iSECpartners
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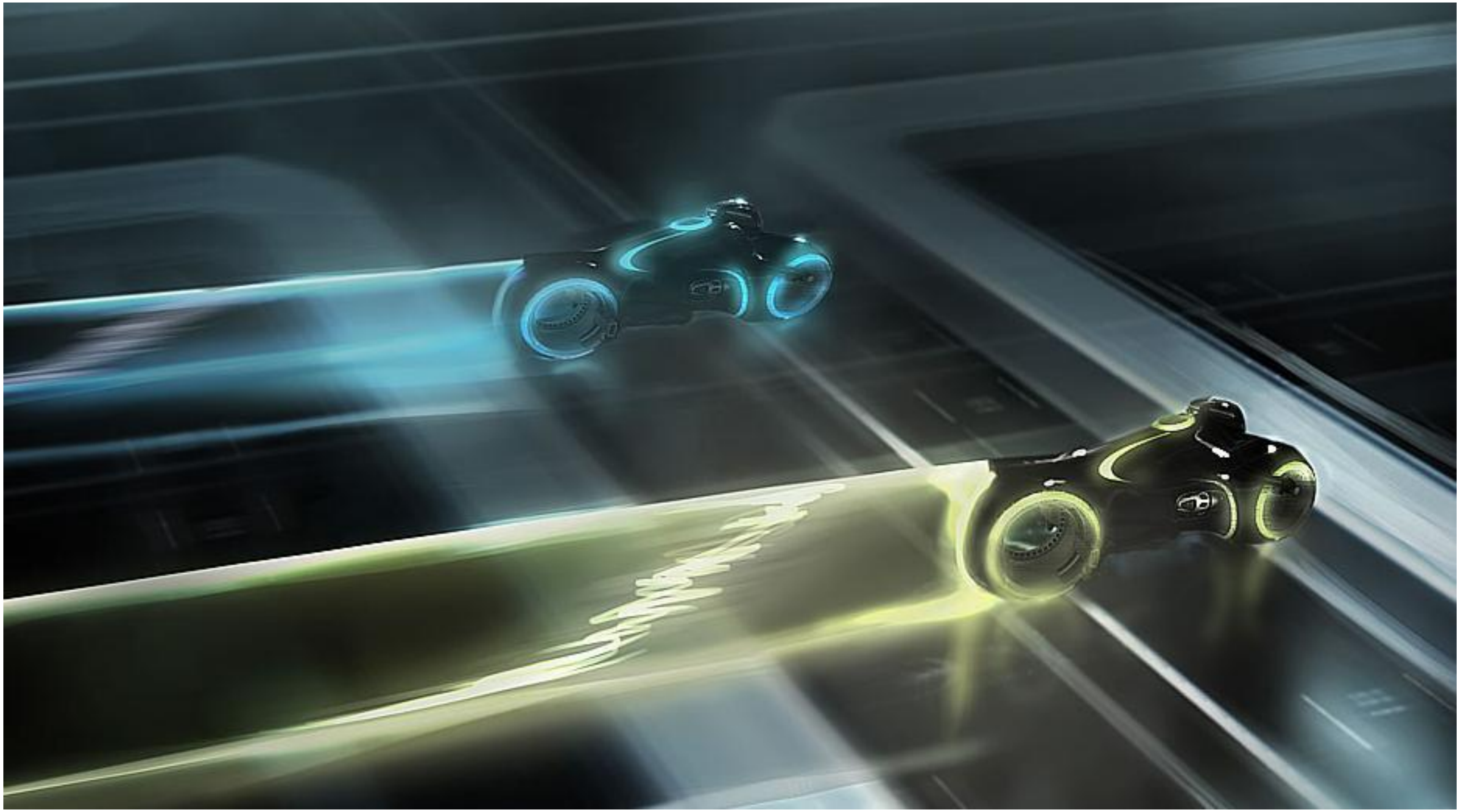
Funderbolt

Adventures in Thunderbolt DMA Attacks

Russ Sevinsky

A Trip Down Memory Lanes



A Trip Down Memory Lanes

- Background
  - Thunderbolt
    - Apple and Intel
    - External Port
    - PCI Express (PCIe) and DisplayPort using the same port
  - DMA
    - Direct Memory Access
    - Processor becomes bottleneck for high-speed transfers
    - Lets devices read and write directly to RAM

A Trip Down Memory Lanes

- Why external buses matter for security experts?
  - Digital Forensics
    - Getting data to solve a mystery
  - User protection
    - So RAM contents can be safe
  - Sneaky DRM
    - Bus encryption

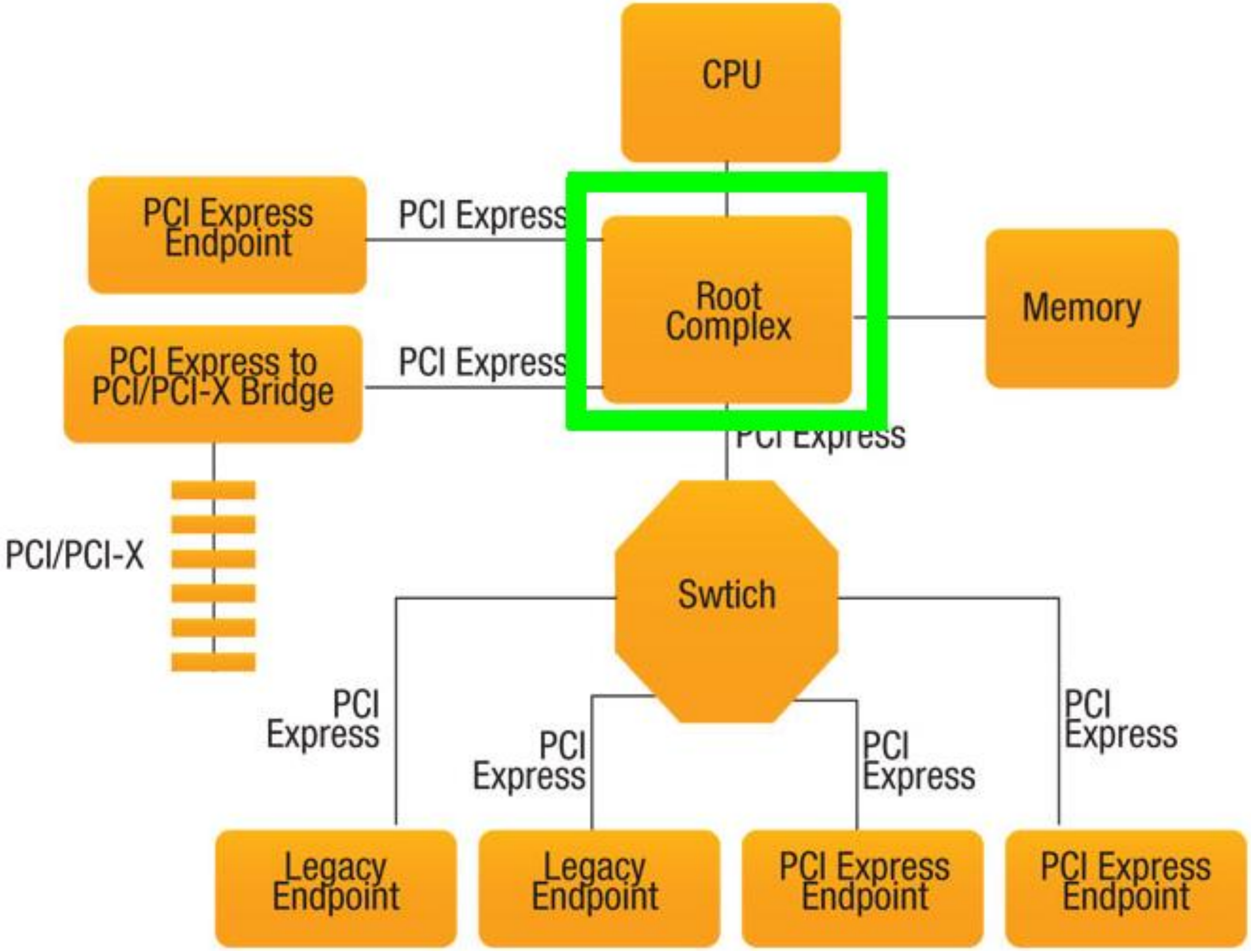
A Trip Down Memory Lanes

- PCI Express (PCIe)
  - High-speed serial bus
  - Data sent via “lanes”
  - A Lane is made up of differential wire pairs
    - One + and one – wire offset a small amount
    - Helps reducing noise
  - One lane (x1) is made up of two differential pairs
    - Transmit pair (PET)
    - Receive pair (PER)

A Trip Down Memory Lanes

- PCIe (cont)
  - Four lanes (x4) has eight pairs, x8 has 16 pairs, etc…
  - All lanes use another differential pair for clock
    - REFCLK
  - So… x1 uses 6 wires for data communication
    - PET, PER and REFCLK
  - Data sent via "packets"
  - Point-to-point topology using Root Complex
    - Requests for devices and memory go to "root complex"

A Trip Down Memory Lanes



A Trip Down Memory Lanes

- Mitigations
  - Epoxy (really?)
  - Input/Output Memory Management Units (IOMMUs)
    - Maps physical memory addresses to logical addresses
    - Think "VM for DMA"
    - Prevents devices from requesting physical addresses directly
  - Secure Configurations
- Current attacks?
  - Daisy chaining Thunderbolt and Firewire
  - Inception

How My Adventures Went

How My Adventures Went

- Improvised Tools for Analysis
  - Multimeter
  - Soldering station
  - Heat gun
  - Desoldering tools
  - Ethernet cable
  - Epoxy (really?)
  - Logic Analyzer
  - Image Editor

How My Adventures Went

- Reversing Thunderbolt – The Process
  - Research a product
  - Take it apart
  - Trace all interesting chips
  - Look for datasheets
  - Sniff buses
  - Develop a map

How My Adventures Went

- Looking at consumer products
  - Buffalo MiniStation Thunderbolt/USB3 Hard Drive
    - 500GB and 1TB model
    - USB3 and Thunderbolt
    - Decent form factor for reversing
  - Apple Thunderbolt to Gigabit Ethernet Adapter
    - Tiny
    - Small
    - Little

How My Adventures Went

- External Hard Drive
  - Researching the product
  - Taking it apart
  - Tracing all interesting chips
  - Looking for datasheets
  - Sniffing buses
  - Developing a map

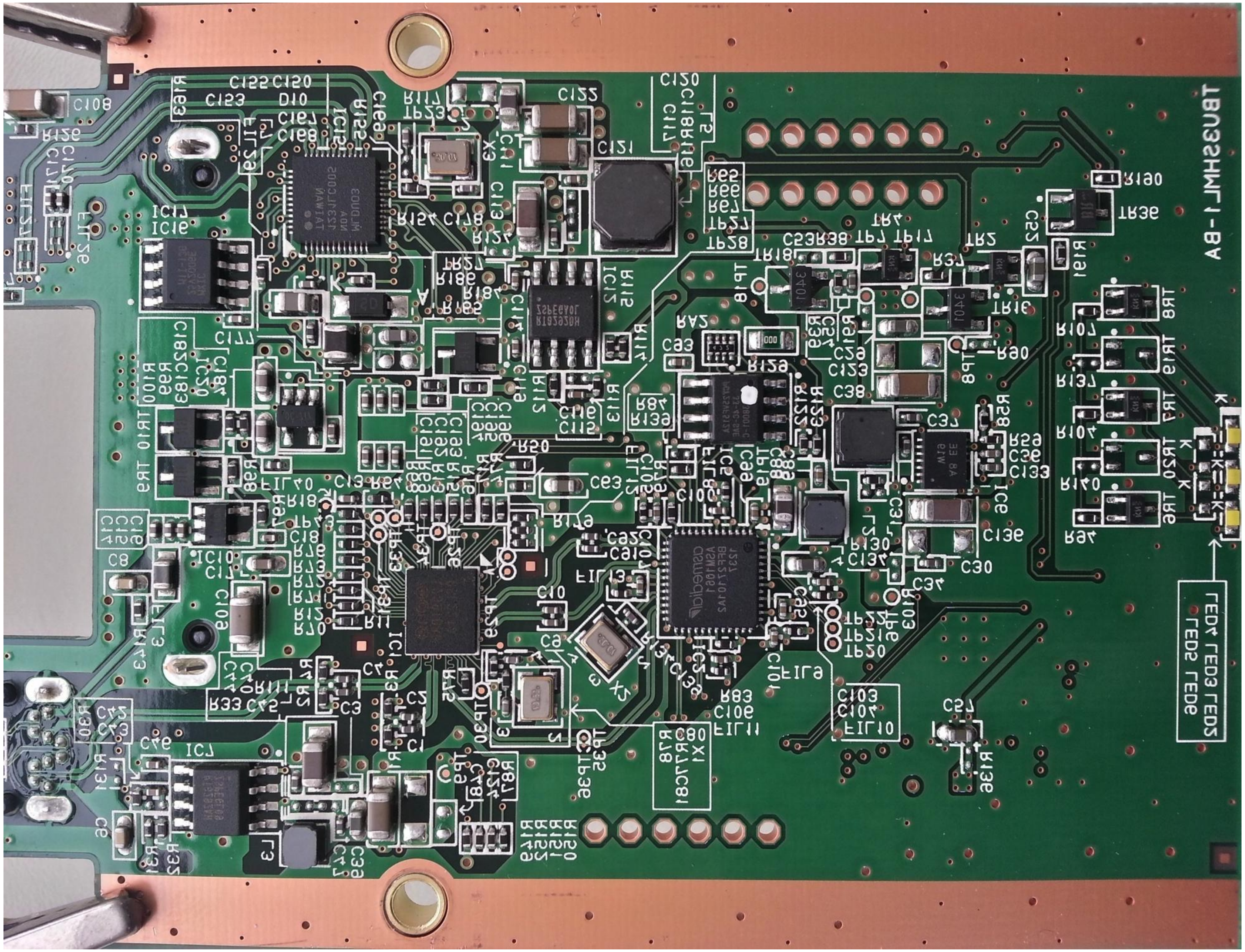
How My Adventures Went

- Excellent Anandtech review:
    - http://www.anandtech.com/show/6127/buffalo-ministation-thunderbolt-review-an-external-with-usb-30-and-thunderbolt
- Identified ICs for us!

How My Adventures Went

- Main ICs
  - MLDU03
    - Medial Logic USB3.0 to SATA 6G Bridge
  - ASM1061
    - ASMedia PCIe to SATA Controller
  - DSL2210 (Peak Ridge)
    - Intel Thunderbolt Controller
    - Supports PCIe x1
  - LPC1114
    - NXP ARM Cortex M0

How My Adventures Went



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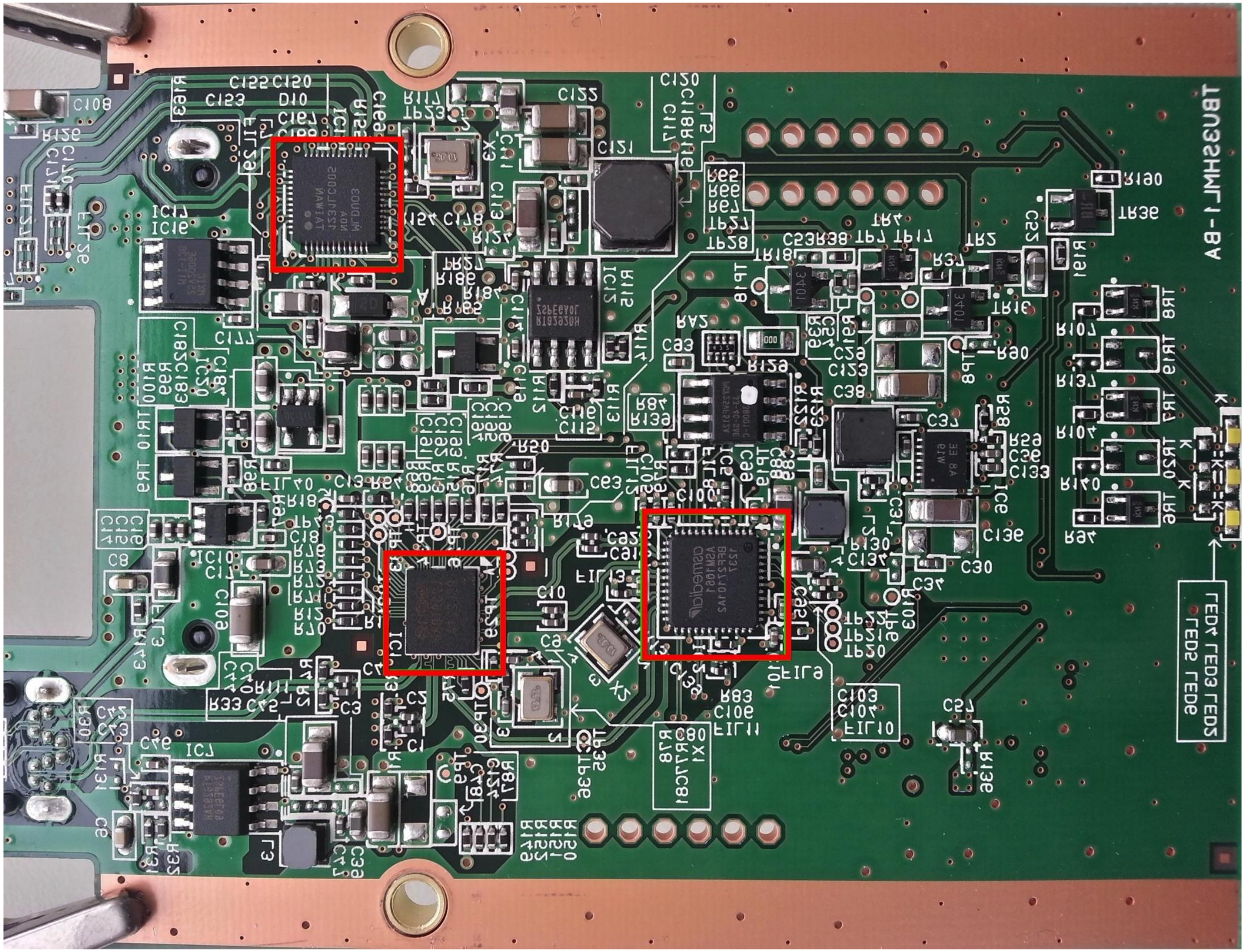

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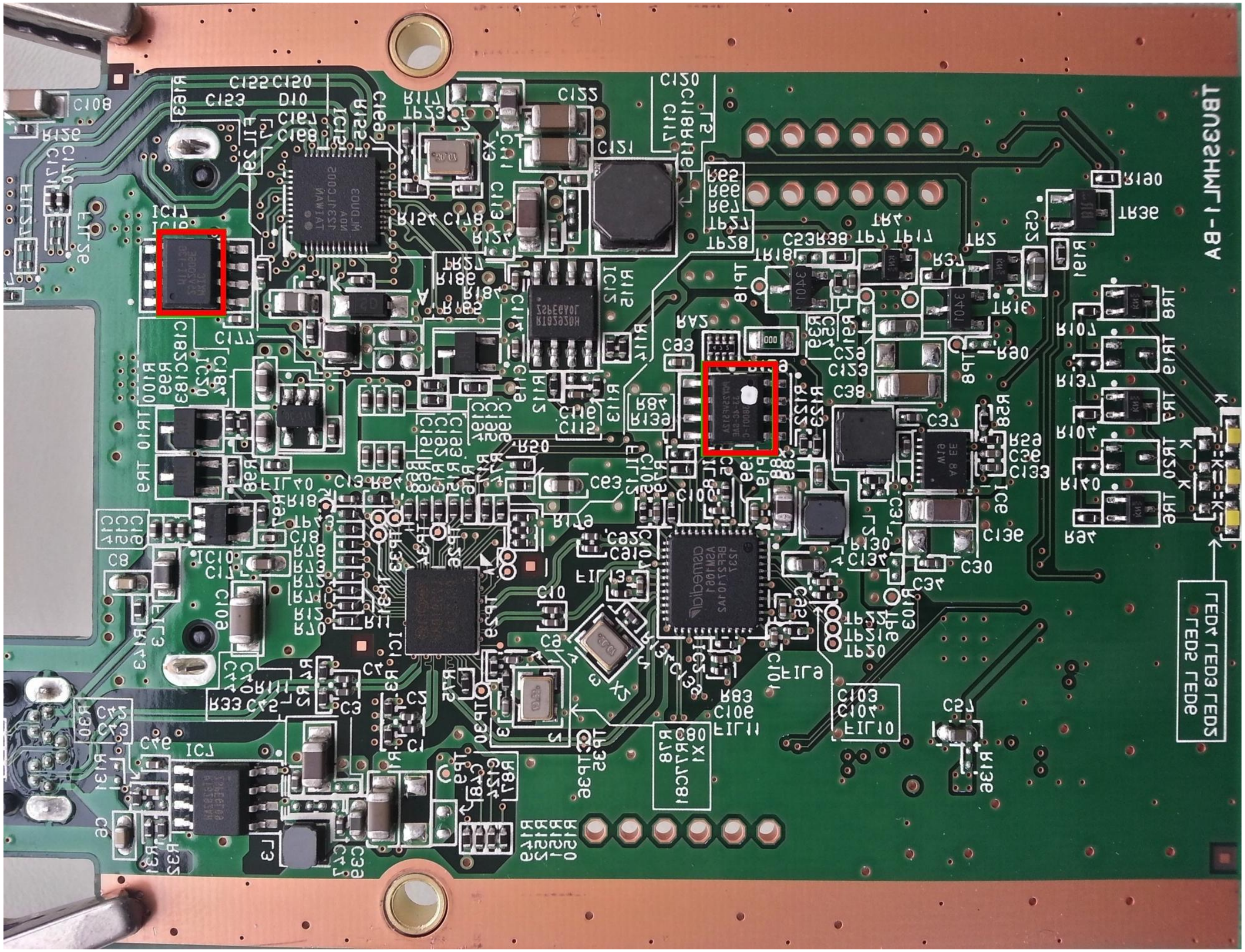

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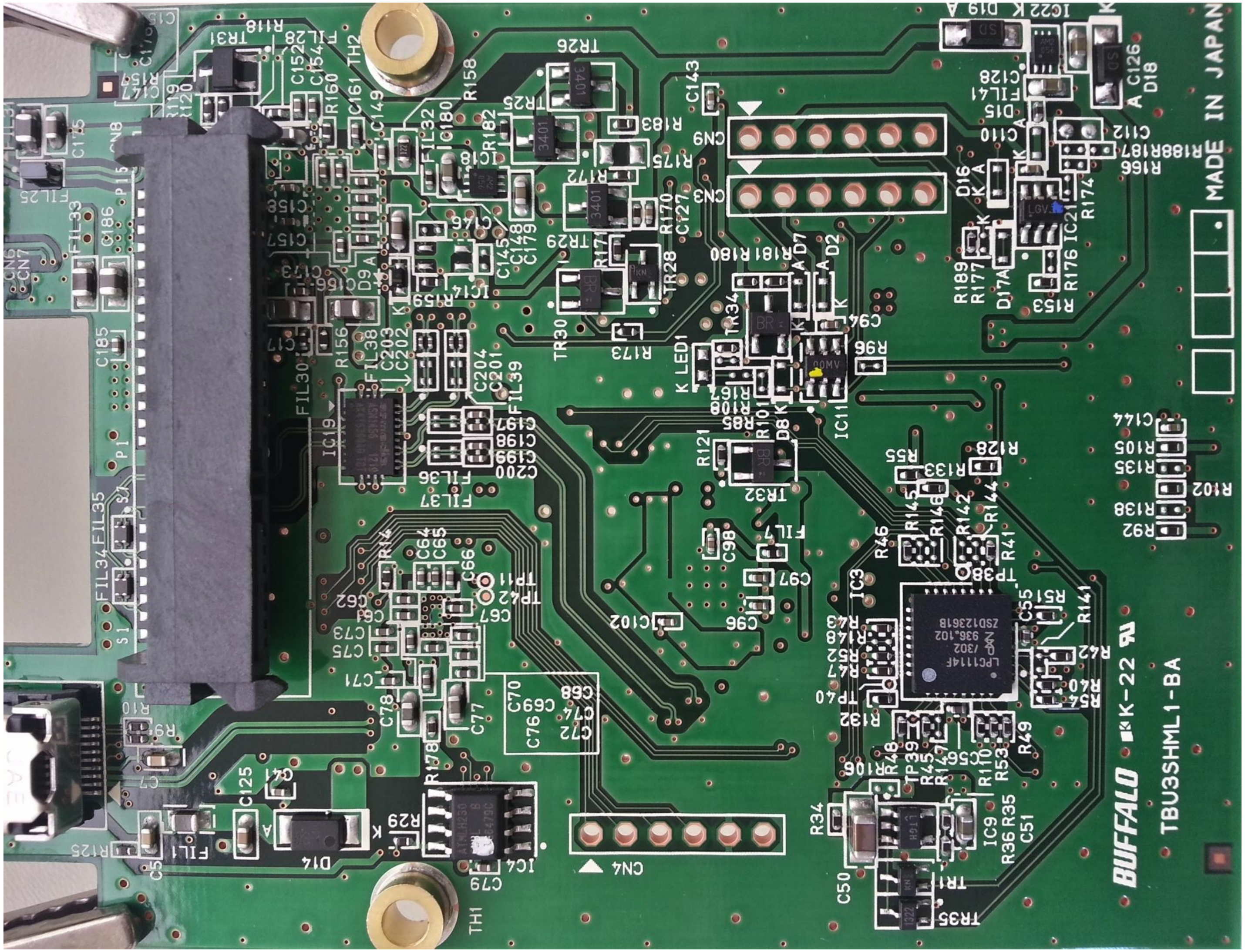

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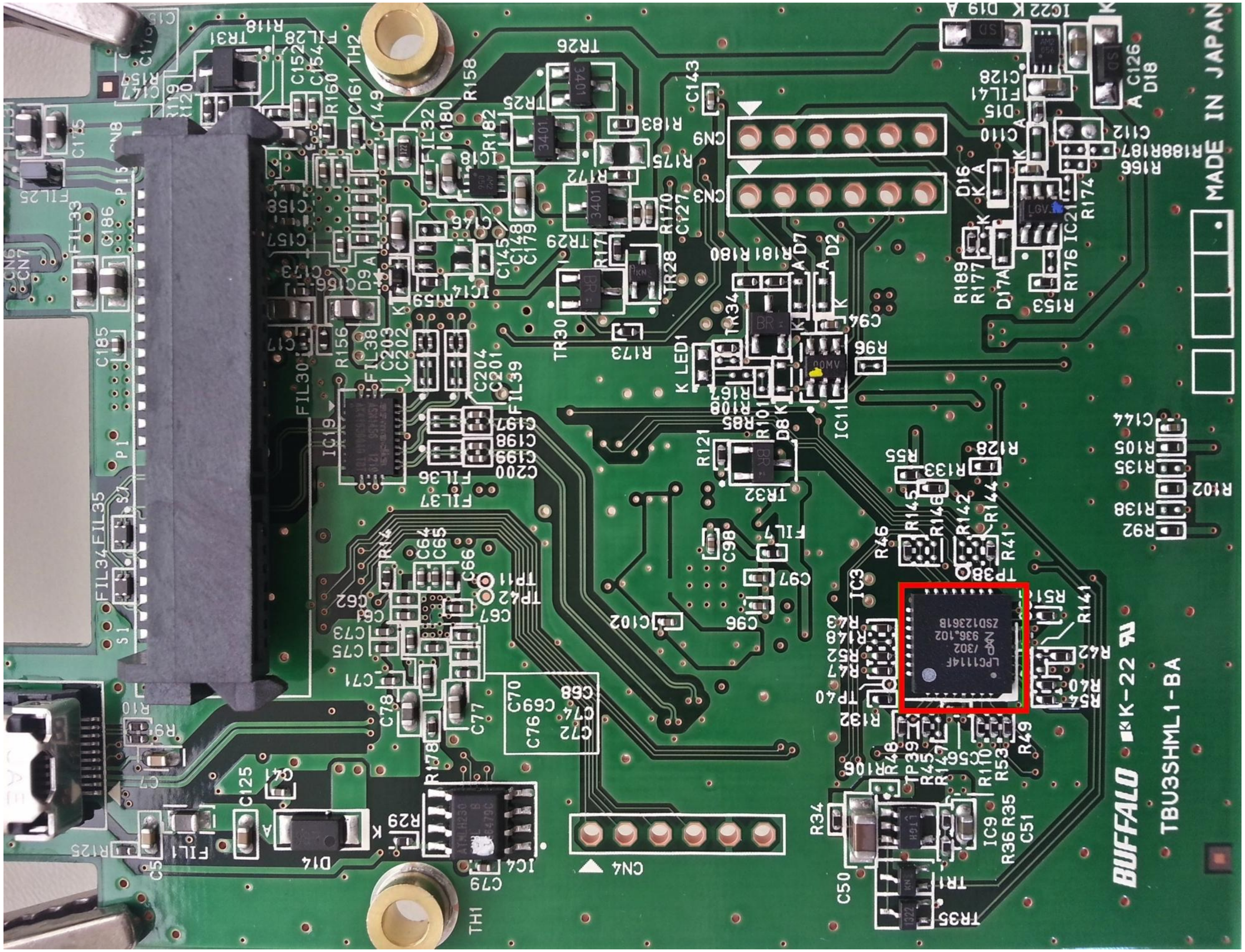

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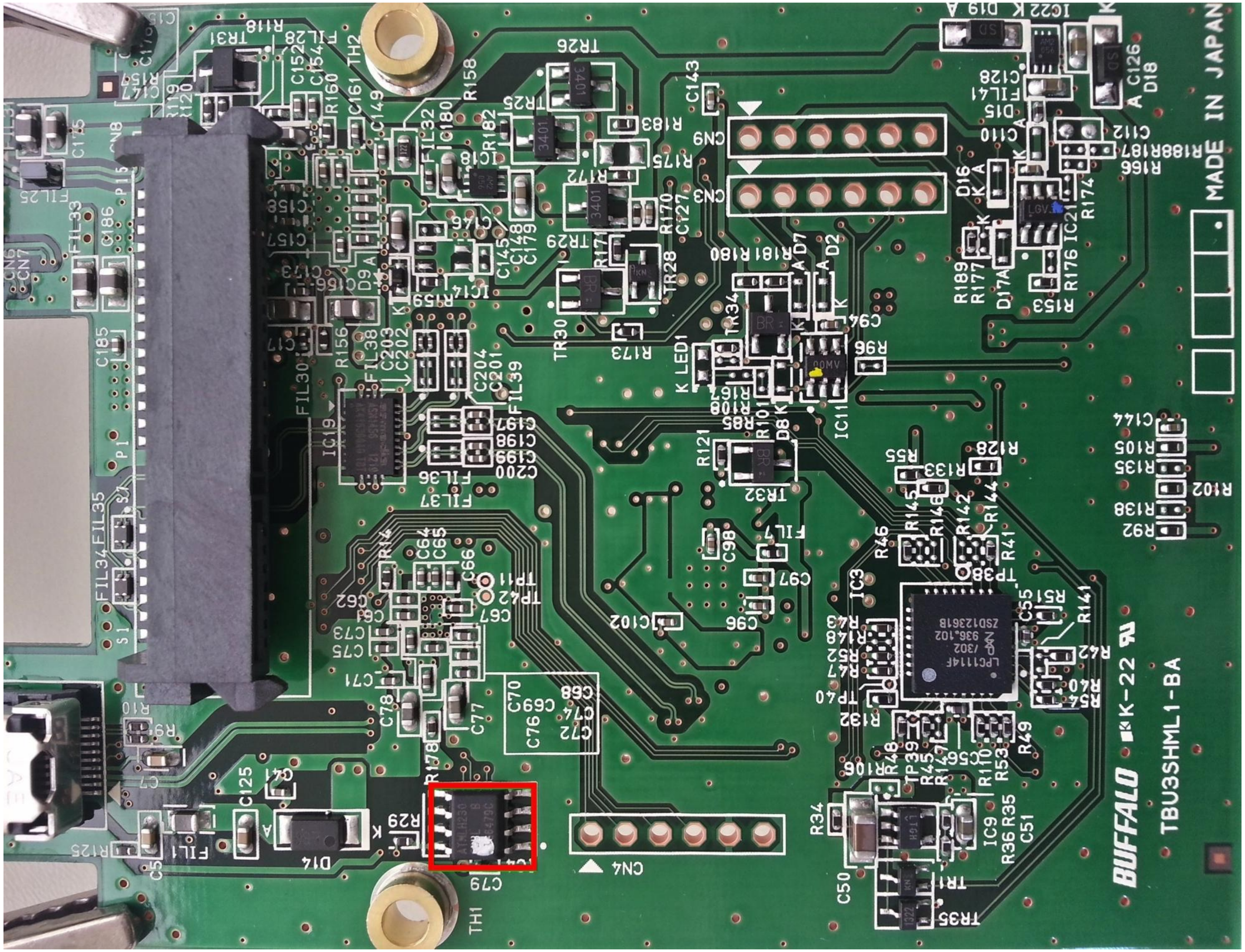
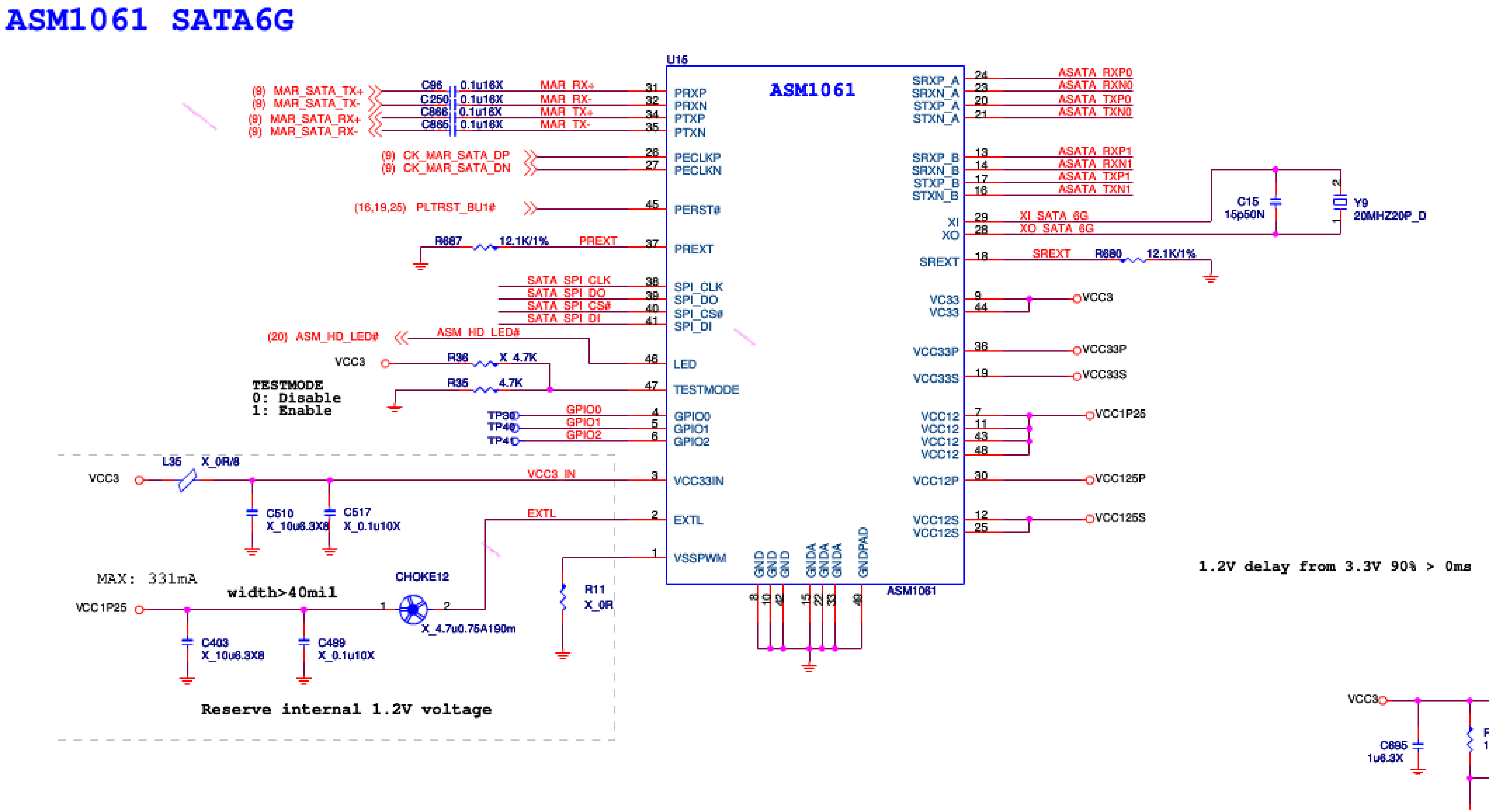


How My Adventures Went

- ASMedia ASM1061
  - PCIe/SATA Controller
  - Datasheets?
  - ROMs/Flashes?

How My Adventures Went



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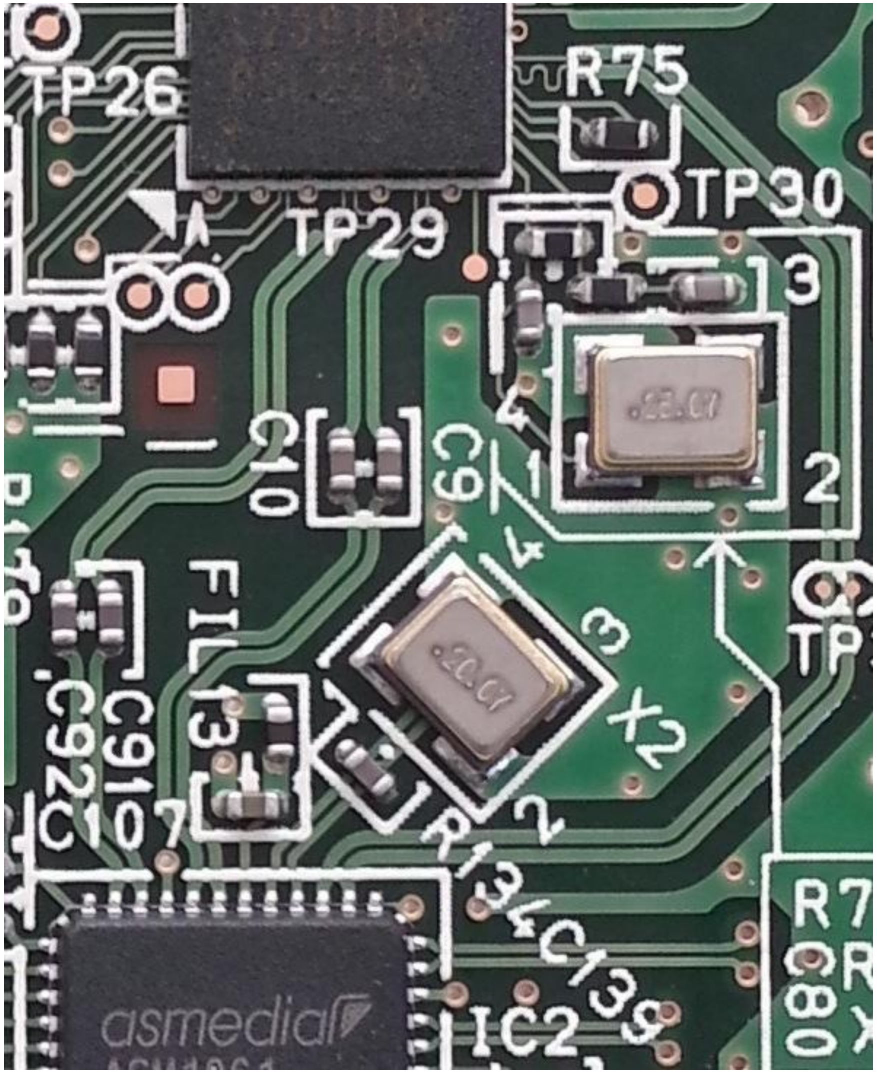
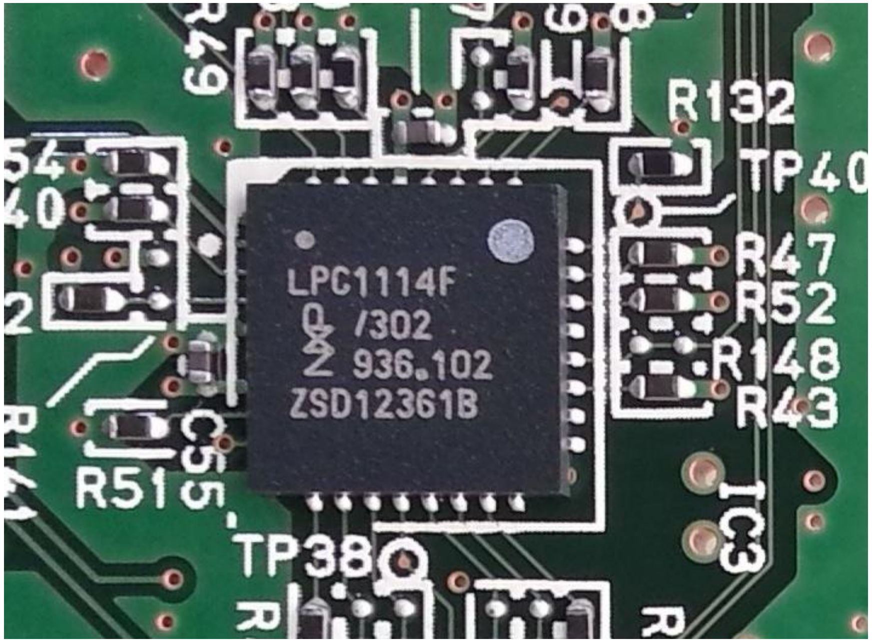


How My Adventures Went

- Patch PCIe Controllers' SPI ROM to send DMA read requests?

How My Adventures Went

- NXP LPC1114
  - ARM Cortex M0
  - Used for… ??
  - No ROMs or Flashes
  - TONS of info
  - Connects into DSL2201
    - How do I know?



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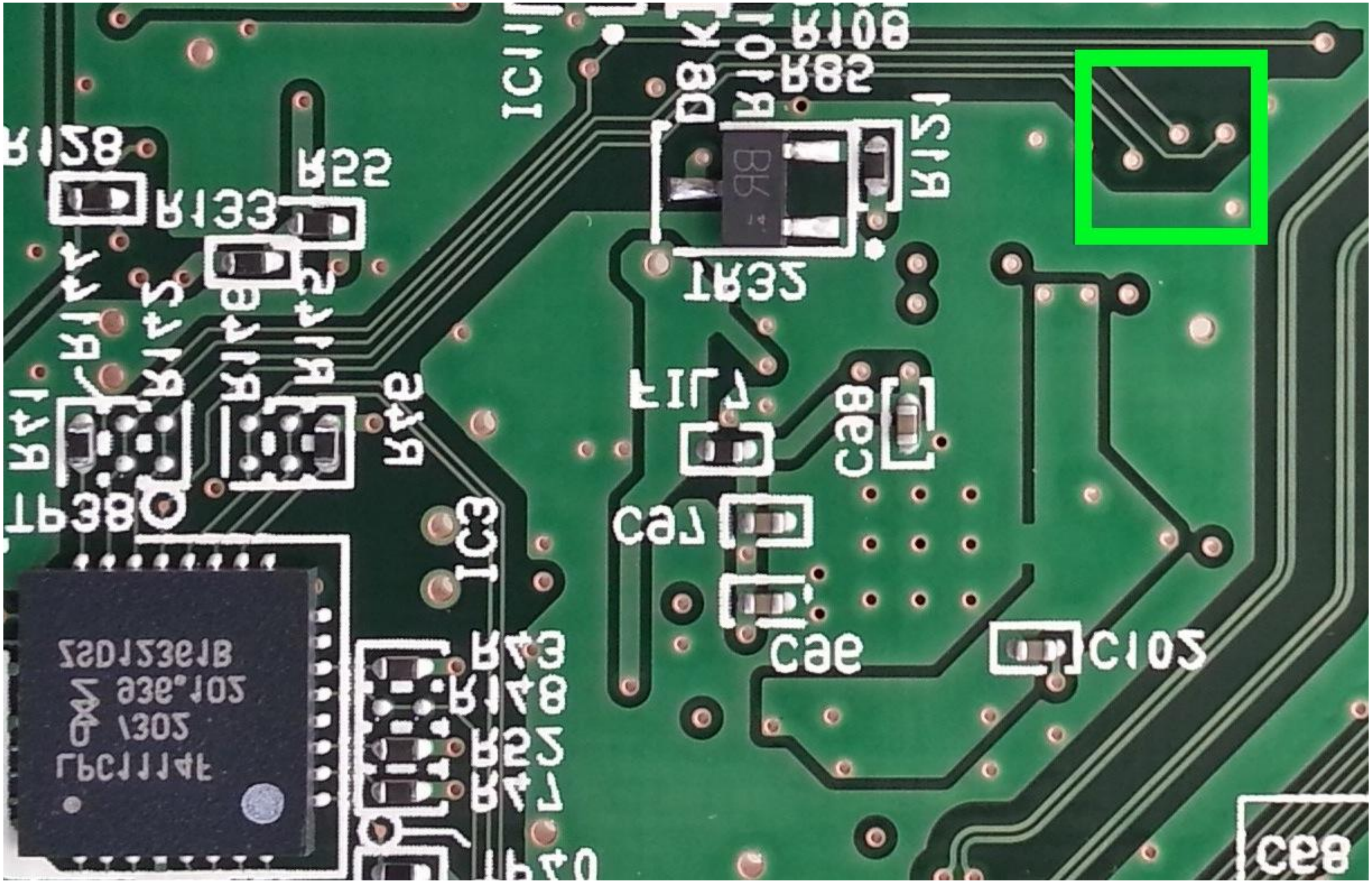

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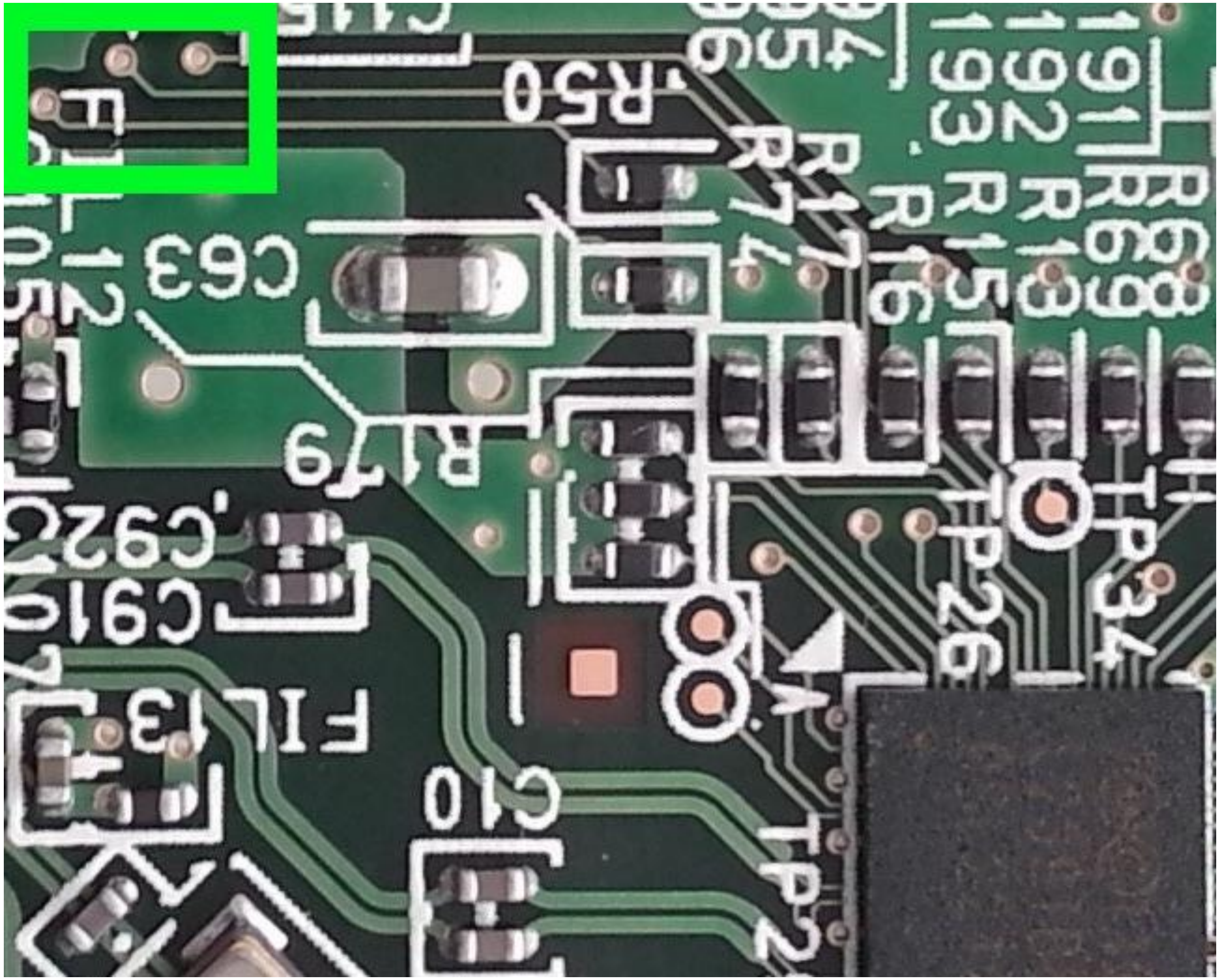

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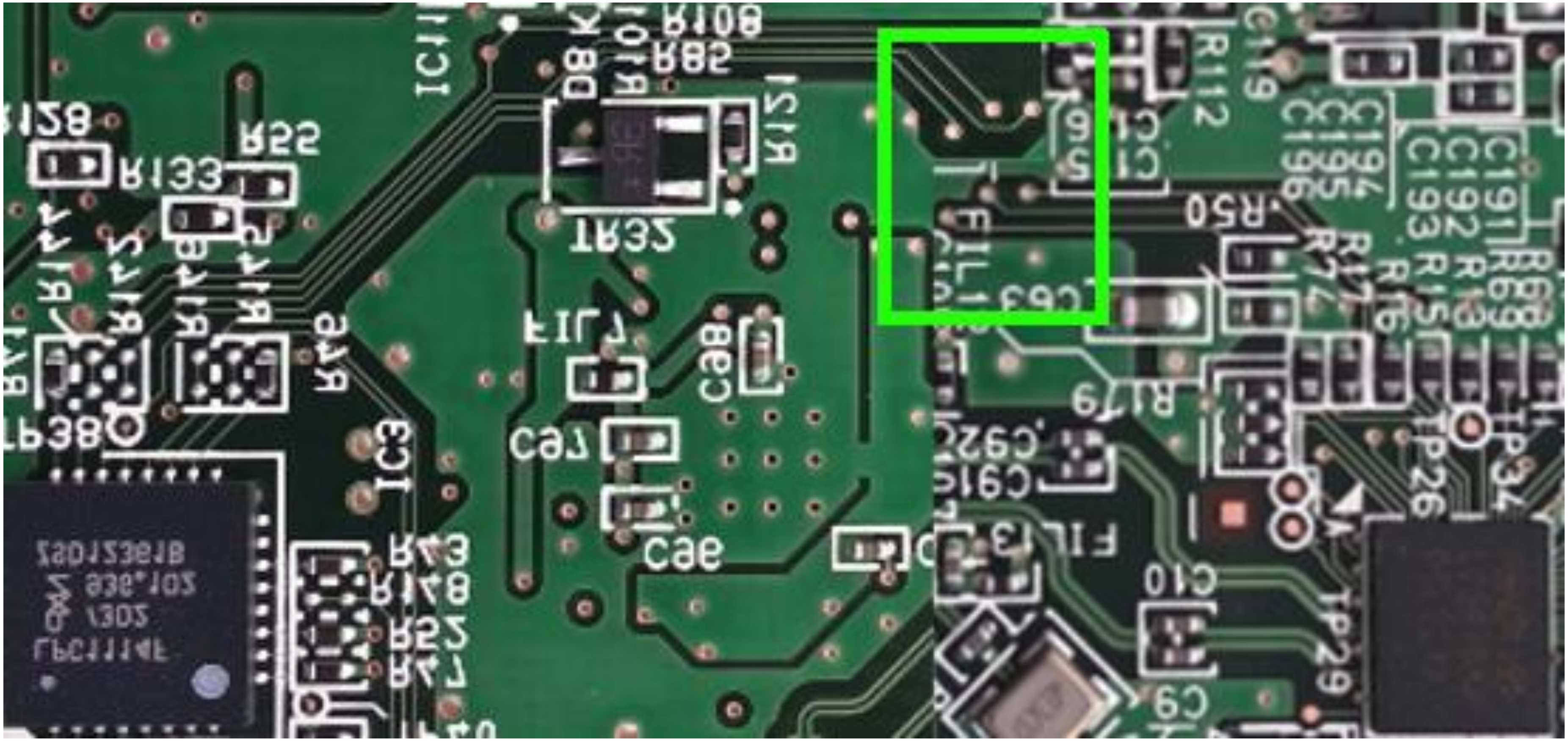

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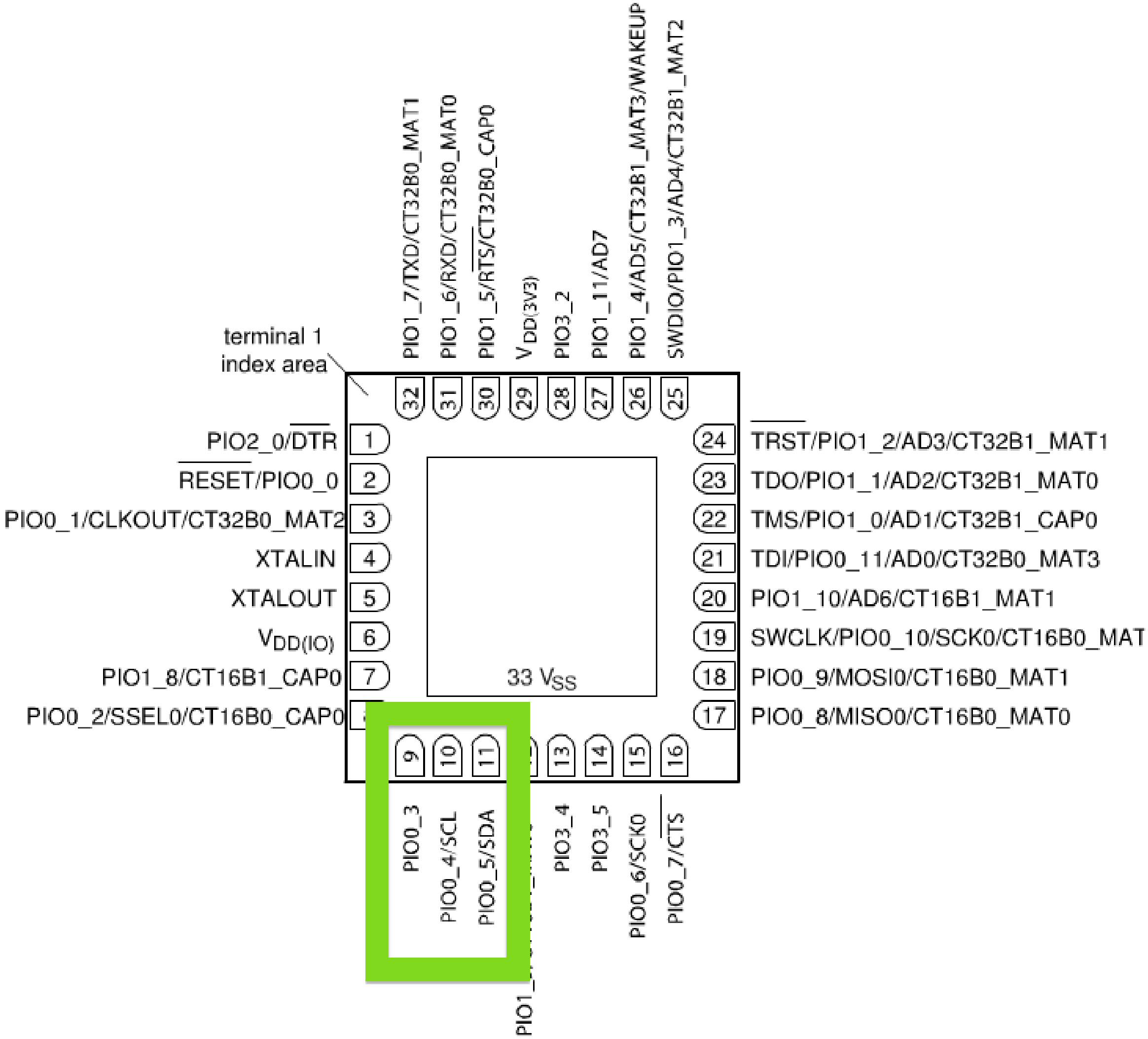
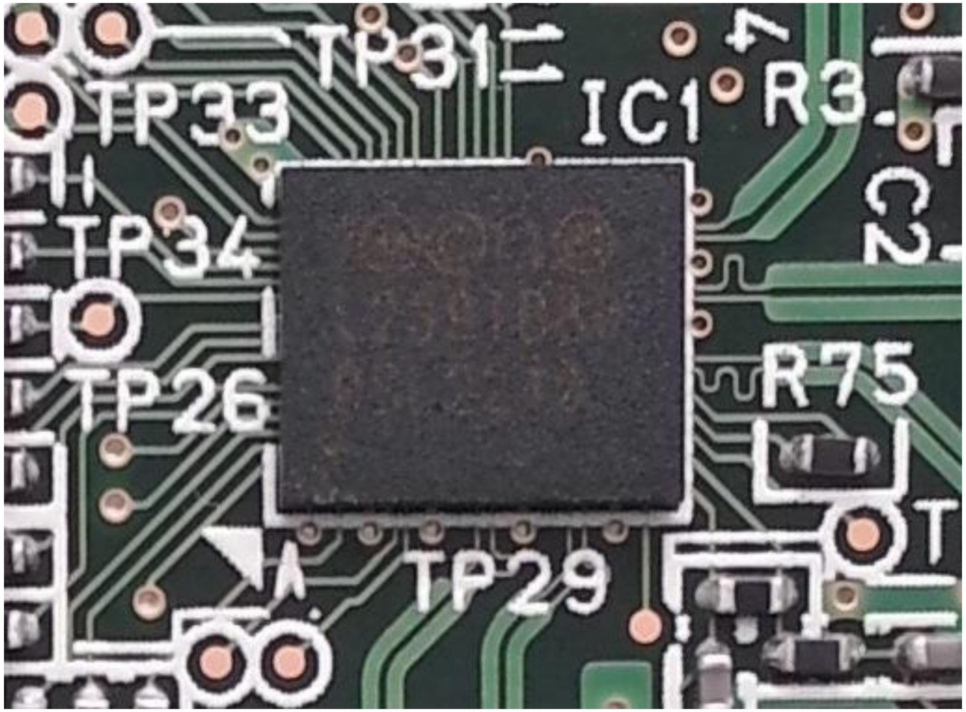


How My Adventures Went

- Intel DSL2210
  - Thunderbolt Controller
  - No Datasheets
  - Promo info only
  - ROMs/Flashes?



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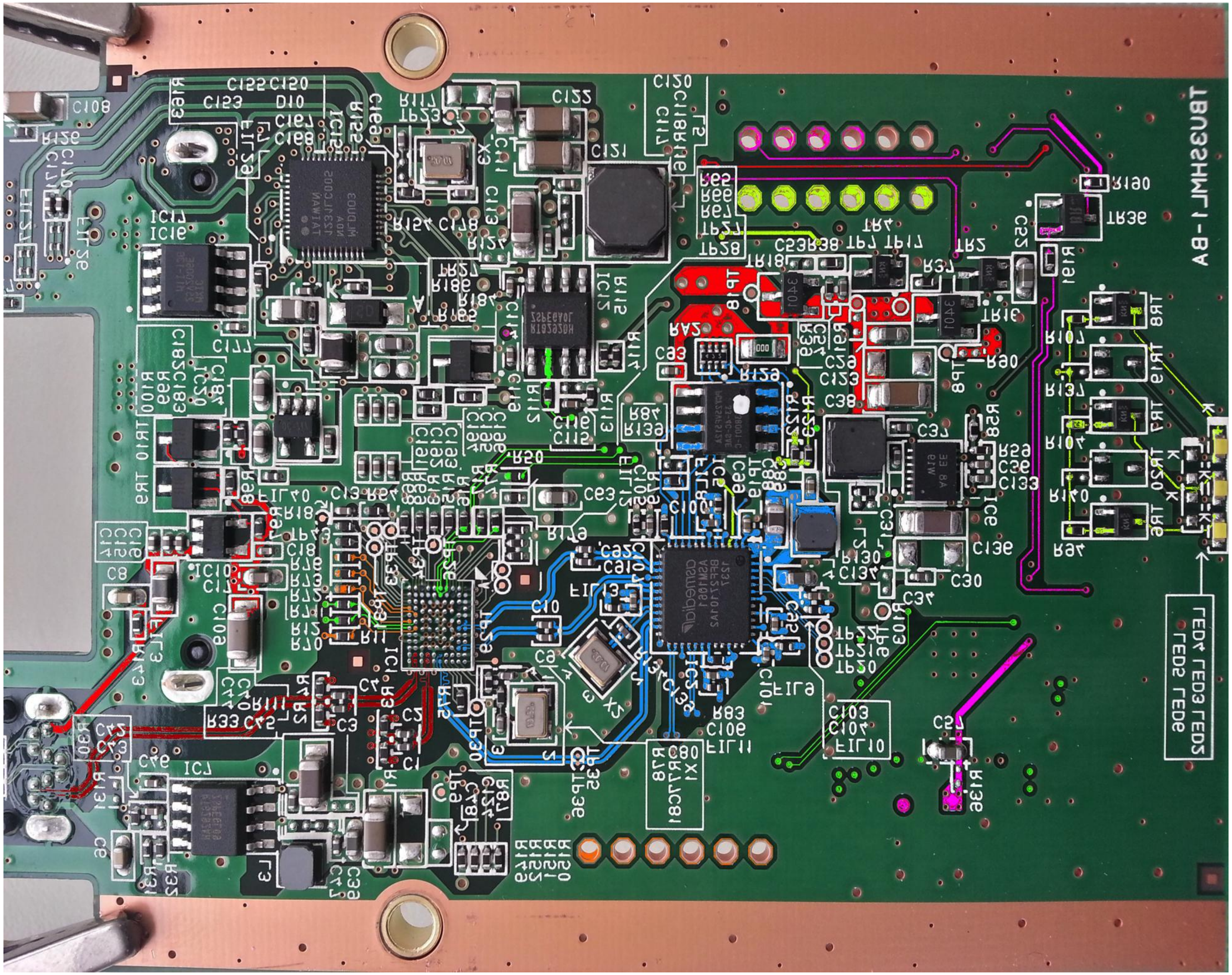

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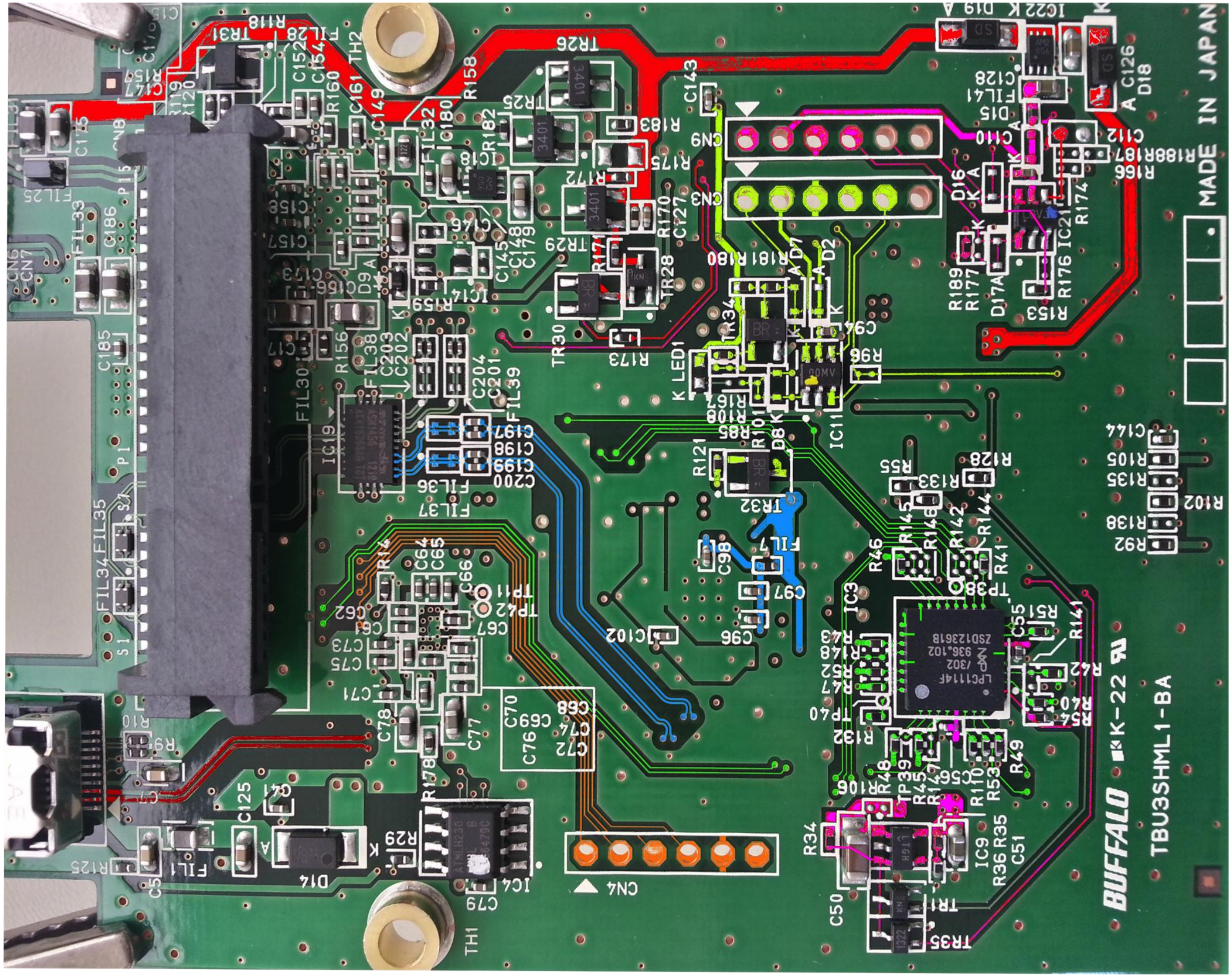

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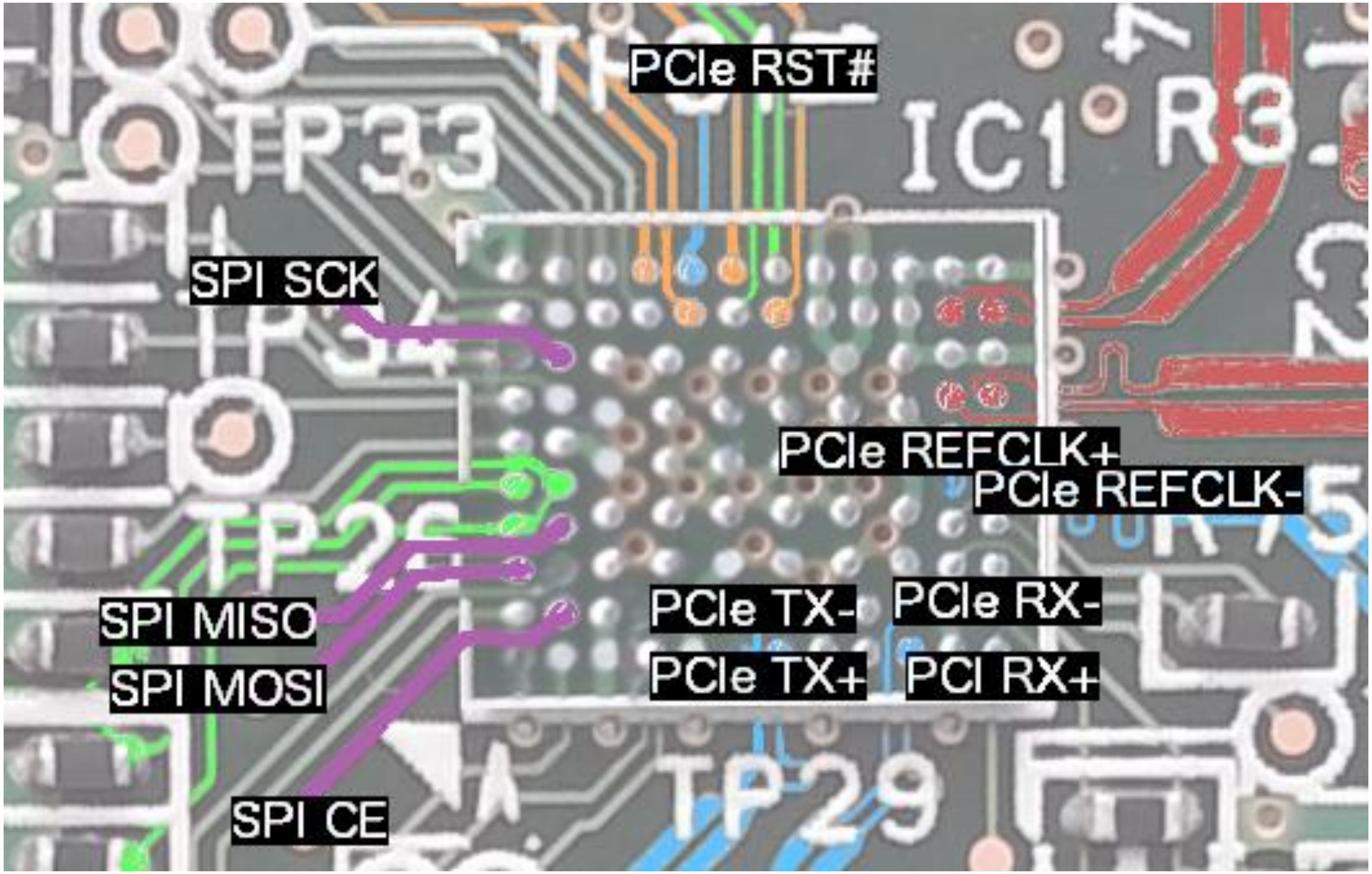
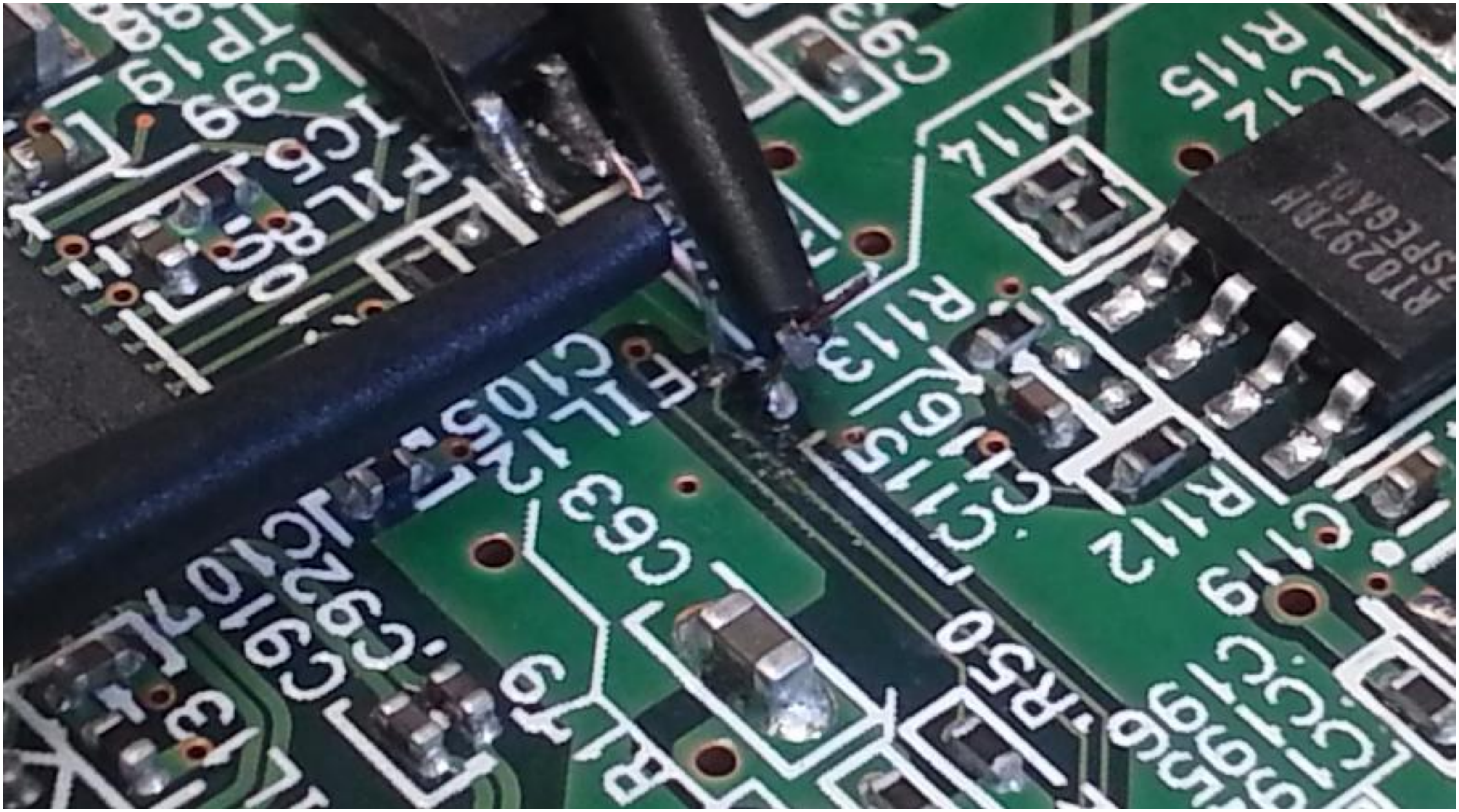


How My Adventures Went

- Thunderbolt Connector
  - 1 pair of High Speed lanes
    - TX and RX
  - All others pulled to ground
  - “LowSpeed” lines go into ARM’s UART?

How My Adventures Went



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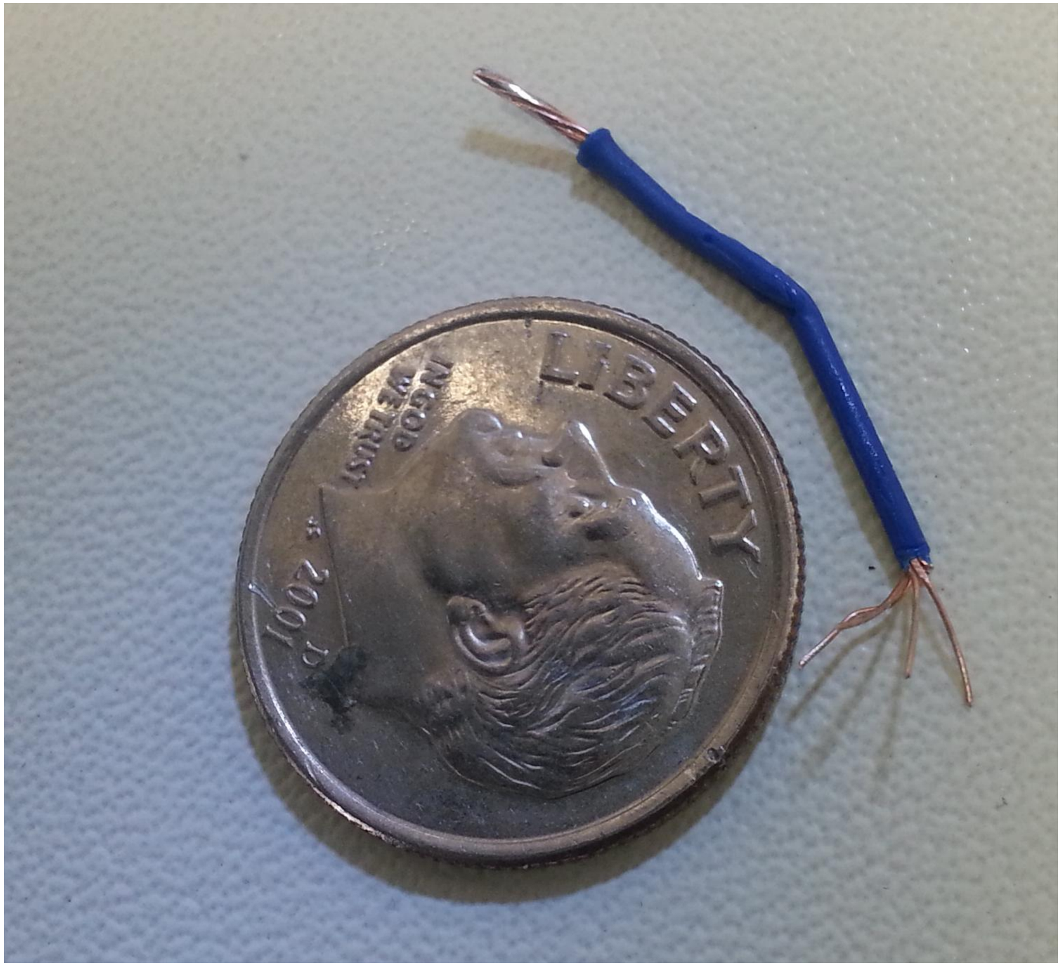

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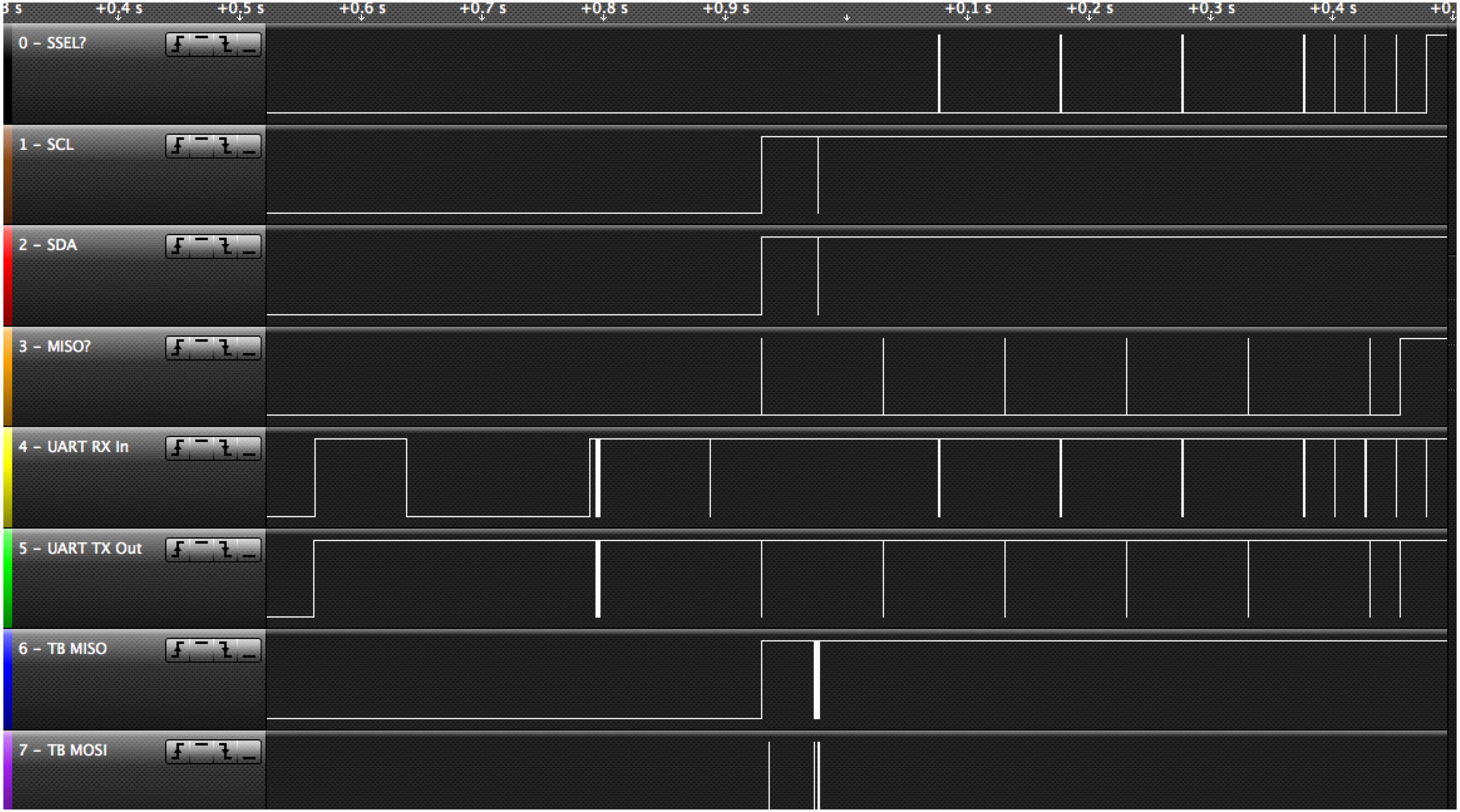
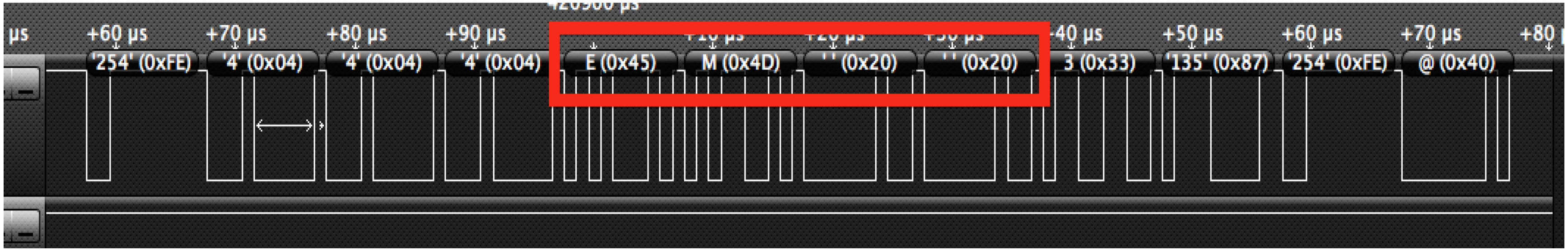
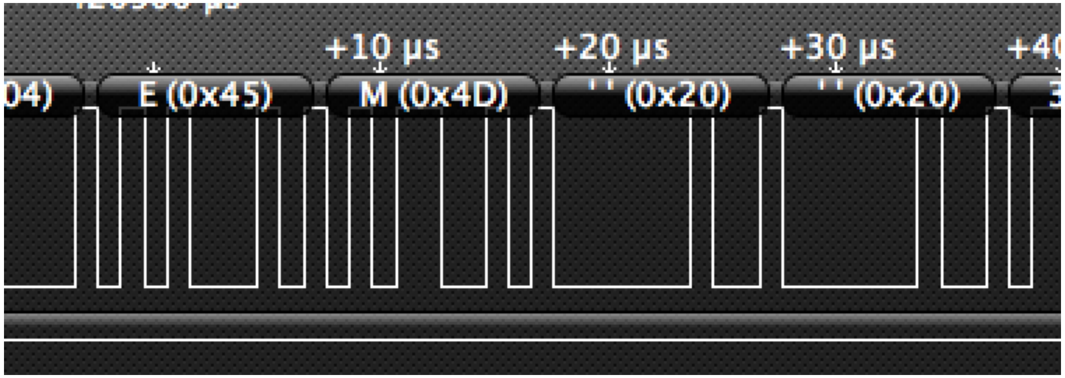


How My Adventures Went

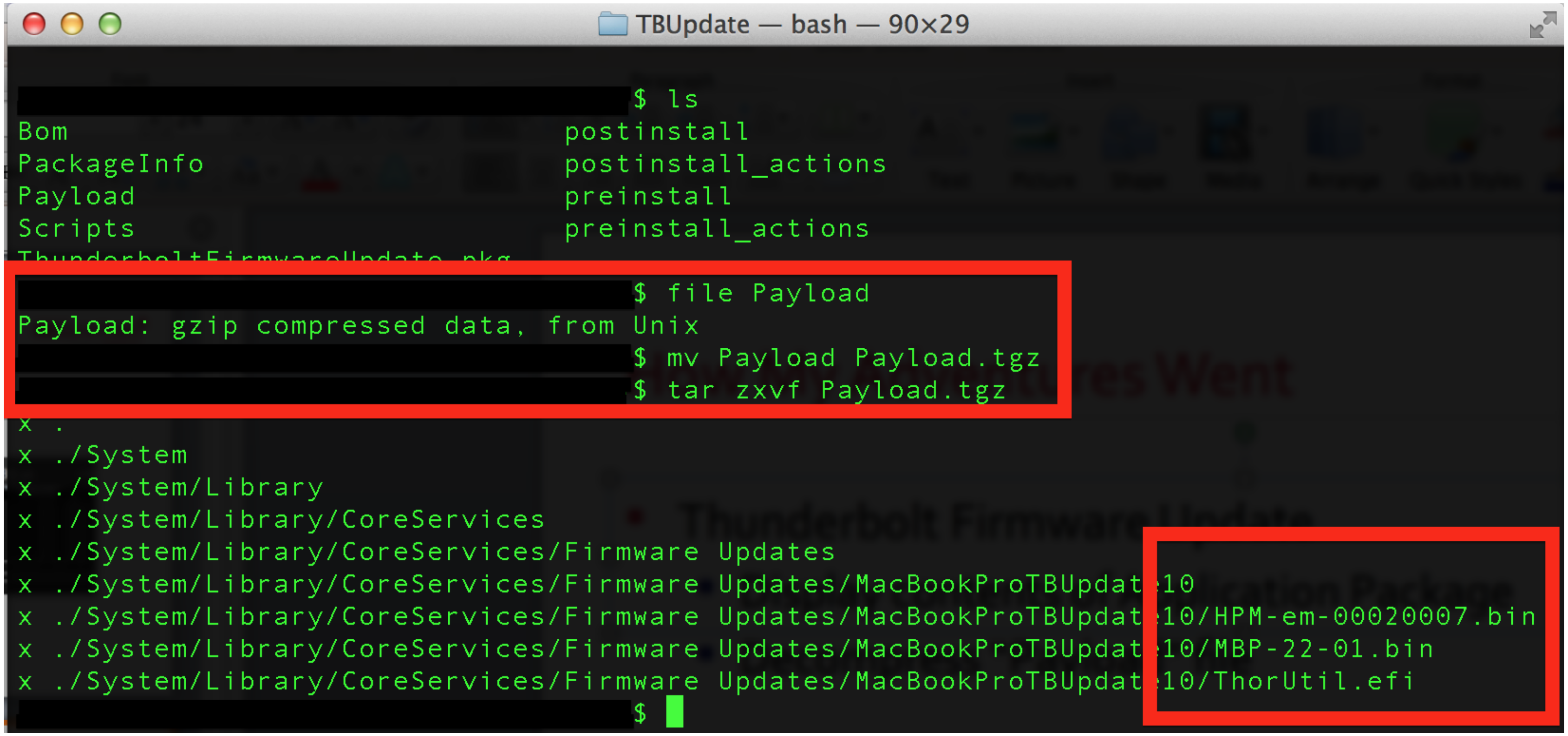
- ARM UART Traffic
  - String “EM “





How My Adventures Went

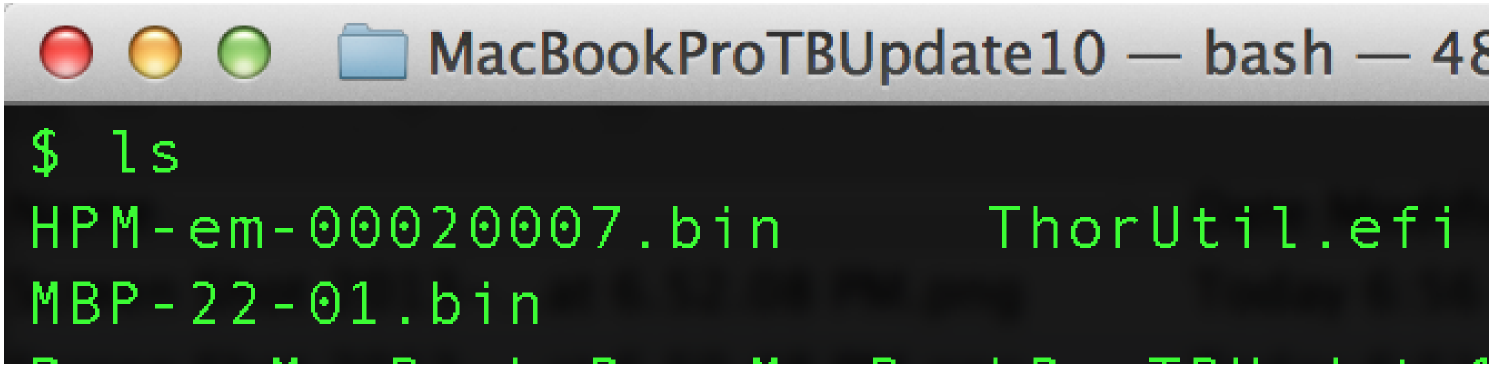
- Thunderbolt Firmware Update
  - Display contents of Application Package
  - Decompress “Payload” file



```
[redacted]$ ls
Bom                              postinstall
PackageInfo                      postinstall_actions
Payload                          preinstall
Scripts                          preinstall_actions
ThunderboltFirmwareUpdate.pkg
[redacted]$ file Payload
Payload: gzip compressed data, from Unix
[redacted]$ mv Payload Payload.tgz
[redacted]$ tar zxvf Payload.tgz
x .
x ./System
x ./System/Library
x ./System/Library/CoreServices
x ./System/Library/CoreServices/Firmware Updates
x ./System/Library/CoreServices/Firmware Updates/MacBookProTBUpdate10
x ./System/Library/CoreServices/Firmware Updates/MacBookProTBUpdate10/HPM-em-00020007.bin
x ./System/Library/CoreServices/Firmware Updates/MacBookProTBUpdate10/MBP-22-01.bin
x ./System/Library/CoreServices/Firmware Updates/MacBookProTBUpdate10/ThorUtil.efi
[redacted]$ 
```

How My Adventures Went

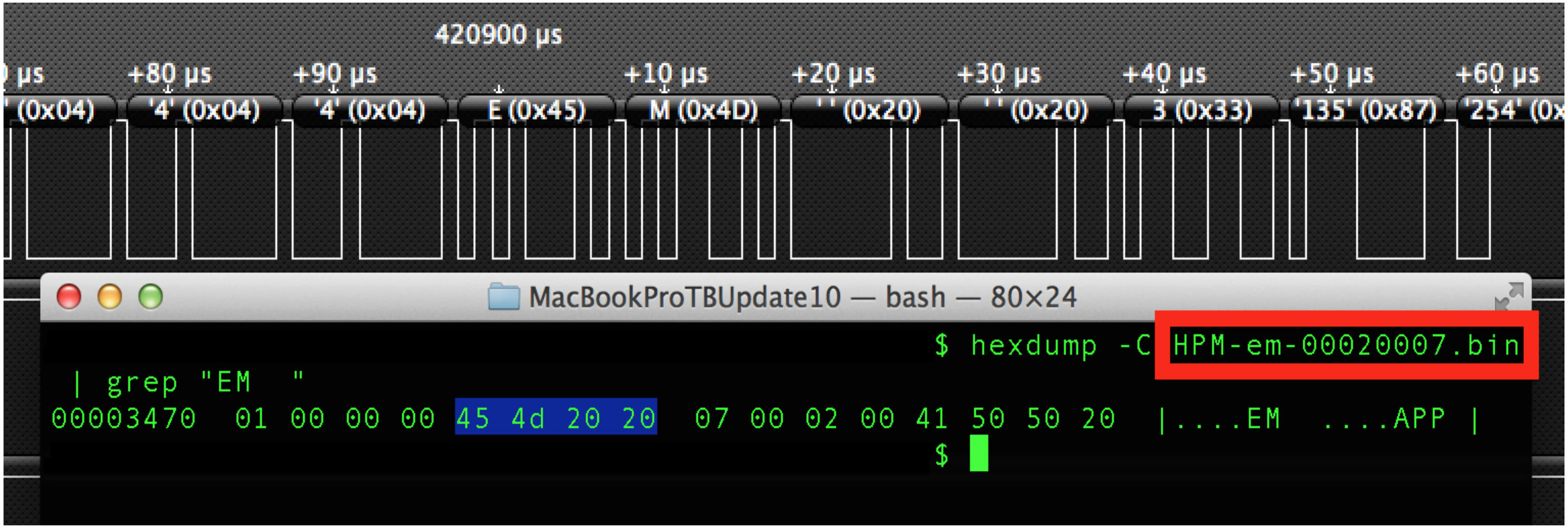
- Two Firmwares for Thunderbolt?
  - One is probably ARM
  - Let's look for string "EM "



```
$ ls
HPM-em-00020007.bin      ThorUtil.efi
MBP-22-01.bin
```

How My Adventures Went

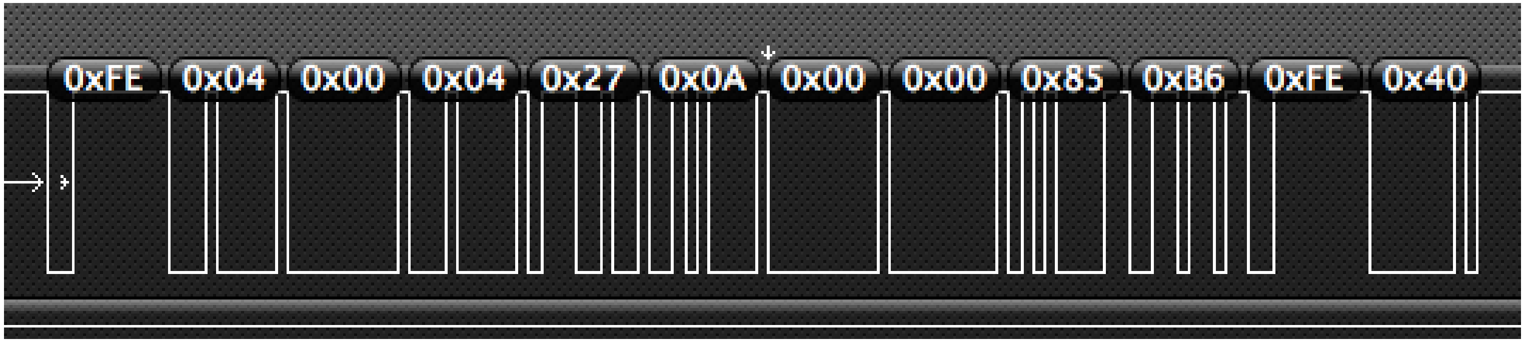
Jackpot!



```
                                                  $ hexdump -C HPM-em-00020007.bin
 | grep "EM  "
00003470  01 00 00 00 45 4d 20 20  07 00 02 00 41 50 50 20  |....EM  ....APP |
                                                  $ 
```

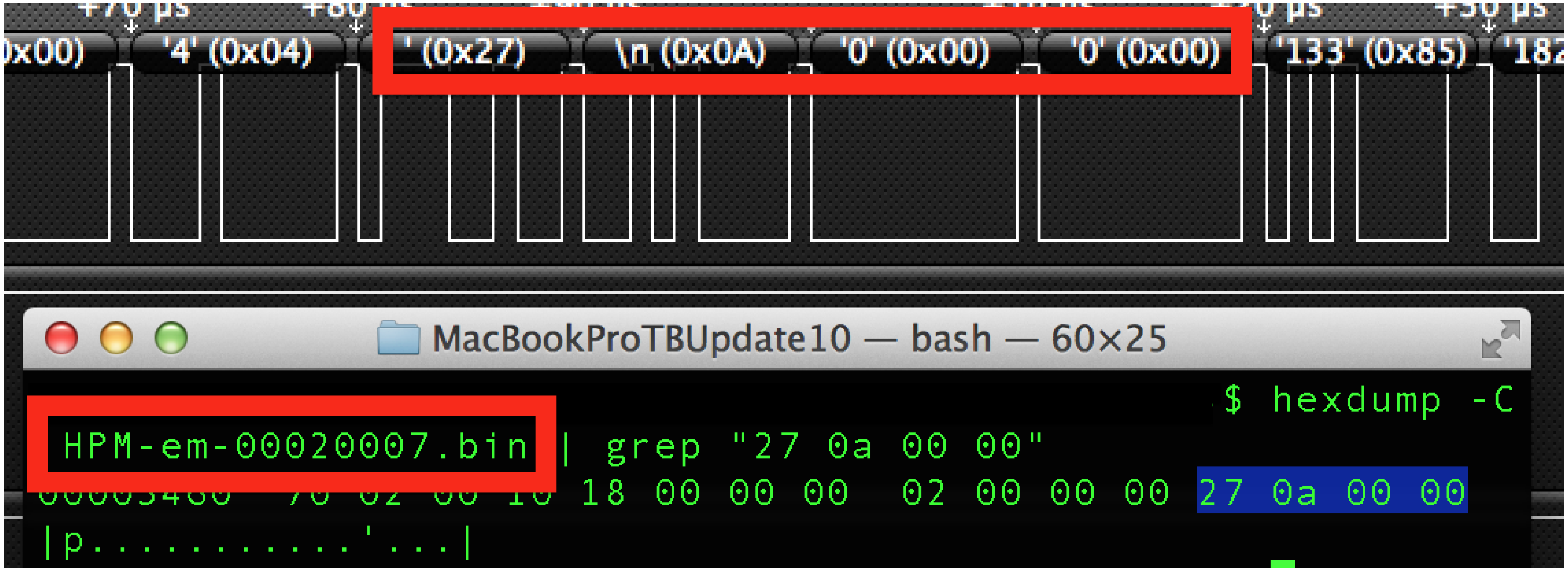
How My Adventures Went

- Round 2…
  - String "\x27\x0a\x00\x00"



How My Adventures Went

Successaroo!



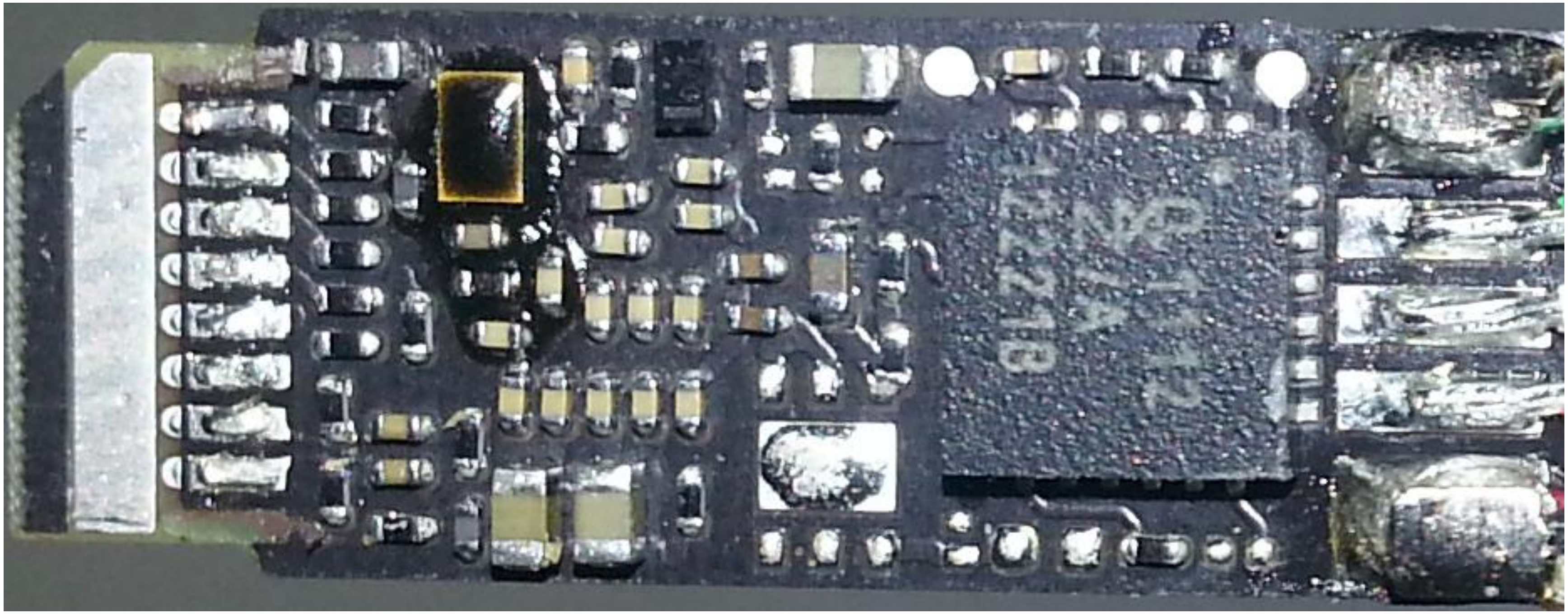
```
                                                $ hexdump -C
HPM-em-00020007.bin | grep "27 0a 00 00"
00003460  70 02 00 10 18 00 00 00  02 00 00 00 27 0a 00 00
|p...........'...|
```

How My Adventures Went

- Gigabit Ethernet Adapter
  - Researching the product
  - Taking it apart
  - Attack vectors

How My Adventures Went

How My Adventures Went



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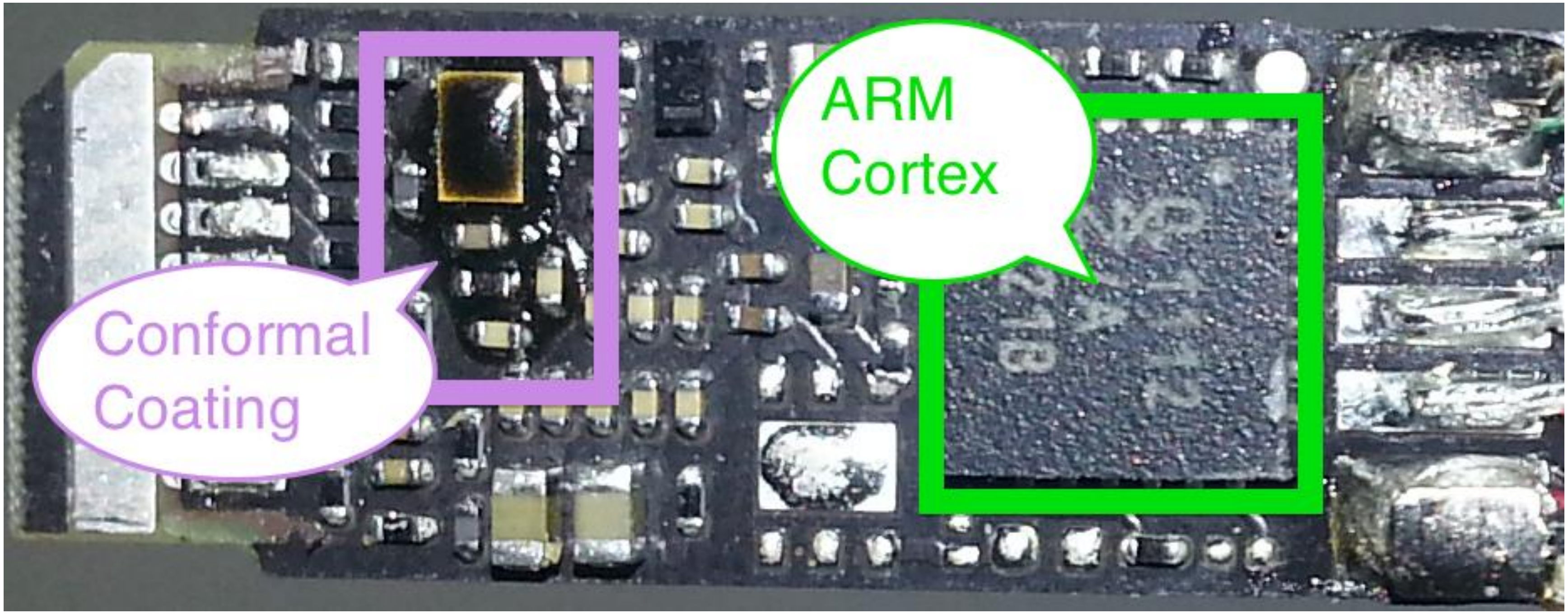

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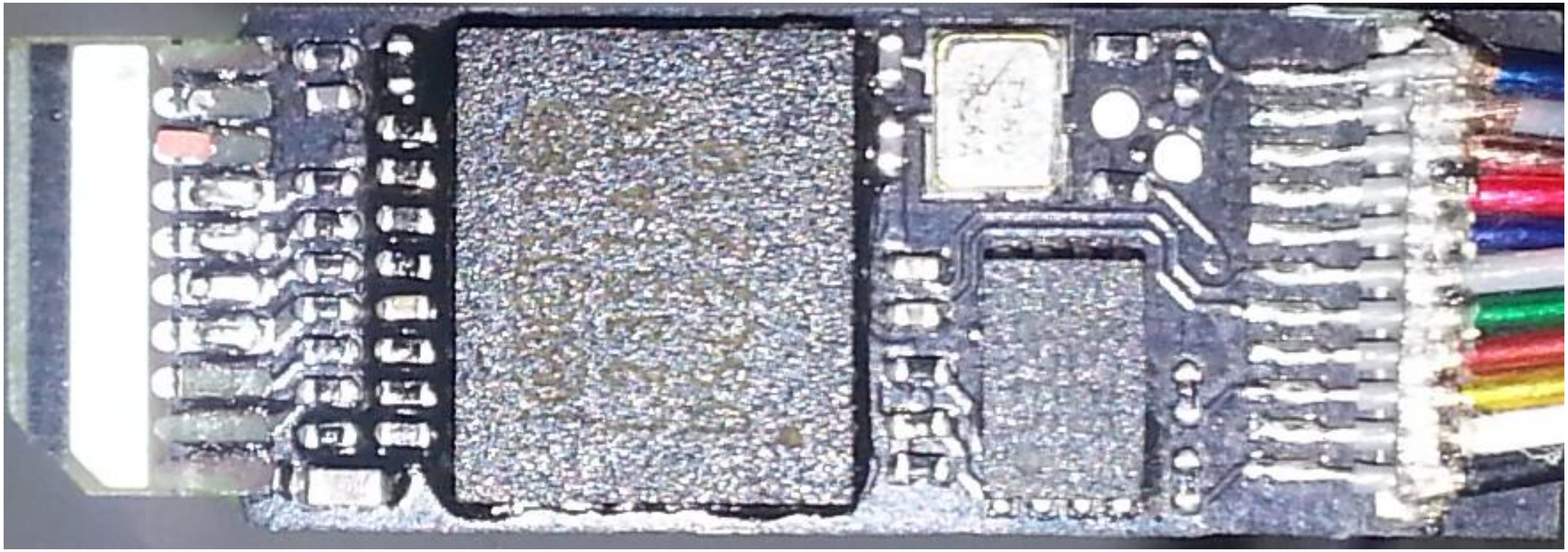

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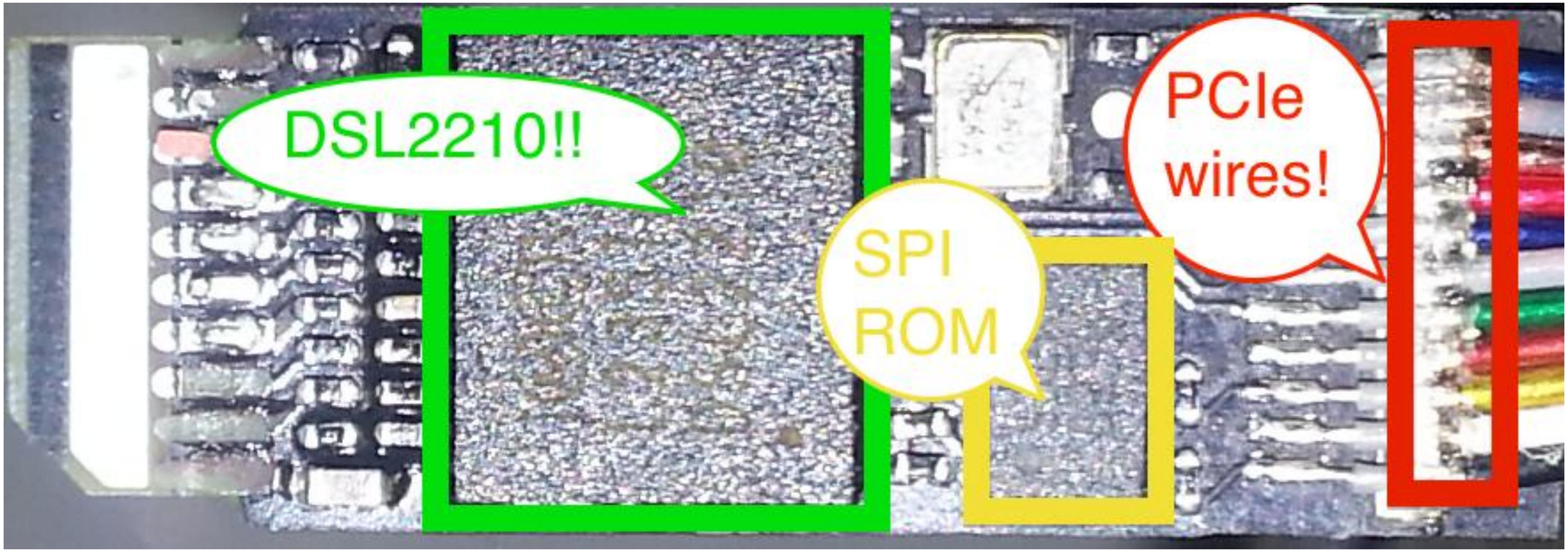

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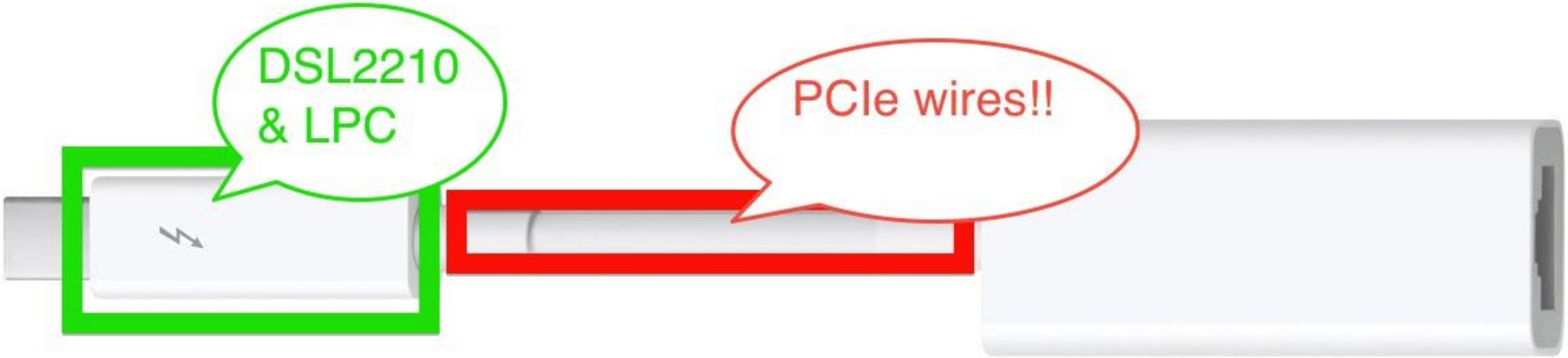

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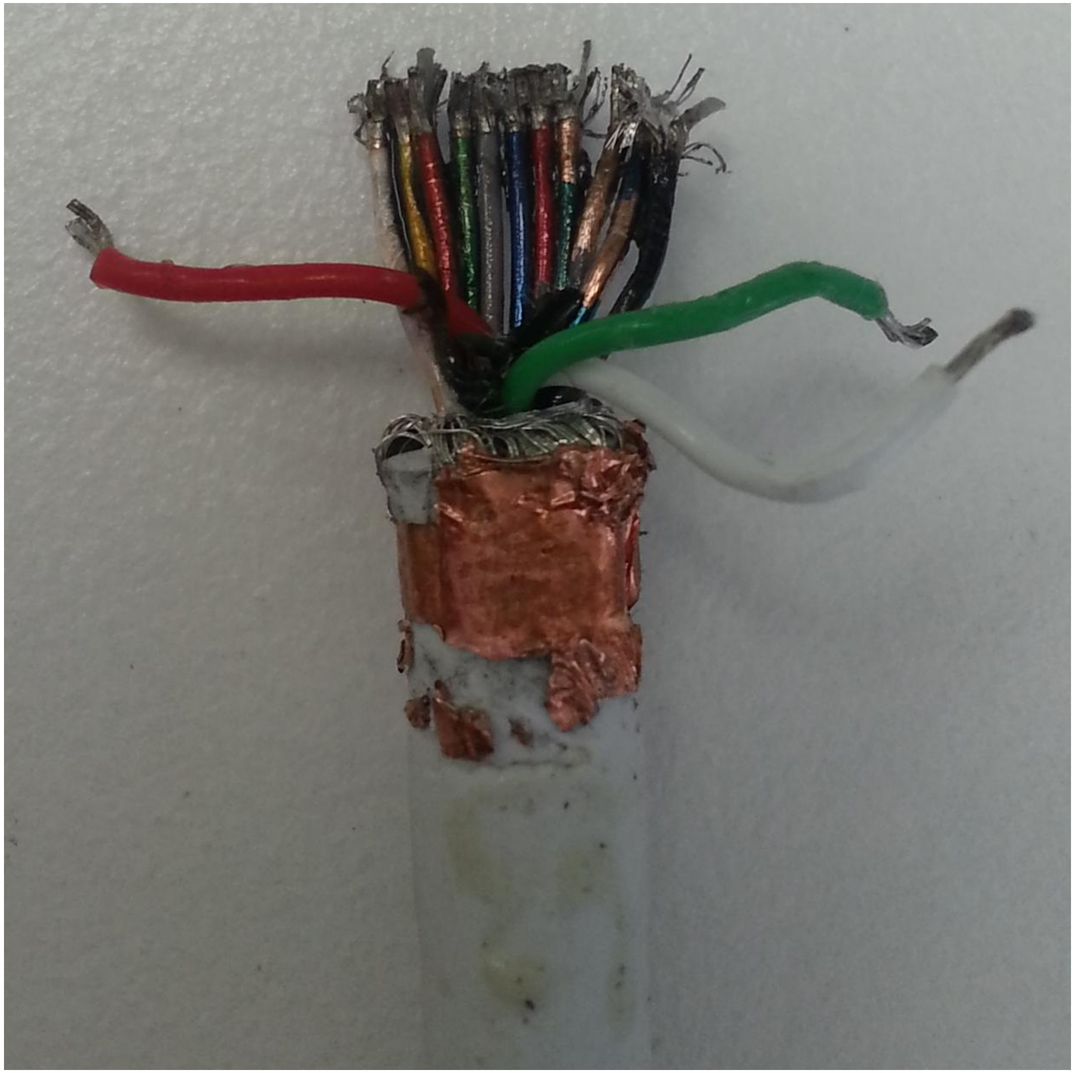
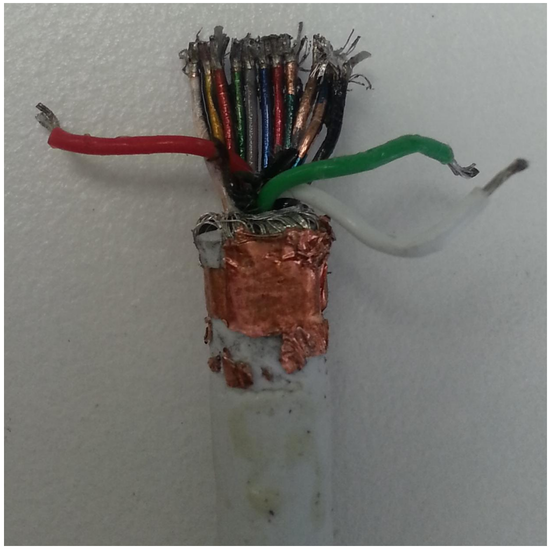


How My Adventures Went

- Altera Cyclone IV GX Transceiver Starter Kit
  - Hard IP for PCIe
  - PCIe x1
  - ~$450

How My Adventures Went



How My Adventures Went

- Tips and Tricks
    - Get A LOT of devices!
    - Heat up everything SLOWLY!
    - Continuity testing WINS
    - Sniff EVERYTHING
    - Read all ROMs/Flashes

Thank You

- Russ Sevinsky
  - Security Consultant at iSEC Partners
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- Special thanks to:
  - Jesse Burns
  - Everyone @ iSEC Partners

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