How Do I Crack Satellite and Cable Pay TV?

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Attacking the Digicipher 2 conditional access system used in millions of TV set-top-boxes in North America.

Digital Television

Satellite

Modulation:

DC2 QPSK ~27 Mbit

8PSK Turbo FEC ~38 Mbit

Cable

Modulation:

QAM 256 ~38 Mbit

Out-of-band:

QPSK 2 Mbit

Video format:

MPEG-2 or H.264 Transport Stream (MPEG TS)

Encryption:

Digicipher 2 (not DVB standard)

MPEG Transport Stream
27 – 38 Mbit

188-byte packets
Categorized by 13-bit **PID**
(0 - 0x1FFF)

MPEG PES
Packetized Elementary Streams
64 Kbit – 19 Mbit
Video, audio

Service Information Tables
8-bit table ID (0 – 0xFF)
Up to 1024 bytes, with CRC32

Table 0x00 – (PID 0) Program Association Table
Table 0x01 – (PID 1) Conditional Access Table
Table 0x02 – Program Map Table

PAT contains list of programs: PID carrying PMT
PMT contains list of PIDs for video, audio, ECM

Table 0x40 – ECM40
Table 0x41 – ECM41
Table 0x95 – EMM95

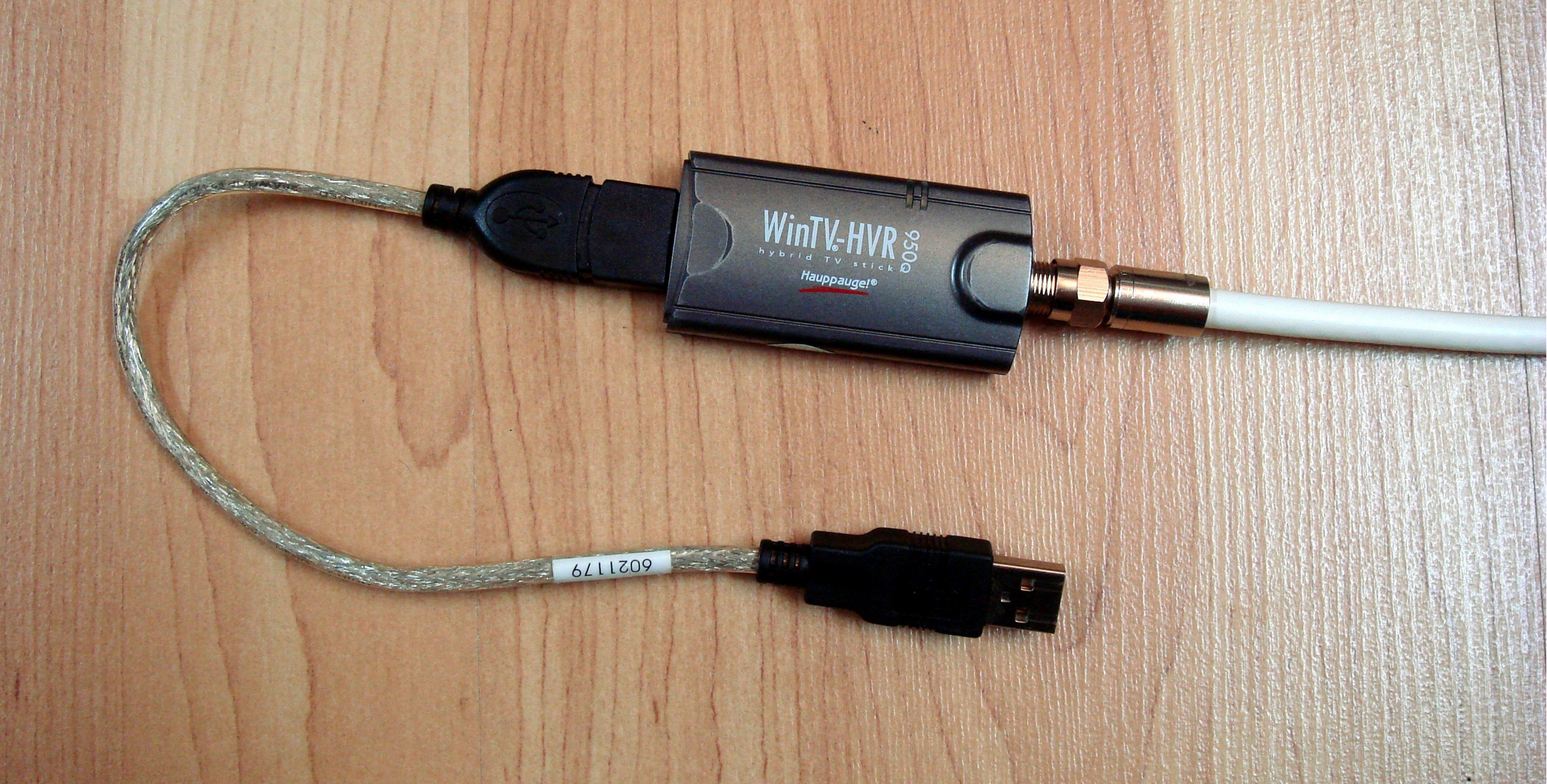
ECM are sent in pairs
Cable: EMM are OOB

Genpix SkyWalker-1 USB satellite interface

http://updatelee.blogspot.ca/2010/09/genpix-skywalker-1-linux-driver-mods.html

https://bitbucket.org/updatelee/v4l-updatelee

Hauppauge HVR 950Q ATSC / QAM USB interface



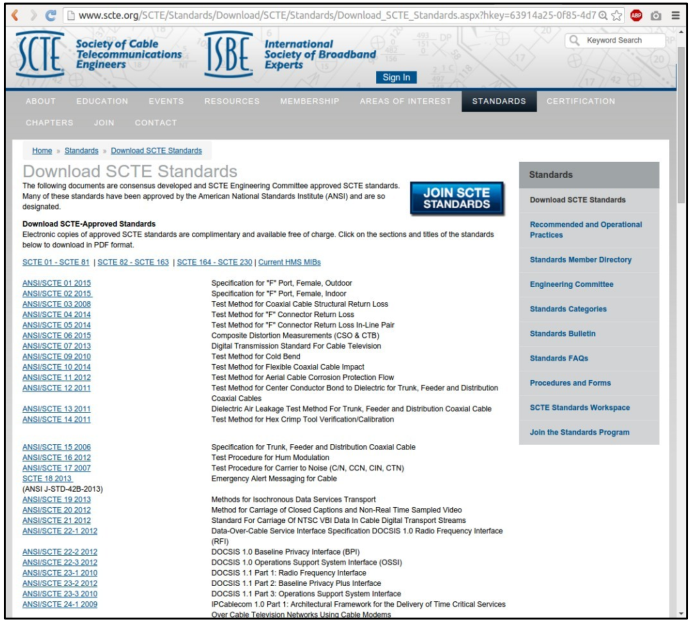
Using dvbsnoop to view PMT PID 0x129

```
$ dvbsnoop -if log-11959.ts -s ts -tssubdecode 0x129

dvbsnoop V1.4.50 -- http://dvbsnoop.sourceforge.net/

------------------------------------------------------------
TS-Packet: 00000001   PID: 297 (0x0129), Length: 188 (0x00bc)
from file: 2016-05-21-full-log-11959.ts
------------------------------------------------------------
  0000:  47 61 29 1b 00 02 80 26  00 0f 15 00 00 01 10 00   Ga)....&........
  0010:  06 09 04 47 49 01 29 80  01 10 00 03 83 01 00 81   ...GI.).........
  0020:  01 11 00 06 0a 04 65 6e  67 00 6c c4 86 25 40 00   ......eng.l..%@.
  0030:  11 00 3b 40 0f 2a 63 4a  22 04 00 00 02 0a cf 4f   ..;@.*cJ"......O
  0040:  fe 3b 41 40 31 10 20 00  3b 40 0f 75 e5 22 27 3b   .;A@1. .;@.u."';
  0050:  09 e3 40 85 71 da 6c fe  7f e6 ca 00 00 00 08 01   ..@.q.l.........
  0060:  00 01 59 03 00 00 72 03  01 00 d7 2b 46 ee d4 bf   ..Y...r....+F...
  0070:  6c c5 06 d2 2d 09 ff ff  ff ff ff ff ff ff ff ff   l...-...........
  0080:  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   ................
  0090:  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   ................
  00a0:  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   ................
  00b0:  ff ff ff ff ff ff ff ff  ff ff ff ff               ............

Sync-Byte 0x47: 71 (0x47)
Transport_error_indicator: 0 (0x00)  [= packet ok]
Payload_unit_start_indicator: 1 (0x01)  [= Packet data starts]
transport_priority: 1 (0x01)
PID: 297 (0x0129)  [= ]
transport_scrambling_control: 0 (0x00)  [= No scrambling of TS packet payload]
adaptation_field_control: 1 (0x01)  [= no adaptation_field, payload only]
continuity_counter: 11 (0x0b)  [= (sequence ok)]
    Payload: (len: 184)
        ==> pointer_field: 0 (0x00)
        ==> Section table: 2 (0x02)  [= Program Map Table (PMT)]
    Data-Bytes:
          0000:  00 02 80 26 00 0f 15 00  00 01 10 00 06 09 04 47   ...&...........G
          0010:  49 01 29 80 01 10 00 03  83 01 00 81 01 11 00 06   I.).............
          0020:  0a 04 65 6e 67 00 6c c4  86 25 40 00 11 00 3b 40   ..eng.l..%@...;@
          0030:  0f 2a 63 4a 22 04 00 00  02 0a cf 4f fe 3b 41 40   .*cJ"......O.;A@
          0040:  31 10 20 00 3b 40 0f 75  e5 22 27 3b 09 e3 40 85   1. .;@.u."';..@.
          0050:  71 da 6c fe 7f e6 ca 00  00 00 08 01 00 01 59 03   q.l...........Y.
          0060:  00 00 72 03 01 00 d7 2b  46 ee d4 bf 6c c5 06 d2   ..r....+F...l...
          0070:  2d 09 ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   -...............
          0080:  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   ................
          0090:  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   ................
          00a0:  ff ff ff ff ff ff ff ff  ff ff ff ff ff ff ff ff   ................
          00b0:  ff ff ff ff ff ff ff ff                            ........
==========================================================
```

```
TS sub-decoding (1 packet(s) stored for PID 0x0129):
=====================================================
TS contains Section...
SI packet (length=41):
    PID:  297 (0x0129)

    Guess table from table id...
    PMT-decoding....
    Table_ID: 2 (0x02)  [= Program Map Table (PMT)]
    section_syntax_indicator: 1 (0x01)
    (fixed '0'): 0 (0x00)
    reserved_1: 0 (0x00)
    Section_length: 38 (0x0026)
    Program_number: 15 (0x000f)
    reserved_2: 0 (0x00)
    Version_number: 10 (0x0a)
    current_next_indicator: 1 (0x01)  [= valid now]
    Section_number: 0 (0x00)
    Last_Section_number: 0 (0x00)
    reserved_3: 0 (0x00)
    PCR PID: 272 (0x0110)
    reserved_4: 0 (0x00)
    Program_info_length: 6 (0x0006)

           MPEG-DescriptorTag: 9 (0x09)  [= CA_descriptor]
           descriptor_length: 4 (0x04)
           CA_system_ID: 18249 (0x4749)  [= General Instrument]
           reserved: 0 (0x00)
           CA_PID: 297 (0x0129)

    Stream_type loop:

        Stream_type: 128 (0x80)  [= User private]
        reserved_1: 0 (0x00)
        Elementary_PID: 272 (0x0110)
        reserved_2: 0 (0x00)
        ES_info_length: 3 (0x0003)

              DVB-DescriptorTag: 131 (0x83)  [= User defined/ATSC reserved]
              descriptor_length: 1 (0x01)
              Descriptor-data:
                   0000:  00                                                 .


        Stream_type: 129 (0x81)  [= User private]
        reserved_1: 0 (0x00)
        Elementary_PID: 273 (0x0111)
        reserved_2: 0 (0x00)
        ES_info_length: 6 (0x0006)

              MPEG-DescriptorTag: 10 (0x0a)  [= ISO_639_language_descriptor]
              descriptor_length: 4 (0x04)
                 ISO639_language_code:  eng
                 Audio_type: 0 (0x00)  [= undefined]


    CRC: 1824818725 (0x6cc48625)
```

DC2 Service Information Tables

SCTE 65: Service Information Delivered Out-Of-Band For Digital Cable Television



http://www.scte.org

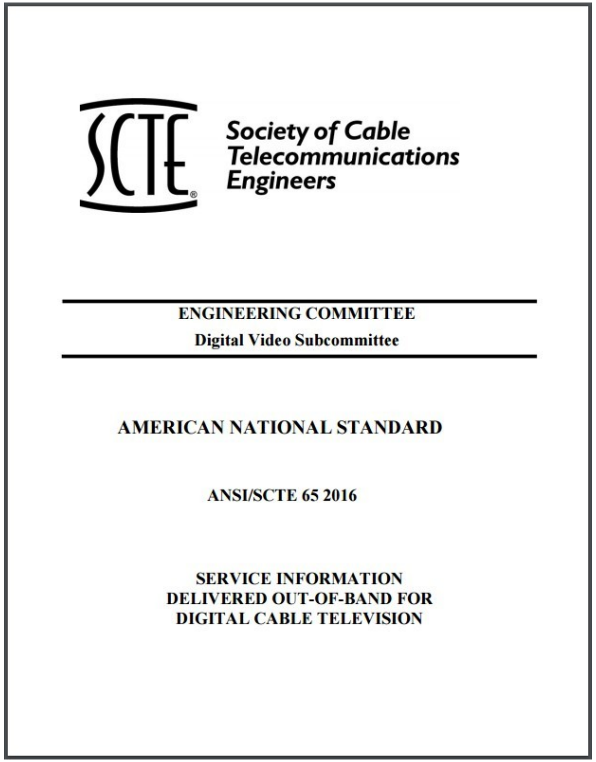
DC2 tables

VCT – Virtual Channel Table
NIT – Network Information Table
NTT – Network Text Table
MGT – Master Guide Table

Many DVB standard tables are not used:

DVB equivalent

BAT – Bouquet Association Table
SDT – Service Description Table
EIT – Event Information Table



http://www.scte.org/SCTEDocs/Standards/ANSI_SCTE 65 2016.pdf


logic
www.saleae.com
HDHomeRun
Internal connections
to CableCard slot
for QPSK output

SCTE 55-1 Decoding Software

https://www.scte.org/documents/pdf/Standards/ANSI_SCTE-55-1-2009.pdf

SCTE Society of Cable Telecommunications Engineers

ENGINEERING COMMITTEE

Digital Video Subcommittee

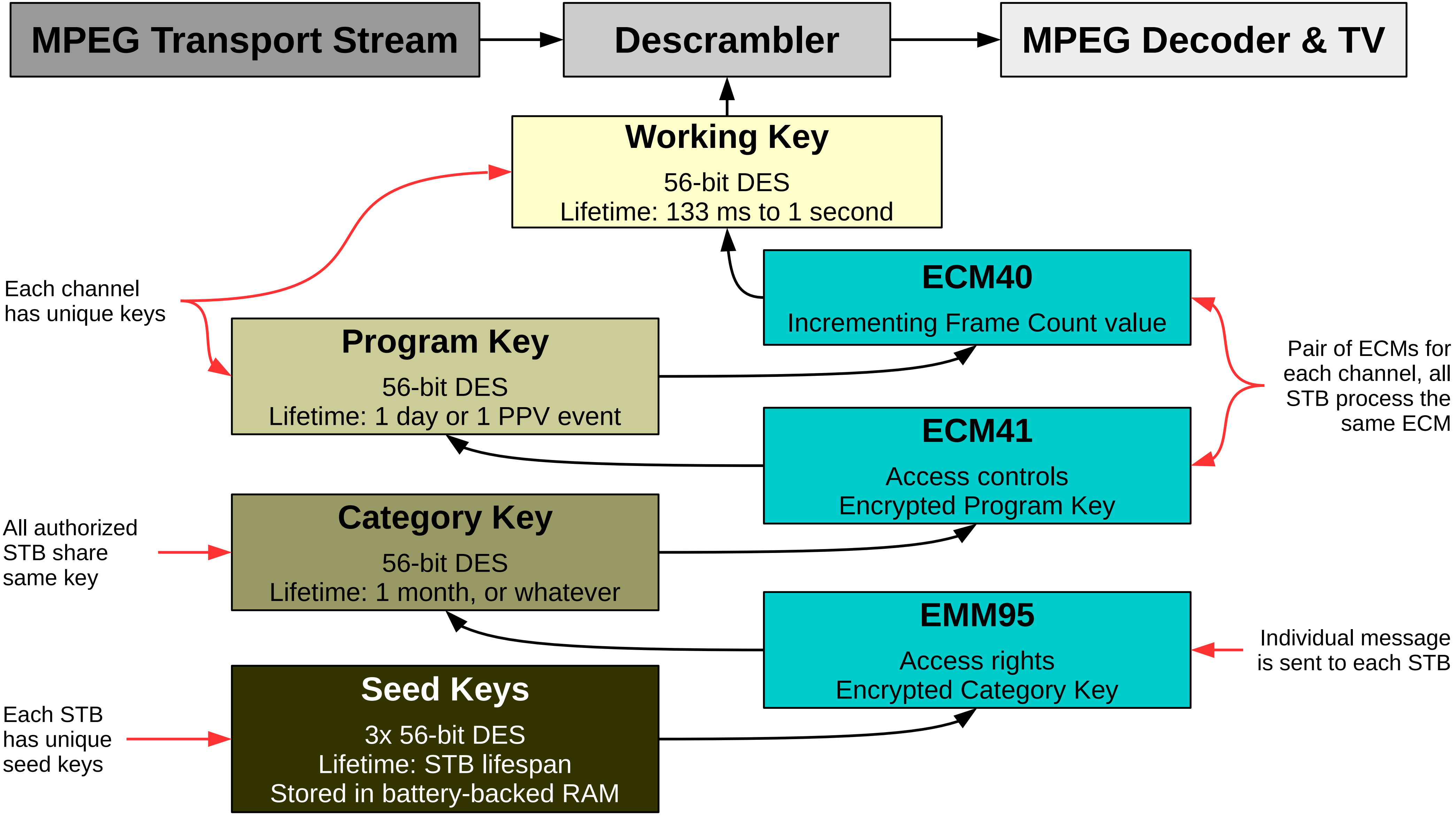
AMERICAN NATIONAL STANDARD

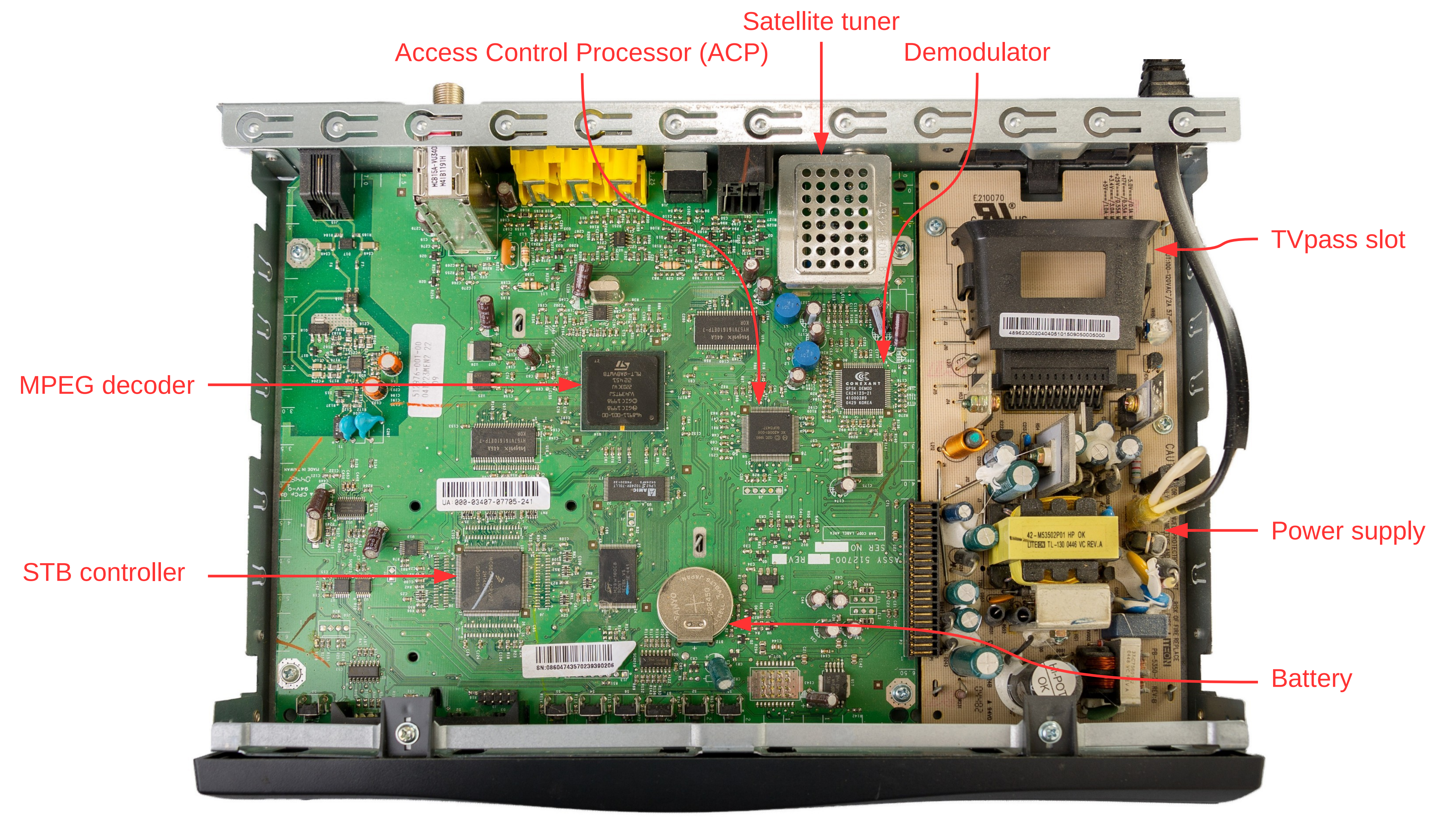
ANSI/SCTE 55-1 2009

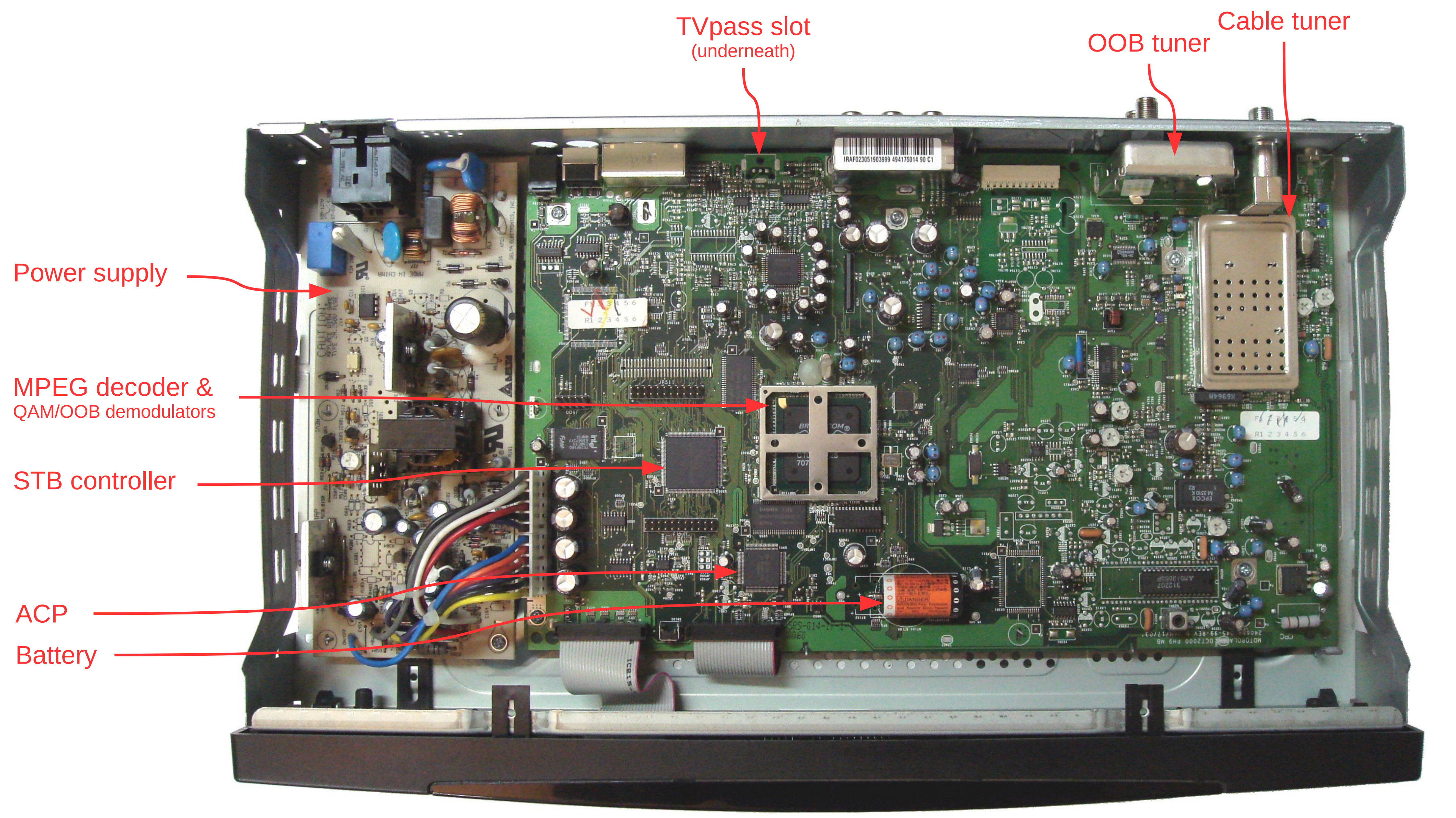
Digital Broadband Delivery System:
Out of Band Transport Part 1: Mode A

https://github.com/akacastor/noob
https://github.com/akacastor/oobin

```
//-----------------------------------------------------------
// The process going from QPSK demodulator to TS data:
//-----------------------------------------------------------

    for( i=0; i+383<len; i+=384 )
    {
// 0. Synchronize bitstream (find 0x47 0x64 0x47 0x64 ... sequence)

        i += oob_synchronize_bitstream( data, i, len );
        if( i+384+768>len )
            break;      // didn't synchronize before end of the bitstream

// data[0] is a 0x47 sync byte, data[192] is a 0x64 sync byte, there are two packets (384 bytes) to process


// 1. De-interleaver       - run it twice (96 bytes x 2) to de-interlave a full ts packet

// works over 8 * 96-byte blocks, returns a single 96-byte assembled block
// data_in[] must contain at least 768 bytes
// return value: 0 if successful
        for( n=0; n<4; n++ )
        {
            oob_de_interleaver( data+i + n*96, data_work + n*96 );
            memcpy( data+i + n*96, data_work + n*96, 96 );
        }

// 2. Reed Solomon Decoder - run it twice (96 bytes x 2) to fec a full ts packet, 4 times for a 384-byte block
// works over 96-byte blocks (runs twice for each ts packet)
// return value: 0 if successful - this 96-byte block is valid

        if( do_fec )
        {
            for( n=0; n<4; n++ )
                fec_error[n] = oob_de_fec( data+i + n*96 );
        }


// 3. Derandomizer         - run it over ts packet - need to track even/odd sequence to be able to decrypt next packet
//                                                OR
//                                                - work on pairs of ts packets

// works over 384-byte blocks (2x ts packet)
// len is number of bytes to de_randomize - usually this is 384, but less is accepted
// frame_pos is the position within 384-byte randomizer frame  (ie: 192 if de_randomizing 2nd ts packet alone)
// return value: 0 if successful
        oob_de_randomizer( data+i, 384, 0 );


        if( do_fec )
        {
            for( n=0; n<2; n++ )    // loop through 2 TS packets to set TS error indicator if necessary
            {
                if( fec_error[n*2] < 0 || fec_error[n*2 + 1] < 0 )
```


MPEG Transport Stream
Descrambler
MPEG Decoder & TV
Working Key
56-bit DES
Lifetime: 133 ms to 1 second
Each channel has unique keys
ECM40
Incrementing Frame Count value
Program Key
56-bit DES
Lifetime: 1 day or 1 PPV event
Pair of ECMs for each channel, all STB process the same ECM
ECM41
Access controls
Encrypted Program Key
All authorized STB share same key
Category Key
56-bit DES
Lifetime: 1 month, or whatever
EMM95
Access rights
Encrypted Category Key
Individual message is sent to each STB
Each STB has unique seed keys
Seed Keys
3x 56-bit DES
Lifetime: STB lifespan
Stored in battery-backed RAM


Satellite tuner
Access Control Processor (ACP)
Demodulator
TVpass slot
MPEG decoder
Power supply
STB controller
Battery



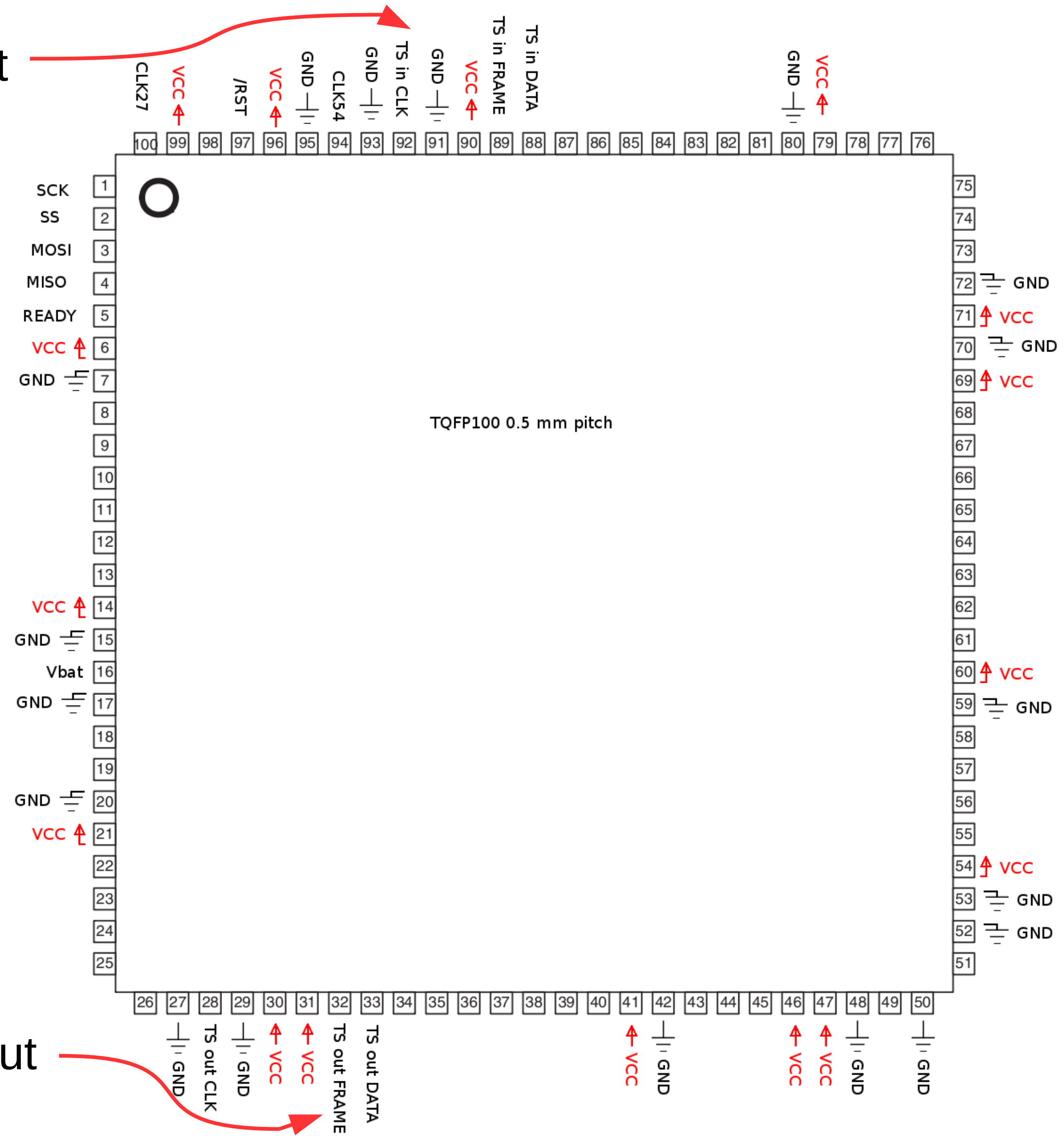
TVpass slot
(underneath)
OOB tuner
Cable tuner
Power supply
MPEG decoder &
QAM/OOB demodulators
STB controller
ACP
Battery

C59
C54
R29
C58
75
51
C251
U8
50
76
C57
R53
C60
C48
C77
GIC 1998
XC 420061-006
HTF0203
C152
R61
C63
R73
C79
C47
C84
C5
26
R63
R93
C80
1
C45
C49
R79
R74
C55
R70
R171
C64
R62

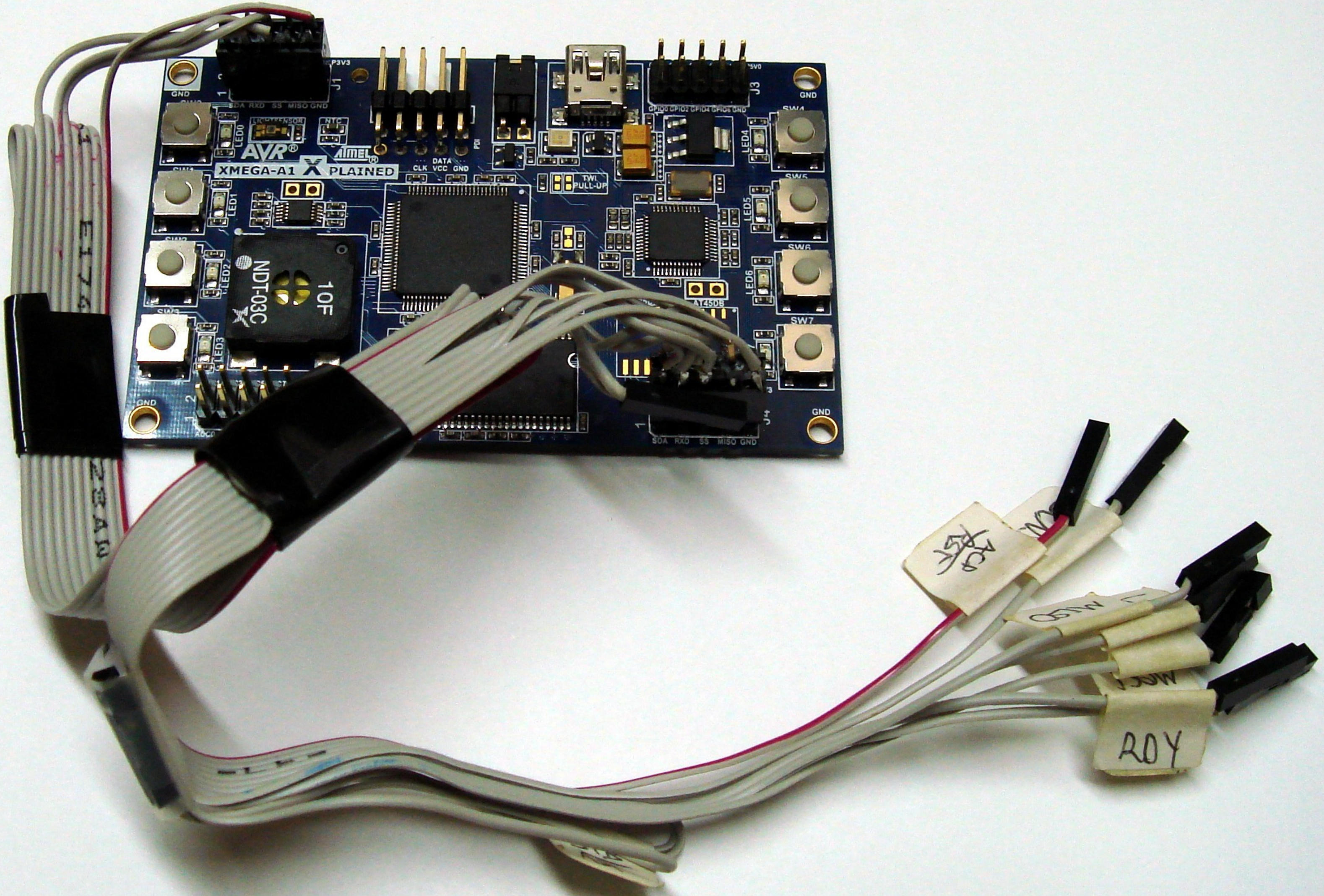
Transport Stream input
(from tuner)

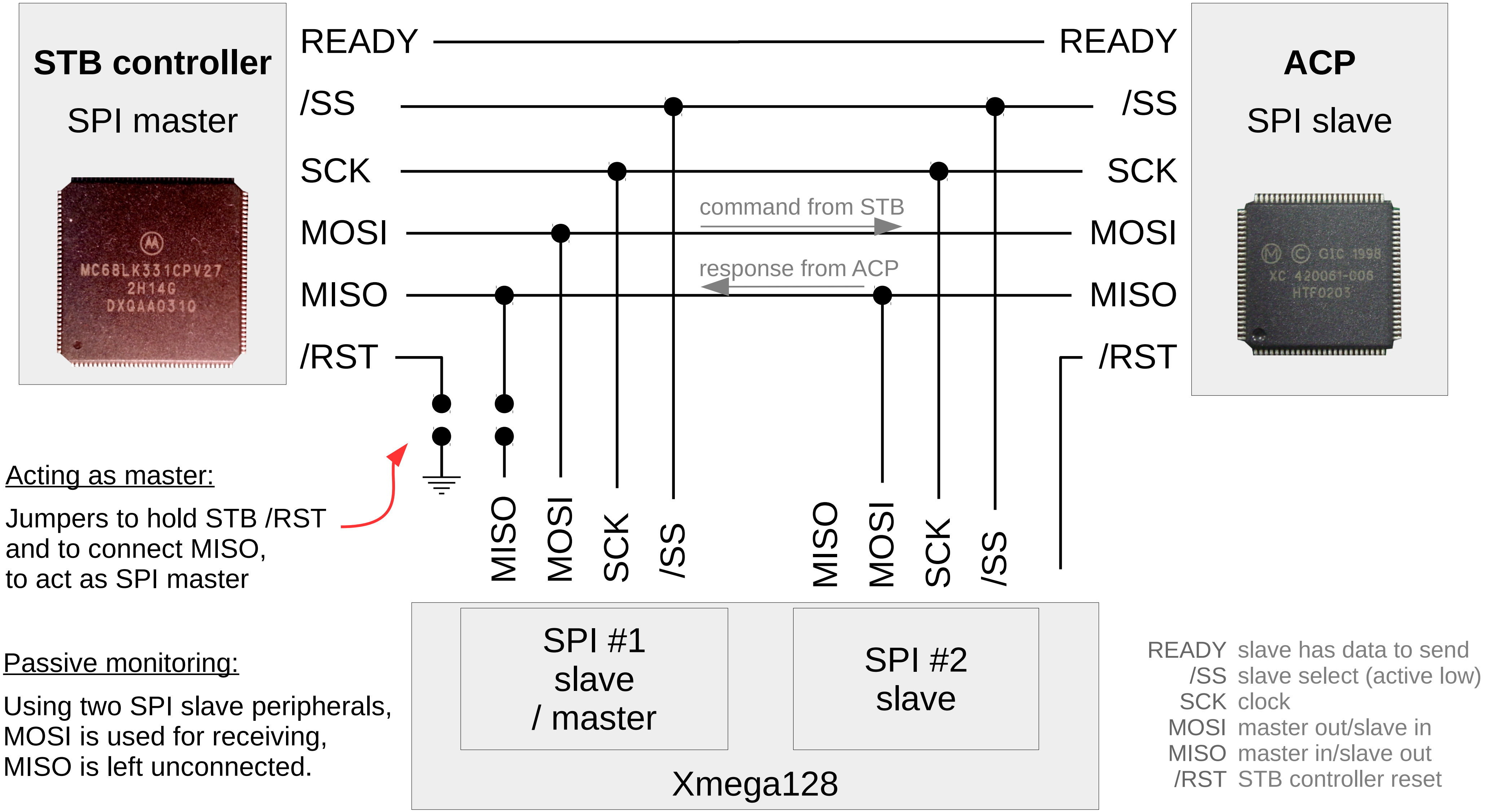
SPI slave

Battery



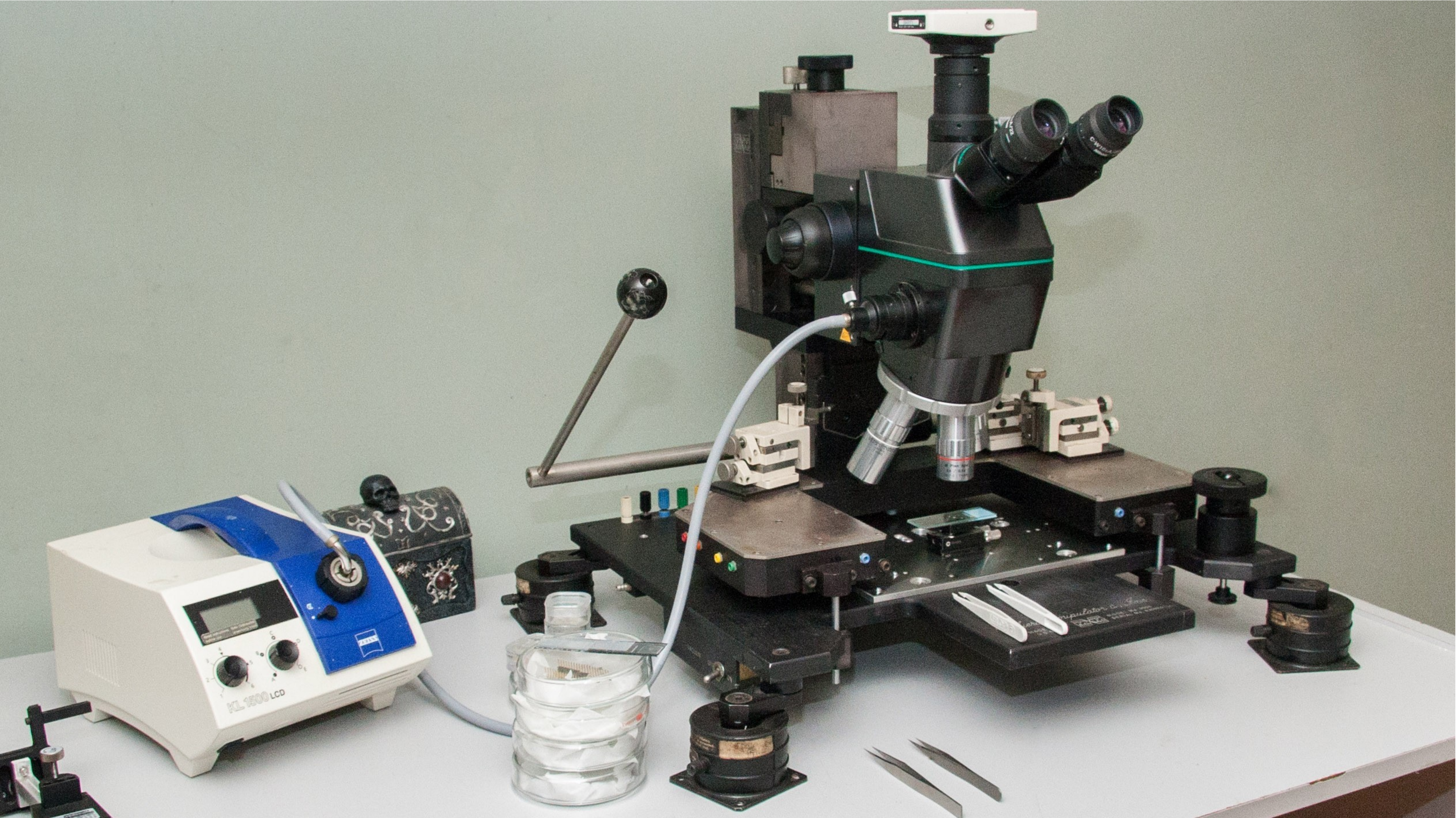
Transport Stream ouptut
(to MPEG decoder)


AVR
ATMEL
XMEGA-A1 XPLAINED
NDT-03C
10F
ROY


STB controller
SPI master
MC68LK331CPV27
2H14G
DXQAA0310
READY
/SS
SCK
MOSI
MISO
/RST
command from STB
response from ACP
READY
/SS
SCK
MOSI
MISO
/RST
ACP
SPI slave
GIC 1998
XC 420061-006
HTF0203
Acting as master:
Jumpers to hold STB /RST
and to connect MISO,
to act as SPI master
MISO
MOSI
SCK
/SS
MISO
MOSI
SCK
/SS
SPI #1
slave
/ master
SPI #2
slave
Xmega128
Passive monitoring:
Using two SPI slave peripherals,
MOSI is used for receiving,
MISO is left unconnected.
READY slave has data to send
/SS slave select (active low)
SCK clock
MOSI master out/slave in
MISO master in/slave out
/RST STB controller reset

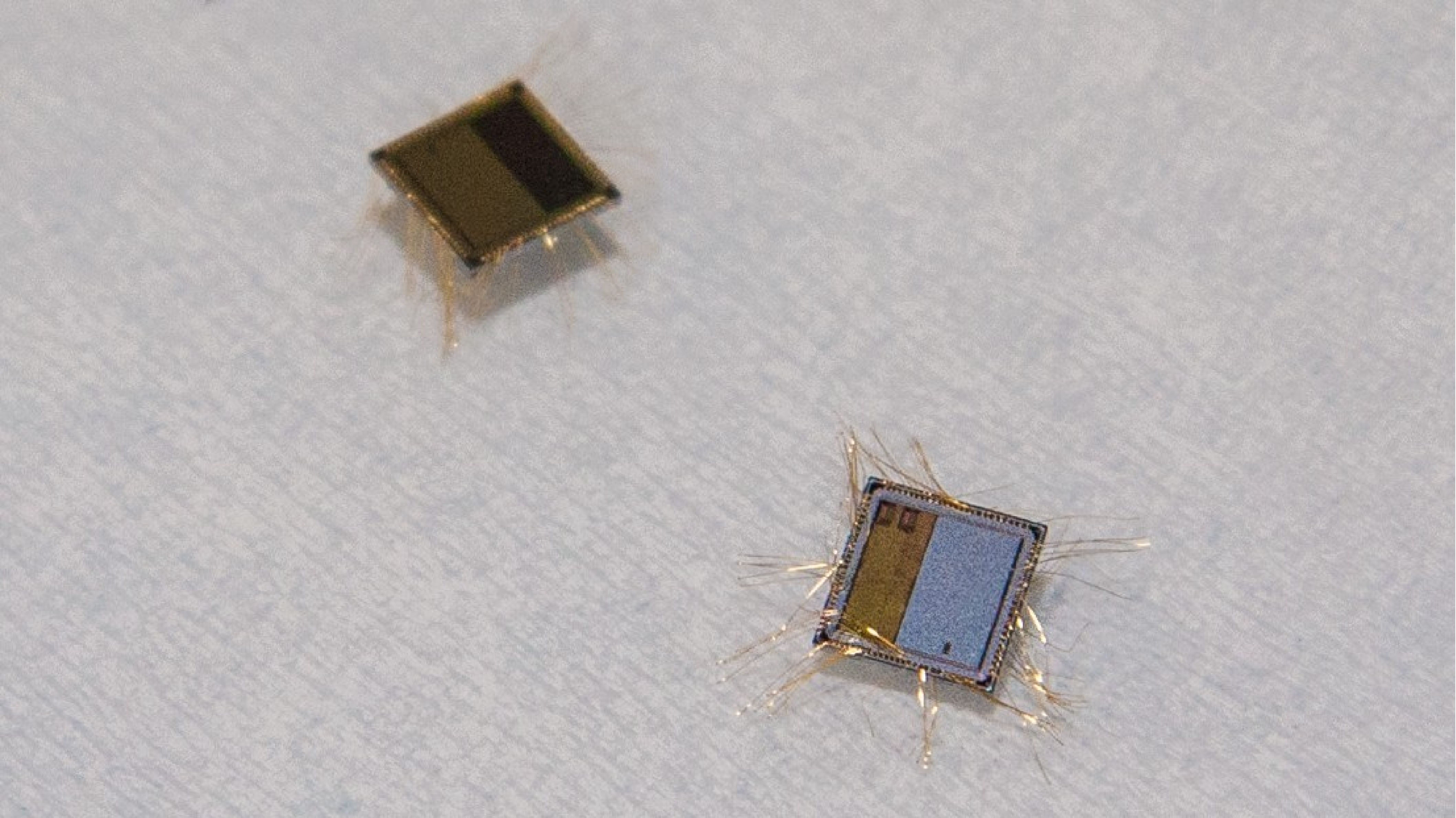
SPI data log

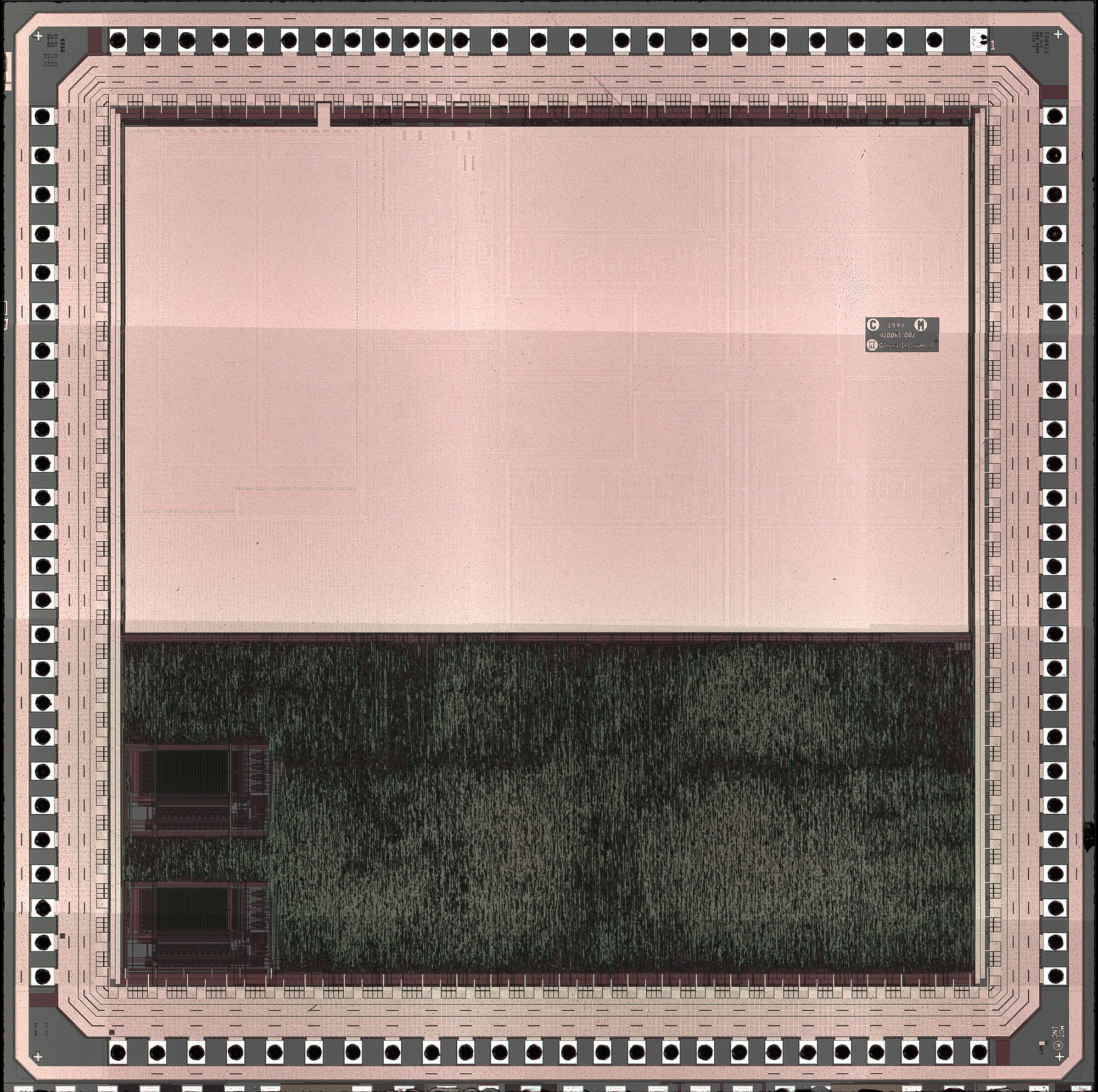
```
< 80 04 00 04
> 55 04 14 10 20 FC FD 00 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00 61
           ^^^^^ ^^ ^^                                                   ^^
           ||    || Next category epoch                                  Checksum
           ||    Current category epoch
           Provider ID

< 80 05 00 05
> 55 05 09 FE 16 00 10 D3 99 FA 20 00 64
                 ^^^^^^^^^^^^^^
                 UA# - Unit Address of STB

< 80 12 00 12
> 55 12 13 00 00 02 04 03 04 02 04 03 04 0C 6D 05 14 0D FC 00 00 00 80
                 ^^^^^^^^^^^ ^^^^^^^^^^^
                 ||          Keyselect for next category epoch
                 Keyselect for current category epoch

< 80 13 02 00 00 11
> 55 13 22 00 C0 4C 61 87 11 00 51 A1 00 DF 23 80 E0 01 98 D1 3F 00 80 41 00 08 20 48 00 00 00 D0 41 15 81 00 44 B1
                 ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
                 Subscription tiers

> 55 87 13 00 11 22 33 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
     ^^    ^^ ^^^^^^^^ ^^ ^^                   ^^
     ||    || ||       || ||                   Next program key epoch
     ||    || ||       || Current program key epoch
     ||    || ||       Encryption mode – ZK / FP / FW S
     ||    || Service ID of this channel
     ||    00 = Tuner0, 80 = Tuner1
     07 = Response to Cmd07
     87 = Unprompted response due to change in access rights (channel change etc)
```


KL 1500 LCD


STOCKER & YALE
KL 1500 LCD
1998
420061-002
DELL
SONY
SONY
ViewSonic

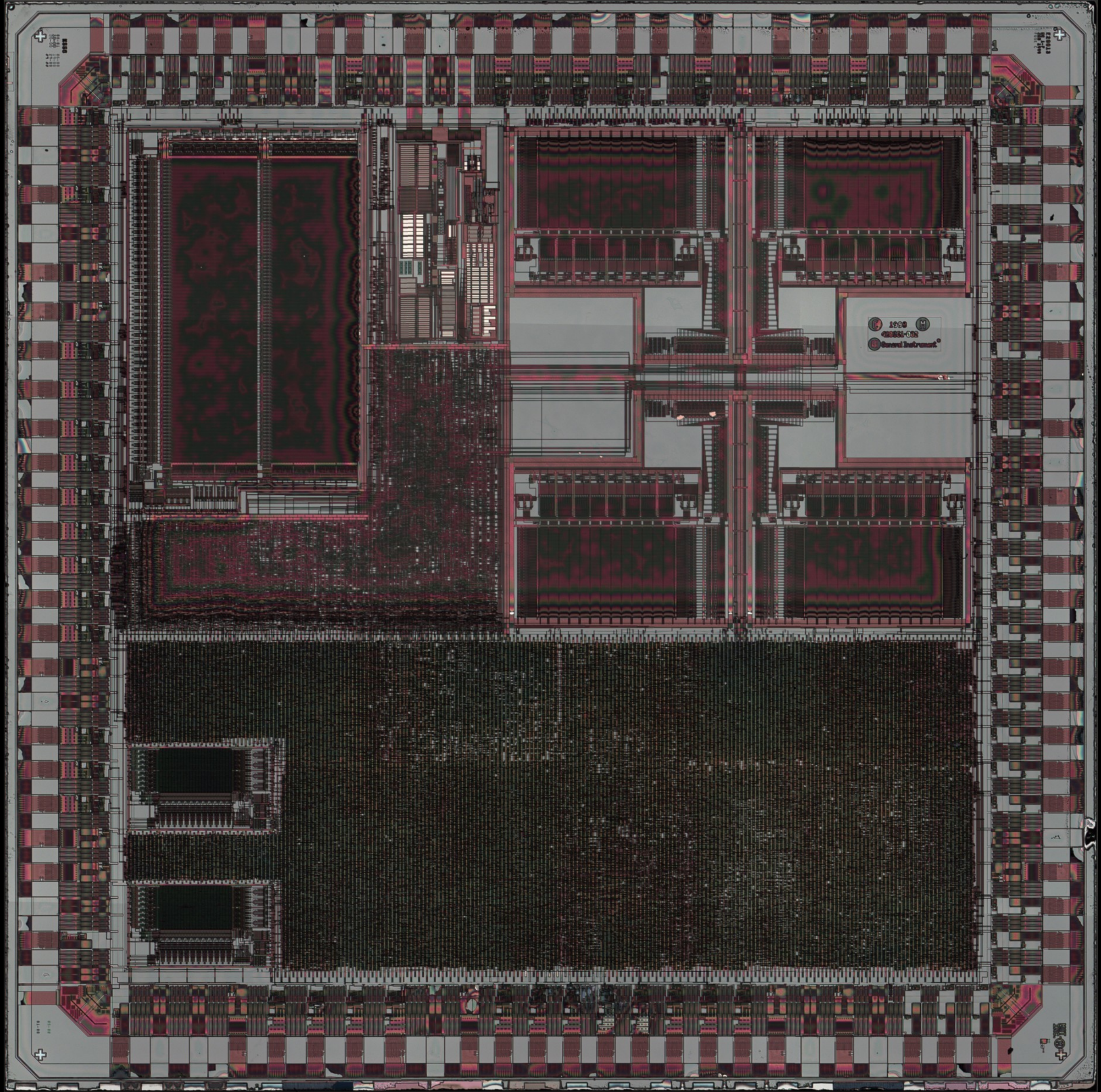
Baker
500 mL
9624-02
Nitric Acid,
Fuming, 90%
Acide Nitrique, Fumant
'BAKER ANALYZED'® A.C.S. Reagent
HNO3
FW 63.01
LOT H38N67
Meets A.C.S. Specifications
100 mL
ValueWare™
80
60
40
20
KIMAX
NO. 14000V
MADE IN CZECH REPUBLIC

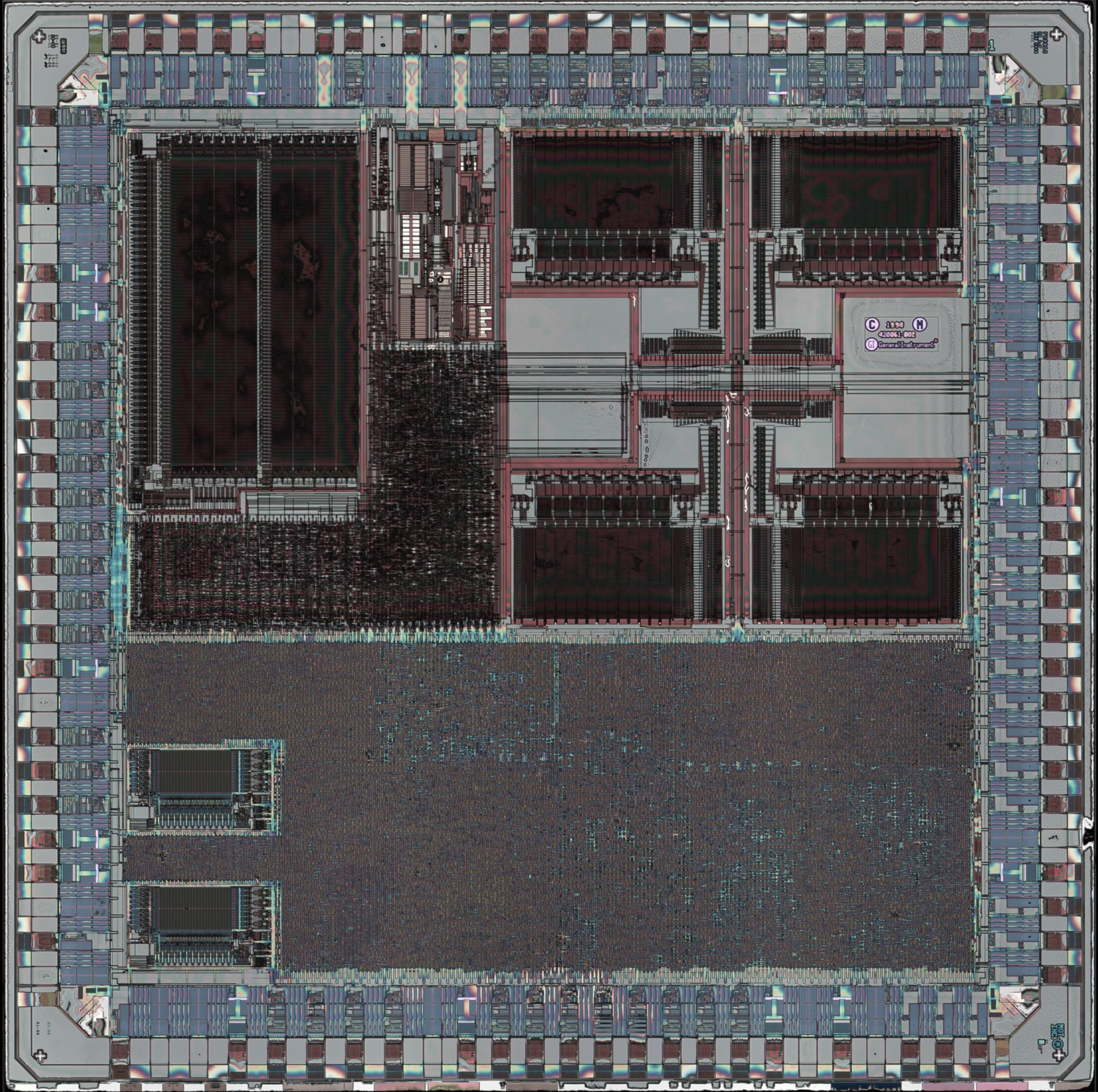


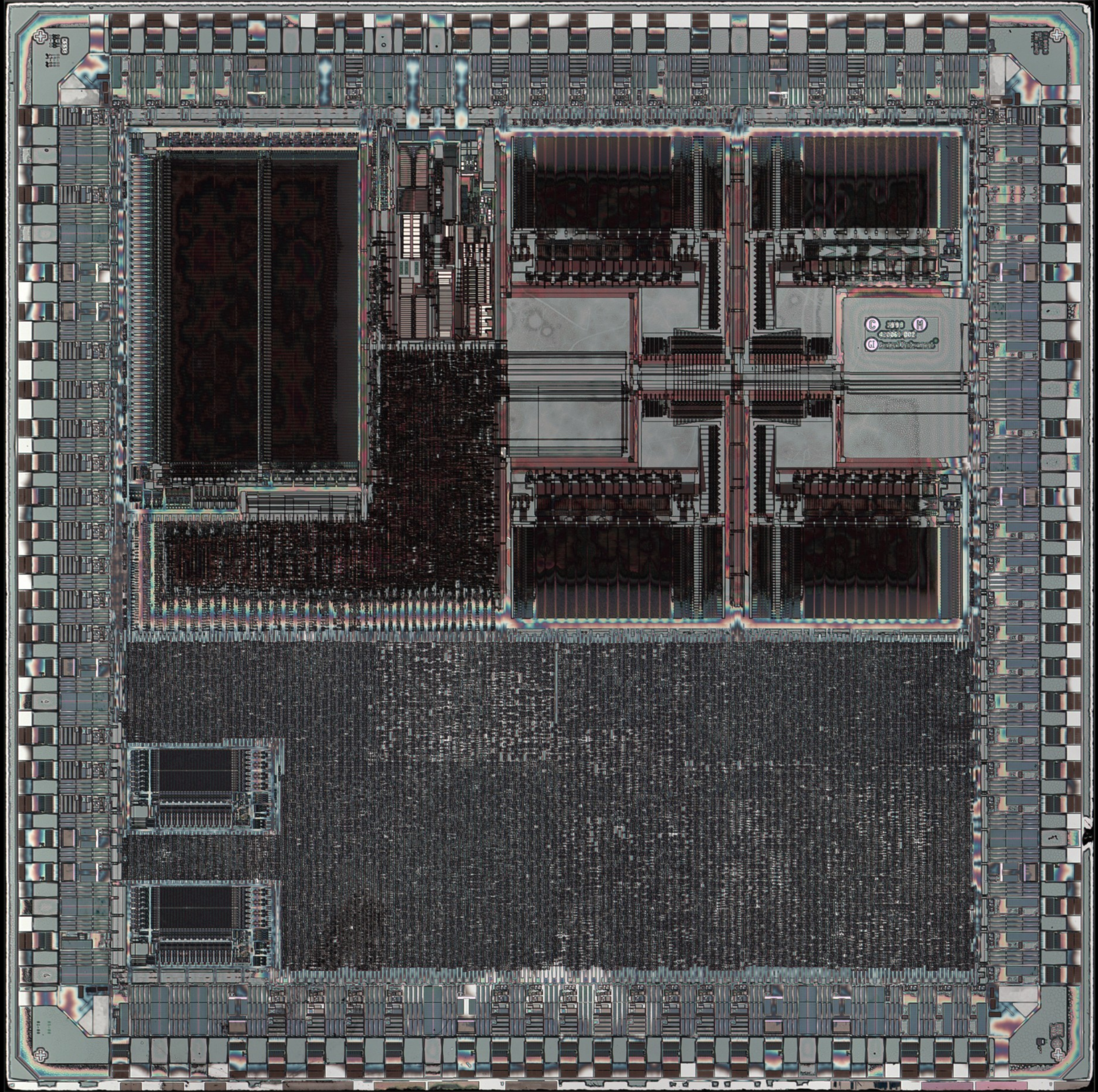


C 1998 M
420061-002
GI General Instrument


whink
RUST STAIN REMOVER
FOR ALL COLORFAST FABRICS
white sinks and white toilet bowls
Not a general purpose rust remover.
Read precautions and directions before using.
Do not use this product if you do not intend to follow the directions.
DANGER: MAY BE FATAL OR CAUSE PERMANENT DAMAGE. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. VAPOR HARMFUL. CONTAINS HYDROFLUORIC ACID. KEEP OUT OF REACH OF CHILDREN. Use only with heavy duty household rubber gloves. Read back panel for additional precautions and directions.
10 fl oz (296 mL)
J.T.Baker
500 mL
9624-02
Nitric Acid, Fuming, 90%
Acide Nitrique, Fumant
'BAKER ANALYZED'® A.C.S. Reagent
HNO3
FW 63.01
LOT H38N67
MADE IN USA
For Laboratory, Research or Manufacturing Use
9624-02
Nitric Acid, Fuming, 90%
FW 63.01


General Instrument


420061-002
GI General Instrument



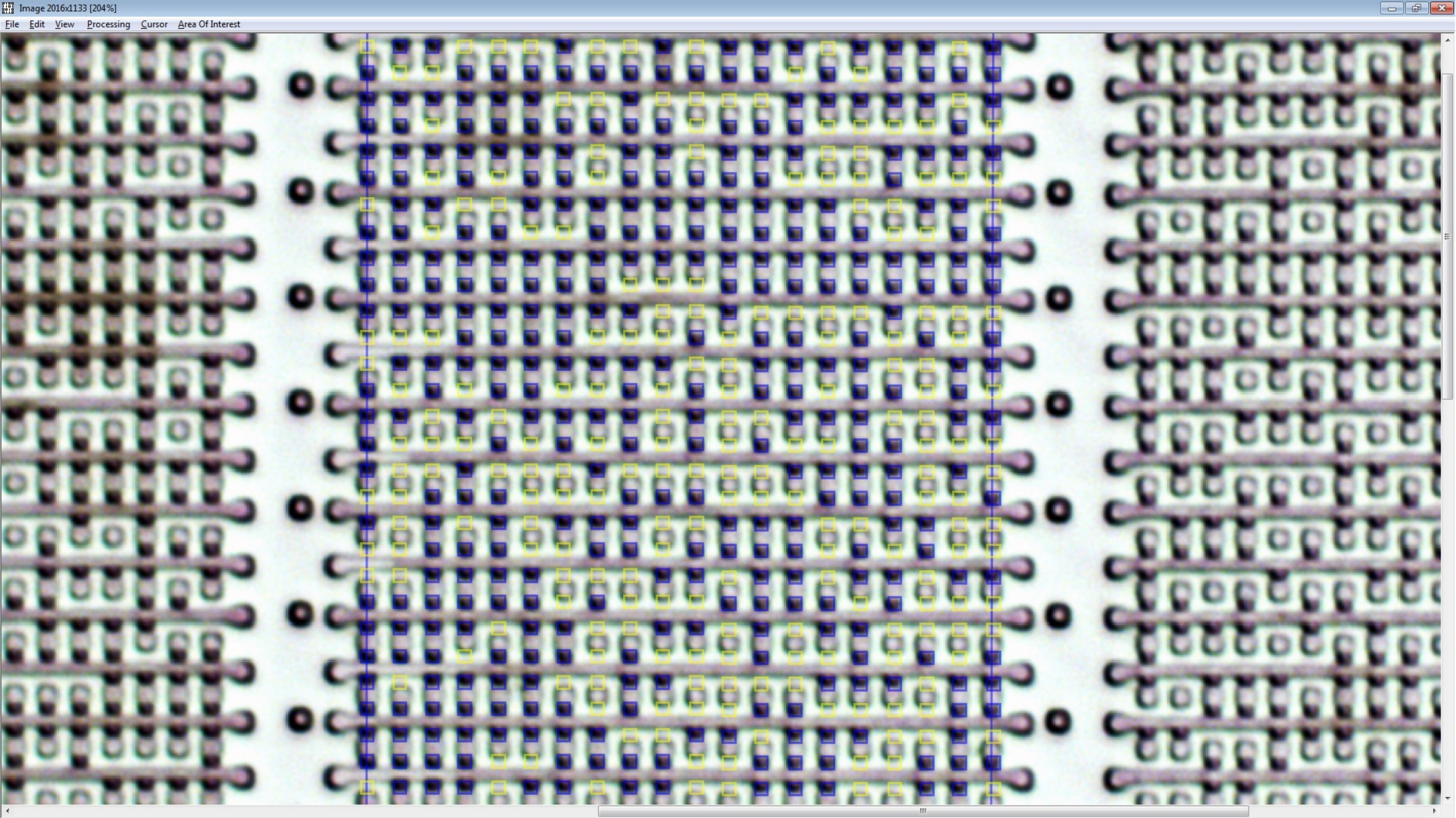
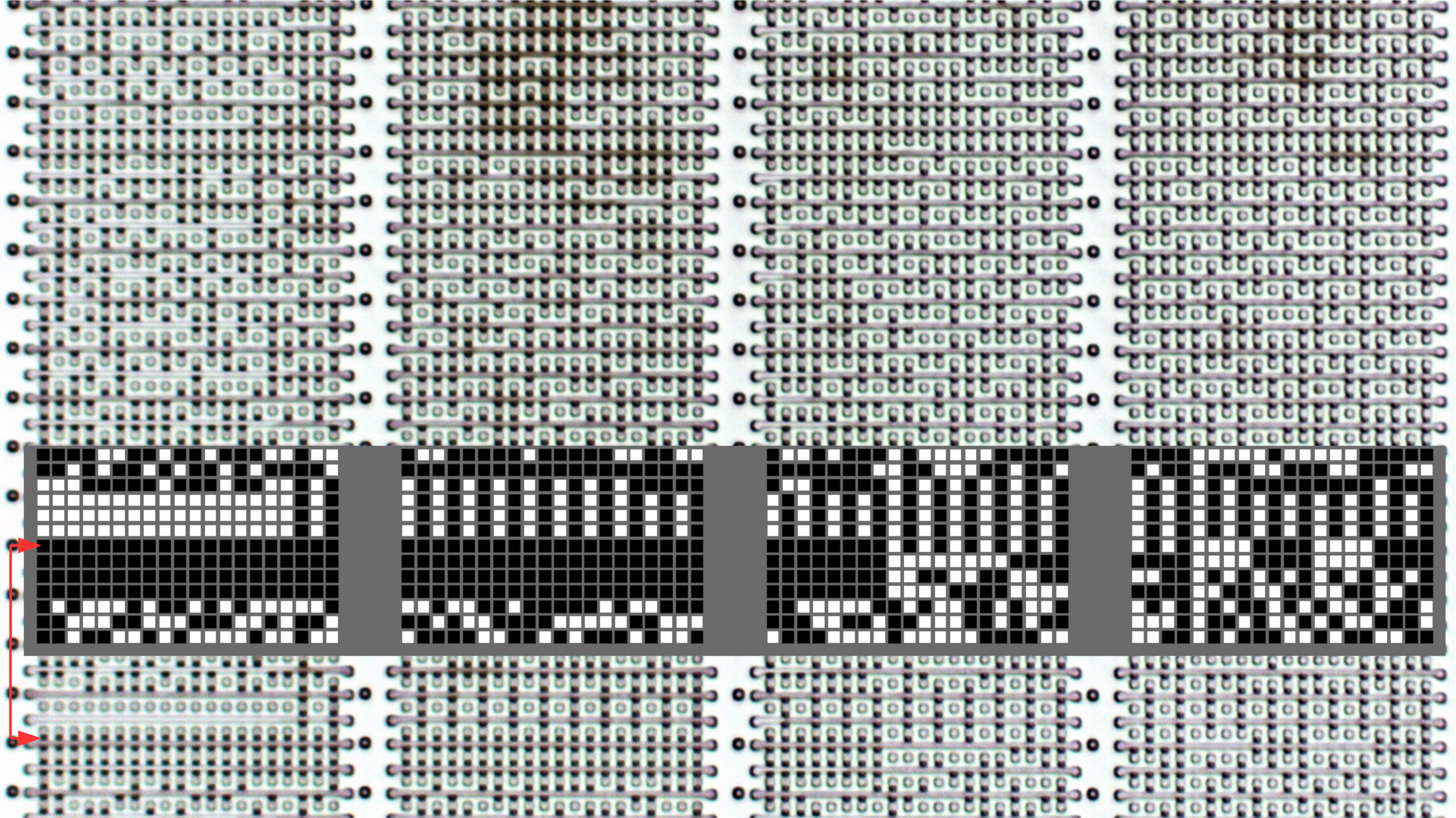
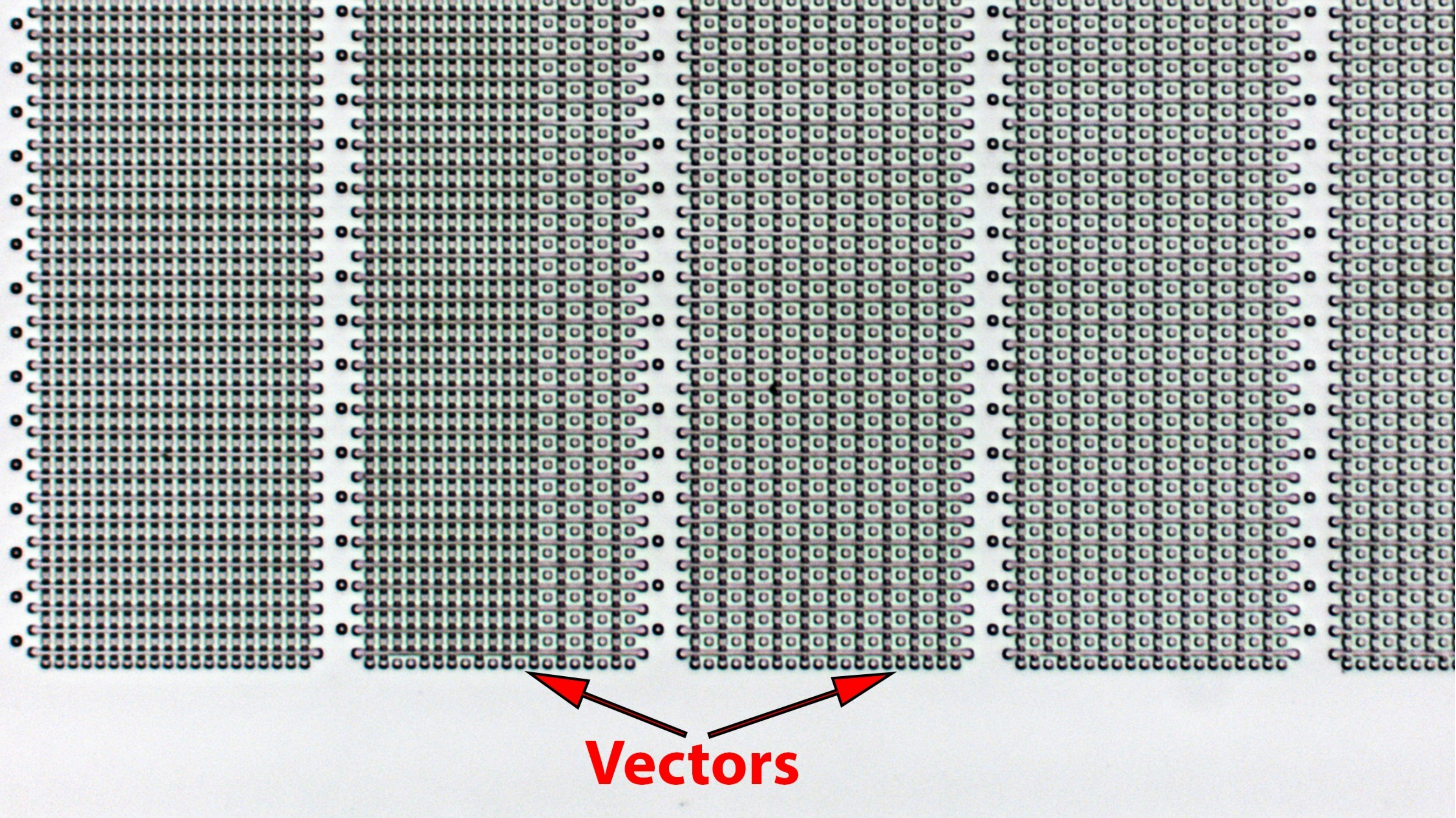
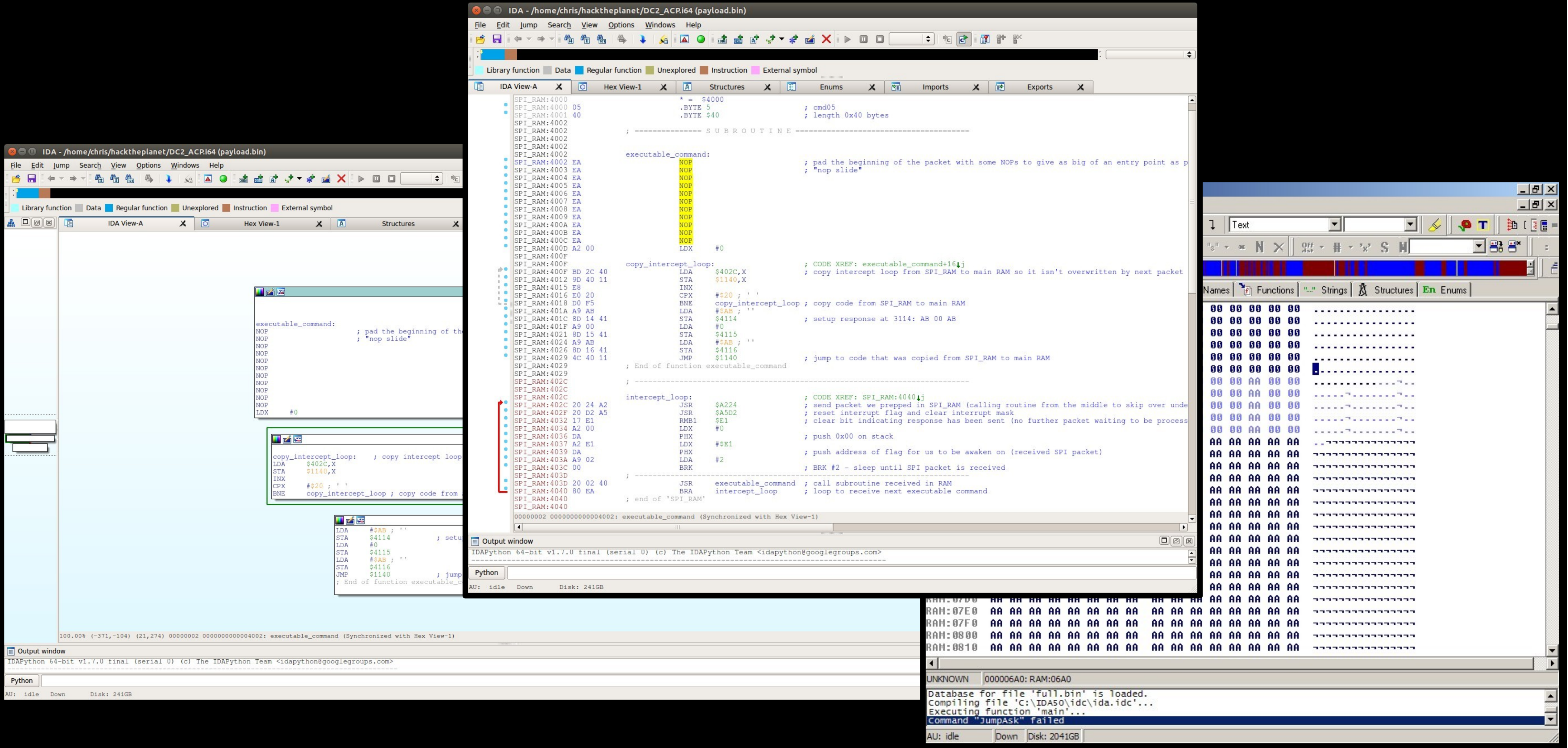


Image 2016x1133 [204%]
File
Edit
View
Processing
Cursor
Area Of Interest




Vectors

Software disassembly (IDA)



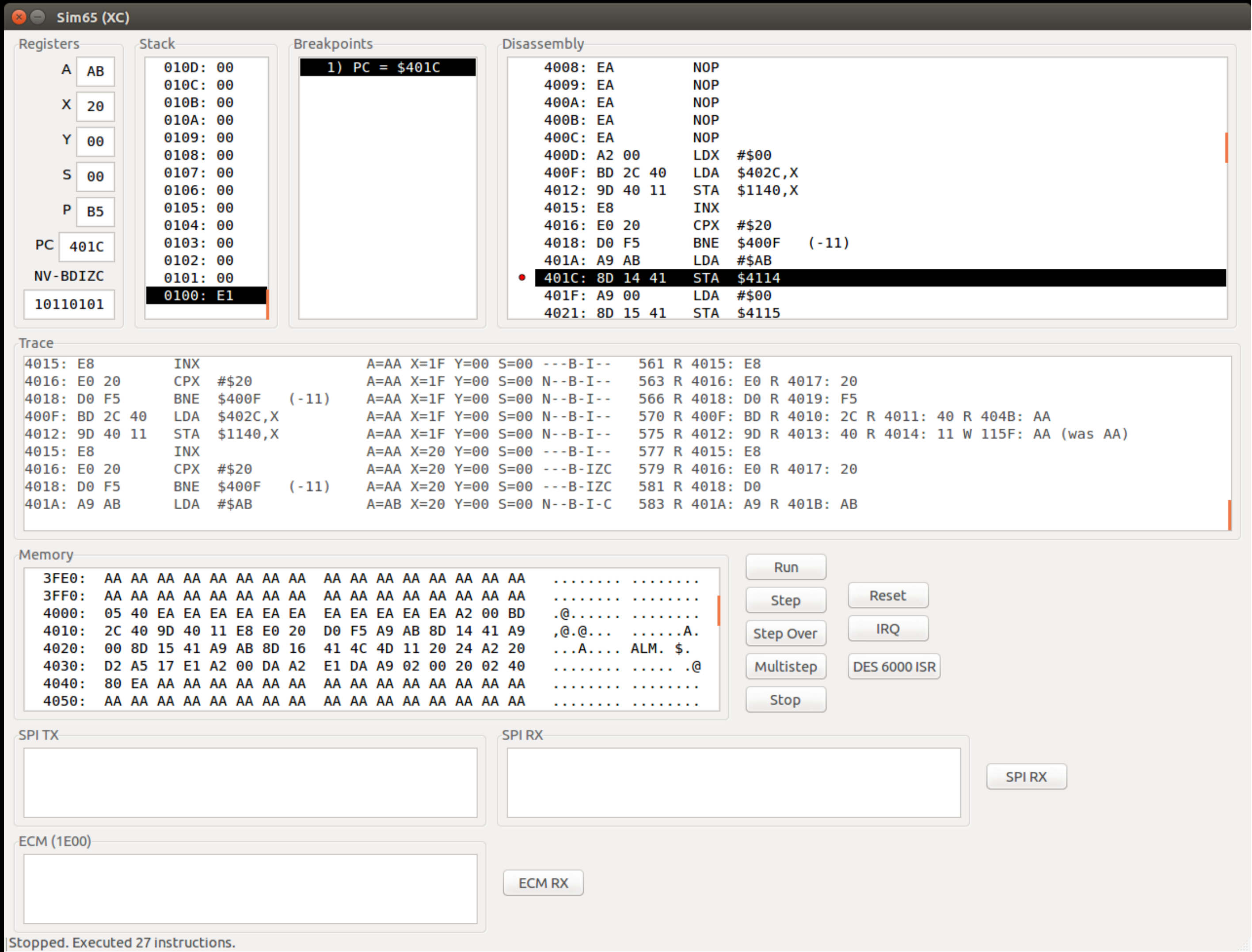
Simulator

Sim65:

a 65c02 simulation system

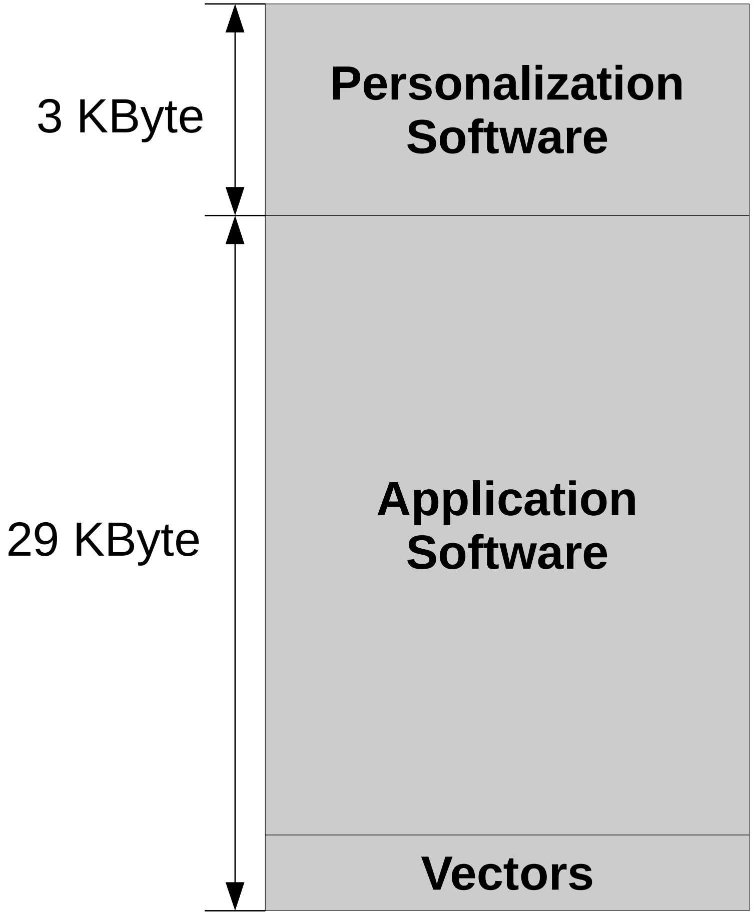
http://www.wsxyz.net/sim65/

Customizations for ACP



Software organization

ROM layout



Personalization software is used during manufacturing to initialize the device – setup UA#, keys, etc.

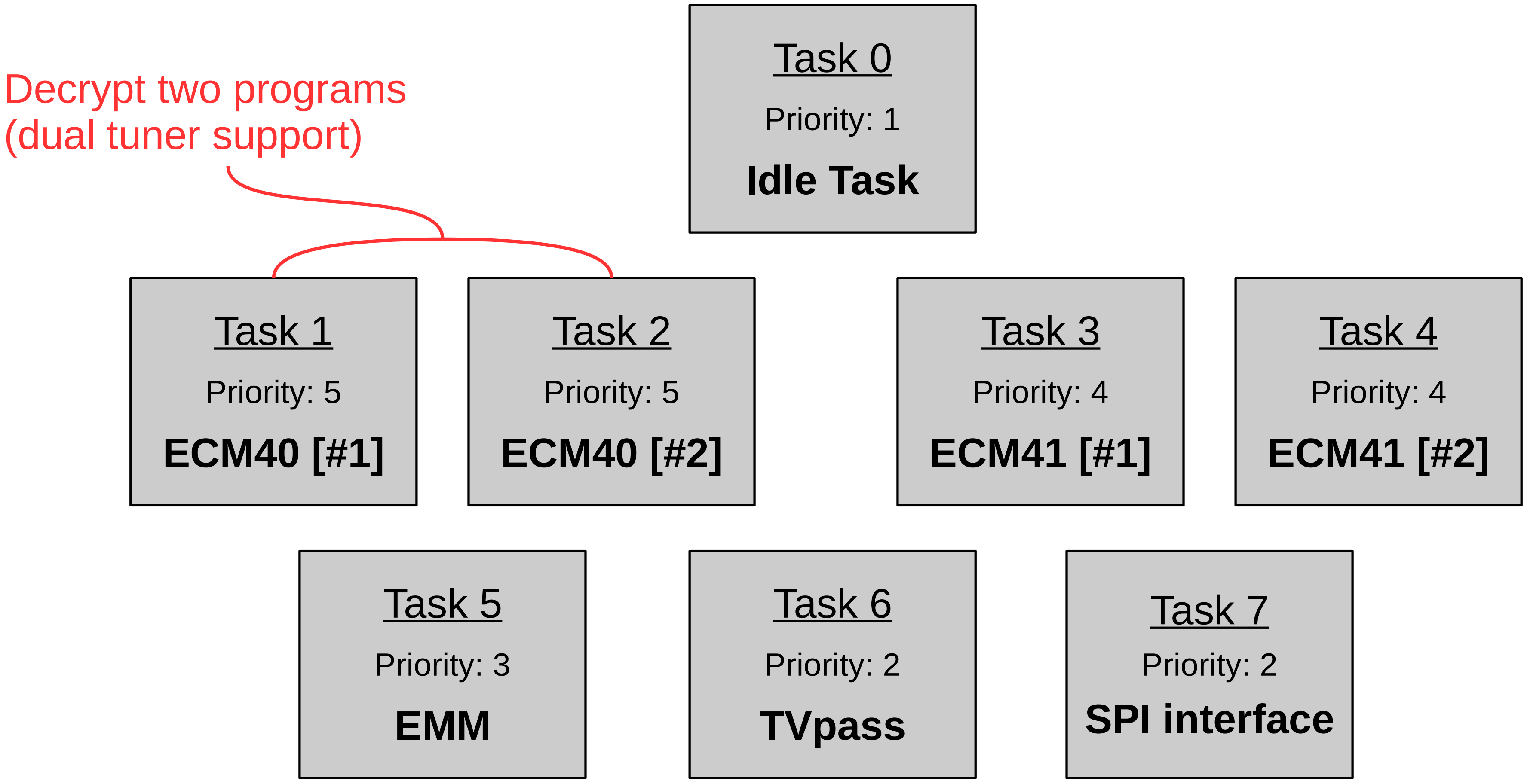
After initialization is complete, access to personalization software is disabled.

Application software always running after STB leaves factory.

This contains all the conditional access functionality.

Vectors area contains reset and interrupt addresses.

Task switcher



Hardware Peripherals

SPI slave

- RX RAM buffer
- TX RAM buffer
- Flag set when transfer complete

Transport Stream PID filter

- SPI selects ECM PID
  - Tables placed in RAM and RX flag set
- SPI selects PIDs to decrypt
- Software selects Provider ID filter for ECM

DES hardware

- Hardware encrypt/decrypt
- 56 bit key, 64 bit data
- Standard and custom modes

TS descrambler

- Software sets working key
- Selected PIDs are decrypted
- DES standard and custom modes

System analysis

- ✔ MPEG Transport stream – ECM & EMM logging
- ✔ SPI bus – logging and understanding of ACP messages
- ✔ ROM dump (entire ACP firmware)
- ✔ Software disassembly and simulation
- ✔ Keys: Fixed keys found in ROM

Possible bit errors from optical extraction ruled out by valid checksum on key area

we are here

- ➔ Understanding of ECM and EMM algorithms

- ✗ Keys: Seed keys, category keys, program keys only exist in RAM

ECM40 – Working Key

Three sequential ECM40 messages (133 ms apart)

```
40 00 11 00 2D 80 07 2B 16 FA 22 04 00 00 00 BB
40 00 11 00 2D 80 07 2B 16 FB 22 04 00 00 01 42
40 00 11 00 2D 80 07 2B 16 FC 22 04 00 00 00 D2
            ^^^^^^^^ ^^^^^^^^    ^^    ^^
          Service ID Frame Count HW  Crypt Mode
```

Frame Count is used to generate Working Key

ECM41 – Program Key

```
41 40 41 10 20 00 2D 80 07 75 6E 2A CE 13 09 E3
40 9E F1 9F E7 76 9A 7E BC 00 00 00 08 05 00 01
35 03 00 00 06 03 00 00 83 03 00 00 A9 03 00 00
C0 03 00 02 54 03 01 00 AB 69 1C D1 12 A8 CE D5
```

1020	Provider ID	8-byte	Initialization Vector
2D8007	Service ID	00	Hardware crypto select
75	Category Epoch	08	Bitmapped (bit 6 indicates PPV)
6E	Program Epoch	05	Number of acceptable tiers (6, each 4 bytes)
2ACE13	Validity start		
09E340	Valid period (24 hr.)	8-byte	Encrypted Program Key

```
40 00 11 00 2D 80 07 2B 16 FA 22 04 00 00 00 BB
```
ECM40 Frame Count 2B16FA

```
41 40 41 10 20 00 2D 80 07 75 6F 34 B1 53 09 E3
40 44 37 29 A0 2E 25 4B A2 00 00 00 08 05 00 01
35 03 00 00 06 03 00 00 83 03 00 00 A9 03 00 00
C0 03 00 02 54 03 01 00 E8 F1 E4 74 45 B9 85 73
```
ECM41 Validity Start 34B153 (next key)

```
40 00 11 00 2D 80 07 2B 16 FB 22 04 00 00 01 42
```
ECM40 Frame Count 2B16FB

```
41 40 41 10 20 00 2D 80 07 75 6E 2A CE 13 09 E3
40 9E F1 9F E7 76 9A 7E BC 00 00 00 08 05 00 01
35 03 00 00 06 03 00 00 83 03 00 00 A9 03 00 00
C0 03 00 02 54 03 01 00 AB 69 1C D1 12 A8 CE D5
```
ECM41 Validity Start 2ACE13 (current key)

```
41 40 41 10 20 00 2D 80 07 75 6F 34 B1 53 09 E3
40 44 37 29 A0 2E 25 4B A2 00 00 00 08 05 00 01
35 03 00 00 06 03 00 00 83 03 00 00 A9 03 00 00
C0 03 00 02 54 03 01 00 E8 F1 E4 74 45 B9 85 73
```
ECM41 Validity Start 34B153 (next key)

```
40 00 11 00 2D 80 07 2B 16 FC 22 04 00 00 00 D2
```
ECM40 Frame Count 2B16FC

```
41 40 41 10 20 00 2D 80 07 75 6E 2A CE 13 09 E3
40 9E F1 9F E7 76 9A 7E BC 00 00 00 08 05 00 01
35 03 00 00 06 03 00 00 83 03 00 00 A9 03 00 00
C0 03 00 02 54 03 01 00 AB 69 1C D1 12 A8 CE D5
```
ECM41 Validity Start 2ACE13 (current key)

```
40 00 11 00 2D 80 07 2B 16 FD 22 04 00 00 01 58
```
ECM40 Frame Count 2B16FD

EMM95 – delivered in 4 parts

0x0013274945 = UA: 0000 3213 41765

```
95 10 A6 00 13 27 49 45 00 00 00 00 00 00 BE C0
00 75 00 00 40 29 20 8E 2D 88 B1 6B 44 1C 10 C3
C3 FB 21 B3 EB 02 04 03 04 02 04 03 04 0D 6C 09
90 0D AA 00 00 00 00 00 00 00 00 00 00 02 10 20
00 80 01 DF 00 60 87 03 00 50 F1 00 DF 23 00 80
00 80 91 33 80 00 40 00 00 22 48 00 00 01 00 41
05 80 00 44 0F 00 FF FF FF 01 FF FF FF 02 FF FF
FF 03 FF FF FF 04 FF FF FF 05 FF FF FF 06 FF FF
FF 07 FF FF FF 08 FF FF FF 09 FF FF FF 0A FF FF
FF 0B FF FF FF 0C FF FF FF 0D FF FF FF 0E FF FF
FF 0F FF FF FF
```

```
95 10 94 00 13 27 49 45 00 00 00 00 00 02 84 C0
00 75 00 00 40 BC 98 1E 16 6E 0E A0 1A 67 99 71
F2 8B 53 5E 25 02 04 03 04 02 04 03 04 02 00 03
DF 00 00 04 00 00 00 00 00 10 00 02 40 42 00 00
80 40 00 02 1A C0 1F 00 A0 07 B8 7B D4 0C 80 FF
87 DF E0 3F 00 E0 07 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 DF 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00
```

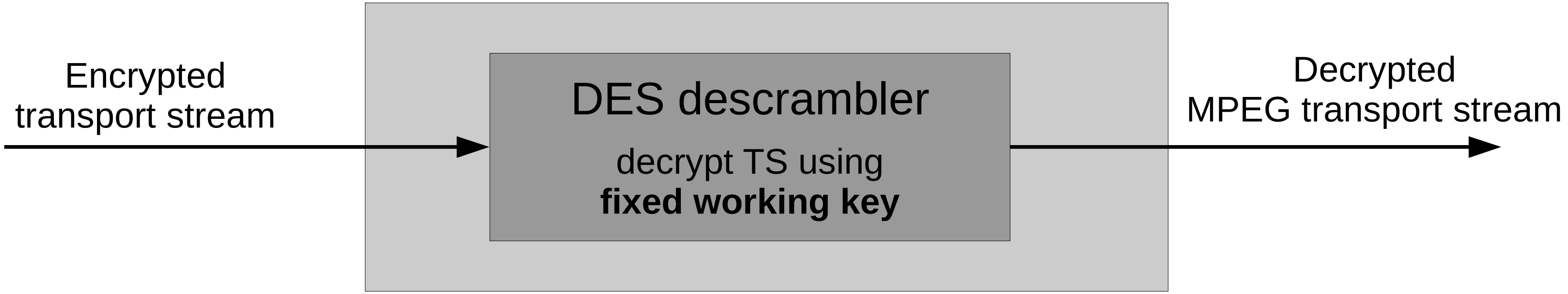
```
95 10 93 00 13 27 49 45 00 00 00 00 00 01 86 C0
00 75 00 00 40 75 77 07 CD E5 79 84 A7 12 BD 46
30 60 41 D2 B2 02 04 03 04 02 04 03 04 01 00 01
DF 30 14 00 00 00 00 C0 02 00 00 00 81 13 5E 20
1C 42 00 00 46 20 00 00 00 10 40 00 00 00 08 80
2F 0F 10 FF FF FF 11 FF FF FF 12 FF FF FF 13 FF
FF FF 14 FF FF FF 15 FF FF FF 16 FF FF FF 17 FF
FF FF 18 FF FF FF 19 FF FF FF 1A FF FF FF 1B FF
FF FF 1C FF FF FF 1D FF FF FF 1E FF FF FF 1F FF
FF FF
```

```
95 10 94 00 13 27 49 45 00 00 00 00 00 03 84 C0
00 75 00 00 40 DB 9B 83 88 DA 80 81 FE CD 14 50
FC A7 ED 27 69 02 04 03 04 02 04 03 04 05 40 03
DF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 DF 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 DF 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00
```

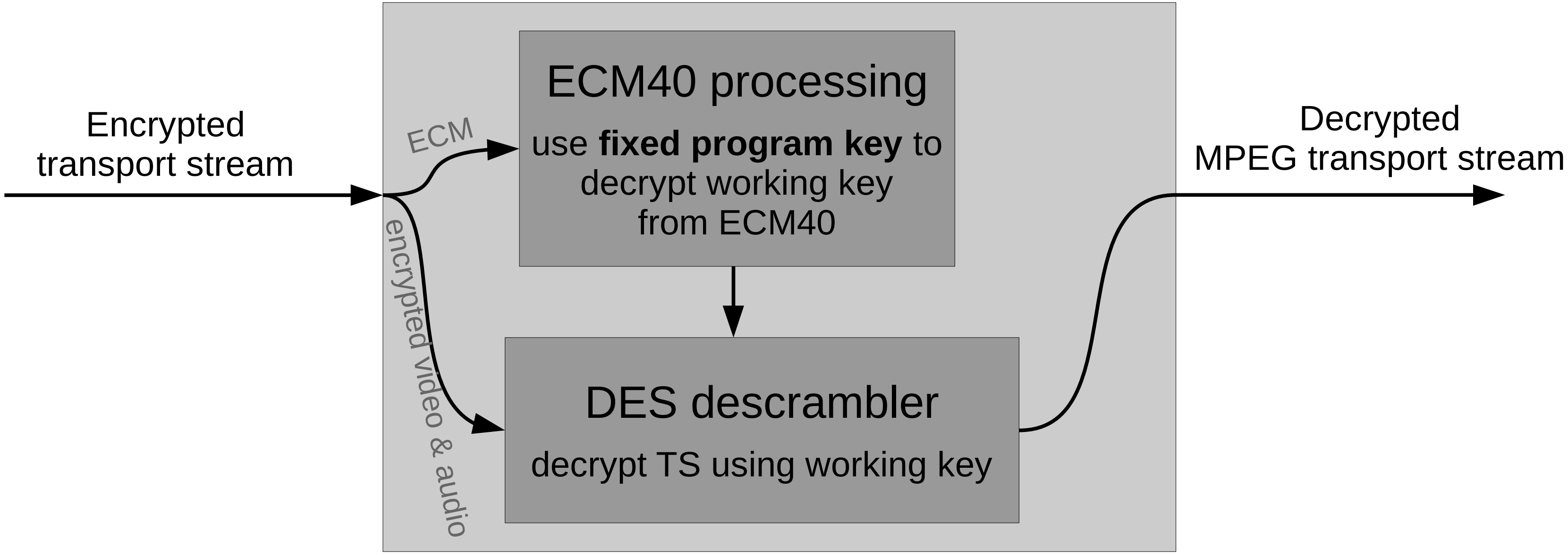
```
95 10 A6 00 13 27 49 45 00 00 00 00 00 00 BE C0
00 75 00 00 40 29 20 8E 2D 88 B1 6B 44 1C 10 C3
C3 FB 21 B3 EB 02 04 03 04 02 04 03 04 0D 6C 09
90 0D AA 00 00 00 00 00 00 00 00 00 00 02 10 20
00 80 01 DF 00 60 87 03 00 50 F1 00 DF 23 00 80
00 80 91 33 80 00 40 00 00 22 48 00 00 01 00 41
05 80 00 44 0F 00 FF FF FF 01 FF FF FF 02 FF FF
FF 03 FF FF FF 04 FF FF FF 05 FF FF FF 06 FF FF
FF 07 FF FF FF 08 FF FF FF 09 FF FF FF 0A FF FF
FF 0B FF FF FF 0C FF FF FF 0D FF FF FF 0E FF FF
FF 0F FF FF FF
```

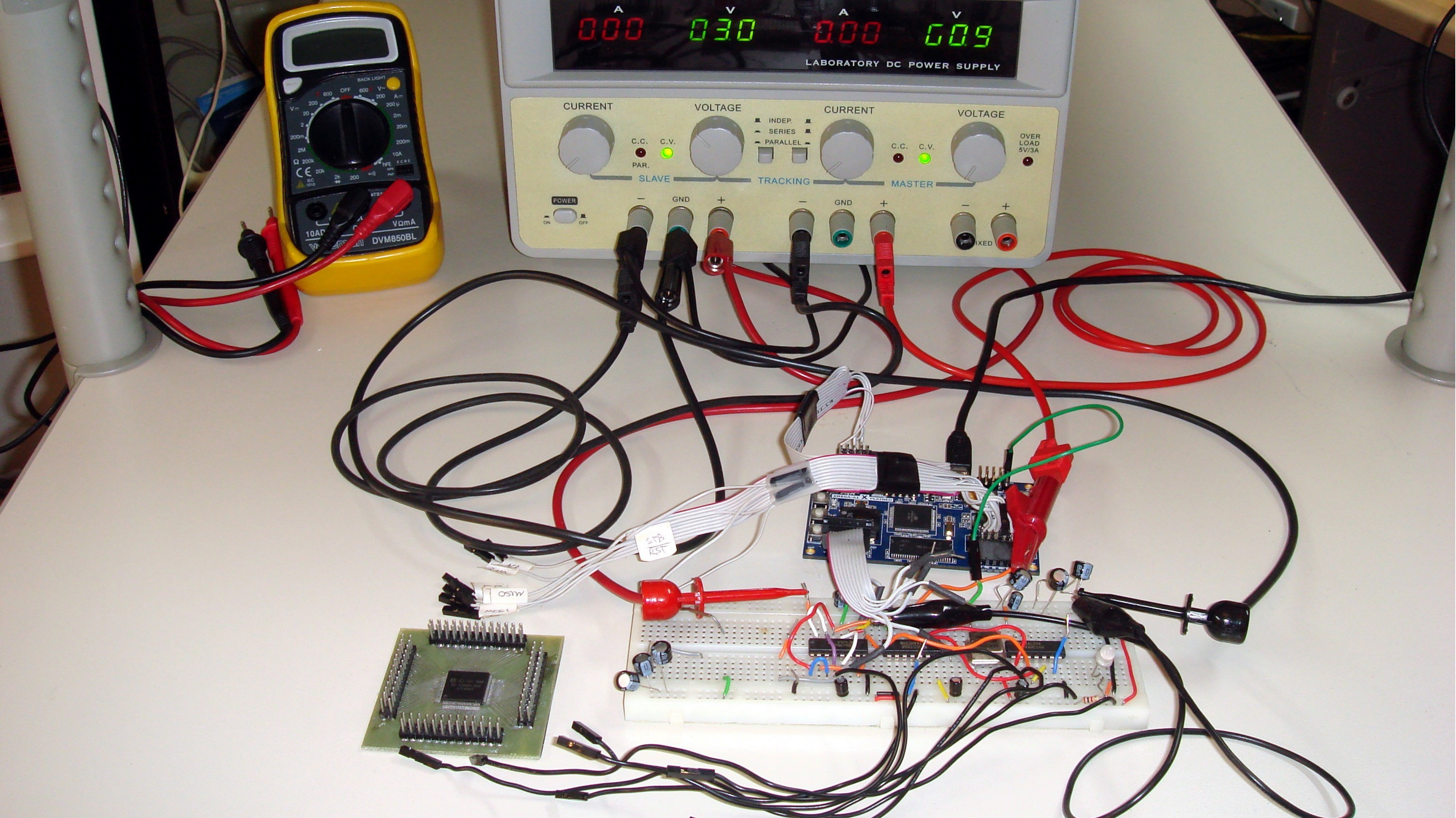
0013274945	Unit Address (UA)
00	EMM part #
BEC0	Bitmap indicating data items to follow
00	Hardware crypto select
75	Category Epoch
8-byte	Encrypted Category key
8-byte	Encrypted Category key (next)
02040304	Keyselect
02040304	Keyselect (next)
7-byte	Geographic location
1020	Provider ID
00	Start of tier bank 0

Decryption using Fixed Working Key



Decryption using Fixed Program Key





LABORATORY DC POWER SUPPLY
CURRENT
VOLTAGE
CURRENT
VOLTAGE
INDEP.
SERIES
PARALLEL
C.C.
C.V.
PAR.
OVER LOAD 5V/3A
SLAVE
TRACKING
MASTER
POWER
GND
GND
DVM850BL

```
Normal SPI RX: [7289]:  55 05 09 FC 16 C2 88 48 74 58 85 84 C9

Glitch 4/11412 [7293]:  55 13 09 FC 16 C2 88 48 74 58 85 84 DF
Glitch 4/11418 [7292]:  55 FF 09 FC 16 C2 88 48 74 58 85 84 33
Glitch 4/11419 [7290]:  55 BF 09 FC 16 C2 88 48 74 58 85 84 73
Glitch 4/11436 [7435]:  55 13 22 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 4/11439 [7292]:  55 13 09 FC 16 C2 88 48 74 58 85 84 DF
Glitch 4/11452 [7442]:  55 05 22 FC 16 C2 88 48 74 58 85 84 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 4/11456 [7437]:  55 05 22 FC 16 C2 88 48 74 58 85 84 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 4/11483 [11636]: 55 05 09 00 00 00 00 00 00 00 00 00 0C
Glitch 4/11491 [7286]:  55 05 09 00 16 C2 88 48 74 58 85 84 35
Glitch 4/11506 [7285]:  55 05 09 FC 00 C2 88 48 74 58 85 84 DF
Glitch 4/11514 [7293]:  55 05 09 FC 3E C2 88 48 74 58 85 84 E1
Glitch 4/11522 [7295]:  55 05 09 FC 00 C2 88 48 74 58 85 84 DF
Glitch 4/11527 [7294]:  55 05 09 FC BE C2 88 48 74 58 85 84 61
Glitch 4/11537 [7293]:  55 05 09 FC 00 C2 88 48 74 58 85 84 DF
Glitch 4/11560 [7293]:  55 05 09 FC 16 C2 88 48 74 16 85 84 87
Glitch 4/11578 [7292]:  55 05 09 FC 16 C2 88 48 74 00 85 84 91
Glitch 4/11599 [7260]:  55 05 09 FC 16 00 00 00 00 58 00 78 C6
Glitch 4/11622 [7291]:  55 05 09 FC 16 C2 88 48 58 58 85 84 E5
Glitch 4/11626 [7286]:  55 05 09 FC 16 C2 88 48 21 58 85 84 9C
Glitch 4/11654 [7292]:  55 05 09 FC 16 C2 88 48 00 58 85 84 BD
Glitch 4/11677 [7271]:  55 05 09 FC 16 00 00 00 74 58 00 7C B6
Glitch 4/11685 [7292]:  55 05 09 FC 16 C2 88 74 74 58 85 84 F5
Glitch 4/11694 [7286]:  55 05 09 FC 16 C2 88 00 74 58 85 84 81
Glitch 4/11700 [7295]:  55 05 09 FC 16 C2 88 80 74 58 85 84 01
Glitch 4/11741 [7277]:  55 05 09 FC 16 00 00 48 74 58 85 84 83
Glitch 4/11746 [10738]: 55 85 09 FC 16 00 00 48 74 58 00 00 02
Glitch 4/11751 [10740]: 55 05 09 FC 16 00 00 48 74 58 00 00 82
Glitch 4/11767 [7292]:  55 05 09 FC 16 C2 FE 48 74 58 85 84 BF
Glitch 4/11779 [7278]:  55 05 09 FC 16 00 88 48 74 58 85 84 0B
Glitch 4/11790 [7293]:  55 05 09 FC 16 C2 00 48 74 58 85 84 41
Glitch 4/11812 [10747]: 55 85 09 FC 16 00 88 48 74 58 00 00 8A
Glitch 4/11843 [7289]:  55 05 09 FC 16 00 88 48 74 58 85 84 0B
Glitch 4/11901 [7288]:  55 05 09 FC 16 C2 88 48 74 58 00 84 4C
Glitch 4/11937 [7290]:  55 05 09 FC 16 C2 88 48 74 58 85 00 4D
```

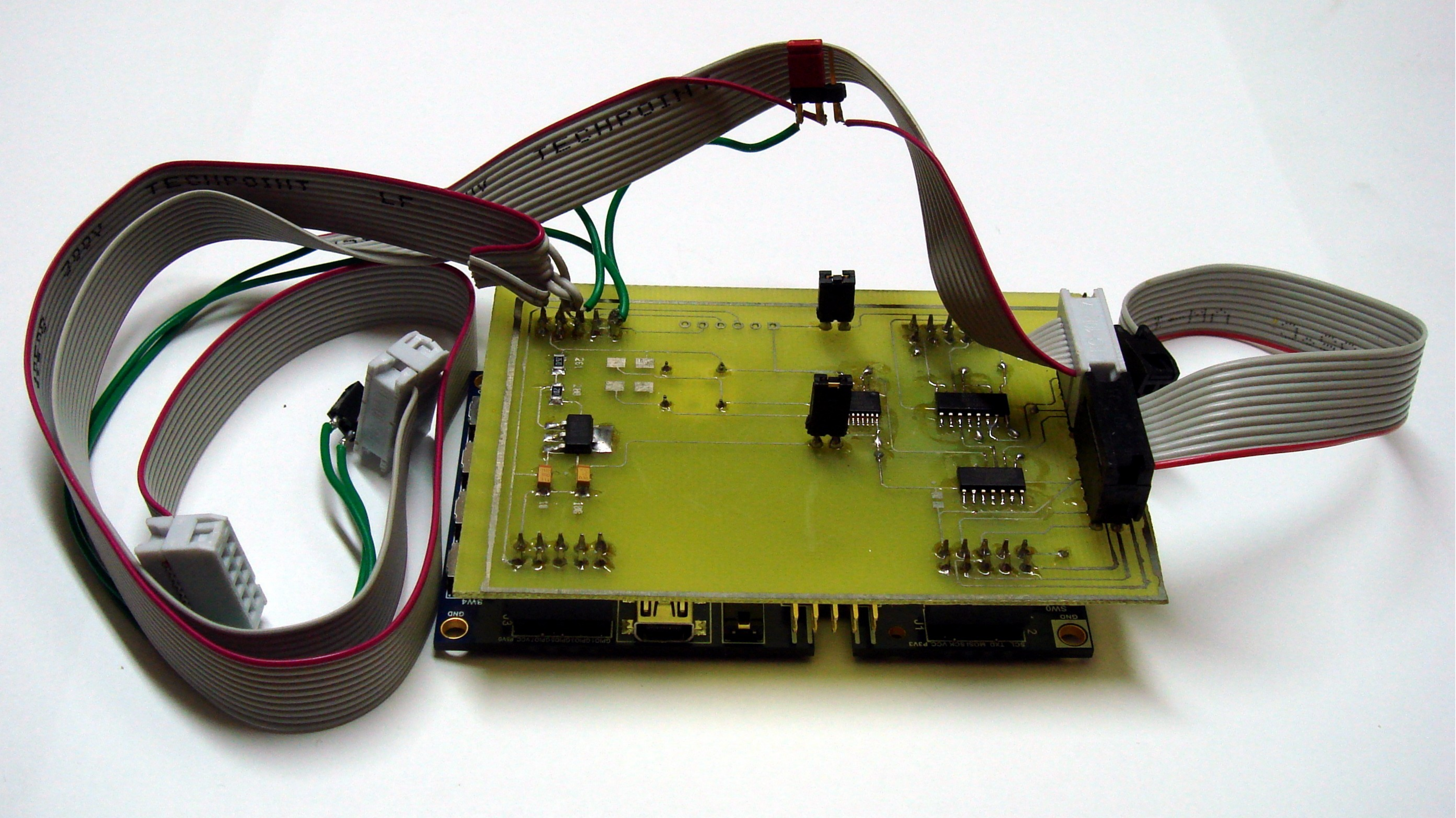
Normal (no glitch) response

Responses changed by glitch

Checksum

Time until READY

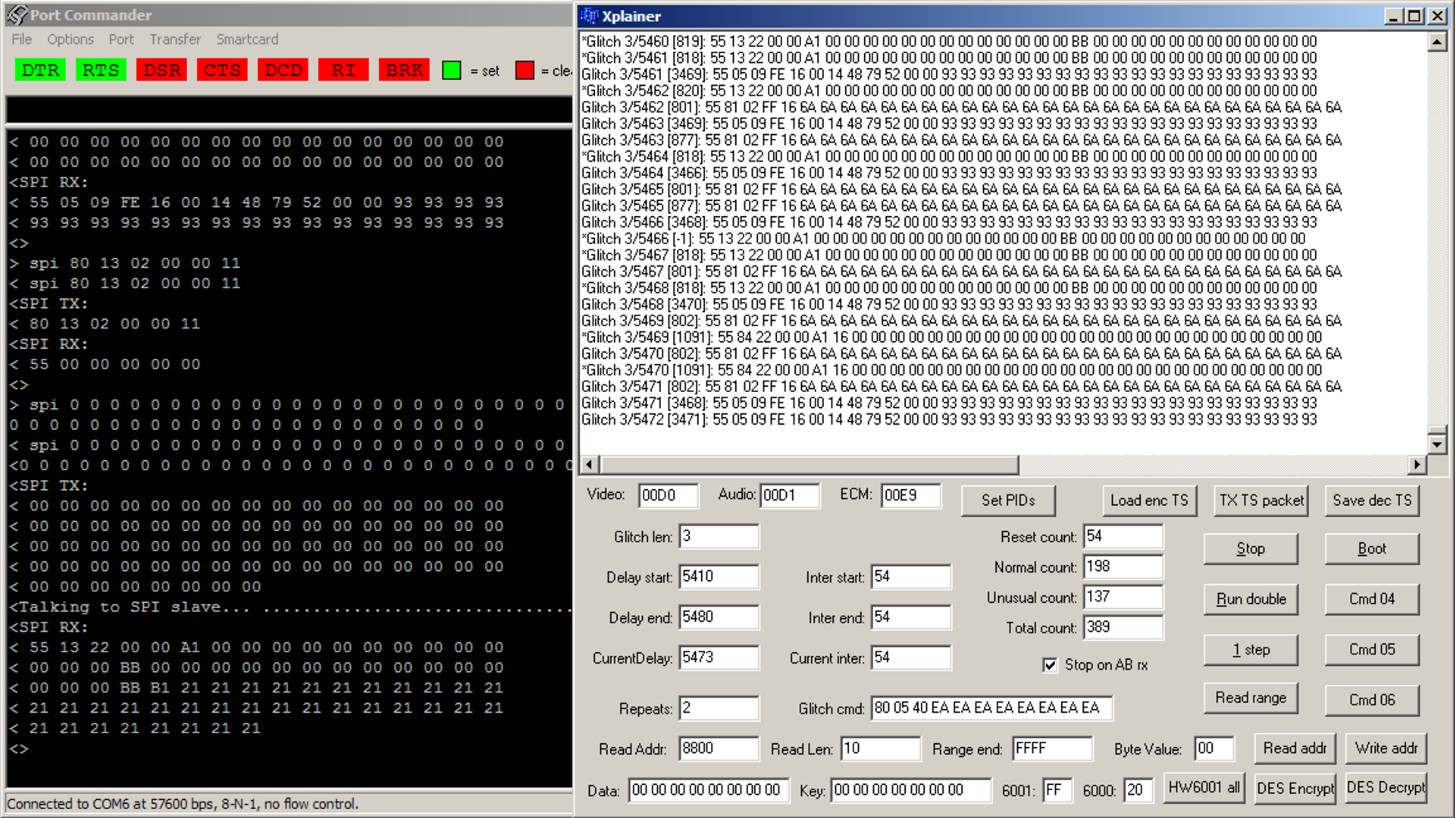
Delay before glitch


TECHPOINT

Glitch payload - RAM intercept loop

(addresses have been changed)

```
SPI_RAM:4000 05                 .BYTE 5                   ; cmd05
SPI_RAM:4001 40                 .BYTE $40                 ; length 0x40 bytes
SPI_RAM:4002            ; ---------------------------------------------------------------------------
SPI_RAM:4002
SPI_RAM:4002            executable_command:               ; pad the beginning of the packet with some NOPs to give as big of an entry point as possible
SPI_RAM:4002 EA                 NOP
SPI_RAM:4003 EA                 NOP                       ; "nop slide"
SPI_RAM:4004 EA                 NOP
SPI_RAM:4005 EA                 NOP
SPI_RAM:4006 EA                 NOP
SPI_RAM:4007 EA                 NOP
SPI_RAM:4008 EA                 NOP
SPI_RAM:4009 EA                 NOP
SPI_RAM:400A EA                 NOP
SPI_RAM:400B EA                 NOP
SPI_RAM:400C EA                 NOP
SPI_RAM:400D A2 00              LDX     #0
SPI_RAM:400F
SPI_RAM:400F            copy_intercept_loop:              ; CODE XREF: SPI_RAM:4018
SPI_RAM:400F BD 2C 40           LDA     $402C,X           ; copy intercept loop from SPI_RAM to main RAM so it isn't overwritten by next packet
SPI_RAM:4012 9D 40 11           STA     $1140,X
SPI_RAM:4015 E8                 INX
SPI_RAM:4016 E0 20              CPX     #$20 ; ' '
SPI_RAM:4018 D0 F5              BNE     copy_intercept_loop ; copy code from SPI_RAM to main RAM
SPI_RAM:401A A9 AB              LDA     #$AB ; ''
SPI_RAM:401C 8D 14 41           STA     $4114             ; setup response at 3114: AB 00 AB
SPI_RAM:401F A9 00              LDA     #0
SPI_RAM:4021 8D 15 41           STA     $4115
SPI_RAM:4024 A9 AB              LDA     #$AB ; ''
SPI_RAM:4026 8D 16 41           STA     $4116
SPI_RAM:4029 4C 40 11           JMP     $1140             ; jump to code that was copied from SPI_RAM to main RAM
SPI_RAM:402C            ; ---------------------------------------------------------------------------
SPI_RAM:402C
SPI_RAM:402C            intercept_loop:
SPI_RAM:402C 20 24 A2           JSR     $A224             ; send packet we prepped in SPI_RAM (calling routine from the middle to skip over undesired behaviour)
SPI_RAM:402F 20 D2 A5           JSR     $A5D2             ; reset interrupt flag and clear interrupt mask
SPI_RAM:4032 17 E1              RMB1    $E1               ; clear bit indicating response has been sent (no further packet waiting to be processed)
SPI_RAM:4034 A2 00              LDX     #0
SPI_RAM:4036 DA                 PHX                       ; push 0x00 on stack
SPI_RAM:4037 A2 E1              LDX     #$E1
SPI_RAM:4039 DA                 PHX                       ; push address of flag for us to be awaken on (received SPI packet)
SPI_RAM:403A A9 02              LDA     #2
SPI_RAM:403C 00                 BRK                       ; BRK #2 - sleep until SPI packet is received
SPI_RAM:403D            ; ---------------------------------------------------------------------------
SPI_RAM:403D 20 02 40           JSR     executable_command  ; call subroutine received in RAM
SPI_RAM:4040 80 EA              BRA     intercept_loop      ; loop to receive next executable command
```


Port Commander
File Options Port Transfer Smartcard
DTR RTS DSR CTS DCD RI BRK = set = cle
< 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
< 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
<SPI RX:
< 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93
< 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
<>
> spi 80 13 02 00 00 11
< spi 80 13 02 00 00 11
<SPI TX:
< 80 13 02 00 00 11
<SPI RX:
< 55 00 00 00 00 00
<>
> spi 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
< spi 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
<0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
<SPI TX:
< 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
< 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
< 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
< 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
< 00 00 00 00 00 00 00 00
<Talking to SPI slave... ....
<SPI RX:
< 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00
< 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00
< 00 00 00 BB B1 21 21 21 21 21 21 21 21 21 21 21
< 21 21 21 21 21 21 21 21 21 21 21 21 21 21 21 21
< 21 21 21 21 21 21 21 21
<>
Connected to COM6 at 57600 bps, 8-N-1, no flow control.
Xplainer
*Glitch 3/5460 [819]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*Glitch 3/5461 [818]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5461 [3469]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
*Glitch 3/5462 [820]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5462 [801]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
Glitch 3/5463 [3469]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
Glitch 3/5463 [877]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
*Glitch 3/5464 [818]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5464 [3466]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
Glitch 3/5465 [801]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
Glitch 3/5465 [877]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
Glitch 3/5466 [3468]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
*Glitch 3/5466 [-1]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*Glitch 3/5467 [818]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5467 [801]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
*Glitch 3/5468 [818]: 55 13 22 00 00 A1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 BB 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5468 [3470]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
Glitch 3/5469 [802]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
*Glitch 3/5469 [1091]: 55 84 22 00 00 A1 16 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5470 [802]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
*Glitch 3/5470 [1091]: 55 84 22 00 00 A1 16 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Glitch 3/5471 [802]: 55 81 02 FF 16 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A 6A
Glitch 3/5471 [3468]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
Glitch 3/5472 [3471]: 55 05 09 FE 16 00 14 48 79 52 00 00 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93 93
Video: 00D0
Audio: 00D1
ECM: 00E9
Set PIDs
Load enc TS
TX TS packet
Save dec TS
Glitch len: 3
Reset count: 54
Stop
Boot
Delay start: 5410
Inter start: 54
Normal count: 198
Unusual count: 137
Run double
Cmd 04
Delay end: 5480
Inter end: 54
Total count: 389
CurrentDelay: 5473
Current inter: 54
Stop on AB rx
1 step
Cmd 05
Repeats: 2
Glitch cmd: 80 05 40 EA EA EA EA EA EA EA EA
Read range
Cmd 06
Read Addr: 8800
Read Len: 10
Range end: FFFF
Byte Value: 00
Read addr
Write addr
Data: 00 00 00 00 00 00 00 00
Key: 00 00 00 00 00 00 00 00
6001: FF
6000: 20
HW6001 all
DES Encrypt
DES Decrypt

Bit errors found in optical ROM dump

Result of ROM extraction from single sample

Errors marked in red

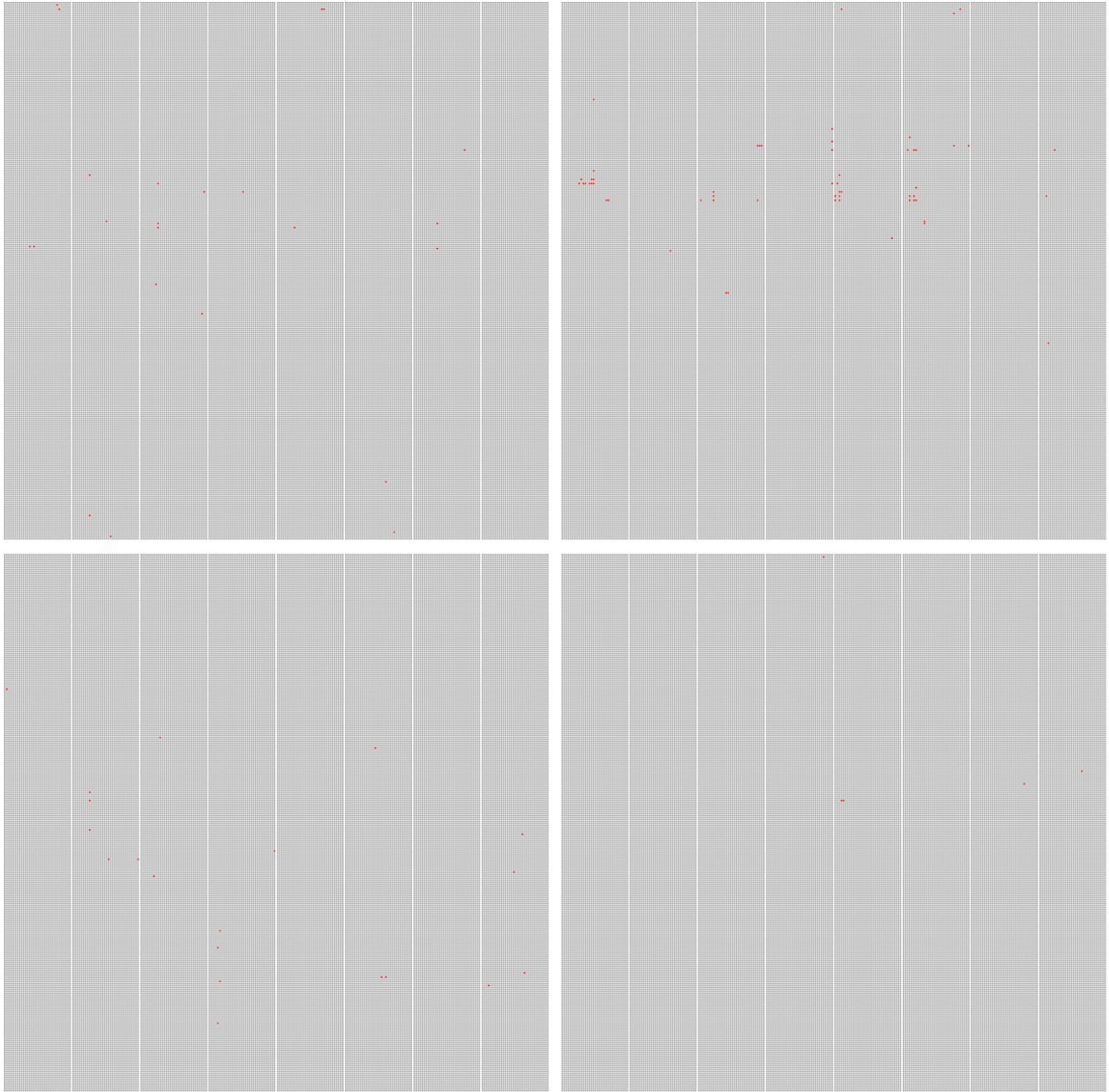
By the bit

262,144 bits total
105 bit errors
= 0.04 % error rate (99.96% accuracy)

By the byte

32,768 bytes total
104 byte errors
= 0.32 % error rate (99.68% accuracy)

Only one byte had more than a single flipped bit.



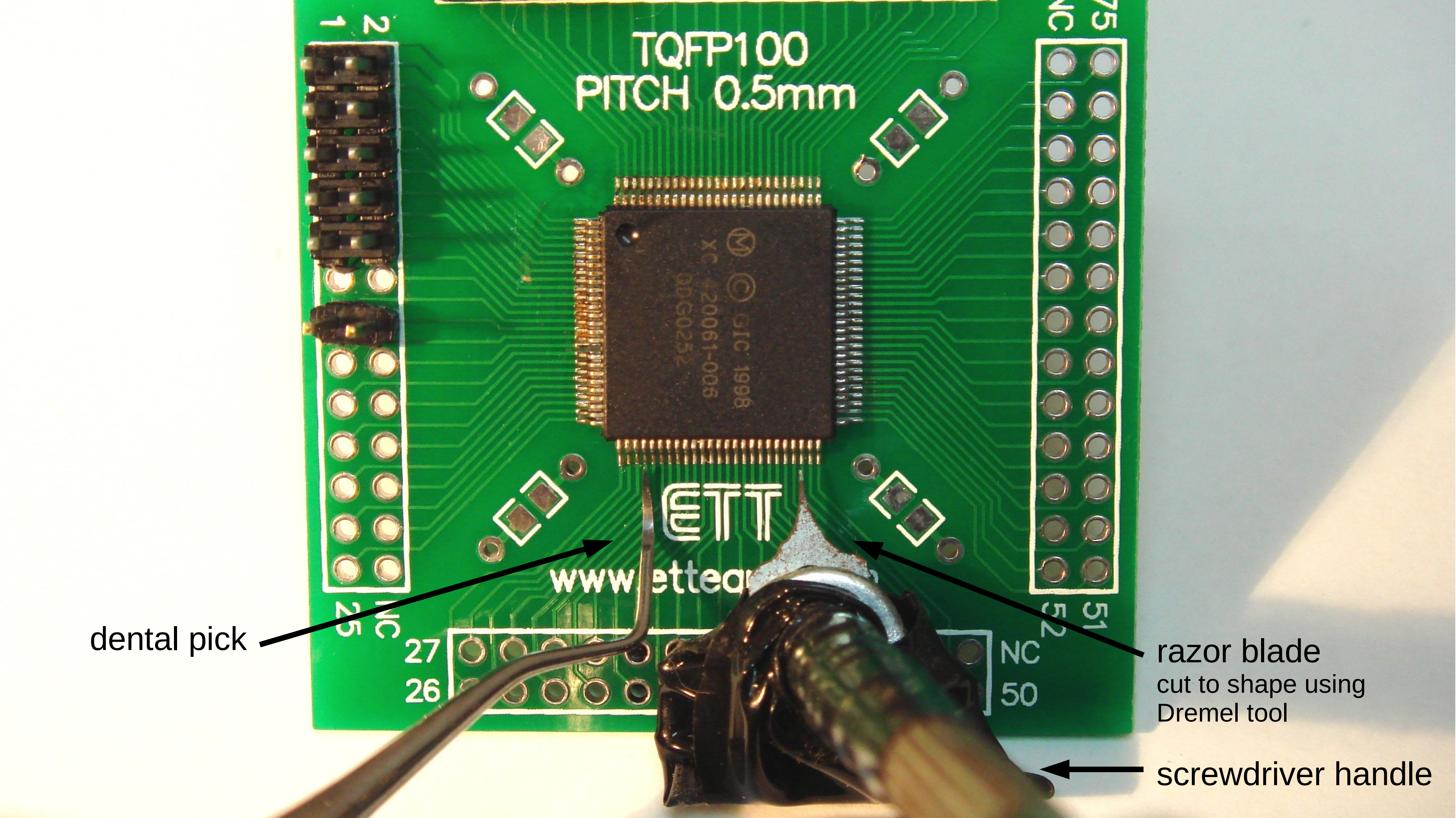
Key extraction from RAM

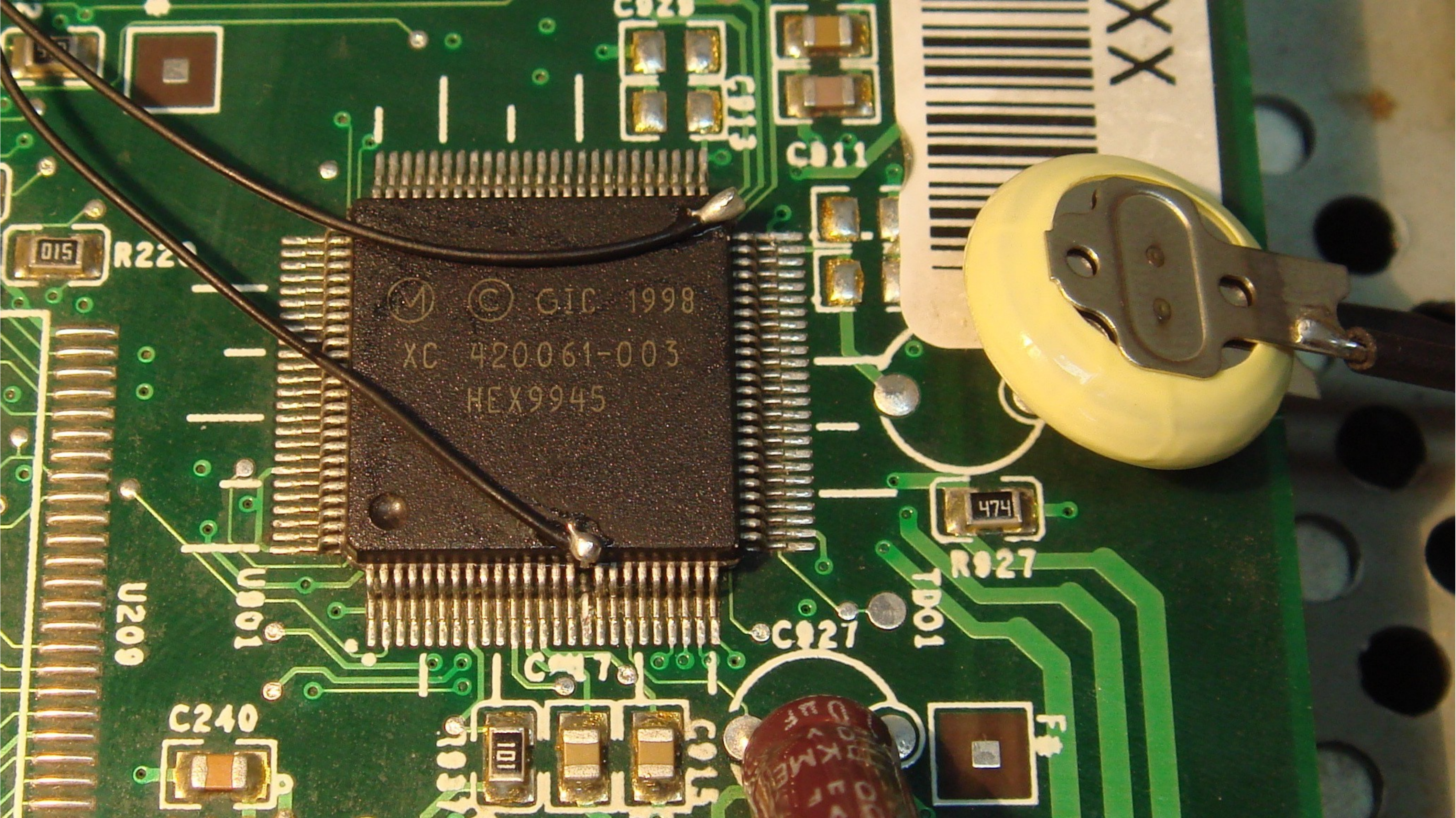
- All keys are stored only in RAM.
- RAM is battery-backed.
- Until now, glitching has been done on chips desoldered and put on test board.
  - This isolates the 16 VCC pins from each other and other components.
- RAM contents lost when chip is desoldered.
- If we can successfully glitch ACP with RAM intact then all keys can be read.
  - Category and Seed Keys are desirable.

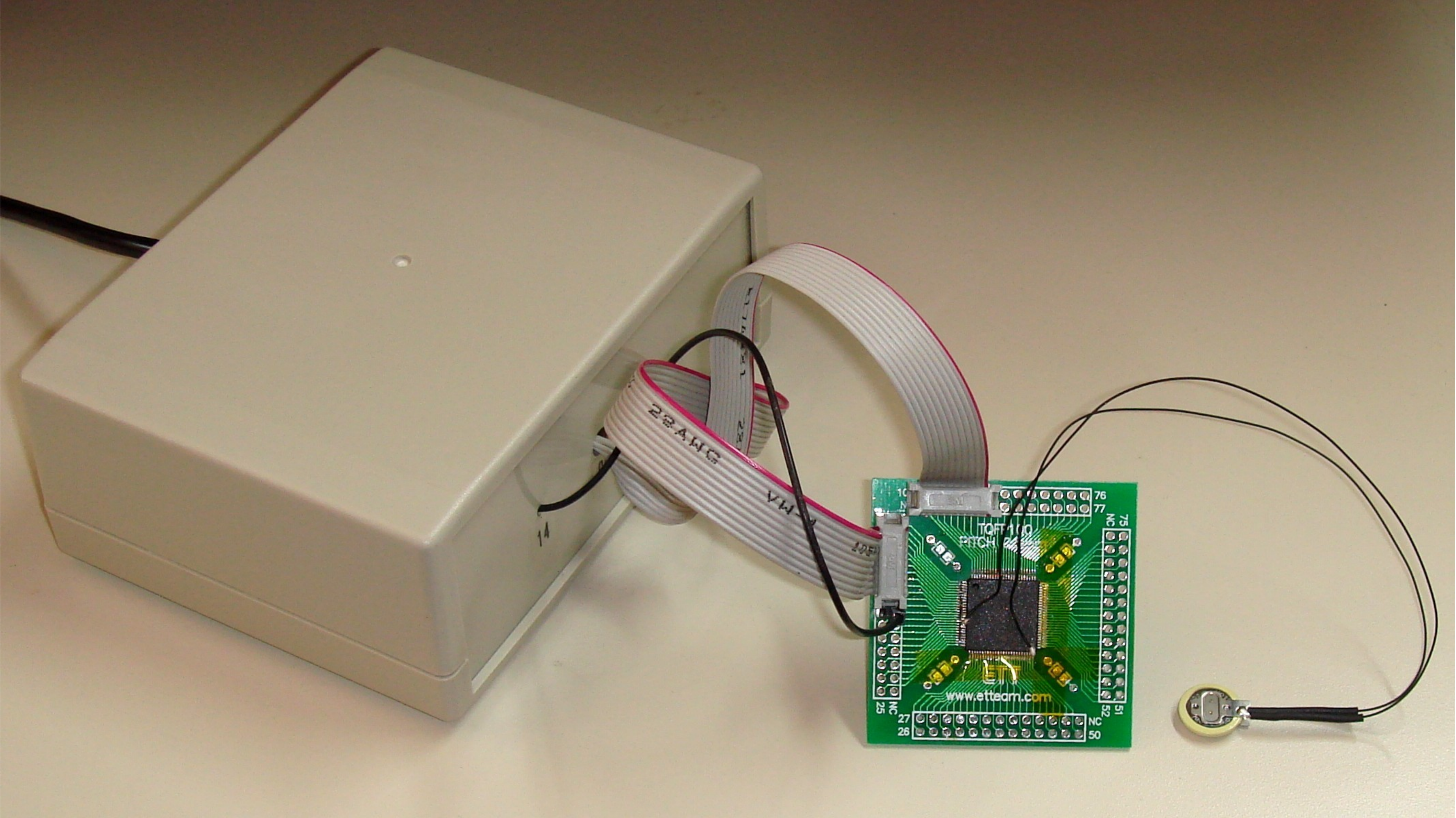
Adapt glitcher to work on ACP in-circuit

or

Remove ACP from STB without losing RAM contents


TQFP100
PITCH 0.5mm
ETT
dental pick
razor blade
cut to shape using
Dremel tool
screwdriver handle


© GIC 1998
XC 420061-003
HEX9945
015
474
R927
C927
C911
C240
U200
TD01


22AWG
ETT
www.etteam.com

Transport Stream scrambling

188-byte TS packet

```
47 12 34 00
01 01 01 01 01 01 01 01  02 02 02 02 02 02 02 02  03 03 03 03 03 03 03 03  04 04 04 04 04 04 04 04
05 05 05 05 05 05 05 05  06 06 06 06 06 06 06 06  07 07 07 07 07 07 07 07  08 08 08 08 08 08 08 08
09 09 09 09 09 09 09 09  10 10 10 10 10 10 10 10  11 11 11 11 11 11 11 11  12 12 12 12 12 12 12 12
13 13 13 13 13 13 13 13  14 14 14 14 14 14 14 14  15 15 15 15 15 15 15 15  16 16 16 16 16 16 16 16
17 17 17 17 17 17 17 17  18 18 18 18 18 18 18 18  19 19 19 19 19 19 19 19  20 20 20 20 20 20 20 20
21 21 21 21 21 21 21 21  22 22 22 22 22 22 22 22  23 23 23 23 23 23 23 23
```

4-byte header

23 blocks of 8 bytes crypted data

Analyzing scrambling

- Flip bits in ciphertext to observe results in decrypted result (CBC/ECB/OFB modes)
  - *one bit flipped corrupts one 8-byte block plus corresponding bit in next block: CBC mode*
- Observe timing of decryption, look for changes in timing due to algorithm differences
  - *changes to algorithm such as number of rounds should have effect on timing*
- Use DES HW as oracle
  - *send test data through ACP, controlling data, key, and all H/W registers*
- Use DES weak keys (all 0 or all 1) and observe if behaviour matches standard DES
  - *encryption and decryption operations are equivalent when using key made of all 0 or all 1 bits*

DES “weak keys”

Weak key

```
   DES key: 00 00 00 00 00 00 00
 Plaintext: 01 23 45 67 89 AB CD EF
 Encrypted: 61 7B 3A 0C E8 F0 71 00

   DES key: 00 00 00 00 00 00 00
Ciphertext: 01 23 45 67 89 AB CD EF
 Decrypted: 61 7B 3A 0C E8 F0 71 00
```

With DES key of all zero bits, encryption and decryption have same effect.

Non-weak key

```
   DES key: 80 00 00 00 00 00 00
 Plaintext: 01 23 45 67 89 AB CD EF
 Encrypted: F2 C4 69 25 D1 0D 86 BD

   DES key: 80 00 00 00 00 00 00
Ciphertext: 01 23 45 67 89 AB CD EF
 Decrypted: 00 7B 46 D4 9E AA 83 60
```

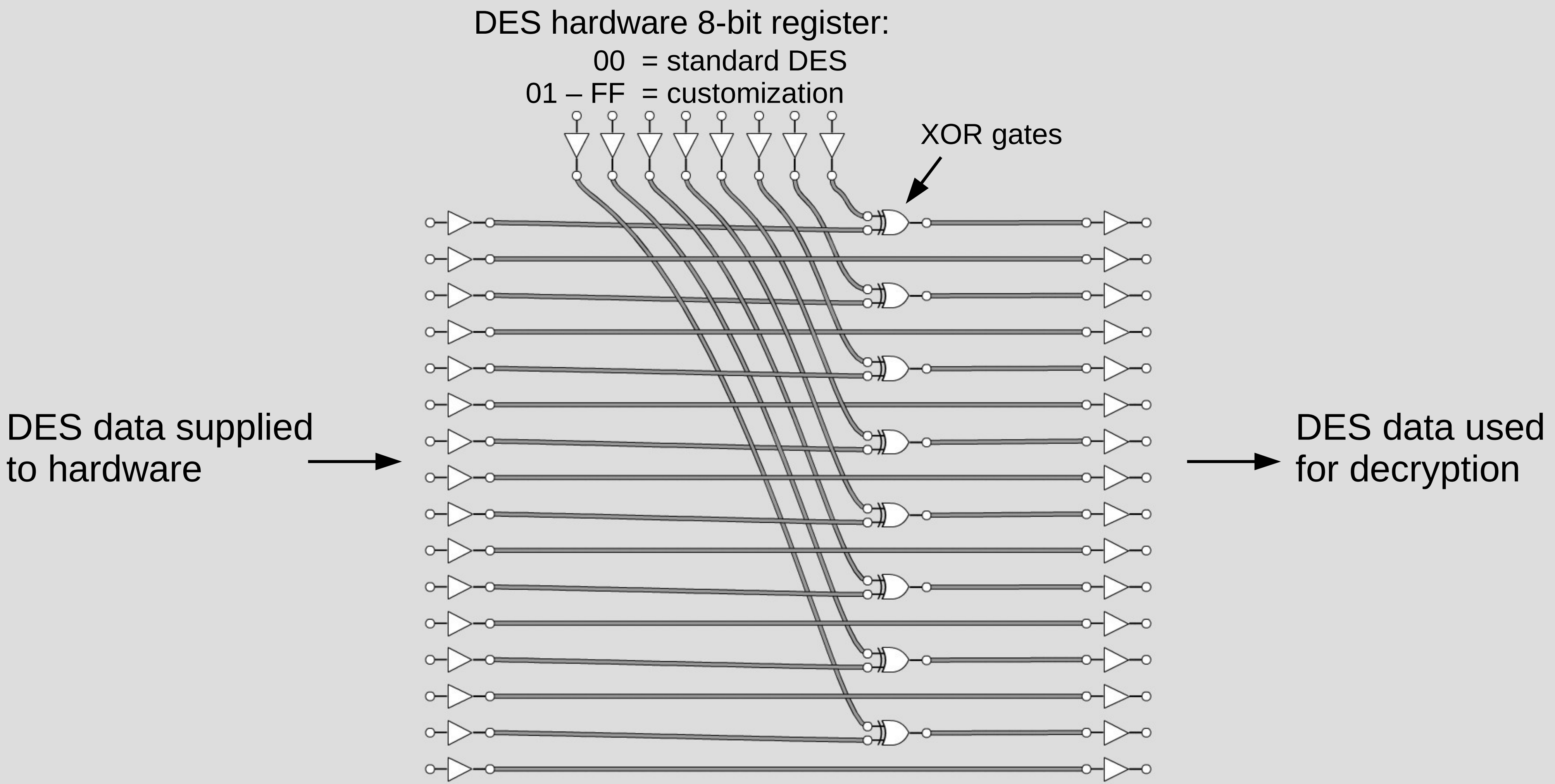
If even one bit is nonzero, encryption and decryption produce different effects.

Cracking Hardware Customization: DES key XOR taps

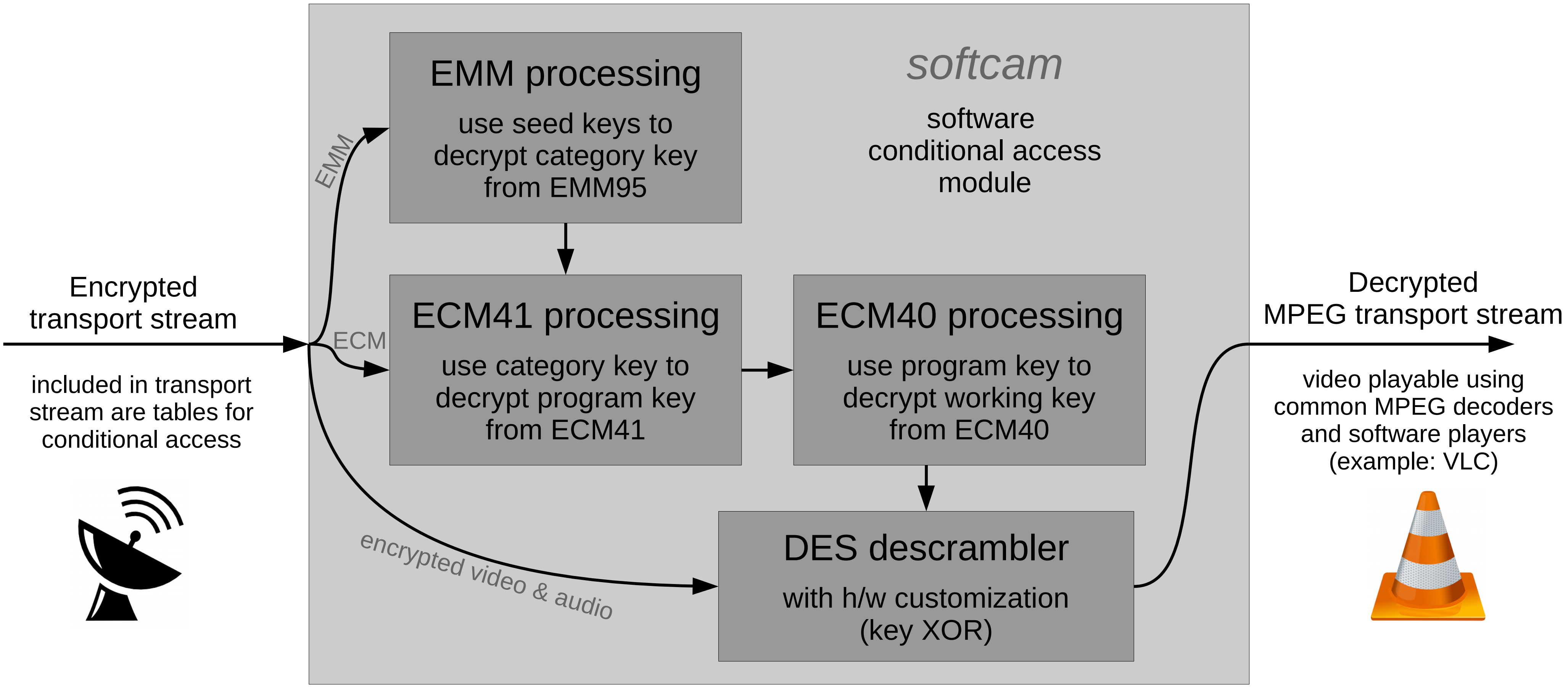
- Using H/W DES engine: Decrypt 23 blocks of 00 data, with 00 key, and customization enabled
- In software: Try decrypting 00 data with all combinations of key having 1 or more bits flipped
- Check for decryption matching any of the 23 blocks
- Positive results seen within seconds – some XOR masks have as few as 3 bits set

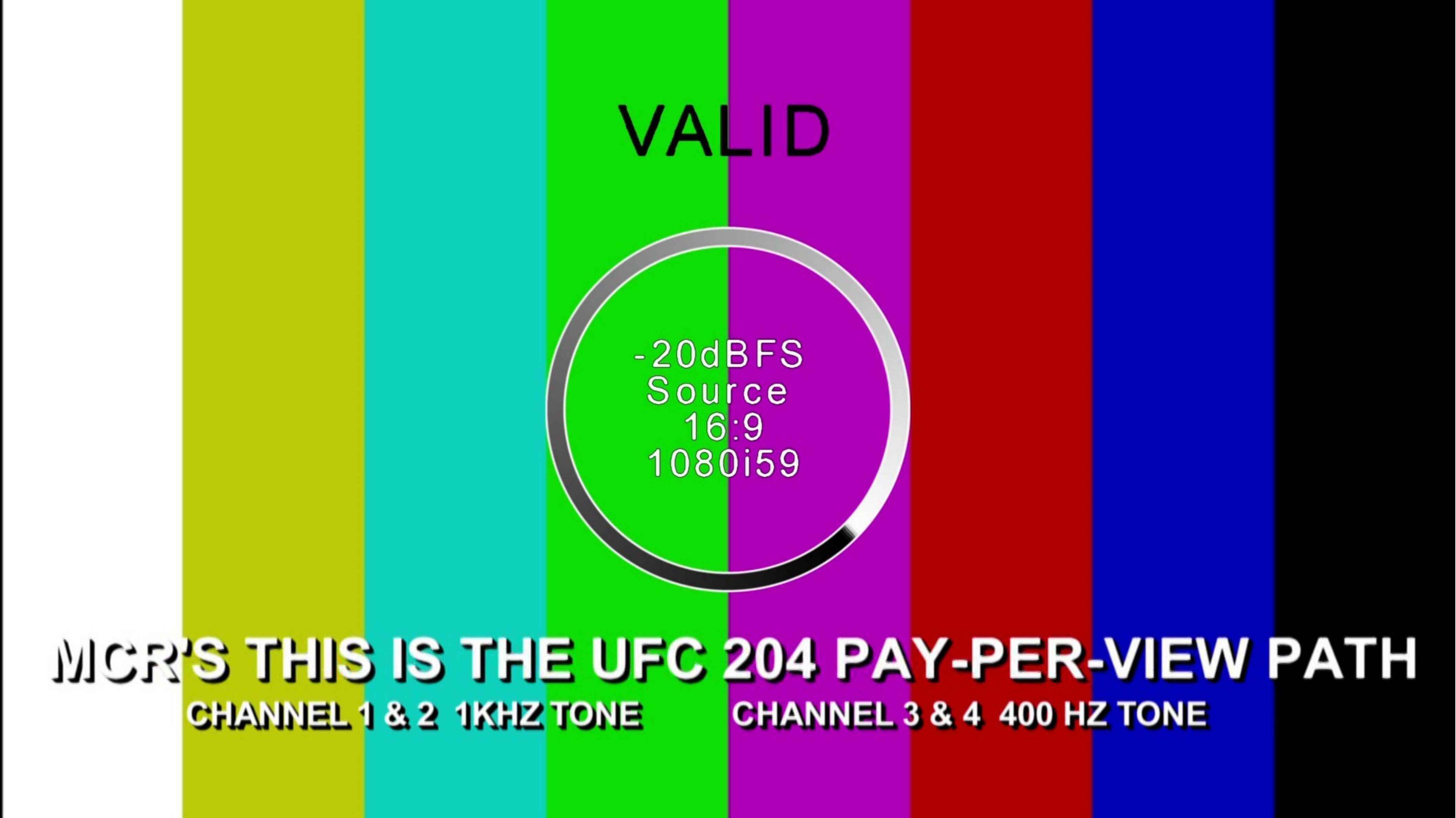
```
for( flip[0] = -1; flip[0] < 56; flip[0]++ ) {                 // loop through all bit positions
 for( flip[1] = -1; flip[1]<56; flip[1]++ ) {
   if( flip[1] <= flip[0] && flip[0] != -1 ) continue;         // don't need to test with bits already tested flipped
   for( flip[2] = -1; flip[2]<56; flip[2]++ ) {
     if( flip[2] <= flip[1] && flip[1] != -1 ) continue;
     for( flip[3] = -1; flip[3]<56; flip[3]++ ) {
       if( flip[3] <= flip[2] && flip[2] != -1 ) continue;
       for( flip[4] = -1; flip[4]<56; flip[4]++ ) {
         if( flip[4] <= flip[3] && flip[3] != -1 ) continue;
         for( flip[5] = -1; flip[5]<56; flip[5]++ ) {
           if( flip[5] <= flip[4] && flip[4] != -1 ) continue;
           for( flip[6] = -1; flip[6]<56; flip[6]++ ) {
             if( flip[6] <= flip[5] && flip[5] != -1 ) continue;
             for( flip[7] = -1; flip[7]<56; flip[7]++ ) {
               if( flip[7] <= flip[6] && flip[6] != -1 ) continue;
               for( flip[8] = -1; flip[8]<56; flip[8]++ ) {
                 if( flip[8] <= flip[7] && flip[7] != -1 ) continue;
                 for( flip[9] = -1; flip[9]<56; flip[9]++ ) {
                   if( flip[9] <= flip[8] && flip[8] != -1 ) continue;
                   for( flip[10] = -1; flip[10]<56; flip[10]++ ) {
                     if( flip[10] <= flip[9] && flip[9] != -1 ) continue;
                     for( flip[11] = -1; flip[11]<56; flip[11]++ ) {
                       if( flip[11] <= flip[10] && flip[10] != -1 ) continue;
                       for( flip[12] = -1; flip[12]<56; flip[12]++ ) {
                         if( flip[12] <= flip[11] && flip[11] != -1 ) continue;
                         for( flip[13] = -1; flip[13]<56; flip[13]++ ) {
                           if( flip[13] <= flip[12] && flip[12] != -1 ) continue;
                           for( flip[14] = -1; flip[14]<56; flip[14]++ ) {
                             if( flip[14] <= flip[13] && flip[13] != -1 ) continue;
                             for( flip[15] = -1; flip[15]<56; flip[15]++ ) {
                               if( flip[15] <= flip[14] && flip[14] != -1 ) continue;

                               for( i=0; i<8; i++ ) {
                                 des_key[i] = 0;                            // initialize des_deskey[] to all zero key
                                 des_data[i] = 0;                           // initialize des_data[] to all zero ciphertext
                               }

                               for( i=0; i<16; i++ )
                               {
                                 if( flip[i] >= 0 )                         // XOR bits that are selected for this test
                                   des_key[flip[i]/7] ^= 1<<((flip[i]%7)+1);   // the +1 is because bit 0 is parity bit (unused)
                               }

                               ecb_crypt( (char *)des_key, (char   *)des_data, 8, DES_DECRYPT );

                               for( i=0; i<encrypted_blocks; i++ ) {        // check des_data[] against encrypted blocks for a match
                                 for( n=0; n<8; n++ )
```

Cracking Hardware Customization: DES data XOR taps



Softcam implementation




VALID
-20dBFS
Source
16:9
1080i59
MCR'S THIS IS THE UFC 204 PAY-PER-VIEW PATH
CHANNEL 1 & 2 1KHZ TONE
CHANNEL 3 & 4 400 HZ TONE

Weaknesses

- Relatively old technology – easier for invasive analysis today
  - TQFP100 package easy to deal with compared to modern alternatives
- Voltage glitching
- Von Neumann architecture, no strong MMU protection
- No possibility for code updates for countermeasure purposes
- Hardware crypto customizations are simple

Strengths

- Key handling and decryption contained within single chip makes it difficult to do key sharing.
- Fast working key change interval (133 ms) makes key sharing difficult.
- No possibility for code update means nowhere to write code for permanent backdoor.
- Internal CLK prevents clock glitching.
- Dead addresses to prevent linear readout of keys.
- Personalization ROM appears to be inaccessible.
- Keys kept only in RAM – must maintain battery backup at all times!
  - Keys appear non-rewritable, preventing cloning units.
- No group keys for EMMs – all unit addressing is to individual units.
  - Must pull keys from a subscribed box in order to get active keys.
- Software appears generally well-designed and written.
- Although DES is used, EMMs are signed using 3 DES keys.
  - Multiple rounds of DES are used, increasing brute force complexity.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