# DIY Hardware implant over I2C

## Part of the NSA Playset

*This slide deck will change for the talk to include more information and details!*

Josh Datko and Teddy Reed

DEF CON 2Σ

August 10, 2014

# Outline

# NSA Playset Series

**What is the NSA Playset?**

*We hope the NSA Playset will make cutting edge security tools more accessible, easier to understand, and harder to forget.*

NSA Playset Talks

| | | | |
|---|---|---|---|
| RF Retroreflector | Penn & Teller | Friday | 12:00 |
| **DIY Hardware Implant** | **Penn & Teller** | **Sunday** | **11:00** |
| GSM Sniffing | Penn & Teller | Sunday | 12:00 |
| PCIe | Penn & Teller | Sunday | 14:00 |

# Inspired by the NSA

The NSA apparently has a hardware hacking catalog.[1]

Flip. . . Flip. . . Flip. . .

[1] like SkyMall for spies and without the Bigfoot.

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That's nice dear.

> *I wonder how that works. . .*

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# Requirements for the implant

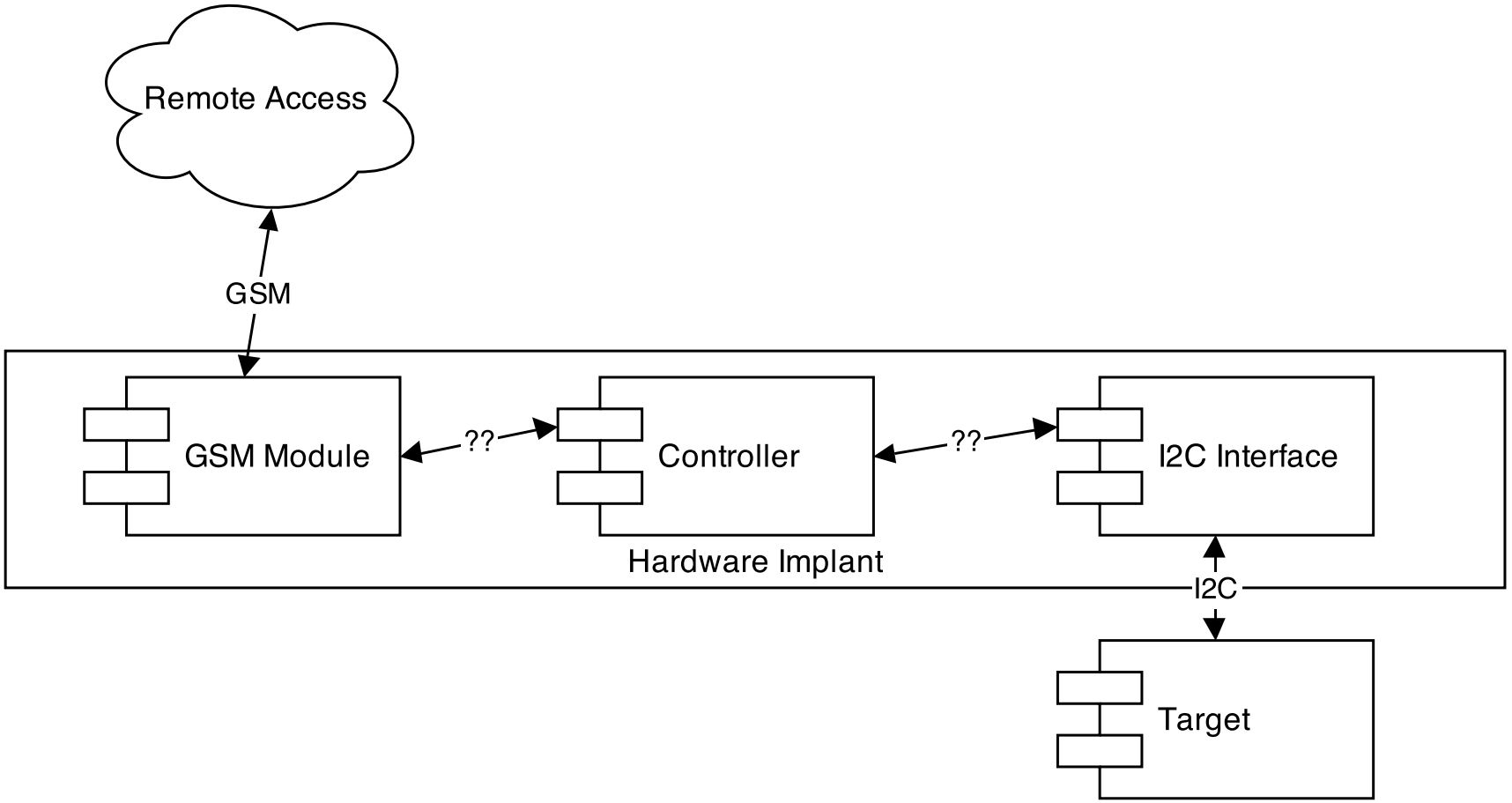
Reverse-engineered requirements:

- Must attach over $I^2C$ to the target.
- Must include GSM reachback to the implant.

Our requirements:

- Easy to use.
- As much commodity hardware as possible.
- Fun.

# Implant Control Diagram



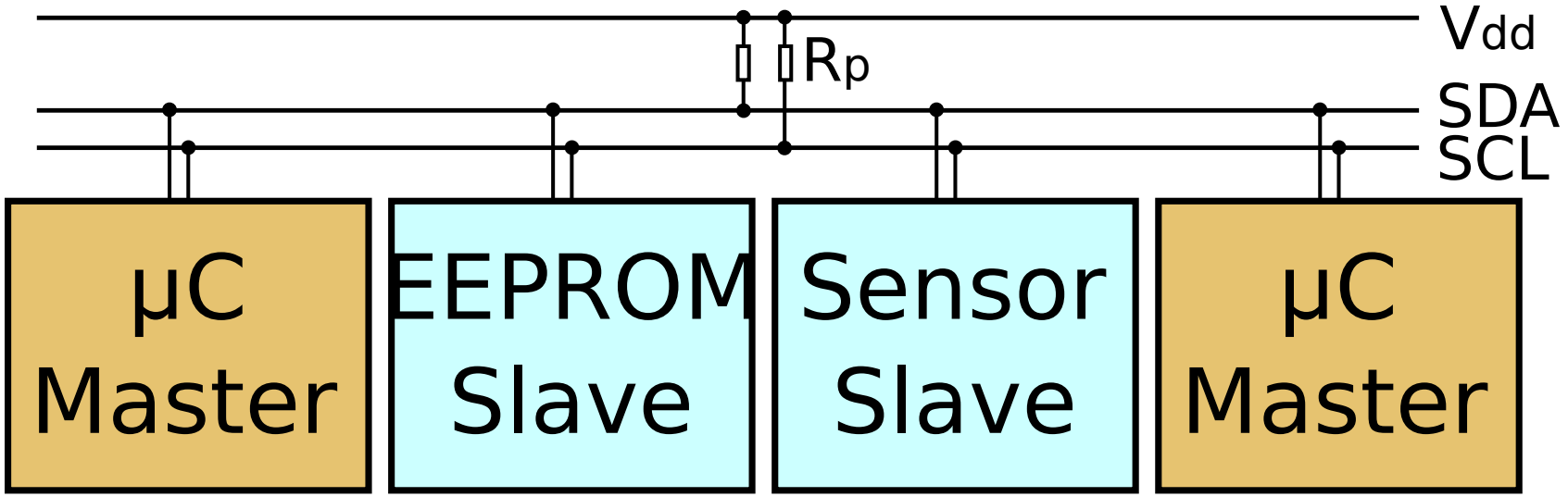
# Background: What is I$^2$C

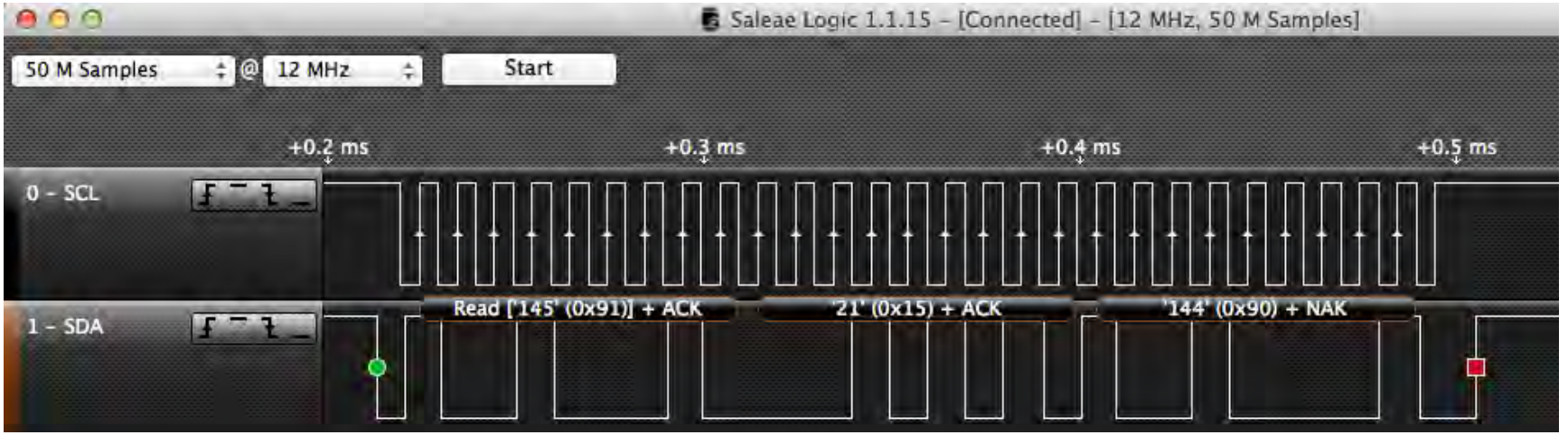
- Serial bus.
- Two-wires: (plus power and ground).[2]
  - Data: SDA
  - Clock: SCL
- Multi-master.
- Multi-slave.[3]
- Addressable.
- Standard speed is 100kHz (100kbps). High Speed: 3.2Mbps theoretical max.

[2] Typically 5 or 3.3V

[3] Note to SJWs, this is the technical correct term.

# Background: $I^2C$ in visual form



# $I^2C$ attack surfaces

- EEPROMs
- PCI and PCIe
- Battery controllers
- Video . . .

# Video $I^2C$

Why is there $I^2C$ on your monitor adapter?

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How does your computer "automatically detect" monitor resolution?

# Video I$^2$C

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How does your computer "automatically detect" monitor resolution?

**EDID**

Extended Display Identification Data

**DDC**

Data Display Channel, a.k.a. 5V I$^2$C

# EDID

```
➜  ~  sudo get-edid
This is read-edid version 3.0.1. Prepare for some fun.
Attempting to use i2c interface
No EDID on bus 0
No EDID on bus 2
No EDID on bus 3
No EDID on bus 4
No EDID on bus 5
1 potential busses found: 1
128-byte EDID successfully retrieved from i2c bus 1
??????"??&h"???SE?$PT?▣0*?Q*@0pT?2MS
      ?HP L1710
    ?CNC822NZ8B
Looks like i2c was successful. Have a good day.
  a
```

# $ edid-decode

```
➜  card0-VGA-1  pwd
/sys/class/drm/card0-VGA-1
➜  card0-VGA-1  cat edid | edid-decode
Extracted contents:
header:          00 ff ff ff ff ff ff 00
serial number:   22 f0 eb 26 01 01 01 01 16 12
version:         01 03
basic params:    68 22 1b 8c ee
chroma info:     af c0 a7 53 45 9d 24 17 50 54
established:     ad ef 80
standard:        81 80 01 01 01 01 01 01 01 01 01 01 01 01 01 01
descriptor 1:    30 2a 00 98 51 00 2a 40 30 70 13 00 54 0e 11 00 00 1e
descriptor 2:    00 00 00 fd 00 32 4d 18 53 0e 00 0a 20 20 20 20 20 20
descriptor 3:    00 00 00 fc 00 48 50 20 4c 31 37 31 30 0a 20 20 20 20
descriptor 4:    00 00 00 ff 00 43 4e 43 38 32 32 4e 5a 38 42 0a 20 20
extensions:      00
checksum:        61
```

```
ioreg -lw0 -r -c "IODisplayConnect"
```

# EDID Extension Blocks

| Tag Number | Extension Block Description |
|---|---|
| 00h | Timing Extension |
| 02h | CEA-EXT: CEA 861 Series Extension |
| 10h | VTB-EXT: Video Timing Block Extension |
| 20h | EDID 2.0 Extension |
| 40h | DI-EXT: Display Information Extension |
| **50h** | **LS-EXT: Localized String Extension** |
| 60h | DPVL-EXT: Digital Packet Video Link Extension |
| A7h, AFh, BFh | DTCDB-EXT: Display Transfer Characteristics |
| F0h | EXTENSION Block Map |
| **FFh** | **EXTENSIONS defined by the OEM** |

Parsing implemented by the OS-supplied VESA driver or GPU driver manufacturer.

# Exploiting EDID/EDID Extension parsing

Hacking Displays Made Interesting
Blackhat EU 2012
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Discover proprietary EDID extensions! Moar fuzzing!
Or assume a-priori software control...

# $I^2C$ everywhere $IC^4$

A video card may have multiple $I^2C$ buses and devices. NVIDIA cards may have $I^2C$ for the following:

- EEPROM for encrypted HDCP keys
- Onboard voltage regulator
- Thermal sensor
- TV decoder chip (older cards)

[4] C'mon, it's punny

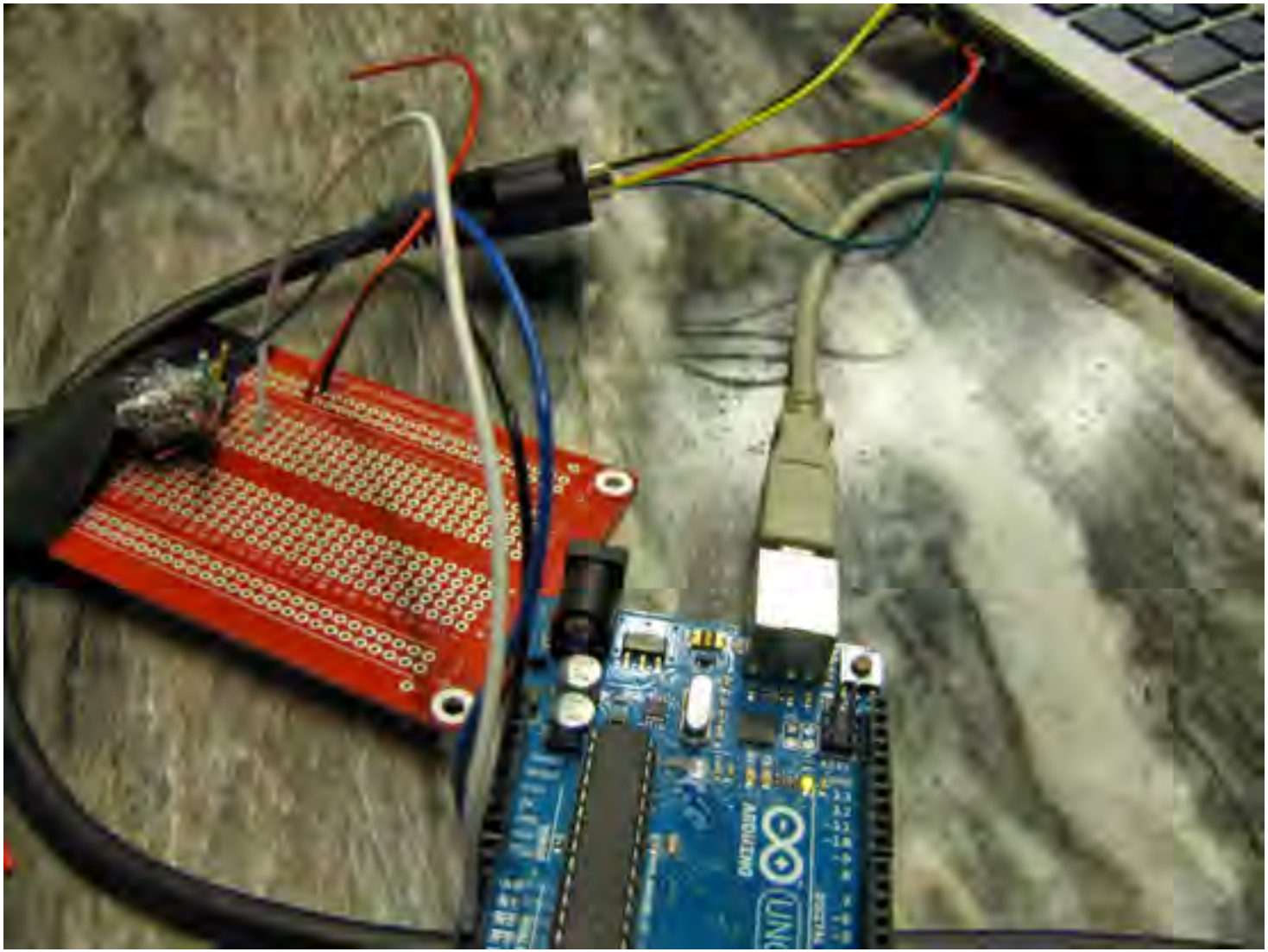
# Exploring VGA I$^2$C

Let's start exploring our attack surface.

| Pin | Name | Description |
|---|---|---|
| 1 | RED | Red Video |
| 2 | GREEN | Green Video |
| 3 | BLUE | Blue Video |
| ⋮ | ⋮ | ⋮ |
| **5** | **GND** | **Ground** |
| **9** | **KEY** | **Optional +5V output from graphics card** |
| **12** | **SDA** | **I2C data** |
| **15** | **SCL** | **I2C data clock** |

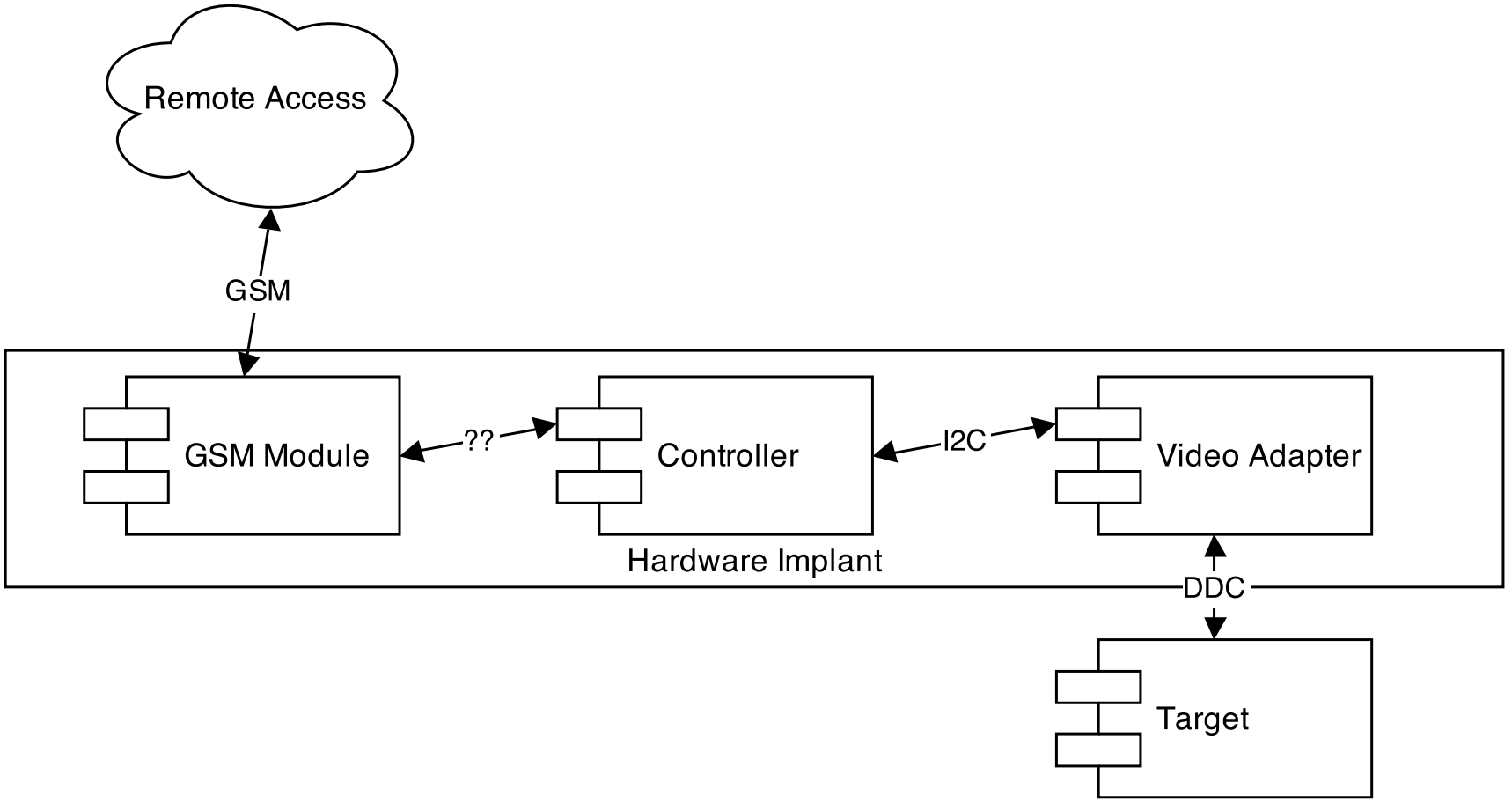
VGA Pinout

# I want my I$^2$C [5]



[5] Dire Straights fans, anyone?

# Filling in the details



# Controller Selection

# Controller Selection

BeagleBone Black is the embedded hacker's friend:

- 1GHz AM3358 ARM® Cortex-A8
- 512MB DDR3 RAM
- Two independent Programmable Real-Time Units (32bit)
- Crypto accelerators for AES, SHA, MD5
- UARTs, PWM, LCD, GPMC, SPI, ADC, CAN, Timers
- **Two $I^2C$ buses**

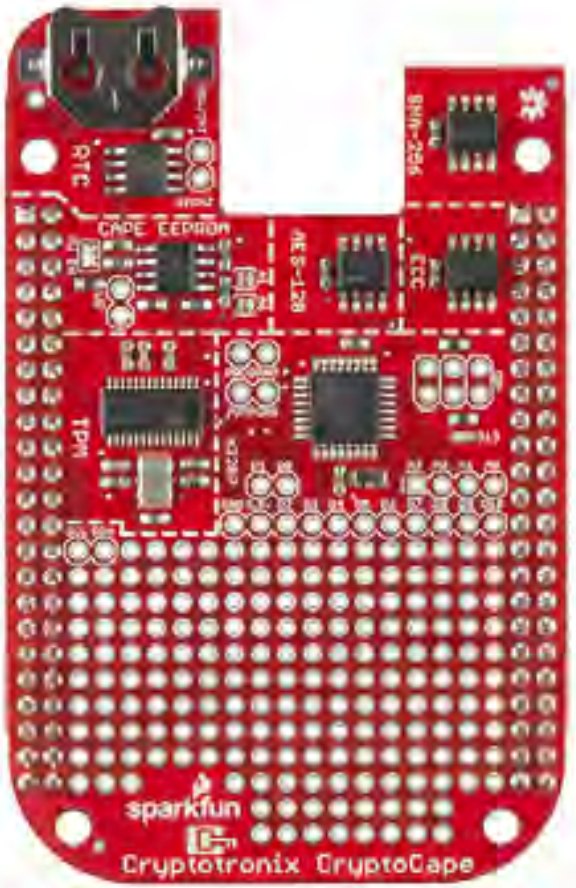
# CryptoCape

Let's add some hardware security ICs:

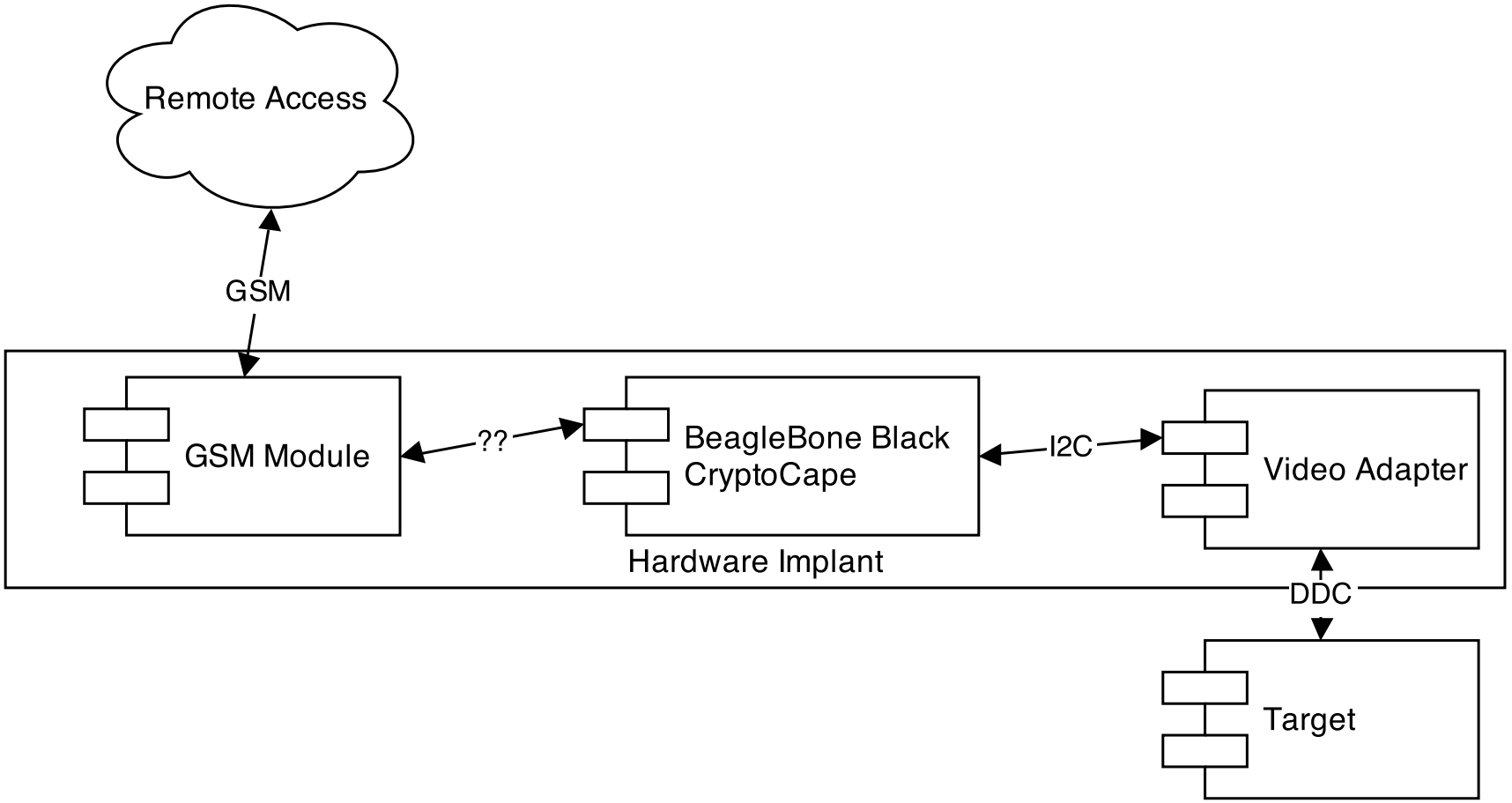
# CryptoCape

Let's add some hardware security ICs:

- Authenticators: ECC & MAC (SHA256)
- Encrypted EEPROM (AES-128-CCM)
- Battery backed up Real-time clock
- **Trusted Platform Module**
- **ATmega328p**, because Arduino.



# Add the controller



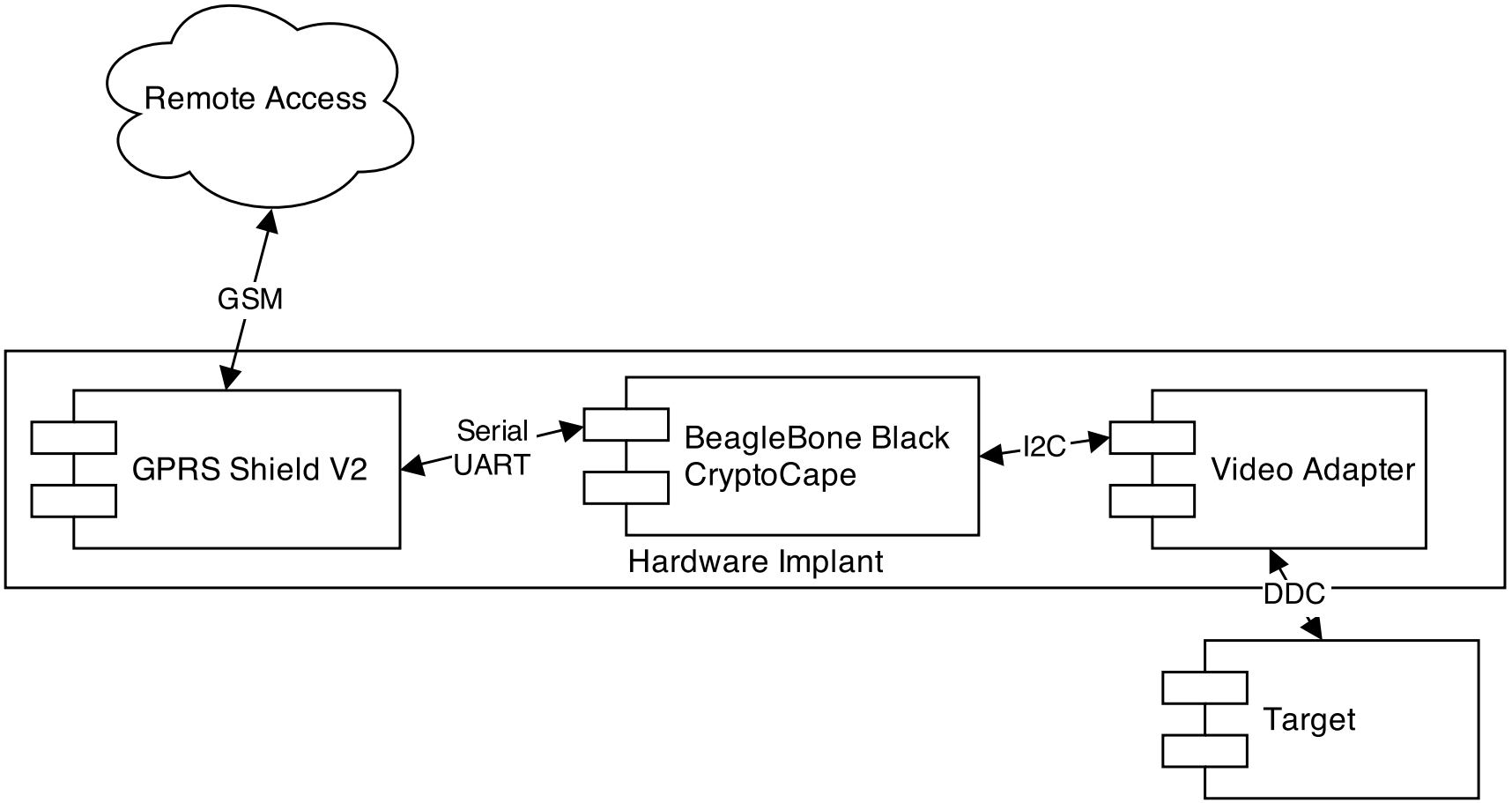
# GSM Module

# GSM Module

Seeed Studo GPRS Shield v2:

- Arduino form factor
- GSM Quad band support
- TCP support
- SIM card holder
- Works with Tmobile, AT&T

# Add the GSM module



# Moar Power?

- BBB draws 460mA on boot
- CryptoCape
- GSM Shield draws 300mA on average for "talk", but peak of 2.0 A!!!

Meet the *LiPo*WerCape

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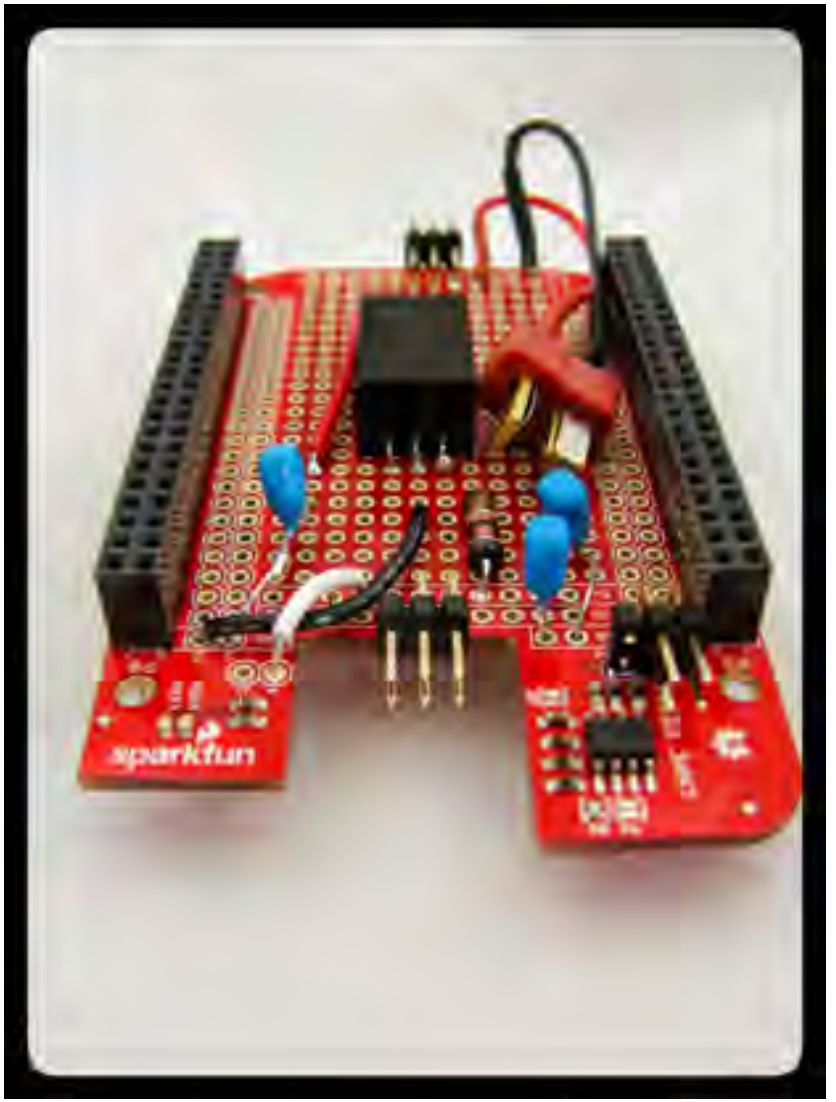

# CHUCKWAGON

We still need a way to easily connect to the video adapter. Meet CHUCKWAGON:

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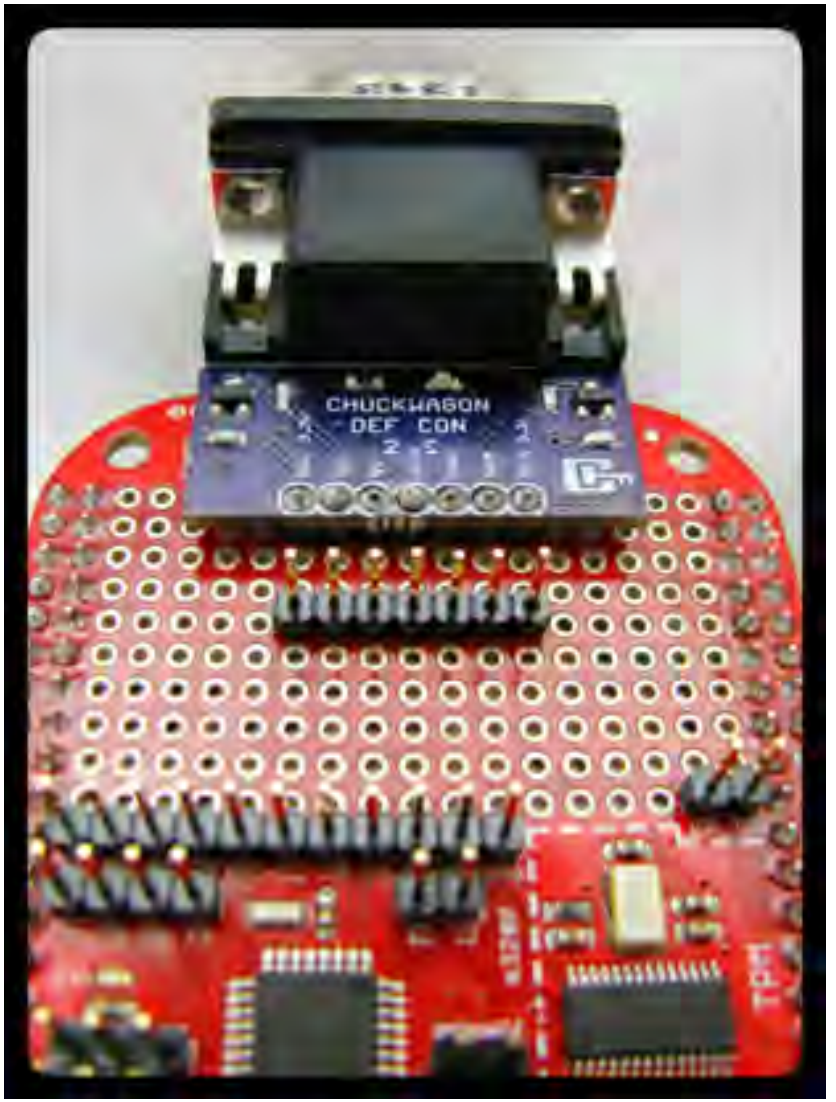
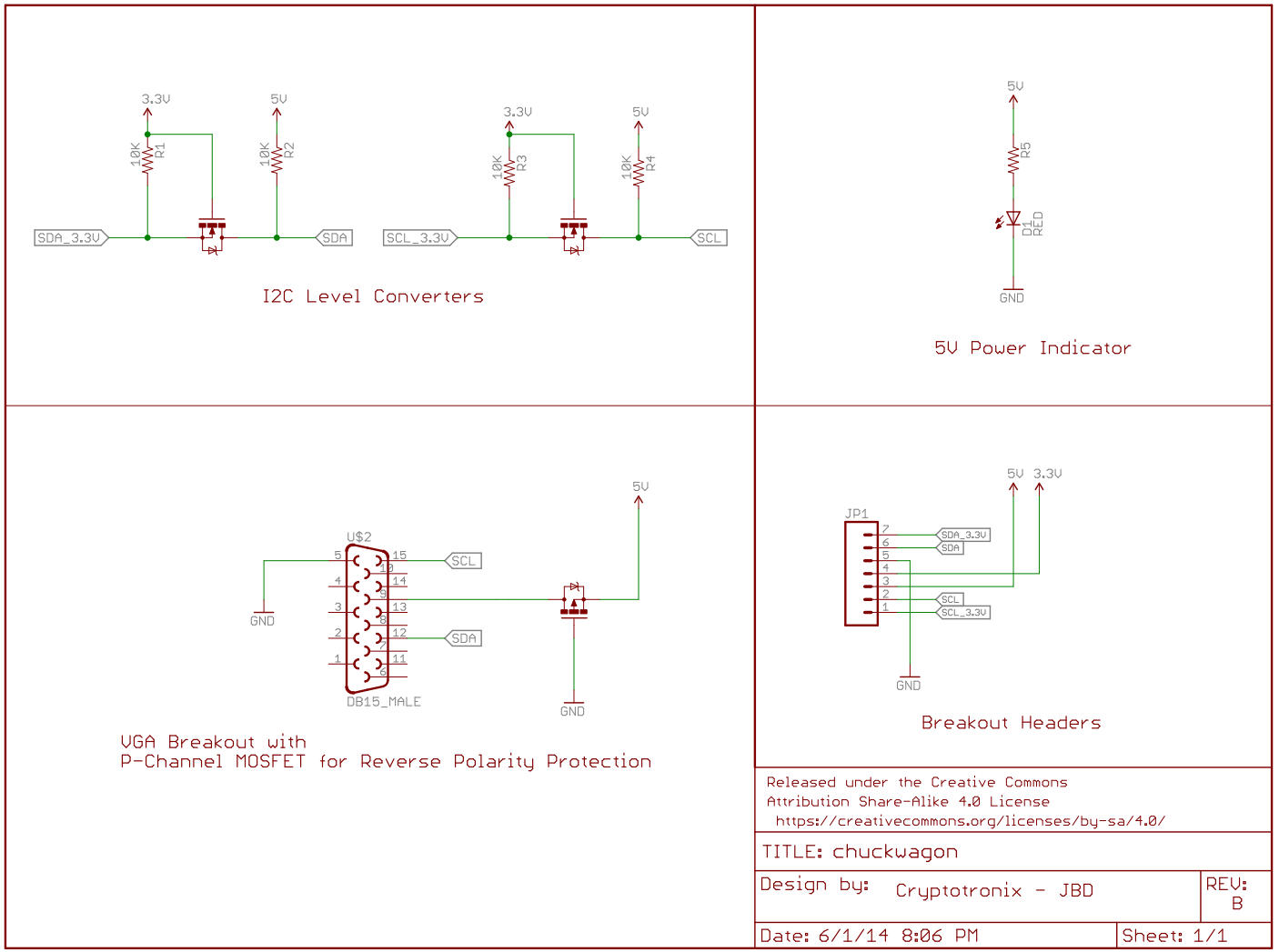
We still need a way to easily connect to the video adapter. Meet CHUCKWAGON:

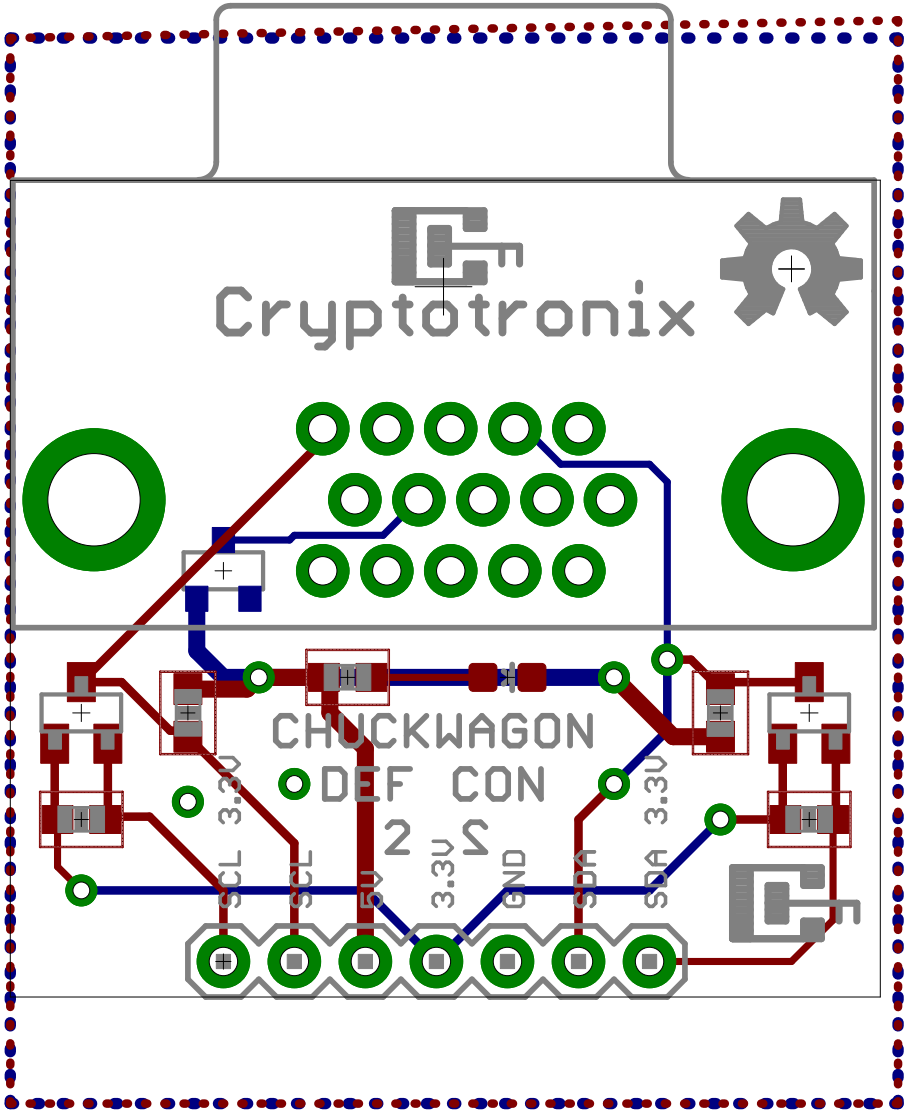
- Breadboard friendly.
- Logic level converters for I2C.
- Supplies 5V.
- Power indicator.
- Attaches to CryptoCape



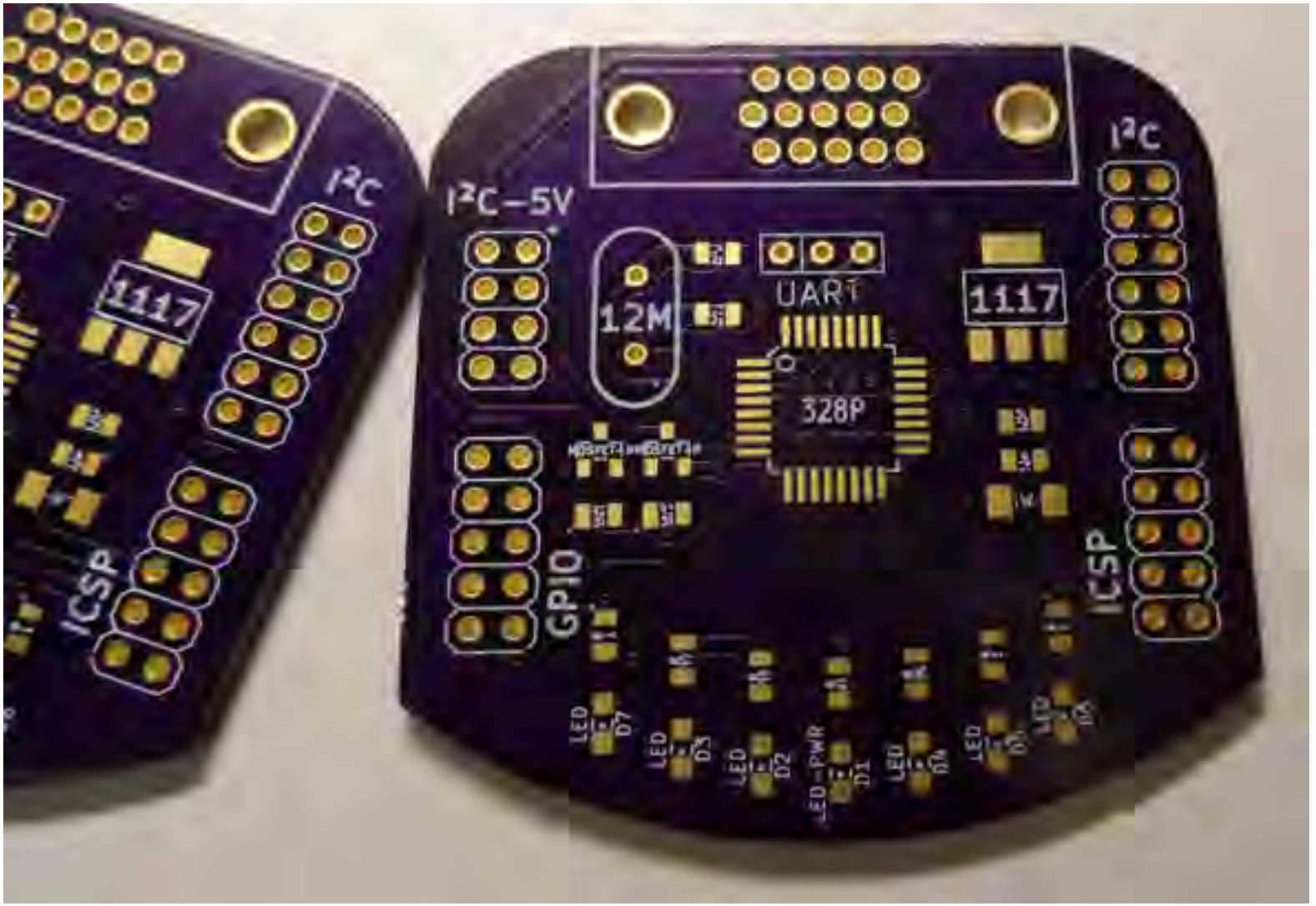
# CHUCKWAGON schematic



# CHUCKWAGON board

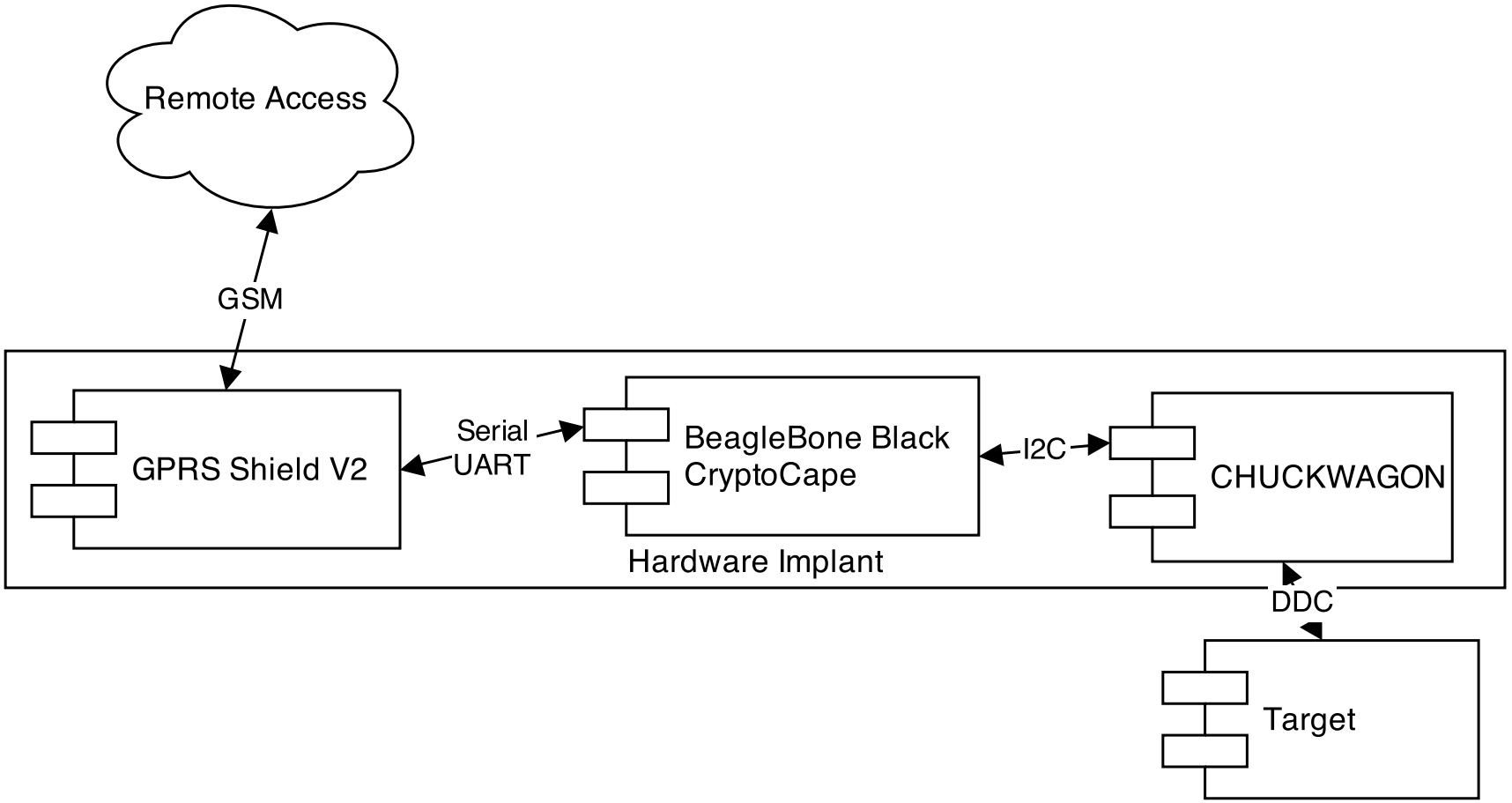


# I²C hack not that new...




As seen on Hackaday

# Add the CHUCKWAGON



# Connect to GSM module

Ok, so let's connect to the GSM Shield from the Beagle!

- BBB's UART4, broken-out by ATmega's program jumpers.
- GSM's shield software-serial, D7 and D8
- /me checks datasheet one last time...

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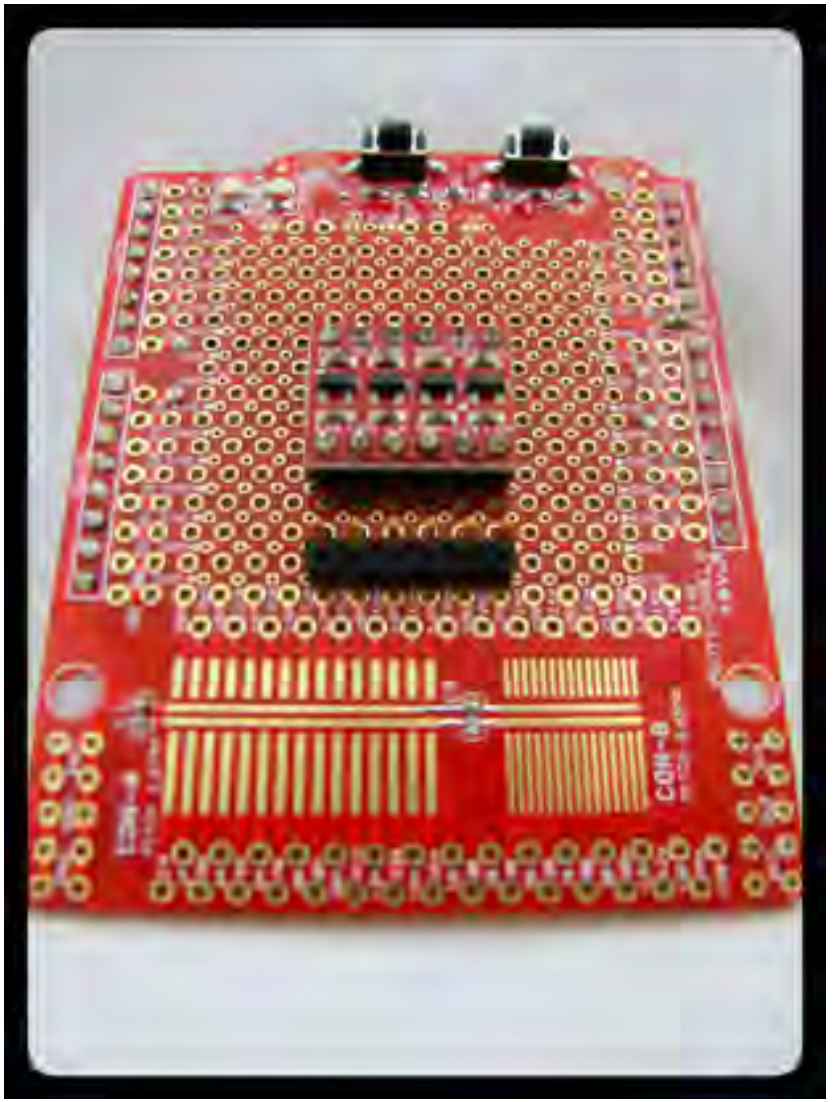
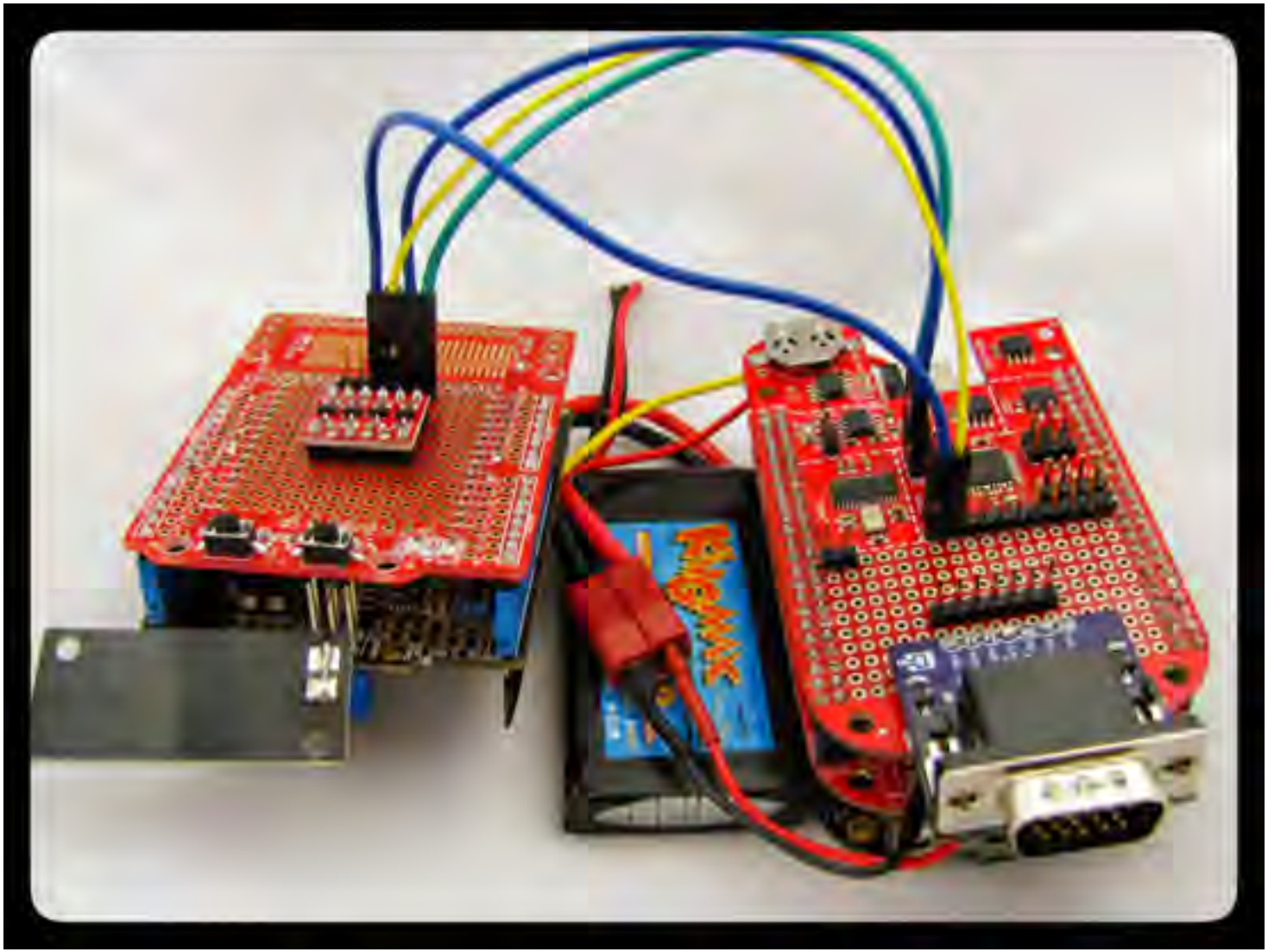
- Needs logic level converters!



# Completed Hardware with Battery



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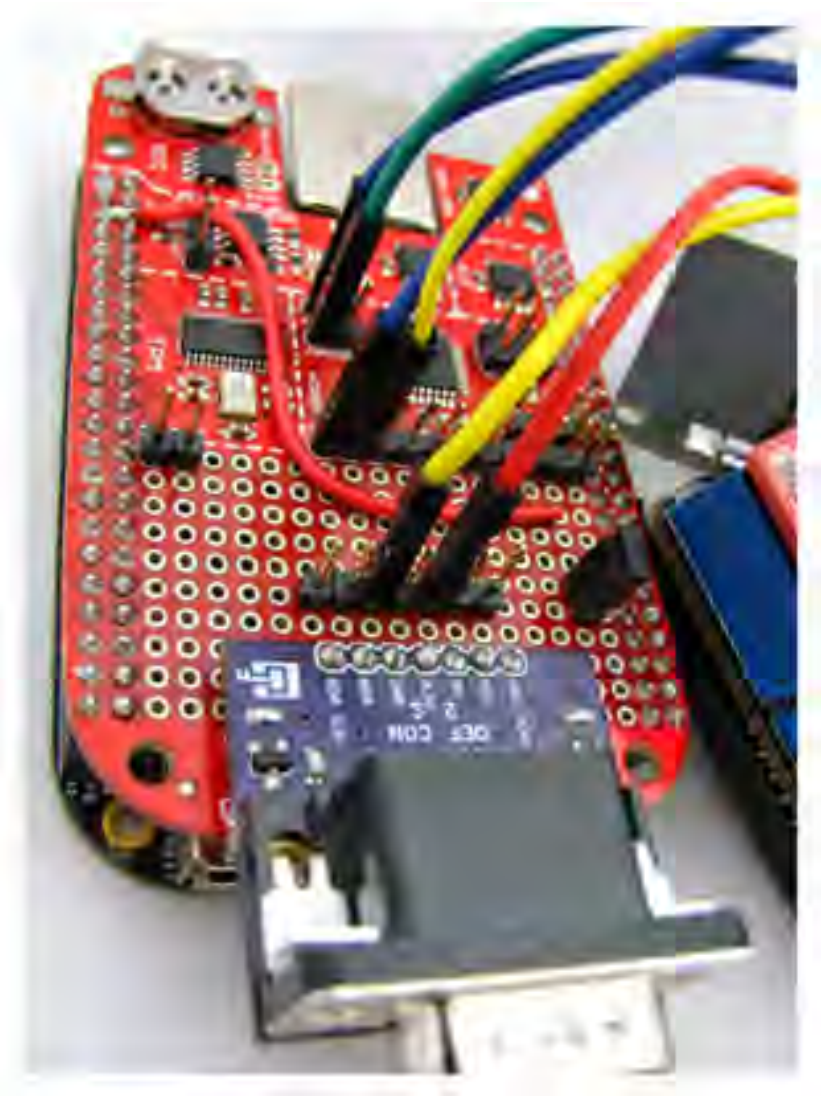

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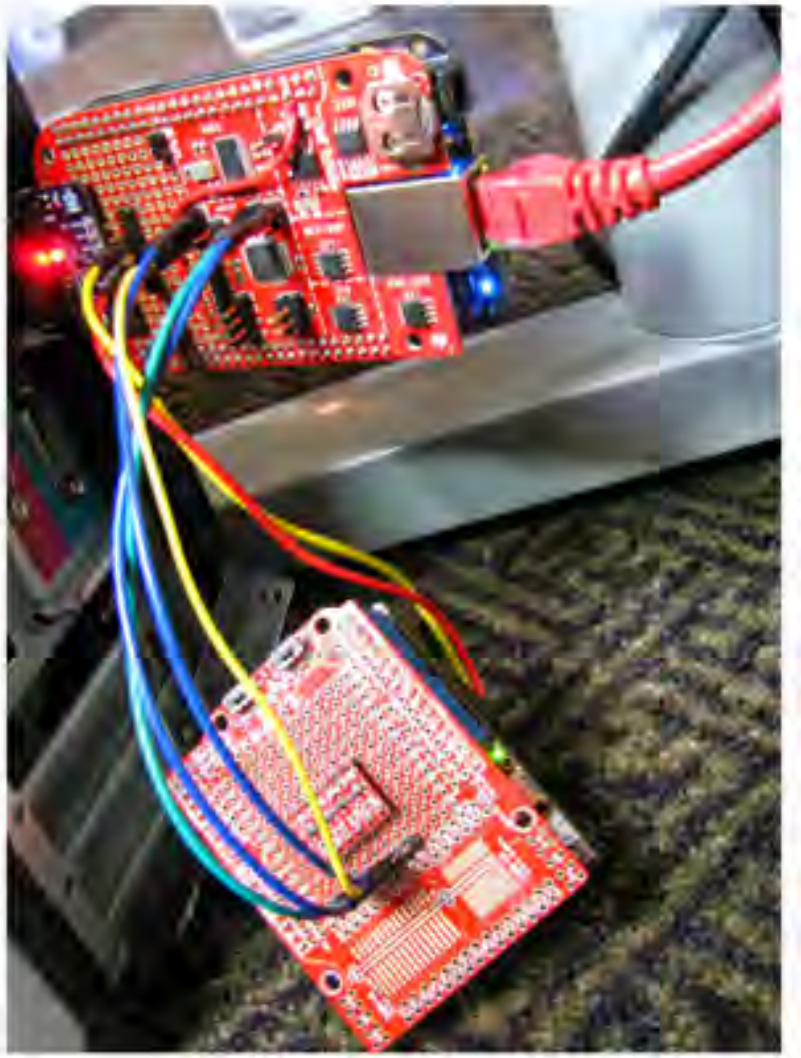

# Software flow

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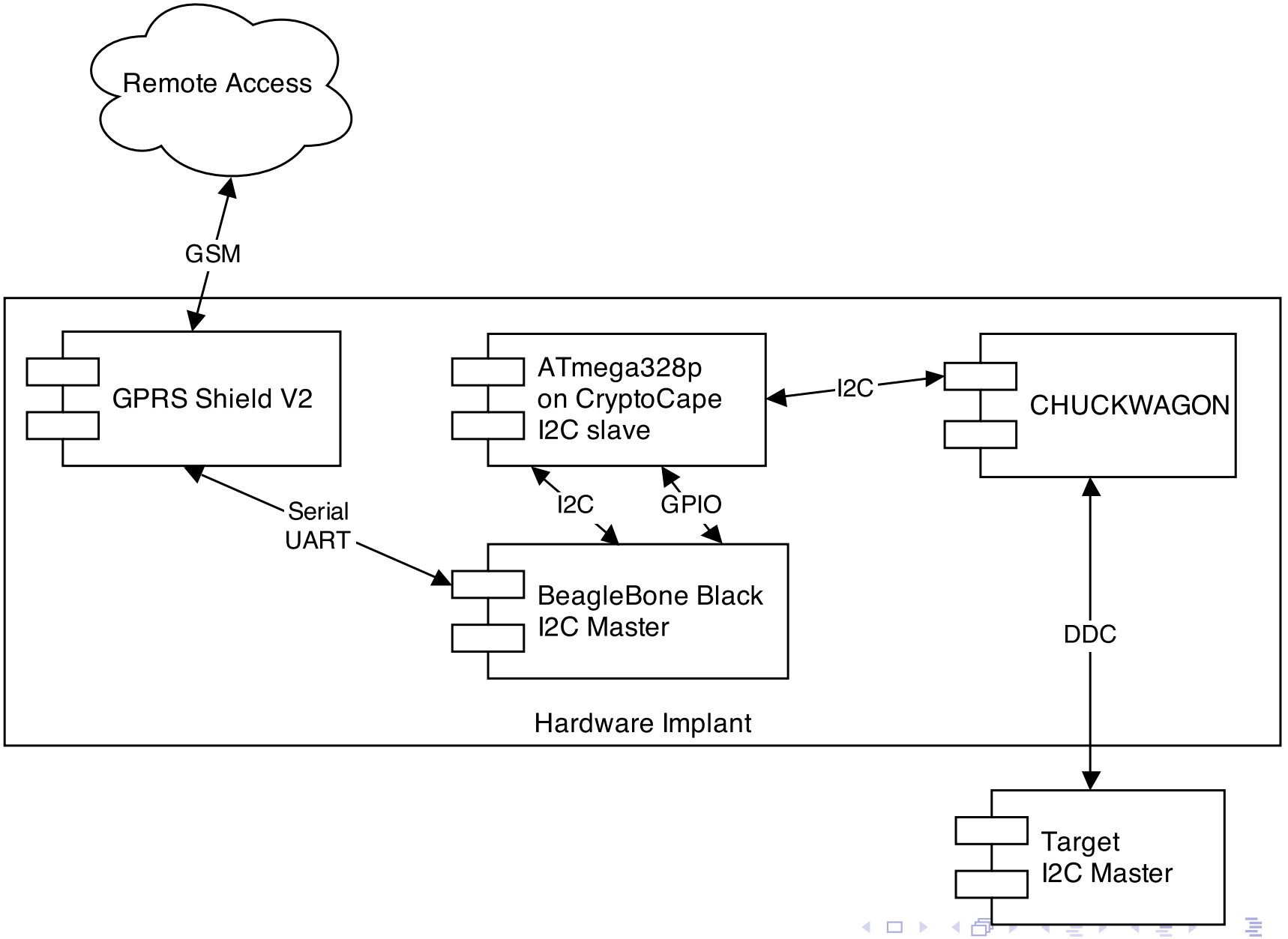

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- Target can exfil out to implant for storage.
- Implant can provide code for target to run.
- Control the implant over GSM $\rightarrow$ control the target over GSM

# Accessorize!

Prepared for anything or NSA hacking toolkit?

# How to improve the CHUCKWAGON

What does CHUCKWAGON rev. B look like?

- Consolidate into one board: *ImplantCape*
- Eliminate flywires.
- HDMI footprint vs. VGA
- Could all be done from AVR (less power), but BBB is more fun.

# Using Crypto for Evil!

Long history of Cryptography and Malware!

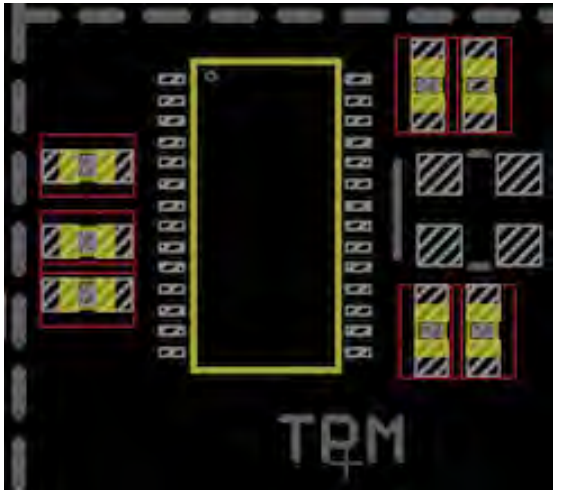
Cryptoviral Extortion:

- 1989 PC Cybord, Joseph Popp
- 1996 Macintosh SE/30 crytovirus PoC, Young and Yung
- 2006 Gpcode.AG/AK, Cryzip
- 2013 CryptoLocker, CryptorBit

Reversing Anti-Analysis:

- Packers, Obfuscator, VM-based JIT
- 2011 TPM "cloaking" malware
- 2014 Uroburos, encrypted VFS
- **2014 TPM-enabled super-targeted malware**

# Using Crypto for Evil!




The CryptoCape includes a TPM...

- I$^2$C friendly
- Protected RSA private key storage
- Windows 8 friendly
- More or less optional, as there is most likely an onboard TPM

# Cloaking Malware with the Trusted Platform Module

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Alan M. Dunn, Owen S. Hofmann, Brent Waters, Emmett Witchel
Summary: Use TPM-protected keys and an Intel TXT PAL to protect malicious code execution from observation, analysis, and tamperment.

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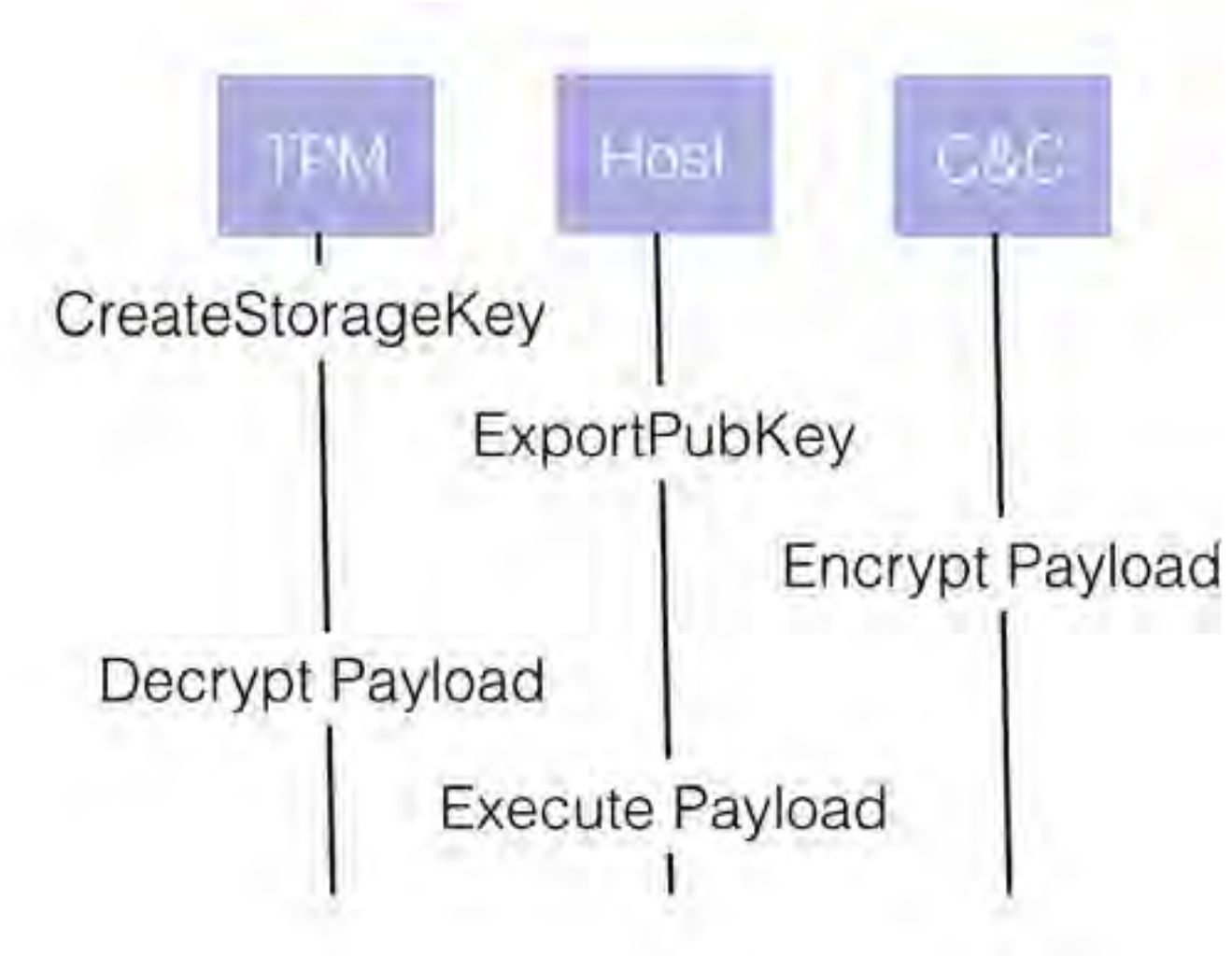
Put a TPM on your implant and protect against nasty network interception. Also restrict analysis to the target machine upon discovery (or force memory analysis).

# TPM-enabled super-targeted Malware



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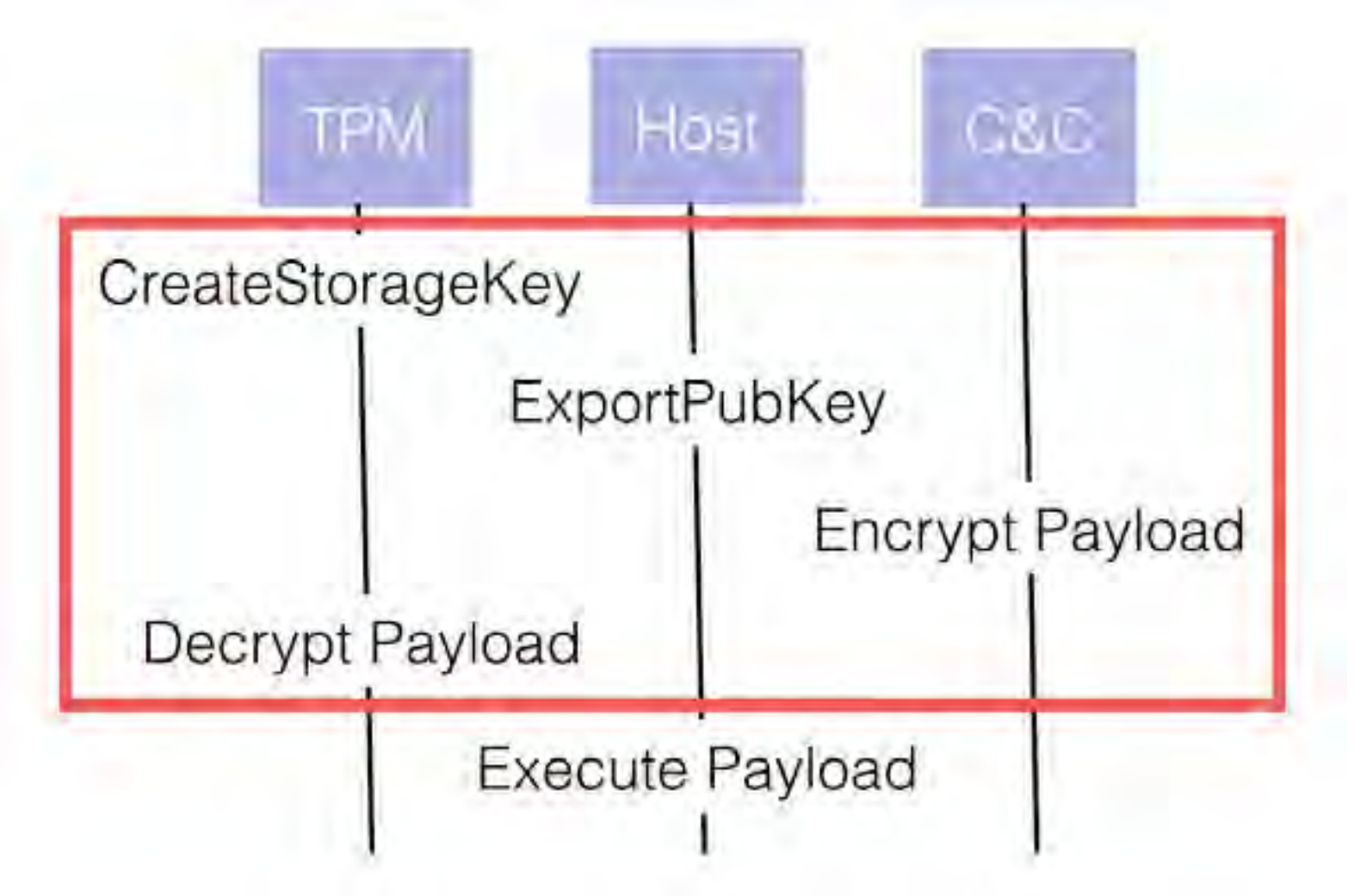

# TPM-enabled super-targeted Malware

Windows 8 automatically enables/initializes a TPM, then creates and manages your owner password. Access to TPM is abstracted through Microsoft CSP.

Windows `PcpTool` Kit:

`NCryptOpenStorageProvider`
`NCryptCreatePersistedKey`
`NCryptExportKey`
`NCryptDecrypt`

In memory process creation:

`CreateProcess`
`ZwUnmapViewOfSection`
`VirtualAllocEx`
`WriteProcessMemory`

Python `pefile` to inject encrypted PE section into a decryption stub.

# TPM-enabled super-targeted Malware

# tpm-malcrypt

## fork tpm-malcrypt!

`https://github.com/theopolis/tpm-malcrypt`

- `tpm-keyextract`, create and exfil a storage public key
- `malcrypter`, encrypt and inject into decryption stub
- `malcrypt`, decryption stub, process creation/injection

# Malicious Exfiltration via Audio

Backstory: **#badBIOS** thought to use Audio as an out-of-band exfiltration or C&C mechanism. Dismissed as infeasable by BIOS development SMEs.

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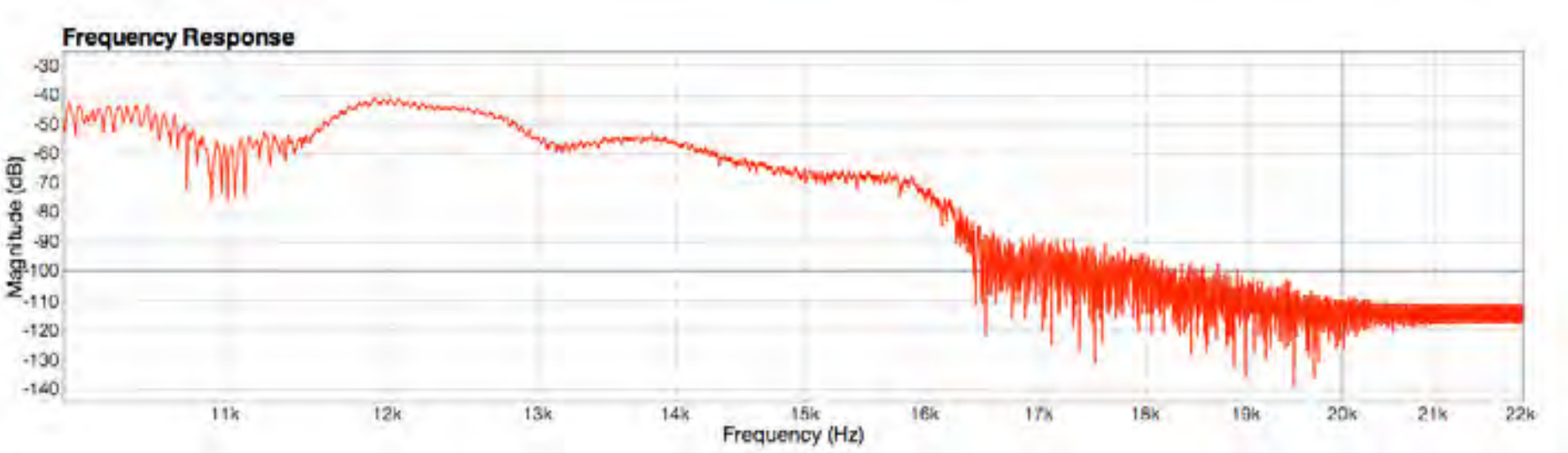
# Malicious Exfiltration via Audio

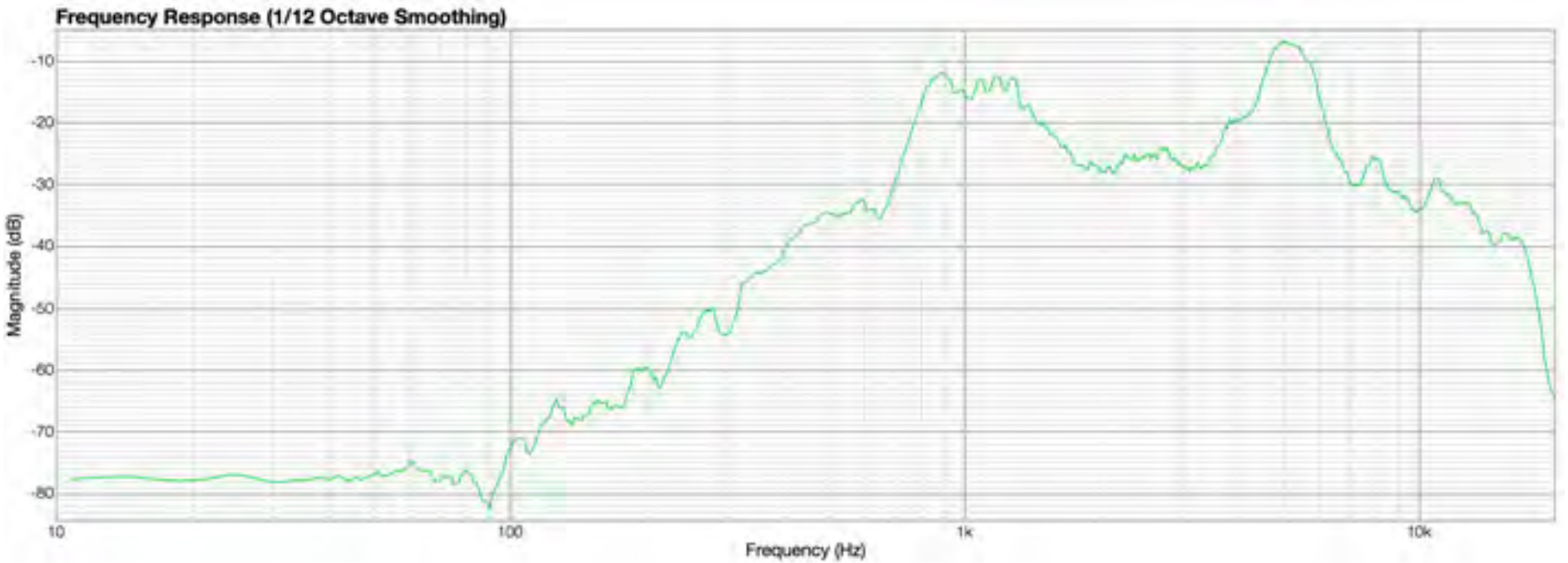
Data of Audio Protocols are very well defined and resiliant.

**QPSK10** (10 baud), **QPSK05** (5 baud), quadrature phase shift keying modulation to provide forward error correction.



# Malicious Exfiltration via Audio

Possible to "pivot" through colluding machines. Local network exploitation creates a mesh of audio-capable relays such as idle headphones.



# Demos, Learning, and Fabulous Prizes

Join us in the HHV for CryptoCape and WAGONBED demos!

Challenge: Solve the puzzle here: [redacted]
(URL redaction removed during actual DEFCON 22 talk)

The first 5 correct submissions win a DIY hardware implant kit
(No hardware hacking experience required)

# Demos, Learning, and Fabulous Prizes

Thank you!