Proprietary RFID Systems

CanSecWest '08

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Starbug

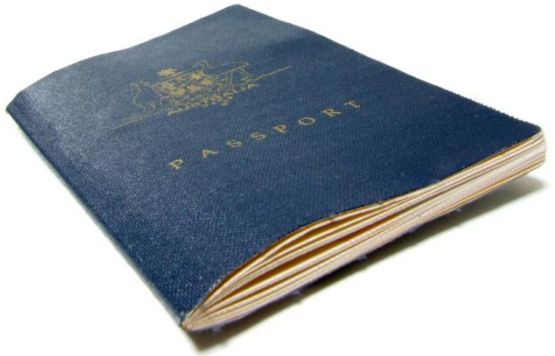
RFID tags

- Radio Frequency IDentification
- Tiny computer chips
- Passively Powered

RFID Applications

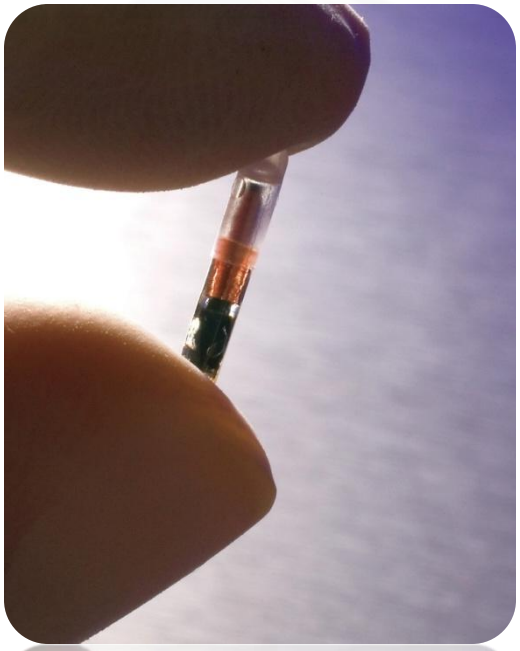
- RFIDs become ubiquitous
- Integrated in many *security* applications
  - Payment
  - Access Control
  - Car Ignition

RFID Trends



- Passports
- Implants
- …

RFIDs become *universal identifier*. Might replace passwords, PINs, and fingerprints.

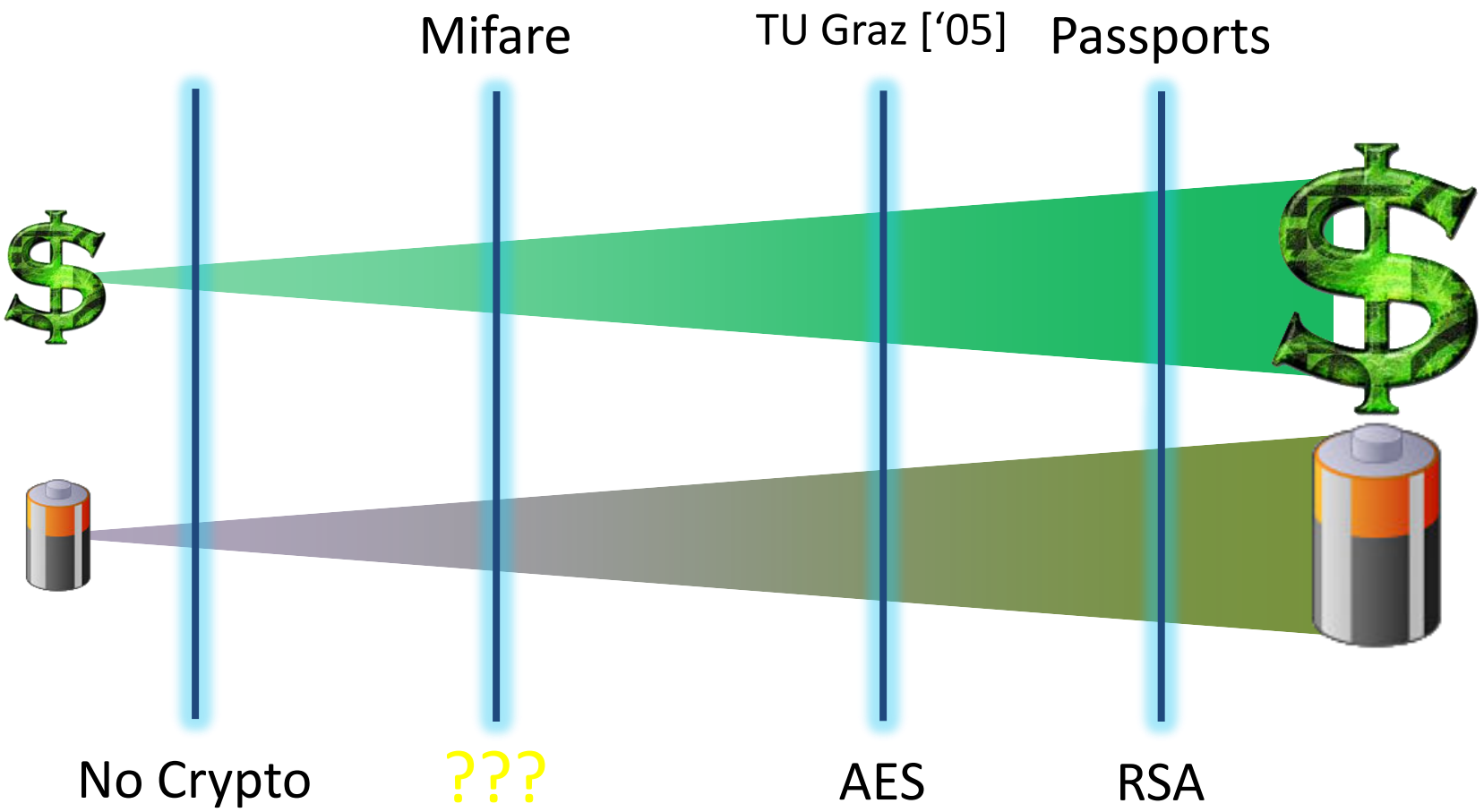


RFID Trends (II)

- Tagging of consumer goods
  - Will replace bar-codes!

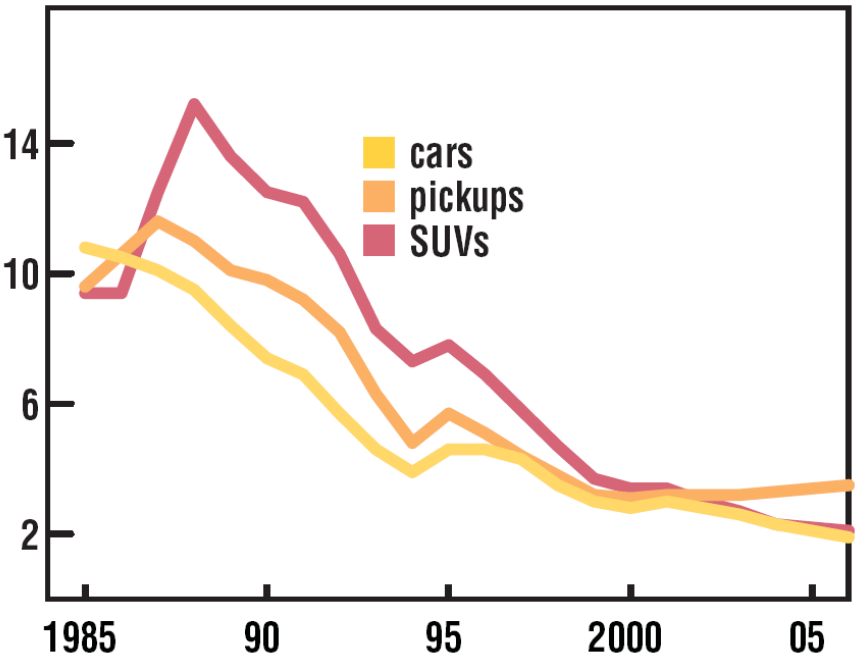
- Threat to *Privacy*
  - Customer tracking
  - Leaks internal business information!

RFID-Crypto Mismatch



Mifare Security

- NXP claimed:
  - “approved authentication”
  - “advanced security levels”
- 48 bit key



Car thefts
(source: hldi.org)

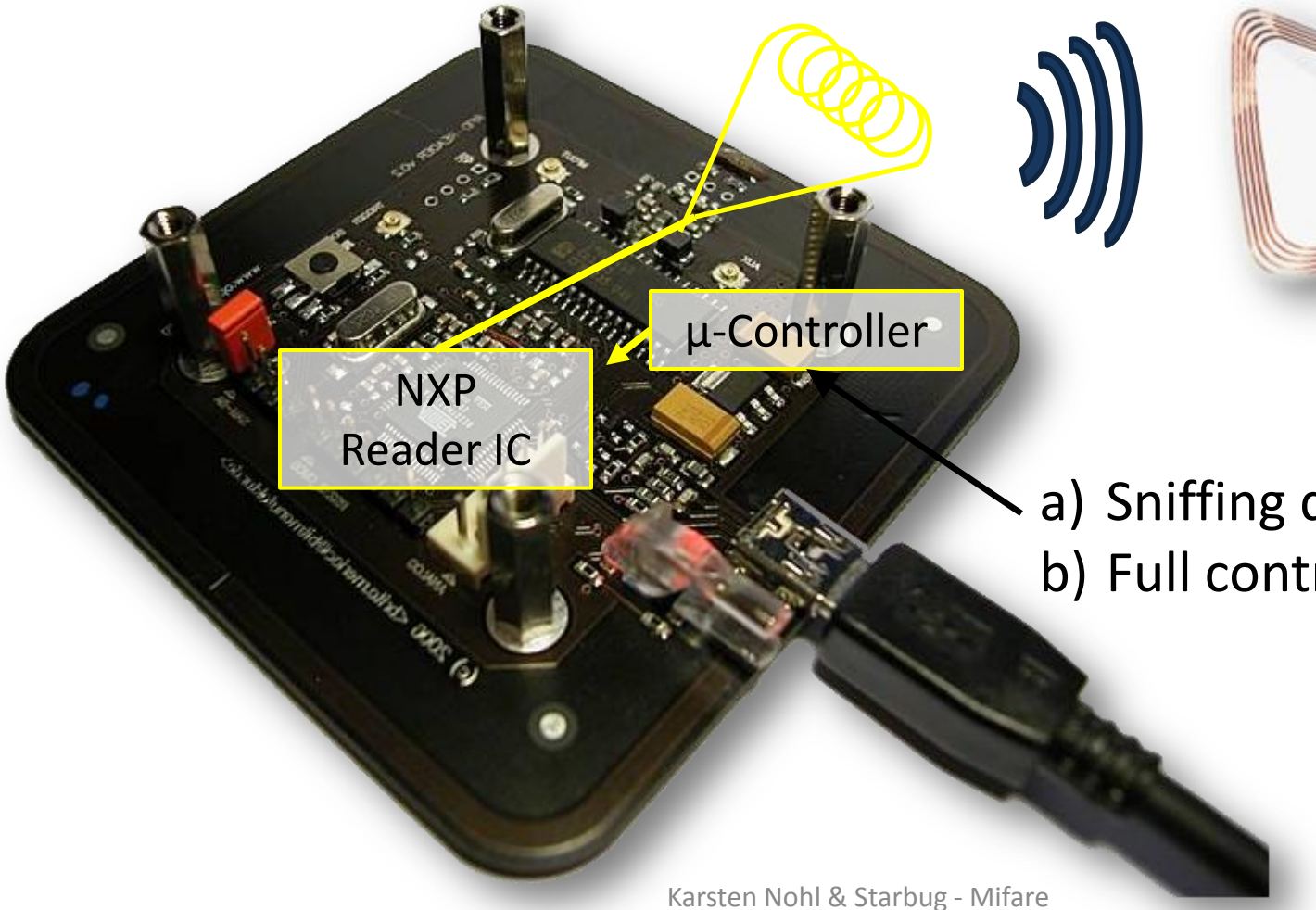
Our Project

Reverse-engineering of the Mifare crypto and evaluating its security

- Reconstruct circuit from photos of chip
- Sniff reader-tag communication

verify

Hardware: OpenPCD (+PICC)

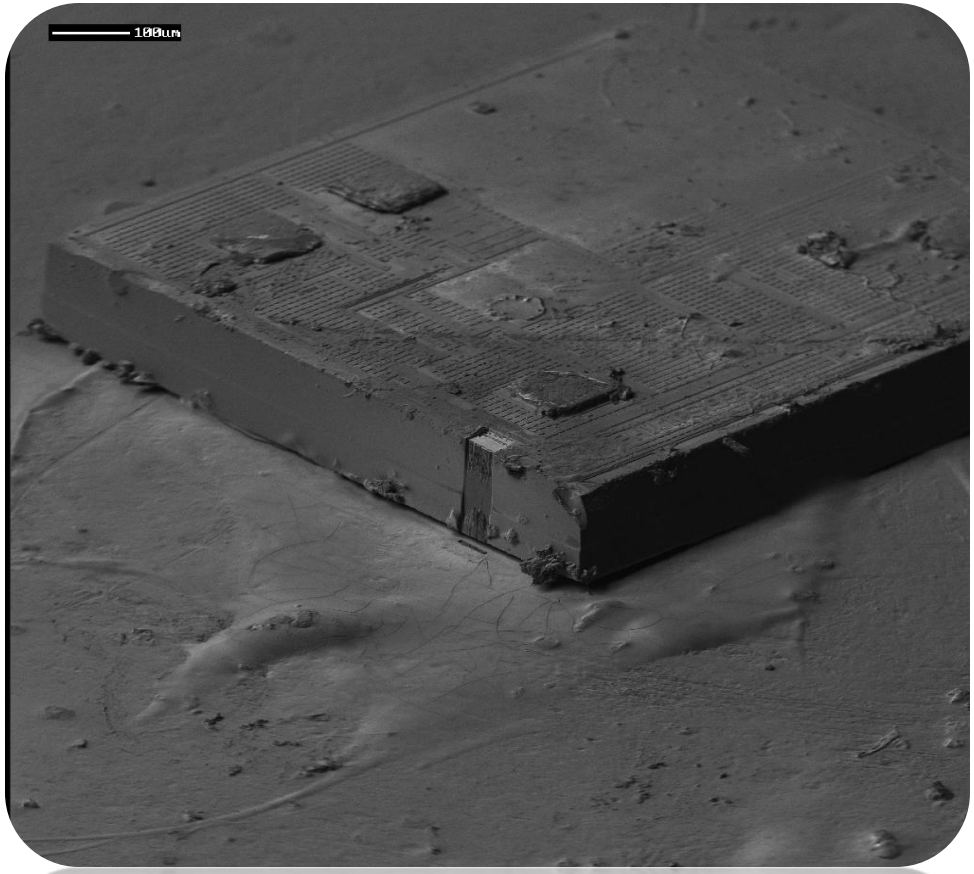


a) Sniffing data
b) Full control over timing!

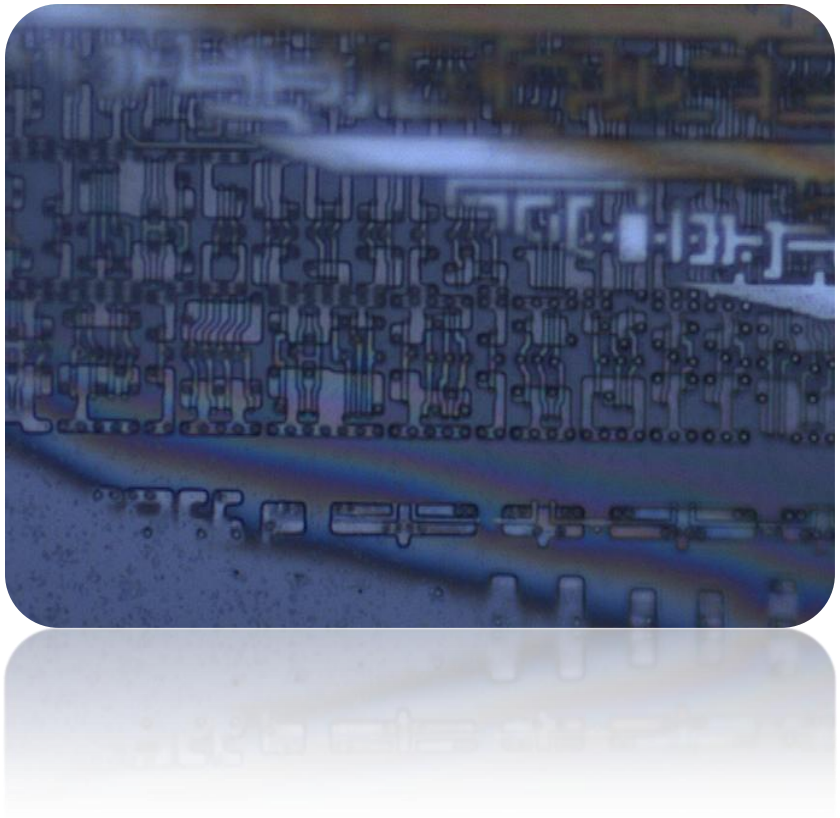
Obtaining Chips

- Extract chip from card or token using chemicals:
  - acetone
  - fuming nitric acid
- Shortcut: buy blank chips!

Mifare RFID tag



Getting Ready to Polish



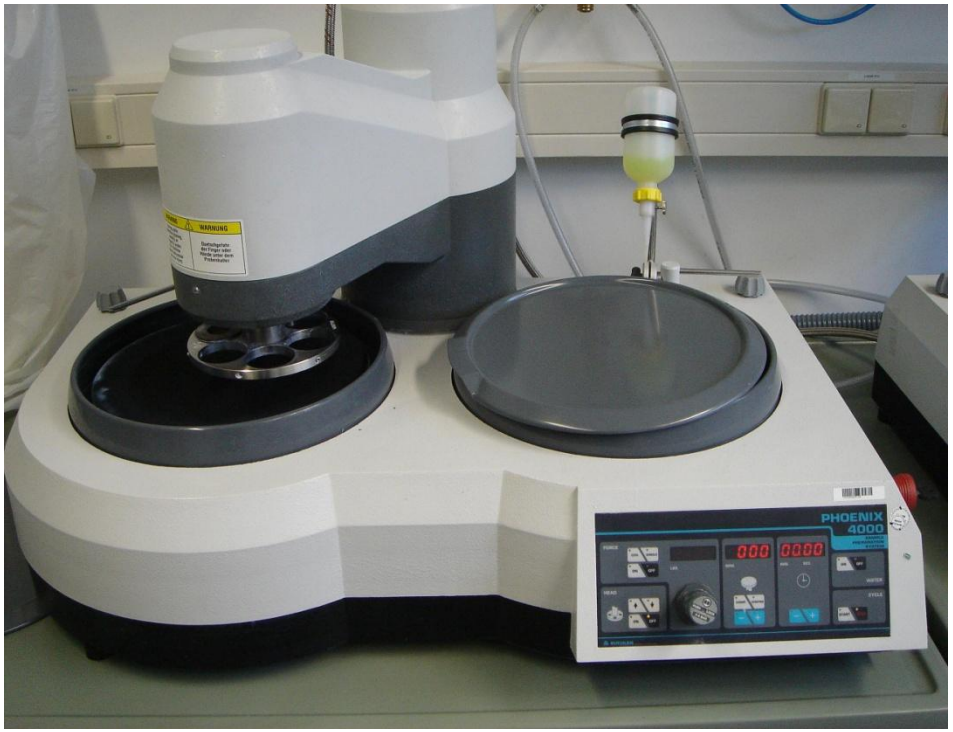
- Embed chip in plastic
  - Downside: tilt

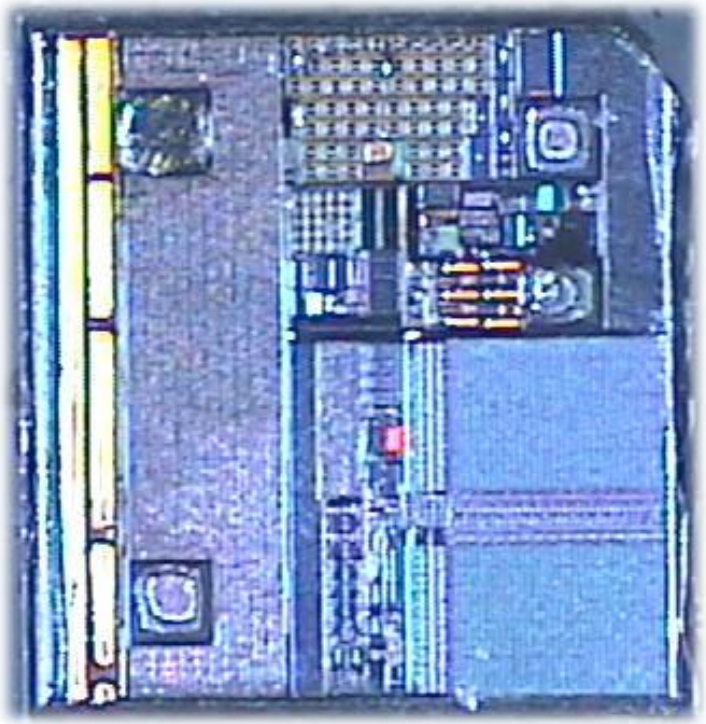
Alternative:

- Glue back of chip to plastic plate
  - Good results since backside is mostly plane

Polishing

- Manual or automatic
  - Polishing paper (0.3µm)
  - Polishing fluid (0.04µm)

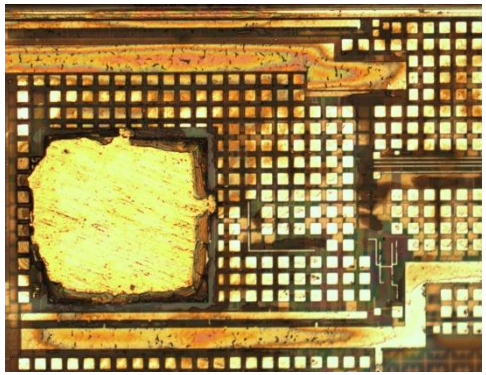




Imaging Chip

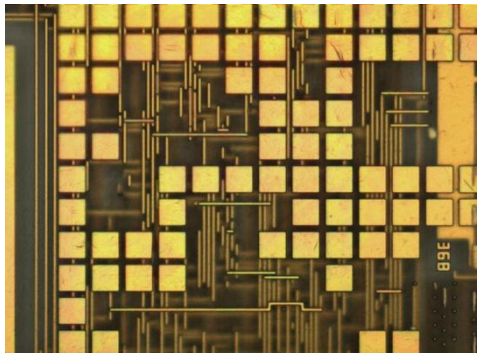
- Optical microscope (Zeiss)
  - 500x magnification
  - Camera 1 Mpixel
  - Black and white
- Stitching 2 x 10 images
  - Panorama software (hugin)
  - Each image ~100x100 µm
- Align different layers

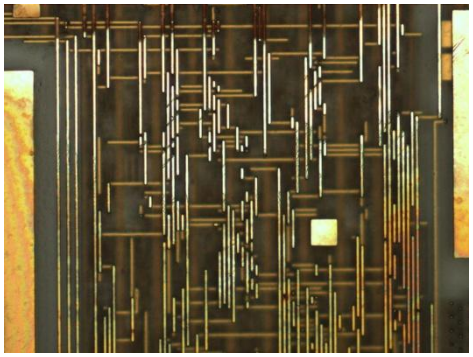
Chip Layer

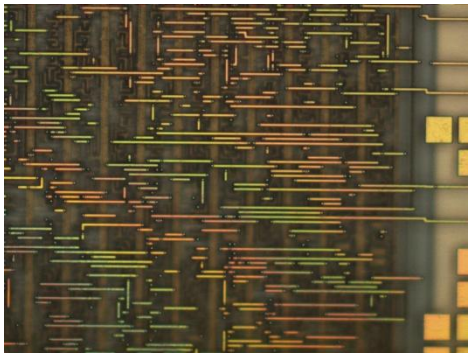


Cover layer

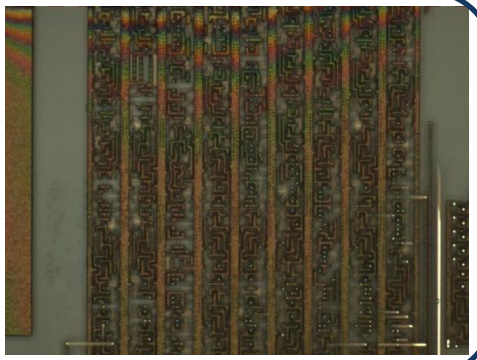
3 interconnection layer

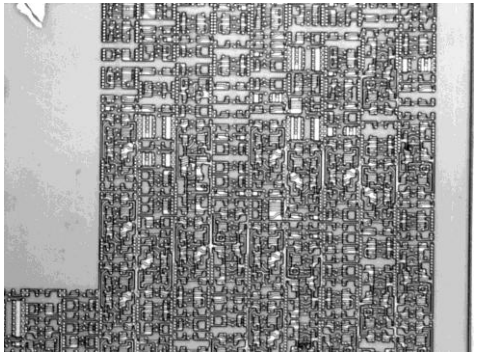






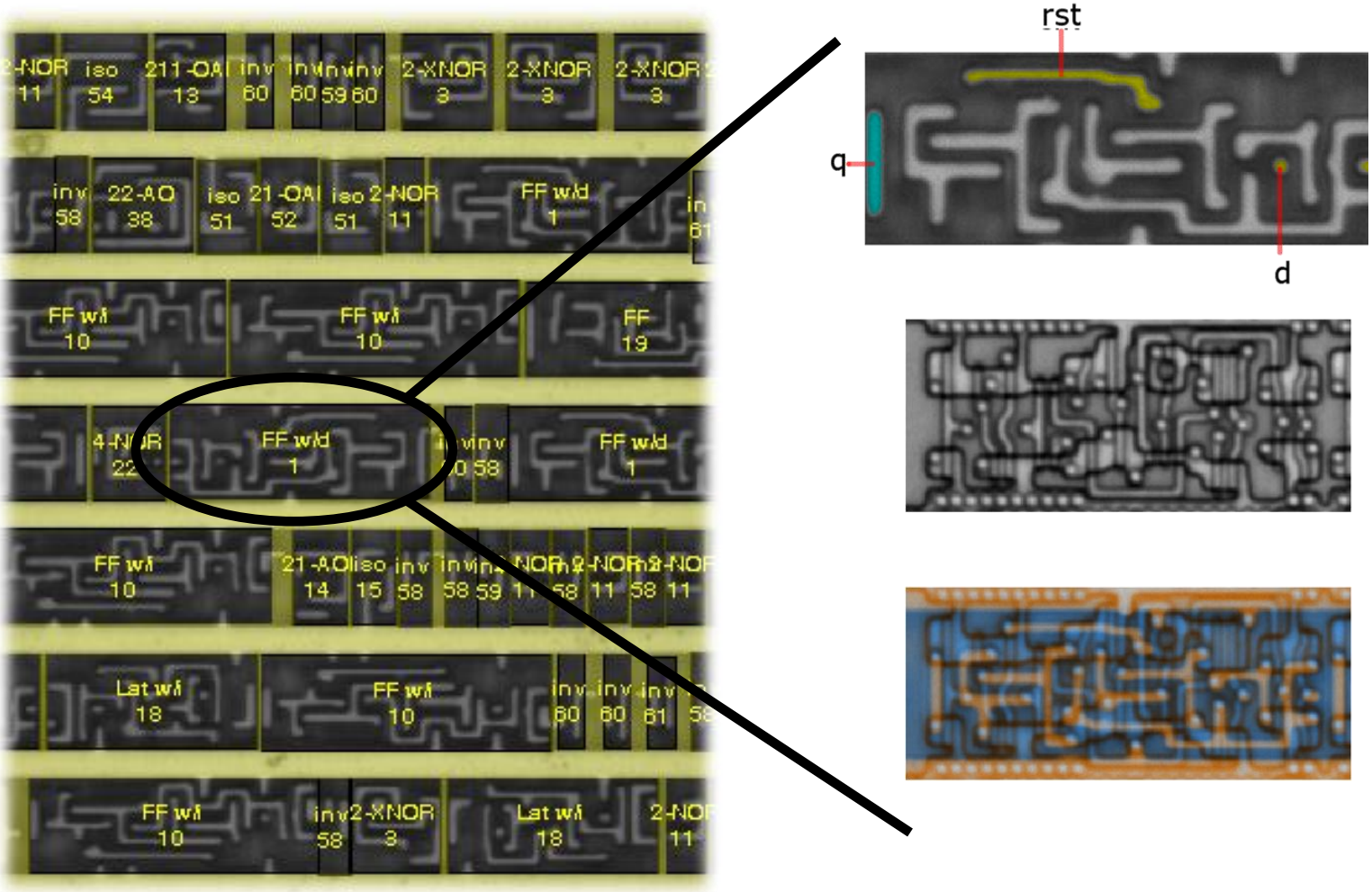
Logic layer





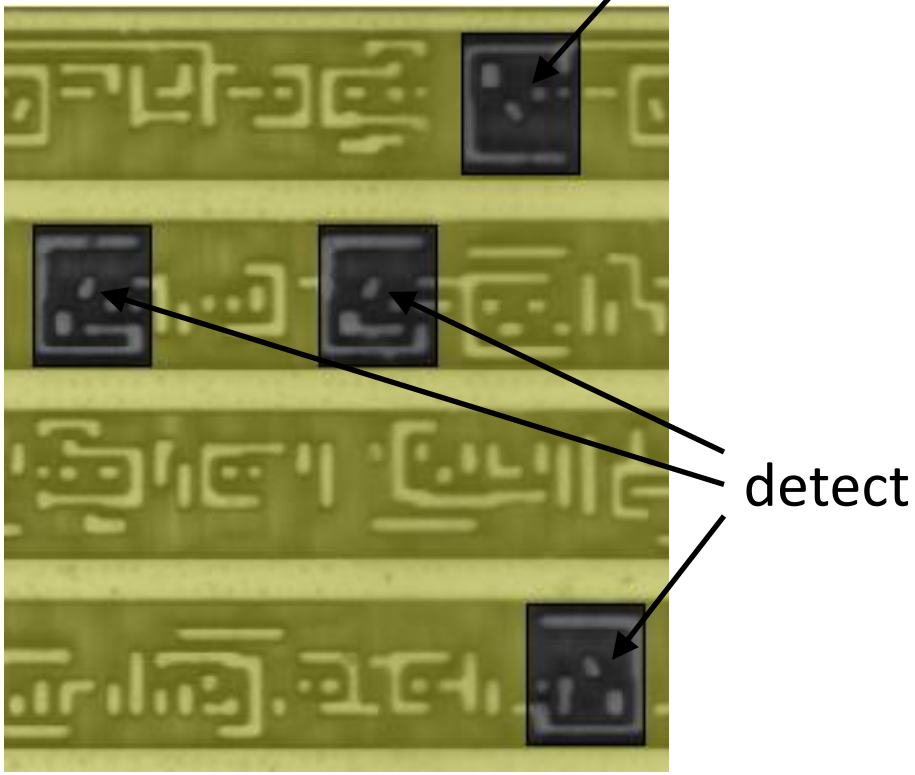
Transistor layer

Logic Gates



Logic Gates Library

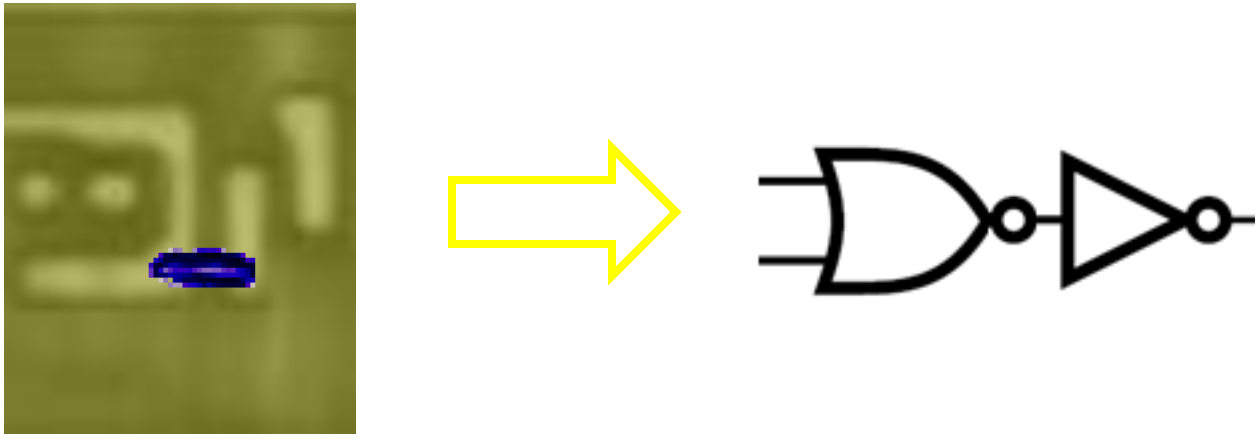
- Chip has several thousand gates
- But only ~70 different types
  - Detection can be automated



Tracing Connections

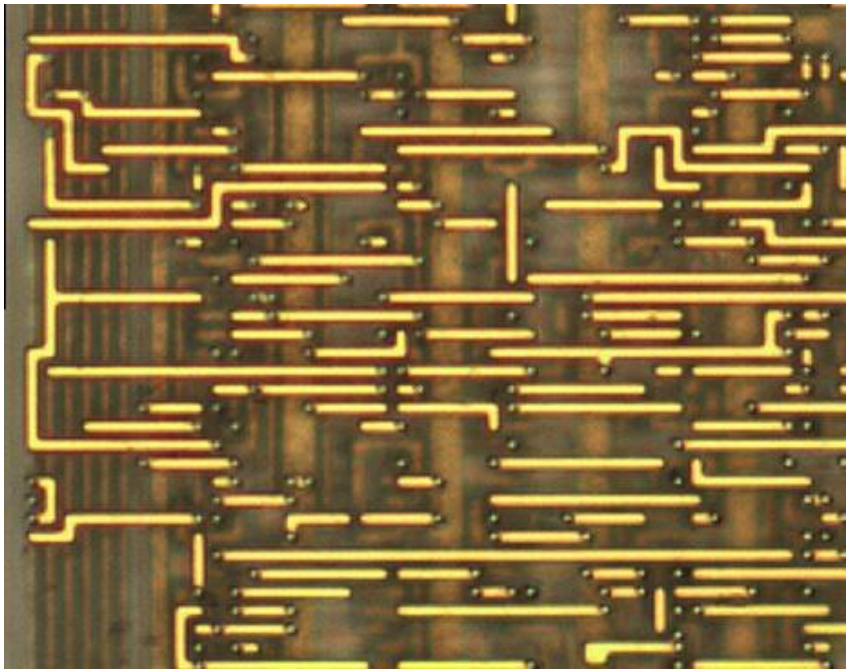
Logic Gates Interconnect

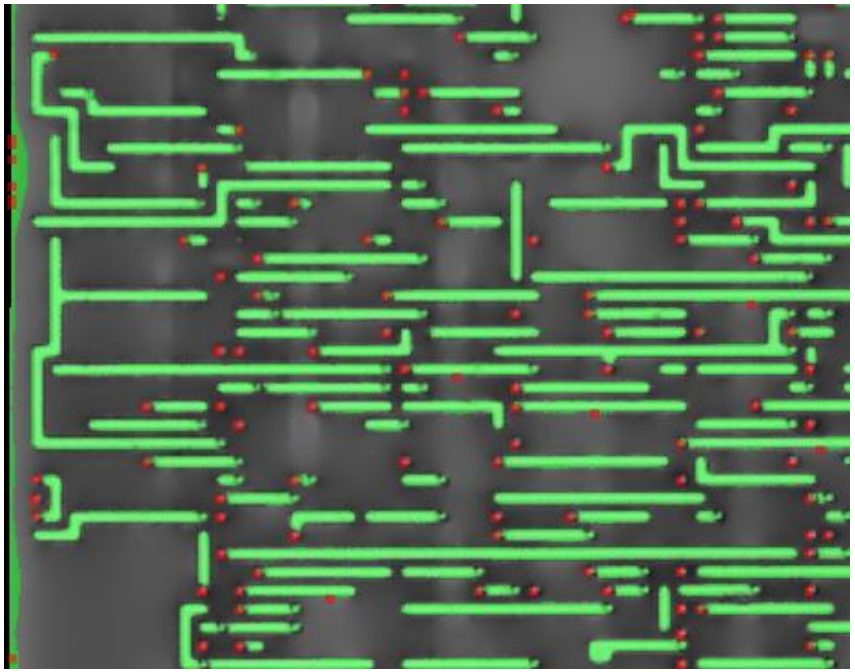
- Connections across all layers



- Traced 1500 (!) connections manually
  - Tedious, time consuming
  - Error-prone, (but errors easily spottable)

Automated Tracing





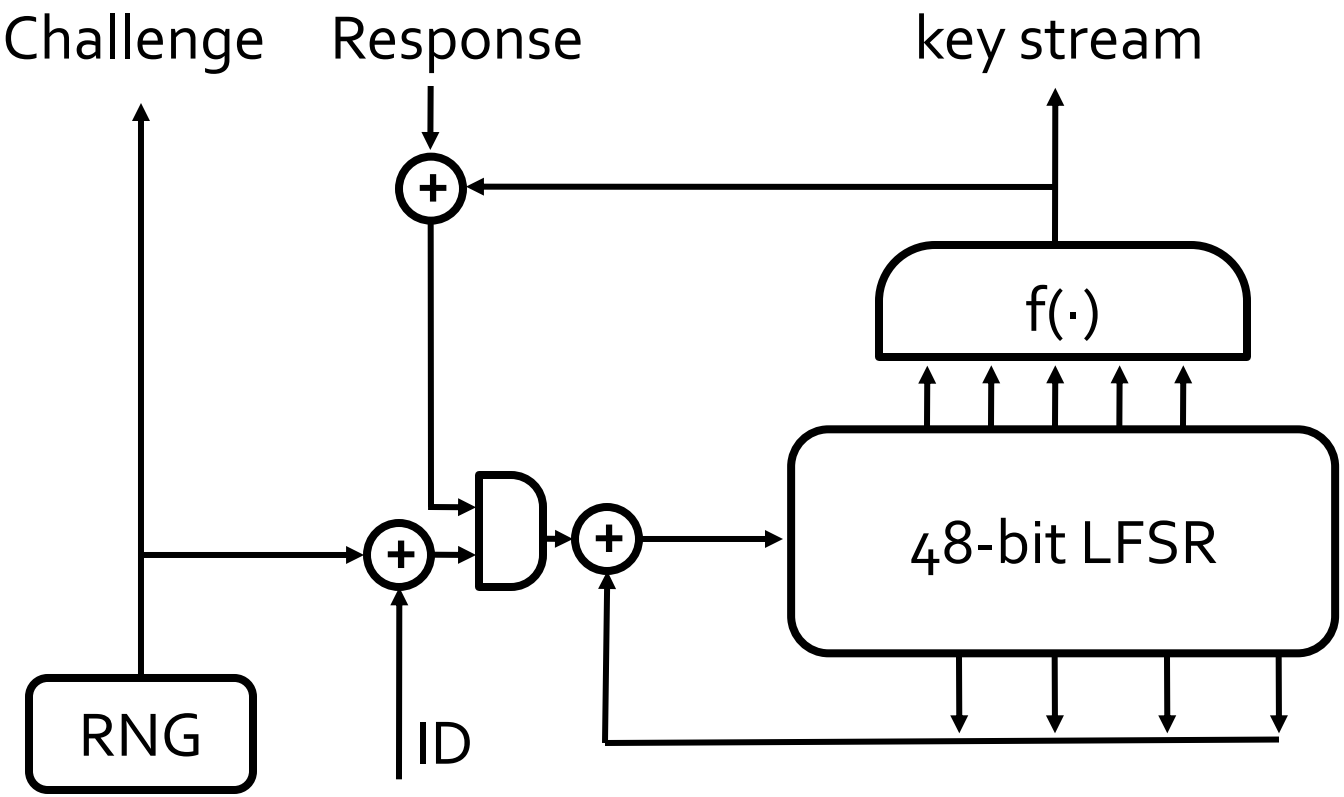
Metal wire

Intra-layer via

Encircle Crypto

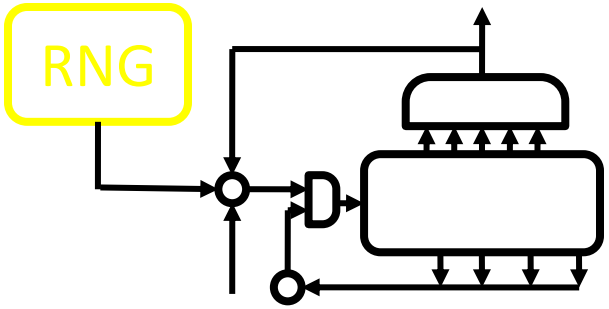
- Even tiny RFID chip too large to analyze entirely
  - Crypto <10% of gates!
- Focus on interesting-looking parts:
  - Strings of flip-flops (registers)
  - XOR
  - Units around edges that sparsely connected to the rest of the chip

Mifare Crypto-1



Random Number Generator

- 16(!!)-bit random numbers
  - LFSR –based
  - Value derived from time of read



Our Attack:

- Control timing (OpenPCD)

  = control random number (works for tag and reader!)

  = break Mifare security :)

Linear feedback shift register

From Wikipedia, the free encyclopedia
(Redirected from LFSR)

A **linear feedback shift register** (LFSR) is a shift register whose input bit is a linear function of its previous

The only linear functions of single bits are xor and inverse-xor; thus it is a shift register whose input bit is driv

The initial value of the LFSR is called the seed, and because the operation of the register is deterministic, the state. Likewise, because the register has a finite number of possible states, it must eventually enter a repeat which appears random and which has a very long cycle.

Applications of LFSRs include generating pseudo-random numbers, pseudo-noise sequences, fast digital cou common.

Fibonacci LFSRs

The list of the bits' positions that affect the next state is called the tap sequence. In the diagram below, the s the output and then feed back into the leftmost bit.

- The outputs that influence the input are called *taps* (blue in the diagram below).
- A maximal LFSR produces an n-sequence (i.e. cycles through all possible $2^n - 1$ states within the shift reg never change.

The sequence of numbers generated by an LFSR can be considered a binary numeral system just as valid as

The tap sequence of an LFSR can be represented as a polynomial mod 2. This means that the coefficients of polynomial. For example, if the taps are at the 16th, 14th, 13th and 11th bits (as below), the resulting LFSR p

$$x^{16} + x^{14} + x^{13} + x^{11} + 1$$

The 'one' in the polynomial does not correspond to a tap - it corresponds to the input to the first bit (i.e. x^0, wh The first and last bits are always connected as an input and tap respectively.

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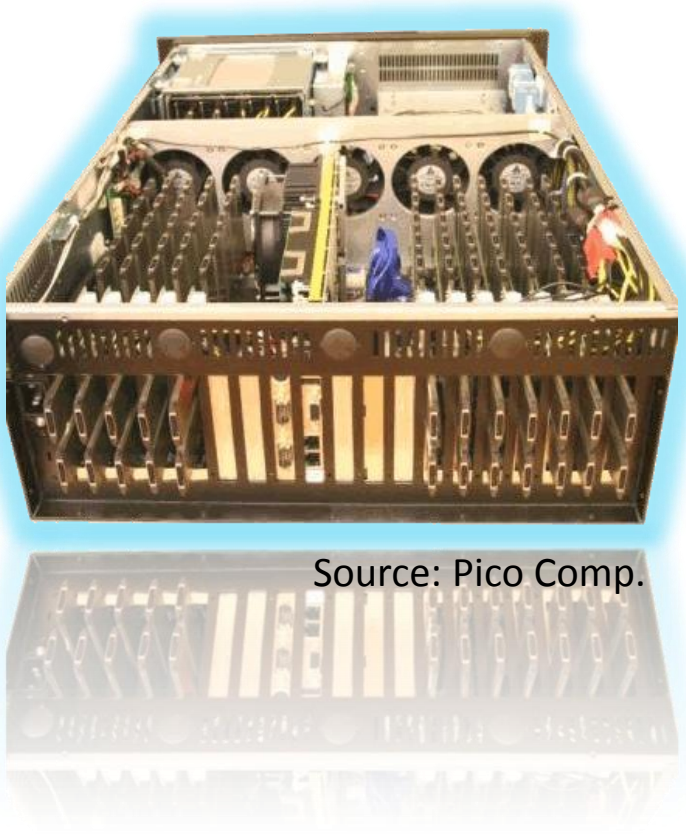
For Starters: Brute-Force

- Cipher complexity low
  - Has probably been a primary design goal
  - Allows for very efficient FPGA implementation

$1000 key cracker finds key in days! (much faster even when trading space for time)

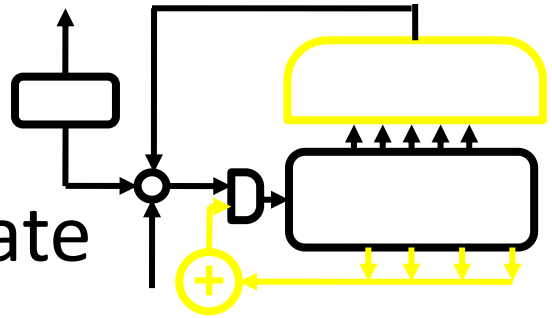


Source: Pico Comp.

Structural Weaknesses

1) Filter function is biased

→ Output bits disclose cipher state



2) No non-linear component in feedback loop

→ Cipher state discloses key

Attack on key faster than brute-force (known-plaintext)

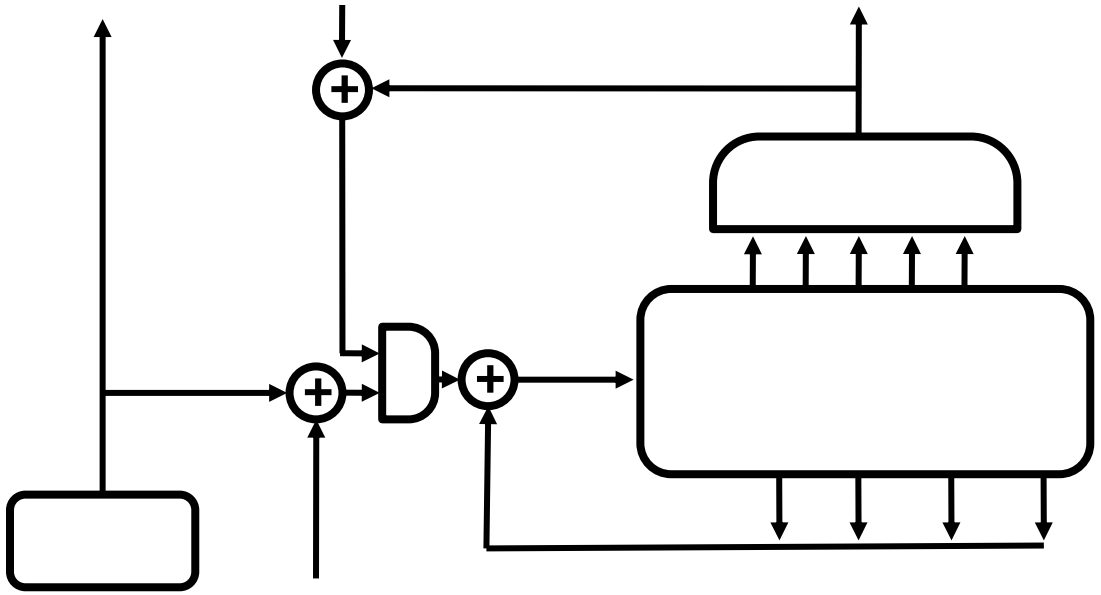
Mifare Security

- Protection perhaps sufficient to protect transactions of very small value
  - E.g., Micro-payments, privacy
- Security too weak for:
  - Access control, car theft protection, credit cards, …

Lessons Learned

- Obscurity and proprietary crypto add security only in the short-run
  - (but lack of peer-review hurts later)
- Constraints of RFIDs make good crypto extremely hard
  - Where are the best trade-offs?
  - How much security is needed?

Questions?



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