016-0015	0:16:44.968	Control Transfer	Set Report (Output l…		out
URB	0017-0014	0:16:44.968	Control Transfer	Set Report (Output l…		out
URB	0018	0:16:45.109	Class Interface	Set Report (Output l…	03	out
URB	0019	0:16:45.109	Class Interface	Set Report (Output l…	03	out
URB	0020-0019	0:16:45.109	Control Transfer	Set Report (Output l…		out
URB	0021-0018	0:16:45.109	Control Transfer	Set Report (Output l…		out
URB	0022	0:16:45.265	Class Interface	Set Report (Output l…	07	out
URB	0023	0:16:45.265	Class Interface	Set Report (Output l…	07	out

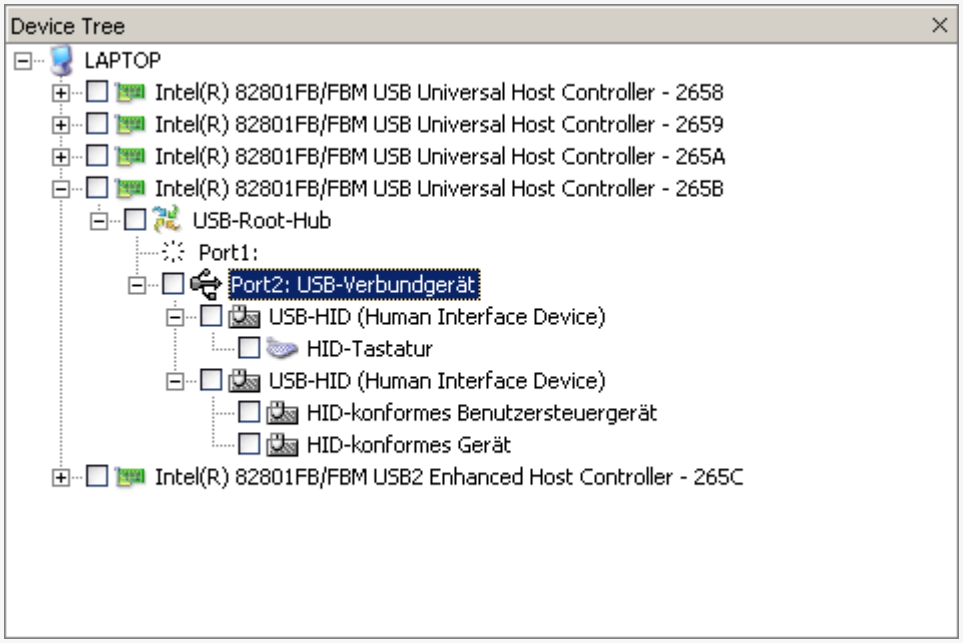
Detecting USB Hardware Keylogger

- Software needs to communicate with KL…
  - 1 Byte output reports (set LEDs)
  - Fixed header + HKL password + footer
  - Password char is encoded with 4 Bytes

- Brute Force (default) passwords
  - Create Lookup Table for PW chars
  - Perform attack via software
  - Works for: KeyCarbon models

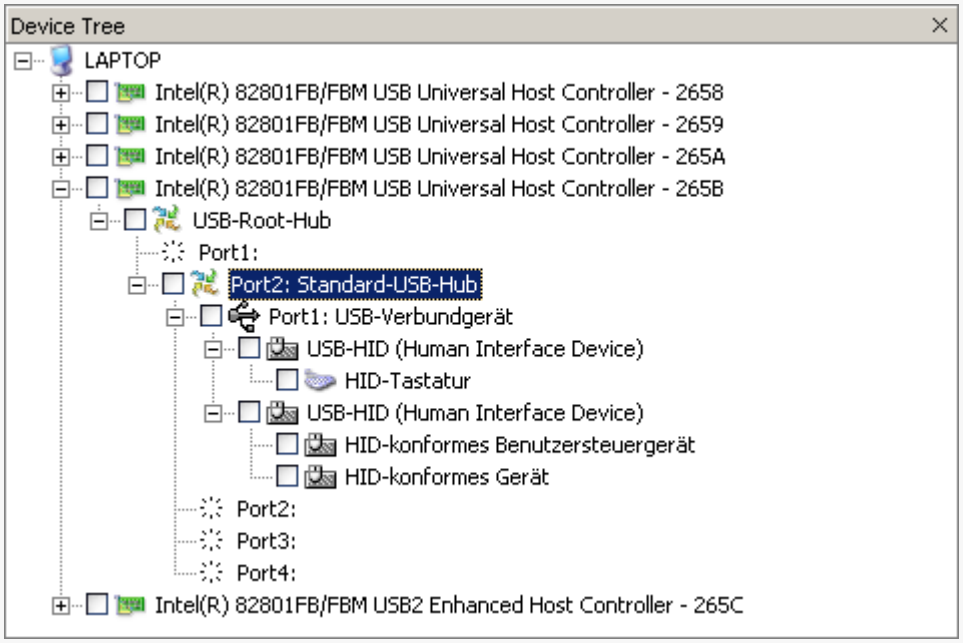
Detecting USB Hardware Keylogger

- Changes to USB Properties / Topology
  - Keyboard only:



Detecting USB Hardware Keylogger

- Changes to USB Properties / Topology
  - Keyboard + KeyCarbon:



Detecting USB Hardware Keylogger

- Changes to USB Properties / Topology
  - Addtional USB HUB if KeyCarbon is present

    „Why is the device undetectable, in practice, by software? The device shows up in Windows 'Device Manager' as a generic USB hub. This generic USB hub has no ID strings, and is indistinguishable from the generic USB hub found in 90% of all USB hubs. "
  - Well...

Device Descriptor

Offset	Field	Size	Value	Description
0	bLength	1	12h	
1	bDescriptorType	1	01h	Device
2	bcdUSB	2	0110h	USB Spec 1.1
4	bDeviceClass	1	09h	Hub
5	bDeviceSubClass	1	00h	
6	bDeviceProtocol	1	00h	
7	bMaxPacketSize0	1	08h	8 bytes
8	idVendor	2	0451h	Texas Instruments, Inc.
10	idProduct	2	2046h	
12	bcdDevice	2	0125h	1.25
14	iManufacturer	1	00h	
15	iProduct	1	00h	
16	iSerialNumber	1	00h	
17	bNumConfigurations	1	01h	

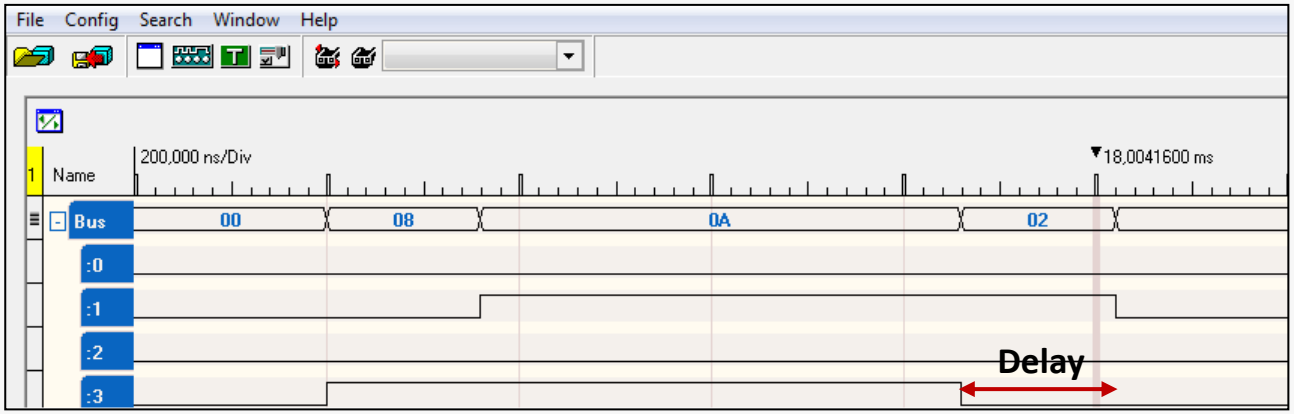
USB HUB Controller used:
Texas Instruments (TUSB2046B)

Detecting USB Hardware Keylogger

- Changes to USB Properties / Topology
  - KeyGhost changes device properties
    - USB Speed
      - Keyboard: *bMaxPacketSize0* 08 / Speed: Low
      - KeyGhost: *bMaxPacketSize0* 64 / Speed: Full
    - Device Status
      - Keyboard : Bus Powered (0x0000)
      - KeyGhost : Self Powered (0x0001)
  - More details later…

Detecting USB Hardware Keylogger

- Time Measurement
  - Like PS/2
  - HKL are placed inline -> introduces a delay



Detecting USB Hardware Keylogger

- Time Measurement
  - Basically the same idea like for PS/2
  - Has to be adjusted for USB
- PC can send 1 Byte output report to KB (LED)
  - sent as Control-Transfer
  - Control-Transfer are ACKed
  - Like PS/2 „ping“
  - Can be used for runtime measurement ;)
- Implementation
  - Send output report to KB
  - Wait until ACKed
  - Do it various times (10.000)
  - Measure runtime
- Measurement can be performed from userland
  - e.g. libusb

Detecting USB Hardware Keylogger

- Time Measurement
  - Results

Setup	Milliseconds
Keyboard	40034
KeyGhost	56331
KeyCarbon	43137

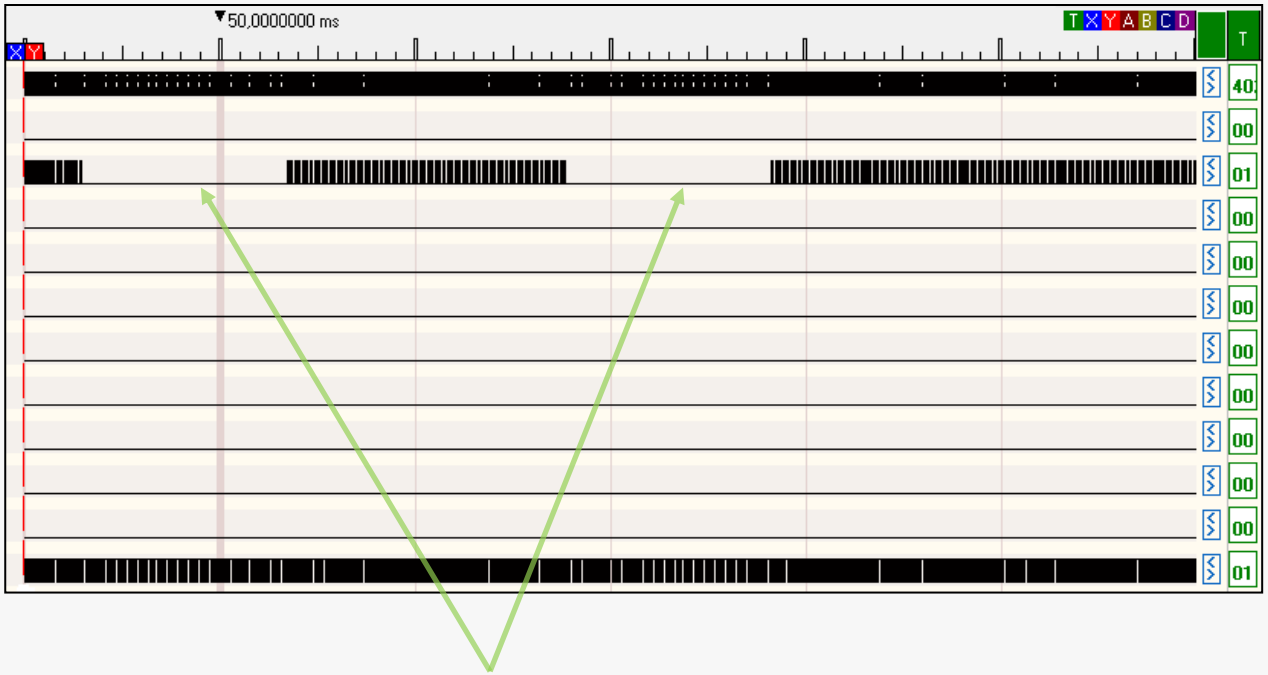
  - USB HKL can be detected using Time Measurement
    - Create baseline for default setup (HUBs, etc.)
    - Measure again
    - Win ;)

Detecting USB Hardware Keylogger

- Different keyboard behaviour
  - Normal behaviour:
    - Interrupt read (8 Byte): *\x81\x06\x00\x22\x00\x00\x00\x04*
    - Send USB Reset
    - Interrupt read (8 Byte): *\x00\x00\x00\x00\x00\x00\x00\x00*
  - KeyGhost behaviour:
    - Interrupt read (8 Byte): *\x81\x06\x00\x22\x00\x00\x00\x04*
    - Send USB Reset
    - Interrupt read (8 Byte): *\x81\x06\x00\x22\x00\x00\x00\x04*

Detecting USB Hardware Keylogger

- Different keyboard behaviour
  - Analysis on the wire…
  - Reason: keyboard never receives USB Reset



Before Keylogger

After Keylogger

USB Reset (D-/D+ pulled low)

Detecting USB Hardware Keylogger

- Keyboard never receives USB Reset
- USB single-chip host and device controller (ISP1161A1BD)
  - Acts as Device for PC (causes changes to device properties)
  - Acts as Host Controller for KB
- Behaviour can be tested via software
  - e.g. libusb
- Note: Time Measurement for this design bug is possible too

Conclusion

- PS/2
  - All tested models were placed „inline“
  - Time Measurement as general technique to detect them
  - Scancode 1 as general technique to defeat them
- USB
  - Detection via USB behaviour (USB speed, etc.)
  - Individual bugs
  - More research to come…
- All tested HKL contained bugs that can be used to detect them
  - Generic and individual bugs
  - Each HKL has to be analyzed seperately
  - Bugs can be combined (Pattern)
- PoC code
  - Soon: https://code.google.com/p/hkd/

Thank you for your interest!

Questions and Feedback