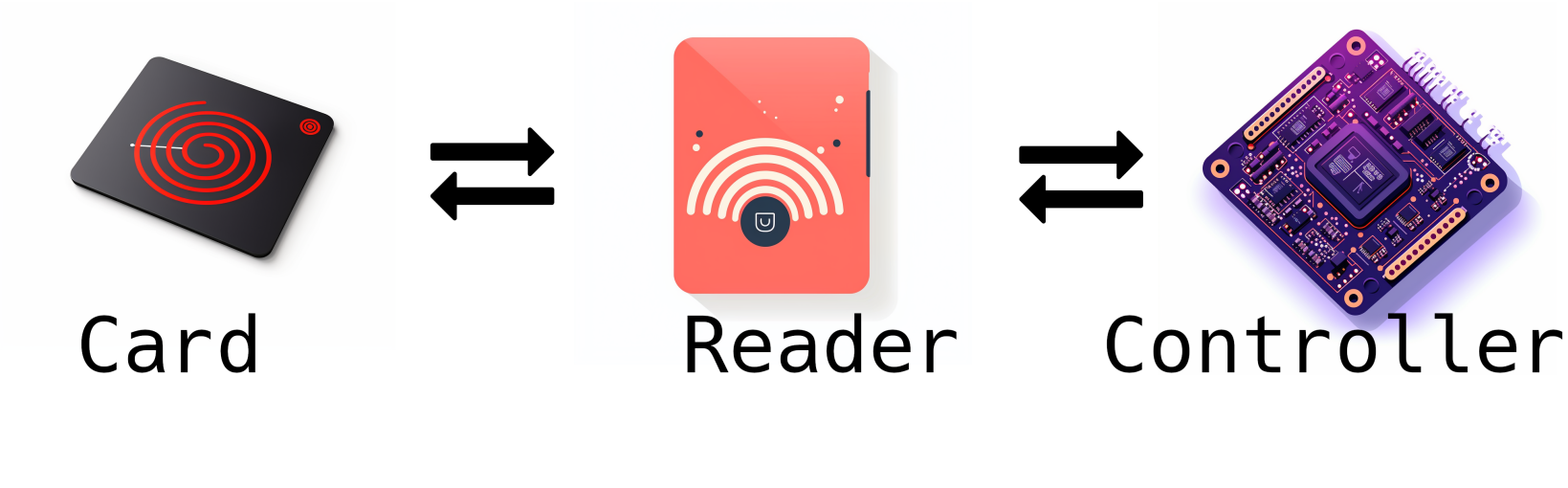
RFID access control system, what it is and how to defeat it

Nemanja Nedeljkovic

About me

- nemanjan00
- I like to take things apart
- Sometimes put them back together
- Reverse Engineering, RND and DevOps @ Constallation

Access control system



About presentation

Scope:

- RFID credentials (cards)
- RFID readers
- Wiegand (Reader <-> controller protocol)
- Highlevel controller overview
- Integrator and manufacturers mistakes and problems

Out of scope:

- Magnetic tape
- Biometrics
- Plate recognition
- OSDP (Reader <-> controller protocol)
- Business logic

Card (ass grab tech)

Unique ID

- Different length
- Magic cards (Backdoored cards - changable UID)

Power supply:

- Active (Battery powered)
- Passive (Reader powered)

Frequency:

- LF (125kHz, 134khz)
- HF (13.56Mhz)
- UHF (300Mhz - 3Ghz) - Mostly for inventory systems, parking and tolls

Powering card - Electromagnetic induction

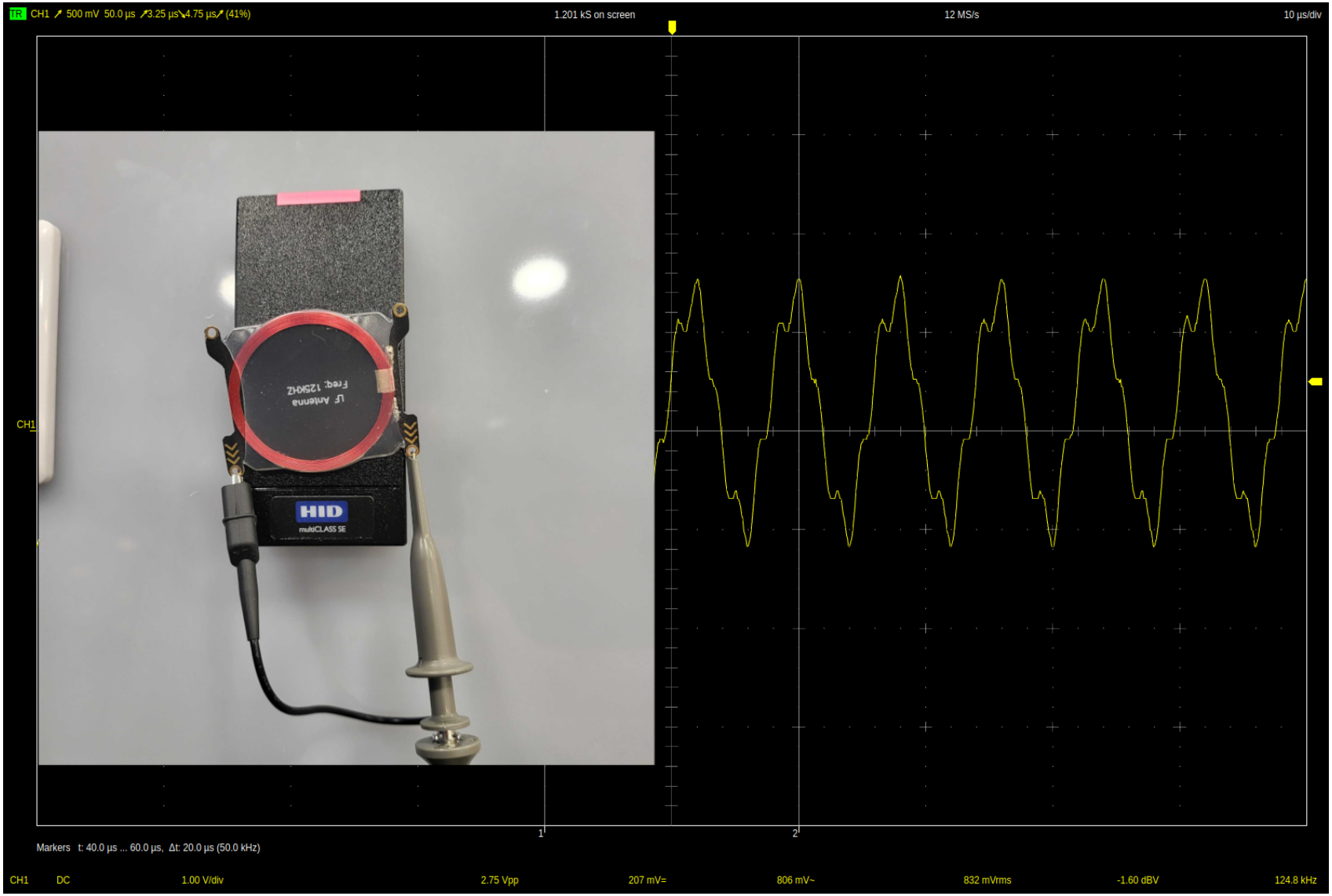
Current gets induced in one of these cases:

- Conductor moves in constant field
- Conductor is in alternating field

How is this used?

- Sinusoid signal at proper frequency (125kHz for example)
- Resonant antenna
  - Antenna length depends on wavelength (length light travels during one oscilation)
  - Lower frequency, bigger antenna

Powering card showcase



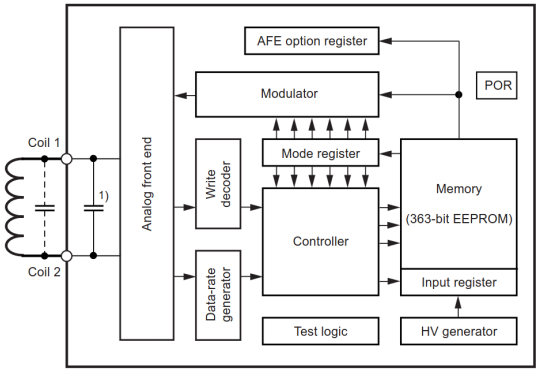
Command modulation - Reader to card

- Capacitor can be used to store power
- Sine cycles can be skipped, to modulate data (commands)

3. ATA5577C – Functional Blocks

The following figure illustrates the functional block of ATA5577C.

Figure 3-1. Block Diagram



1) Mask option

3.1 Analog Front End (AFE)

The AFE includes all circuits that are directly connected to the coil terminals. It generates the IC's power supply and handles the bidirectional data communication with the reader.

The AFE consists of the following blocks:

- Rectifier to generate a DC supply voltage from the AC coil voltage
- Clock extractor
- Switchable load between "Coil 1 and Coil 2" for data transmission from the tag to the reader
- Field gap detector for data transmission from the base station to the tag
- Electrostatic Discharge (ESD) protection circuitry

Data modulation - Load modulation - Card to reader

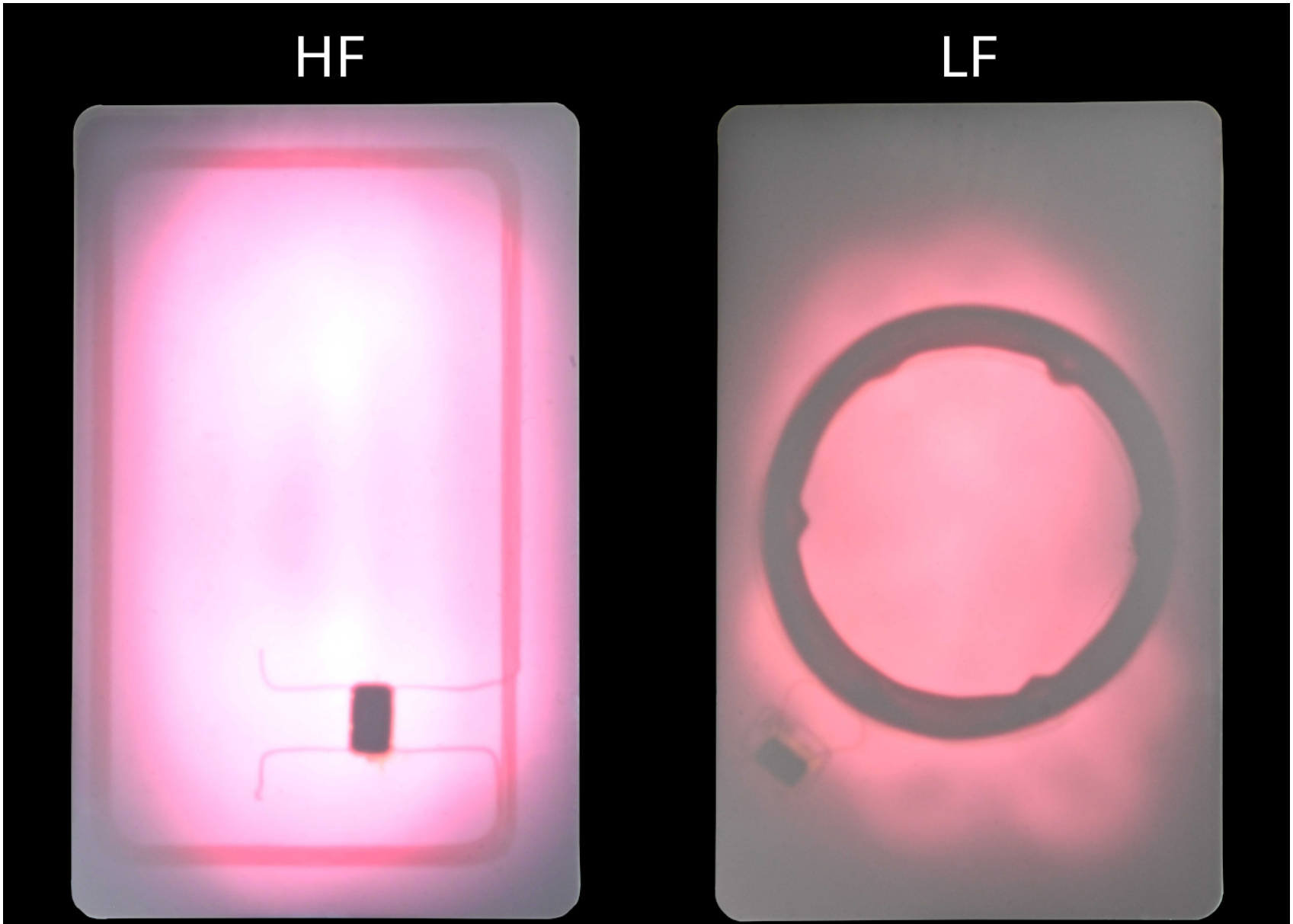
- Load on card = Load on power source
- Increase in load = Decrease in voltage
- It can be measured across both antennas
- It can be measured in field (sniffing)
- Switching load on and off can be used for modulation

```
# showcase load modulation phenomenon
hf tune --mix
lf tune --mix

# showcase card demodulation
data plot
lf search
lf em 410x demod
```

Figuring out the frequency

- Flashlight (antennas do not look the same)
- Field detector



LF cards

- One-way communication or simple two-way communication
- Slow communication
- Mostly no security features (auth or encryption)
- Simple implementations
  - Modulation
  - Baudrate
  - Inverted

LF card standards

- HID Proxcard
- EM4100
- HiTag
- Indala

...

- T5577 can emulate other cards
- ISO 11784 / 11785 Standard - Animal chips

Vulnerabilities and characteristics

- Trivial to read
- Trivial to clone or emulate
- Requires big antennas for great performance, due to low frequency

Tools

Tool	Read	Write	Emulate	Note
Proxmark3	Yes	Yes	Yes	Steep learning curve
White cloner	Yes	Yes	No	No display for ID
Blue cloner	Yes	Yes	No	Sets password
Tinylabs Keysy	Yes	Yes	Yes	Closed source
Chameleon Ultra	Yes	Yes	Yes	Only EM4100 right now
Flipper Zero	Yes	Yes	Yes	Great support
ICopyX	Yes	Yes	No	

HF cards

- Two-way communication
- Fast communication
- Very flexible in terms of features
- Quite a few standards, substandards and classes of standards implementations
- Some standards support anti-collision

Vulnerabilities and characteristics

- More advanced modulation techniques
- Proprietary communication protocols
- Sometimes encrypted
- Sometimes programmable (Java SmartCard)
- Readers do not always use proprietary features and sometimes rely on low level stuff like UID)
- Can be cloned, but relies on understandind the tech implemented in a card
- Higher frequency means smaller performant antennas = long range cloning (few 10s of cm)

HF card standards

RF communication: ISO 14443 A, ISO 14443 B, ISO 15693, ISO 18092

Application protocols: ISO 7816 (APDU) over ISO 14443 A/ISO 14443 B, Mifare Classic, Mifare Ultralight, ISO 15693 (NFC-V)

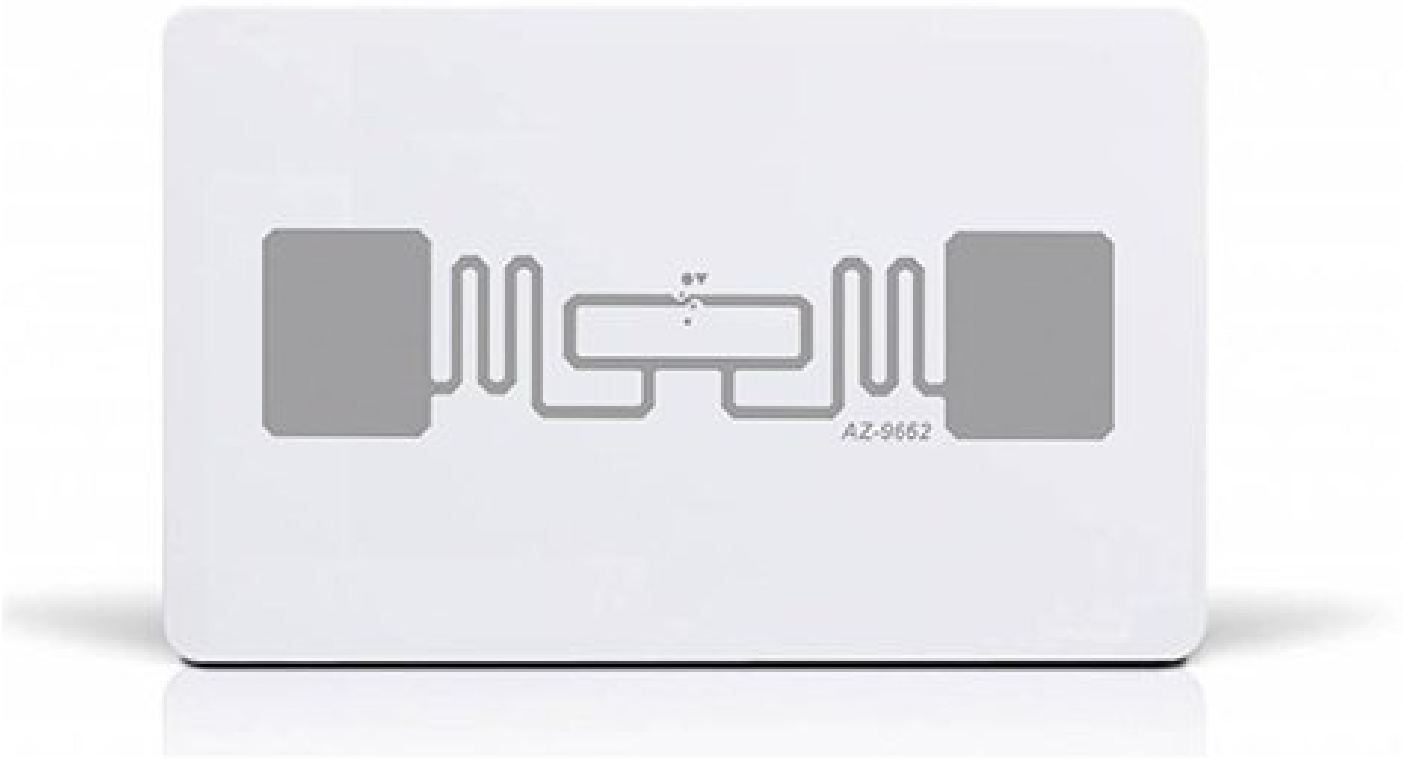
Implementations either extend existing command set or utilize ISO 7816 (APDU) over underlaying protocols.

Tools

Tool	Read	Write	Emulate	Note
Proxmark3	Yes	Yes	Yes	Timing issues for emulation
Chameleon Mini (Tiny)	Yes	No	Yes	Timing issues for emulation
Chameleon Ultra	Yes	No	Yes	Still too new
Flipper Zero	Yes	Yes	Yes	Timing issues for emulation
Long Range Raders	Yes	Yes	Yes	10-20cm
PN532	Yes	Yes	Yes	LibNFC
DL533N	Yes	Yes	Yes	LibNFC

Type of card dependant

UHF cards



Controller

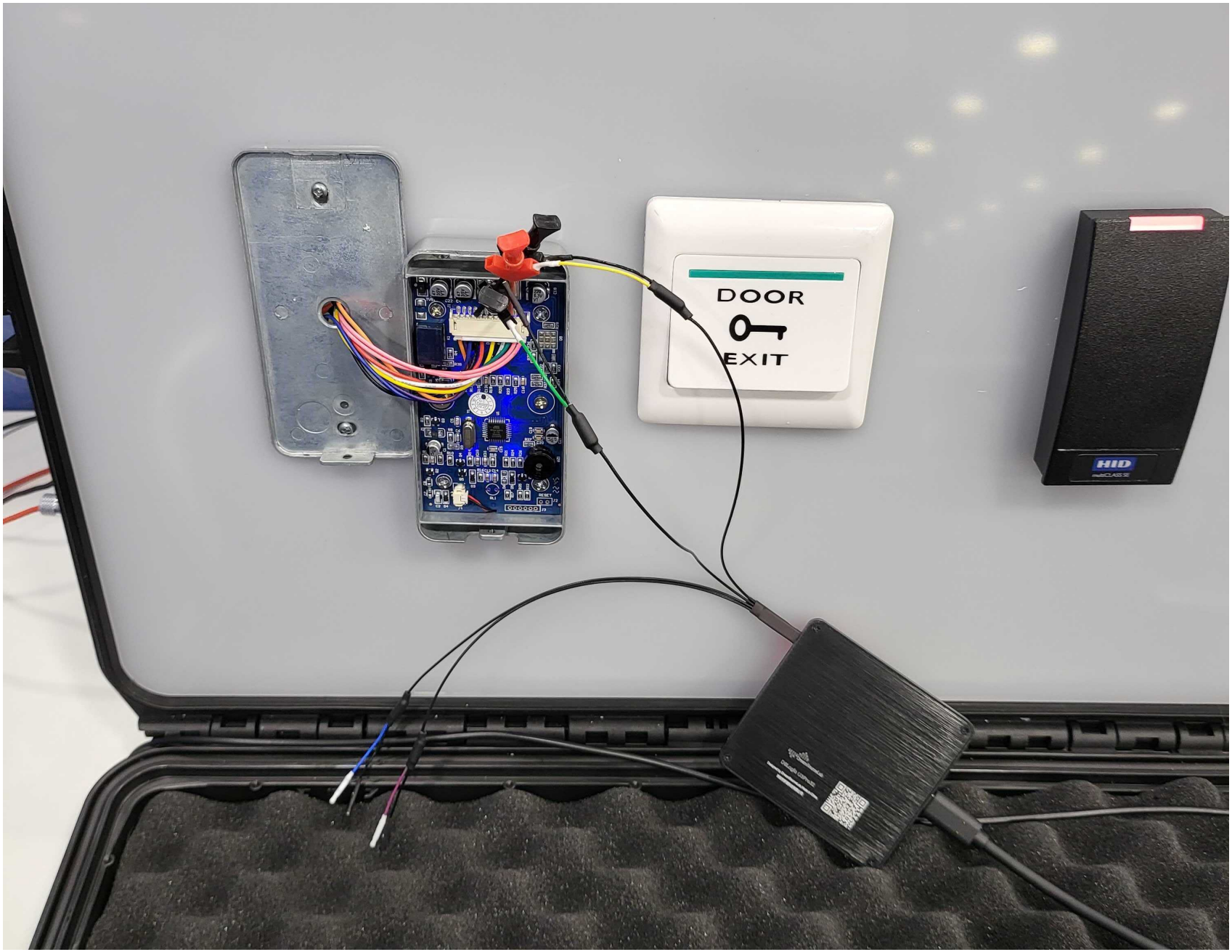
Input signal:

- Wiegand
- OSDP (out of scope)

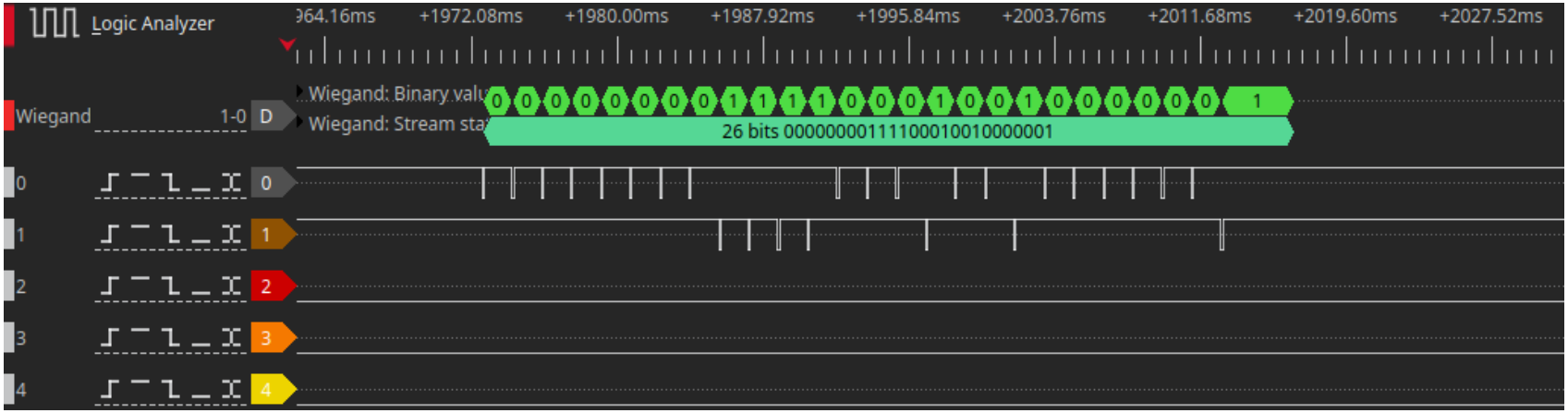
Output signal:

- Control the relay
- Audiovisual feedback

Wiegand



Wiegand to ID



Wiegand Calculator - 26-bit format

Binary Data

P	F	F	F	F	F	F	F	F	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	P
0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	1

Even Parity Field | Odd Parity Field

Facility Code
Decimal: 0
Hex: 00

Card Code
Decimal: 61728
Hex: F120

Raw Data - Decimal: 123457 Hex: 001E241

Convert

Attacks

- Cloning credentials
- Hardcoded/default credentials
- Fuzzing attacks
- Downgrade attacks
- Crypto or PRNG implementation attacks (for example nested, hardnested and darkside attacks on Crypto1)
- Wiegand sniffing and replay
- Controller and reader combo attacks

Hardcoded/default credentials

- Some controllers come with default credentials hardcoded
- There are backdoor credentials
- Some of them have been leaked (No security by obscurity)

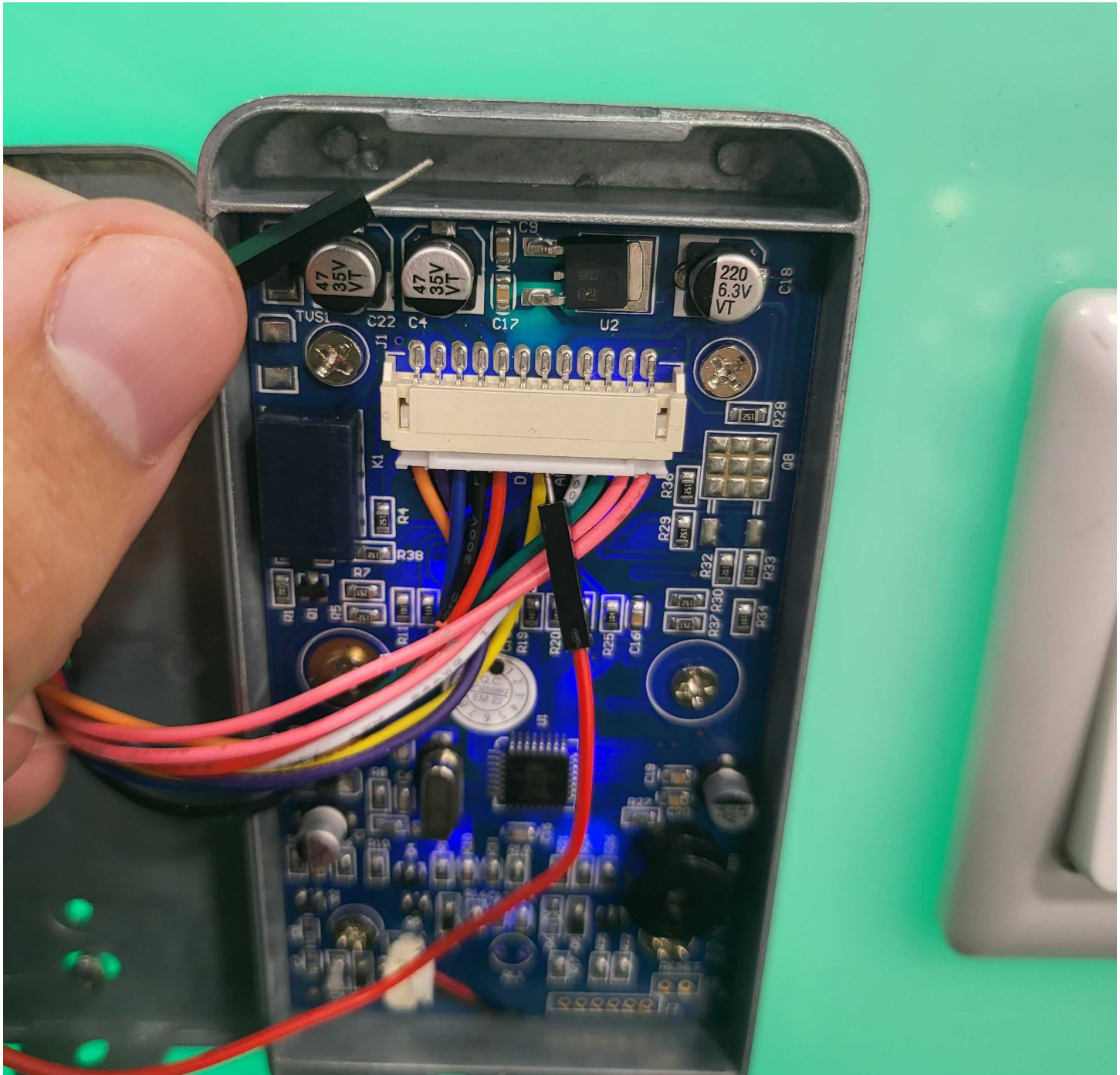
Fuzzing attacks

- There have been cases where readers did unlock for some extreme values
- 0x0000000000
- 0xFFFFFFFFFF

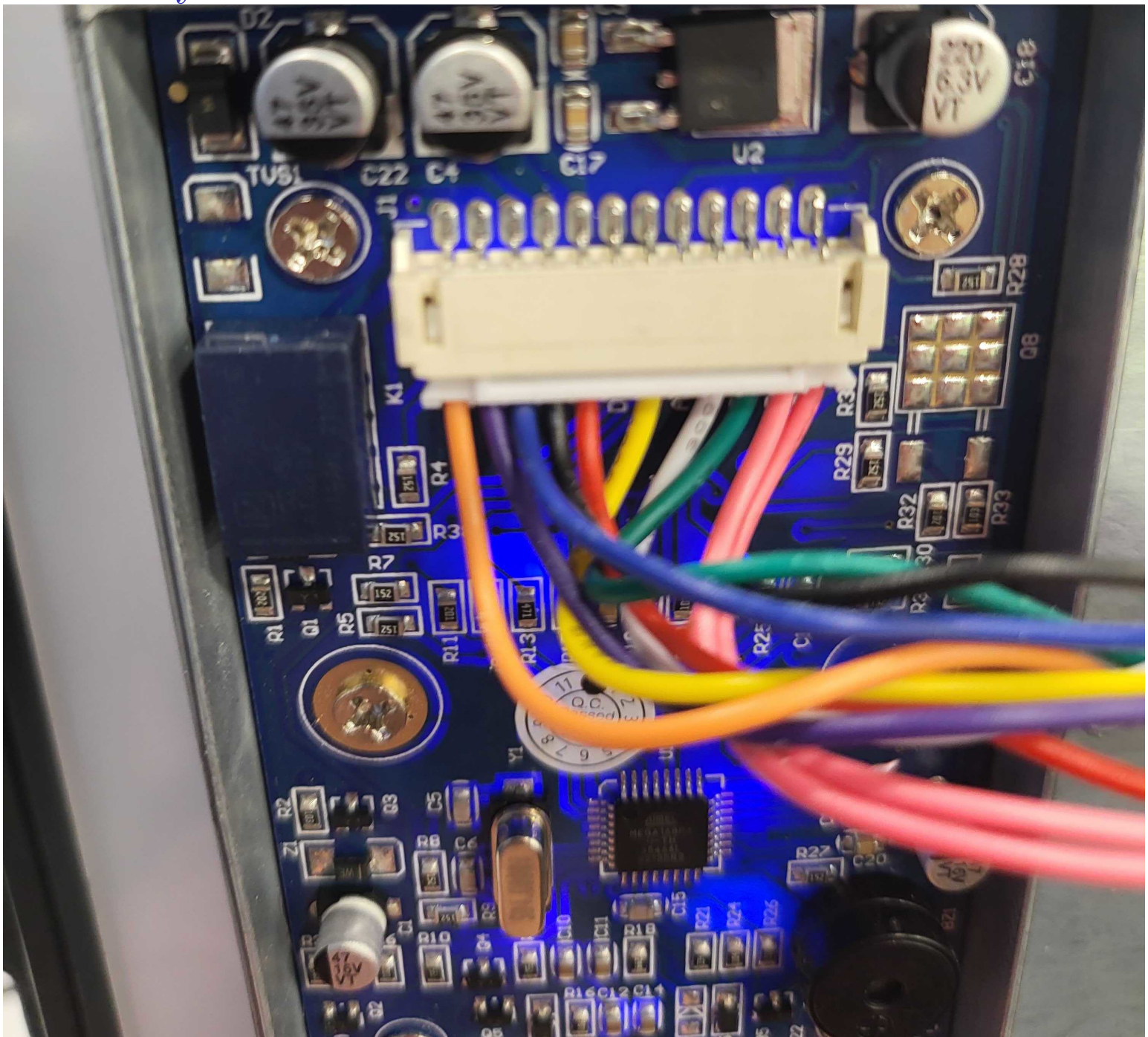
Controller and reader combo attacks

- Default password can be used to register new credentials
- Push to unlock button is on the outside
  - Signal wire is connected to VCC using pull up resistor
  - Button connects signal wire to ground
  - When voltage falls below certain value, relay is connected, to unlock
  - Color scheme for wiring is well known
- Relay is on the outside
  - Relay = Electromagnet connected to metal plate and metal plate on spring
  - External magnetic field can activate relay
- Unused wiegand wires usually present

Push to exit


47
35V
VT
47
35V
VT
220
6.3V
VT
C9
C22
C4
C17
U2
C18
TVS1
J1
K1
R28
Q8
R36
R29
R4
R38
R7
R32
R33
R30
R37
R34
R19
R20
R25
C16

External relay



Extra - Privacy concerns with UHF RFID cards

Product identification by GS1 standards

- UPC
  - Company prefix
  - Item reference number
- EPC
  - Company prefix
  - Item reference number
  - Product serial number

H&M

```
SVC="https://app2.hm.com/hmwebservices/service"
EPC="07314308132190"

ID=$(curl "$SVC/app/getArticleByScannedBarcode/hm-serbia?gtinCodes=$EPC
    -H "user-agent: targetapp_android_21" | jq -r ".[0]")

REAL_ID=$(echo $ID | cut -c1-10)

curl "$SVC/article/get-article-by-code/hm-serbia/Online/$REAL_ID/sr.jso
    -H "user-agent: targetapp_android_21" | jq ".product.name"
```

About the community

- Iceman Discord
- RRG Github