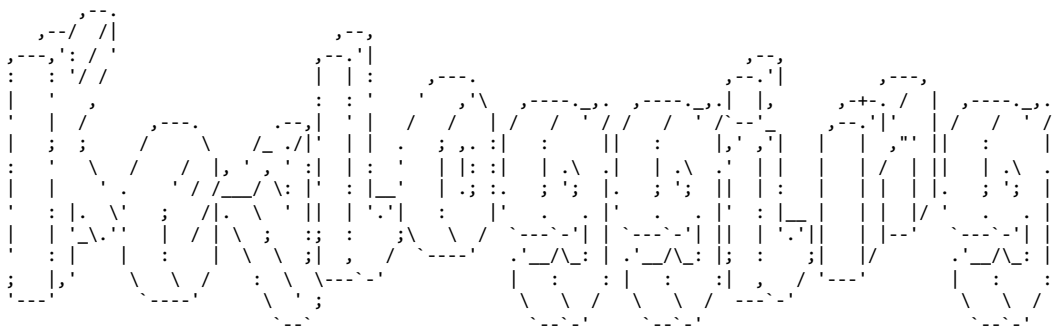


What is Keylogging?

- Something used to monitor the keys that are pressed on a computer
- Can be implemented in hardware or software
- Possible uses both legitimage and not
  - Allows for things to happen based on key presses
    - Hotkeys
    - Writing text
  - Allows for recording of text, passwords, etc.

Why is it bad?

- Allows for criminals to intercept passwords, personal information, confidential information, etc.
- Bypasses common protections like disk encryption, good password storage (hashing), etc.
- Significant interaction with a computer is through typing, and that can all be intercepted

How a keyboard works

- A keyboard is a small computer
- A local microcontroller scans keys being pressed
- Each key has a number assigned to it (scan code)
- Number maps to keyboard matrix map
- Two scan codes are generated per key press
  - One for when a user presses the key
  - One for when a user releases the key
  - Some keys have a function when they are pressed and held (Shift, Control, Alt)

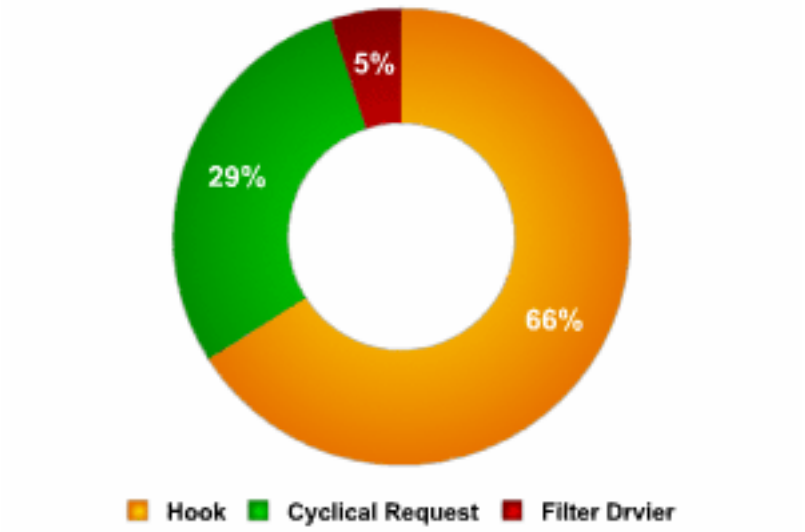
How a keyboard works

- When a key is pressed an electrical circuit is closed
- When the microcontroller scans next and detects the key is pressed it sends an interrupt request and scan code to the computer
- Same thing occurs when the key is released

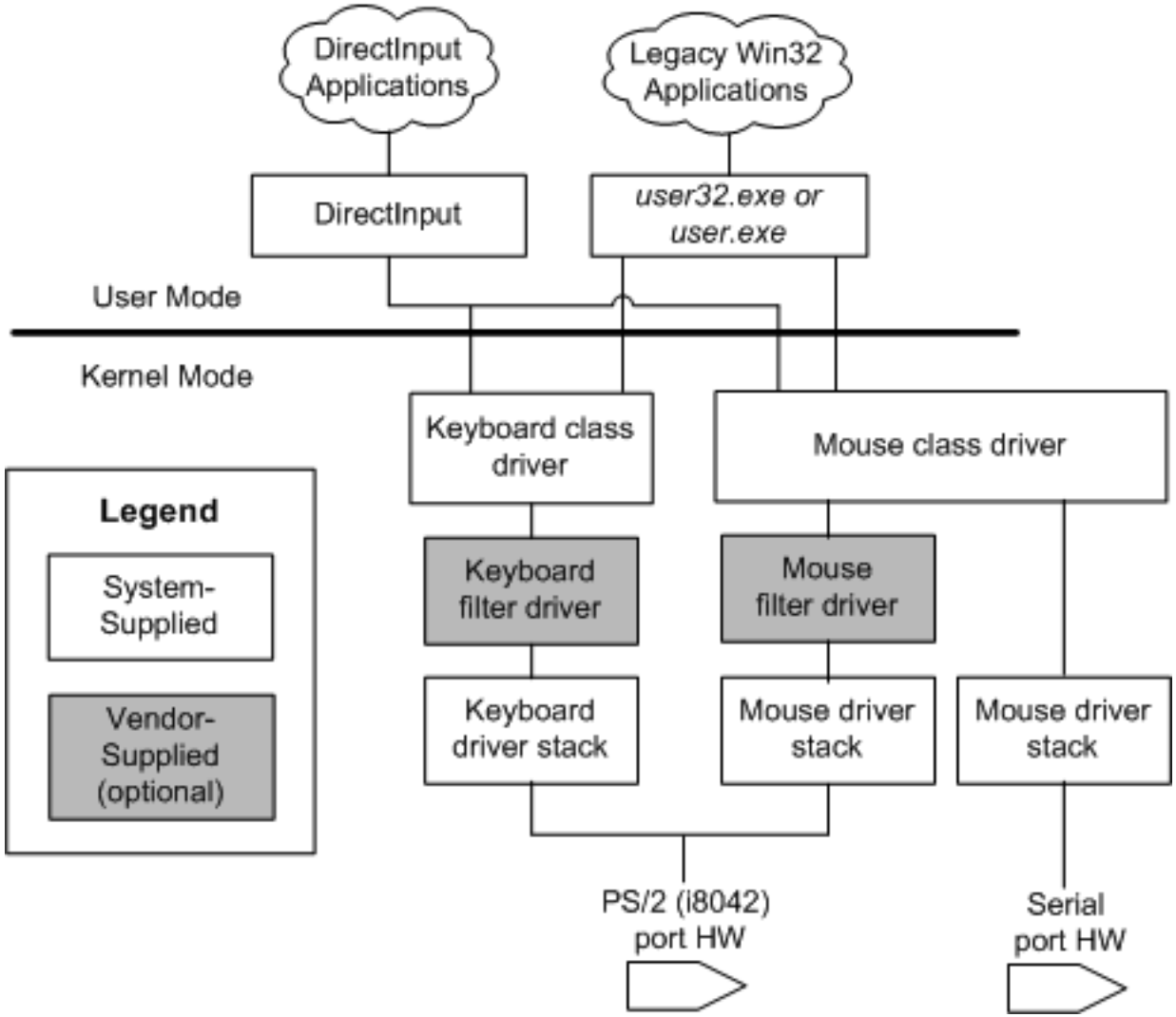
Hardware Keyloggers

Software Keyloggers

- Use various techniques to monitor keys as they are sent to the operating system
- On Windows:
  - A system hook which intercepts notification that a key has been pressed
  - A cyclical information keyboard request from the keyboard
  - Using a filter driver

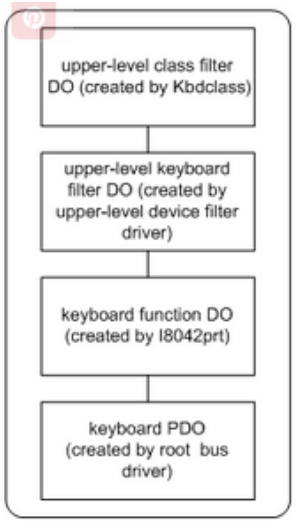


Windows driver stack for keyboards

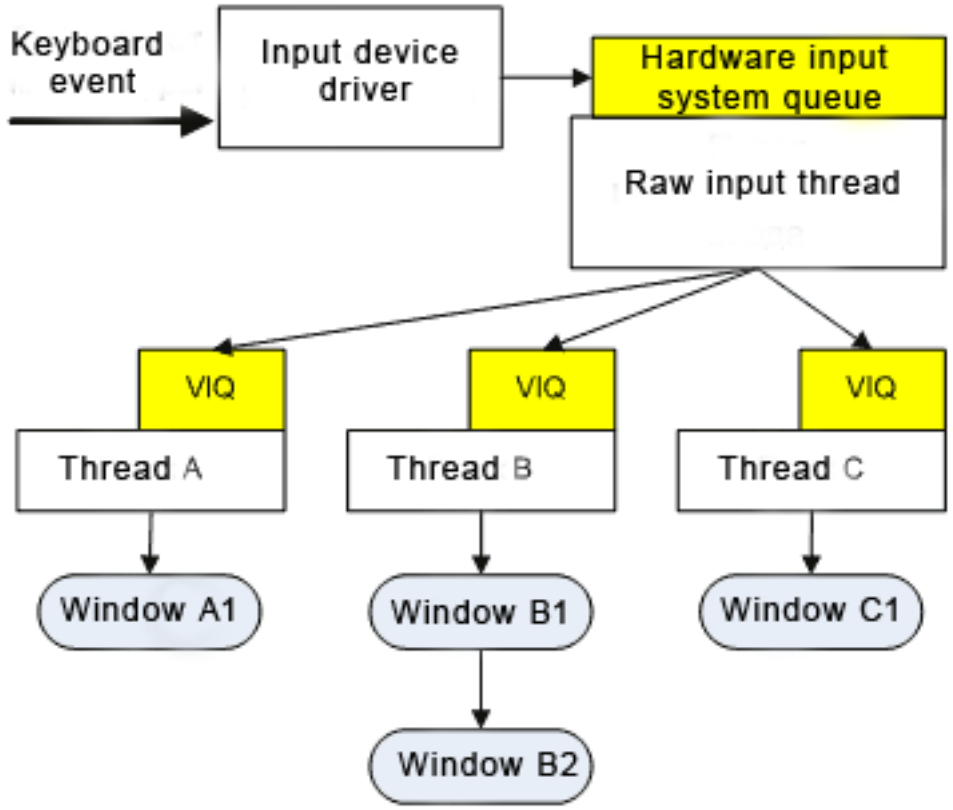


Device Object Stack

1. Physical device object (PDO) – driver bus
2. Functional device object (FDO) – i8042ptr port
3. Optional: filter object for keyboard device
   - Developed by third parties
4. High level filter objects – DeviceKeyboardClass0



PS/2
Keyboard
Device Stack


Keyboard event
Input device driver
Hardware input system queue
Raw input thread
VIQ
VIQ
VIQ
Thread A
Thread B
Thread C
Window A1
Window B1
Window C1
Window B2

Raw Input Thread

- All incoming keyboard events are placed in hardware input system queue
- Transformed to Windows Messages
- Placed at the end of the virtualized input queue (VIQ) of the active thread
- Key scan codes are replaced with virtual key codes
  - Transforms keys from simply locations to actions

Last Mile

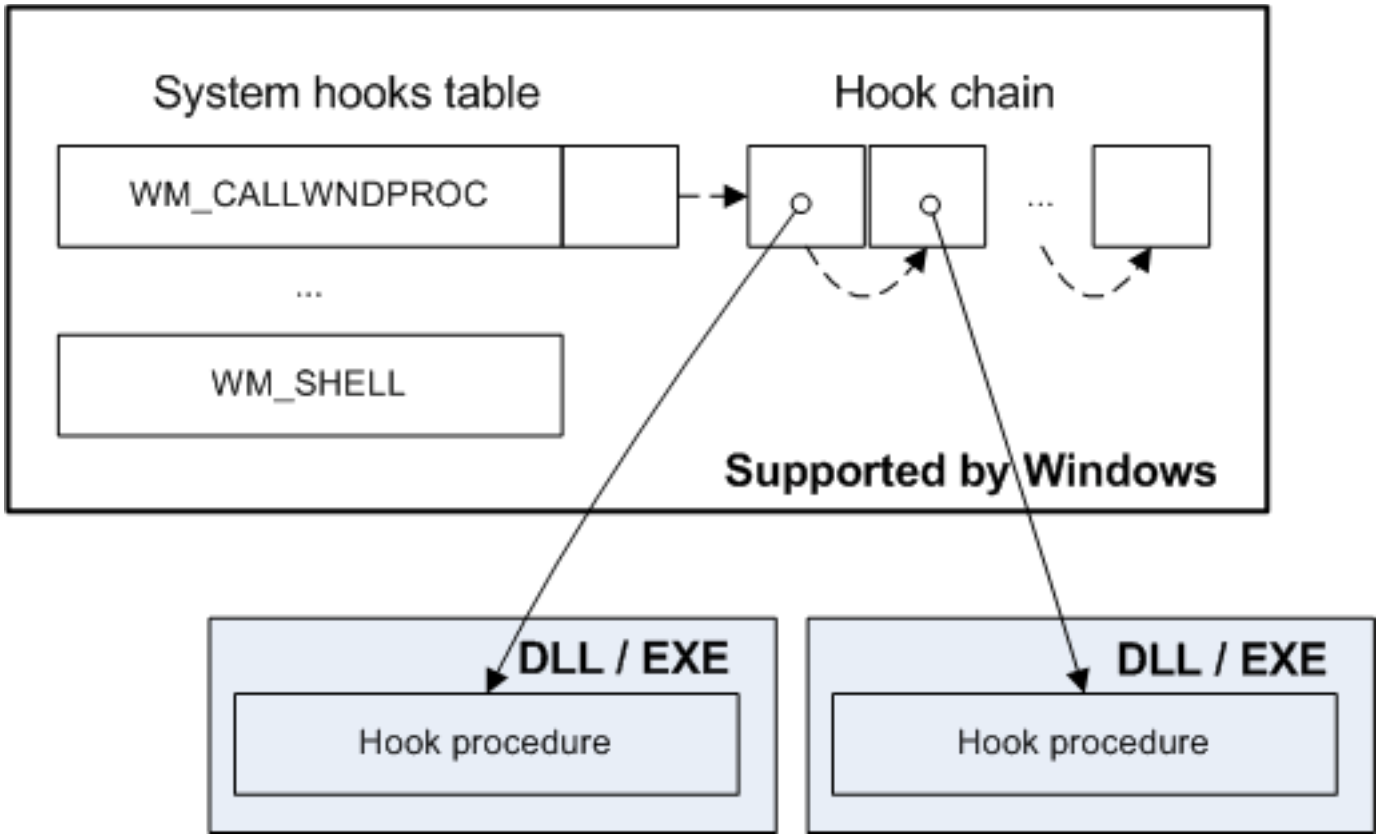
- Once a message has entered the thread message queue they are pulled from the queue with GetMessage
- Redirected to the window procedure with DispatchMessage
- Window proceedure processes messages for the window where input is currently focussed
- If the window has an input focus all keyboard messages from the system queue will reach the appropriate function of the window

Keyboard Hooks

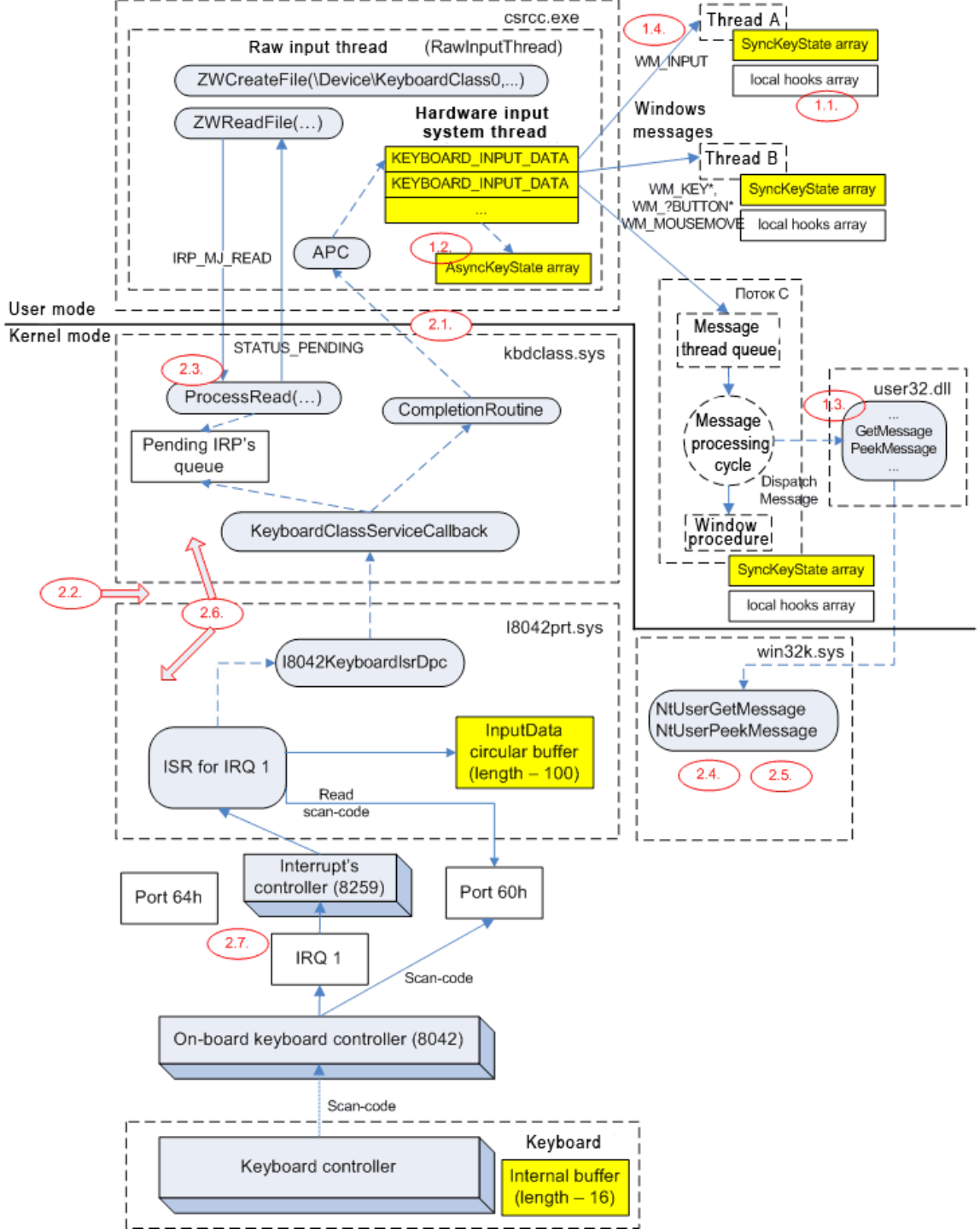
- Hooking is a mechanism used to intercept events using specific functions
- This function reacts to an event
- Filter functions are functions that receive notification of events
- A filter function is bound to a hook using the Win32 API:
  - SetWindowsHookEx
  - UnhookWindowsHookEx
- Hooks can be set system wide or for a thread

Hooks

- If multiple filter functions can be bound to a hook and are put in a function queue
- Most recently bound hook starts the queue and first function bound ends the queue
- The actions that can be performed by filter functions depends on the type of hook, but may include:
  - Track the occurrence of an event
  - Modify message parameters
  - Initiate message processing
  - Prevent the next filter function from being called


System hooks table
Hook chain
WM_CALLWNDPROC
...
WM_SHELL
...
Supported by Windows
DLL / EXE
Hook procedure
DLL / EXE
Hook procedure

So where does keylogging occur?


csrcc.exe
Raw input thread (RawInputThread)
ZWCreateFile(\Device\KeyboardClass0,...)
ZWReadFile(...)
Hardware input system thread
KEYBOARD_INPUT_DATA
KEYBOARD_INPUT_DATA
...
AsyncKeyState array
APC
IRP_MJ_READ
1.2.
Thread A
SyncKeyState array
local hooks array
1.1.
1.4.
WM_INPUT
Windows messages
Thread B
WM_KEY*, WM_?BUTTON* WM_MOUSEMOVE
SyncKeyState array
local hooks array
Поток C
Message thread queue
Message processing cycle
Dispatch Message
Window procedure
SyncKeyState array
local hooks array
user32.dll
...
GetMessage
PeekMessage
...
1.3.
User mode
Kernel mode
2.1.
STATUS_PENDING
kbdclass.sys
2.3.
ProcessRead(...)
CompletionRoutine
Pending IRP's queue
KeyboardClassServiceCallback
2.2.
2.6.
i8042prt.sys
I8042KeyboardIsrDpc
ISR for IRQ 1
InputData circular buffer (length – 100)
Read scan-code
win32k.sys
NtUserGetMessage
NtUserPeekMessage
2.4.
2.5.
Port 64h
Interrupt's controller (8259)
Port 60h
2.7.
IRQ 1
Scan-code
On-board keyboard controller (8042)
Scan-code
Keyboard
Keyboard controller
Internal buffer (length – 16)

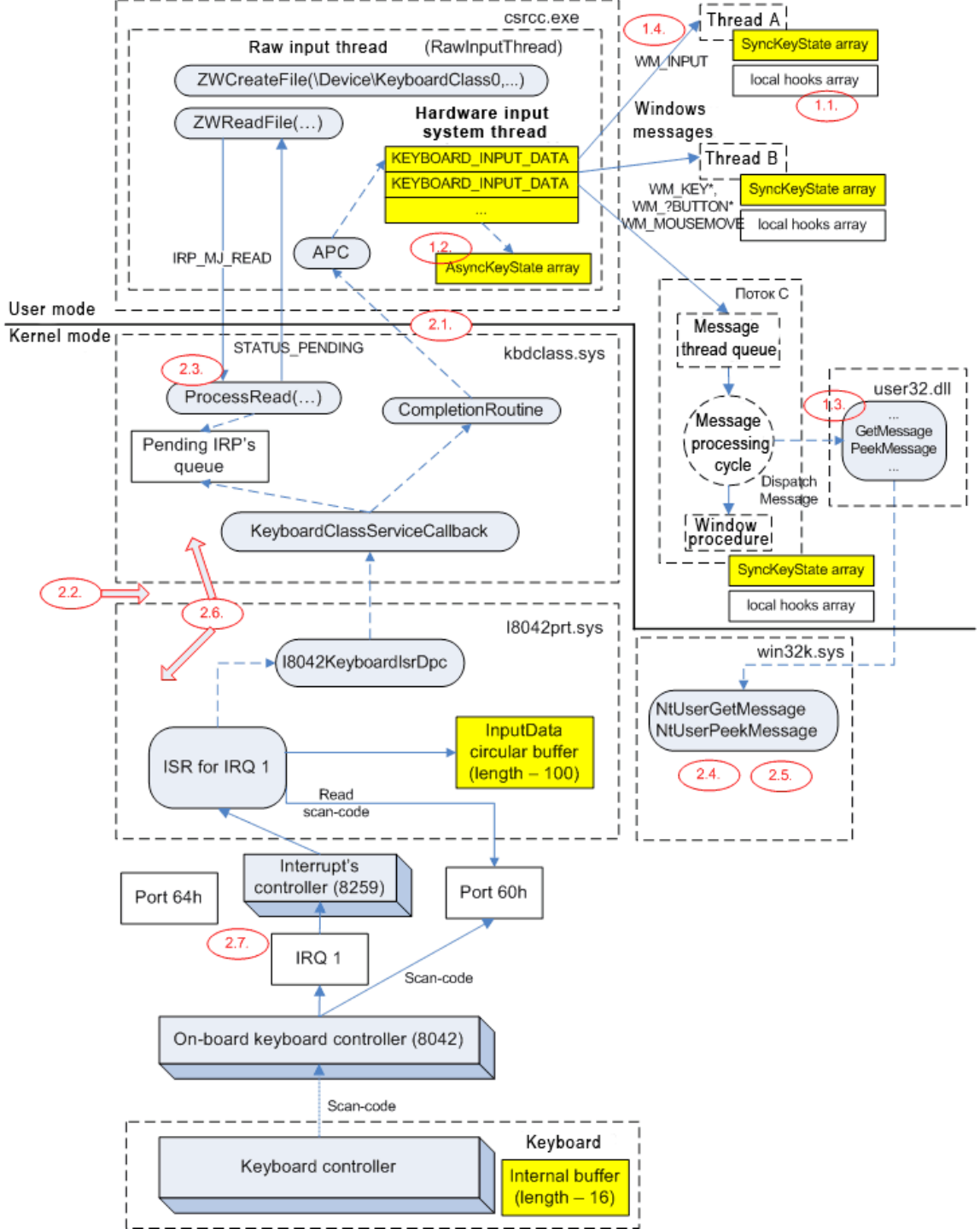
User mode keyloggers

1.1 Setting hooks for keyboard messages
- Set a global hook for all keyboard events for all threads in the system

1.2 Using cyclical query of the keyboard
- The state of the keyboard is queried constantly

1.3 Hooking message processing functions by injecting into processes
- Injection into all processes and intercept GetMEssage or PeekMessage functions

1.4 Using the raw input model
- Keylogger registers itself as a device that wants input from the keyboard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Поток C
Message thread queue
Message processing cycle
Dispatch Message
Window procedure
SyncKeyState array
local hooks array
user32.dll
...
GetMessage
PeekMessage
...
1.3.
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IRQ 1
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On-board keyboard controller (8042)
Scan-code
Keyboard
Keyboard controller
Internal buffer (length – 16)

Kernel Mode Keyloggers

2.1 Using the keyboard driver filter Kbdclass
- Installs a filter above the device created by the Kbdclass driver

2.2 Using the filter driver of the i8042prt function driver
- Installs a filter on top of the device created by the i8042prt driver

2.3 Modifying the dispatch table of the Kbdclass driver
- Changes the IRP_MJ_READ entry point in the dispatch table for the Kbdclass driver

2.4 Modifying the system service table KeServiceDescriptorTableShadow
- Patches the entry point for NtUserGetMessage/PeakMessage in the second table of system services of the win32k.sys driver

2.5 Modifying the code of the NtUserGerMessage or NtUserPeekMessage function by splicing
- Splices the NtUserGetMessage or NtUserPeakMessage to modify the code

2.6 Substituting a driver in the keyboard stack of drivers
- Drop in a whole new Kbdclass driver or keyboard driver

2.7 Implementing a handler driver for interupt 1 (IRQ 1)
- Write a kernel mode driver which hooks the keyboard interrupt and directly contacts the keyboard input and output ports

Sources / References

- https://securelist.com/analysis/publications/36138/keyloggers-how-they-work-and-how-to-detect-them-part-1/
- https://securelist.com/analysis/publications/36358/keyloggers-implementing-keyloggers-in-windows-part-two/
- http://phrack.org/issues/59/14.html