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# Targeting the iOS Kernel

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# Who am I?

## Stefan Esser

- from Cologne/Germany
- Information Security since 1998
- PHP Core Developer since 2001
- Suhosin / Hardened-PHP 2004
- Month of PHP Bugs 2007 / Month of PHP Security 2010
- ASLR for jailbroken iPhones 2010 / untethered jailbreak for iOS 4.3.1/2
- Head of Research & Development at SektionEins GmbH

# Motivation

- iPhone security heavily relies on kernel level protections
    - code signing / sandboxing
    - NX / ASLR
- public iPhone exploit payloads are very limited in what they can do
- security researchers have relied on the jailbreakers to provide kernel pwnage
- this session is an introduction to finding bugs in the iOS kernel

# Agenda

- Introduction
- How to get the iOS kernelcache
- Analysing the content of the kernelcache
- Trying to get some kernel symbols
- Using the kernelcache to determine attack surface
- Learning how to use the iOS kernel debugger

- Exploitation is not covered in this session - contact me to discuss this topic

# Part I

## Introduction

# Finding Vulnerabilities in the iOS Kernel (I)

- For OS X Apple provides
  - the source code for the latest OS X version (XNU)
  - the source code of some OS X kernel extensions
  - symbols for the binary kernel and some extension (in DebugKit)
- For iOS Apple provides neither

# Finding Vulnerabilities in the iOS Kernel (II)

- because iOS is also XNU based the public source is partly useable
- however the kernel of OS X and iOS are very out of sync
- kernel vulnerabilities that are only interesting for iOS are not fixed in OS X
- auditing XNU will reveal a bunch of vulnerabilities already fixed in iOS
- interesting parts like the ASLR are not yet in any public XNU release

# Finding Vulnerabilities in the iOS Kernel (III)

- source code of kernel extensions is less likely to be desync
- however only a small subset of kernel extensions have source code available
- finding vulnerabilities in iOS kernel extension requires binary analysis



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# Interesting Kernel Bugs - OS X

## OS X Kernel

- user-land dereference bugs are not exploitable
- privilege escalation to root usually highest goal
- memory corruptions or code exec in kernel nice but usually not required
- kernel exploits only triggerable as root are not interesting

# Interesting Kernel Bugs - iOS

## iOS Kernel

- user-land dereference bugs are partially exploitable
- privilege escalation to root just a starting point
- memory corruptions or code exec in kernel always required
- kernel exploits only triggerable as root are interesting

# Part II

The iOS Kernelcache

# Getting the iOS Kernelcache (I)

- iOS kernel is stored within a 6mb file
- stored in /System/Library/Caches/com.apple.kernelcaches/kernelcache
- easier to extract from a firmware image

```
$ ls -la iPhone3,1_4.3.2_8H7_Restore/
total 1362456
drwxr-xr-x  11 sesser staff       374 18 Apr 22:05 .
drwxr-xr-x  24 sesser  staff       816 18 Apr 22:02 ..
-rw-r--r--@  1 sesser  staff  630358016  5 Apr 04:58 038-1025-007.dmg
-rw-r--r--@  1 sesser  staff   25004228  5 Apr 03:47 038-1031-007.dmg
-rw-r--r--@  1 sesser  staff   23709892  5 Apr 04:14 038-1035-007.dmg
-rw-r--r--@  1 sesser  staff      22691  5 Apr 05:02 BuildManifest.plist
drwxr-xr-x   5 sesser  staff        170  5 Apr 03:15 Firmware
-rw-r--r--@  1 sesser  staff       2076  5 Apr 04:58 Restore.plist
-rw-r--r--@  1 sesser  staff    6179844  5 Apr 02:30 kernelcache.release.k48
-rw-r--r--@  1 sesser  staff    6086404  5 Apr 02:30 kernelcache.release.n81
-rw-r--r--@  1 sesser  staff    6204036  5 Apr 02:30 kernelcache.release.n90
```

# Getting the iOS Kernelcache (II)

- kernelcache is a packed and encrypted IMG3 file
- can be decrypted and unpacked with xpwntool
- decryption IV + KEY can only be generated with exploited devices
- but can be found on the internet or inside redsn0w

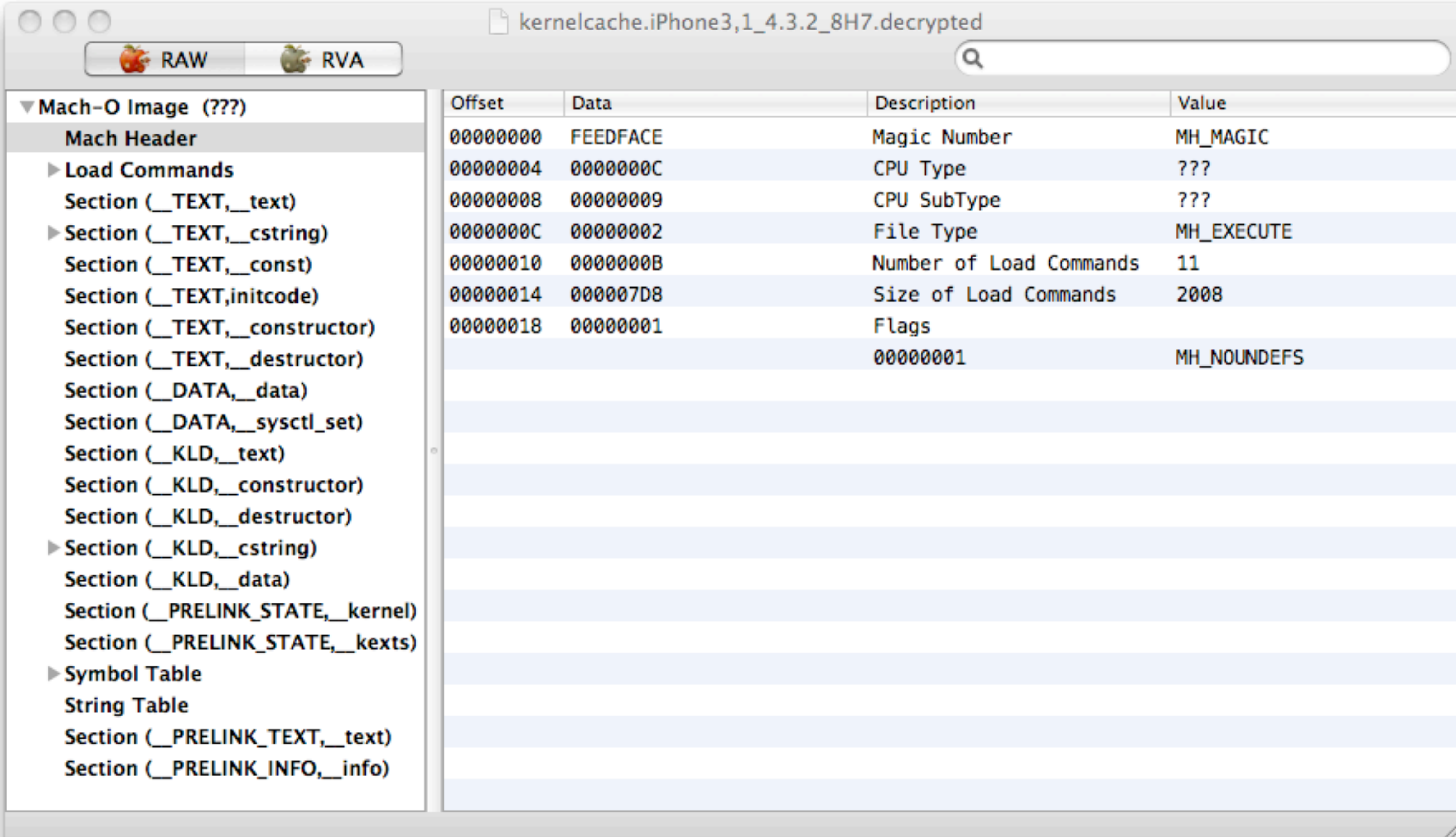
```
00000000  33 67 6d 49 84 aa 5e 00  70 aa 5e 00 38 a2 5e 00  |3gmI..^.p.^.8.^.|
00000010  6c 6e 72 6b 45 50 59 54  20 00 00 00 04 00 00 00  |lnrkEPYT .......|
00000020  6c 6e 72 6b 00 00 00 00  00 00 00 00 00 00 00 00  |lnrk............|
00000030  00 00 00 00 41 54 41 44  2c a1 5e 00 16 a1 5e 00  |....ATAD,.^...^.|
00000040  04 59 a3 f2 af f3 29 69  38 f4 2f bb dd 7f 41 ae  |.Y....)i8./...A.|
00000050  13 49 fa 56 4a cd bd 46  09 2c 77 6f 03 8c cc eb  |.I.VJ..F.,wo....|
00000060  95 29 39 c2 2f 68 4f 18  5a c3 7d 5b 9c 12 8c ac  |.)9./hO.Z.}[....|
00000070  8c f9 75 76 db a5 85 70  8d 90 7a ed 7b 94 b2 b3  |..uv...p..z.{...|
00000080  7b dc 95 5f de aa e6 0d  0b ad d6 94 ba dd 7e fe  |{.._..........~.|
00000090  a8 aa e9 44 da b2 62 41  3a df dd 5e 24 f3 8a 76  |...D..bA:..^$..v|
000000a0  f2 3b 12 3f ab 7f da 60  d3 db ad 92 5c f3 90 ef  |.;.?...`....\...|
```

# Getting the iOS Kernelcache (III)

- decrypting and unpacking reveals an ARMv7 MACH-O binary
- all MACH-O tools will work out of the box with the kernelcache
- this includes IDA but also otool and MachOView

```
00000000  ce fa ed fe 0c 00 00 00  09 00 00 00 02 00 00 00  |................|
00000010  0b 00 00 00 d8 07 00 00  01 00 00 00 01 00 00 00  |................|
00000020  d0 01 00 00 5f 5f 54 45  58 54 00 00 00 00 00 00  |....__TEXT......|
00000030  00 00 00 00 00 10 00 80  00 d0 27 00 00 00 00 00  |..........'.....|
00000040  00 d0 27 00 05 00 00 00  05 00 00 00 06 00 00 00  |..'.............|
00000050  00 00 00 00 5f 5f 74 65  78 74 00 00 00 00 00 00  |....__text......|
00000060  00 00 00 00 5f 5f 54 45  58 54 00 00 00 00 00 00  |....__TEXT......|
00000070  00 00 00 00 00 20 00 80  dc 00 21 00 00 10 00 00  |..... ....!.....|
00000080  0c 00 00 00 00 00 00 00  00 00 00 00 00 04 00 80  |................|
00000090  00 00 00 00 00 00 00 00  5f 5f 63 73 74 72 69 6e  |........__cstrin|
000000a0  67 00 00 00 00 00 00 00  5f 5f 54 45 58 54 00 00  |g.......__TEXT..|
```

# Kernelcache is just a Mach-O Binary




| Offset | Data | Description | Value |
|---|---|---|---|
| 00000000 | FEEDFACE | Magic Number | MH_MAGIC |
| 00000004 | 0000000C | CPU Type | ??? |
| 00000008 | 00000009 | CPU SubType | ??? |
| 0000000C | 00000002 | File Type | MH_EXECUTE |
| 00000010 | 0000000B | Number of Load Commands | 11 |
| 00000014 | 000007D8 | Size of Load Commands | 2008 |
| 00000018 | 00000001 | Flags | |
| | | 00000001 | MH_NOUNDEFS |

# Part III

Analysing the Kernelcache

# iOS Kernelcache vs. IDA

- IDA can load the iOS kernelcache as an ARMv7 Mach-O binary
- however the autoanalysis will fail completely
- large parts not analysed
- code recognized as data and vice versa
- functions not marked as functions
- **IDA clearly needs help**

# Helping IDA - Pointerlists


- **pointerlists**
  - __constructor and __destructor contain pointers to code
  - __sysctl_set is a pointerlist to sysctl_oid structs
  - second __data section contains only pointers
- can be changed with an IDAPython script easily



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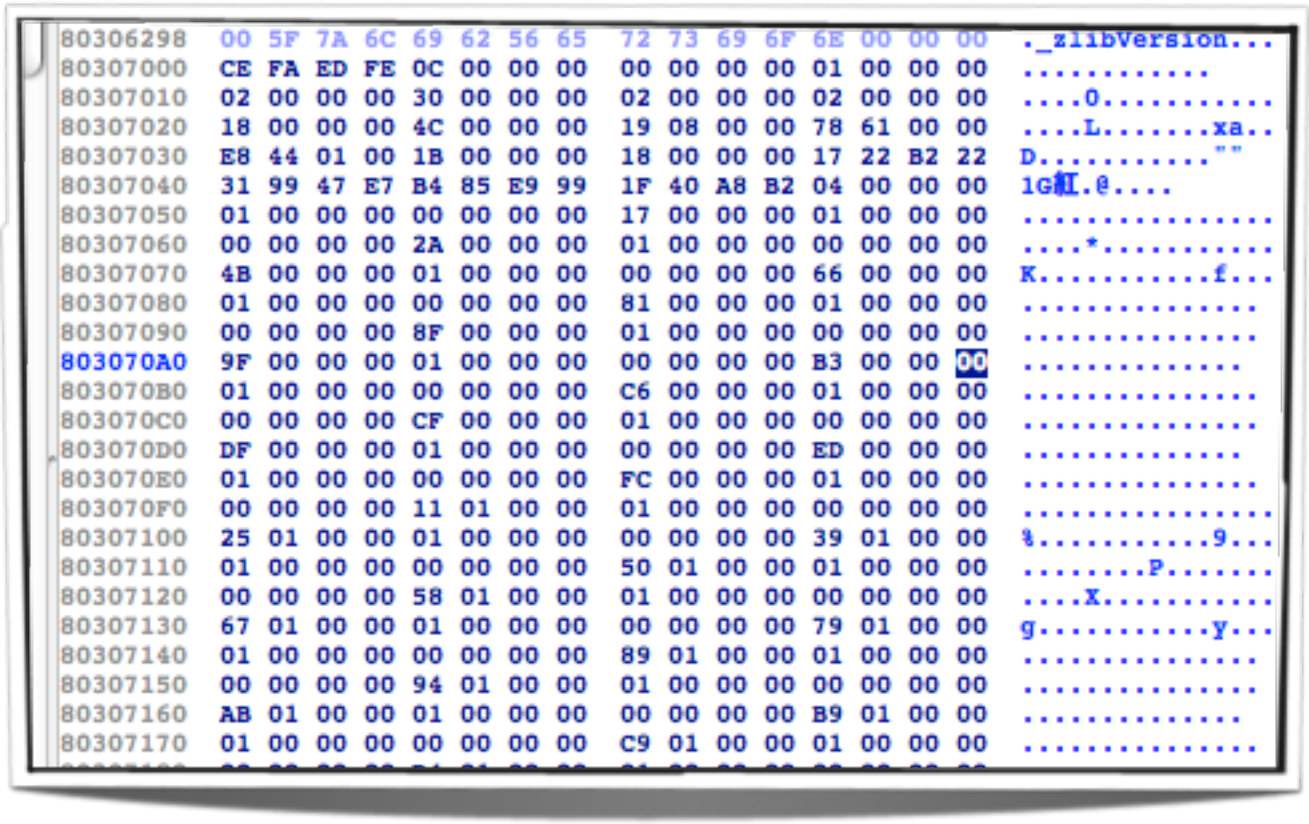
# Helping IDA - Kernel Extensions




- __PRELINK_TEXT seems to contains Mach-O files
- these files are loaded KEXT
- more than 130 of them
- IDA cannot handle this by default
- need a IDAPython script that finds all KEXT and adds their segments



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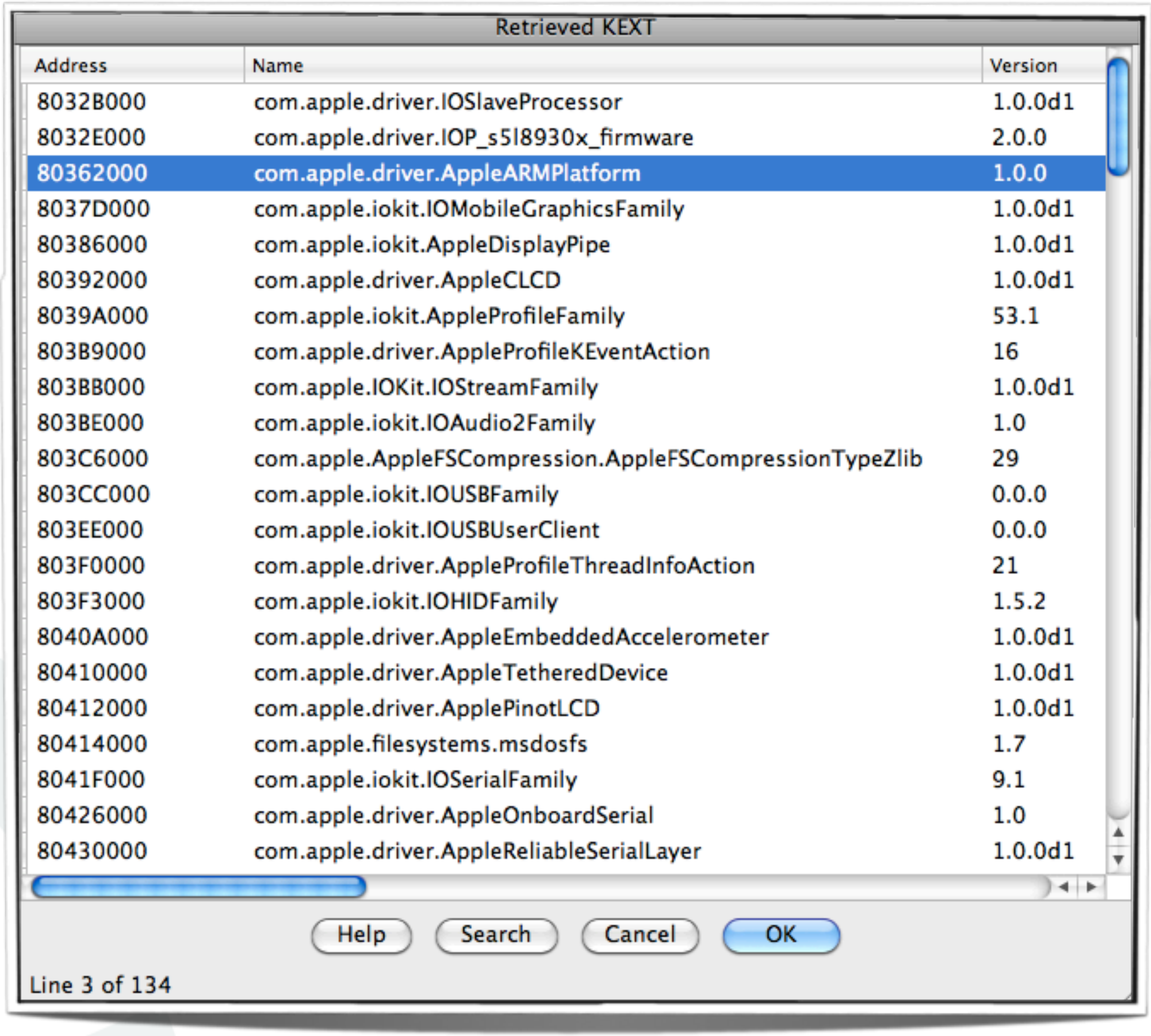
# Helping IDA - findAndMarkKEXT.py

- IDAPython script that
  - scans the __PRELINK_TEXT segment for Mach-O files
  - adds new segments for each KEXT section
  - marks code segments as THUMB code
  - handles __destructor and __constructor
  - adds kmod_info to sqlite database
  - shows a list of KEXT

# Helping IDA - findAndMarkKEXT.py



Retrieved KEXT

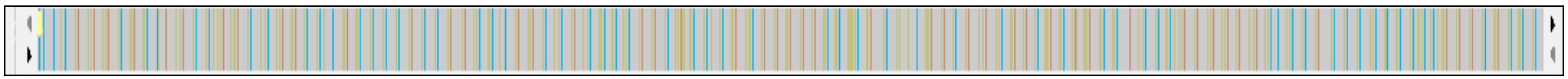
| Address | Name | Version |
|---|---|---|
| 8032B000 | com.apple.driver.IOSlaveProcessor | 1.0.0d1 |
| 8032E000 | com.apple.driver.IOP_s5l8930x_firmware | 2.0.0 |
| 80362000 | com.apple.driver.AppleARMPlatform | 1.0.0 |
| 8037D000 | com.apple.iokit.IOMobileGraphicsFamily | 1.0.0d1 |
| 80386000 | com.apple.iokit.AppleDisplayPipe | 1.0.0d1 |
| 80392000 | com.apple.driver.AppleCLCD | 1.0.0d1 |
| 8039A000 | com.apple.iokit.AppleProfileFamily | 53.1 |
| 803B9000 | com.apple.driver.AppleProfileKEventAction | 16 |
| 803BB000 | com.apple.IOKit.IOStreamFamily | 1.0.0d1 |
| 803BE000 | com.apple.iokit.IOAudio2Family | 1.0 |
| 803C6000 | com.apple.AppleFSCompression.AppleFSCompressionTypeZlib | 29 |
| 803CC000 | com.apple.iokit.IOUSBFamily | 0.0.0 |
| 803EE000 | com.apple.iokit.IOUSBUserClient | 0.0.0 |
| 803F0000 | com.apple.driver.AppleProfileThreadInfoAction | 21 |
| 803F3000 | com.apple.iokit.IOHIDFamily | 1.5.2 |
| 8040A000 | com.apple.driver.AppleEmbeddedAccelerometer | 1.0.0d1 |
| 80410000 | com.apple.driver.AppleTetheredDevice | 1.0.0d1 |
| 80412000 | com.apple.driver.ApplePinotLCD | 1.0.0d1 |
| 80414000 | com.apple.filesystems.msdosfs | 1.7 |
| 8041F000 | com.apple.iokit.IOSerialFamily | 9.1 |
| 80426000 | com.apple.driver.AppleOnboardSerial | 1.0 |
| 80430000 | com.apple.driver.AppleReliableSerialLayer | 1.0.0d1 |

Help Search Cancel OK

Line 3 of 134

# Functions and Code

- after performing previous fixups IDA is already a lot better



- however a lot of functions are not recognized
- script that scans for code outside of functions and creates functions
- many cases still require manual work

# IOKit Driver Classes (I)

- IOKit drivers are implemented in a subset of C++
- classes and their method tables can be found in kernelcache
- main kernel IOKit classes even come with symbols

```
8026A2A8 ; `vtable for'IOService
8026A2A8 __ZTV9IOService DCB     0              ; DATA XREF: IOResources::getWorkLoop(void)+C|o
8026A2A8                                        ; __text:off_801D1AE0|o ...
8026A2A9                 DCB     0
8026A2AA                 DCB     0
8026A2AB                 DCB     0
8026A2AC                 DCB     0
8026A2AD                 DCB     0
8026A2AE                 DCB     0
8026A2AF                 DCB     0
8026A2B0 off_8026A2B0    DCD sub_801D6F10+1     ; DATA XREF: IOService::IOService(void)+E|o
8026A2B0                                        ; __text:off_801D6A14|o ...
8026A2B4                 DCD __ZN9IOServiceD0Ev+1
8026A2B8                 DCD __ZNK8OSObject7releaseEi+1
8026A2BC                 DCD __ZNK8OSObject14getRetainCountEv+1
8026A2C0                 DCD __ZNK8OSObject6retainEv+1
8026A2C4                 DCD __ZNK8OSObject7releaseEv+1
8026A2C8                 DCD __ZNK8OSObject9serializeEP11OSSerialize+1
8026A2CC                 DCD __ZNK9IOService12getMetaClassEv+1
8026A2D0                 DCD __ZNK15OSMetaClassBase9isEqualToEPKS_+1
8026A2D4                 DCD __ZNK8OSObject12taggedRetainEPKv+1
8026A2D8                 DCD __ZNK8OSObject13taggedReleaseEPKv+1
8026A2DC                 DCD __ZNK8OSObject13taggedReleaseEPKvi+1
8026A2E0                 DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase3Ev+1
8026A2E4                 DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase4Ev+1
8026A2E8                 DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase5Ev+1
8026A2EC                 DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase6Ev+1
8026A2F0                 DCD __ZN15OSMetaClassBase25_RESERVEDOSMetaClassBase7Ev+1
8026A2F4                 DCD __ZN8OSObject4initEv+1
8026A2F8 off_8026A2F8    DCD __ZN9IOService4freeEv+1
8026A2F8                                        ; DATA XREF: IOMapper::free(void)+18|o
8026A2F8                                        ; IOUserClient::free(void)+1E|o ...
8026A2FC                 DCD __ZNK15IORegistryEntry12copyPropertyEPKcPK15IORegistryPlanem+1
```

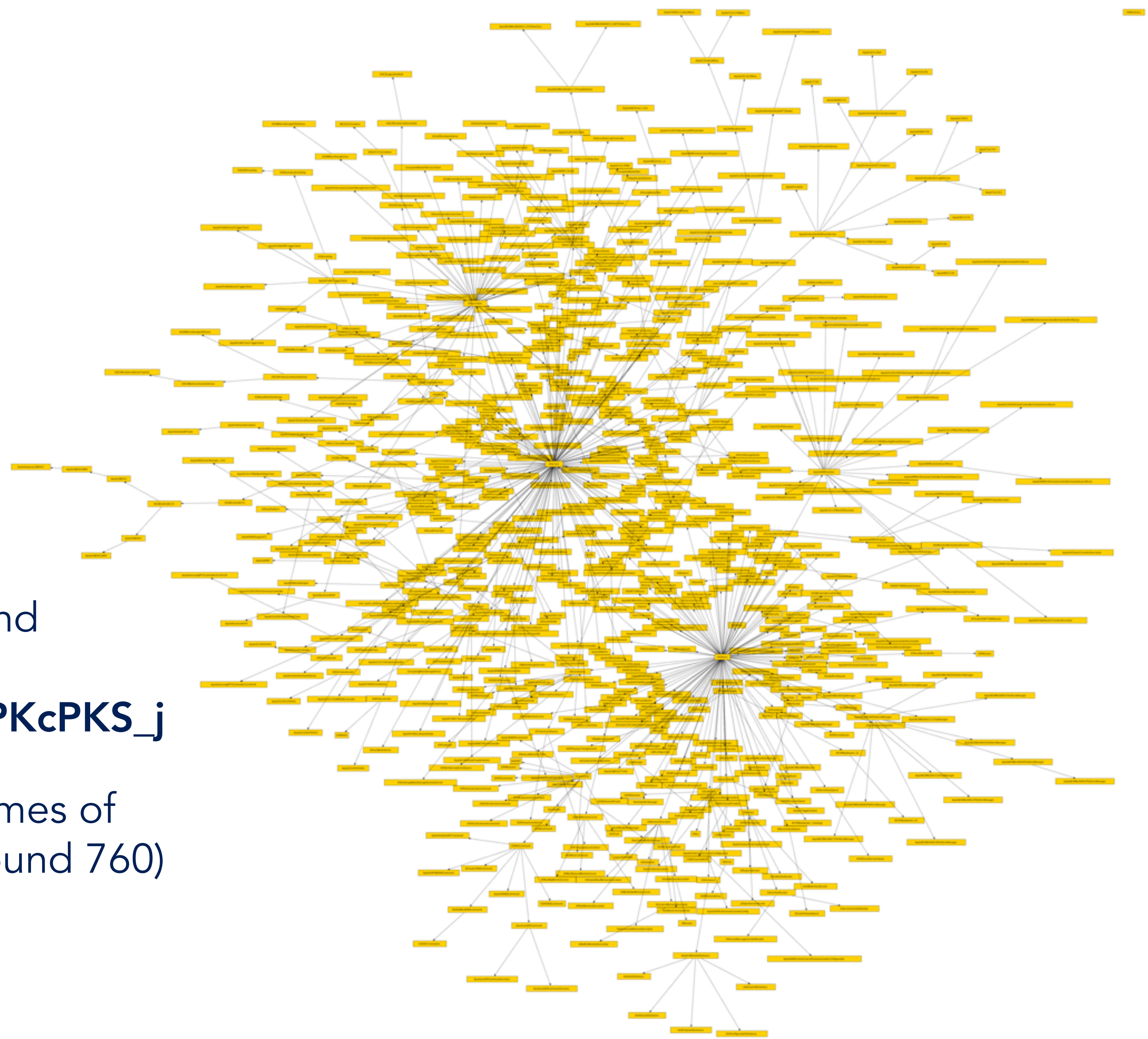
# IOKit Driver Classes (II) - MetaClass

- most iOS IOKit classes come without symbols
- however IOKit defines for almost all classes a so called MetaClass
- MetaClass contains runtime information about the original object
- constructors of MetaClass‘es leak name and parent objects

```
801D5A00 ; IOService::MetaClass::MetaClass(void)
801D5A00                 EXPORT __ZN9IOService9MetaClassC1Ev
801D5A00 __ZN9IOService9MetaClassC1Ev              ; CODE XREF: sub_801D5A28+1E↓p
801D5A00                 PUSH            {R4,R7,LR}
801D5A02                 ADD             R7, SP, #4
801D5A04                 MOVS            R3, #0x50 ; 'P'
801D5A06                 LDR             R1, =aIoservice ; "IOService"
801D5A08                 LDR             R2, =__ZN15IORegistryEntry10gMetaClassE ; IOR
801D5A0A                 LDR.W           R12, =(__ZN11OSMetaClassC2EPKcPKS_j+1)
801D5A0E                 MOV             R4, R0
801D5A10                 BLX             R12 ; OSMetaClass::OSMetaClass(char  const*,O
801D5A12                 LDR             R3, =off_8026A25C
801D5A14                 STR             R3, [R4]
801D5A16                 POP             {R4,R7,PC}
801D5A16 ; End of function IOService::MetaClass::MetaClass(void)
```

**R1 = Object Name**
**R2 = Parent’s MetaClass**
**R3 = Methods of MetaClass**

# IOKit Object Hierarchy - Full View

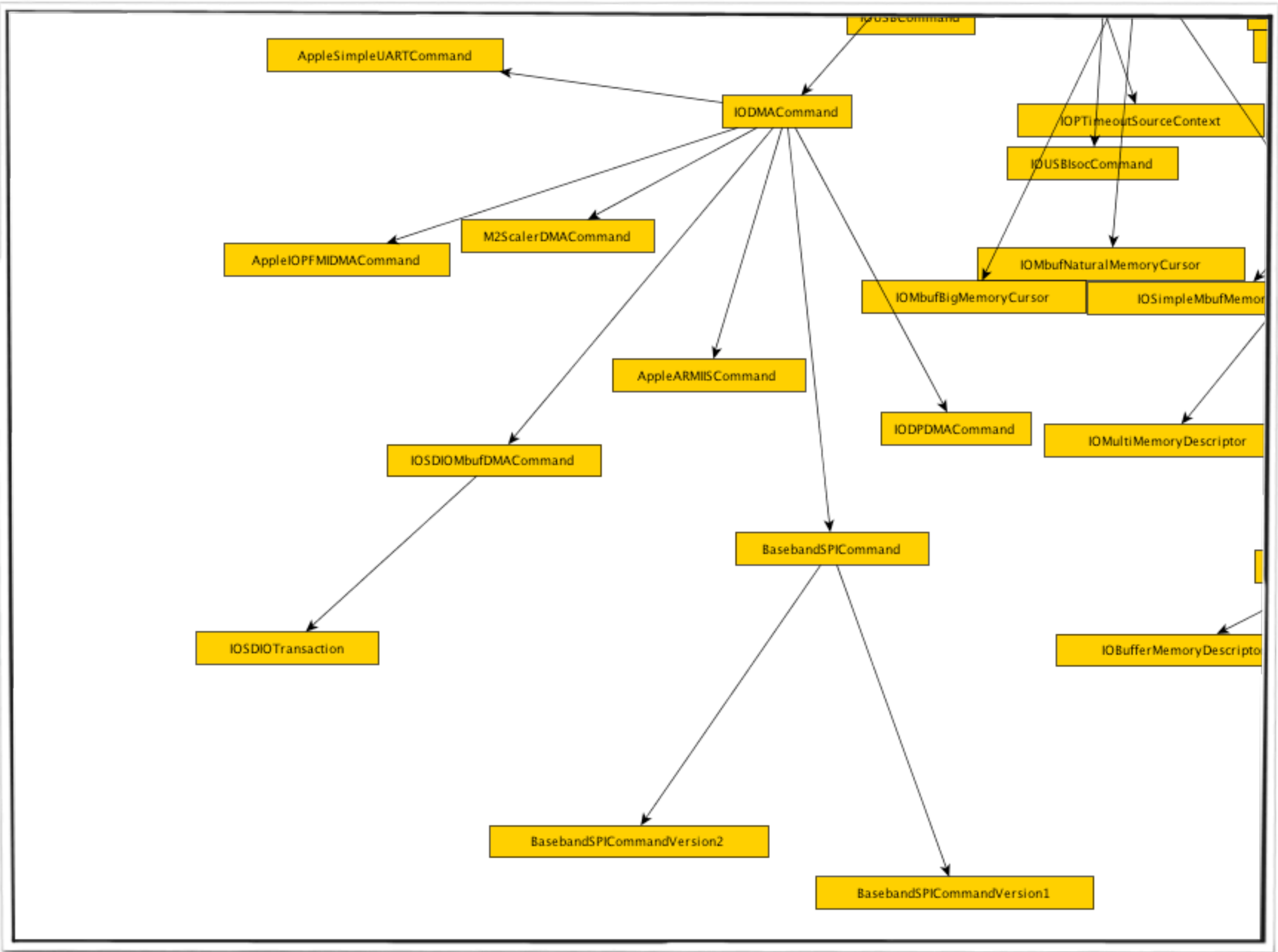


all MetaClasses can be found through xrefs of
**__ZN11OSMetaClassC2EPKcPKS_j**

allows to determine the names of almost all IOKit classes (around 760)

and allows to build the IOKit object hierarchy tree

# IOKit Object Hierachy - Zoomed



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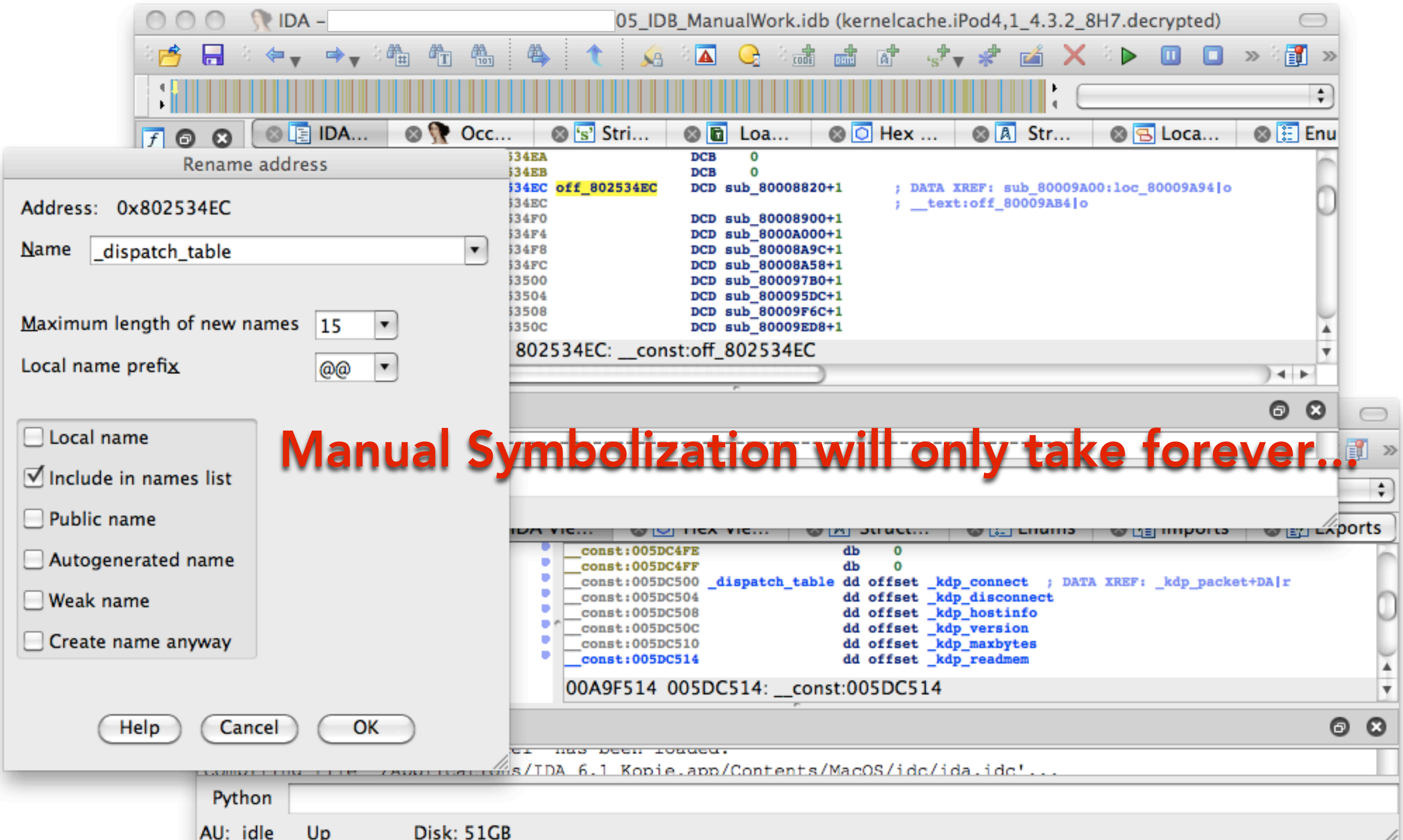
# Part IV

iOS Kernel Where Are your Symbols?

# iOS Kernel Symbols ???

- iOS kernel contains around 4000 symbols
- but more than 30000 functions and many more variables
- Apple won‘t help us (at least willingly)
- need to combine several methods to get more symbols

# Kernel Symbols - Manual Symbolization




**Manual Symbolization will only take forever...**

# Little Helpers

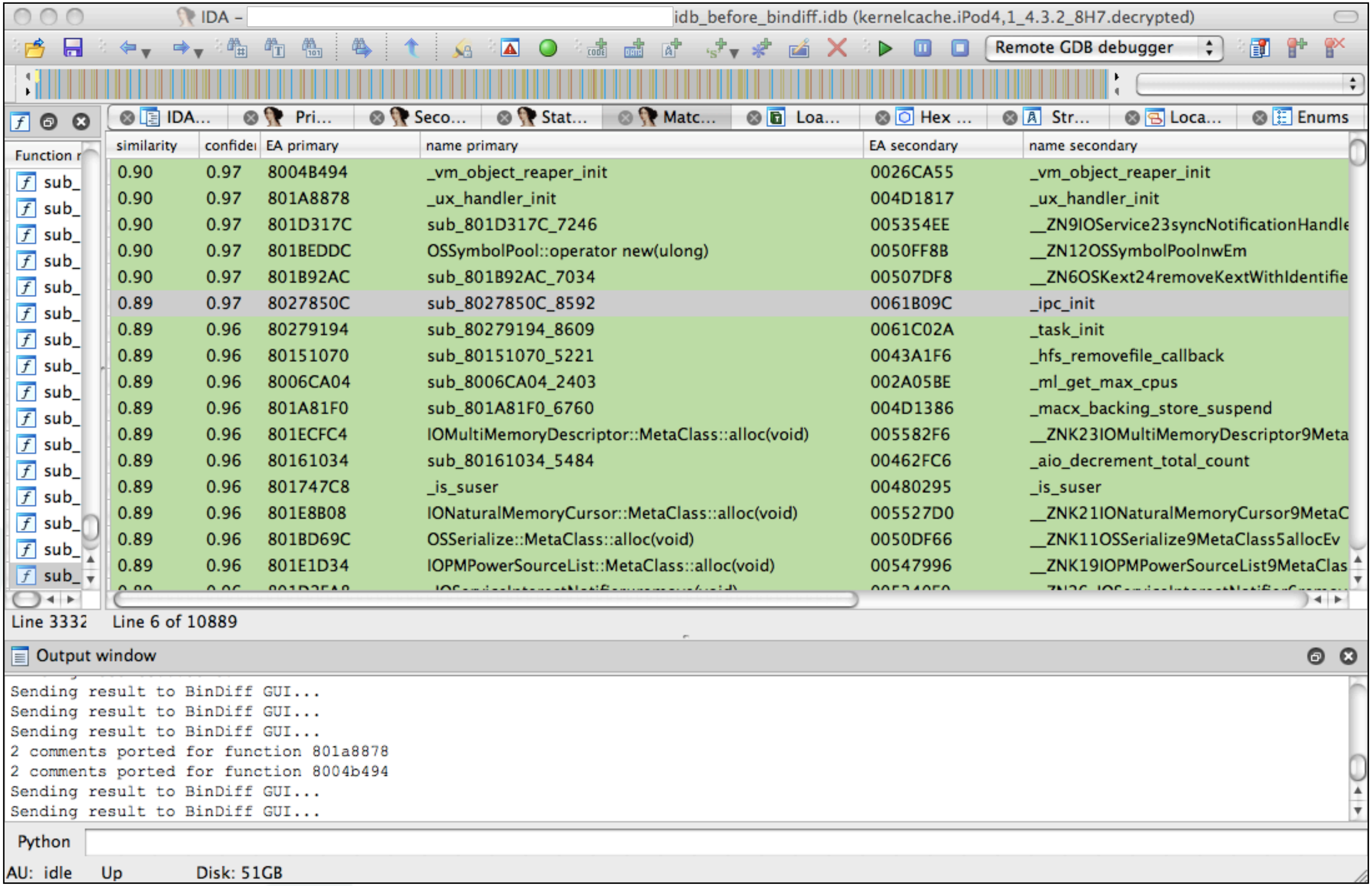
- porting all symbols manually will take forever
- we can automate porting common structs
    - pointer list
    - arrays of structs
- special helper for porting sysctl_set

# Zynamic's BinDiff

- Zynamic's BinDiff is a great tool
  - not only to find differences in binaries
  - but also to port symbols
  - even cross platform

- Using BinDiff to diff OS X kernel against iOS 4.3.2
  - works but initally gives bad results
  - other ways to add symbols are required
  - BinDiff can then be repeated

# Zynamic's BinDiff - Demo (I)





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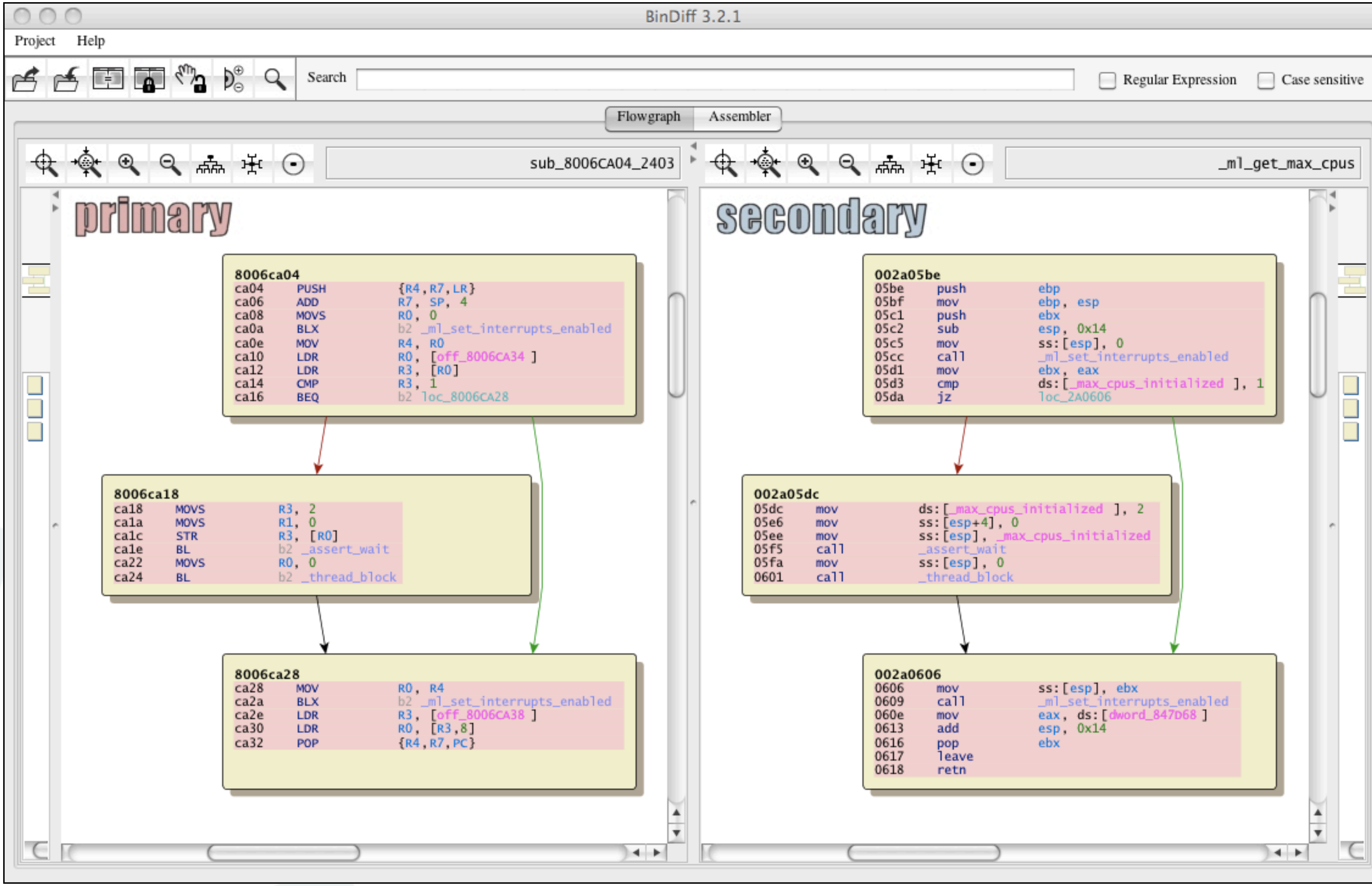
# Zynamic's BinDiff - Demo (II)



# Using IOKit Class Hierarchy for Symbols

- most IOKit classes are without symbols
- however they are derived from base IOKit classes with symbols
- we can create symbols for overloaded methods

```
Some Methods from AppleBasebandUserClient

__const:8043A270     DCD __ZN9IOService12tellChangeUpEm+1
__const:8043A274     DCD __ZN9IOService16allowPowerChangeEm+1
__const:8043A278     DCD __ZN9IOService17cancelPowerChangeEm+1
__const:8043A27C     DCD __ZN9IOService15powerChangeDoneEm+1
__const:8043A280     DCD loc_80437D80+1
__const:8043A284     DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1
__const:8043A288     DCD __ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1
__const:8043A28C     DCD __ZN12IOUserClient12initWithTaskEP4taskPvm+1
__const:8043A290     DCD sub_80437D5C+1
__const:8043A294     DCD __ZN12IOUserClient10clientDiedEv+1
__const:8043A298     DCD __ZN12IOUserClient10getServiceEv+1
__const:8043A29C     DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1
__const:8043A2A0     DCD __ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

# Using IOKit Class Hierarchy for Symbols

- n
- h
- w

Same Methods from IOUserClient

```
__const:80270100      DCD __ZN9IOService12tellChangeUpEm+1
__const:80270104      DCD __ZN9IOService16allowPowerChangeEm+1
__const:80270108      DCD __ZN9IOService17cancelPowerChangeEm+1
__const:8027010C      DCD __ZN9IOService15powerChangeDoneEm+1
__const:80270110      DCD __ZN12IOUserClient14externalMethodEjP25IOExternalMet...
__const:80270114      DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1
__const:80270118      DCD __ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1
__const:8027011C      DCD __ZN12IOUserClient12initWithTaskEP4taskPvm+1
__const:80270120      DCD __ZN12IOUserClient11clientCloseEv+1
__const:80270124      DCD __ZN12IOUserClient10clientDiedEv+1
__const:80270128      DCD __ZN12IOUserClient10getServiceEv+1
__const:8027012C      DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1
__const:80270130      DCD __ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

Some M

```
__cons
__cons
__const:8043A278      DCD __ZN9IOService17cancelPowerChangeEm+1
__const:8043A27C      DCD __ZN9IOService15powerChangeDoneEm+1
__const:8043A280      DCD loc_80437D80+1
__const:8043A284      DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1
__const:8043A288      DCD __ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1
__const:8043A28C      DCD __ZN12IOUserClient12initWithTaskEP4taskPvm+1
__const:8043A290      DCD sub_80437D5C+1
__const:8043A294      DCD __ZN12IOUserClient10clientDiedEv+1
__const:8043A298      DCD __ZN12IOUserClient10getServiceEv+1
__const:8043A29C      DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1
__const:8043A2A0      DCD __ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

# Using IOKit Class Hierarchy for Symbols

➡ borrowing from the parent class we get

- AppleBasebandUserClient::externalMethod(unsigned int, IOExternalMethodArguments *, IOExternalMethodDispatch *, OSObject *, void *)
- AppleBasebandUserClient::clientClose(void)

```
Symbolized Methods from AppleBasebandUserClient

__const:8043A270      DCD __ZN9IOService12tellChangeUpEm+1
__const:8043A274      DCD __ZN9IOService16allowPowerChangeEm+1
__const:8043A278      DCD __ZN9IOService17cancelPowerChangeEm+1
__const:8043A27C      DCD __ZN9IOService15powerChangeDoneEm+1
__const:8043A280      DCD __ZN23AppleBasebandUserClient14externalMethodEjP25IOExtern...
__const:8043A284      DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmy+1
__const:8043A288      DCD __ZN12IOUserClient12initWithTaskEP4taskPvmP12OSDictionary+1
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__const:8043A298      DCD __ZN12IOUserClient10getServiceEv+1
__const:8043A29C      DCD __ZN12IOUserClient24registerNotificationPortEP8ipc_portmm+1
__const:8043A2A0      DCD __ZN12IOUserClient24getNotificationSemaphoreEmPP9semaphore+1
```

# Exporting Symbols

- IDA cannot export symbols back into Mach-O files
- no easy way to use symbols with GDB
- little helper IDAPython symbol exporter was developed

# Part V

## iOS Kernel Attack Surface

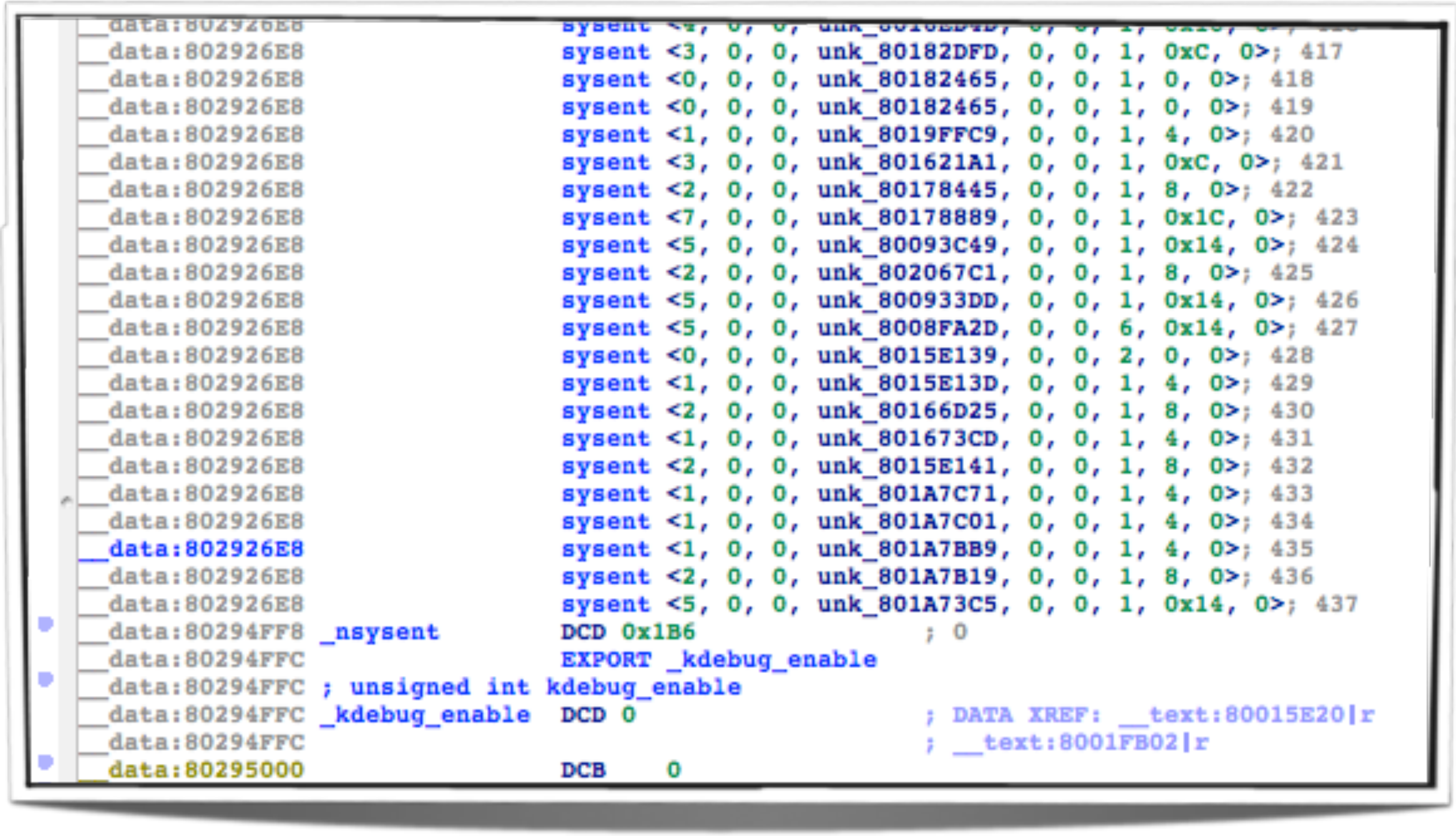
# iOS Kernel Attack Surface

- **simple rule** you can only attack the kernel where it interfaces with
  - user space code
  - the network
  - the hardware
  - the filesystem

# Attacking from User Space - Syscalls

- syscalls are directly callable from user space
- for all OS X syscalls source code is available
- however iOS has 8 additional syscalls
- after syscall table is found syscall handlers can be audited

# Finding and Marking the Syscall Table




- Apple removed symbols _***sysent*** and _***nsysent***
- however the syscall table is still easy to find
  - ➡ _***nsysent*** = _***kdebug_enable*** - 4
  - ➡ _***sysent*** = _***nsysent*** - (*_***nsysent*** * 36)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# Attacking from User Space - Mach-Traps

- Mach-traps are the “syscalls“ of the mach subsystem
- harder to find because no symbols nearby
- best solution is to search for string references
- interesting string is “kern_invalid mach trap“
- function “kern_invalid“ will be repeatedly referenced from mach trap handler table

# Attacking through Network Protocols

- network protocols are added by **net_add_proto()**
- script scanning for xrefs can find all defined network protocols
- dumping content of **protosw** and **domain** structures
- interesting for vulnerability research are
  - setsockopt handler
  - network packet parser

# Attacking through Network Protocols (II)

```
main kernel
-----------
net_add_proto() call at 800eb3c6
type: 0      - protocol: 00000000 - domain: internet

type: DGRAM  - protocol: 00000011 - domain: internet
  -> setsockopt handler at 800f8e95
  -> packet parser at 800f9001

type: STREAM - protocol: 00000006 - domain: internet
  -> setsockopt handler at 800f7a95
  -> packet parser at 800ef249

type: RAW    - protocol: 000000ff - domain: internet
  -> setsockopt handler at 800edfc1
  -> packet parser at 800ee28d

type: RAW    - protocol: 00000001 - domain: internet
  -> setsockopt handler at 800edfc1
  -> packet parser at 800e8fa5
```

# Attacking through Network Protocols (III)

```
net_add_proto() call at 8027ce2c
type: STREAM - protocol: 00000000 - domain: unix
  -> setsockopt handler at 8019e7b5

type: DGRAM  - protocol: 00000000 - domain: unix
  -> setsockopt handler at 8019e7b5


com.apple.nke.ppp
-----------------
net_add_proto() call at 808179ca
type: RAW    - protocol: 00000001 - domain: PPP


com.apple.nke.pptp
------------------
net_add_proto() call to complex for this script at 80a84774
---

com.apple.nke.lttp
------------------
net_add_proto() call to complex for this script at 8081f714
```



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# Attacking through Devices

- character and block devices added by the functions
    - **cdevsw_add()**
    - **cdevsw_add_with_bdev()**
    - **bdevsw_add()**
- script scanning for xrefs can find all defined devices
- interesting for vulnerability research are the ioctl handlers

# Attacking through Devices (II)

```
com.apple.driver.AppleOnboardSerial
-----------------------------------
_cdevsw_add() call at 8042842a
  -> ioctl handler at 804282e1


com.apple.driver.AppleReliableSerialLayer
-----------------------------------------
_cdevsw_add() call at 8043373e
  -> ioctl handler at 80432525


com.apple.iokit.IO80211Family
-----------------------------
_cdevsw_add() call at 8057252c
  -> ioctl handler at 80571ab9


com.apple.driver.AppleSerialMultiplexer
---------------------------------------
_cdevsw_add() call at 80456e26
  -> ioctl handler at 80455d2d

_cdevsw_add() call at 8045cbd4
  -> ioctl handler at 8018243d
```

```
com.company.driver.modulename
-----------------------------
_cdevsw_add() call at 80490a08
  -> ioctl handler at 8049184d

_cdevsw_add() call at 8049118c
  -> ioctl handler at 8049184d

_bdevsw_add() call at 804909ee
  -> ioctl handler at 80492201

_bdevsw_add() call at 80491172
  -> ioctl handler at 80492201


com.apple.iokit.IOCryptoAcceleratorFamily
-----------------------------------------
_cdevsw_add() call at 805410d0
  -> ioctl handler at 80540529

_cdevsw_add() call at 80542014
  -> ioctl handler at 805419a9
```

# Attacking from User-Land: Sysctl

- sysctl is interface that gives user-land access to kernel variables
- sysctl variables get added by the functions
  - **sysctl_register_oid()**
  - **sysctl_register_set() / sysctl_register_all()**
- script scanning for xrefs can find all defined sysctl variables
- interesting for vulnerability research are
  - sysctl handlers
  - writeable variables

# Dumping List of Sysctl Handlers

```
main kernel
-----------
sysctl handler at 8017a805 (sub_8017A804)
sysctl handler at 8017c015 (_sysctl_handle_quad)
sysctl handler at 8017ae21 (sub_8017AE20)
sysctl handler at 80089625 (sub_80089624)
sysctl handler at 8017b2b1 (sub_8017B2B0)
sysctl handler at 8019ce29 (sub_8019CE28)
sysctl handler at 8017c231 (sub_8017C230)
sysctl handler at 8017e23d (sub_8017E23C)
sysctl handler at 8017a1b5 (sub_8017A1B4)
sysctl handler at 8017a441 (sub_8017A440)
sysctl handler at 800f4445 (sub_800F4444)
sysctl handler at 8011cc49 (sub_8011CC48)
sysctl handler at 8017a84d (sub_8017A84C)
sysctl handler at 8008c051 (sub_8008C050)
sysctl handler at 8017e1b9 (sub_8017E1B8)
...
```

```
com.apple.iokit.AppleProfileFamily
----------------------------------
sysctl handler at 8039ef51 (sub_8039EF50)

com.apple.driver.AppleD1815PMU
------------------------------
sysctl handler at 807b513d

com.apple.iokit.IOUSBFamily
---------------------------
sysctl handler at 803cd165 (sub_803CD164)

com.apple.iokit.IOUSBMassStorageClass
-------------------------------------
sysctl handler at 808dd019

com.apple.driver.AppleARMPlatform
---------------------------------
sysctl handler at 8036ecf1 (sub_8036ECF0)

com.apple.iokit.IOSCSIArchitectureModelFamily
---------------------------------------------
sysctl handler at 80794cd1 (sub_80794CD0)
```

# Dumping Writeable Sysctl Variables

```
com.apple.iokit.IOSCSIArchitectureModelFamily
---------------------------------------------
sysctl_register_oid() call at 80794e1c - struct at 80796a88
  -> sysctl name:    debug.SCSIArchitectureModel
  -> sysctl handler: 80794cd1 (sub_80794CD0)

sysctl_register_oid() call at 80794ef0 - struct at 80796a88
  -> sysctl name:    debug.SCSIArchitectureModel
  -> sysctl handler: 80794cd1 (sub_80794CD0)

com.apple.driver.AppleProfileThreadInfoAction
---------------------------------------------
sysctl_register_oid() call at 803f1c6e - struct at 803f2700
  -> sysctl name:    appleprofile.actions.threadinfo.default_continuous_buffer_size
  -> sysctl handler: 8017bfb9 (_sysctl_handle_int)
  -> var address:    803f2760 00000000

sysctl_register_oid() call at 803f1c72 - struct at 803f2730
  -> sysctl name:    appleprofile.actions.threadinfo.max_memory
  -> sysctl handler: 8017bfb9 (_sysctl_handle_int)
  -> var address:    803f281c 00000000

com.apple.security.sandbox
--------------------------
sysctl_register_oid() call at 8093647a - struct at 8093b57c
  -> sysctl name:    security.mac.sandbox.debug_mode
  -> sysctl handler: 8017bfb9 (_sysctl_handle_int)
  -> var address:    8093b548 00000000
```

# Attacking from User-Land: IOKit Drivers

- IOKit drivers can also talk with user-space through their objects
- all classes derived from IOUserClient can communicate with kernel
- script can list all classes derived from IOUserClient
- e.g. user-space baseband method calls will go through this method
    - AppleBasebandUserClient::externalMethod(unsigned int, IOExternalMethodArguments *, IOExternalMethodDispatch *, OSObject *, void *)

# Part VI

## iOS Kernel Debugging

# iOS Kernel Debugging

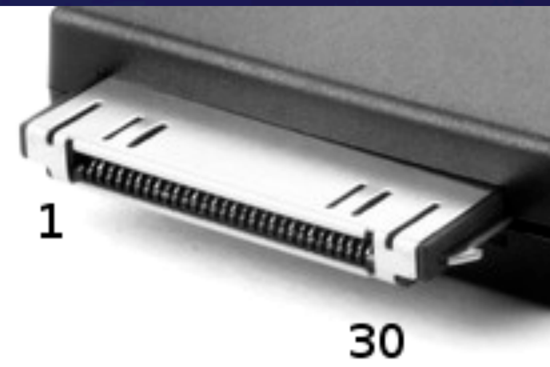
- no support for kernel level debugging by iOS SDK
- developers are not supposed to do kernel work anyway
- strings inside kernelcache indicate the presence of debugging code
- boot arg “debug” is used
- and code of KDP seems there

# KDP on iOS 4

- the OS X kernel debugger KDP is obviously inside the iOS kernel
- but KDP does only work via ethernet or serial interface
- how to communicate with KDP?
- the iPhone / iPad do not have ethernet or serial, do they?

# iPhone Dock Connector (Pin-Out)

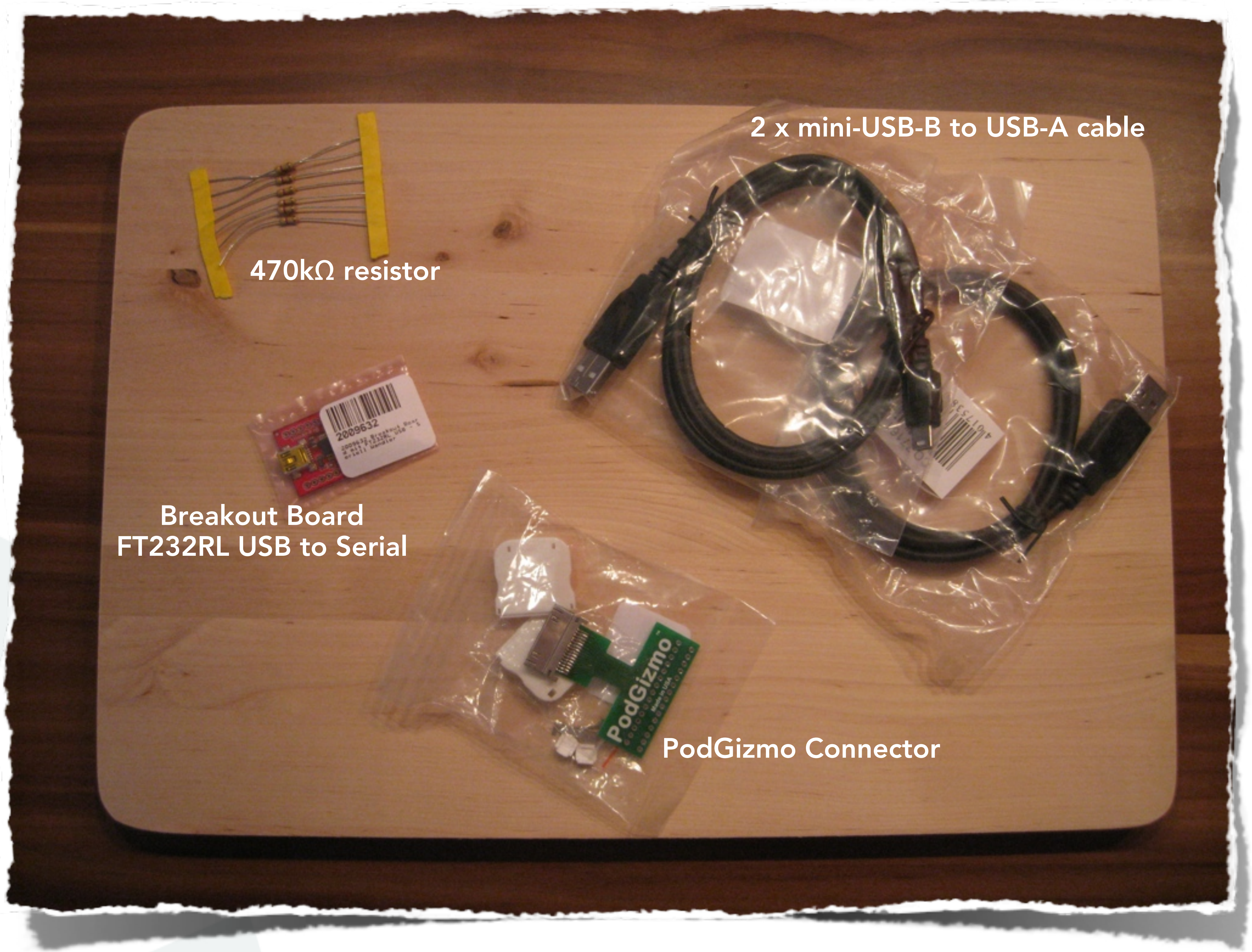
| PIN | Desc |
|---|---|
| 1,2 | GND |
| 3 | Line Out - R+ |
| 4 | Line Out - L+ |
| 5 | Line In - R+ |
| 6 | Line In - L+ |
| 8 | Video Out |
| 9 | S-Video CHR Output |
| 10 | S-Video LUM Output |
| 11 | GND |
| 12 | Serial TxD |
| 13 | Serial RxD |
| 14 | NC |
| 15,16 | GND |
| 17 | NC |
| 18 | 3.3V Power |
| 19,20 | 12V Firewire Power |
| 21 | Accessory Indicator/Serial Enable |
| 22 | FireWire Data TPA- |
| 23 | USB Power 5 VDC |
| 24 | FireWire Data TPA+ |
| 25 | USB Data - |
| 26 | FireWire Data TPB- |
| 27 | USB Data + |
| 28 | FireWire Data TPB+ |
| 29,30 | GND |




iPhone Dock Connector has PINs for

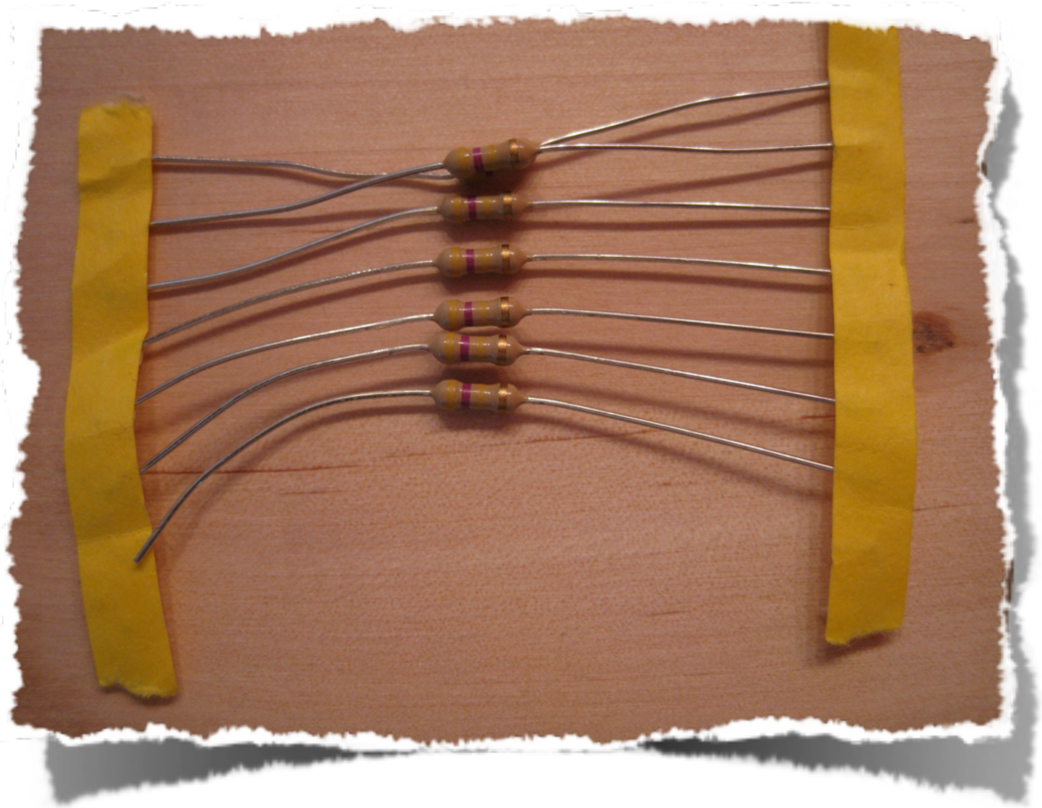
- Line Out / In
- Video Out
- USB
- FireWire
- Serial

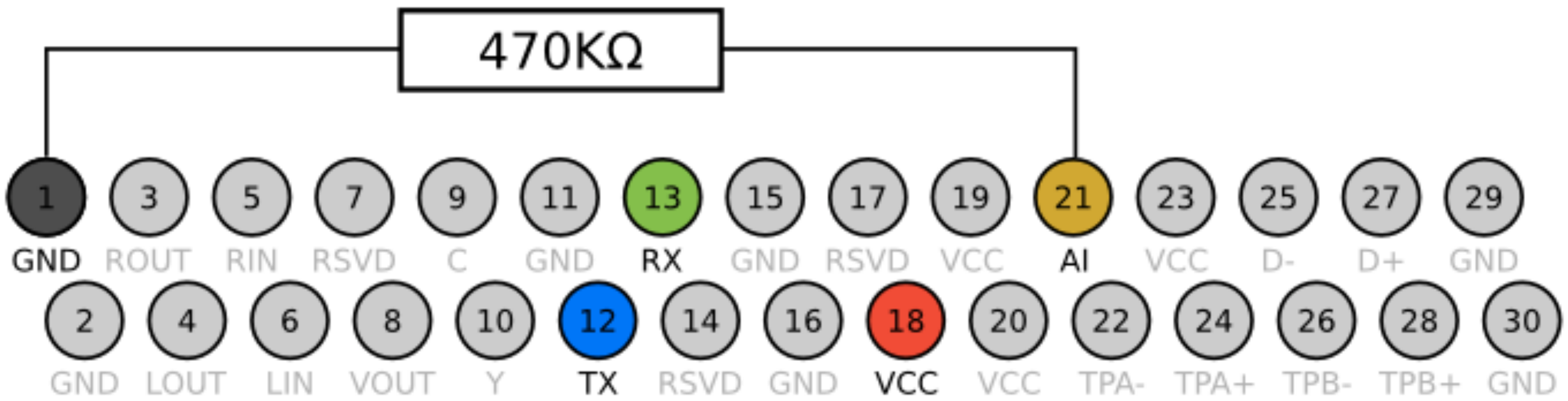
# USB Serial to iPhone Dock Connector



# Ingredients (I)

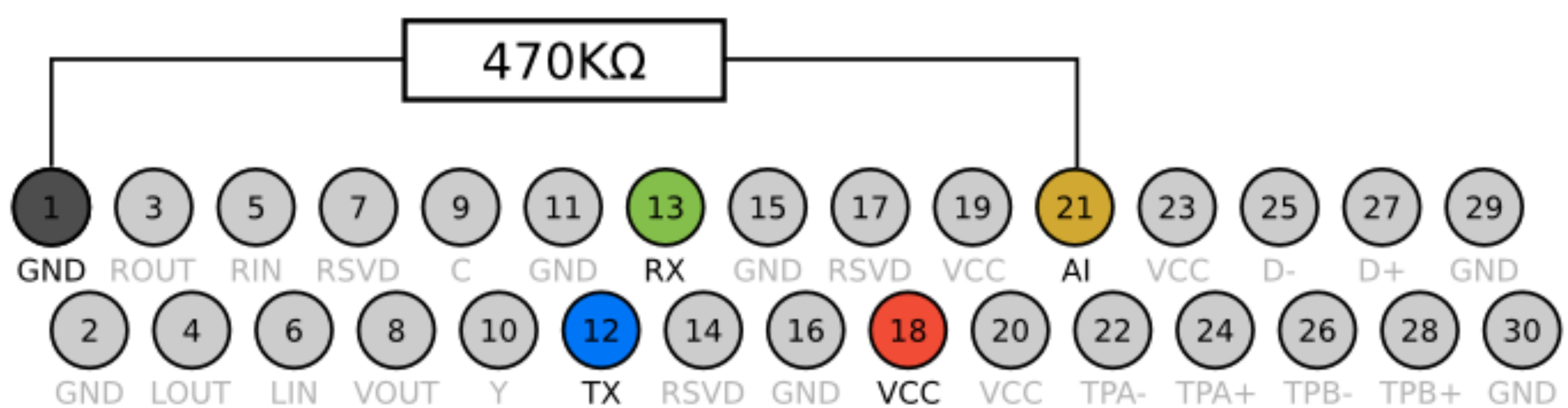
- 470 kΩ resistor
- used to bridge pin 1 and 21
- activates the UART
- costs a few cents





# Ingredients (II)

- PodBreakout
- easy access to dock connector pins
- some revisions have reversed pins
- even I was able to solder this
- about 12 EUR



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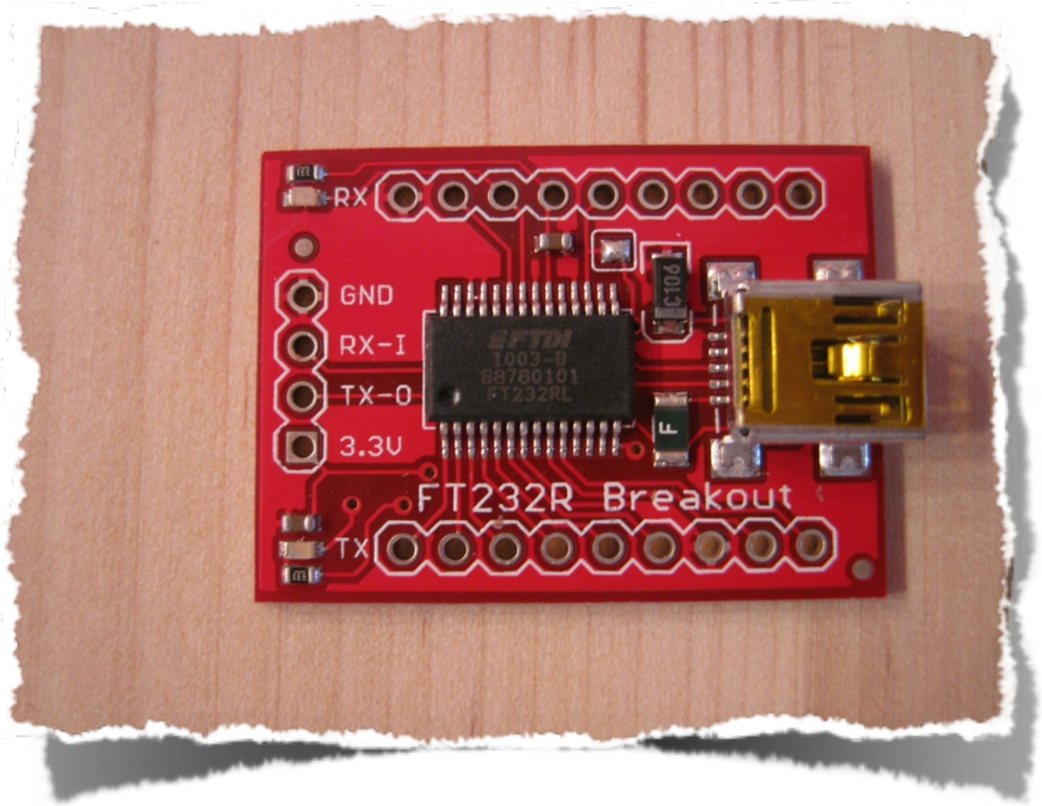
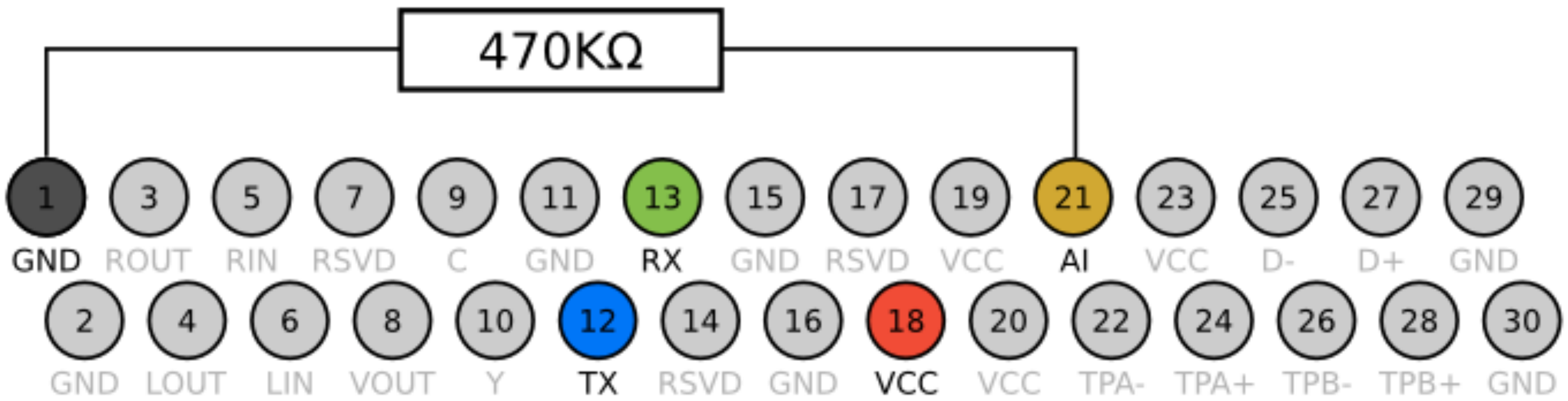
# Ingredients (III)

- FT232RL Breakout Board
- USB to Serial Convertor
- also very easy to solder
- about 10 EUR



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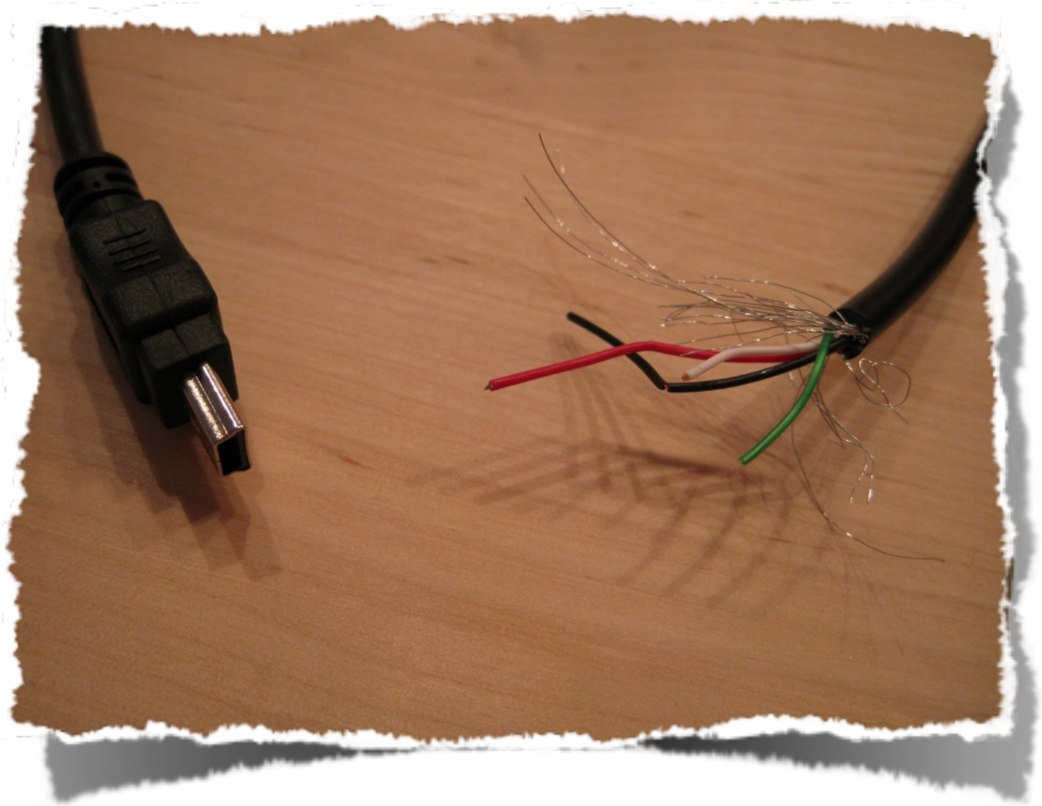
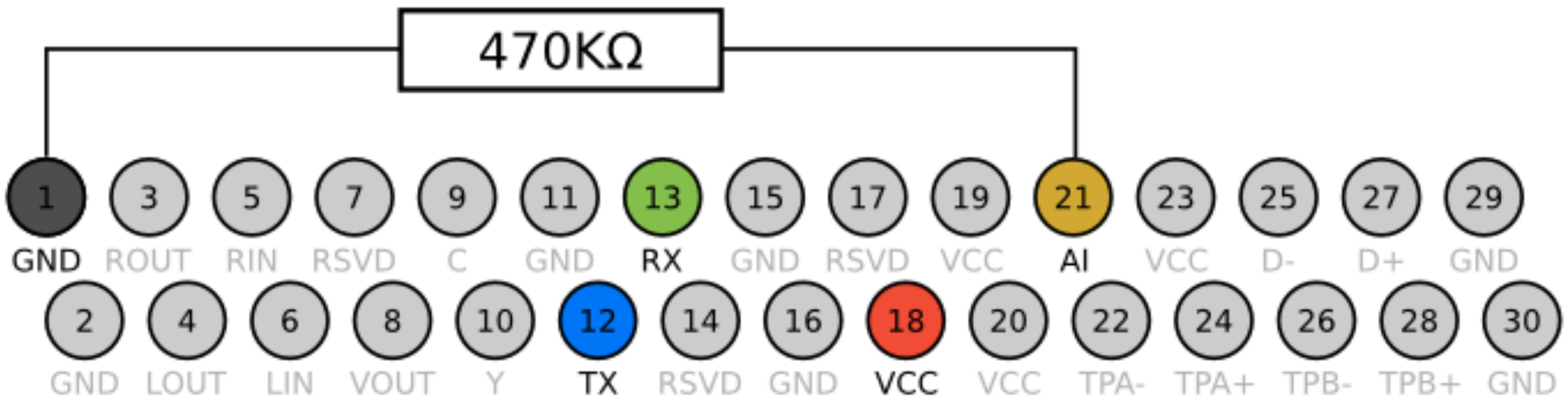
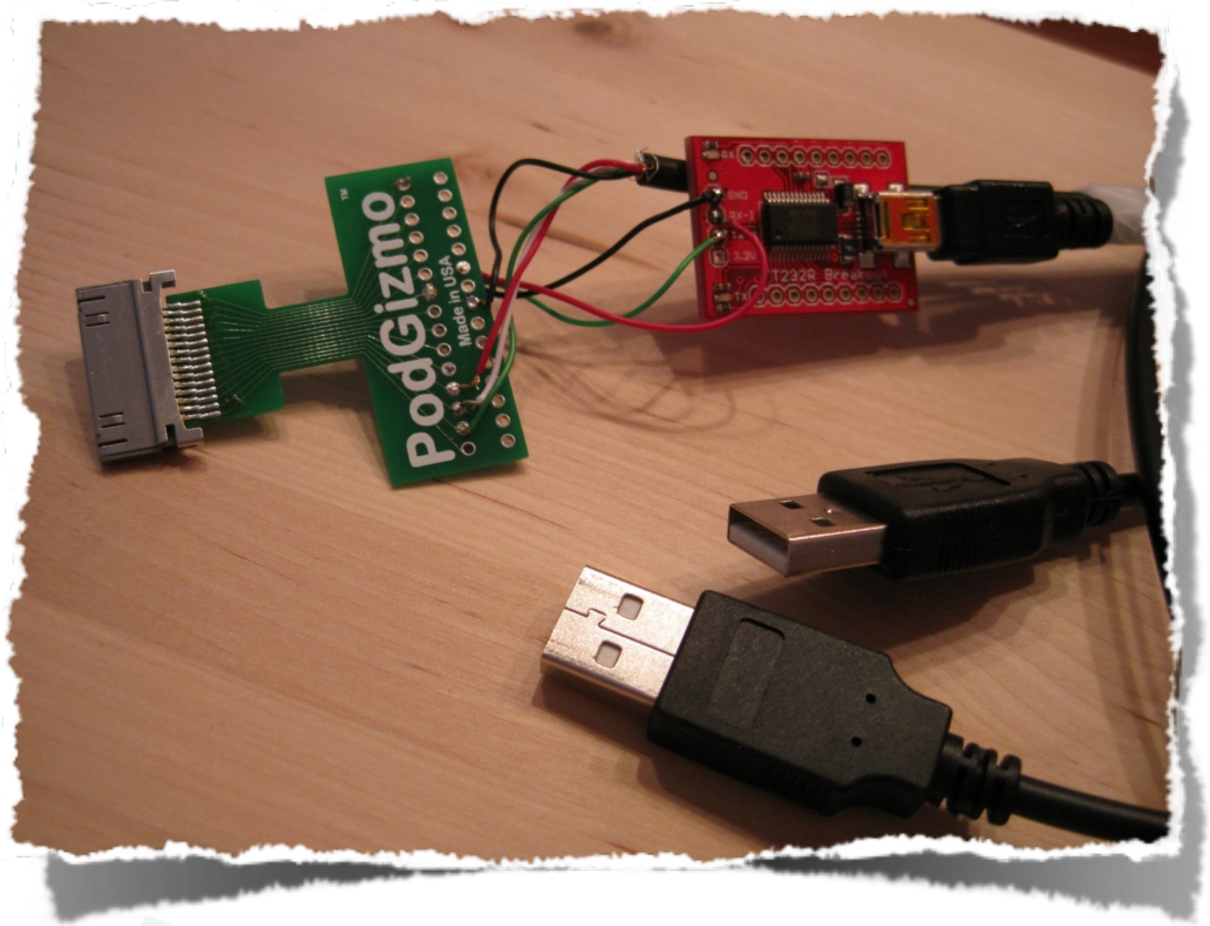
# Ingredients (IV)

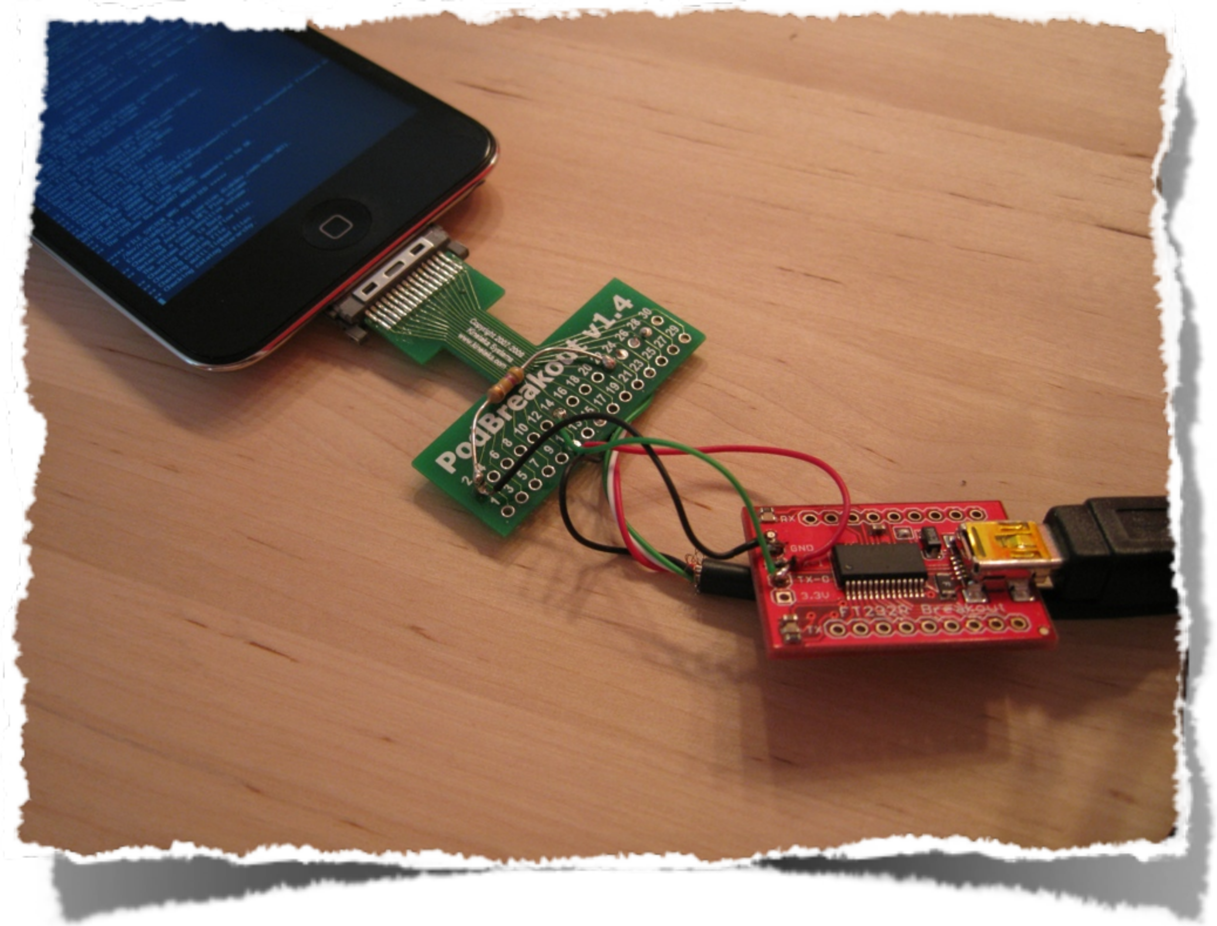
- USB cables
- type A -> mini type B
- provides us with wires and connectors
- costs a few EUR





# Final USB and USB Serial Cable




- attaching a USB type A connector to the USB pins is very usefull
- we can now do SSH over USB
- and kernel debug via serial line at the same time

# GDB and iOS KDP

- GDB comming with the iOS SDK has ARM support
- it also has KDP support
- however it can only speak KDP over UDP
- KDP over serial is not supported

# KDP over serial

- KDP over serial is sending fake ethernet UDP over serial
- SerialKDPProxy by David Elliott is able to act as serial/UDP proxy

```
$ SerialKDPProxy /dev/tty.usbserial-A600exos
Opening Serial
Waiting for packets, pid=362
^@AppleS5L8930XIO::start: chip-revision: C0
AppleS5L8930XIO::start: PIO Errors Enabled
AppleARMPL192VIC::start: _vicBaseAddress = 0xccaf5000
AppleS5L8930XGPIOIC::start: gpioicBaseAddress: 0xc537a000
AppleARMPerformanceController::traceBufferCreate: _pcTraceBuffer: 0xcca3a000 ...
AppleS5L8930XPerformanceController::start: _pcBaseAddress: 0xccb3d000
AppleARMPerformanceController configured with 1 Performance Domains
AppleS5L8900XI2SController::start: i2s0 i2sBaseAddress: 0xcb3ce400 i2sVersion: 2
...
AppleS5L8930XUSBPhy::start : registers at virtual: 0xcb3d5000, physical: 0x86000000
AppleVXD375 - start (provider 0x828bca00)
AppleVXD375 - compiled on Apr  4 2011 10:19:48
```

# Activating KDP on the iPhone

- KDP is only activated if the boot-arg "debug" is set
- boot-args can be set with special version of redsn0w / syringe
- or faked with a custom kernel
- patch your kernel to get into KDP anytime (e.g. breakpoint in unused syscall)

| Name | Value | Meaning |
|---|---|---|
| DB_HALT | 0x01 | Halt at boot-time and wait for debugger attach. |
| DB_KPRT | 0x08 | Send kernel debugging kprintf output to serial port. |
| ... | ... | Other values might work but might be complicated to use. |

# Using GDB...

```
$ /Developer/Platforms/iPhoneOS.platform/Developer/usr/bin/gdb -arch armv7 \
        kernelcache.iPod4,1_4.3.2_8H7.symbolized
GNU gdb 6.3.50-20050815 (Apple version gdb-1510) (Fri Oct 22 04:12:10 UTC 2010)
...
(gdb) target remote-kdp
(gdb) attach 127.0.0.1
Connected.
(gdb) i r
r0             0x00
r1             0x11
r2             0x00
r3             0x11
r4             0x00
r5             0x8021c814    -2145269740
r6             0x00
r7             0xc5a13efc    -979288324
r8             0x00
r9             0x27     39
r10            0x00
r11            0x00
r12            0x802881f4    -2144828940
sp             0xc5a13ee4    -979288348
lr             0x8006d971    -2147034767
pc             0x8006e110    -2147032816
```

# Thank you for listening...

QUESTIONS ?

# Links

- xpwntool - https://github.com/iH8sn0w/xpwn
- SerialKDPProxy - http://tgwbd.org/svn/Darwin/SerialKDPProxy/trunk/
- IDA Scripts used during presentation soon at - http://antid0te.com/idaiostoolkit/