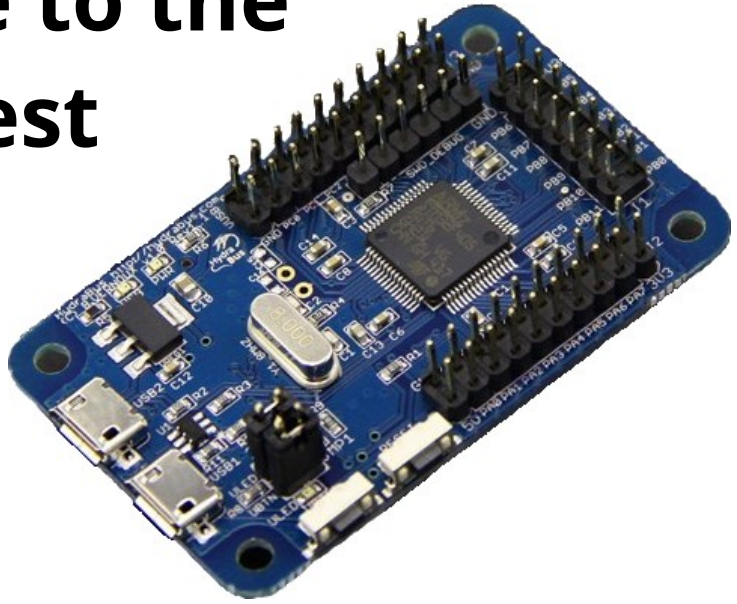
# HydraBus

## Hydrabus: Lowering the entry fee to the IoT bugfest

Hydra Bus

# HydraBus/HydraFW GitHub

- Hardware / Schematics on GitHub (format Eagle 6.x/7.x)
  - https://github.com/hydrabus/hydrabus
  - License CC-BY-NC
- Firmware HydraFW Wiki on GitHub
  - https://github.com/hydrabus/hydrafw/wiki
  - Apache License
    - External libraries use their own license

# HydraFW

- HydraFW is an Open Source embedded software/firmware for HydraBus hardware (support also hw extensions like HydraNFC/HydraFlash/HydraLINCAN ...)
- It is compatible with Bus Pirate commands: http://dangerousprototypes.com/docs/Bus_Pirate_menu_options_guide#Bus_interaction_commands

**FW**=**F**irm**W**are

# Communication with external world / IoT

- Serial Port (USART/UART)
- I2C Bus: Slow Bus, sensors, memories...
- CAN/LIN Bus: Slow Bus, sensors (mainly automotive)
- SPI Bus: Fast Bus Wifi / BlueTooth / NFC...
- SD/SDIO (microSD, SDIO Bluetooth/Wifi...)
- USB Bus
- ADC & DAC (Analog <=> Digital)
- GPIO (Input/Output)
- Parallel Bus (Nand Flash)

# What to do with an HydraBus ?

- The HydraBus is 40x faster than a BusPirate or an Arduino Uno, which is very convenient in order to communicate with fast signals (Serial/Parallel...)
- MCU HydraBus: STM32F415@168MHz Cortex M4F 32bits, 44/IO (84MHz max), 1MB flash, 192KB SRAM, power consumption < 100mA (less than 2mA with low power mode)
- Use cases:
  - "Speak" with electronic device/chipset
    - Sensors like Wifi module(ESP32), NFC, Nand Flash, EEPROM...
    - Arduino (SPI, UART ...)
  - "Spy" (MITM) electronic device (SPI/UART/CAN Bus...)
    - Spy Car(CAN), IoT gadgets...
  - "Analyze" signals (analog or digital) with the help of SUMP protocol and open source software like sigrok / PulseView
  - "Reverse engineering" electronic device (IoT ...)
    - Router(WRT54G JTAG, UART), Car, RFID(NFC...), Smart Lighting...

# HydraFW main console commands

- Commands OS (chibios):
  show system/memory/threads
- Commands sdcard (sd):
  mount/umount, erase, cd <dir>, pwd, ls [opt dir], test_perf, cat <filename>, hd <filename>, rm <filename>, mkdir <filename>, script <filename>
- Commands: ADC/DAC, PWM, GPIO
- Bus Modes: SPI, I2C, UART, JTAG, 1-2&3 wire, CAN (HydraCAN), Flash (HydraFlash), NFC (HydraNFC)

# HydraFW
# Bus Mode protocol Interaction

- Protocol Interaction (similar commands for any protocol support )
  - **[** Start (for SPI, I2C means Enable Chip Select)
  - **]** Stop (for SPI, I2C means Disable Chip Select)
  - **:** Repeat (e.g. r:10)
  - **&** DELAY us (support optional repeat :)
  - **%** DELAY ms (support optional repeat :)
  - **123 0x12 0b110 "hello"** Write 8bits val/string (support optional repeat :)
  - **r** Read or **hd** HexDump (support optional repeat :)
  - During a blocking read or write which wait for data(for example Slave mode) you can abort the wait by pressing HydraBus **UBTN**, else you can also wait timeout which is about 10s.
  - Example: HexDump of an SPI EEPROM: **[ 0b11 0 hd:32 ]**

# Use cases

# What is IoT ?

- Device somehow connected to a smartphone or to the Internet
- Which can be an embedded GNU/Linux system or a proprietary firmware
- Which is a SoC or a micro-controller with peripherals or sensors
- ...
- Which basically is a bunch of chips communicating with each other

# Bug hunting IoT

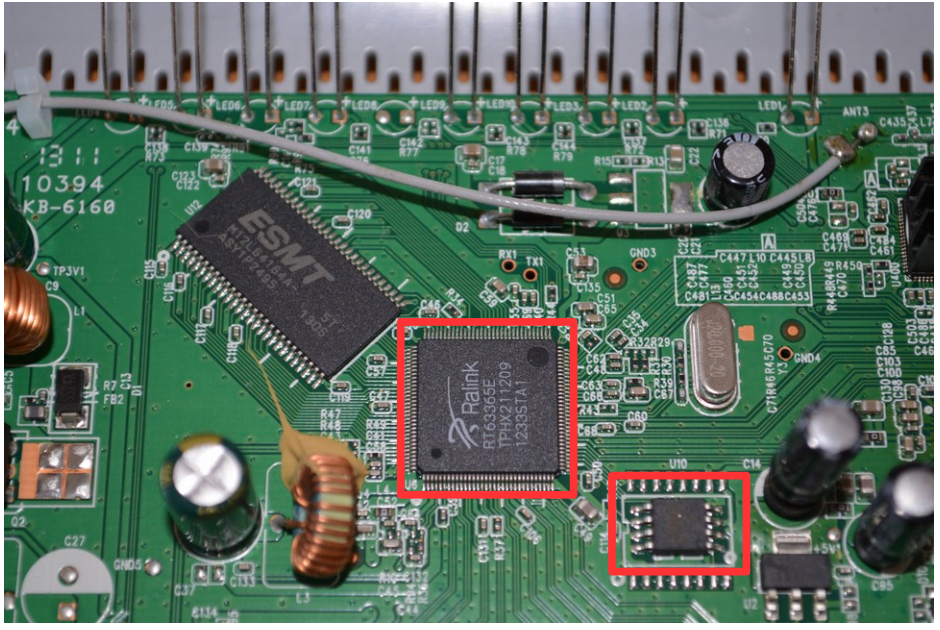
- Primary target : Device firmware
  - Main source of vulnerabilities found there
- Not always accessible from the vendor website
  - Firmware update can be encrypted
- Hidden interfaces can be available
  - Serial console or debugging interfaces

# Case 1 (Home Router)

- Home router
- Crack open the case
- Undoubtedly the trickiest part in the process

# Components

- List main components
  - Read their serial number, search for datasheets



# $CHIP1


- Manufacturer : **Ralink**
- Serial number : **RT63365E**
- Search for serial number online
  - « ADSL2+ processor for residential gateways »
  - MIPS architecture
  - No flash memory
    - Firmware must be stored elsewhere
- Let’s skip this for the moment

# $CHIP2

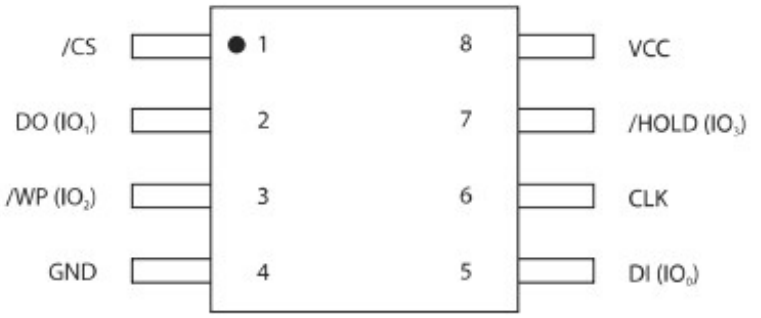

- Manufacturer: **Winbond**
- Serial number : **25Q16BVSIG**
- Search for serial number online
  - SPI EEPROM
- Electrically-Erasable Programmable Read Only Memory
  - Memory array
  - Data is stored even if the chip is not powered
  - Used to store data
- Probable firmware location !

# $CHIP2
# SPI

- Serial Peripheral Interface
- Bus topology
- Four wires
  - SCLK (Clock)
  - MISO (Master In/Slave Out)
  - MOSI (Master Out/Slave In)
  - SS (Slave Select)

# $CHIP2
# Connect EEPROM to HydraBus

- From datasheet, get the chip pinout
- From HydraBus CLI, get the SPI pins
  - *show pins*
- Wire everything together
  - Either wires, hooks or clip



# $CHIP2
# Send EEPROM commands

- Read datasheet, and send correct read command.
- Display hex dump of content

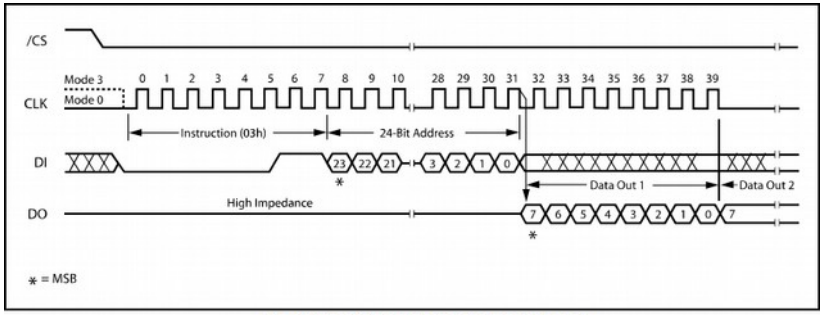



Figure 8. Read Data Instruction Sequence Diagram

```
> spi
Device: SPI1
GPIO resistor: floating
Mode: master
Frequency: 320khz (650khz, 1.31mhz, 2.62mhz, 5.25mhz, 10.50mhz, 21mhz, 42mhz)
Polarity: 0
Phase: 0
Bit order: MSB first
spi1> [ 0x03 0x00:3 hd:16 ]
/CS ENABLED
WRITE: 0x03 0x00 0x00 0x00
00 00 08 25 00 00 10 25  00 00 18 25 00 00 20 25  |  ...%...%...%.. %
/CS DISABLED
spi1>
```

http://www.datasheetlib.com/datasheet/374450/25q16bvsig_winbond-electronic.html

# $CHIP2
# Dump the whole image

- Reading bytes is fine to prove that everything is working
- Now, create a python2 script that dumps the whole EEPROM in a file

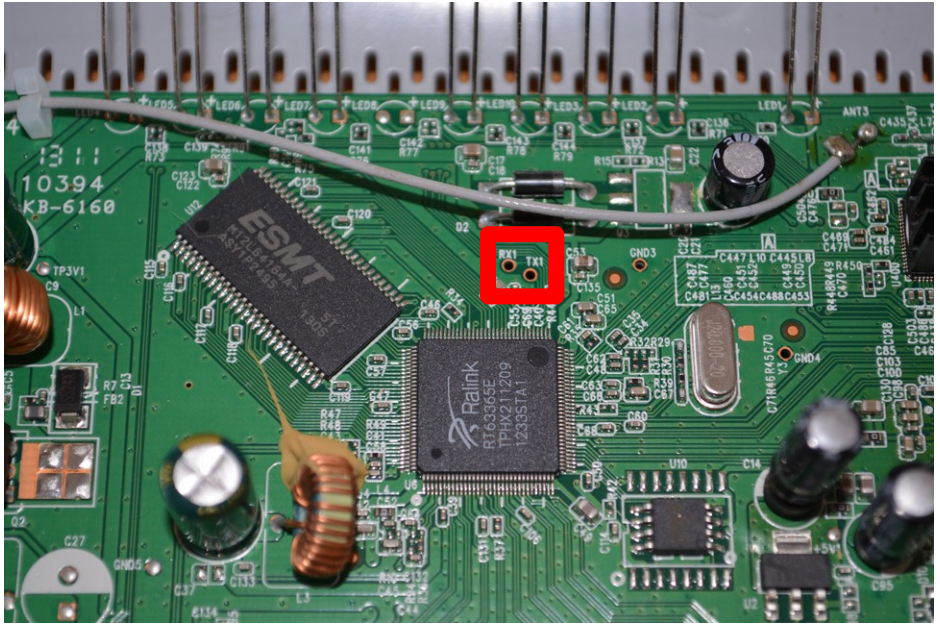
```
import serial
import struct
ser = serial.Serial('/dev/hydrabus', 115200)

for i in xrange(20):
    ser.write("\x00")
if "BBIO1" not in ser.read(5):
    print "Could not get into bbIO mode"
    Quit()

ser.write('\x01')
if "SPI1" not in  ser.read(4):
    print "Cannot set SPI mode"
    quit()

addr = 0
buff=''
print "Reading data"
while (addr < 4096*size):
    ser.write('\x04\x00\x04\x10\x00')
    ser.write('\x03')
    ser.write(struct.pack('>L', addr)[1:])
    ser.read(1)
    buff += ser.read(4096)
    addr+=4096
print ""
end = time.time()

out = open('/tmp/image.bin','w')
out.write(buff)
out.close()
```

# $CHIP2 Result

```
$ strings image.bin
[...]
ATHE
          print help
ATBA
x         change baudrate. 1:38.4k, 2:19.2k, 3:9.6k 4:57.6k 5:115.2k
ATEN
x,(y)     set BootExtension Debug Flag (y=password)
ATSE
          show the seed of password generator
ATTI
(h,m,s)   change system time to hour:min:sec or show current time
ATDA
(y,m,d)   change system date to year/month/day or show current date
ATDS
          dump RAS stack
ATDT
          dump Boot Module Common Area
ATDU
x,y       dump memory contents from address x for length y
[...]
```

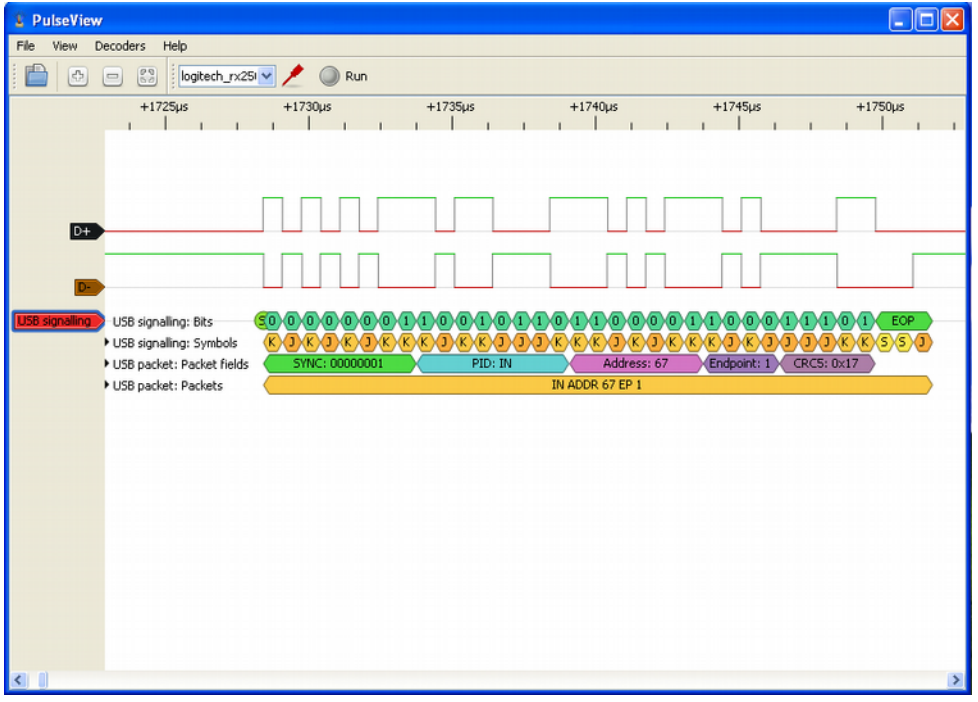
# Signal analysis

- Some unused headers are visible, but we don’t know what they are used for
  - Labeled RX1 / TX1
- Use the logic analyzer function



# Logic Analyzer (PulseView)

- Analyses digital signals
  - Only logic states
- Usually coupled with a PC software
  - Decodes logic signals to values
- Captures *n* samples
  - Capture start can be triggered



# Signal analysis

- Connect those headers to HydraBus
- Open PulseView, setup the capture
- Search through the available decoders to find a match
  - Requires experience / tests to recognize the protocols

# UART Bridge

- HydraBus can act as a USB / UART bridge
  - In UART mode, use the **bridge** command
- Serial console is now available on the router

# Result

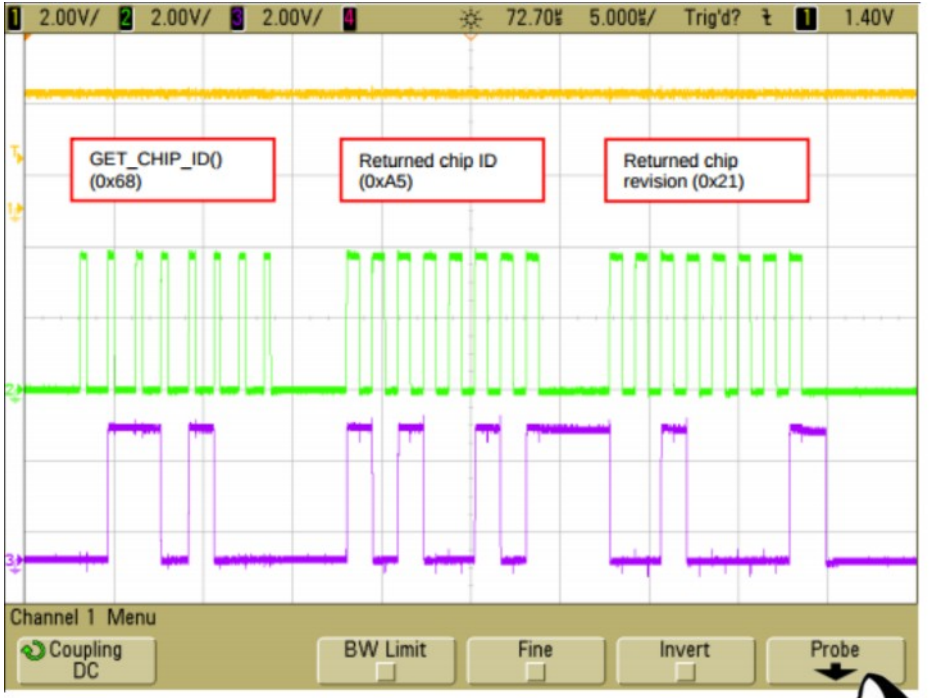
```
Bootbase Version: VTC_SPI1.22 |  2012/4/12 16:30:00
RAM: Size = 8192 Kbytes
Found SPI Flash 2MiB Winbond W25Q16 at 0xbfc00000
SPI Flash Quad Enable
Turn off Quad Mode

RAS Version: 3.0.0 Build 120524 Rel.05221
System   ID: $2.12.58.23(G04.BZ.4)3.20.17.0| 2012/05/18   20120518_V003  | 2012/05/18

Press any key to enter debug mode within 3 seconds.
.....
Enter Debug Mode
ATHE
======= Debug Command Listing =======
AT           just answer OK
ATHE           print help
ATBAx          change baudrate. 1:38.4k, 2:19.2k, 3:9.6k 4:57.6k 5:115.2k
ATENx,(y)      set BootExtension Debug Flag (y=password)
ATSE           show the seed of password generator
ATTI(h,m,s)    change system time to hour:min:sec or show current time
ATDA(y,m,d)    change system date to year/month/day or show current date
ATDS           dump RAS stack
ATDT           dump Boot Module Common Area
ATDUx,y        dump memory contents from address x for length y
ATRBx          display the  8-bit value of address x
ATRWx          display the 16-bit value of address x
ATRLx          display the 32-bit value of address x
ATGO(x)        run program at addr x or boot router
ATGR           boot router
ATGT           run Hardware Test Program
ATRTw,x,y(,z) RAM test level w, from address x to y (z iterations)
ATSH           dump manufacturer related data in ROM
ATDOx,y        download from address x for length y to PC via XMODEM
ATTD           download router configuration to PC via XMODEM
ATUR           upload router firmware to flash ROM
```

# Case 2 (Secret board 2.4GHz ZigBee)

- Unspecified board, sorry
- Uses CC2530 micro-controller
  - Texas Instrument SoC for 2.4GHz ZigBee, IoT network nodes ...
- Debug port available
  - Uses custom debugging protocol
  - No ccDebugger at hand at that time

# Protocol details

- Application note found on TI website
- Simple two wire protocol
  - Clock / Data
  - Master drives the clock
  - Data channel is bidirectional

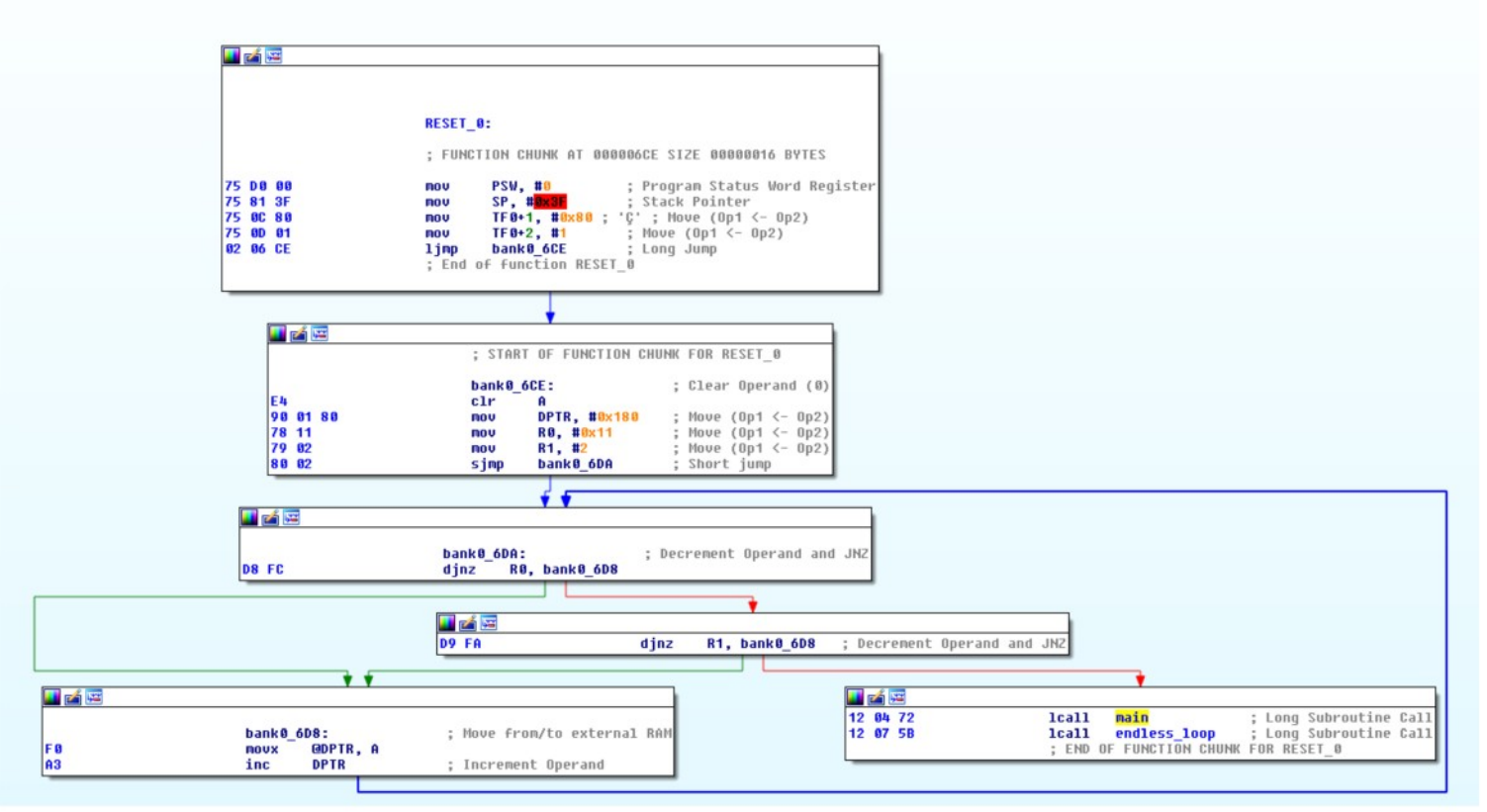



http://www.ti.com/lit/an/swra410/swra410.pdf

# Dumping

- Use 2-wire mode, to communicate with the chip and dump its flash memory

# Result

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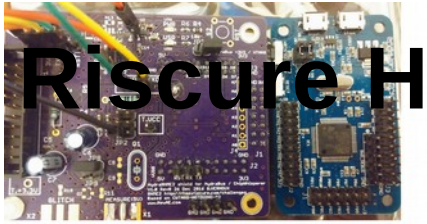
# Riscure Hack me 2 (RHME2) Challenge



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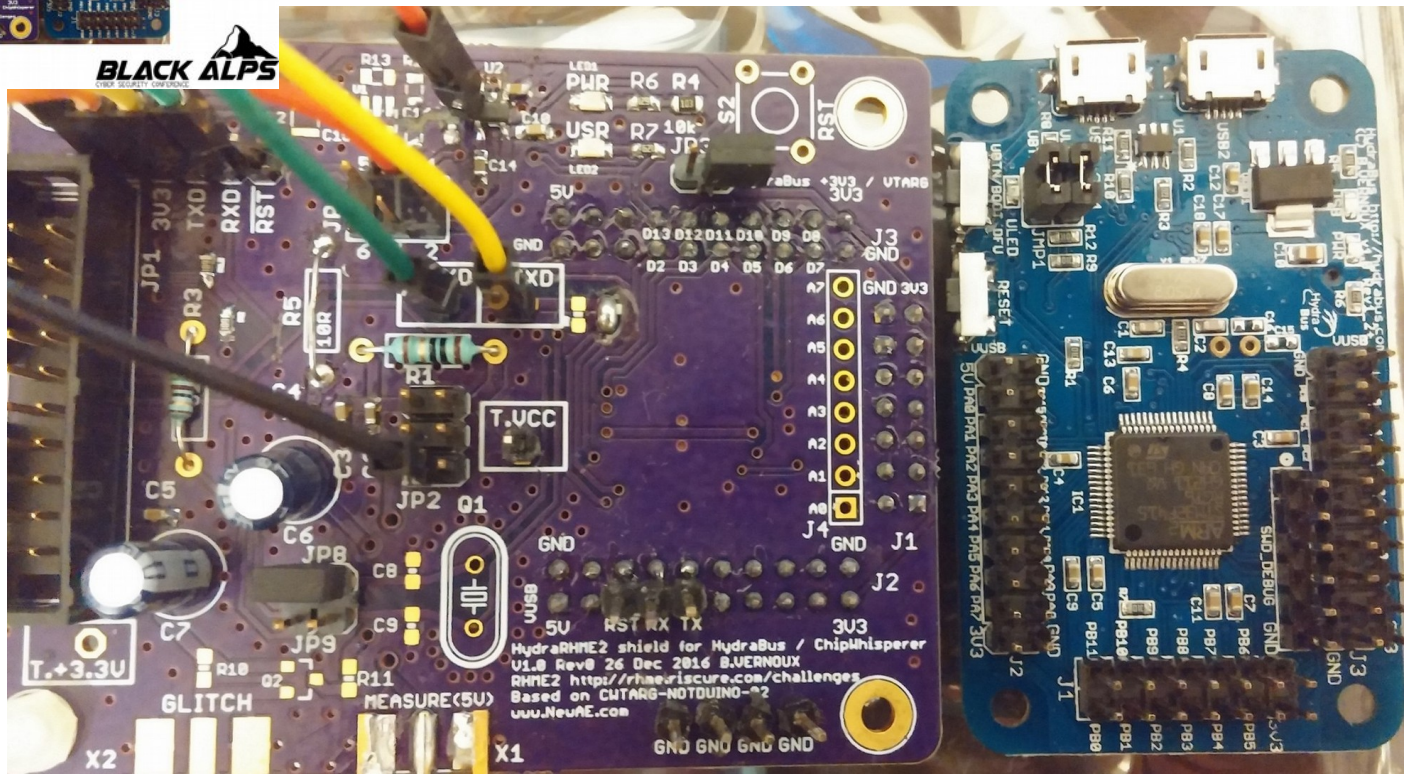
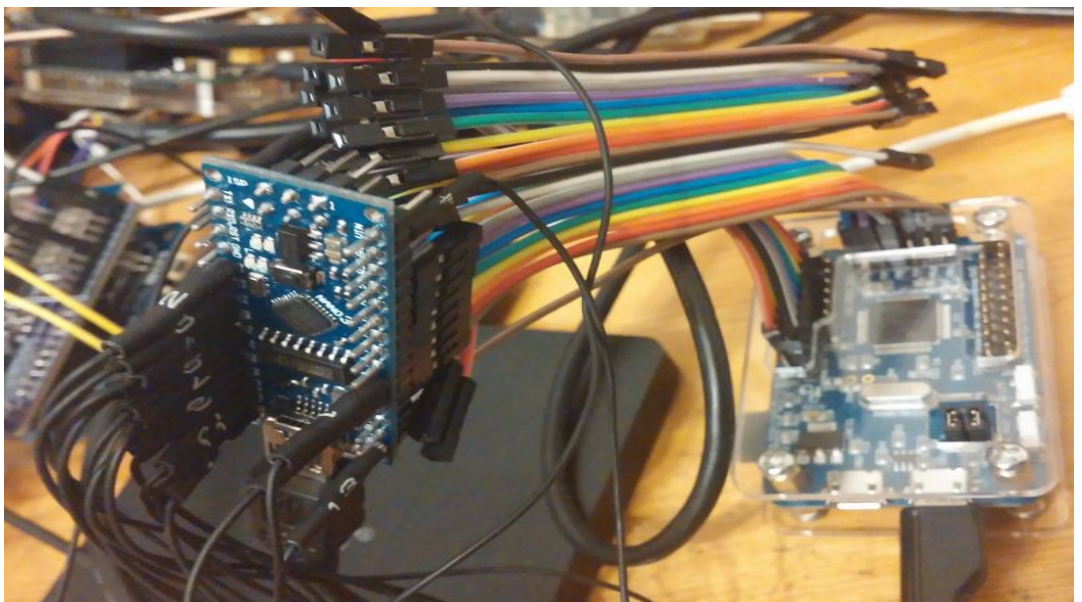


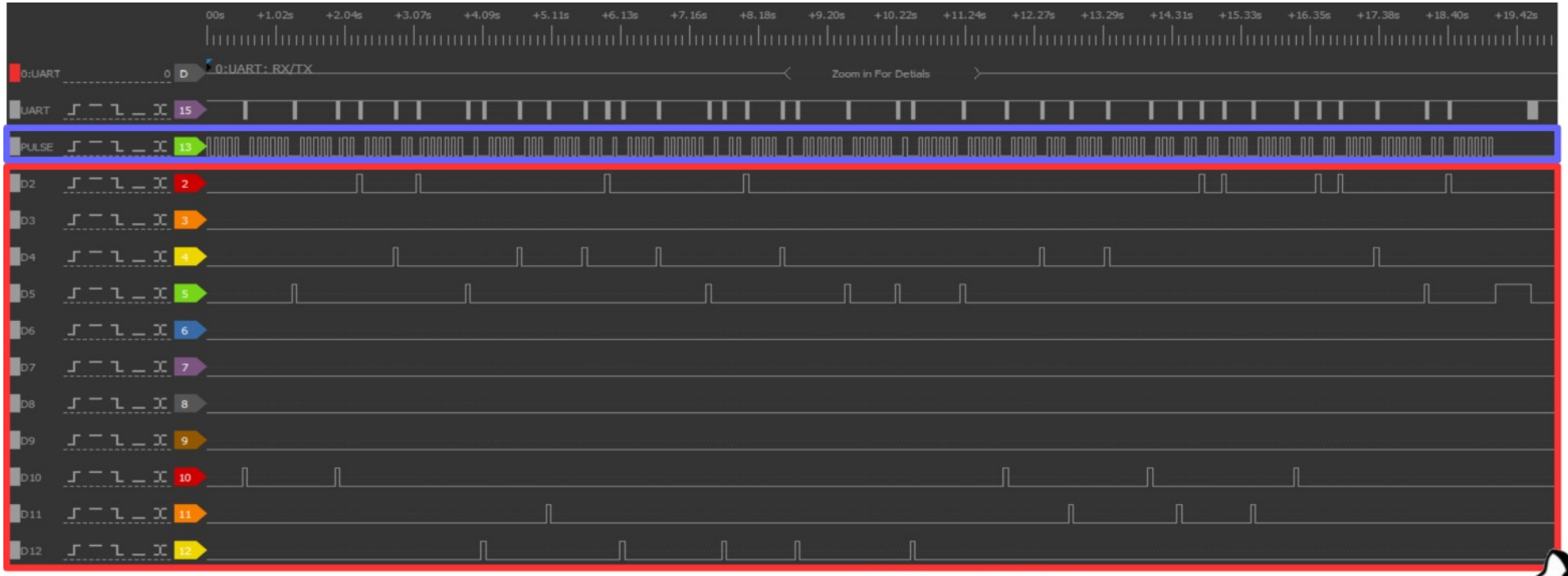
# RHME2 - Whac The Mole

- Whac The Mole Challenge
  - https://github.com/hydrabus/rhme-2016/blob/master/Other/WhackTheMole.md



# RHME2 - Whac The Mole

- Whac The Mole Challenge with Logic Analyzer




The purpose was to set the right digital pin(from D2 to D13) to "1" corresponding to number of flash detected on the LED(so counting number of rising edge on the LED pin/D13) in order to hit the mole.

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# RHME2 - Secret Sauce

- Secret Sauce Challenge
  - This challenge ask for a password so the idea was to recover it using a timing attack with the help of HydraBus
  - https://github.com/hydrabus/rhme-2016/blob/master/Other/SecretSauce.md

# RHME2 - Fiasco (Fault Injection)

- This challenge ask for a password and the idea is to do a VCC Glitch on the Arduino board in order to skip/jump over the check and display the flag
  - Results with HydraBus + Custom Board with MOSFET
  - Please write your password: gpio glitch trigger PB0 pin PC15 length 100 offsets 191200
    Good try, cheater!^M
    Chip locked^M
  - Please write your password: gpio glitch trigger PB0 pin PC15 length 100 offsets 191300
    **Chip unlocked^M**
    **Your flag is: 02ab16ab3729fb2c2ec313e4669d319e**
  - https://github.com/hydrabus/rhme-2016/blob/master/FaultInjection/Fiasco.md

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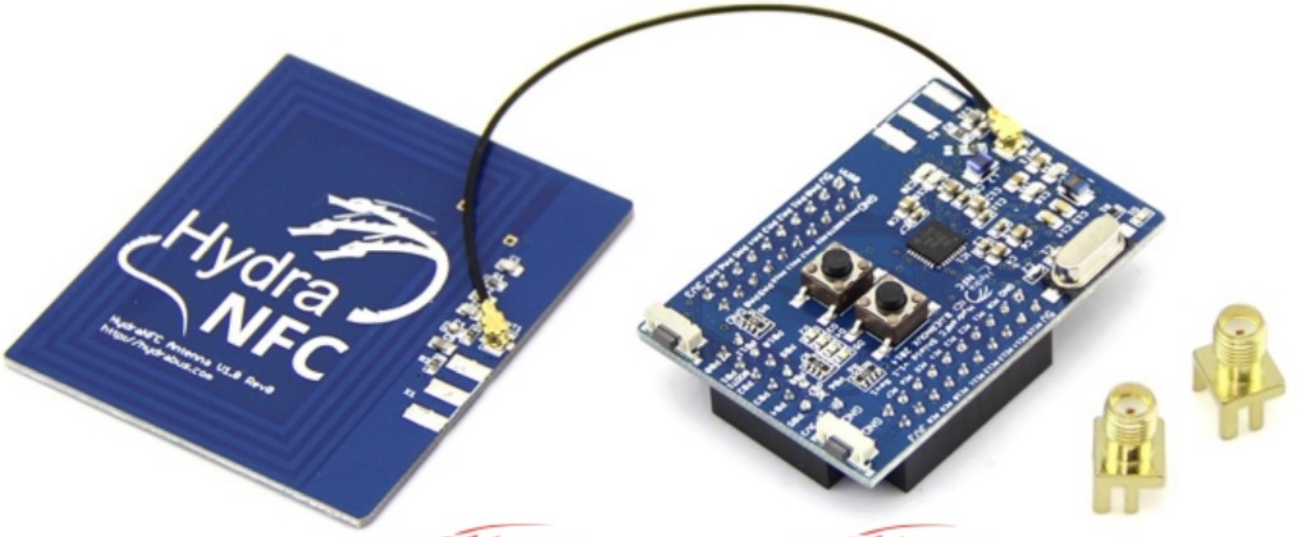
# Shields

# HydraNFC




Hydra Bus

Hydra NFC

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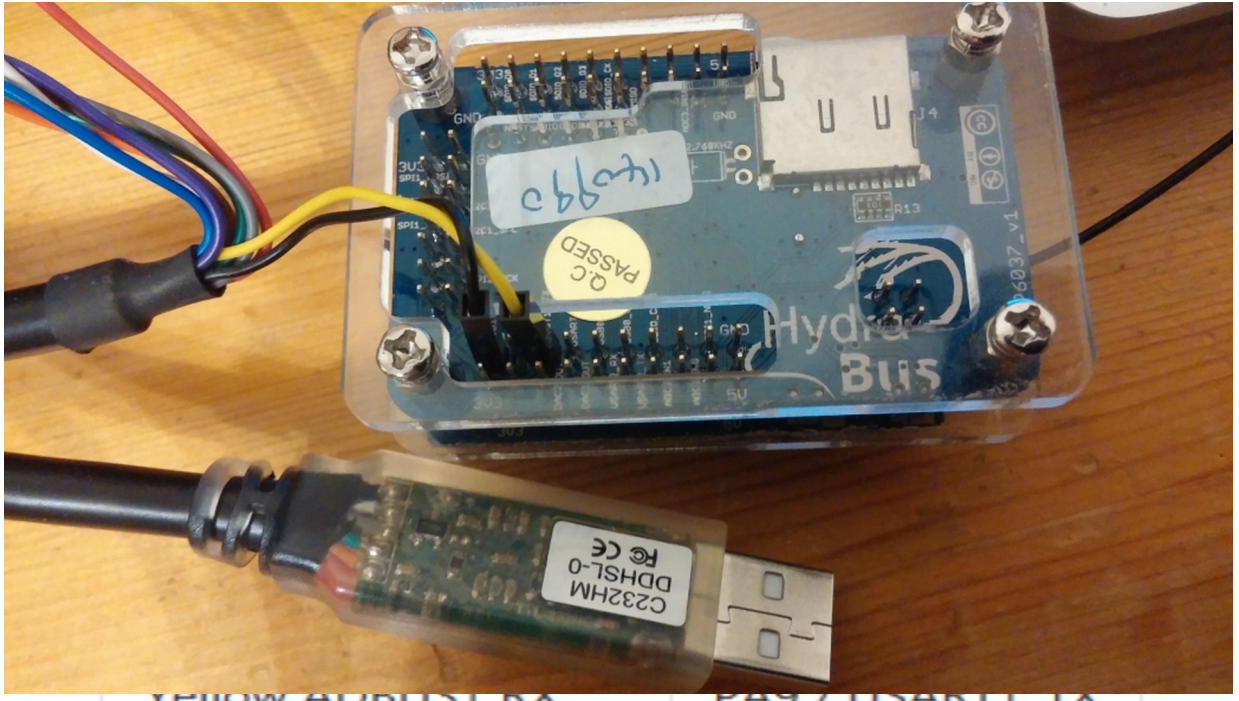
# HydraBus+HydraNFC Firmware

- Actual Firmware features (HydraFW):
  - Read UID NFC Vicinity/ISO15693 and Mifare
  - Read Data on Mifare UL
  - Emulation ISO14443A/Mifare UL/Classic (Alpha)
  - Sniffer ISO14443A with unique hard real-time infinite trace mode (requires FTDI external hw & PC with hydratool sw)
  - Autonomous sniffer ISO14443A (Mifare ...) include data from TAG & READER (data saved in microSD)
  - HydraFW HydraNFC online guide see:
    - https://github.com/hydrabus/hydrafw/wiki/HydraFW-HYDRANFC-guide

# Sniffer real-time infinite trace mode




| | |
|---|---|
| Yellow ADBUS1 RX | PA9 / USART1_TX |
| Black GND | GND (near PA9) |

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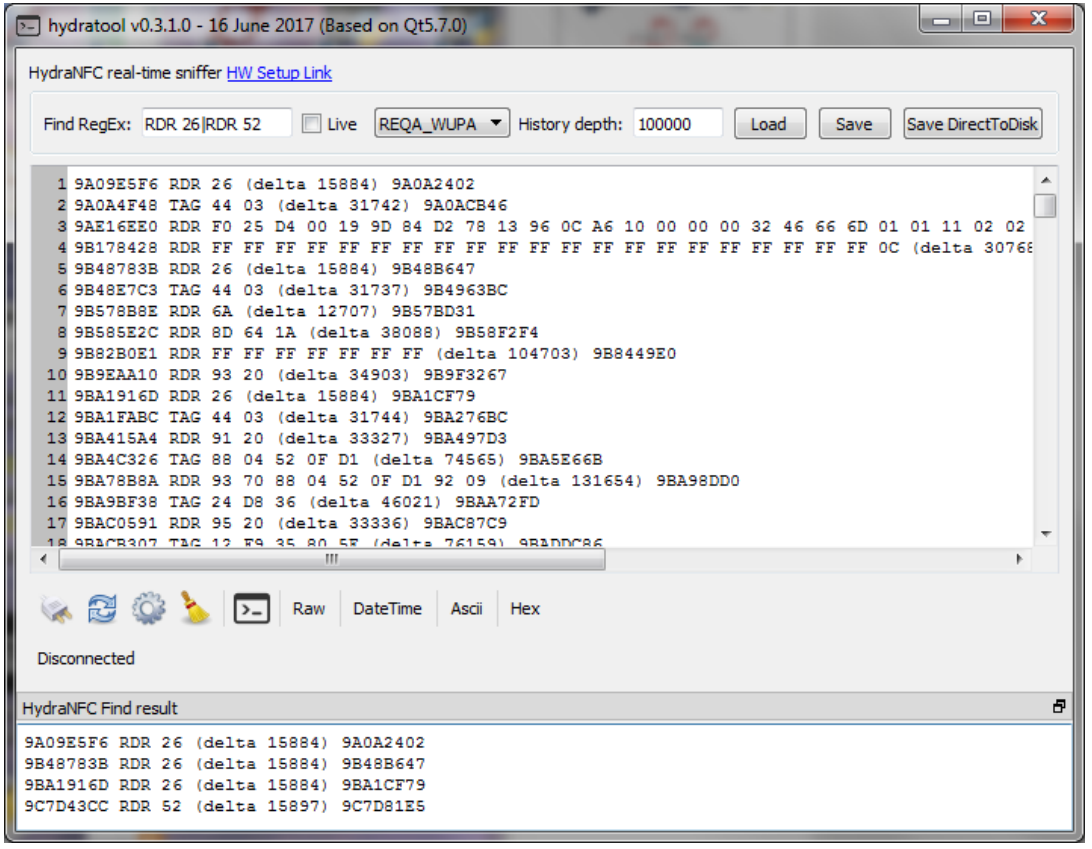
# Sniffer PC GUI (Qt5)

- HydraTool v0.3.1.0 (Windows / GNU-Linux)

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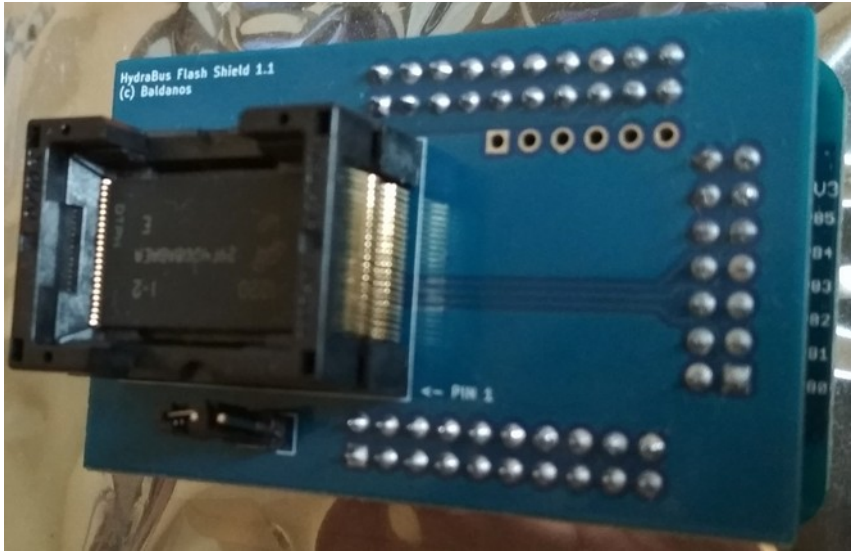
# HydraFlash

- Designed to dump Flash NAND chips
  - Found in more and more devices
- No hardware support from the MCU
  - Uses GPIO in Bit Bang mode



# HydraFlash

- Uses a fork of DumpFlash to handle commands
  - Some manufacturers use different commands
  - Already manages OOB
- Decent reading and writing speeds
  - ~200KB/s on test chip

```
$ python2 DumpFlash.py -d /dev/hydrabus -i
Into BBIO mode
Switching to flash mode
Setting chip enable
Full ID:  AD73AD73AD73
ID Length:      6
Name:           NAND 16MiB 3,3V 8-bit
ID:             0x73
Page size:      0x200
OOB size:       0x10
Page count:     0x8000
Size:           0x10
Erase size:     0x4000
Block count:    1024
Options:        0
Address cycle:  3
Bits per Cell:  4
Manufacturer:   Hynix
```

# HydraFlash – Fun facts

- Got some flash chips from eBay
- Branded as new
- Unfortunately, no juicy information :(

```
$strings /tmp/dump
[...]
Media is write-protected!
FCU failed on ECC/CRC error!
FCU general error!
FCU%s timed out!
 Burst
'Copyright (c) 1996-2004 Express Logic Inc.
* FileX LX4180/Green Hills Version G3.1a.3.1a *
/home/sandbox/sde/lib/c/time/offtime.c
/home/sandbox/sde/lib/c/time/tzfile.h
### Battery_Check : byPowerOnLevelAfterDummy = %
Battery_Check : NiMH Battery  ================
Battery_Check : BEFORE LENS MOVE
Battery_Check : sBattery.byLevel
< BAT_NO_MOVE_LENS_LEVEL
[...]
```

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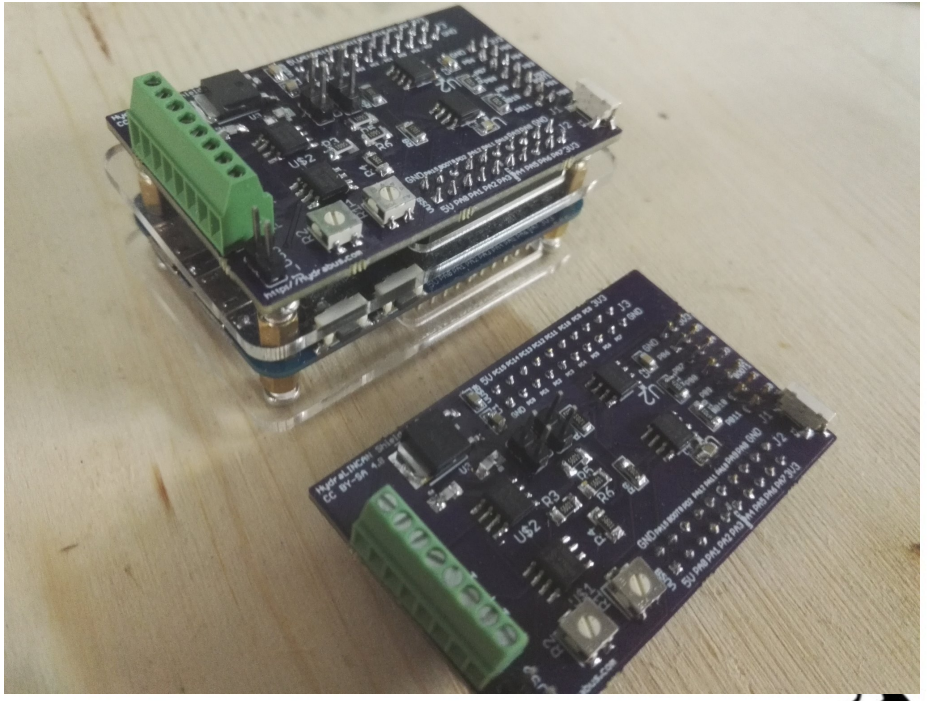
# HydraLINCAN

- Designed to handle CAN and LIN buses communication
  - Mostly found in automotive
- Made by smillier



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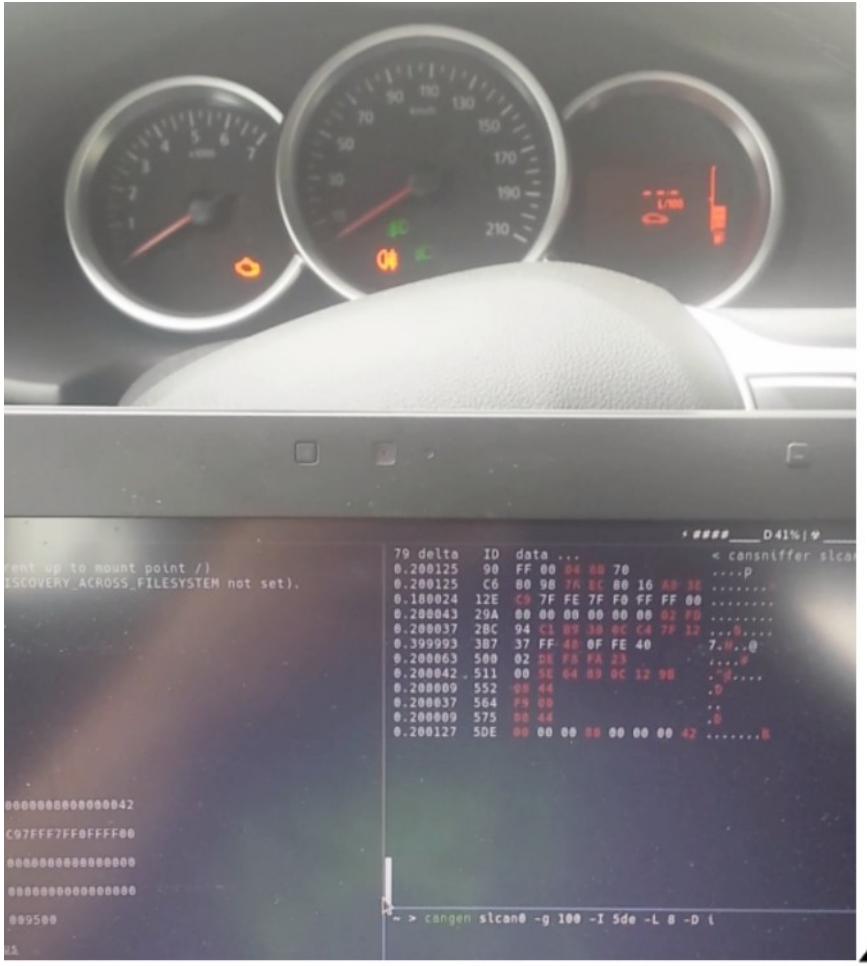
# HydraLINCAN

- CLI and BBIO already implemented and working
- SLCAN implemented in trunk
  - Able to use all utilities provided by can-utils
- Already tested on Balda car
  - Still alive ;-)
- Thanks to Balda for that amazing feature/demo ...



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# Alternative firmwares

- Micropython
  - Python 3.x for microcontrollers
  - Official support
  - http://micropython.org
- BlackMagic
  - JTAG/SWD probe / GDB server
  - Official support
  - https://github.com/blacksphere/blackmagic

# Project status

- Lots of added features last year
  - Frequency measurement
  - Hexdump mode
  - 1-wire mode
  - AVR programming
  - NAND Flash support (HydraFlash HW by Balda/N.OBERLI is available now)
  - CAN SLCAN
  - Hex escapes
  - ...

# Project status – cont.

- Project is getting close to 1.0
  - Will be the first stable version
  - Some modes need to be added to provide full set of features
    - I2c slave mode
    - Data sniffers
      - I2c
      - [1,2,3]-wire

# Conclusions

- Hydrabus will not replace dedicated tools
- However, nice all-in-one device that can be used for hackers and makers for quick prototyping, development and hacking
- Still requires some technical background to be used efficiently

# A BIG THANKS TO

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# TEAM !!

## Thanks to following contributors :

- **Nicolas Oberli (Balda)**
  - Amazing work on the FW & HW like HydraFlash

    ...
- **Sylvain Millier (smillier)** HydraLINCAN HW
- **All contributors**

# Hydrabus Workshop

- Tomorrow afternoon (from 13h30 to 16h30), open to all
- Many different activities
  - HydraFW hackathon
    - HydraBus kits offered for first 2 merged PRs made during BlackAlps17
  - Test HydraBus on practice targets
  - Learn signal analysis
  - Get yours !

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