Java Card

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Smart Cards

Smartcards

Credit-card size piece of plastic with embedded chip, for storing & processing data

Standard applications

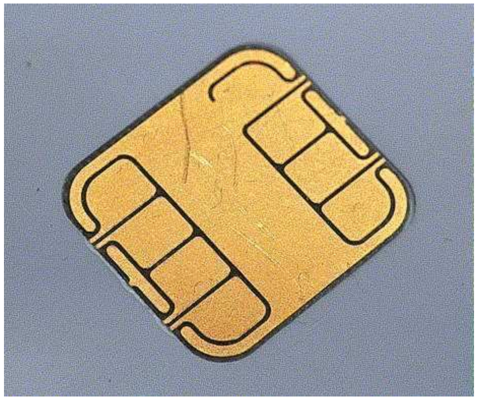
- **bank cards**
- **SIM’s in GSM mobile phones**
- **pay-TV**
- **ov-kaart**
- **. . .**

Smartcards

A smartcard is a miniature computer with

- **limited resources**
  - **ROM: 16-64K :** OS + programmatuur
  - **EEPROM: 4-64K:** persistent data storage
  - **RAM: 256 bye-4K:** scratch-pad memory
- **minimal I/O**
  - **just a serial port** no keyboard, screen, mouse, . . .

External power supply & clock.



Smart vs stupid cards

‘Smart’ refers to ability to compute.

‘Stupid’ cards, providing only provide memory, and no processing power, namely

- **magnetic stripe cards**
- **memory-only chip cards**

Why use smartcards ?

Smartcard can securely store and process information:
data and program stored on smartcard cannot (easily) be read, copied, or alerted.
NB unlike a PC!

Typical application:

- **storing sensitive information:**
  eg. cryptographic keys, passwords, pincodes & pin counter, chipknip balance.
- **using/changing this information:**
  eg. de/encrypt, check pincode, change balance
- **whilst protecting against unauthorized use.**

Why use smartcards ?

Typical use of smartcard for authentication:

- **X sends a random challenge c to smartcard**
- **smartcard responds with $f_K(c)$, ie. c encrypted with some secret key K.**
- **X checks this result**

Eg. used in GSM – for network to authenticate phone –, and in chipknip – for point-of-sale to authenticate chipknip and for chipknip to authenticate oplaadpunt.

NB

- **secret key never leaves the smartcard!**
- **observing traffic between smartcard and terminal leaks no useful information, so communication with smartcard can be over untrusted network.**

Why use smartcards ?

Smartcards typically part of the Trusted Computing Base (TCB), ie. the part of the infrastructure that we *have* to trust.

You want your TCB to be as reliable – and hence as small & simple – as possible!

Eg. for a telecom network operator, the GSM SIM is part of the TCB, but rest of the mobile phone is not.

Smartcard limitations

Primitive I/O is a limitation:
eg. chipknip user has to trust the terminal, for deducting the right amount and to keep pincode secret

Smart card with displays, keyboards, fingerprint detectors, etc. are being developed . . .

Contactless smartcards rapidly getting better.

Security of smartcards

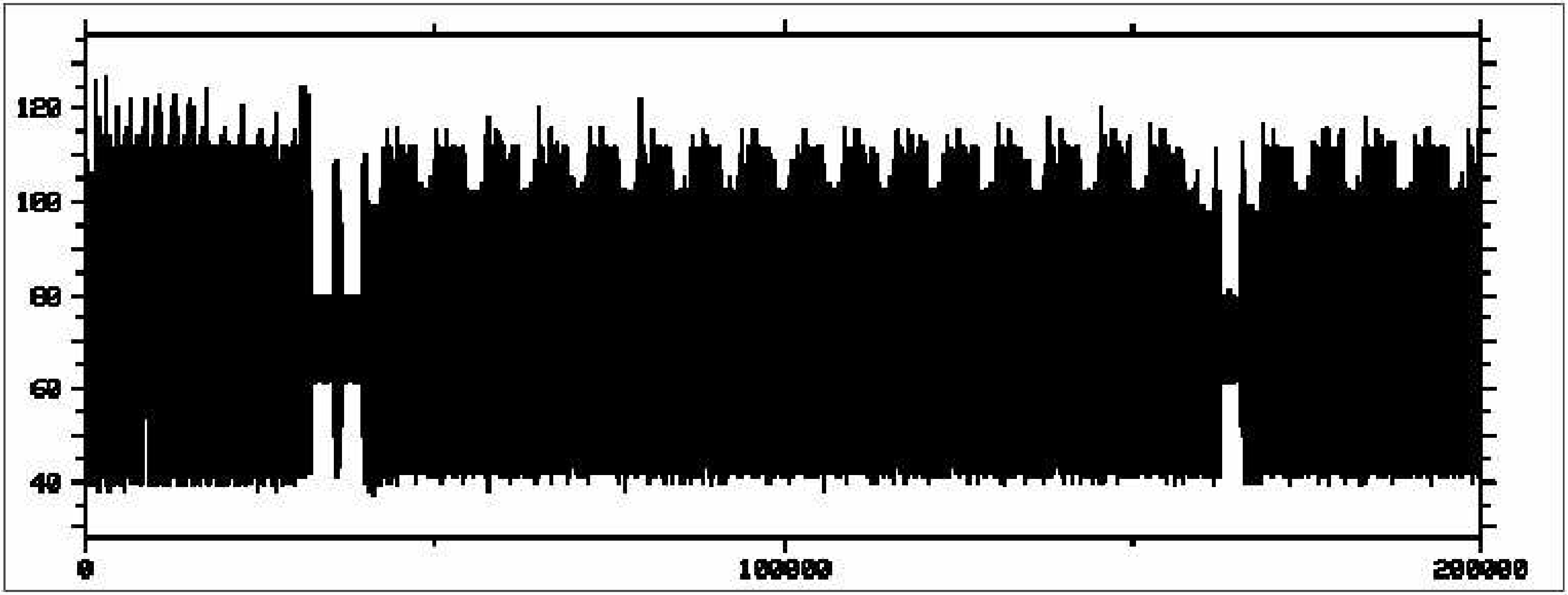
Smartcard is tamper-resistant and tamper-evident, to a degree, but not tamper-proof.

Smart card can be attacked by for instance

- **differential power analysis (DPA), analysis of power consumption of card**
- **fault injection, eg. temporarily dip power supply, flash light on chip**
- **chemical etching/staining to read memory contents**
- **probing to analyse traffic on bus**
- **focused ion beam to remove/deposit material on chip surface**

TNO-EIB in Delft are experts at this.

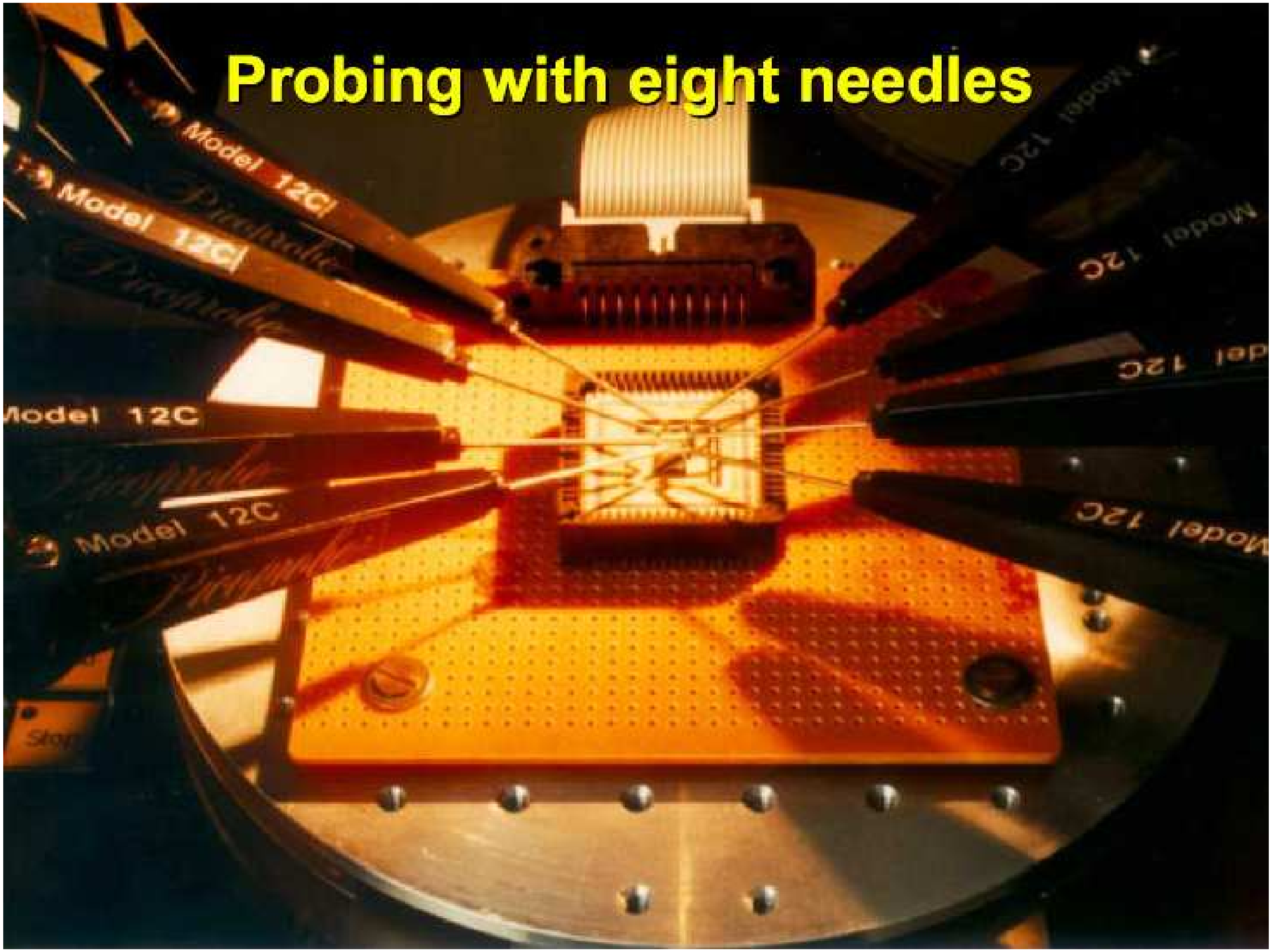
Attacking smartcards: DPA



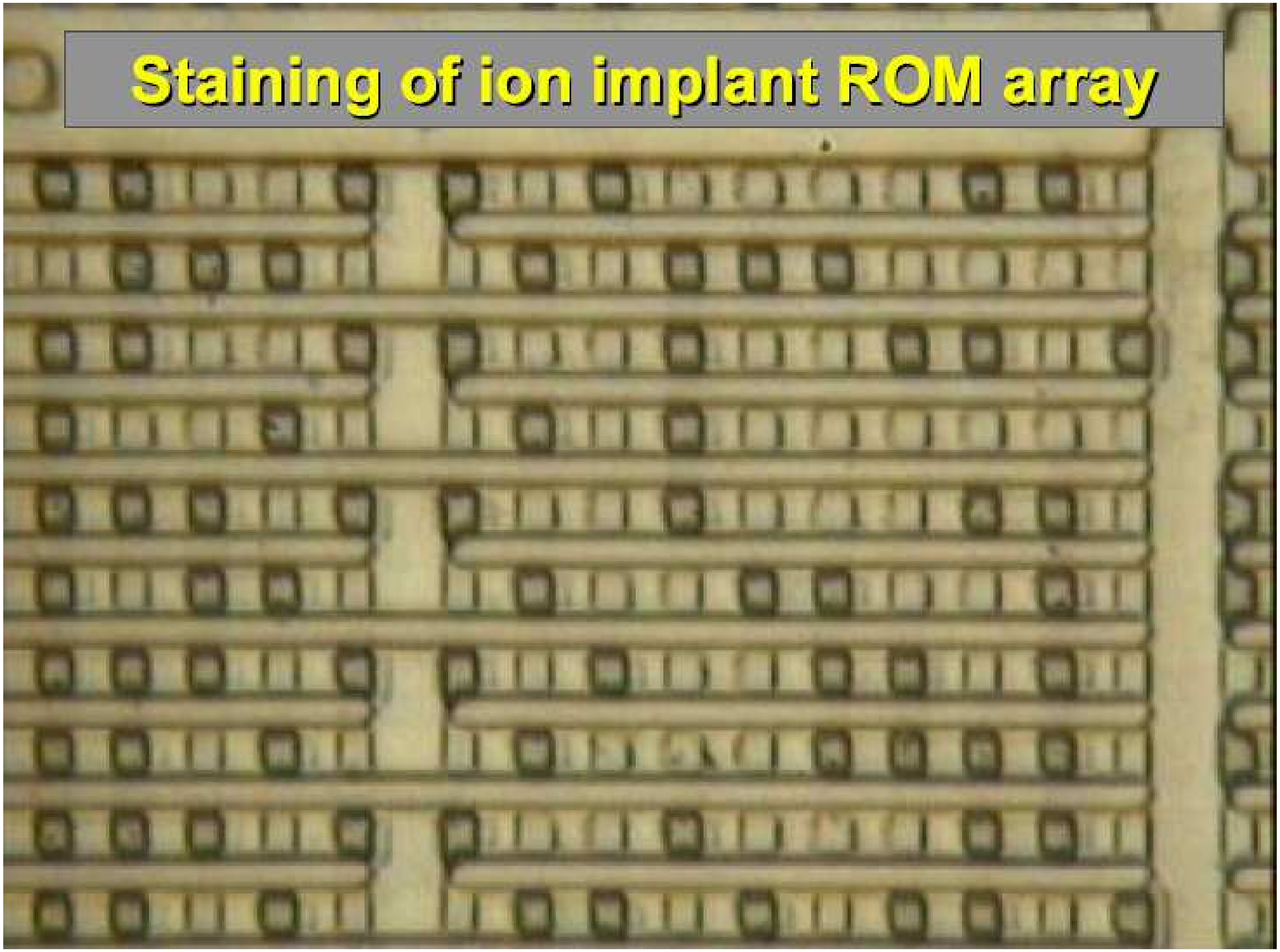
Power analysis of smart card doing a DES encryption

Attacking smartcards: Probing

Attacking smartcards: Probing



Attacking smartcards: Staining



Old vs new smartcards

Traditional smartcard

- programmed in machine-code, specific to the chip
- one application, burnt into ROM

Newer smartcards

- application written in high-level language
- compiled into byte code
- stored in EEPROM
- interpreted on card

Old vs new smartcards

Advantages of newer smartcards

- cheaper development
- quicker time-to-market
- vendor-independence

and

- **multi-application**: several applications can be installed on one smartcard
- **post-issuance download**: applications can be added, updated, removed on card already issued to customer (cf. web browser)

Java Card

Java Card

Dialect of Java for programming smartcards

Slimmed down due of hardware constraints

- not 32-bit but 16-bit arithmetic
- no doubles, no floats, no strings, no threads, . . .
- no / optional garbage collection
- very limited API

plus special features due to hardware peculiarities

- persistent (EEPROM) vs transient (RAM) memory
- applet firewall
- transaction mechanism
- smartcard I/O with APDUs using ISO7816

Java Card platform

The **Java Card platform** consists of

- **Virtual Machine (VM)**
  for interpreting bytecodes

- **API** , **providing**
  - **basic classes (eg. `applet` and `PIN`)**
  - **“interface” to OS (eg. `APDU` class for I/O)**

  Partly written in Java Card, partly native code

JavaCard architecture

applet	applet	$\cdots$	applet	$ROM/EEPROM$
Java Virtual Machine		Java Card API		ROM
Smart card hardware				

J2ME

Java 2 Micro Edition (J2ME) is the bigger brother of Java Card.

J2ME has a bigger memory footprint, as is intended for use in mobile phones, PDAs, set-top boxes, etc.A

Eg MIDP applets that can execute on a mobile phone

Lots of dedicated APIs for TV, Phone, BlueTooth, . . .

Java Card & smartcard hardware

- **ROM:**
  for program code of VM, API, and pre-installed applets

- **EEPROM for persistent data:**
  for objects and their fields (ie. heap) and code of downloaded applets

- **RAM for transient data:**
  for stack and specially allocated scratchpad arrays

  Writing to EEPROM is slower & consumes more power than writing to RAM, and EEPROM lifetime limited to certain number of writes.

Producing & installing applets

Java (Card) source code A.java

$\Downarrow$ **java compiler**

Java (Card) byte code A.class

$\Downarrow$ **cap converter**

'compressed' Java Card cap file A.cap

$\downarrow$ **downloading**

Bytecode verification

Bytecode verification, ensuring type-safety of code, is CRUCIAL for Java (Card) security!

Due to hardware constraints, bytecode verification on smartcard is difficult/not possible.

Instead, code signing is used: bytecode verification done off-card, and only digitally signed code is trusted by the platform.

Java(Card) security by typing (1)

Access-control, eg. no access to **private fields** of other objects

```
PIN pin;
...
for (i=0; i++; i<4)
 System.out.println(pin.thePin[i]);
...
pin.tryCounter = 9999;
```

In fact, Java Card provides a firewall between applets, which forbids most interaction between applets.

Java(Card) security by typing (2)

Type-safety, **eg. no forging of pointers** (as in C doing pointer arithmetic with **&**) **or accessing outside array bounds**

```
...
PIN pin;
byte[] a = new byte[1];
...
a = pin;  // type error !!
for (i=134; i++; i< 137)
        System.out.println(a[i]);
...
a[36] = 9999;  // access outside array bounds !
```

Java Card API

Java Card peculiarities for which the API provides support include

- a APDU class for communication of smartcard with terminal
- a transaction mechanism to cope with card tears, ie. interruptions to power supply.

APDU

(Low-level!) communication with smartcard via byte array buffer aka APDU, following ISO7816

- **Terminal sends card a command APDU**

CLA	INS	P1	P2	Lc	Data	Le

  - **CLA: Class byte**
  - **INS: Instruction byte**
  - **P1, P2: Parameters**
  - **Lc: Length data block**
  - **Le: Expected length response**

- **Card sends terminal a response APDU**

Data	SW1	SW2

  - **SW1, SW2: Status words**

Transactions

Sudden loss of power possible at any time due to card tear, ie. pulling smartcard from reader.

Transaction mechanism provides atomic updates in event of card tears (like transactions in databases).

For example, in

```
...
JCSystem.beginTransaction();
x++;
y++;
JCSystem.endTransaction();
```

either both `x` and `y` are increased, or neither is.

RMI

APDU format very clumsy & antiquated.

Java Card 2.2 supports Remote Method Invocation (RMI)

RMI means one VM (the JVM on the terminal) invokes method on another VM (the JCVM on the smartcard).

For Java Card, such a method invocation (incl. its parameters and any return value it produces) is translated into APDUs handled by the platform.