Smartcards

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Overview

- What is a smartcard?
- Why use smartcards?
- What are the possibilities and limitations of smartcards?
- Attacks on smartcards

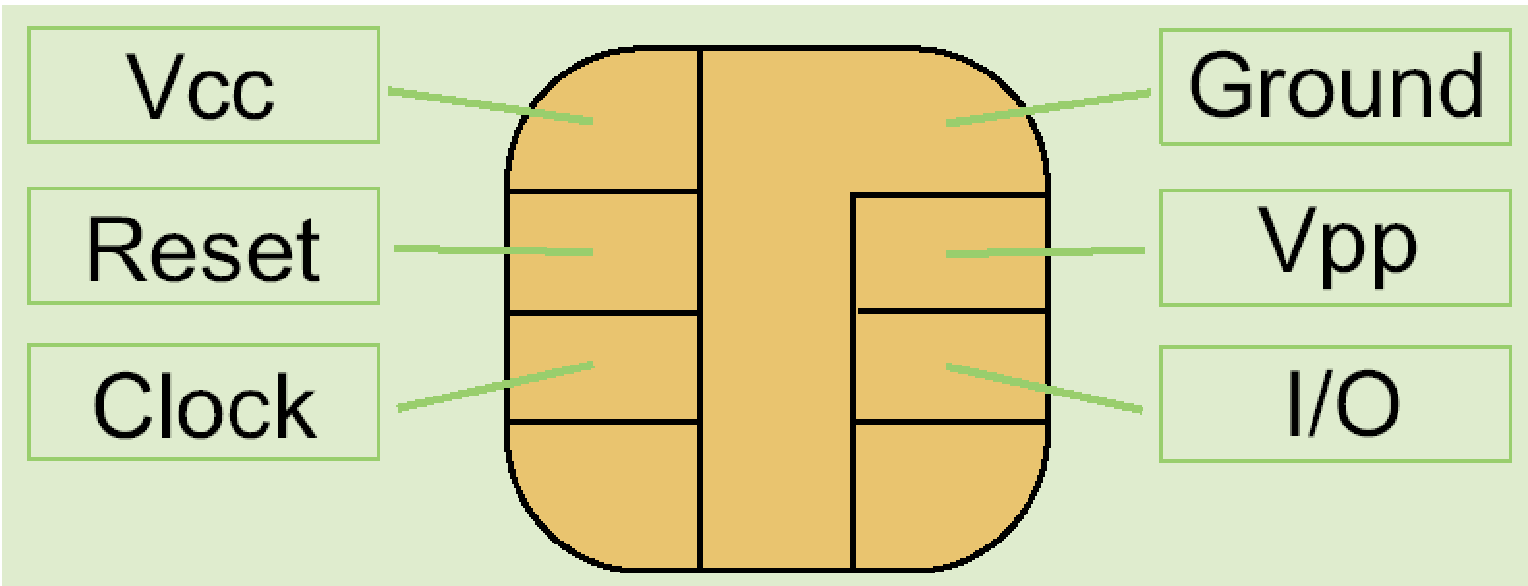
What is a smartcard?

What is a smartcard?

- Tamper-resistant computer, embedded in piece of plastic, with limited resources
- capable of securely
  - storing information
  - processing information

(This is what makes a smartcard smart; stupid cards can store but not process data)

Smartcard contacts



External power supply and external clock

Many modern smartcards are now contactless

Smartcard hardware

- CPU – 8 to 32 bits
- memory
  - RAM
  - ROM (for some program code)
  - EEPROM/Flash/... ("hard disk", for code and data)

  Modern cards may have 1K RAM, 16K ROM, 64K EEPROM
- limited I/O: just a serial port
- possibly: crypto co-processor, random number generator

Smartcard software

- Smartcard contains very simple operating system, capable of executing programs

- Programs can be written in
  - proprietary machine code language, or
  - higher level language, notably Java Card

Most new SIMs are now Java Cards.

Smartcard example uses

- bank card, chipknip
- GSM SIM in mobile phone
- pay TV
- public transport (OV smartcard)
- passport
- student/employee cards to control access buildings, computer networks, ...

Stupid cards

- Stupid cards only store information (securely or insecurely), and can't process it.
- Examples of stupid cards:
  - magnetic-stripe cards
  - some old chipcards are not really smart, because the chip only provides a (passcode protected) file system.

    (Eg chipcard formerly used in pay phones)

Why use smartcards?
What are the possibilities and limitations of smartcards?

Example use of smartcards

- How does electronic purse (chipknip) work?
- How does GSM SIM work?

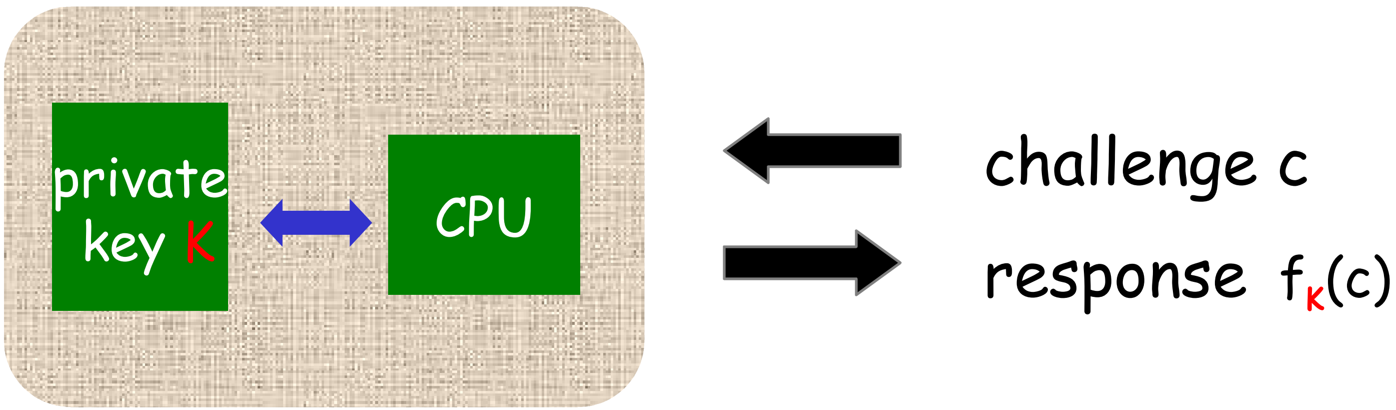
- Where and how do
  - confidentiality
  - integrity
  - authentication
  - non-repudiation

  play a role in these applications?

CIA and smartcards

- Confidentiality:
  - of data (crypto keys) on card
- Integrity:
  - of data and program code
- Authentication:
  - because (data on) card cannot be copied
- Non-repudiation
  - because (data on) card cannot be copied
  - also logging on the smartcard (and integrity of this log)

Typical use of smartcard



- Private key K never leaves the card
- Card issuer does not have to trust the network, the terminal, or card holder

Example: logging on over a network

- Send password unencrypted over net (eg. rlogin)
  Trust network, terminal, user
- Send password encrypted over net (eg. slogin)
  Trust terminal, user
- Idem, but user, not terminal, does encryption

  Trust user
- Using smartcard
  Trust no-one, except the smartcard

(NB smartcard is controlled by card issuer, not card holder!)

NB the problem with cryptography

Any use of crypto introduces problems:

1. key distribution
   - how do we generate & distribute keys?
2. key storage
   - where can we safely store keys?
3. en/decryption
   - who do we trust to perform en/decryption?

Smartcards can offer a solution

Smartcard vs mag-stripe cards

- Smartcard cannot easily be copied or altered, unlike a mag-stripe card
- Copying mag-stripe cards - skimming – is big criminal business, as copying cards, and observing PIN codes, is easy...

Skimming

Skimming

Skimming

Skimming

Example: checking PIN codes

- How can an ATM check PIN codes
  - for mag-stripe card?
  - for smartcard ?

Example: internet banking

- Some internet banking systems use smartcard reader with display
- Why not use smartcard reader in my PC ?
  - better to have simple reader rather than complicated PC not part of TCB
  - possibility of a malicious code on PC
  - typing PIN code on PC not acceptable

TCB and smartcards

- Smartcard typically part of the TCB (Trusted Computing Base), ie. the trusted part of the system
- NB "trusted" is a negative quality: it means "you have to trust it" not "you can trust it"
  - If any part of the TCB fails, security is broken
  - TCB should be as small and reliable as possible

Example: digital signatures

- (How) could smartcard be used to generate digital signatures ?
- What are problems?

- Smartcard limitations (from perspective of card holder):
  - smartcard does not have a (trusted) display
  - smartcard does not have a (trusted) keyboard
  - no way to check if/what the smartcard signs

Attacks on smartcards

Smartcard are not 100% secure

- Growing range of attacks (and associated countermeasures) is known
- Crucial question: is the risk acceptable?
  - are the costs of an attack larger than the potential financial gain for the attacker?
- Threats depend on application
  - eg. cloning more interesting for PayTV than GSM SIMs

Smartcard attacks

- attack confidentiality: eg. get access to keys stored on card, to clone cards
- attack integrity: change data stored on card or change behaviour of card

- Confidentiality and integrity not just important for crypto keys or PIN codes, but also for software on the card and logic implemented in the hardware of the card

Logical attacks

- Find and exploit software bug, using the normal communication channel, eg.
  - hidden commands (eg for initialisation)
  - buffer overflows, eg to read past end of file
  - try to abuse file access privileges
  - exploit weakness in crypto-protocol
  - malicious applet on multi-application smartcard
- No equipment needed, but change of success low

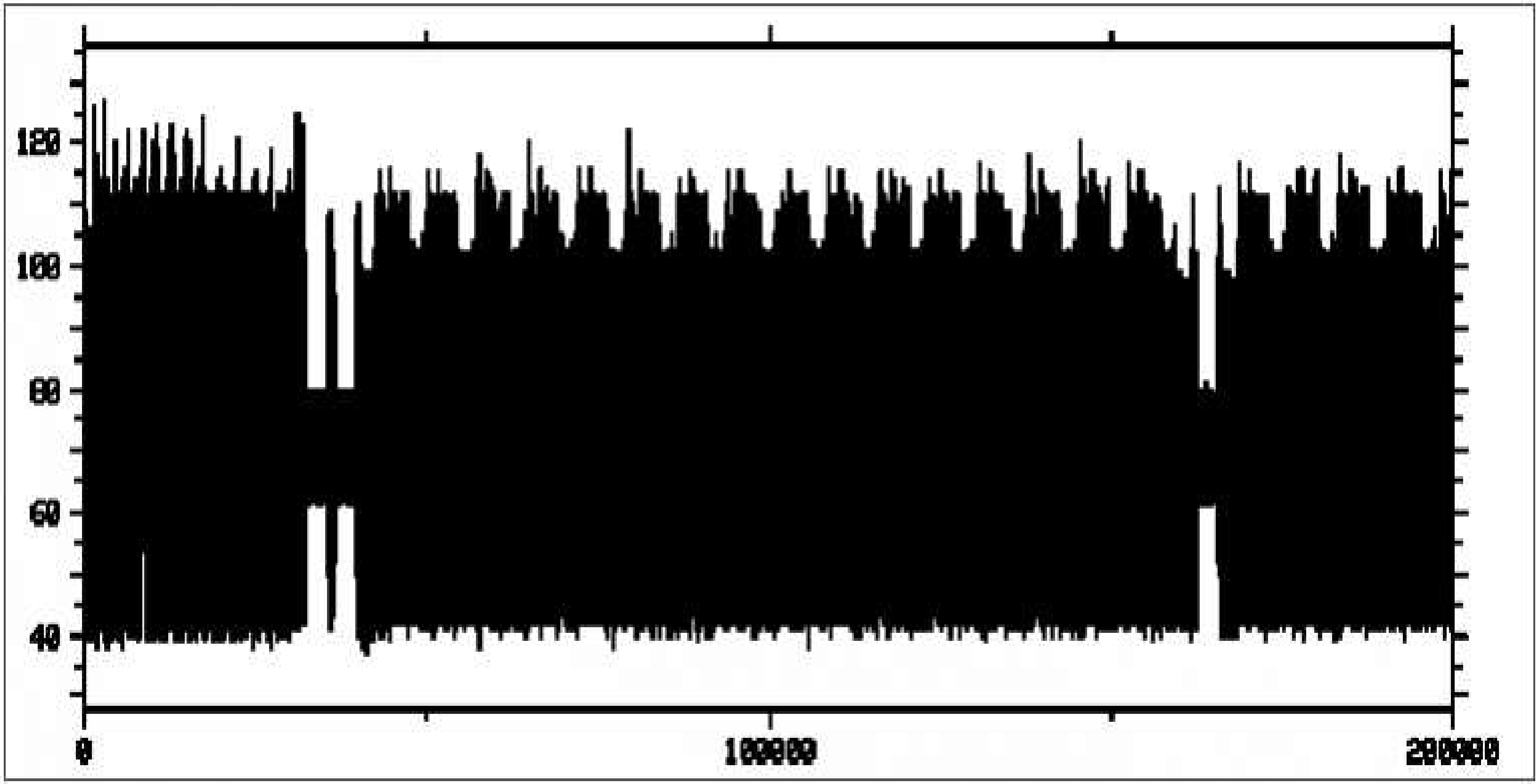
Countermeasures against logical attacks

- Write qualitity software
- Testing
- Formal verification
- Perform code reviews to spot software problems
- Improve OS, APIs, programming languages to make software bugs less likely
- Open research area !!

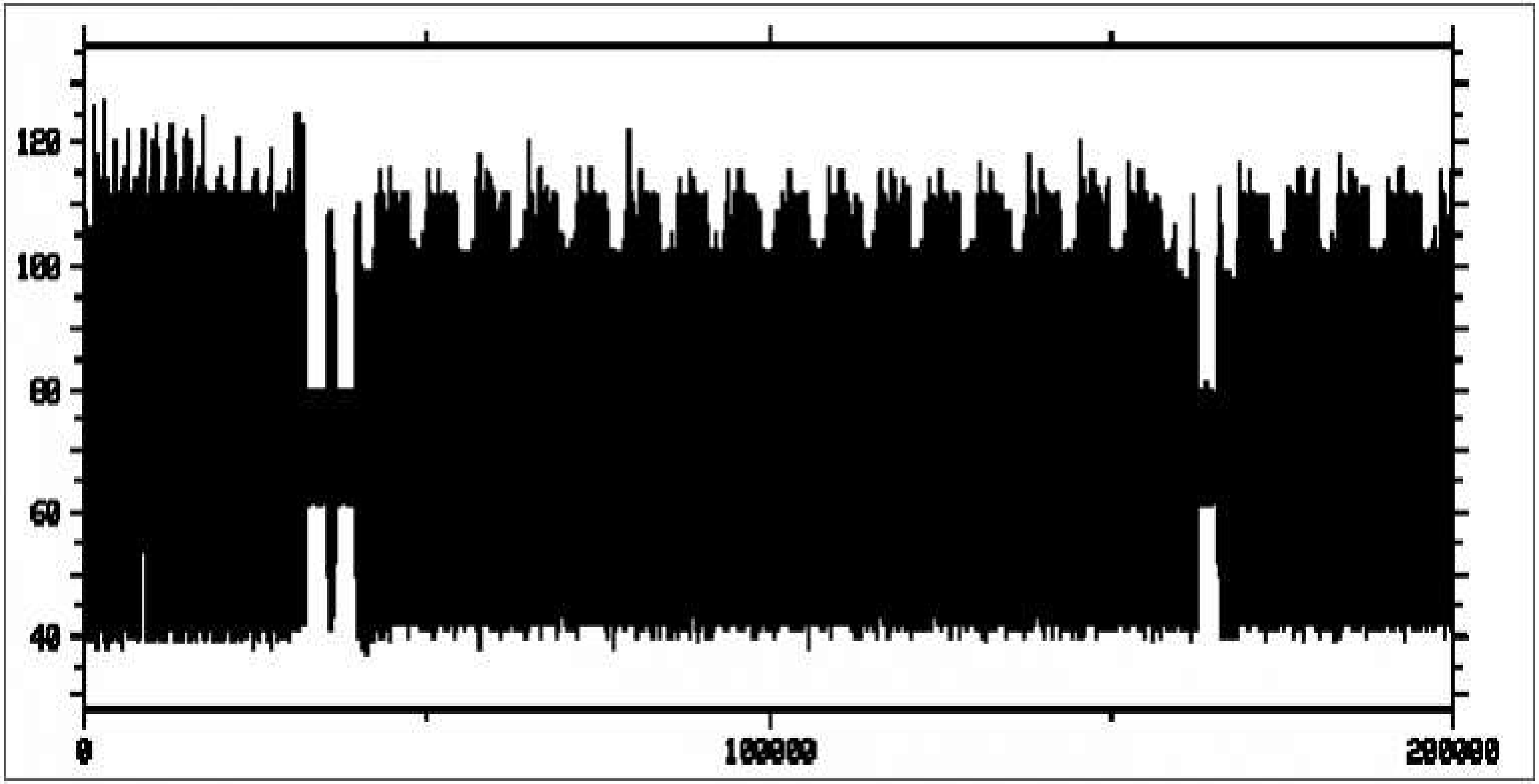
Side-channel attacks

- Side-channel = any other channel than the normal I/O channel that may be observed
- Possible side-channels:
  - power consumption
  - timing
  - electro magnetic radiation
  - ....
- A side-channel might leak information, or be manipulated...

Power consumption of a smartcard



This is probably a DES encryption!



Differential Power Analysis (DPA)

Deduce information from power consumption

Countermeasures against DPA

- in software
  - careful coding of crypto-algorithms
  - redundancy in data representation
- in hardware
  - add clock jitter or other noise
  - dual rail logic

Power glitching

- precisely timed dip in power supply to induce fault, eg
  - prevent an EEPROM write
    - eg to PIN counter
  - read memory contents as zero
    - eg of crypto-key
  - Some crypto-algorithms may be attacked using such fault injections (DFA-Differential Fault Analysis)

Active side-channel attacks

- Other side channels:
  - clock frequency
  - temparature/heat
  - light or X-rays
  - EM radiation
- Countermeasures:
  - hardware: sensors to detect changes in voltage, etc.
  - software: double-checking results of computations

Physical (or invasive) attacks

- reverse engineer and tamper with the physical chip

- first step: getting access to chip's surface
  - remove chip from the smartcard
  - use chemical to remove expoxy resin and the top metal/silicon layers of the chip

Removing chip from smartcard

Etched smartcard with chip exposed

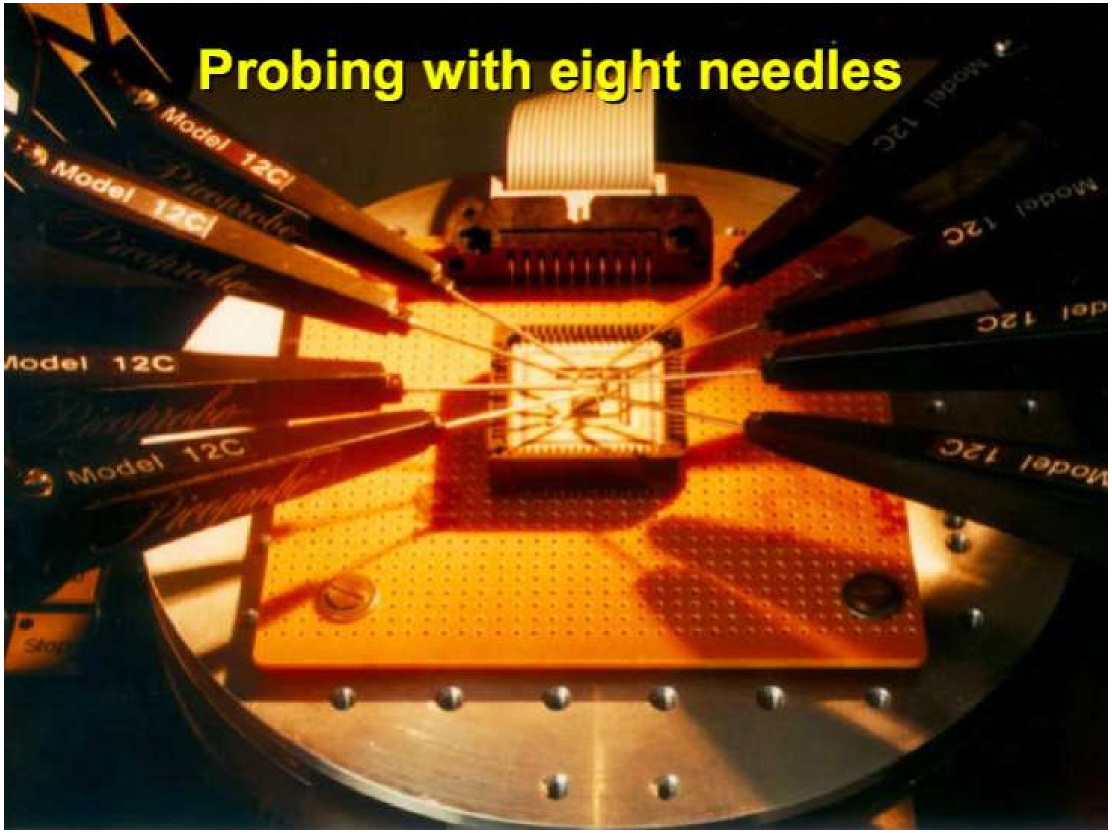
Tools for physical attacks

- Microscope
  - optical or scanning electron microscope (SEM)
- Focused Ion Beam (FIB)
  - not only observe, but also make changes: removing or adding wires, insulators,...
- Probe station
  - to probe wires on the chip

Probing


EEPROM
R A M
R O M
Easy to localise
Bloc
Crypto
Logic

Probing

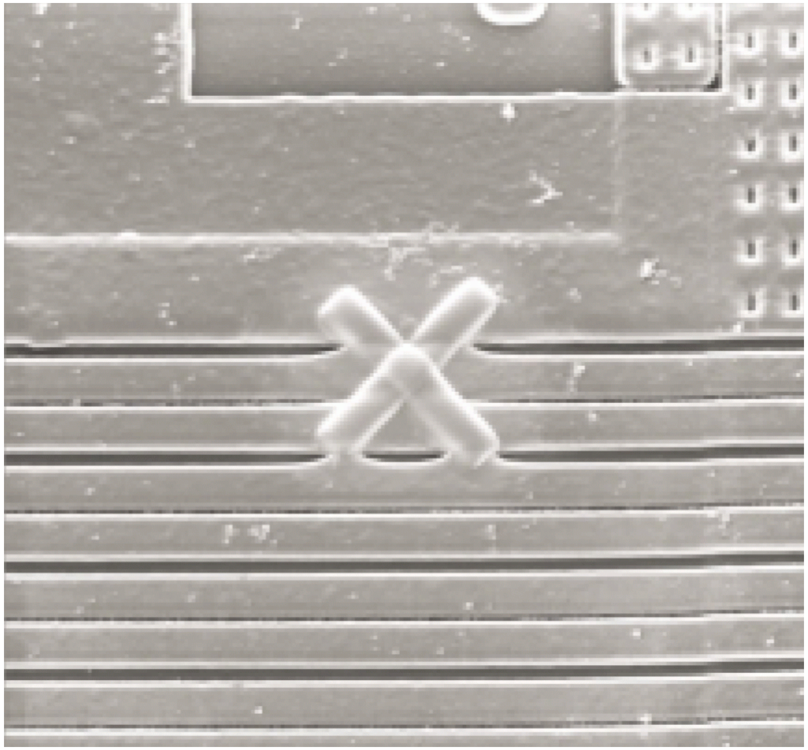


Probing with eight needles
Model 12C
Model 12C
Model 12C
Model 12C
Model 12C
Model 12C
Model 12C

Probing

- Observe data on the chip in operation
- Typically: tap data on bus
  - by putting needle on bus wires
- Probing can be done using
  - physical needles (>0.35 micron) or
  - electron beam

Using Focused Ion Beam in probing



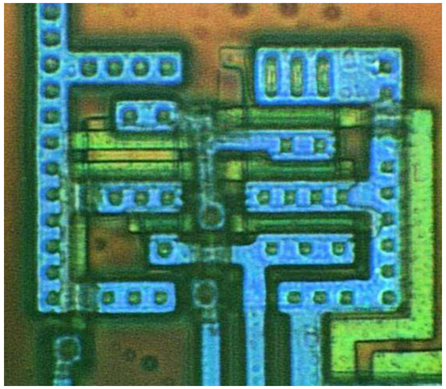
Fibbing can be used to

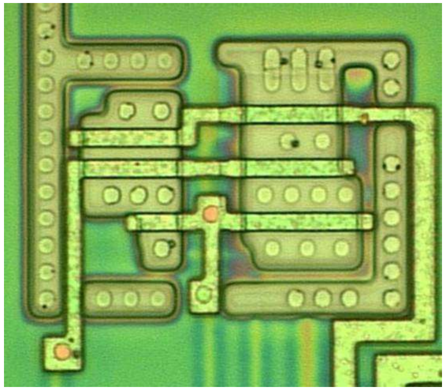
- add probe pads for lines too thin or fragile for needles
- surface buried lines

Countermeasures against probing

- use smaller circuitry
- protective layers or sensors on chip surface
- multiple layers on chip
  - with sensitive data on deeply buried wires
- scramble or encrypt bus
  - attacker then has to reverse engineer the scrambling logic
- use glue logic instead of (easy to spot) bus

Multiple layers on chip

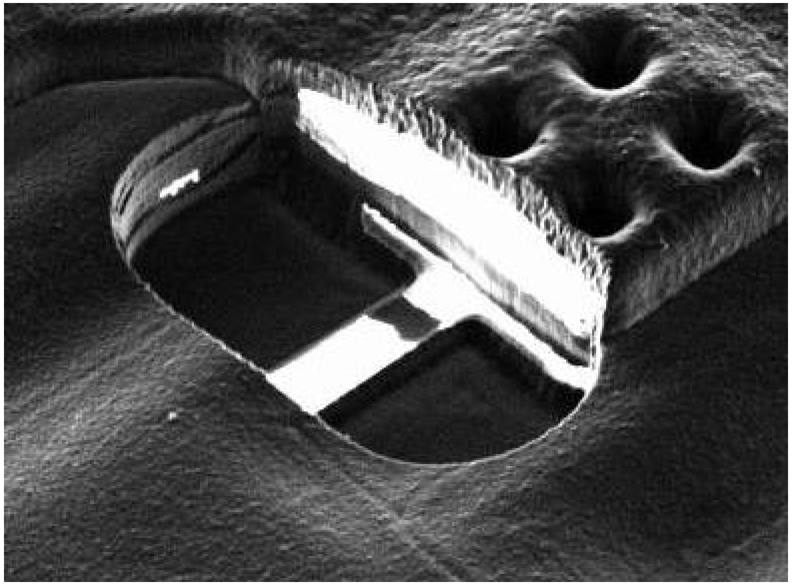




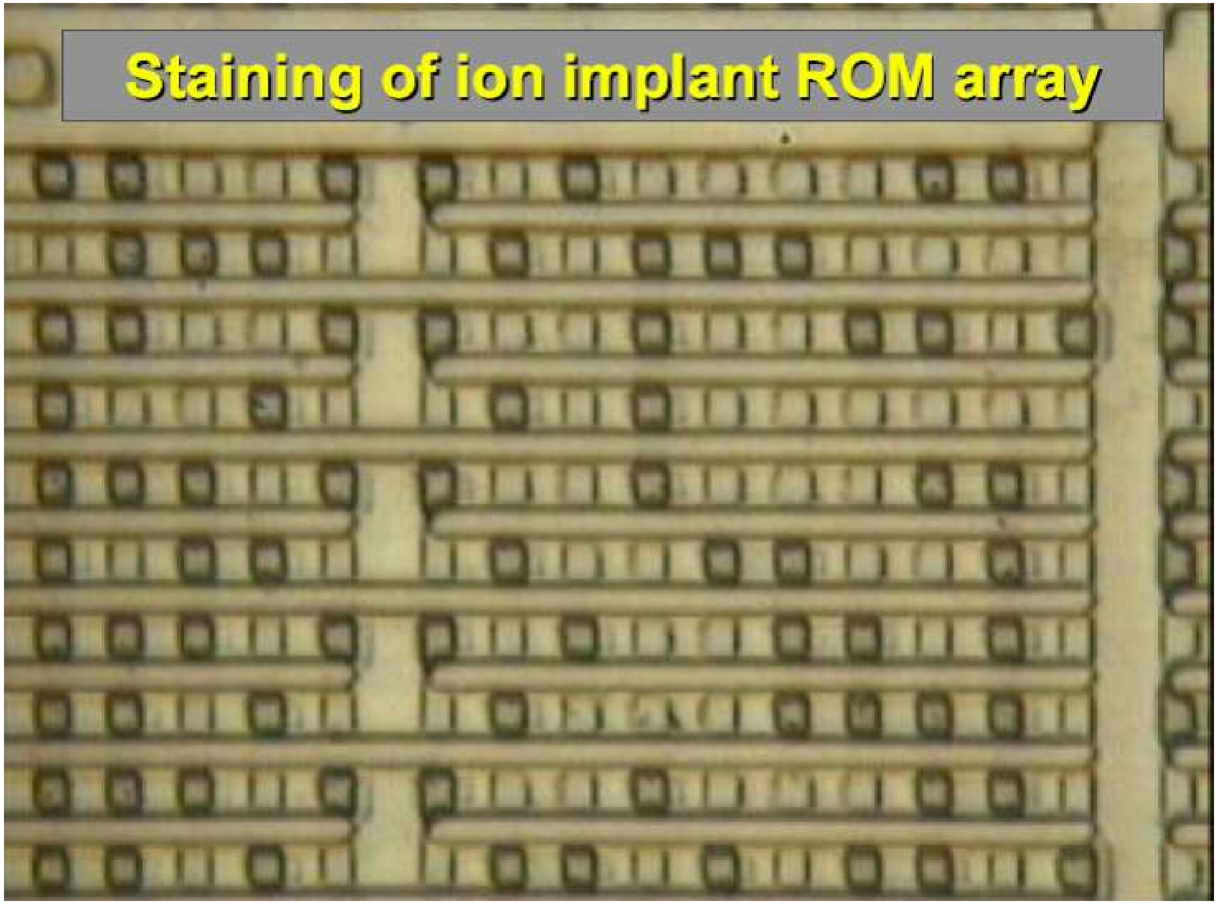
The same gate before and after etching to remove top layer

Using Focused Ion Beam (fibbing)

- all chips contain circuitry to check chip after production
- after testing, test logic is disabled by blowing a fuse
- FIB can restore test logic



ROM memory content extraction

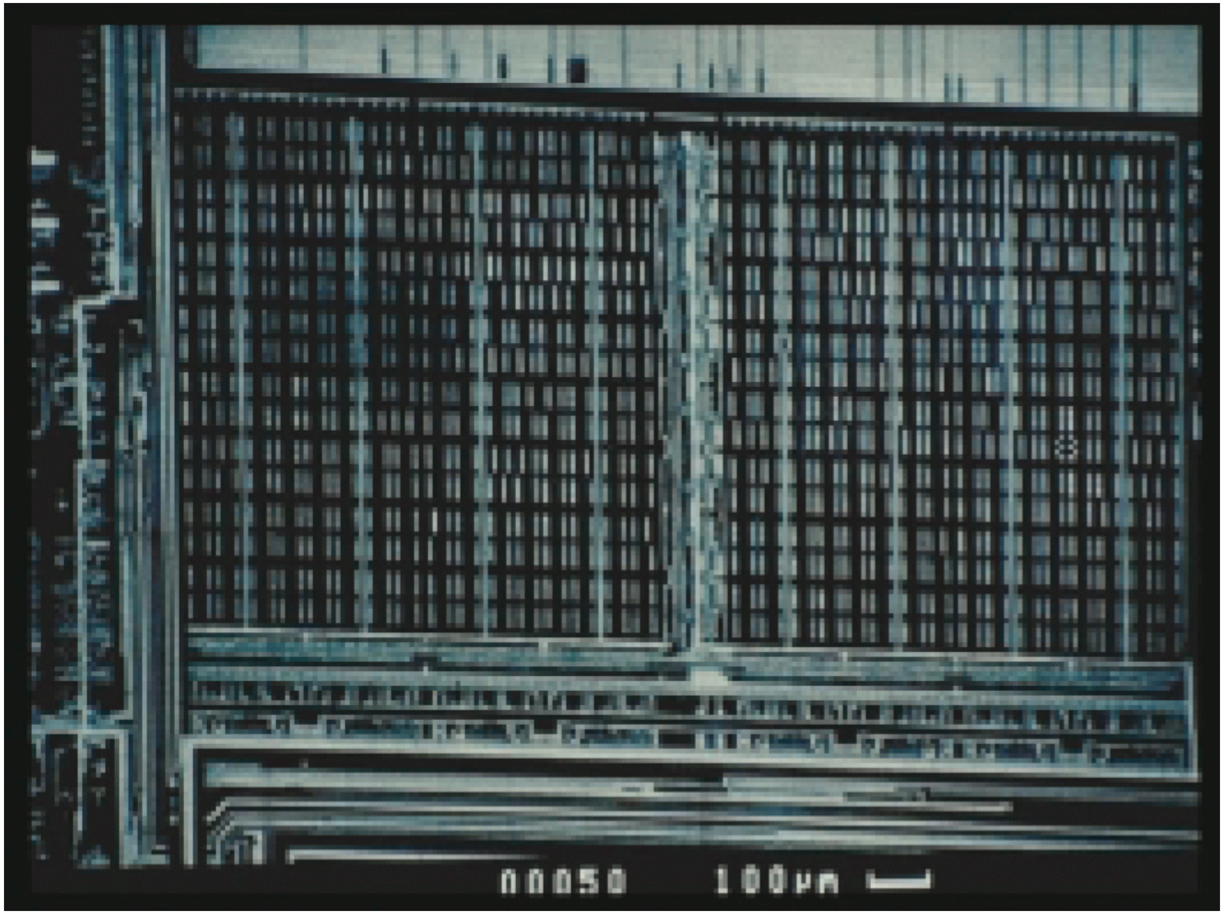


ROM memory content extraction

- ROM contents can be observed
- usually no crypto material in ROM, but knowledge about code stored in ROM can help with other attacks

- Countermeasure: encrypt ROM
  - attacker now has to reverse engineer the encryption logic

RAM voltage contrast SEM



RAM memory content extraction

- Scanning electron microscope can be used to observe RAM contents
- Countermeasure: scramble or encrypt RAM
- Content of EEPROM or Flash is harder to extract

Smartcards attacks - future

- Ongoing arms race between smartcard manufacturers and attackers
- Physical attacks becoming harder, due to improved countermeasures and smaller circuitry
- But increasing complexity of software on smartcard may introduce new logical attacks

Smartcard attacks - conclusions

- Smartcards is not tamper-proof, as witnessed by
  - logical attacks
  - side-channel attacks: DPA, glitching
  - physical attacks
- Smartcards are tamper-resistant and tamper-evident, to a degree