Security Engineering

Hardware security 1. Locks, alarms and seals. Hardware tamper resistance, differential fault analysis, differential power analysis.

Physical Security

- Locks, and walls, will be some part of your infrastructure at some level
- While the techniques are simpler than digital security, the weaknesses are often as subtle.
- Deter-detect-alarm-delay-respond

Who do we need to be secure against?

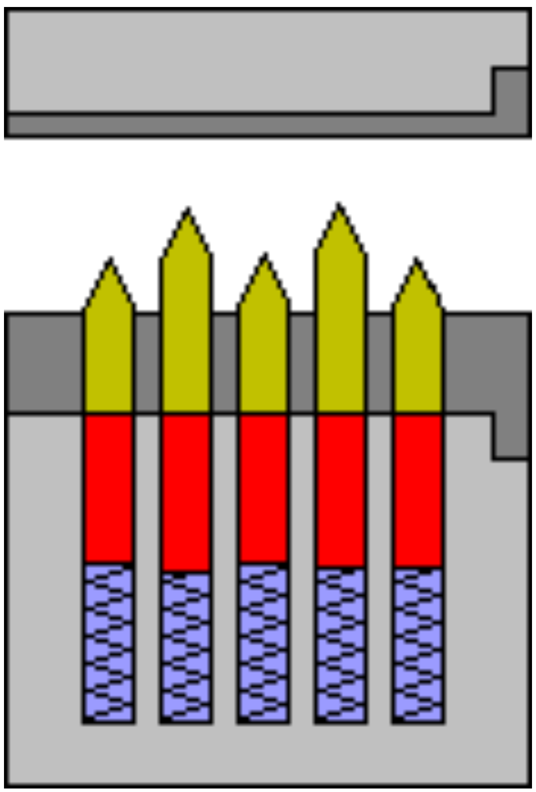
- Derek – 19-year old addict
- Charlie – 40-year old with 7 convictions
- Bruno – “gentleman criminal”
- Abdurrahman – head of a dozen agents

- Unskilled -> Skilled -> Highly Skilled with help -> Highly Skilled with resources

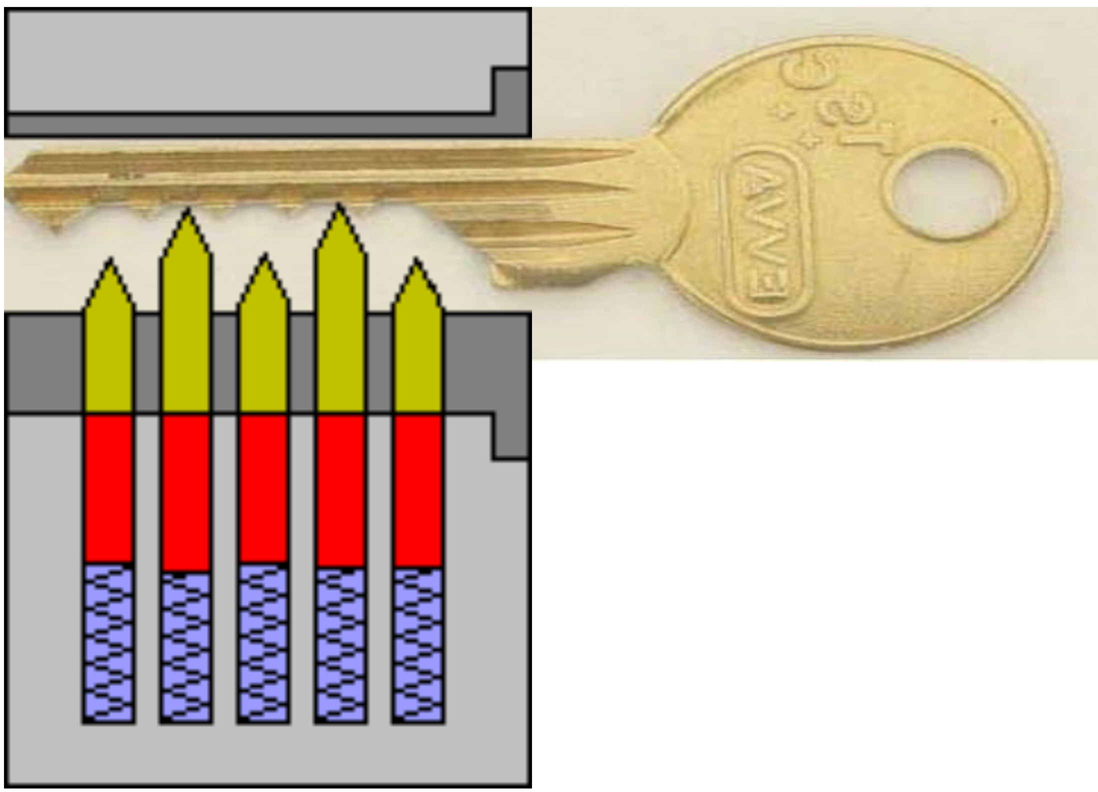
What are you trying to achieve?

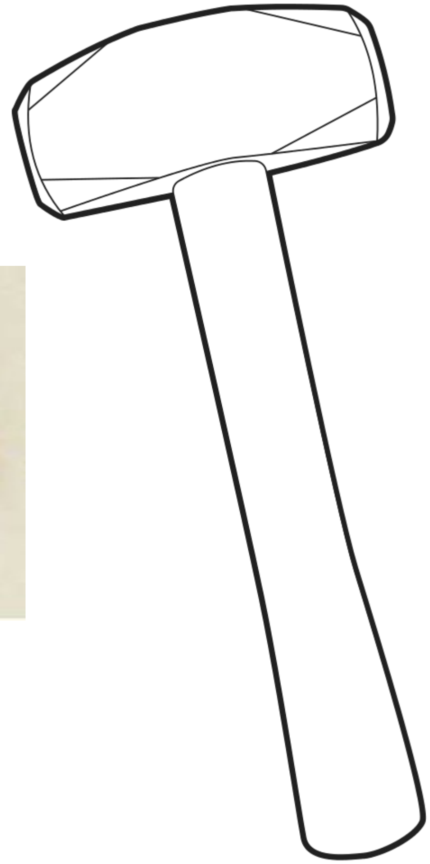
- Deterrence or just redistribution of crime?
- Are you really trying to protect your safe full of money, or your employees' lives?
- Don't just focus on the exciting threats
- Off-the-shelf product standards might use unusual/outdated assumptions

Locks

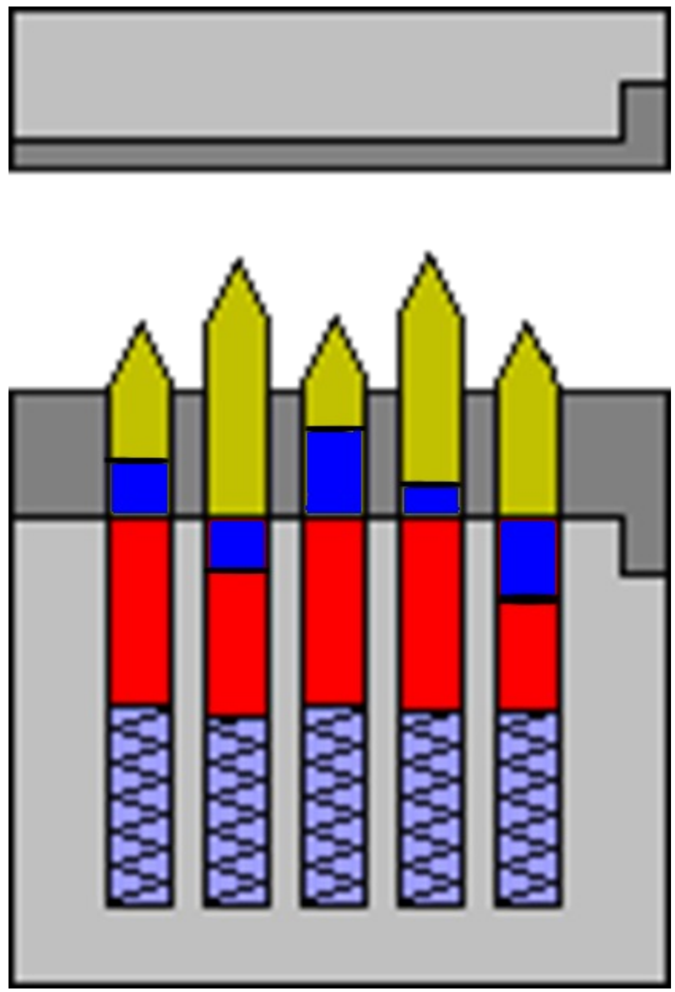


Bumping

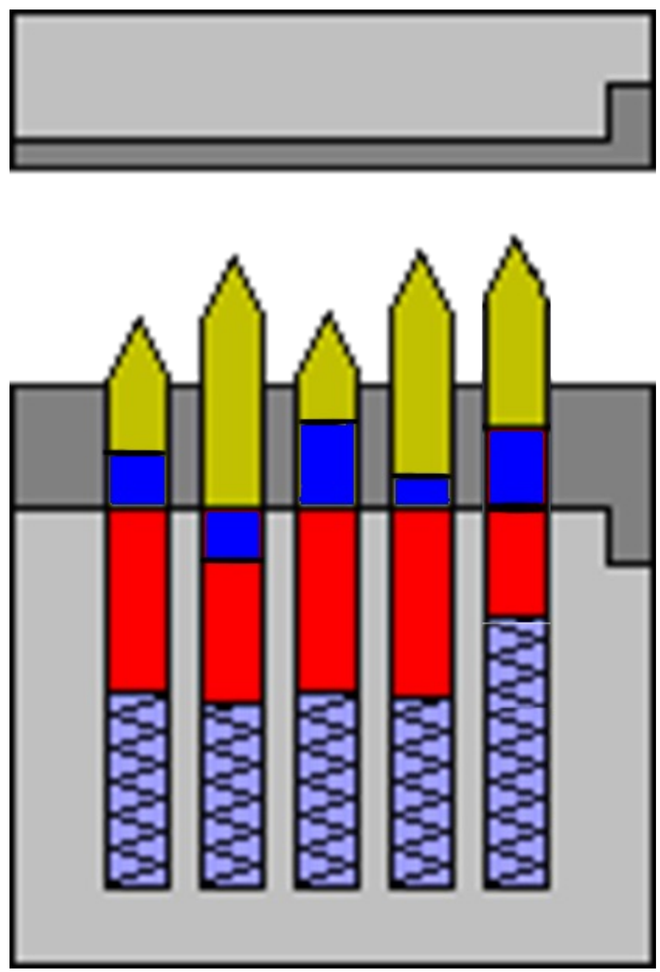




Master-Key Attacks



Master-Key Attacks



Electronic Locks

- E.g. wireless smart cards and card readers using challenge-response protocols
- Mifare Classic: Vulnerable but still widely deployed!
- All the usual crypto issues apply: weak ciphers, bad random number generators, short keys…

Alarms

- Deter-detect-alarm-delay-respond.
- Timeliness very important: if your criminal can get away before the security arrive, there’s no point!
- Don’t get blinded by the “Titanic Effect”

Types of Sensor

- Vibration: fences, footsteps
- Switches: doors/windows
- Infrared heat detection
- Motion detectors e.g. ultrasonics
- Movement sensors e.g. optical cables
- Invisible barriers of light beams
- Pressure pads
- Video cameras, possibly triggered by above

Alarms: Challenges

- False positives: Hurricane? Thunderstorm? Loud lorry?
- Denial of service attacks: keep triggering the alarm till the guards stop listening!
- Choosing a good combination of sensors is key
- Deter-detect-alarm-delay-respond.
- Feature interactions are difficult: if your fire alarm goes off, should you ignore your infrared heat intrusion detectors?

Alarms: Challenges (II)

- Spoofing of "liveness" signals
- Fix: Bury your cables in concrete, or use cryptography?
- Denial of service (II): cut your rivals' phone lines, then wait for the police to come and go again?
- Even if your own infrastructure is buried in concrete, what about the kerbside box your network goes through?

Who watches the watchmen?

- Bribery and corruption of your guards is often an issue.
- Which is worth more: your treasures or your guards' lives?
- Will dual controls help? Yes for bribery, less so for coercion
- An extreme case: prisons. *"How would I do this differently if half my staff were convicts on day release?"*
- Who might you have to contend with: just thieves, or also angry customers, spouses, ex-employees? Shooters?

Lessons

- Locks can be defeated, so alarms matter
- DoS is hard and important.
- Integrate detect-alarm-delay-respond
- Defence in depth
- Perimeter is least reliable and most important.
- Hard to keep guards alert under false alarms.
- Don't design for Charlie to keep about Bruno!
- You'll need specialist subcontractors, but can't leave everything to them, due to integration failures.

Seals and Tamper Resistance

Inspection

- Primary: untrained, possibly negative motivation
- Secondary: competent and motivated, performed in the field
- Tertiary: Full lab with experts

- Standards: FIPS 140 levels 1-4 (V1,2,3), ISO 19790

Security Printing

- Simultan presses, intaglio, letterpress, embossing, watermarks, microprinting, metal threads…
- Primary vs Secondary vs Tertiary inspectors
- Race against the forgers – add new features before your secondary inspectors get fooled

Seals

Tamper Resistance

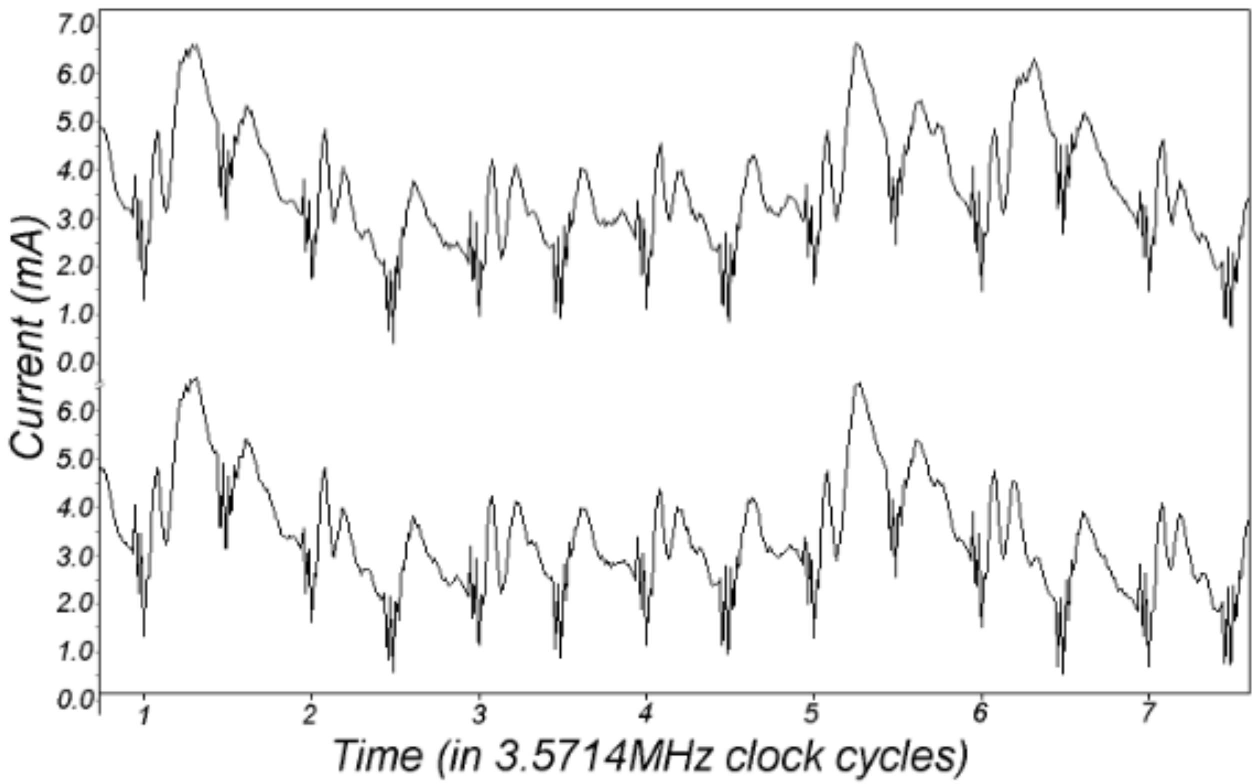
- Will your users (or anyone who can get hold of your device) be motivated to attack your device, and if so, can they attack your ecosystem?
- What are you protecting: authentication, service control, trusted execution, accessory control, manufacturing control?

Hardware Security Modules (HSMs)

Side Channels in HSMs

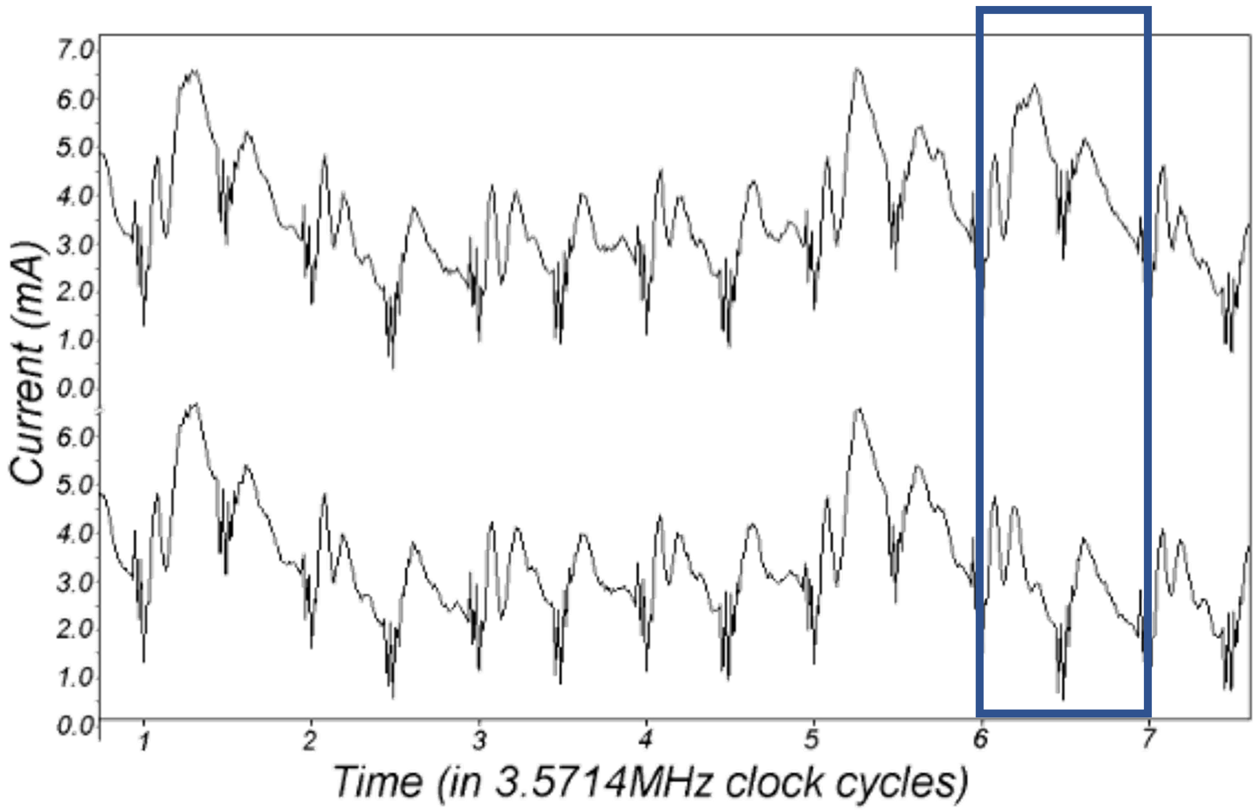
- Can we recover the key even if the device has been switched off – is the wiping mechanism reliable?
- Yes! Memory Remanence – they key will leave an imprint on the SRAM cells!
- Also, the SRAM won't wipe straight away if the power is cut – Cold Temperatures, and Cold Boot Attacks

Side Channels in Smart Cards: Power Analysis



From Differential Power Analysis, Kocher, Jaffe and Jun, CRYPTO ‘99

Side Channels in Smart Cards: Power Analysis



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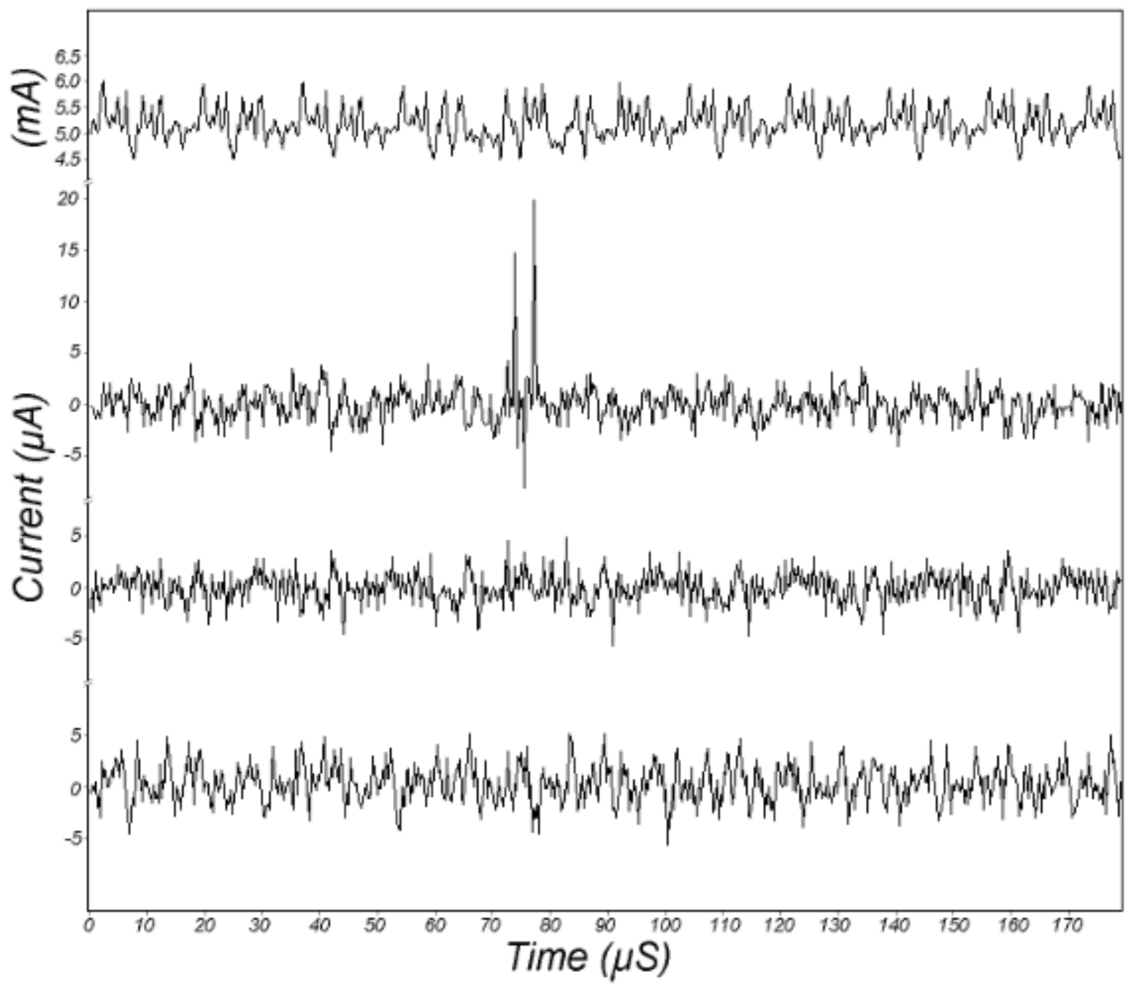
Differential Power Analysis



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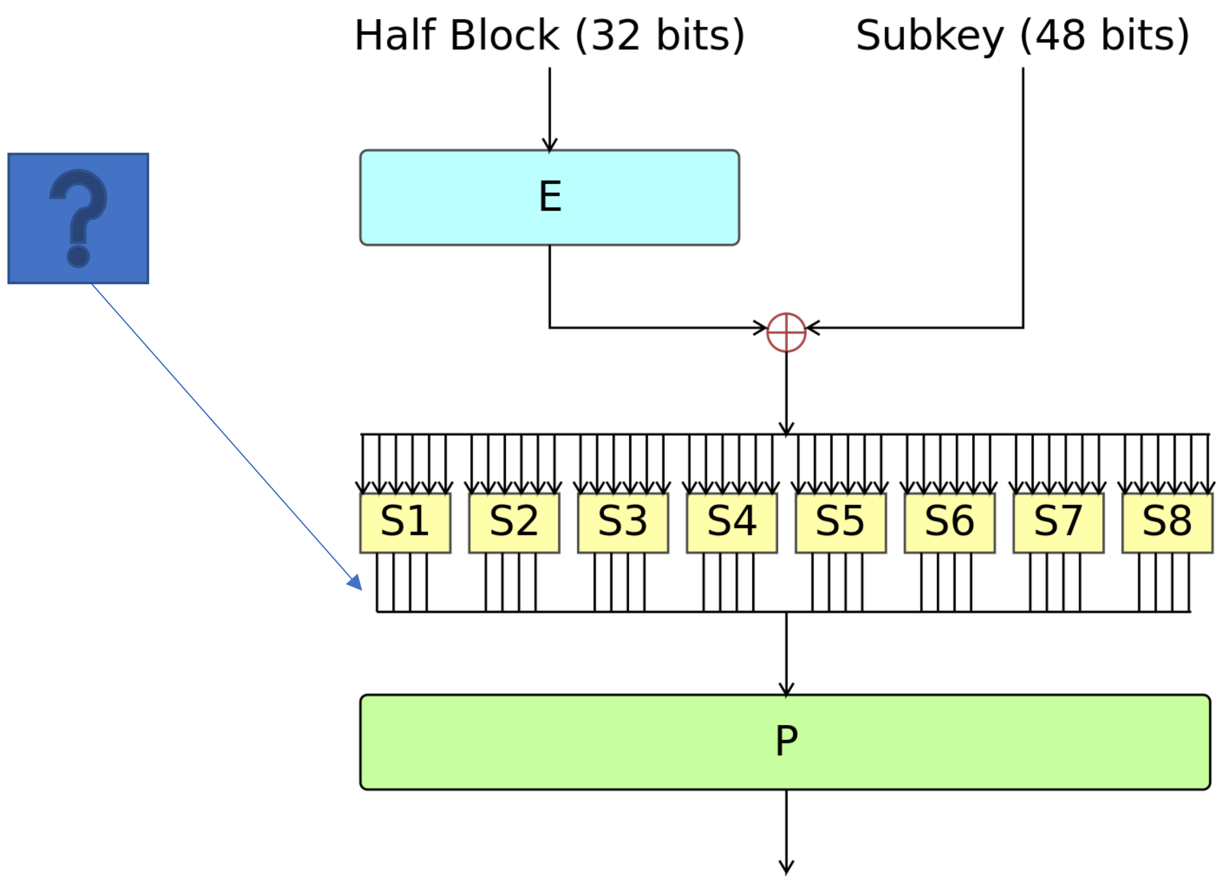
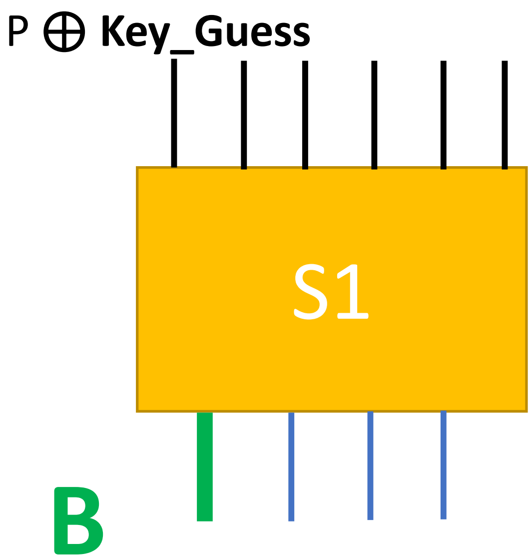
DPA on DES



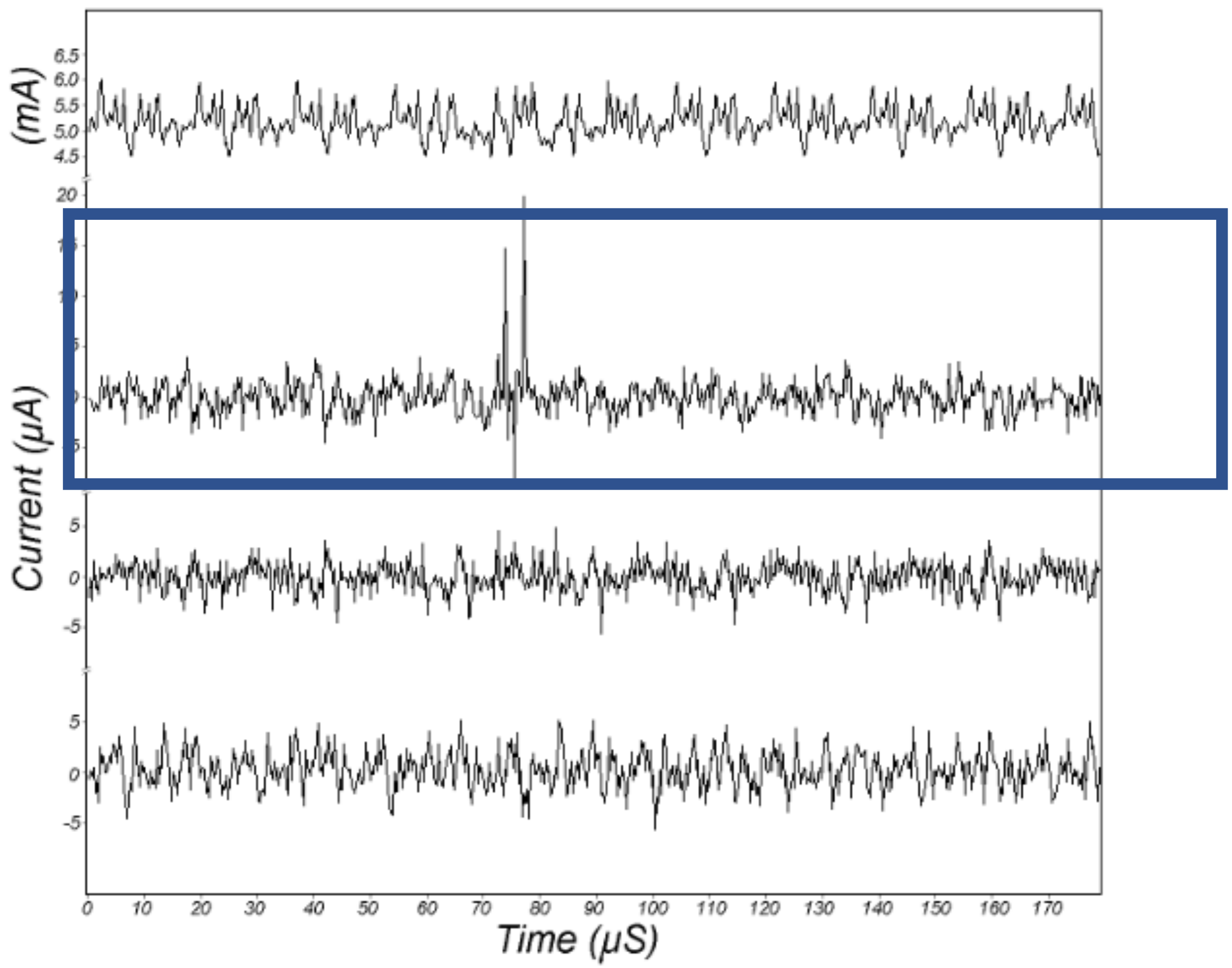
DPA on DES

Guessed Key Input xor Inferred Half Block



Plaintext	Trace
0x12345678…	
0x898979AB…	
0xDE424567…	
0XA0003341…	

Differential Power Analysis



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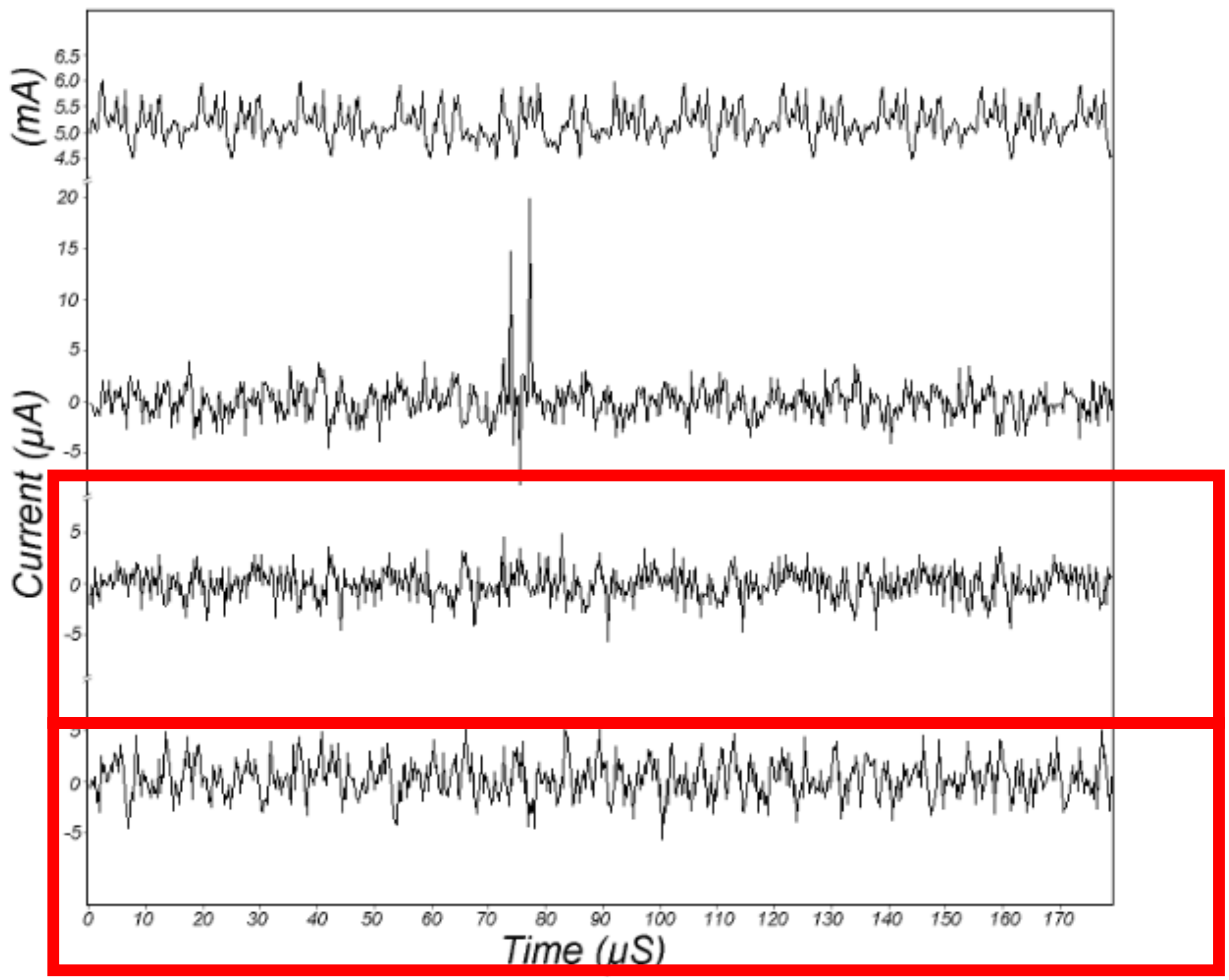

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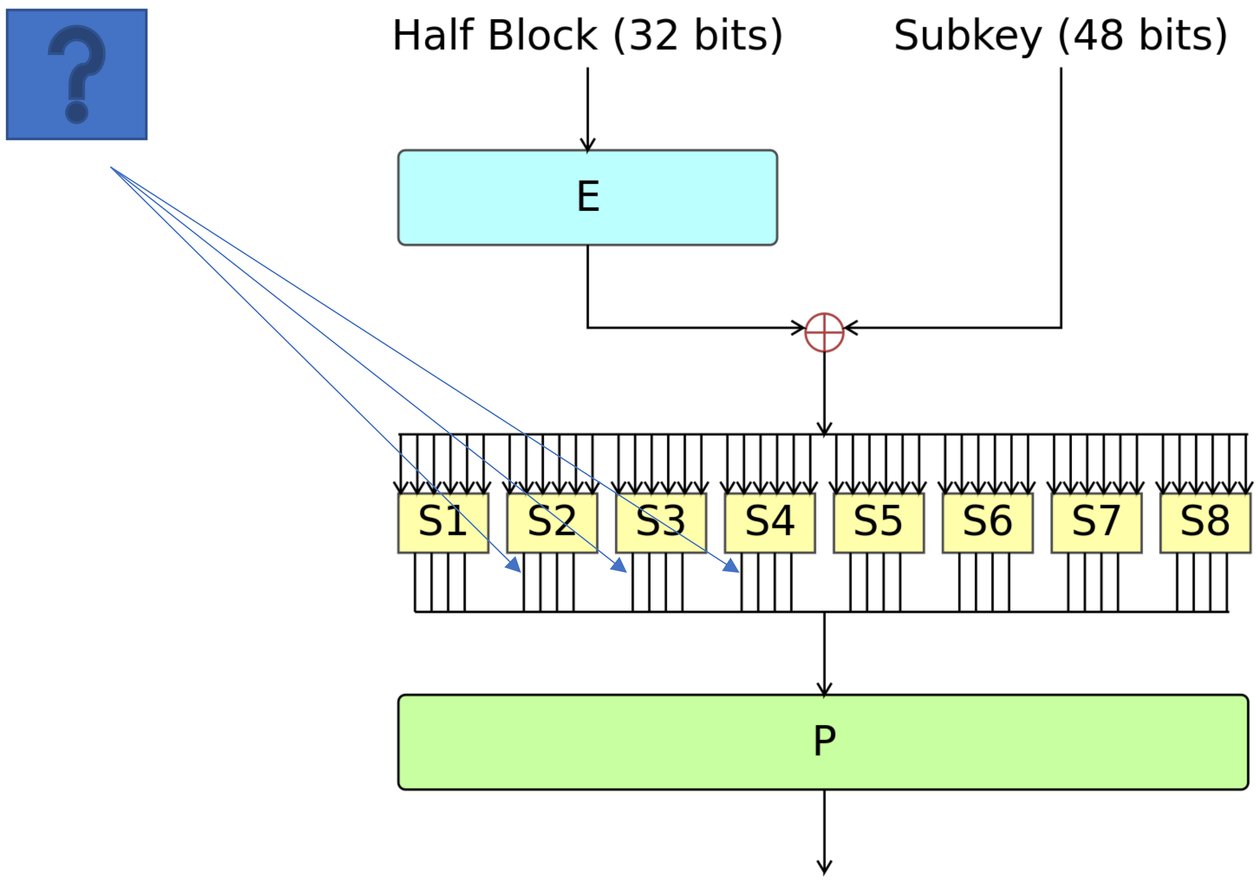

Fault Analysis

- Computers are really analog devices that behave mostly digitally.
- What about with an attacker able to control voltage / with a laser?
- You can cause faults, and security vulnerabilities too…

Fault Analysis on RSA Signatures

Sig = Msg^d (mod n)

n = public key = p * q, two (secret) prime numbers

d = private key (a function of p and q)

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Sig = Msg^{d} (mod n)

n = public key = p * q, two (secret) prime numbers

d = private key (a function of p and q)

Faster to calculate by combining:

Sig1 = Msg^{dp} (mod p)

Sig2 = Msg^{dq} (mod q)

Fault Analysis on RSA Signatures

What if we inject an error in the second one?

Sig1 = Msg^{dp} (mod p)

Sig2’ = Msg^{dq} (mod q)

Sig’ = CRT(Sig1,Sig2’)

Fault Analysis on RSA Signatures

What if we inject an error in the second one?

Sig1 = Msg^{dp} (mod p)

Sig2' = Msg^{dq} (mod q)

Sig' = CRT(Sig1,Sig2')

Msg = Sig'^{e} (mod p)

Msg != Sig'^{e} (mod q)

(e is public exponent)

Fault Analysis on RSA Signatures

What if we inject an error in the second one?

Msg = Sig'^{e} (mod p)

Msg != Sig'^{e} (mod q)

(Sig'^{e} – Msg) is divisible by p

(Sig'^{e} – Msg) is not divisible by q

Fault Analysis on RSA Signatures

What if we inject an error in the second one?

$(Sig'^e - Msg)$ is divisible by p

$(Sig'^e - Msg)$ is not divisible by q

So, $p = GCD(Sig'^e - Msg, n)$

– much simpler than prime_factor(n)

Fault Analysis on RSA Signatures

What if we inject an error in the second one?

(Sig'^{e} – Msg) is divisible by p

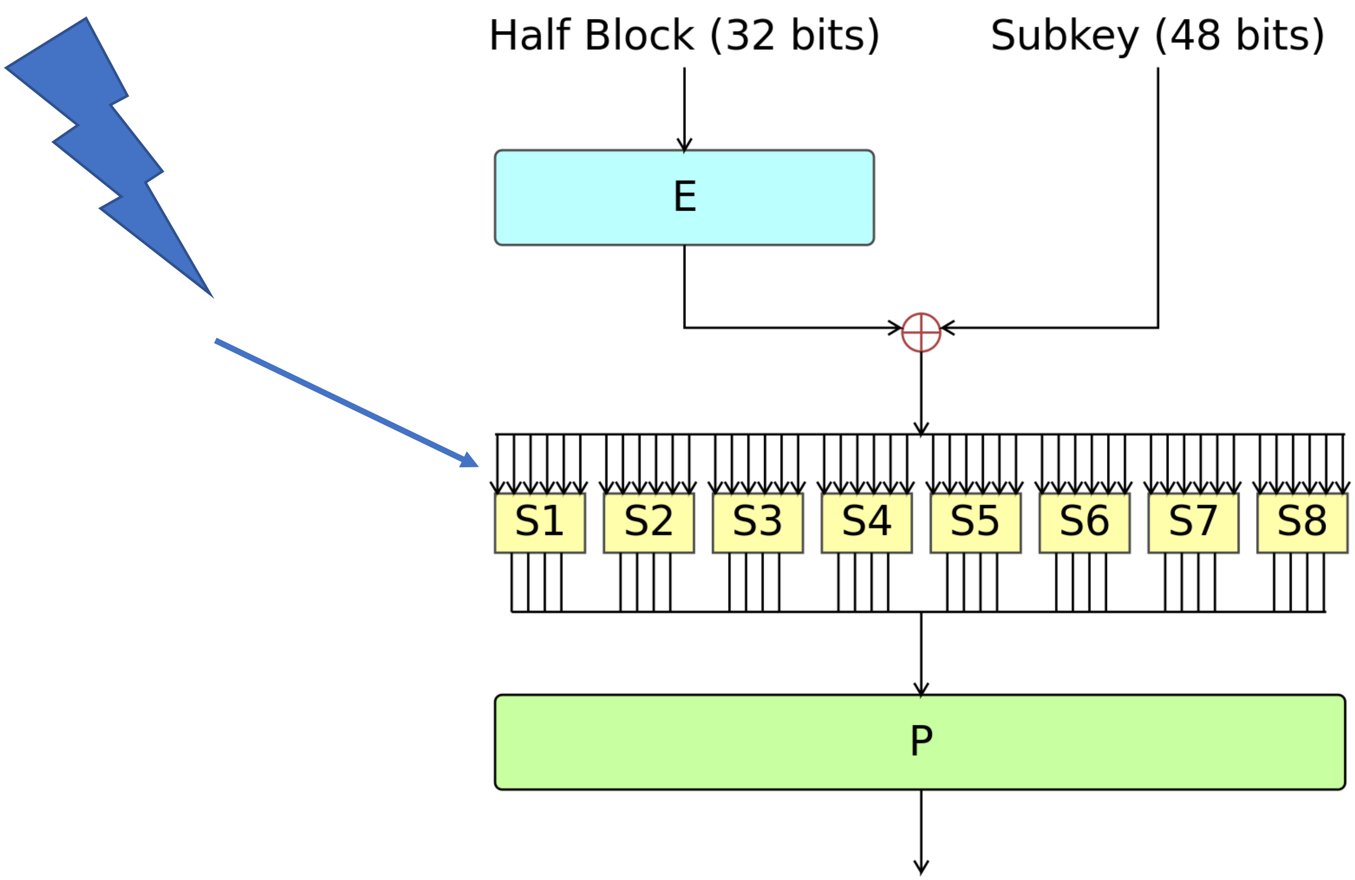
(Sig'^{e} – Msg) is not divisible by q

So, p = GCD(Sig'^{e} – Msg, n)

n = p*q

So q = n/p

Differential Fault analysis on AES



Tamper Resistance: The Moral

- If someone can benefit by physically subverting your system, and that attack can scale, you need to pay attention to physical device properties
- Standards are out-of-date, and manufacturer incentives often misaligned
- You need to know enough about these attacks to work out whether they are valid for your threat model.

Further Reading

- Security Engineering Chapter 13: Locks and Alarms
- Security Engineering Chapter 18: Tamper Resistance
- Security Engineering Chapter 19: Side Channels