MAX PLANCK INSTITUTE
FOR SECURITY AND PRIVACY

High-assurance crypto – Part II: Security

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January 30, 2023

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Optimizing Crypto vs. optimizing "something"

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No – we must not leak secret data to an attacker!

Hello World – with a secret

```
#include <sys/random.h>
#include <unistd.h>
#include <stdio.h>

int main(void)
{
  unsigned char secret;
  getrandom(&secret, sizeof(secret), 0);
  secret &= 1;

  if(secret) sleep(3);

  printf("Hello World!\n");
}
```

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- This code takes different amount of time, depending on s
- Obvious timing leak if s is secret
- Even if A and B take the same amount of cycles this is *generally not* constant time!
- Reasons: Branch prediction, instruction-caches
- **Never use secret-data-dependent branch conditions**

Eliminating branches

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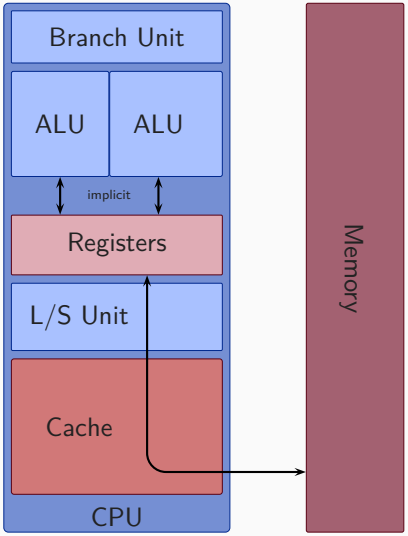
- Can expand s to all-one/all-zero mask and use XOR instead of addition, AND instead of multiplication
- For very fast A and B this can even be faster

Cached memory access



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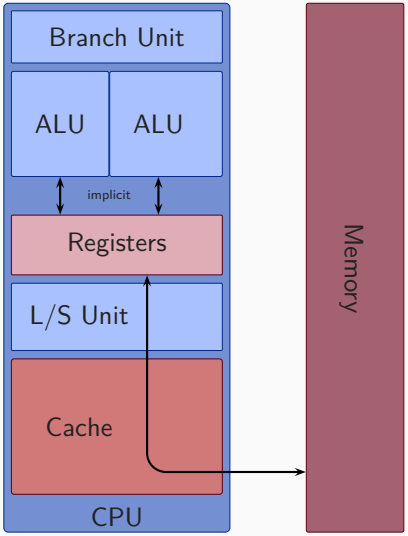

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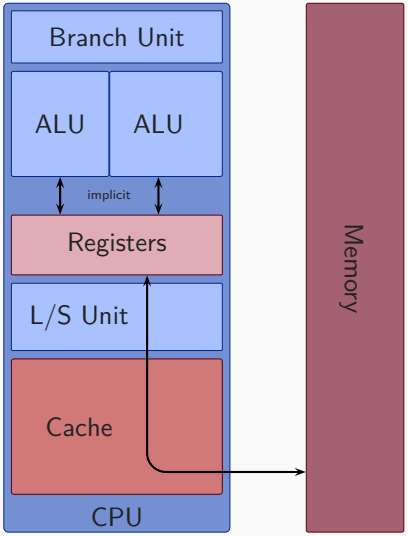

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- Loading data is fast if data is in the cache (**cache hit**)
- Loading data is slow if data is not in the cache (**cache miss**)

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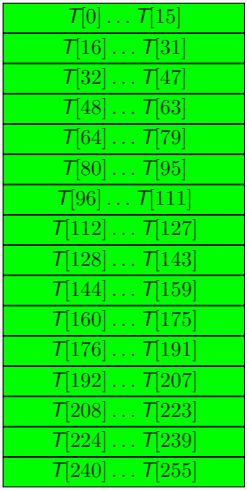

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- Crypto and the attacker's program run on the same CPU
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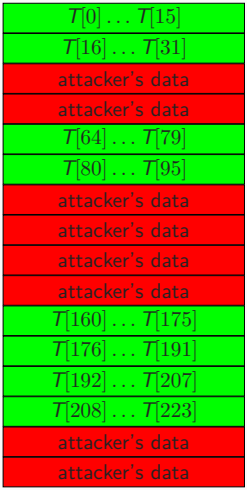

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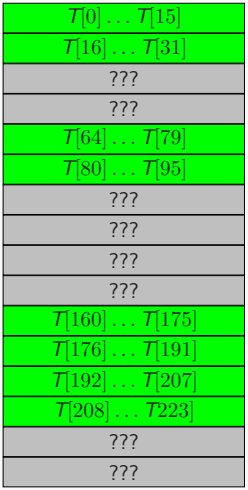

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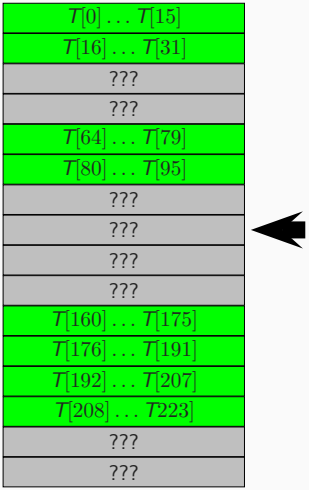

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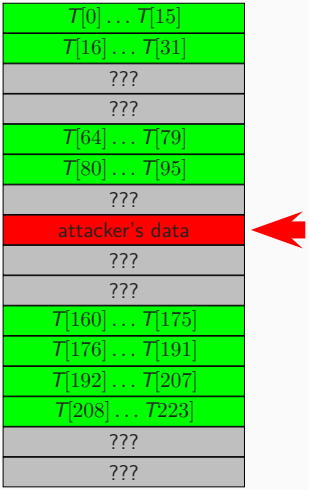

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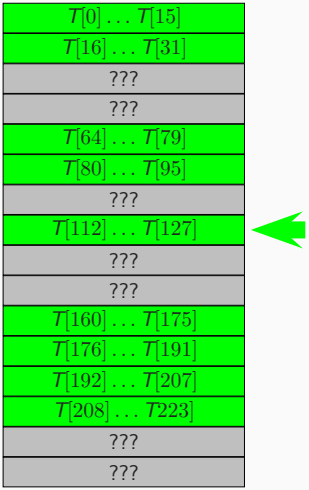

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- Attacker loads his data:
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- *Remote* timing attacks are practical:
  Brumley, Tuveri, 2011: A few minutes to steal ECDSA signing key from OpenSSL implementation

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- Problem 1: if-statements are not constant time (see before)
- Problem 2: Comparisons are not constant time, replace by, e.g.:

```
static unsigned long long eq(uint32_t a, uint32_t b)
{
  unsigned long long t = a ^ b;
  t = (-t) >> 63;
  return 1-t;
}
```

Is that all? (Timing leakage part III)

Lesson so far

- Avoid all data flow from secrets to branch conditions and memory addresses
- This can *always* be done as long as input size is public (or at least upper bounded)
- Cost highly depends on the algorithm

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"So the argument to the `DIV` instruction was smaller and `DIV`, on Intel, takes a variable amount of time depending on its arguments!"
—Langley, Feb. 2013

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Solution

- Avoid these instructions
- Make sure that inputs to the instructions don't leak timing information

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  - Electromagnetic radiation
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- Constant-time remains important **base-line defense**

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- Crypto software must avoid timing leaks
- Mostly two rules:
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- Crypto software must avoid timing leaks
- Mostly two rules:
  1. **Never branch depending on secret data**
  2. **Never access memory at secret locations**
- Additionally: avoid variable-time arithmetic instructions
- This is **necessary base-line defense** for essentially all crypto software
- Does not protect against physical side-channel attacks
- Helps, but does not protect against advanced microarchitectural attacks