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Horror on the bus

Hacking combus in a Paradox security system

Hackfest Decade
Quebec, Canada

Author

- Lead researcher at Possible Security, Latvia
- Hacking and breaking things
  - Network flow analysis
  - Reverse engineering
  - Social engineering
  - Legal dimension
- twitter / @KirilsSolovjovs

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Possible Security

- Pentests & auditing
- Consulting & trainings
- Hard problems & reverse engineering

Thanks!

possiblesecurity.com

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INTRO

Paradox security systems

- Canadian company, founded 1989
- Modular security alarms
  - SPECTRA SP
    - Expandable Security Systems
  - EVO
    - High-Security & Access Systems
  - MAGELLAN
    - Wireless Security Systems

Prior research

- Work on interfacing with SP series via COMBUS
  - Martin Harizanov
    - partially working code, moved on to SERIAL
- Work on interfacing with MG series via SERIAL
  - All over forums
    - leaked docs
  - Gytis Ramanauskas
    - code on github

Responsible disclosure process

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- At first:
  - General claim that there’s a vulnerability met with doubt
  - Clearly no process in place
- In a few of months:
  - The information has been “dealt with”
  - For obvious security reasons, it is our policy to never discuss engineering matters outside of the company and thus we will not be commenting further on this issue
- A couple years later — I’m in Canada

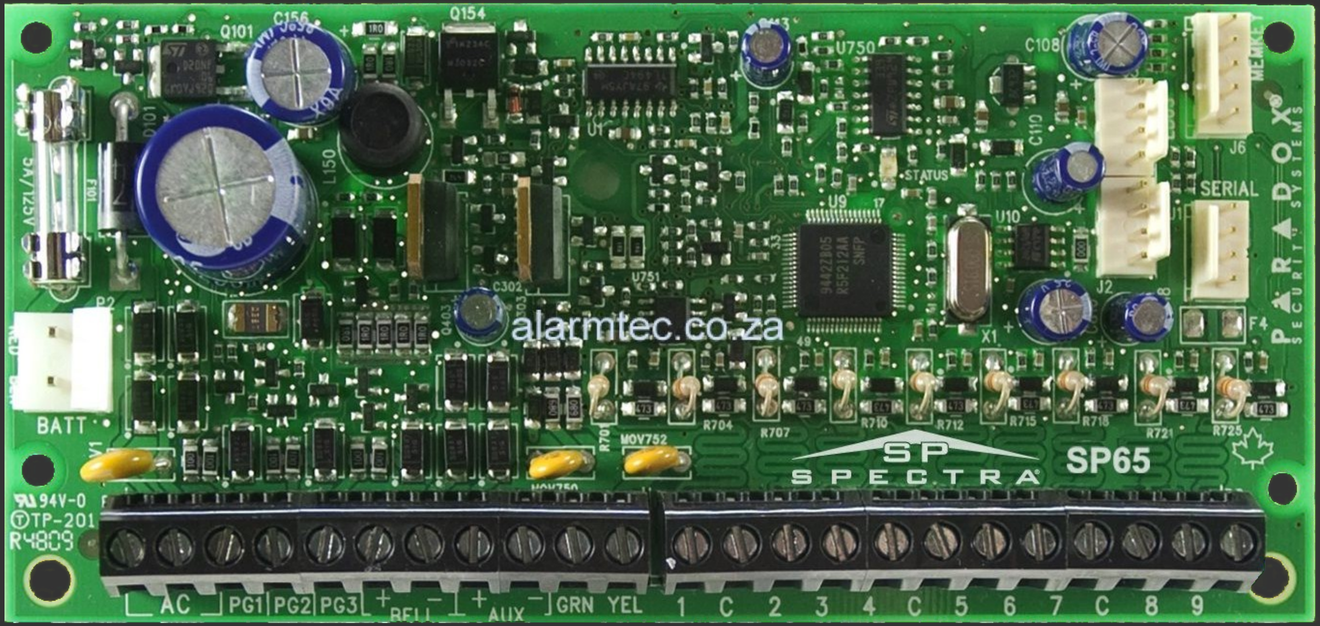
¯_(ツ)_/¯

Components

- **master**

  heart on the system – “motherboard”

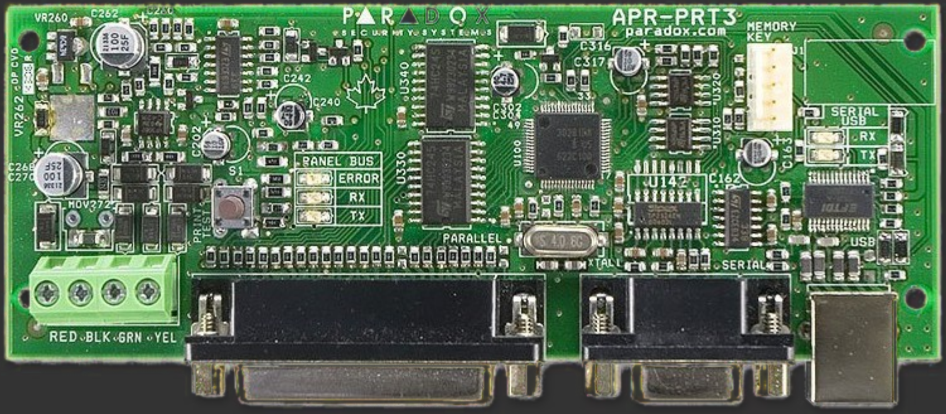
  - panel
- **ancillaries**
  - battery
  - power supply
  - siren



Components

- **combus slaves**

  provide two-way communication
  - keypads
  - modules
    - expansion
    - printer
    - listen-in
    - etc.



Components

- **zone** interrupt devices

  input, measures resistance ⇒ chaining

  - magnetic sensors
  - PIR sensors
  - panic buttons
  - etc.

Components

- **PGM** modules:

  output, 100mA relays (solid state)
  - external actuators
  - boost relays

Components

- **serial** devices:
  - RS485
  - Serial converters (RS232, usb)
  - IP modules
  - GSM modules
  - etc.

EVO192

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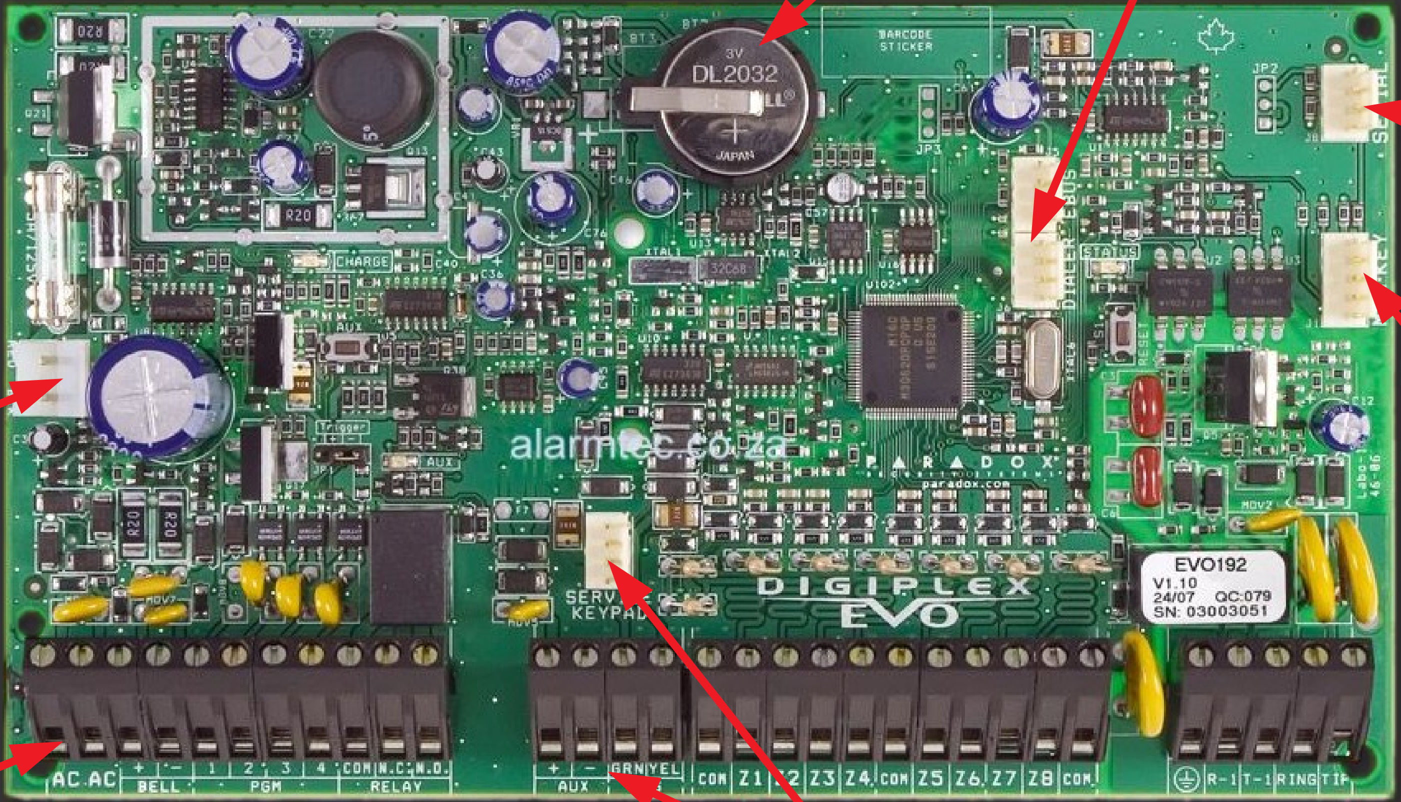

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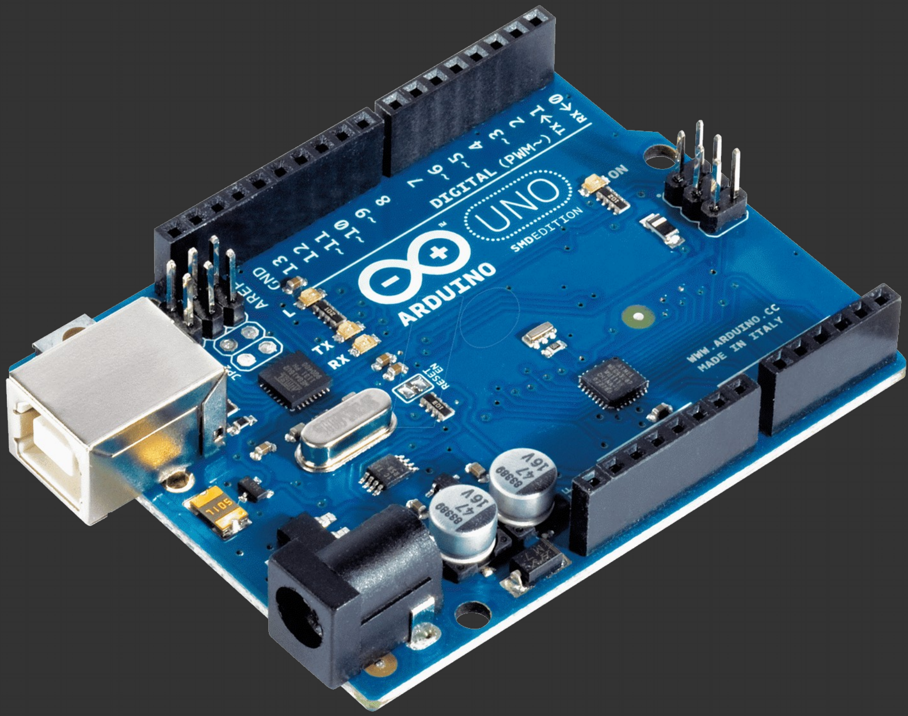
REVERSE ENGINEERING

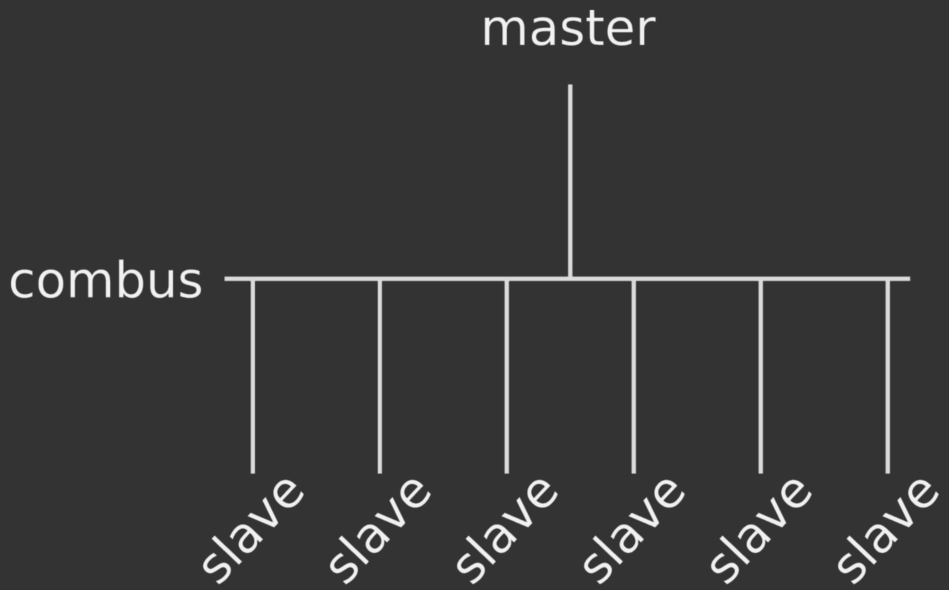
Hardware tools

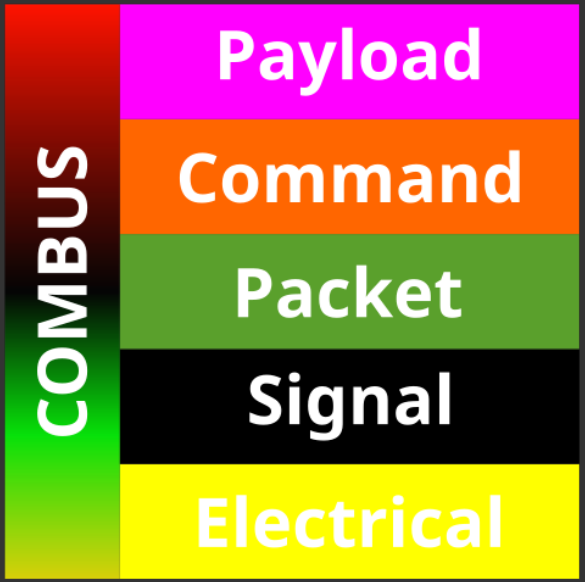
- Saleae Logic 8

- Arduino UNO



COMBUS


master
combus
slave
slave
slave
slave
slave
slave


COMBUS
Payload
Command
Packet
Signal
Electrical

Electrical layer

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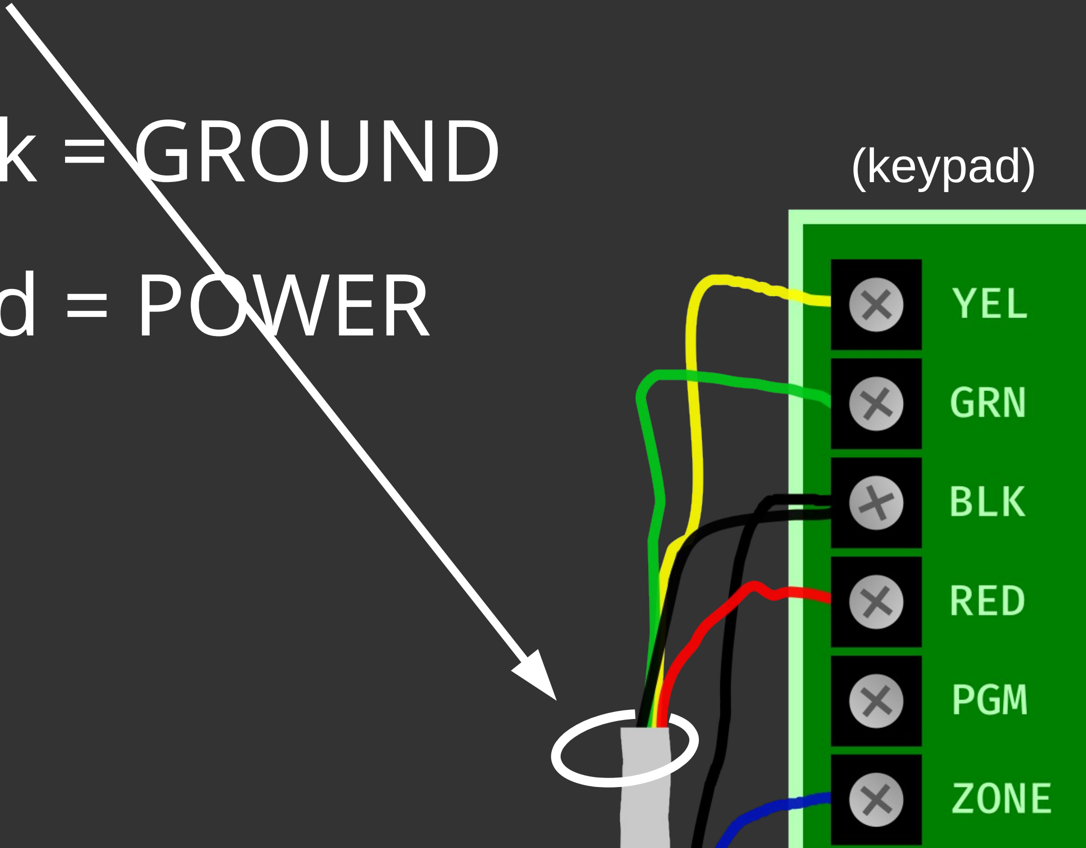
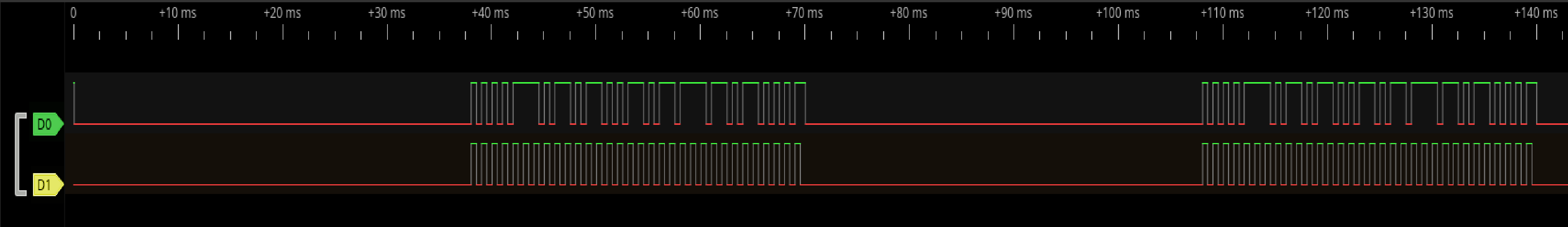
- combus – 4 wire bus
- resistance = 0 ⇒ black = GROUND
- stable ⎓ voltage ⇒ red = POWER
- … ?



Signal layer

- yellow = CLOCK
- green = DATA
- 40ms between packet bursts
- 1 clock cycle = 1ms; signal = 1kHz



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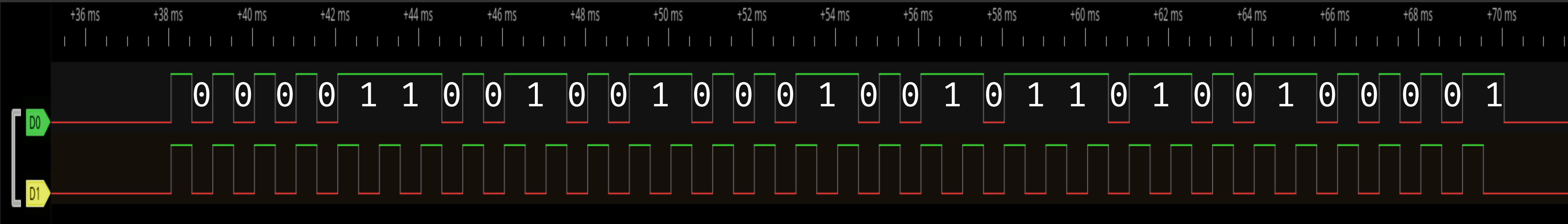
Signal encoding

- CLOCK = low ⇒ data!!! ☺
- … we should have two-way comms

  something is missing ☹

0 C 9 1 2 D 2 1



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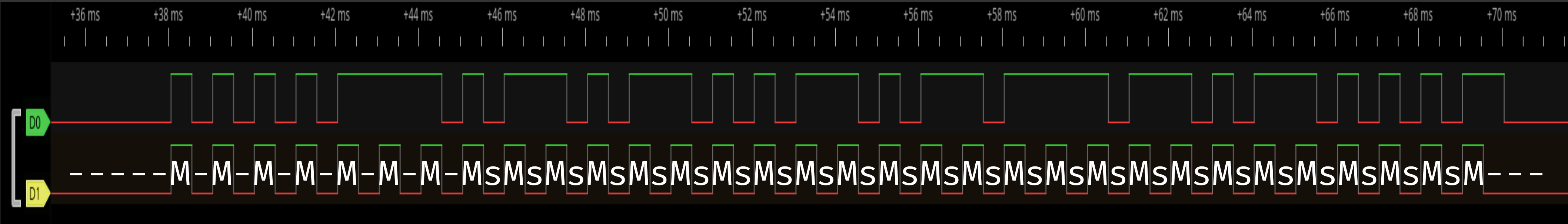
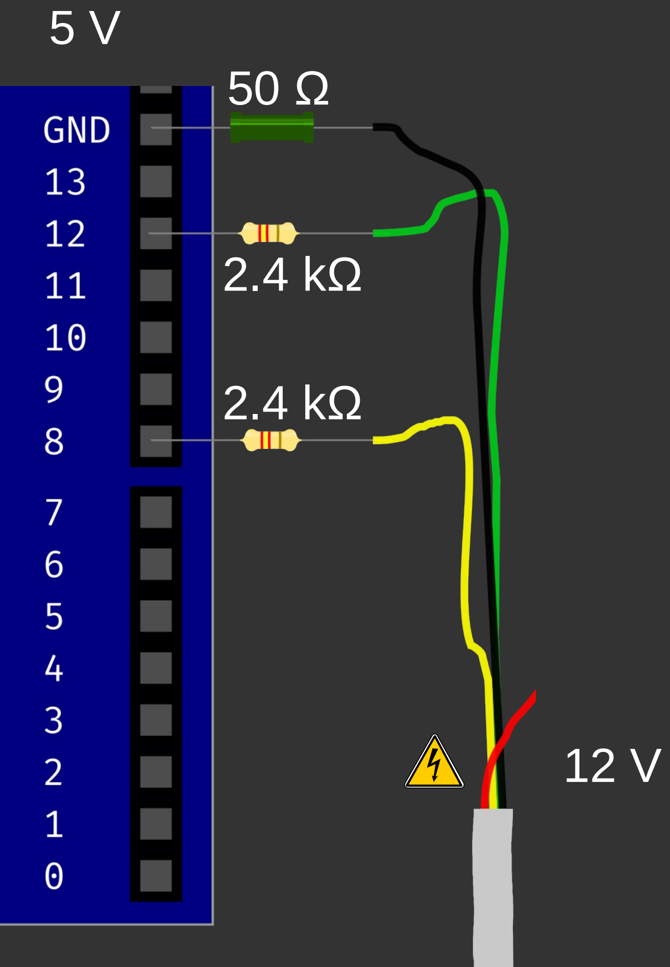
Full signal encoding

- CLOCK = high
  - slave pulls <u>down</u> to send “1”
- CLOCK = low
  - master pulls <u>up</u> to send “1”

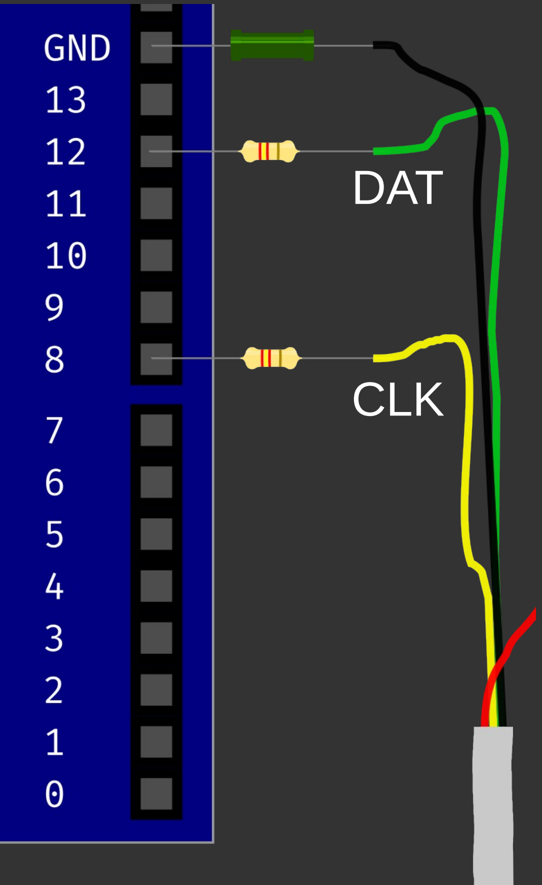


Hardware setup (read-only)



- Resistors to limit
  - voltage
  - current draw

Decoding into bytes



```
on CLK change:
  wait 50µs
  if CLK == high:
    master ← master<<1 +  DAT&1
  else:
    slave  ← slave<<1  + !DAT&1

on idle > 2ms:
  if master > 0:
    print master
    print slave
    master ← 0
    slave ← 0
```

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Packet structure

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
master																						
40	03	92	02	01	EB	01	00	00	00	00	00	00	00	00	00	00	00	00	00	00	C4	~~00~~
E2	14	10	0B	0F	37	05	00	01	5D	~~00~~												
0C	13	38	1B																			
slave																						
~~00~~	02	20	00	00	00	FF	5A	22	00	00	00	00	D5	23	79	E2	00	00	00	C8	B6	00
~~00~~	02	00	00																			

🟧 command 🟩 checksum ⬛ ~~unused~~ 🟥 channel-request

Checksum

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```
checksum ← 0
for i in @command to @checksum - 1:
    checksum ← (checksum + *i) % 100
```

Commands: heartbeat / clock

- 0C NN DD/MM HH/SS
  - NN = xxxxxxxp = sequence number
- p==0 → 0C NN DD HH
  - DD = day of the month
  - HH = hour
- p==1 → 0C NN MM SS
  - MM = minutes
  - SS = seconds

Commands: code entry

- 00 02 20 UT 00 00 CT CC CC 00 00 00 00 SS SS SS SS 00 00 00 00 ## 00
  - UT = pxxxxxxx
    - p = user type == 1 → programmer
  - CT = code type
  - CC CC = code
  - SS SS SS SS = serial number of source device
  - ## = checksum

Payloads

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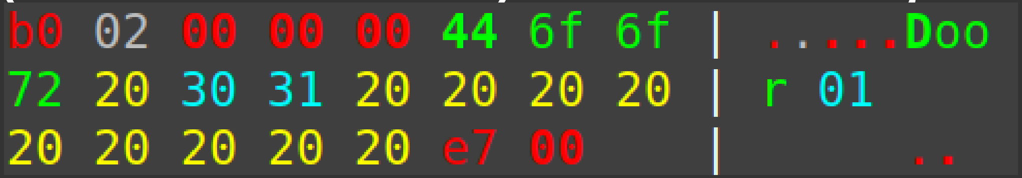
- No encryption used
- Text as fixed length (often 16 chars) ASCII strings
  - 0x20 = filler
- Numbers usually packed BCD
  - “0” is 0b1010 = 0xA
  - on encryption, but hey, at least we got obfuscation!



```
b0 02 00 00 00 44 6f 6f | .....Doo
72 20 30 31 20 20 20 20 | r 01
20 20 20 20 20 e7 00    |      ..
```

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DEMO TIME

⚠ Before connecting a module to the combus, remove AC and battery power from the control panel.

EV0192

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“Digiplex and Digiplex EVO systems provide the highest level of protection for banks, high-security military and government sites, luxurious residential homes and any place where maximum security is essential”

– https://www.paradox.com/Products/default.asp?CATID=7

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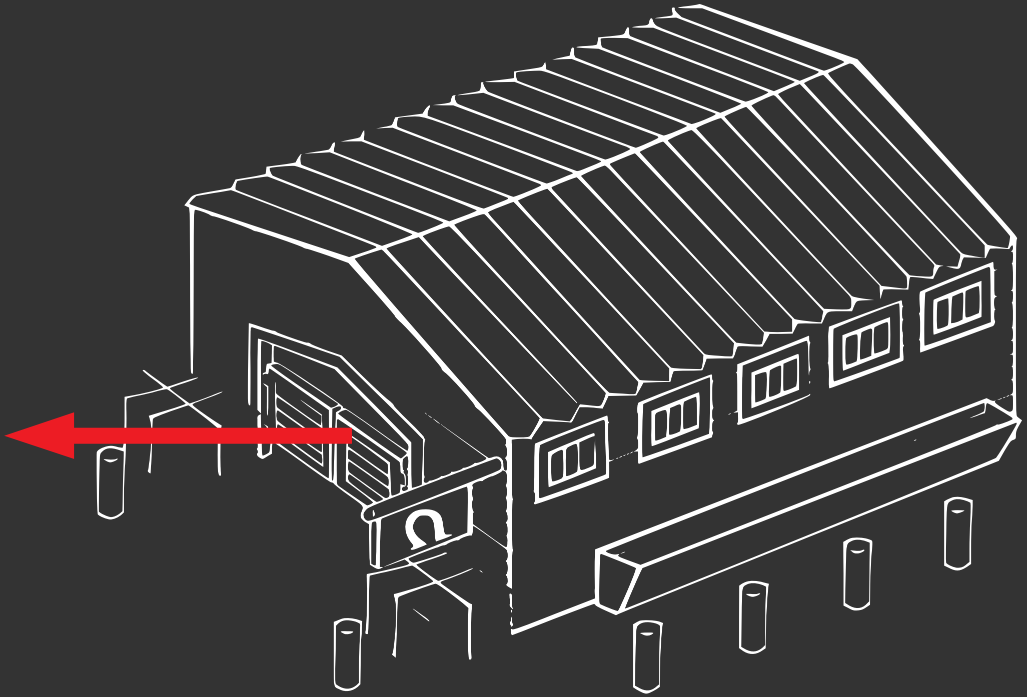
Exploitation scenarios



```
3998 3111 9309 1400
8248 4584 9450 5617
6550 8245 6979 9878
6101 4971 1294 9576
5005 2789 7113 3627
6856 5132 4920 5076
7500 7065 0643 9302
1744 3725 8432 1275
1128 1497 8657 9264
```

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SUMMARY

Results

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- Hardware built, decoding software written
- Protocol partially transcribed
- Impact of possible attacks

Solutions

- Encryption at command layer
  - TLS?
- Mutual slave-master authentication
  - client certificates?
- Sensitive payload encryption
  - with unique per-panel key!

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Further research

- Anti-collision protocol research
- DoS attacks
- Emulating a slave
- COMBUS over radio
- RF attacks
- Firmware reverse engineering
- Logo. We need a logo, right?

How about this one?

Resources

- Slides available
  - http://kirils.org/
  - 4 November 2018
- Tools available
  - https://github.com/0ki/paradox
  - 18 November 2018

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http://kirils.org/ @KirilsSolovjovs