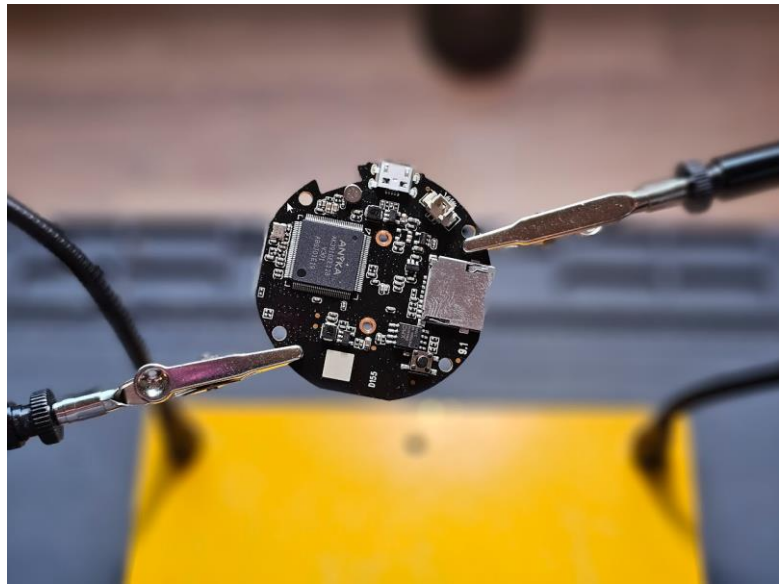
Anyone Can Hack IoT

A Beginner's Guide to Hacking Your First IoT Device.

Andrew Bellini



The “S” in IoT stands for security

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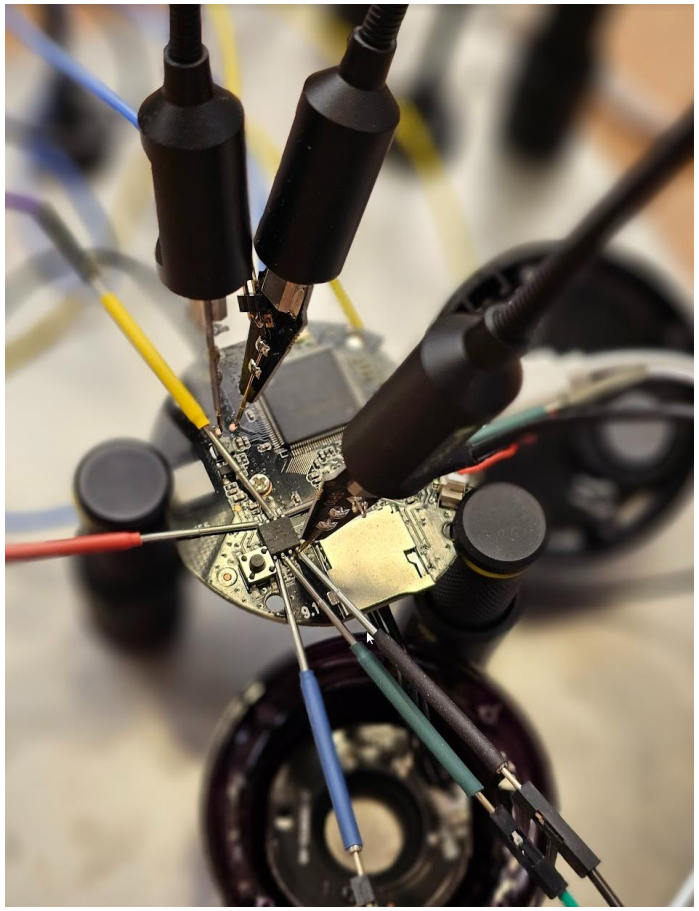
> 15 billion devices in 2024

~ 30 billion devices in 2030

Barriers to learning IoT security

- **$$$ Expensive**
  - Need tools, gear
  - Buy targets to test
  - Lack of affordable training

- **Complicated**
  - Electronics, Circuits, Hardware, Soldering
  - Special protocols

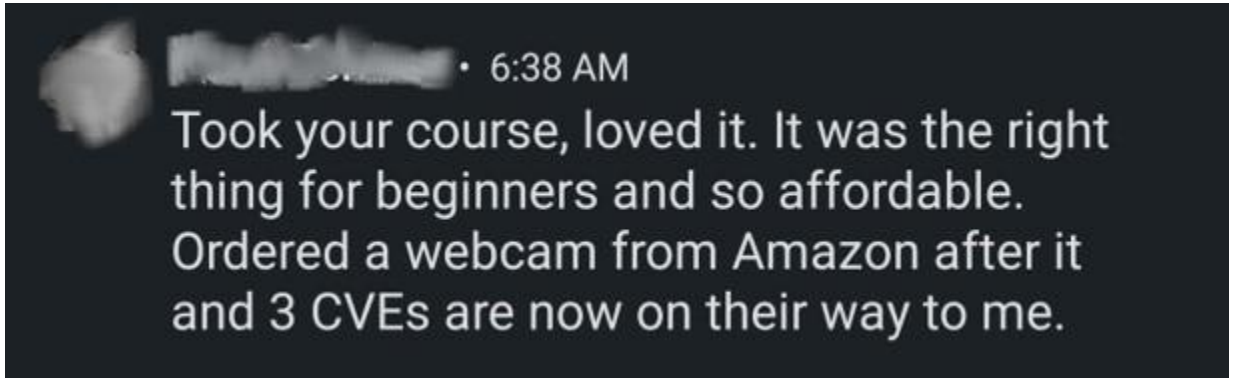


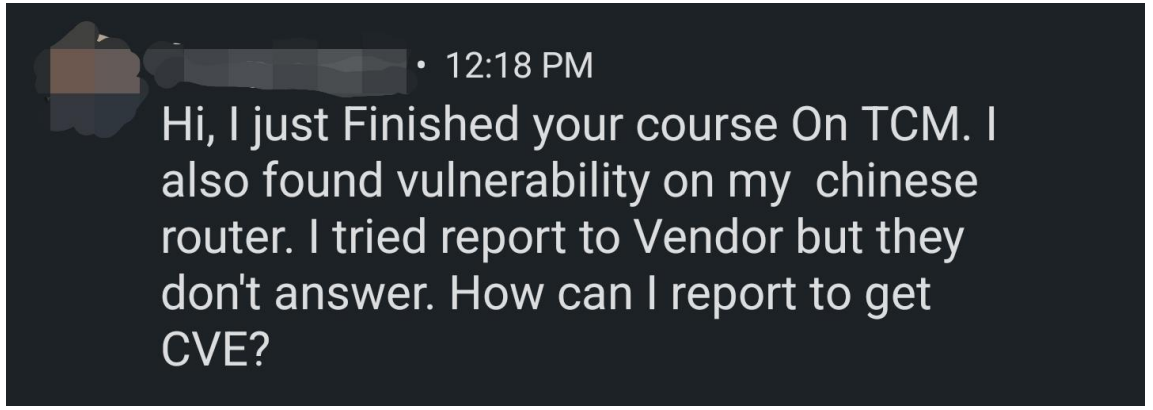
whoami

- Andrew Bellini(DigitalAndrew)
- Electrical Engineer, P.Eng
- Content Creator at TCM Security
- Creator of TCMs IoT Hacking Course and PJIT Certification
- Link up with me: andrewbellini.com

Goal of this talk

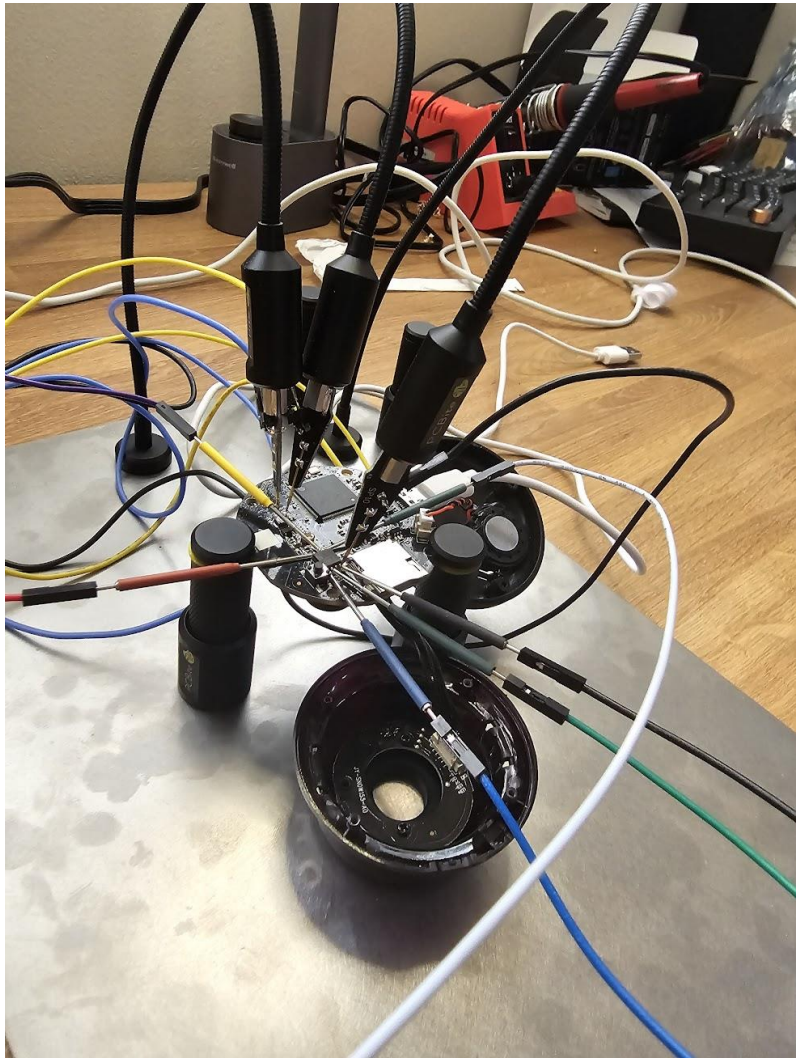
Provide you with a methodology, specifics tools and knowledge to find vulnerabilities(hack)in commercial IoT devices.





Who this talk is for

- Everyone! ☺
- Catered to people who are, new curious or interested in IoT hacking
- Assumes limited or no experience and knowledge about IoT or embedded systems

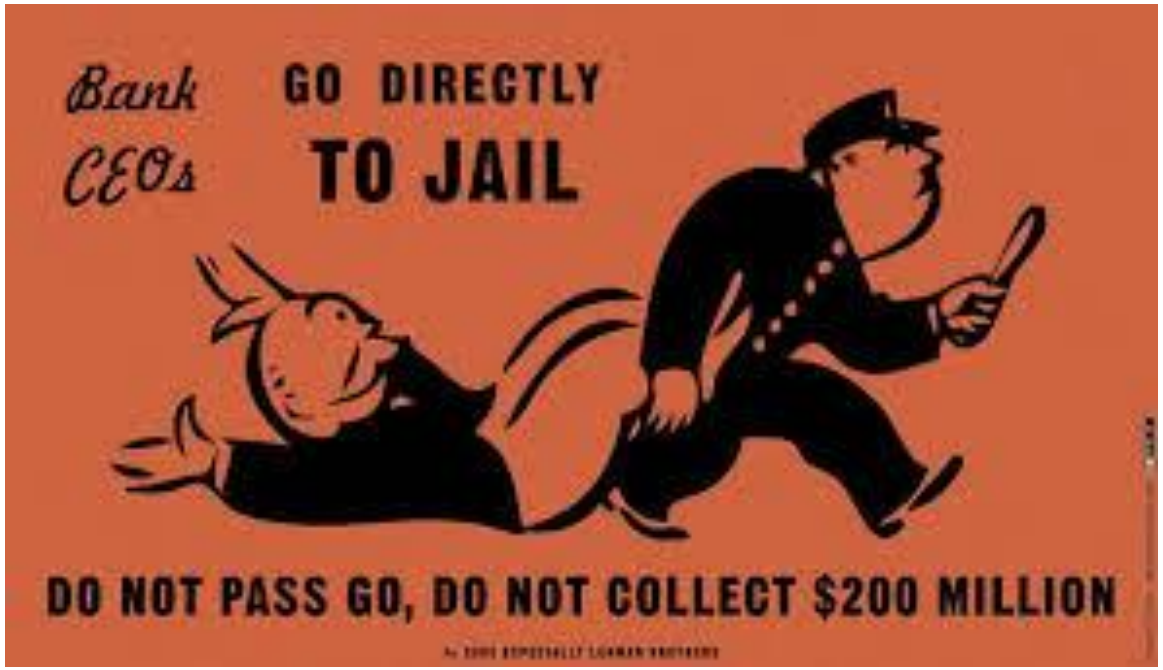


Agenda

1. Safety and Legal Considerations
2. Picking a device to hack
3. Building out an affordable toolkit
4. Locating, using and abusing hardware interfaces
5. Acquiring firmware
6. Analyzing and reverse engineering firmware

Staying out of trouble

- Only test devices you are authorized to
- Be ethical and follow responsible disclosure

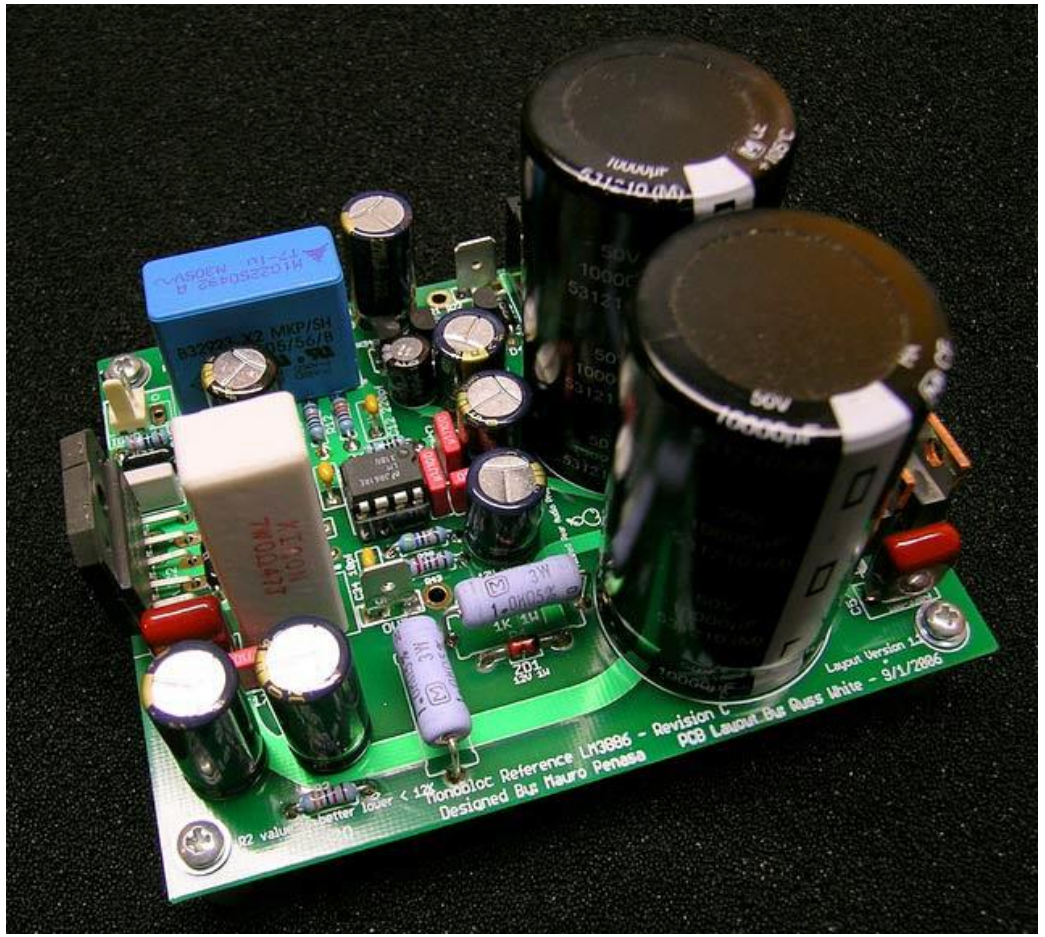


Staying safe

- IoT hacking inherently safe with a few constraints
- Never work on high voltage (the voltage from your outlets)
- Never used damaged or modified power supplies
- Power off circuits when not in use

Staying safe

- Be mindful of large capacitors
- Not common in most IoT devices



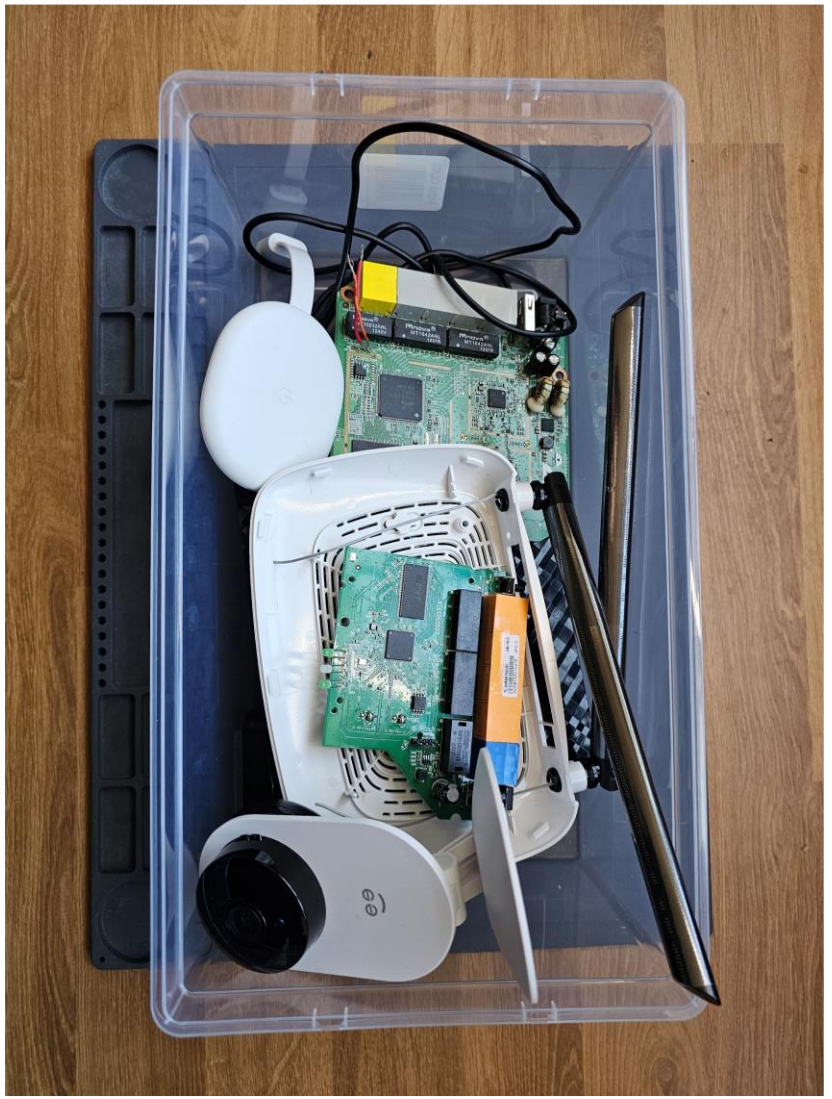
Methodology Step 1

Pick a Target

Picking a target

What device should I start with?

- Cheaper the better!
- Don’t hack anything you don’t mind bricking :P
- I suggest cheap routers and smart/IP cameras as a starting place
- Dumpster diving is cool!

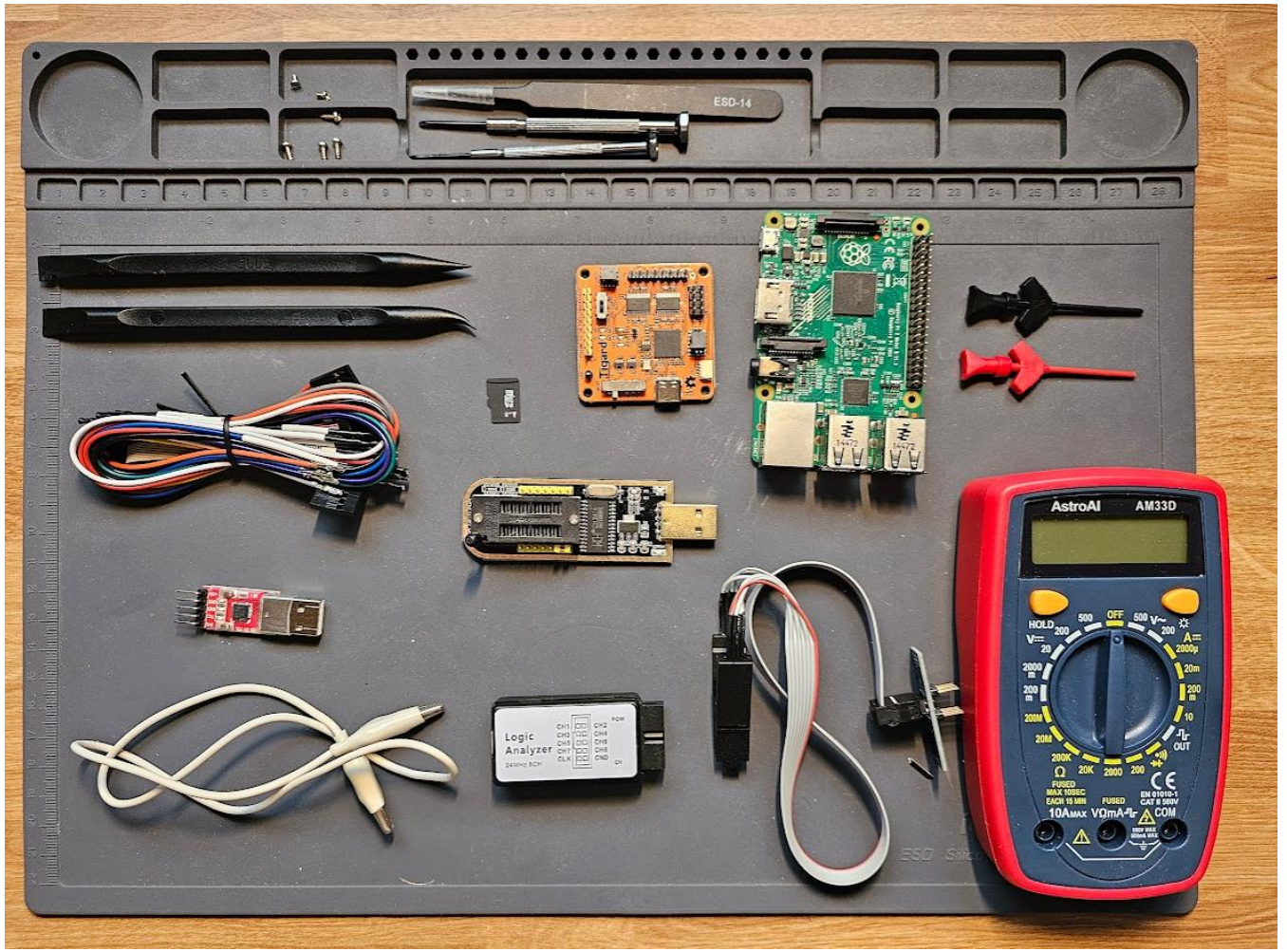


Methodology Step 2

Acquire Gear

Building an affordable toolkit

- Don’t break the bank
- Follow 80/20 rule
- Don’t need a dolphin toy…



Building an affordable toolkit

Building an affordable toolkit

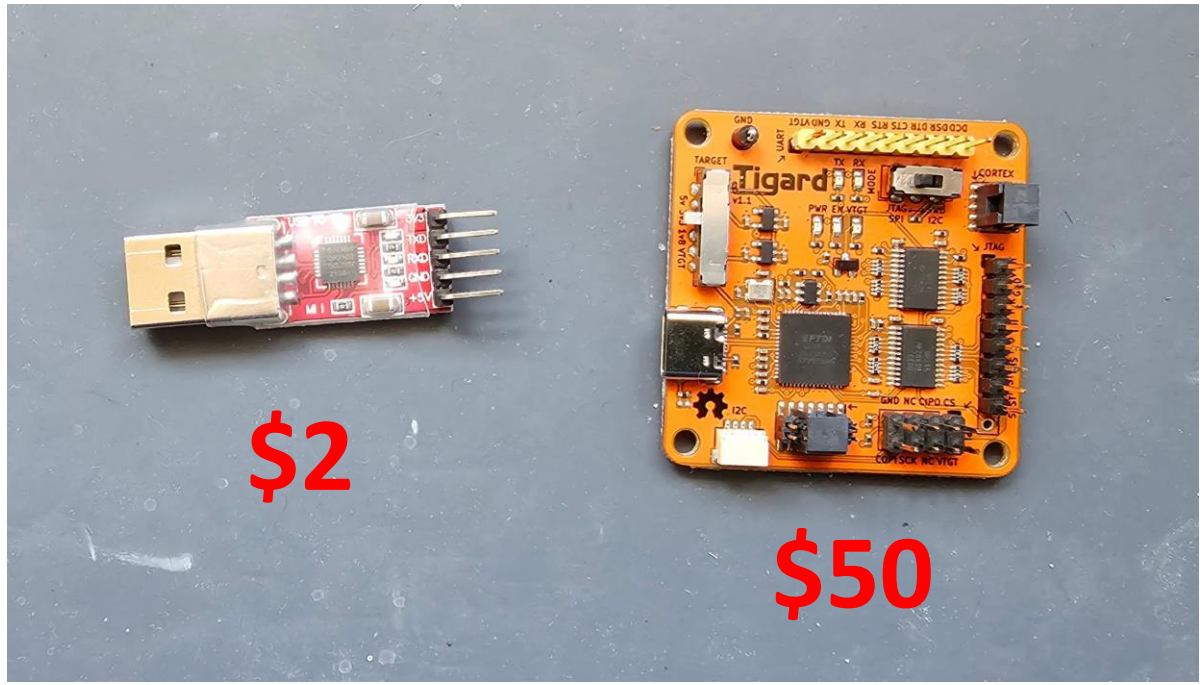
Digital Multimeter

- Swiss army knife of electronics measurements
- Verify voltage levels
- Detect test/debug ports
- $5 - $100

Building an affordable toolkit

USB-X Adapter

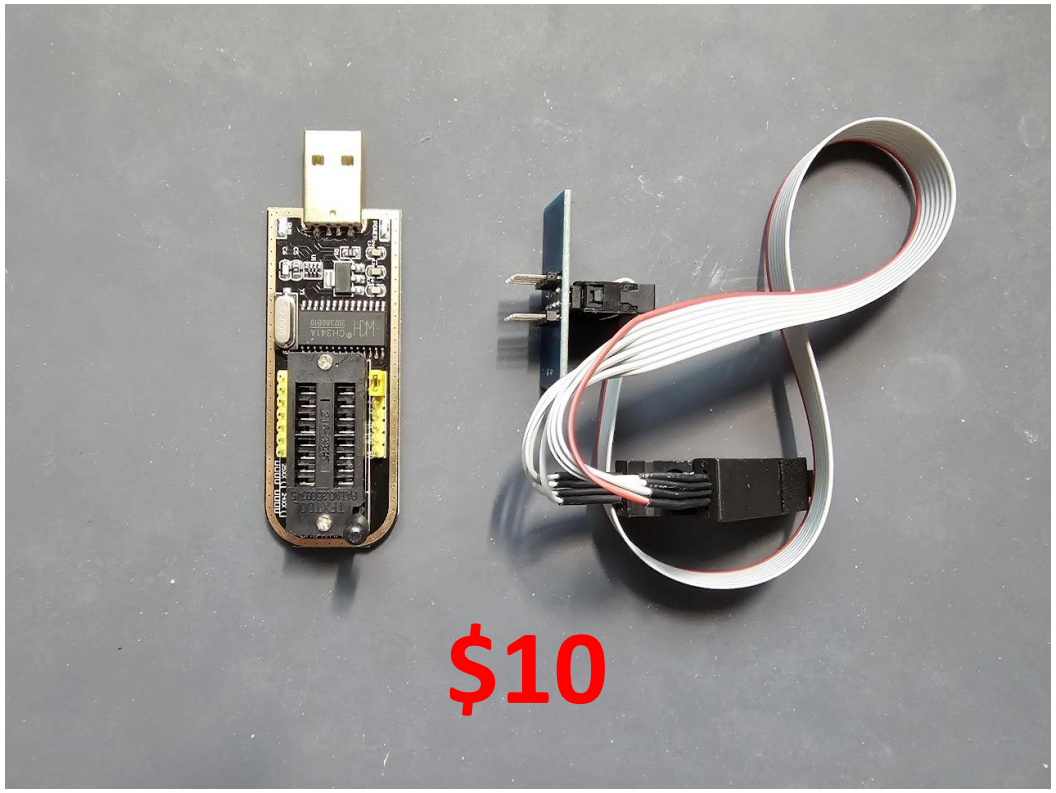
- Something that can talk to debug ports
- Common protocols include UART, SPI, I2C, JTAG , SWD
- UART most common
- 2$ - $50



Building an affordable toolkit

Flash Programmer

- Used to extract firmware and unbrick devices
- Most cheap devices use standard pinout SPI flash
- Tigard is a great option
- May not need when starting out

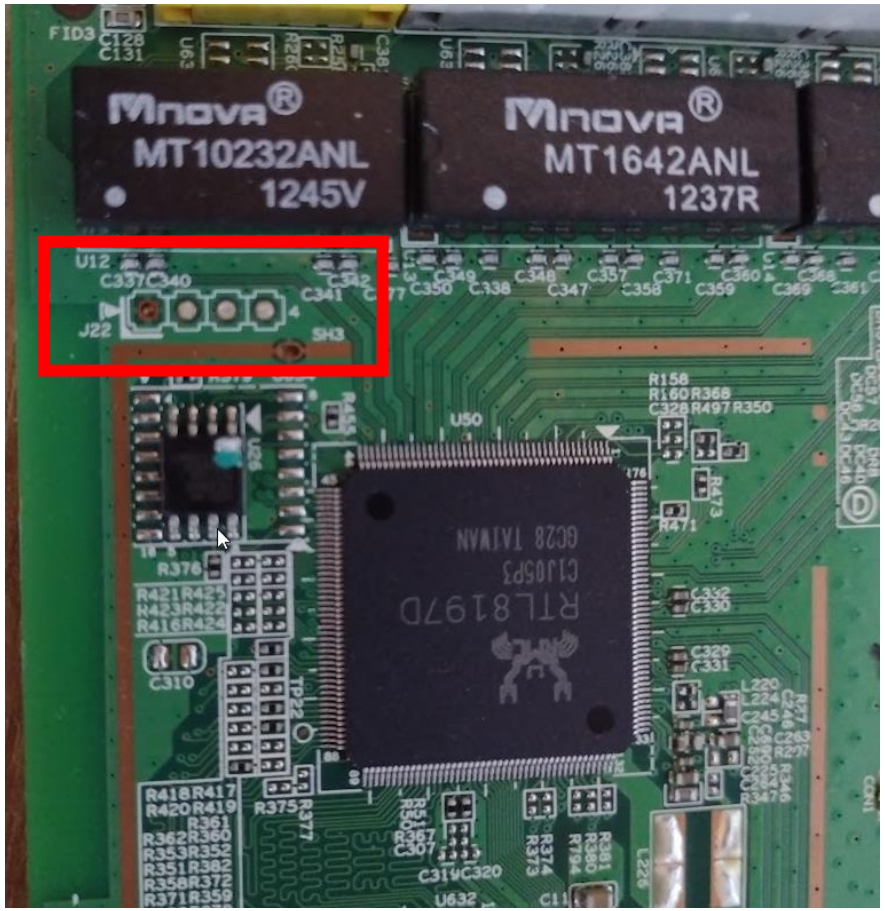


Methodology Step 3

Abuse Debug Ports

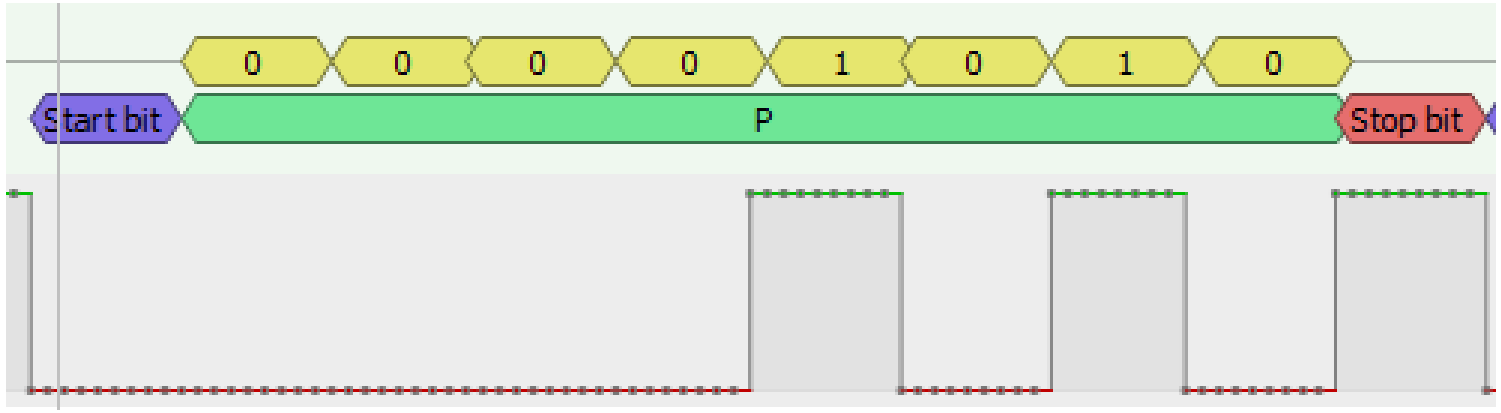
Hardware Debug Interfaces

- Used for debugging, programming and Q/A
- Frequently left on and unsecured
- Most common are UART and JTAG/SWD
- We'll focus on UART



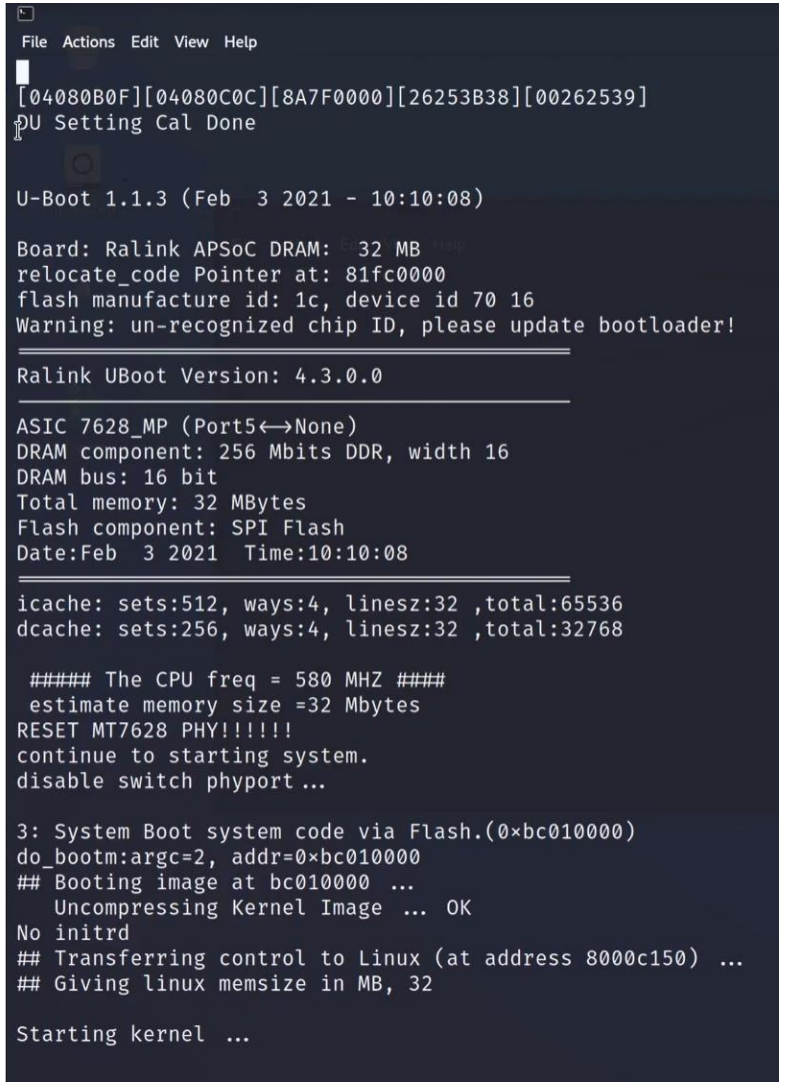
What is UART?

- Universal Asynchronous Receiver Transmitter
- Old and very common protocol for electrical communication
- Uses pulses of voltage to transmit binary



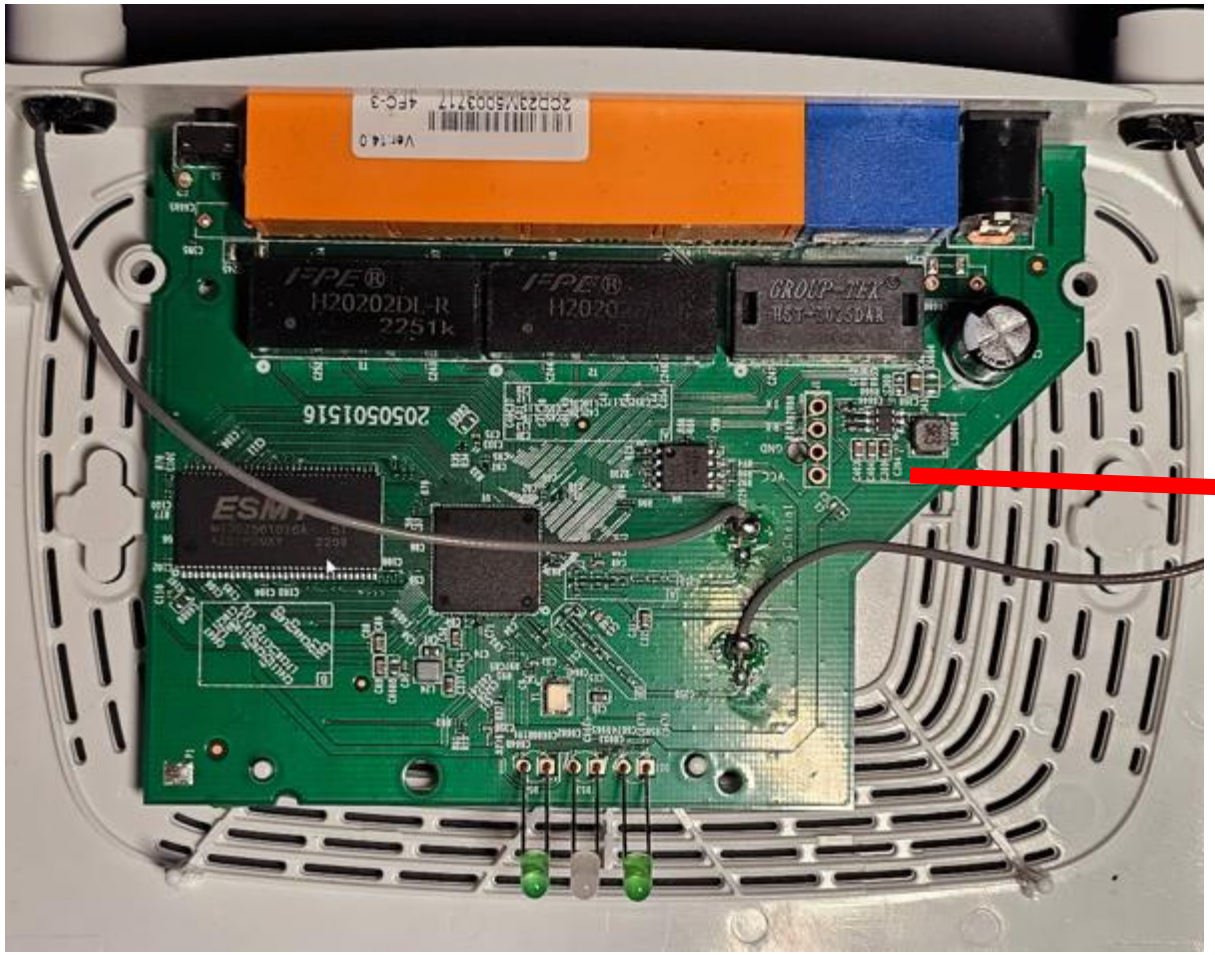
What can we do with UART?

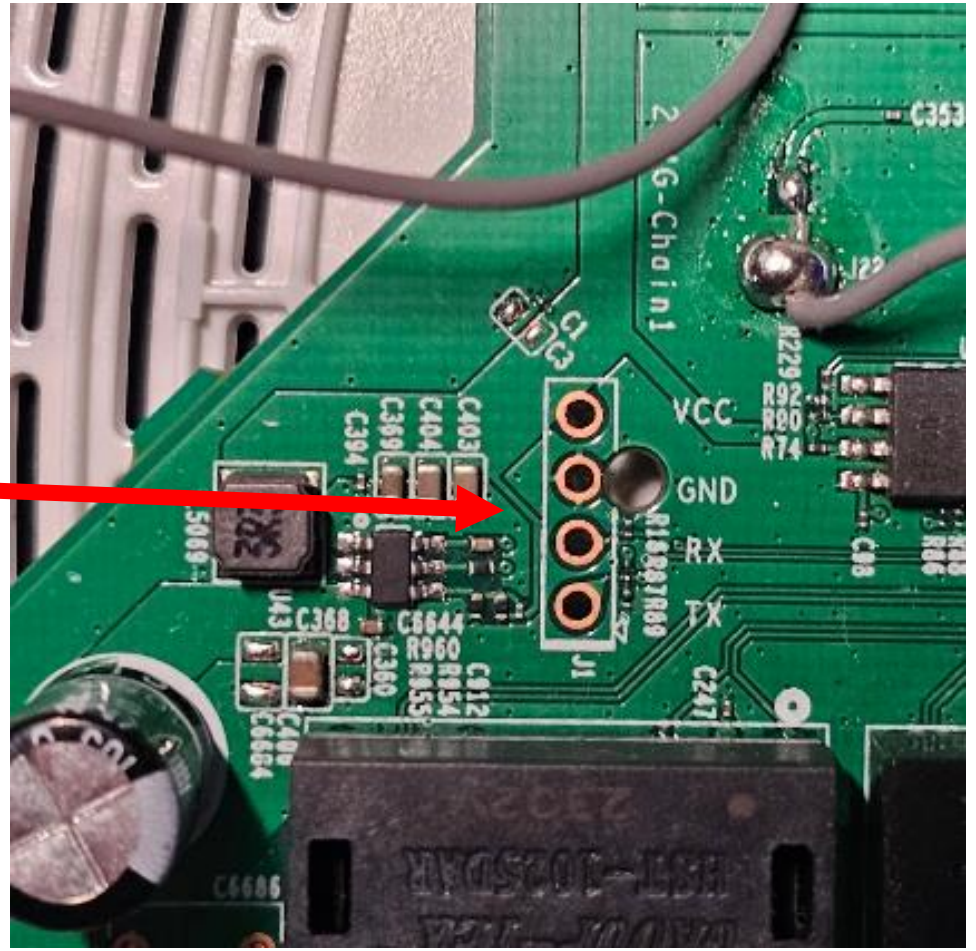
- View device logging
- Get a shell for further enumeration
- Access bootloader
- Dump firmware



How to identify UART connections

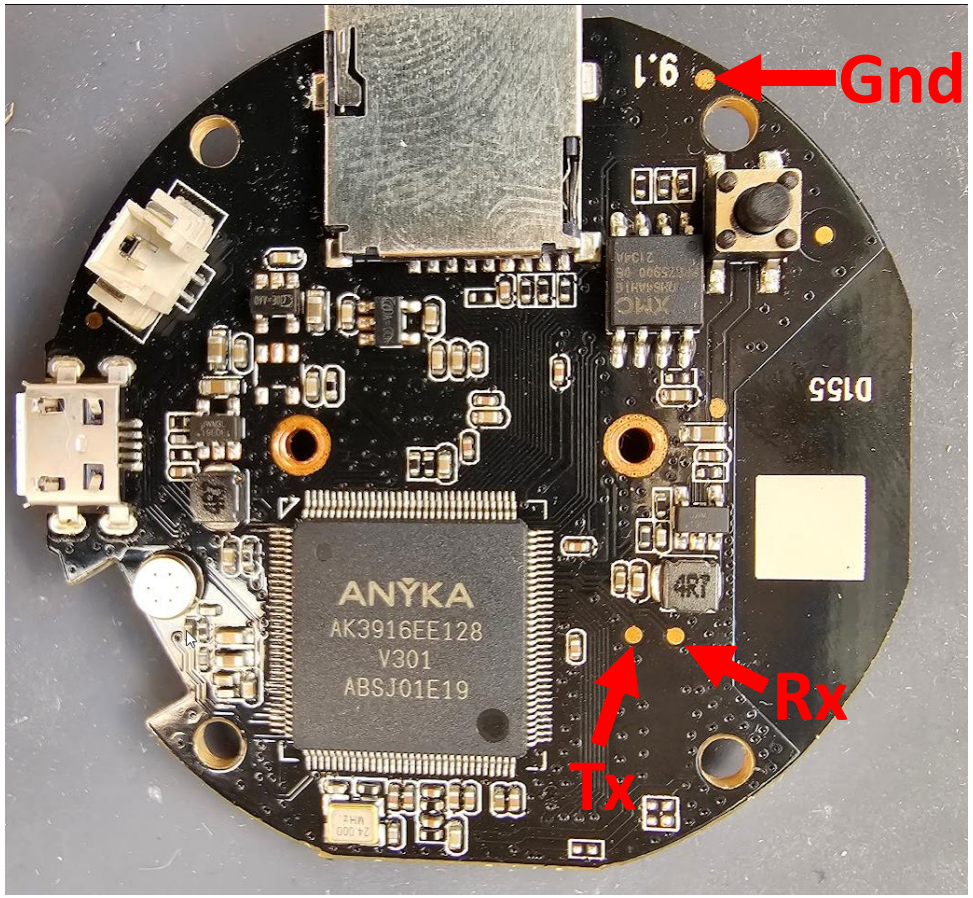
- Full duplex UART at a minimum needs 3 contacts: Transmit(Tx), Receive(Rx) and Ground.





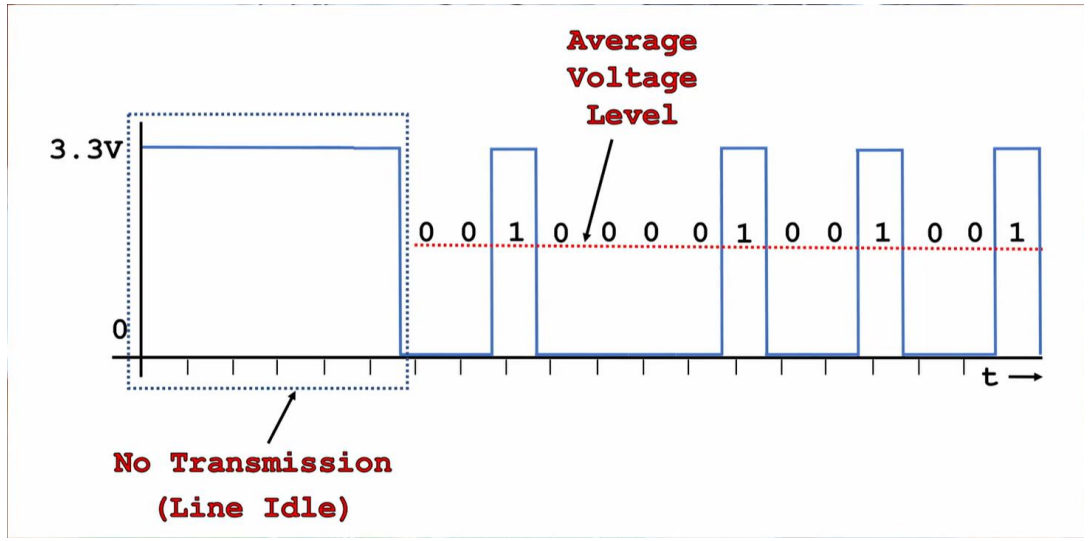
How to identify UART connections

- They won't always make it this easy



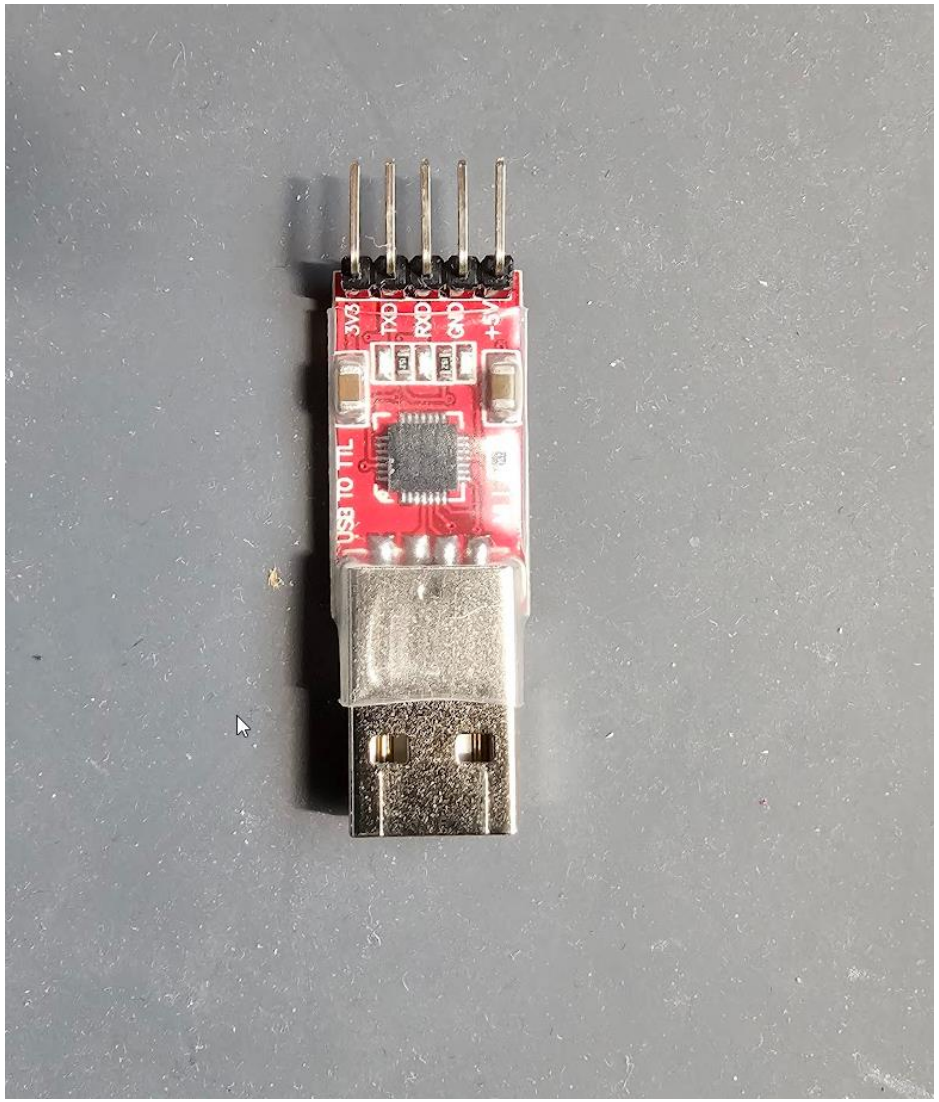
How to identify UART connections

- Use a DMM to test pads/pins
- UART chatty on bootup
- Fluctating voltage on a pin good indication of Tx

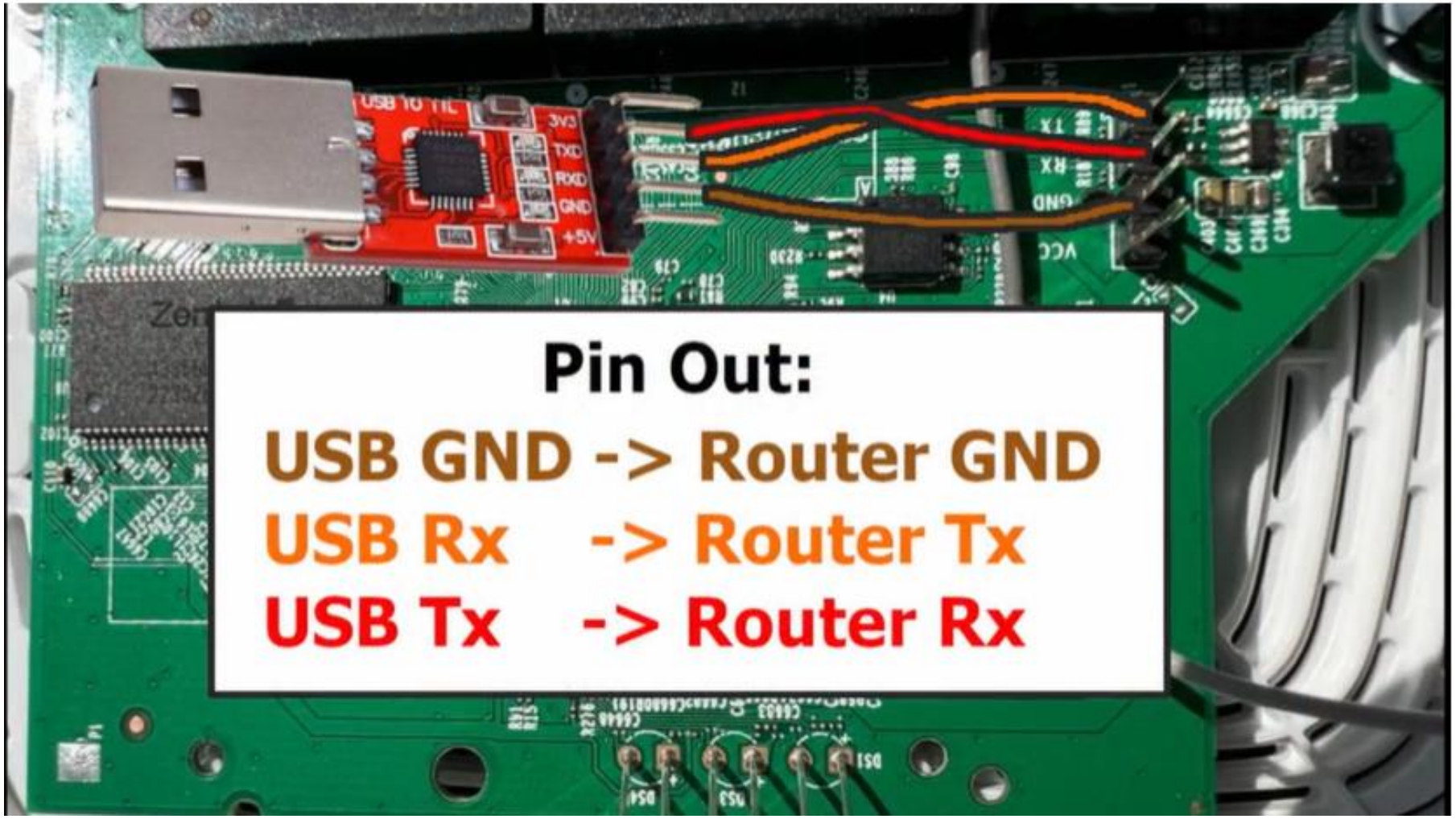


How to connect to it

- UART to USB bridge/adapter to connect to PC
- Rx -> Tx
- Tx -> Rx
- Gnd -> Gnd
- Ignore Vcc (if there is one)

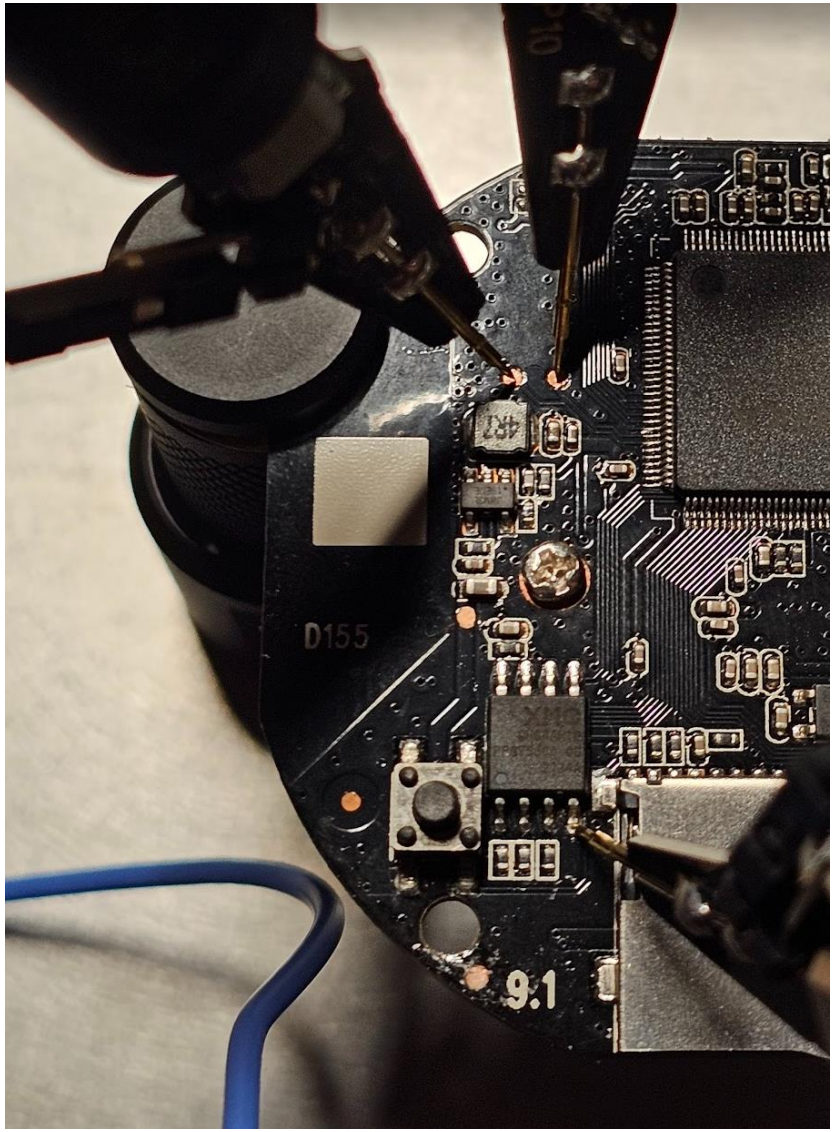


How to connect to it



What if I don’t have header pins?

- Best option is to solder
- Attach male dupont header pins to through hole
- Use clips, clamps, adapters to connect to test pads



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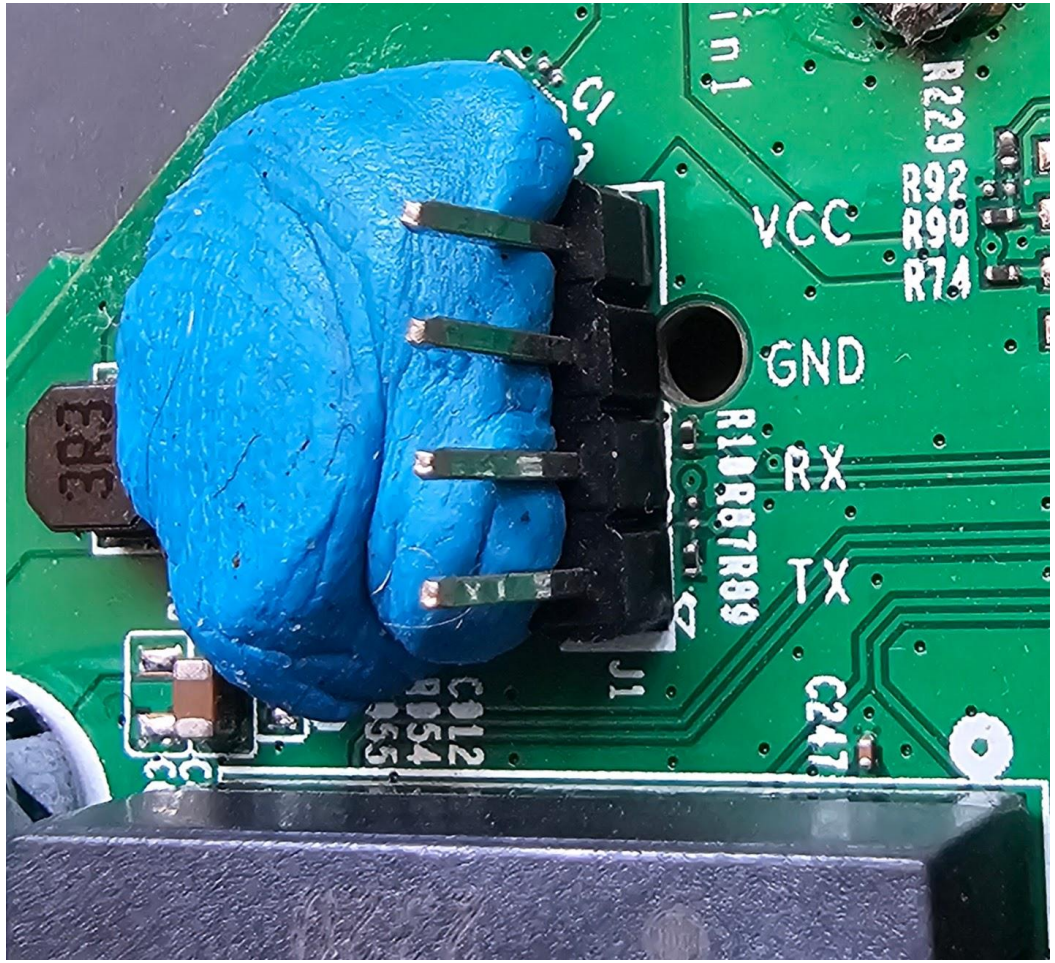
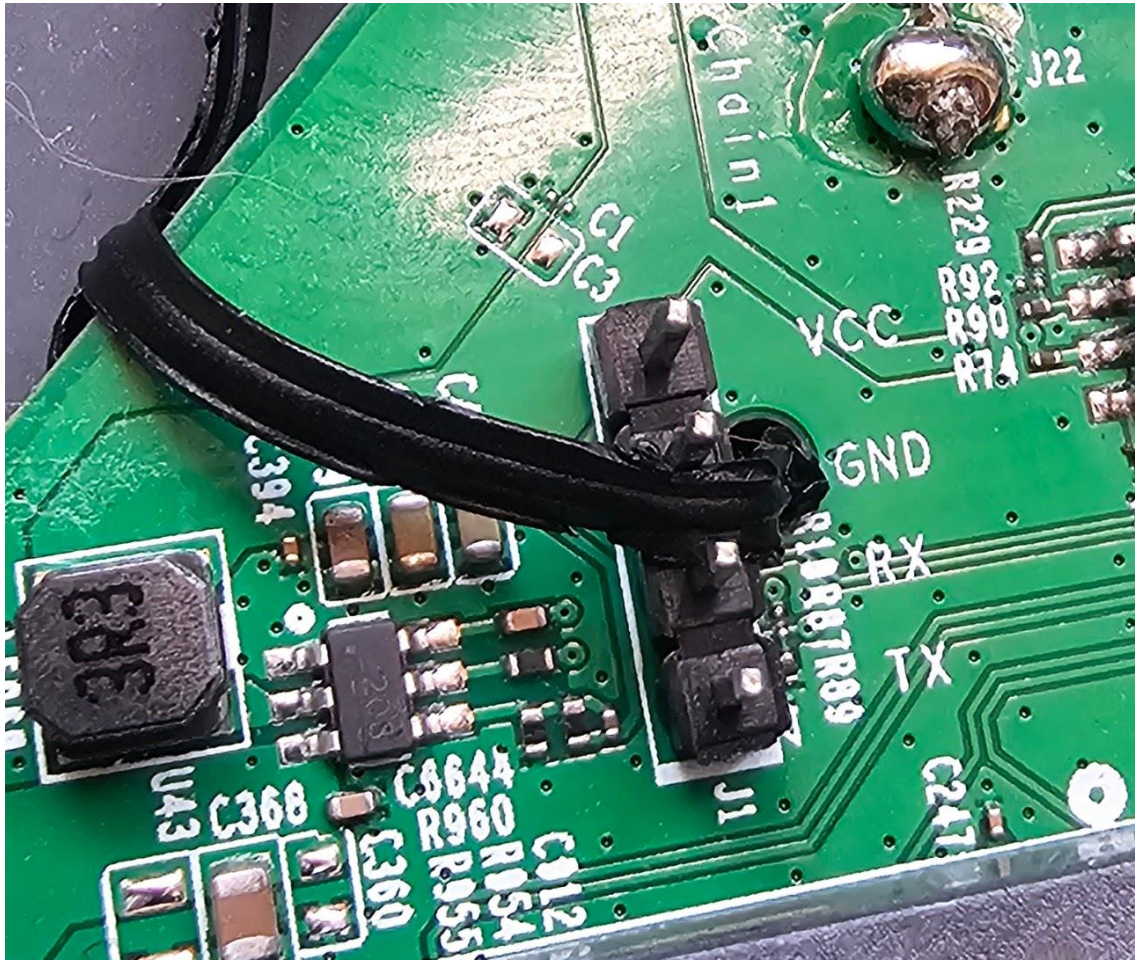




Interacting with UART

Steps for a Linux host

- Check UART device id (will be ttyUSB#):

```
ls -l /dev/serial/by-id
```

- Launch a terminal emulator (screen is the easiest):

```
sudo screen /dev/ttyUSB# 115200
```

Now what?

- If all worked should see boot logs on power up
- Hit enter to try for a shell
- Majority of routers and smart cameras run Linux

```
NR_IRQS:128
console [ttyS1] enabled
Calibrating delay loop... 386.04 BogoMIPS (lpj=772096)
pid_max: default: 4096 minimum: 301
Mount-cache hash table entries: 512
NET: Registered protocol family 16
bio: create slab <bio-0> at 0
Switching to clocksource Ralink Systick timer
NET: Registered protocol family 2
IP route cache hash table entries: 1024 (order: 0, 4096 bytes)
TCP established hash table entries: 1024 (order: 1, 8192 bytes)
TCP bind hash table entries: 1024 (order: 0, 4096 bytes)
TCP: Hash tables configured (established 1024 bind 1024)
TCP reno registered
NET: Registered protocol family 1
squashfs: version 4.0 (2009/01/31) Phillip Lougher
msgmni has been set to 57
io scheduler noop registered
io scheduler deadline registered (default)
Ralink gpio driver initialized
Serial: 8250/16550 driver, 2 ports, IRQ sharing enabled
serial8250: ttyS0 at MMIO 0x10000d00 (irq = 21) is a 16550A
serial8250: ttyS1 at MMIO 0x10000c00 (irq = 20) is a 16550A
brd: module loaded
flash manufacture id: 1c, device id 70 16
Warning: un-recognized chip ID, please update SPI driver!
EN25Q32B(1c 30161c30) (4096 Kbytes)
mtd .name = raspi, .size = 0x00400000 (4M) .erasesize = 0x00010000 (64K)
Creating 5 MTD partitions on "raspi":
0x000000000000-0x000000010000 : "boot"
0x000000010000-0x000000100000 : "kernel"
0x000000100000-0x0000003e0000 : "rootfs"
mtd: partition "rootfs" set to be root filesystem
0x0000003e0000-0x0000003f0000 : "config"
0x0000003f0000-0x000000400000 : "radio"
Register flash device:flash0
PPP generic driver version 2.4.2
PPP MPPE Compression module registered
NET: Registered protocol family 24
```

Now what?

Don’t discount the value of logging! Especially while interacting with the device!

```
[ util_execSystem ] 141:  prepareDropbear cmd is "dropbearkey -t rsa -f /var/tmp/dropbear/dropbear_rsa_host_key"

Will output 1024 bit rsa secret key to '/var/tmp/dropbear/dropbear_rsa_host_key'
Generating key, this may take a while ...
[ util_execSystem ] 141:  prepareDropbear cmd is "dropbearkey -t dss -f /var/tmp/dropbear/dropbear_dss_host_key"

Will output 1024 bit dss secret key to '/var/tmp/dropbear/dropbear_dss_host_key'
Generating key, this may take a while ...
```

```
[ util_execSystem ] 141:  oal_wlan_ra_setWlanBasicCfg cmd is "iwpriv ra0 set A
utoChannelSel=2"

[ util_execSystem ] 141:  oal_wlan_ra_setWlanBasicCfg cmd is "iwpriv ra0 set C
hannel=0"

[ util_execSystem ] 141:  oal_wlan_ra_setWlanBasicCfg cmd is "iwpriv ra0 set S
SID='i''o''t''h''a''c''k''i''n''g'"

[ util_execSystem ] 141:  oal_wlan_ra_setWlanAdvCfg cmd is "iwpriv ra0 set TxP
ower=100"

[ util_execSystem ] 141:  oal_wlan_ra_setWlanAdvCfg cmd is "iwpriv ra0 set Bea
conPeriod=100"
```

```
spiflash_ioctl_read, Read from 0x003e0000 length 0x10000, ret 0, retlen 0x1000
0
.
spiflash_ioctl_erase, erase to 0x003f0000 length 0x0, nerase done
spiflash_ioctl_write, Write to 0x003e0000 length 0x10000, ret 0, retlen 0x1000
0
T#[ util_execSystem ] 141:  oal_startPing cmd is "ipping -c 1 -s 64 -w 1 192.1
68.0.100 -I 192.168.0.1 &"

[ ippingPacketResultHandler ] 4626:  stat: , time: 0, type: 4, pks: 0, result:
 PING 192.168.0.100 (192.168.0.100): 64 data bytes


PING 192.168.0.100 (192.168.0.100): 64 data bytes
[ ippingPacketResultHandler ] 4626:  stat: None, time: 1281, type: 0, pks: 0,
result: 72 bytes from 192.168.0.100: icmp_seq=0 ttl=64 time=1.281 ms
```

If you also got a shell

- Enumerate, enumerate, enumerate
- Places to start /etc /var
- Can you find passwords, hardcoded keys, endpoints?
- What processes and network connections are up?

```
/var #
/var # /var/tmp/_tools/busybox-mipsel find -name '*.xml'
./tmp/upnpd/gatedesc.xml
./tmp/upnpd/gateicfgSCPD.xml
./tmp/upnpd/gateconnSCPD.xml
./tmp/upnpd/dummy.xml
./tmp/wsc_upnp/WFADeviceDesc.xml
./tmp/wsc_upnp/WFAWLANConfigSCPD.xml
```

```
grep: ./tmp/21: No such device or address
grep: ./tmp/7: No such device or address
grep: ./tmp/6: No such device or address
grep: ./tmp/19: No such device or address
grep: ./tmp/25: No such device or address
./tmp/dconf/cmxdns.conf:password
./tmp/dconf/noipdns.conf:password
./tmp/dconf/dyndns.conf:password
./tmp/dropbear/dropbearpwd:password:62c8ad0a15d9d1ca38d5dee762a16e01
/var #
```

Methodology Step 4

Acquire Firmware

Acquiring Firmware

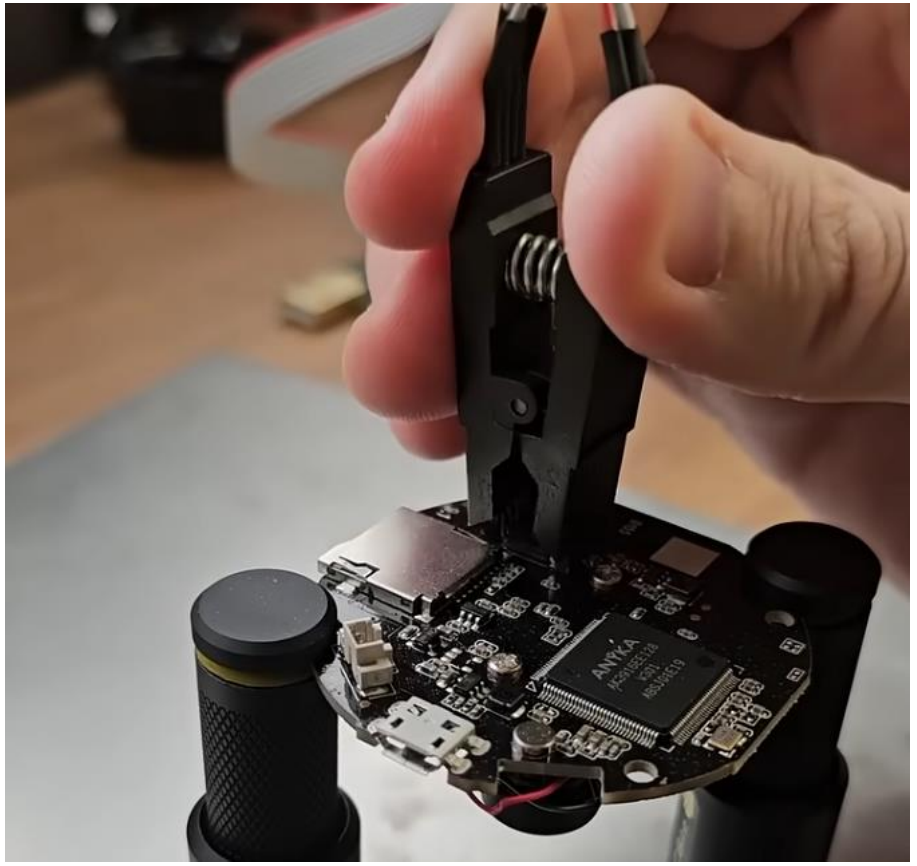
Firmware is the software running on an embedded device

- Embedded Linux is comprised of:
  - bootloader
  - kernel
  - root file system
  - partition(s) for data

- Root file system has most of the goodies

Acquiring Firmware

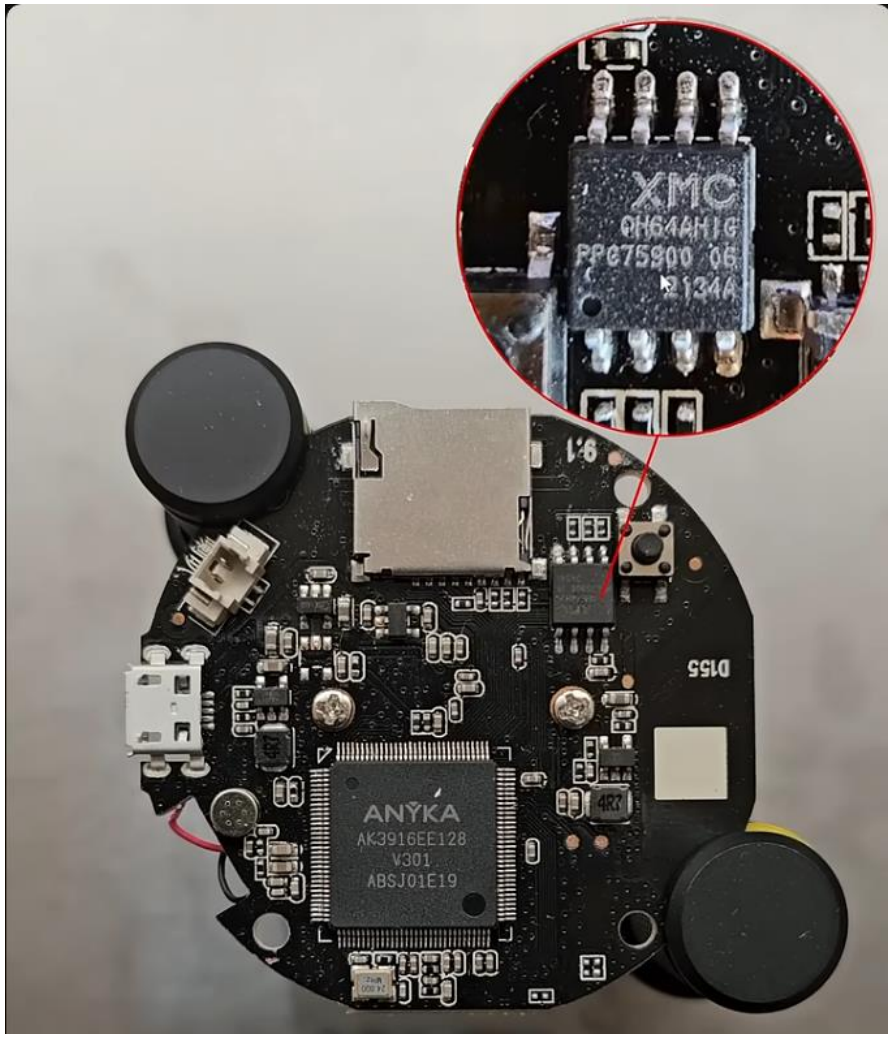
- Easiest method = download from vendor
- Transfer files of interest via UART
- Read from device



Acquiring Firmware

Reading SPI Flash Chips

- Use in majority of “cheap” IoT device
- Frequently in SOP8 package
- Readable using flash programmer and flashrom(FOSS)



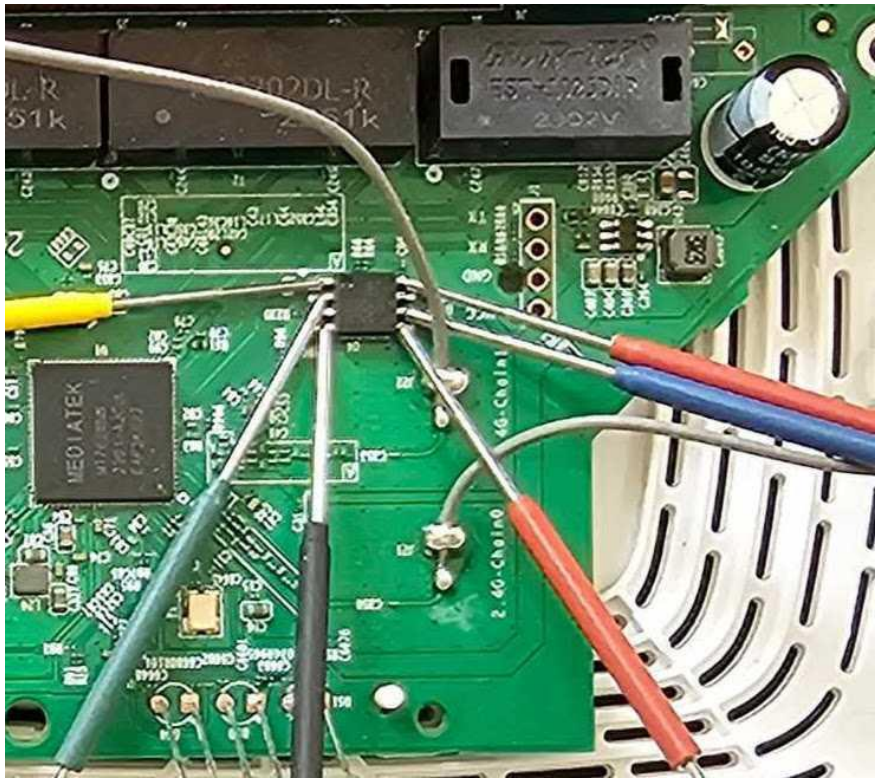
Acquiring Firmware

How to use flashrom

- Flashrom is free and opensource
- With a ch341a programmer:

```
flashrom -p ch341a_spi -r name.bin
```

- Can also use with Tigard



Methodology Step 5

Reverse Engineer

Unpacking firmware

- Cross fingers it’s not encrypted
- Use binwalk to check contents and extract

binwalk -Me firmware_name.bin

```
└─$ binwalk [redacted]_ext.bin

DECIMAL       HEXADECIMAL     DESCRIPTION
--------------------------------------------------------------------------------
53536         0xD120          U-Boot version string, "U-Boot 1.1.3 (Aug 16 2022 - 12:01:12)"
66048         0x10200         LZMA compressed data, properties: 0x5D, dictionary size: 8388608 bytes, uncompressed
32 bytes
1048576       0x100000        Squashfs filesystem, little endian, version 4.0, compression:xz, size: 3001844 bytes
, blocksize: 262144 bytes, created: 2022-08-16 04:14:58
```

Analyzing firmware

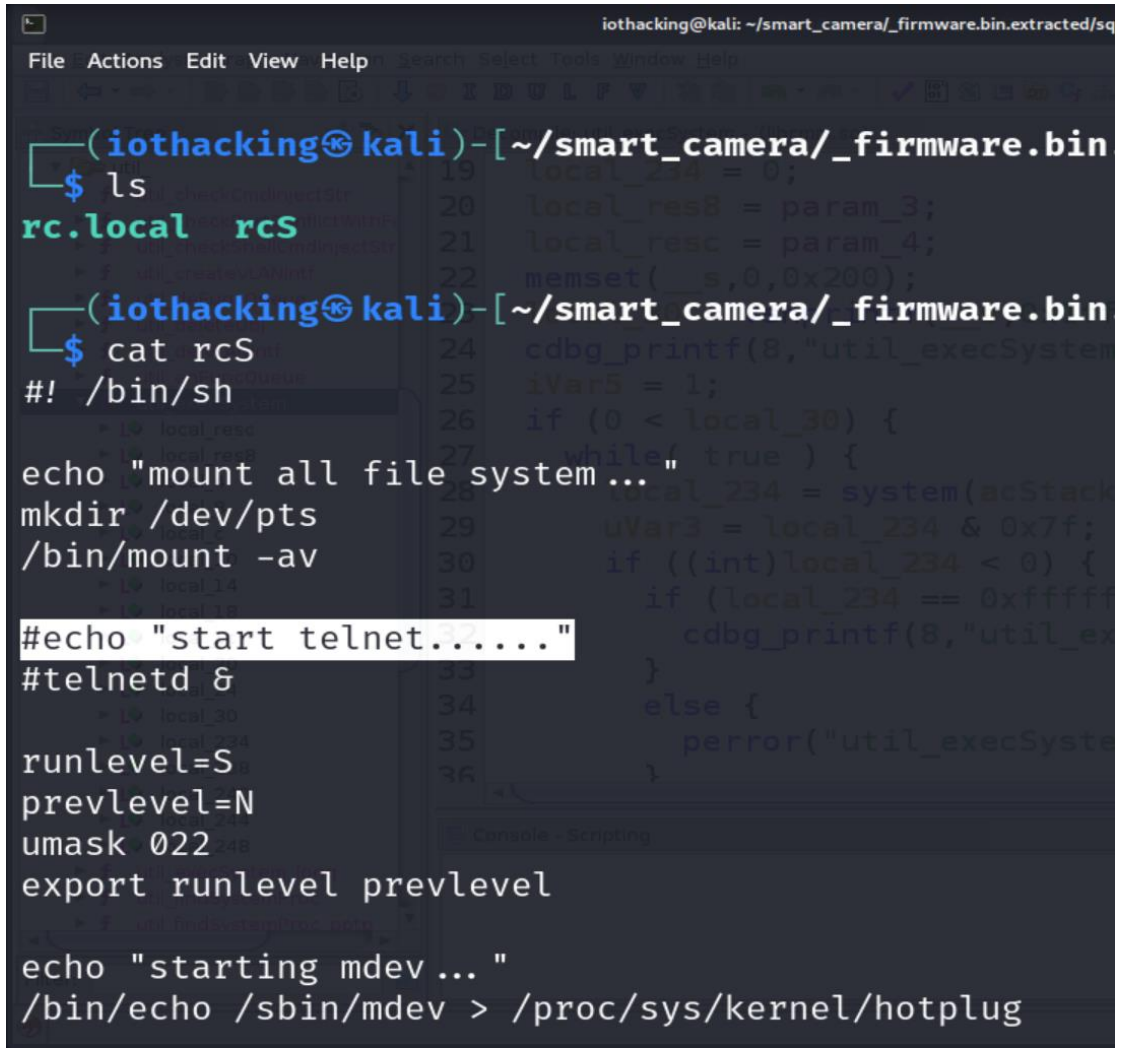
- Now the fun starts!
- Focus on root file system
- Enumerate and look for files of interest
- Low hanging fruit includes config files and scripts

```
find . -name "*.extension"
```

```
strings -f * | grep "pass"
```

Look at the rcS scripts

- Most IoT devices use busybox init system
- Runs the rcS scripts in etc/init.d
- Scripts are responsible for setting up the device
- No decompiling required



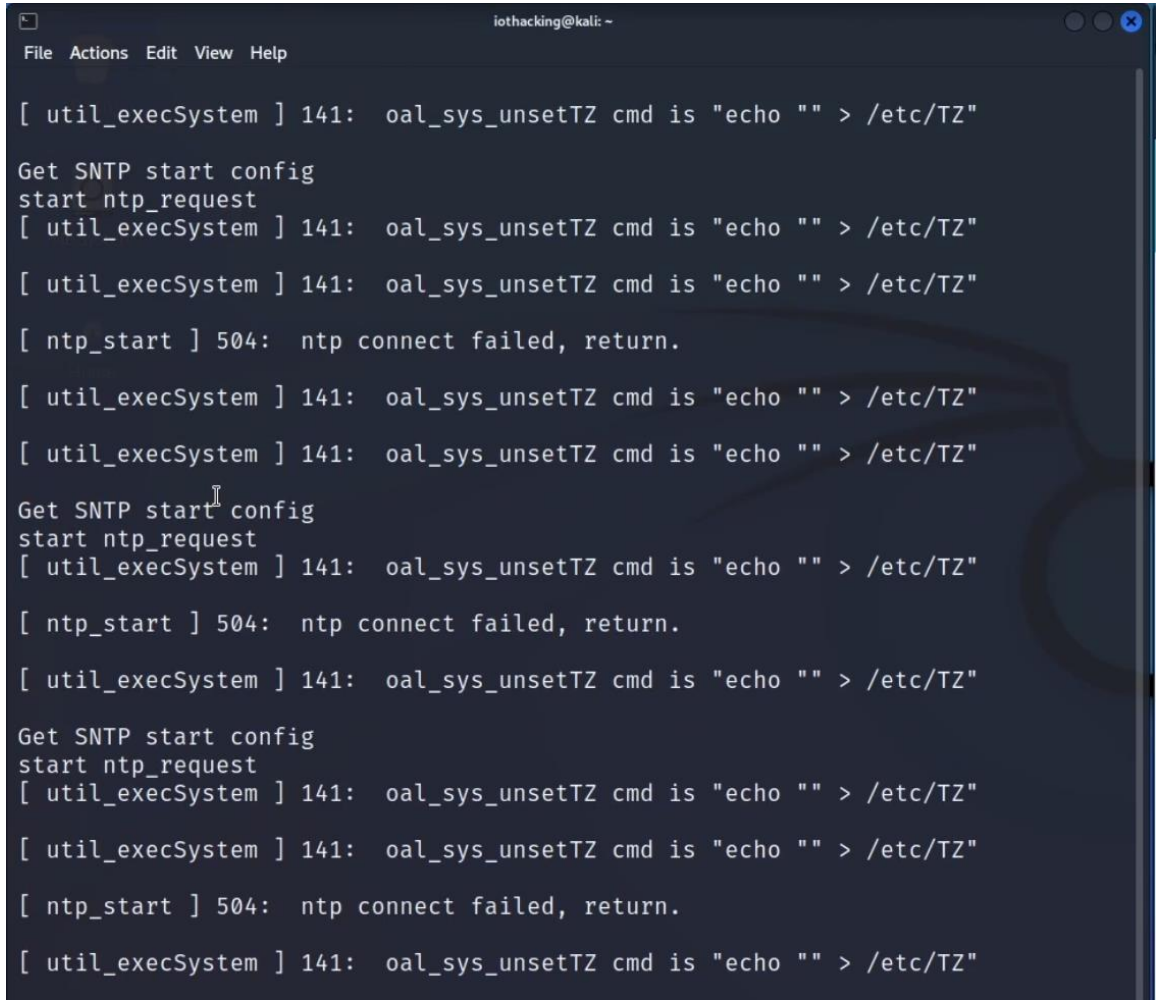
Reverse engineering binaries and libs

- More likely to find a vuln through this
- Rest of the steps are setup leading to support this
- How we pick where to start?

```
┌──(iothacking㉿kali)-[~/smrt_safe/challenge/_s
root/usr/lib]
└─$ ls
engines-3                libgnutlsxx.so
libatomic.so.1           libgnutlsxx.so.30
libatomic.so.1.2.0       libgnutlsxx.so.30.
libcjson.so              libgomp.so.1
libcjson.so.1            libgomp.so.1.0.0
libcjson.so.1.7.18       libhistory.so
libcjson_utils.so        libhistory.so.8
libcjson_utils.so.1      libhistory.so.8.2
libcjson_utils.so.1.7.18 libhogweed.so
libcrypto.so             libhogweed.so.6
libcrypto.so.3           libhogweed.so.6.8
libcrypt.so              libirs.so
libcrypt.so.2            libirs.so.161
libcrypt.so.2.0.0        libirs.so.161.0.1
libcurses.so             libisccfg.so
libdbus-1.so             libisccfg.so.163
libdbus-1.so.3           libisccfg.so.163.0
libdbus-1.so.3.32.4      libisc.so
libdhcp.so               libisc.so.1107
libdhcp.so.0             libisc.so.1107.0.7
libdhcp.so.0.0.0         libjq.so
```

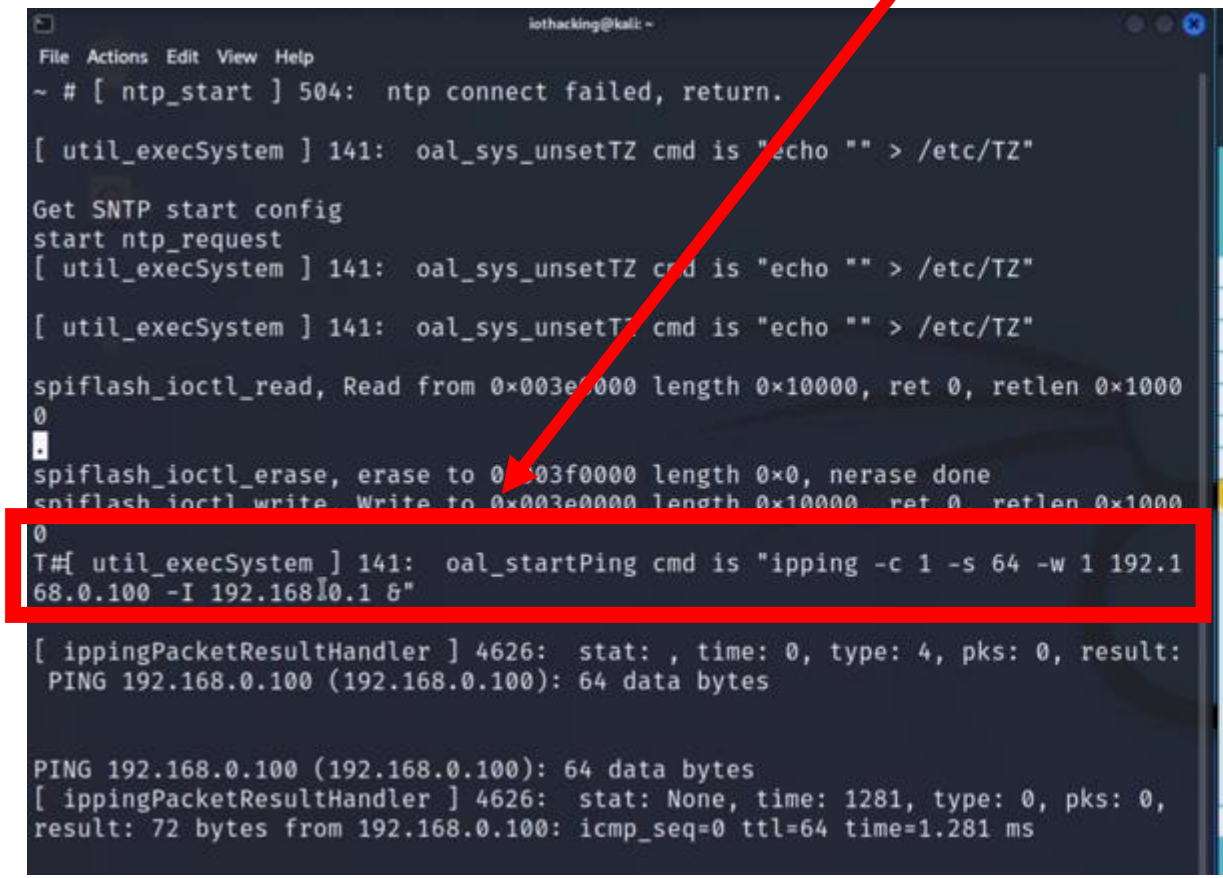
Reverse engineering binaries and libs

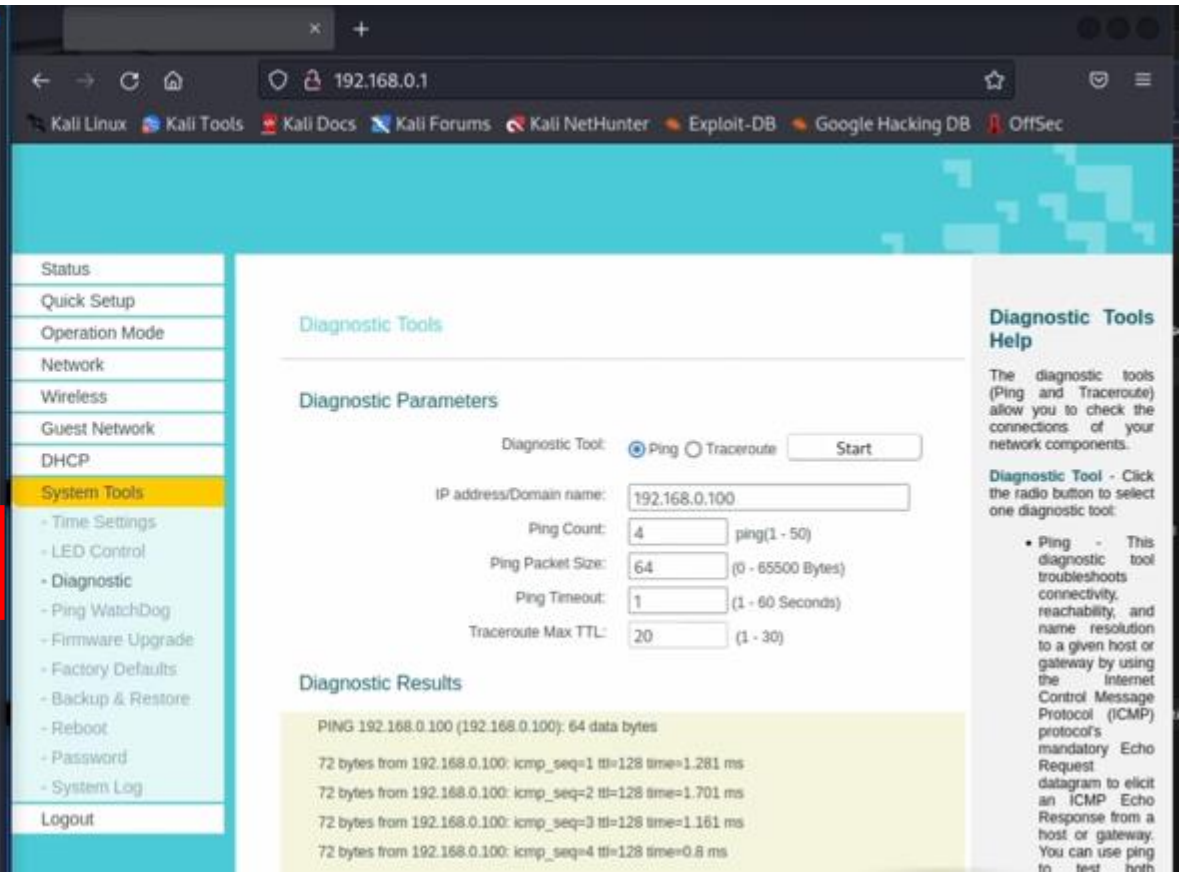
- Start with custom binaries and libraries that are unique to the device
- How do we know what are custom?
- Interact with the device and follow device logging



Reverse engineering binaries and libs

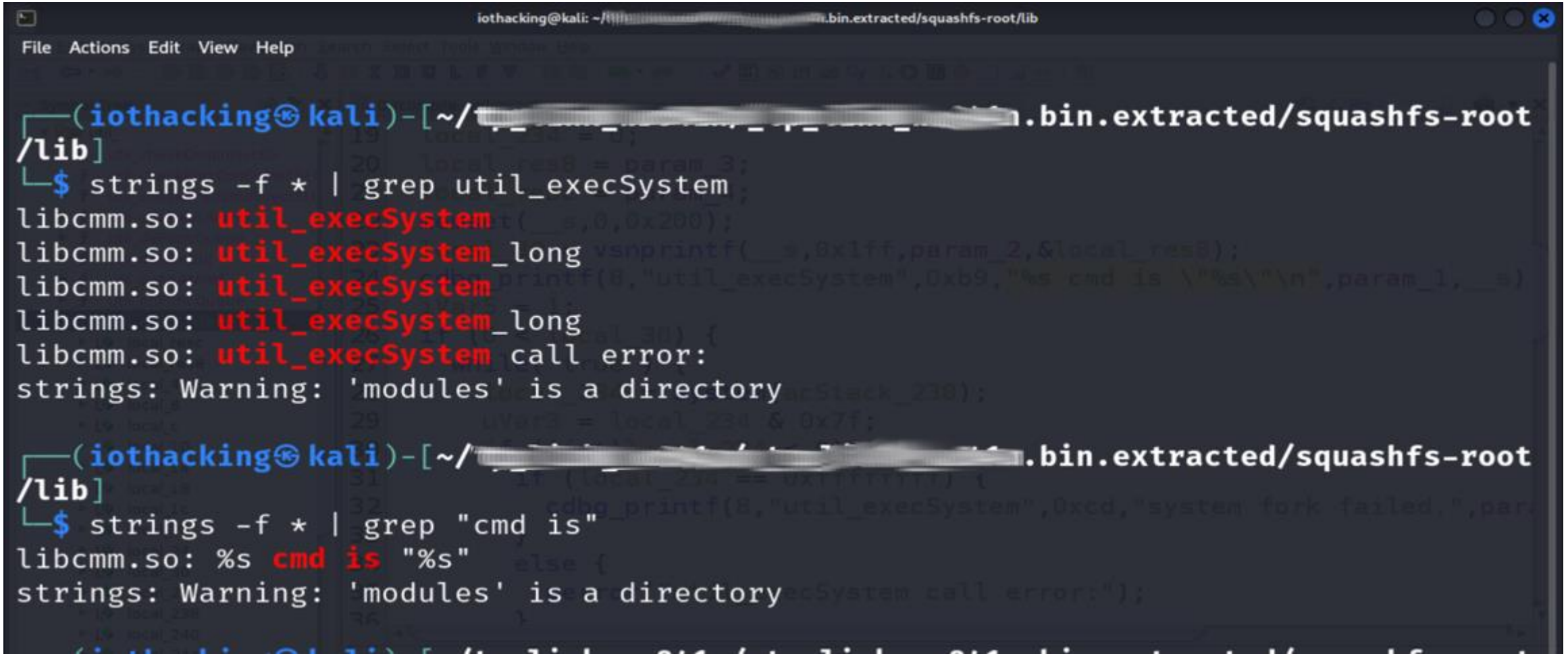
[util_execSystem]141: oal_startPing cmd is “ipping -c …”





Reverse engineering binaries and libs

strings -f * | grep "functionName"



Reverse engineering binaries and libs

CodeBrowser: tp_link_wr841n:/libcmm.so

File Edit Analysis Graph Navigation Search Select Tools Window Help

Symbol Tree

- util_
  - util_checkCmdInjectStr
  - util_checkPortConflictWithFc
  - util_checkShellCmdInjectStr
  - util_createVLANIntf
  - util_deFuncQueue
  - util_deleteObj
  - util_delVLANIntf
  - util_enFuncQueue
  - util_execSystem
  - util_execSystem_long
  - util_findSystemProc
  - util_findSystemProc_pptp
  - util_findSystemProcName
  - util_getTickCount
  - util_makeIfDesc
  - util_netChkColonIp6Addr
  - util_netChkConflictToSetNew
  - util_netChkDotIpAddr
  - util_netChkDualConnIPandD
  - util_netChkIPandDnsConflict
  - util_netChkIpInAllLanSubnet
  - util_netChkLegalIpAddr
  - util_netChkLegalIpMask
  - util_netChkLegalMacAddr
  - util_netChkLegalMask
  - util_netChkSameIpAddrWith
  - util_netChkSameLanSubnet
  - util_netChkSameWanSubnet
  - util_netChkStrMacAddr

Filter:

Decompile: util_execSystem - (libcmm.so)

```
22    memset(__s,0,0x200);
23    local_30 = vsnprintf(__s,0x1ff,param_2,&local_res8);
24    cdbg_printf(8,"util_execSystem",0xb9,"%s cmd is \"%s\"\n",param_1,__s)
25    iVar5 = 1;
26    if (0 < local_30) {
27      while( true ) {
28        local_234 = system(acStack_230);
29        uVar3 = local_234 & 0x7f;
30        if ((int)local_234 < 0) {
31          if (local_234 == 0xffffffff) {
32            cdbg_printf(8,"util_execSystem",0xcd,"system fork failed.",para
33          }
34          else {
35            perror("util_execSystem call error:");
36          }
37        }
38        else if (uVar3 == 0) {
39          iVar6 = (int)(local_234 & 0xff00) >> 8;
```

Console - Scripting

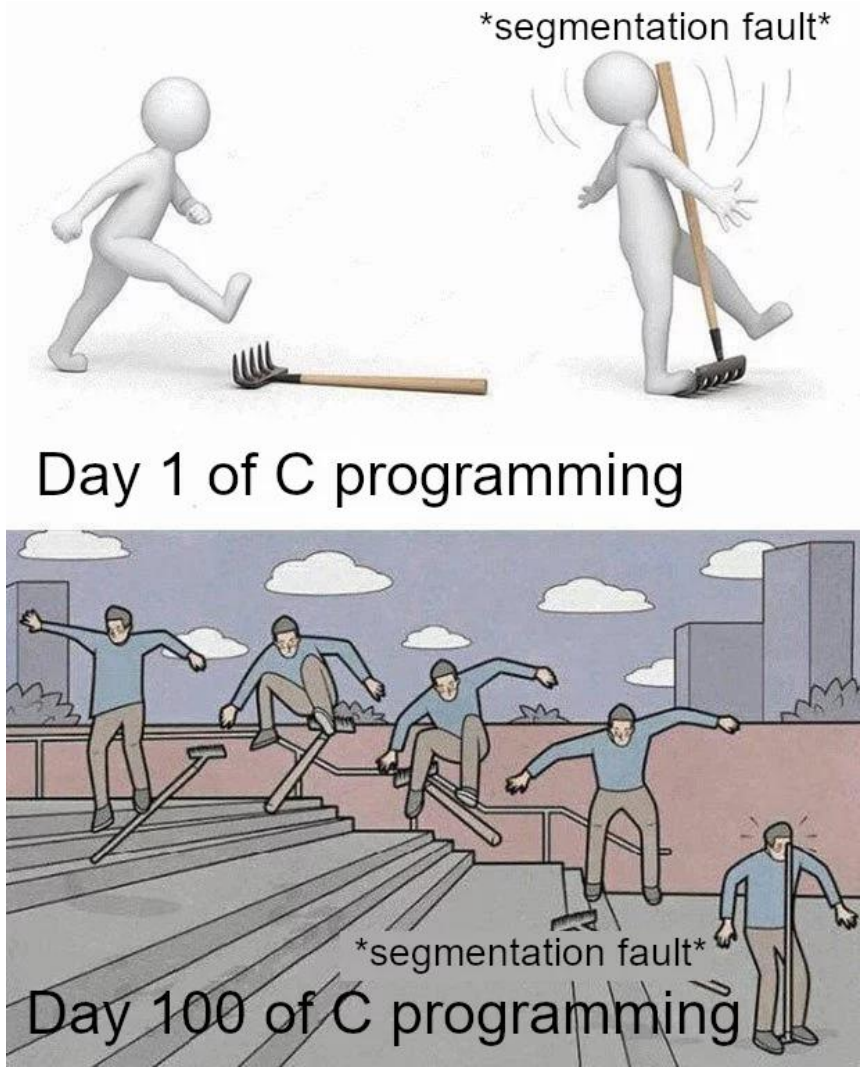
0009691c | util_execSystem | jalr t9

What's next?

- Keep interacting with device and trace logging to underlying binaries or libraries
- Follow the user input in Ghidra and see what happens with it
- Does it end up in a system call unvalidated or sanitized?
- Does it get used in an "unsafe" c function

Unsafe C Functions

- memcopy
- strcopy, strcat
- printf, sprintf
- gets, scanf, fscanf



Thanks!

Thank You!

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