# Crypto tidbits: misuse, side channels

Slides from

- Dave Levin 414-spring2016

# An Empirical Study of Cryptographic Misuse in Android Applications


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A paper from 2013 that looked at how Android apps use crypto, as a function of 6 "rules" that reflect the bare minimum a secure programmer should know:

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A paper from 2013 that looked at how Android apps use crypto, as a function of 6 "rules" that reflect the bare minimum a secure programmer should know:

1. Do not use **ECB** mode for encryption. Period.
2. Do not use a **non-random IV** for CBC encryption.
3. Do not use **constant encryption keys**.
4. (see paper)
5. (see paper)
6. Do not use **static seeds** to seed `SecureRandom(.)`

# Crypto misuse in Android apps

15,134 apps from Google play used crypto;
Analyzed **11,748** of them

| | # apps | violated rule |
|---|---|---|
| 48% | 5,656 | Uses ECB (BouncyCastle default) (R1) |
| 31% | 3,644 | Uses constant symmetric key (R3) |
| 17% | 2,000 | Uses ECB (Explicit use) (R1) |
| 16% | 1,932 | Uses constant IV (R2) |
| | 1,636 | Used iteration count $< 1{,}000$ for PBE(R5) |
| 14% | 1,629 | Seeds SecureRandom with static (R6) |
| | 1,574 | Uses static salt for PBE (R4) |
| 12% | 1,421 | No violation |

# BouncyCastle defaults

- BouncyCastle is a library that conforms to Java's `Cipher` interface:

```
Cipher c =
   Cipher.getInstance("AES/CBC/PKCS5Padding");

// Ultimately end up wrapping a ByteArrayOutputStream
// in a CipherOutputStream
```

- Java documentation specifies:

> If no mode or padding is specified, provider-specific default values for the mode and padding scheme are used. For example, the `SunJCE` provider uses `ECB` as the default mode, and `PKCS5Padding` as the default padding scheme for `DES`, `DES-EDE` and `Blowfish` ciphers.

| #Occurences | Symmetric encryption scheme |
|---|---|
| 5878 | AES/CBC/PKCS5Padding |
| 4803 | AES * |
| 1151 | DES/ECB/NoPadding |
| 741 | DES * |
| 501 | DESede * |
| 473 | DESede/ECB/PKCS5Padding |
| 468 | AES/CBC/NoPadding |
| 443 | AES/ECB/PKCS5Padding |
| 235 | AES/CBC/PKCS7Padding |
| 221 | DES/ECB/PKCS5Padding |
| 220 | AES/ECB/NoPadding |
| 205 | DES/CBC/PKCS5Padding |
| 155 | AES/ECB/PKCS7Padding |
| 104 | AES/CFB8/NoPadding |

**Table 4: Distribution of frequently used symmetric encryption schemes. Schemes marked with * are used in ECB mode by default.**

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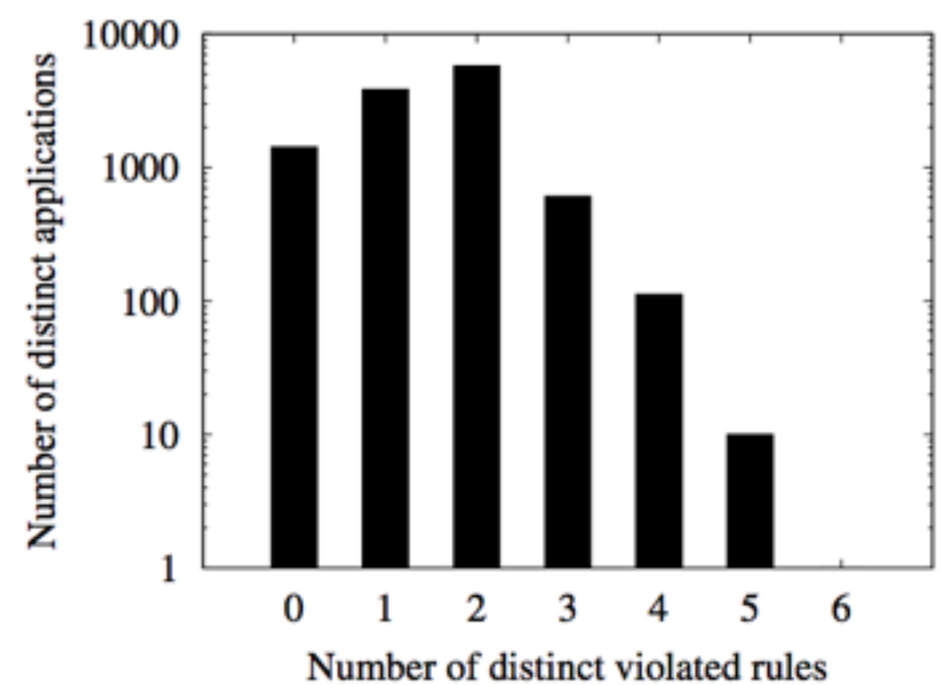
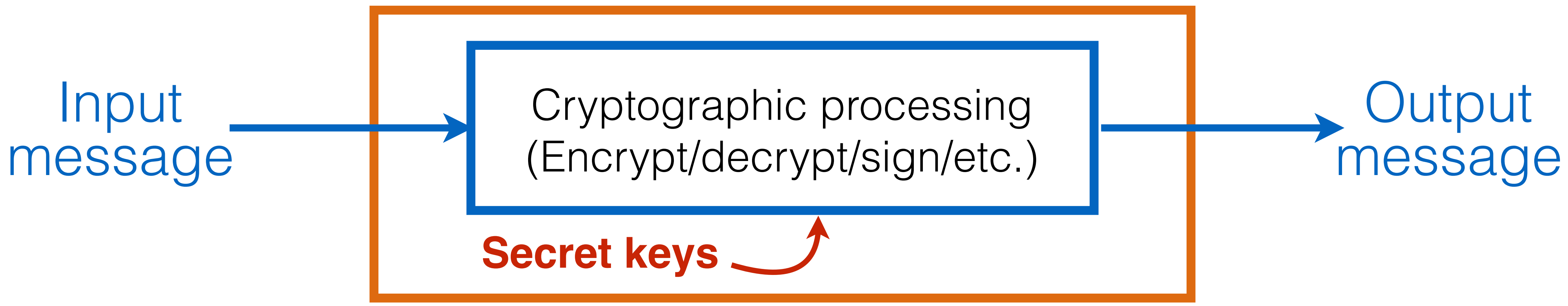



A failure of the programmers to **know the tools** they use

A failure of library writers to **provide safe defaults**

# Side-channel attacks

- Cryptography concerns the *theoretical* difficulty in breaking a cipher



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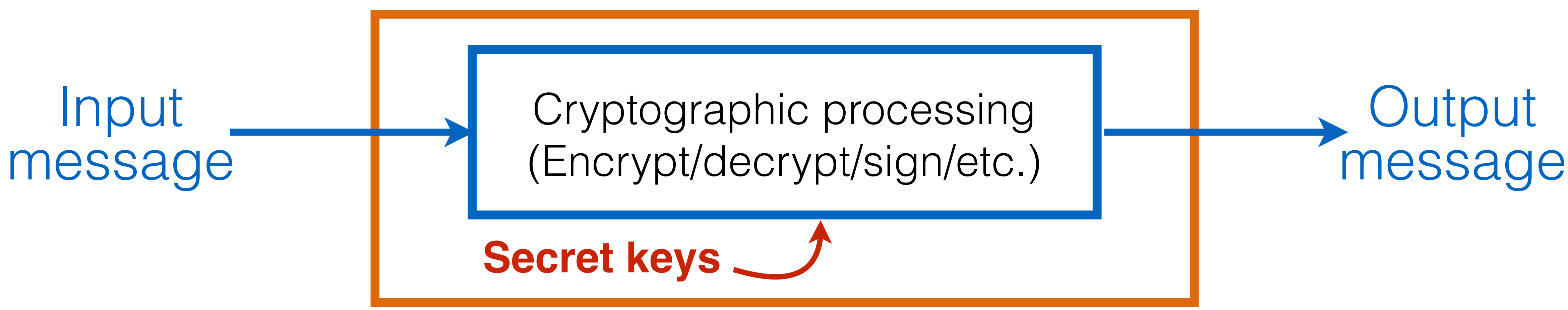


- But what about the information that a particular *implementation* could leak?
  - Attacks based on these are "**side-channel attacks**"

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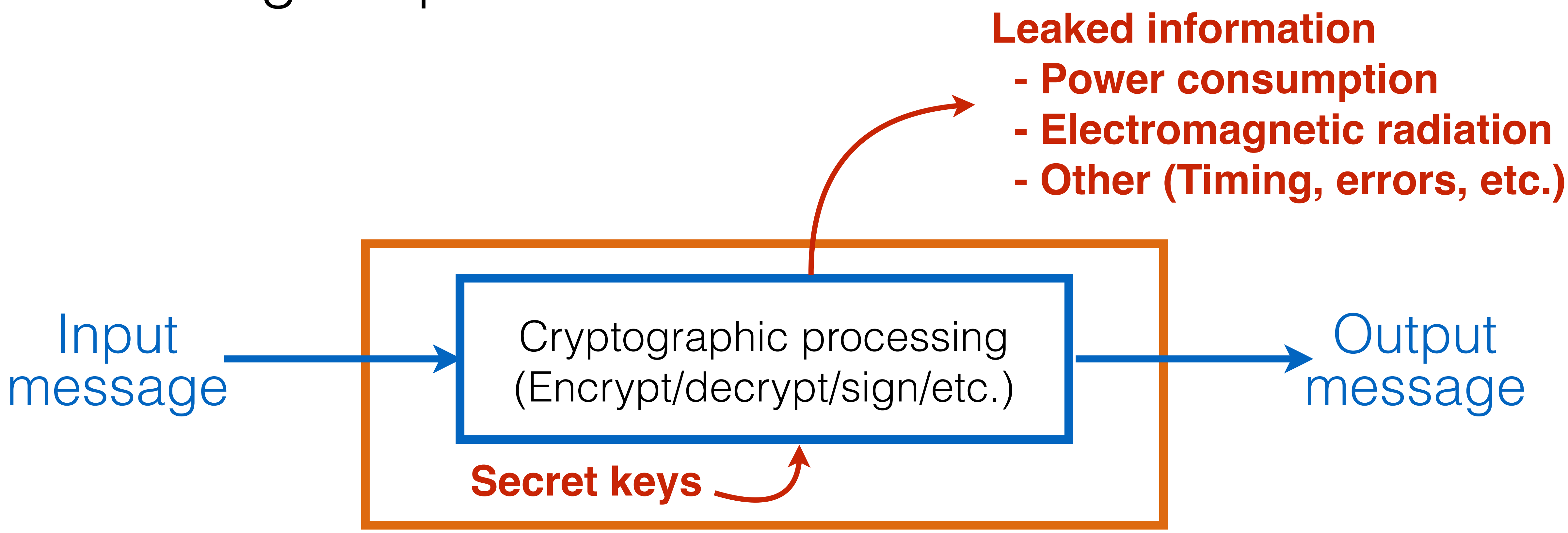


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# Simple Power Analysis (SPA)

- Interpret *power traces* taken during a cryptographic operation

- Simple power analysis can reveal the sequence of instructions executed

# SPA on DES

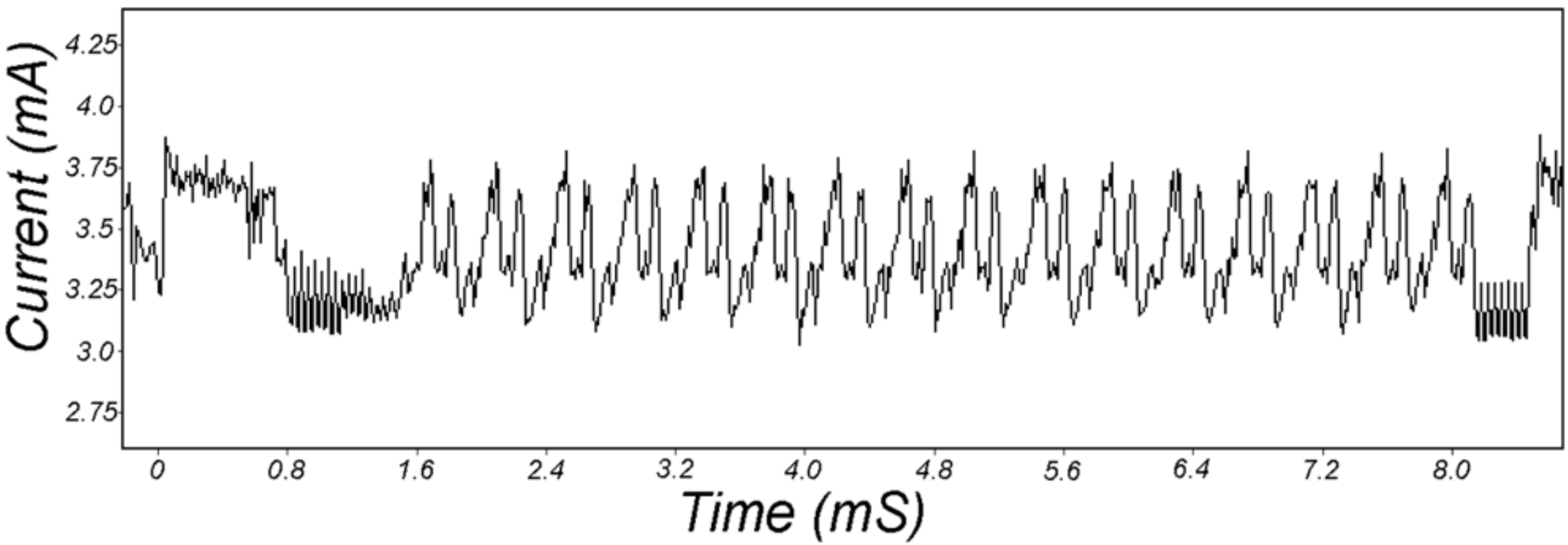


**Figure 1:** SPA trace showing an entire DES operation.

Overall operation clearly visible:
Can identify the **16 rounds of DES**

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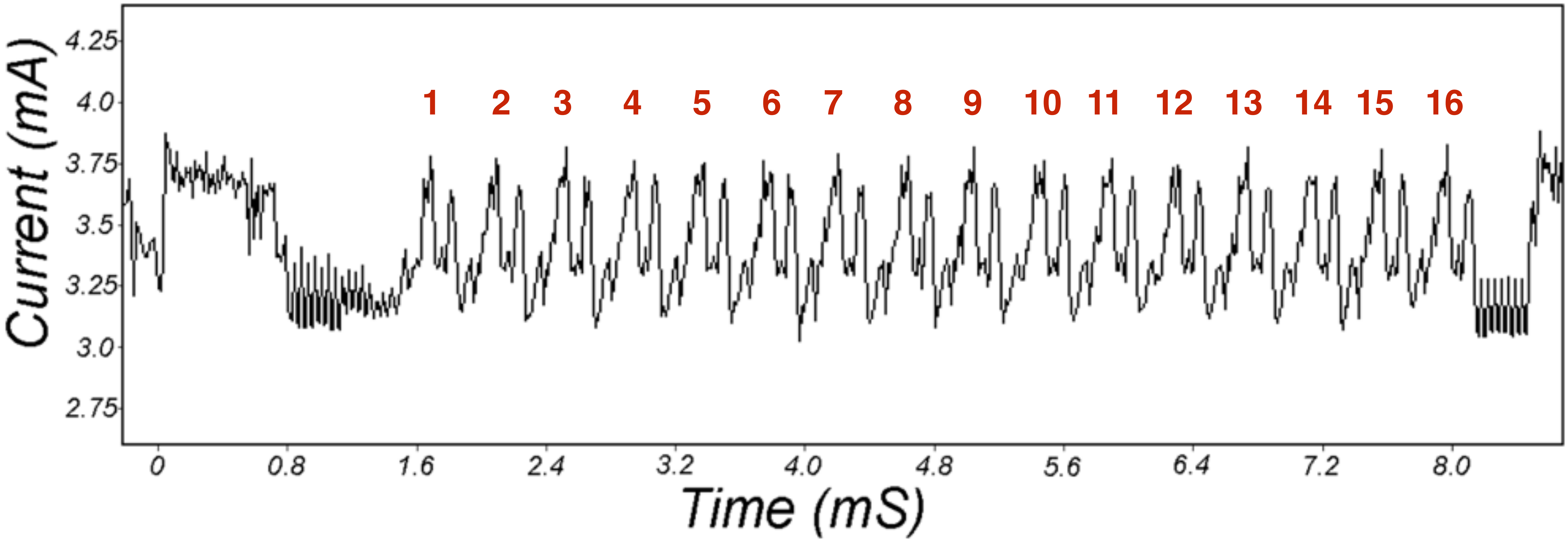


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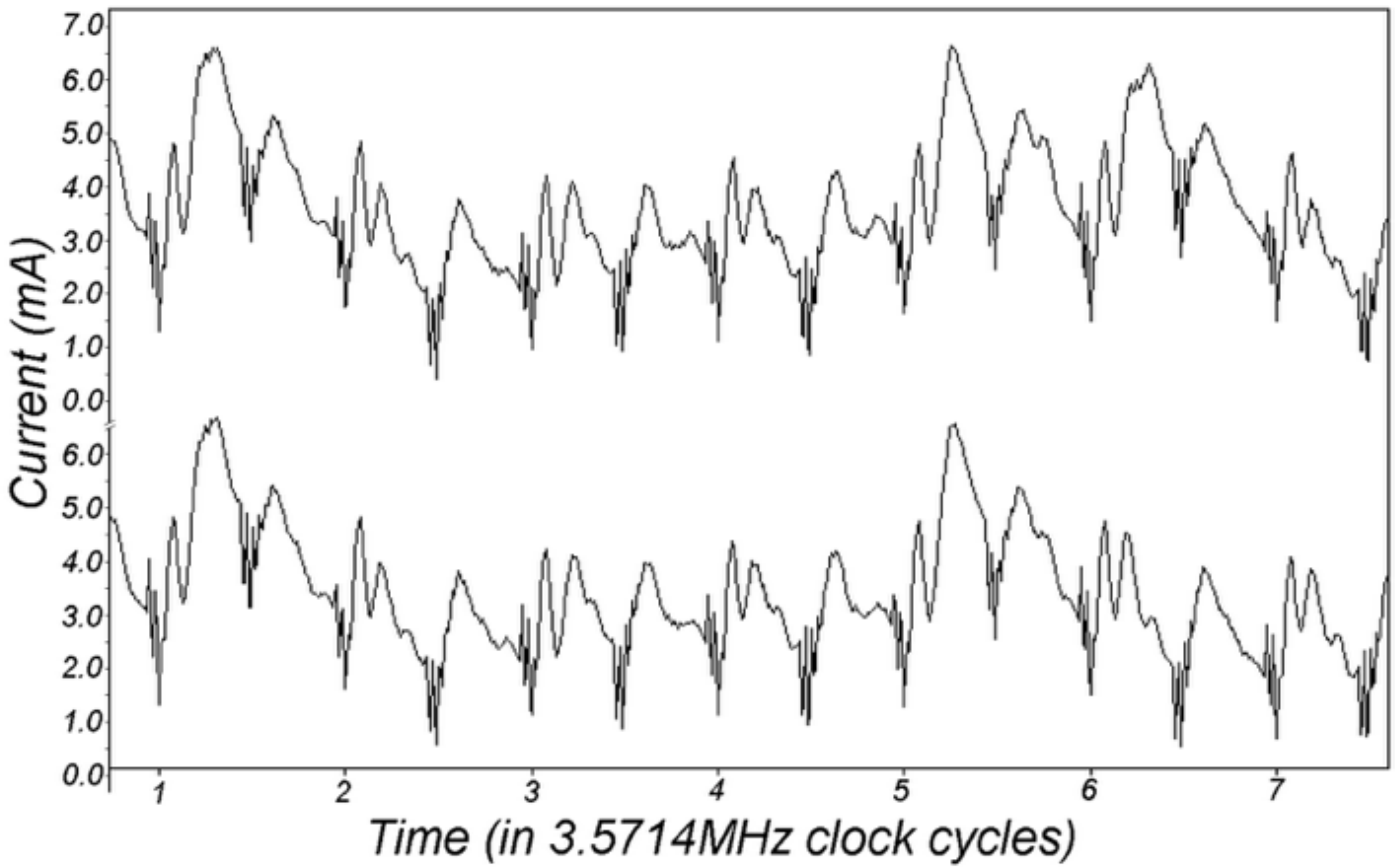


**Figure 3:** SPA trace showing individual clock cycles.

Specific **instructions** are also discernible

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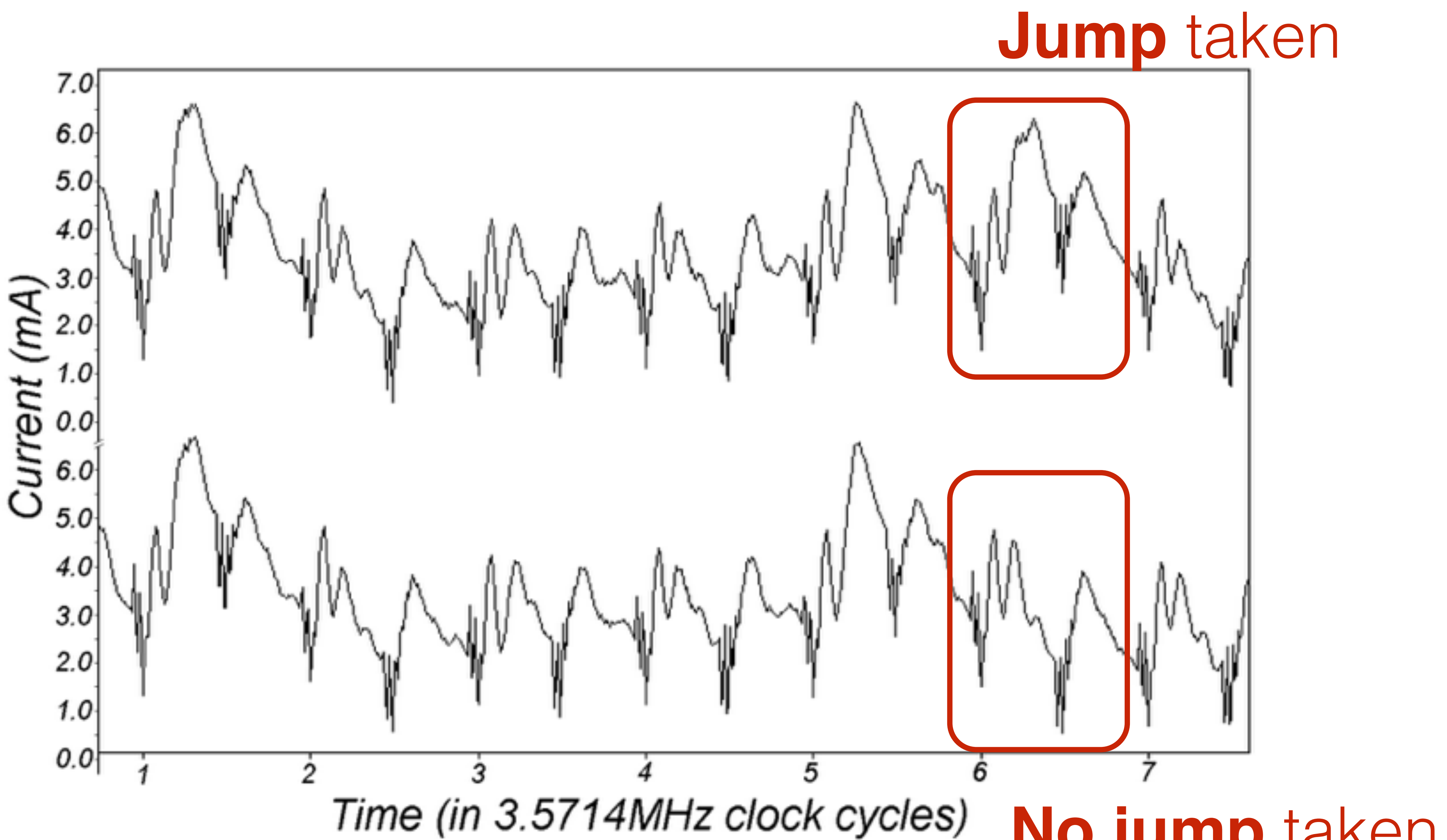


**Figure 3:** SPA trace showing individual clock cycles.

Specific **instructions** are also discernible

# High-level idea

```
HypotheticalEncrypt(msg, key) {
   for(int i=0; i < key.len(); i++) {
      if(key[i] == 0)
         // branch 0
      else
         // branch 1
   }
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What if branch 0
- took longer? (timing attacks)
- gave off more heat?
- made more noise?
- …

Implementation issue: If the execution path depends on the inputs (key/data), then *SPA can reveal keys*

# Differential Power Analysis (DPA)

- SPA just visually inspects a single run
- DPA runs iteratively and reactively
  - Get multiple samples
  - Based on these, construct new plaintext messages as inputs, and repeat

# Mitigating such attacks

- Hide information by making the execution paths depend on the inputs as little as possible
  - Have to *give up some optimizations* that depend on particular bit values in keys
    - Some Chinese Remainder Theorem (CRT) optimizations permitted remote timing attacks on SSL servers

- The crypto community should seek to design cryptosystems under the assumption that some information is going to leak

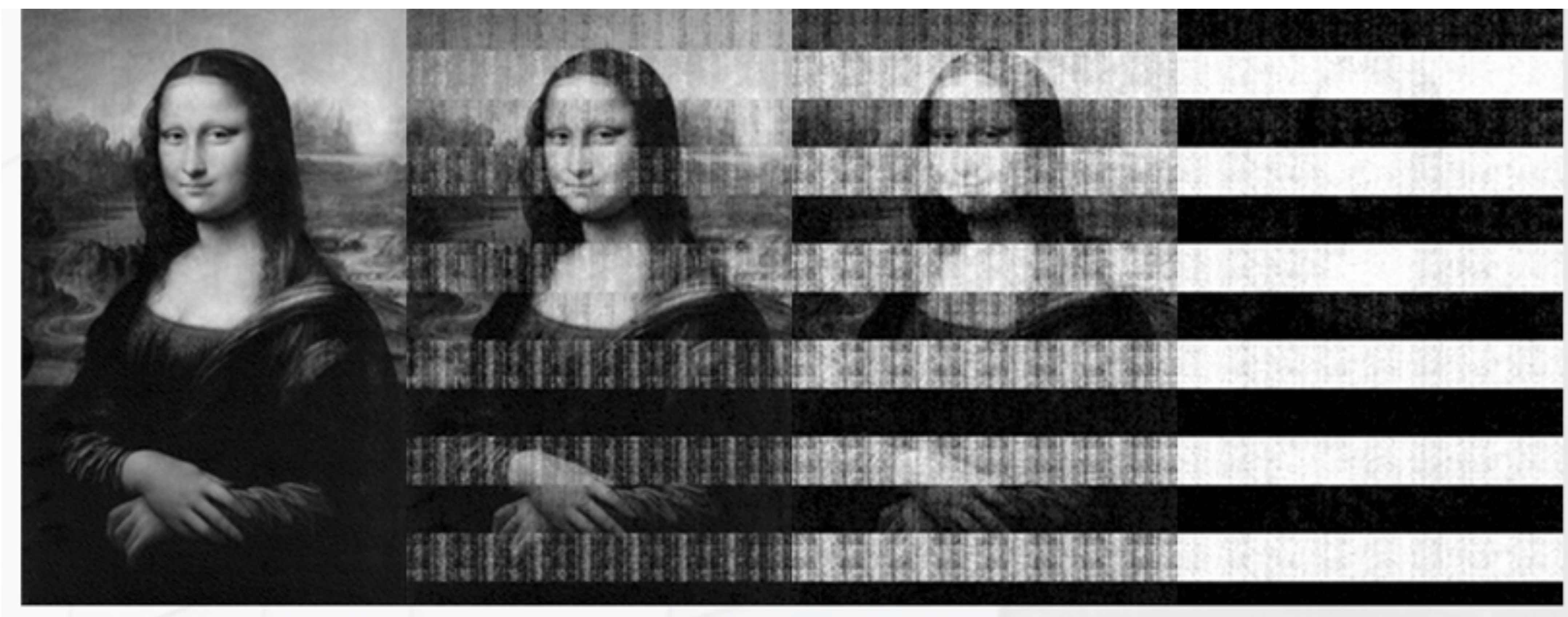
# Other side-channel attacks

- Typical threat model: attacker doesn't have root access to a particular machine
  - So we safely store keys in memory
- But what if the attacker had physical access to the machine?

# Attack

- Attacker's goal: reboot the machine into an OS that that he or she controls to look at memory contents

- Challenge: memory loses state without power



5 sec 30 sec 60 sec 5 min

# Cold boot attack

Memory loses its state slower
at really cold temperatures

| | Seconds w/o power | Error % at operating temp. | Error % at −50°C |
|---|---|---|---|
| A | 60 | 41 | (no errors) |
| | 300 | 50 | 0.000095 |
| B | 360 | 50 | (no errors) |
| | 600 | 50 | 0.000036 |
| C | 120 | 41 | 0.00105 |
| | 360 | 42 | 0.00144 |
| D | 40 | 50 | 0.025 |
| | 80 | 50 | 0.18 |

Table 2: Effect of cooling on error rates

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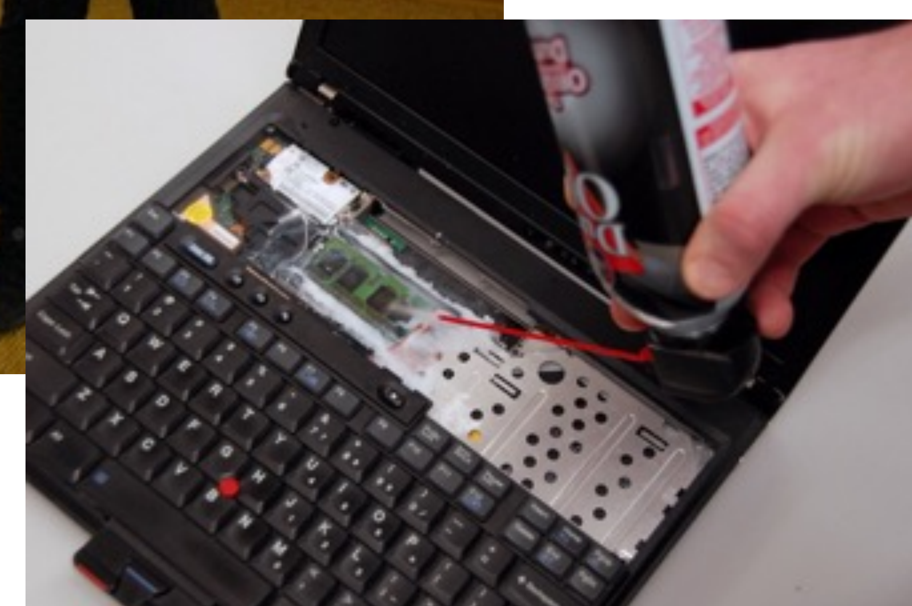

# Cold boot attack

- **Launching** the attack:
  - Cool down the memory & then power off/take it out
  - Boot into your own OS
  - Scan the memory image for keys (non-trivial but doable, especially if the keys have a format that's easy to detect)

- Some **defenses** against the attack:
  - Encrypt all of memory (increased CPU support for this)
  - Use trusted hardware (Xbox does this)
    - TPM (Trusted Platform Module) stores keys in hardware that is very difficult to inspect (some self-destruct)
  - Limit the amount of time keys live in memory
    - E.g., remove keys from memory when you enter Sleep mode