SCIENCE ▪ PASSION ▪ TECHNOLOGY

Fault Injection Attacks, Error Detection Codes & Verifying a Secure Program

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Motivation: Detection of Bit Flips

```
authorized := 0

…

if(authorized) {
    // do secret stuff
}
```

✓ not executed

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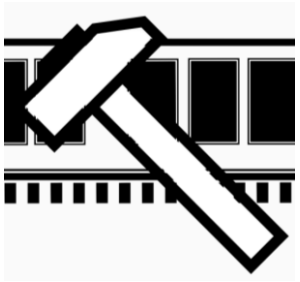
Motivation: Detection of Bit Flips

```
authorized := 0

…

if(authorized) {
    // do secret stuff
}
```

Attacker injects bit flip on `authorized`



✗ executed

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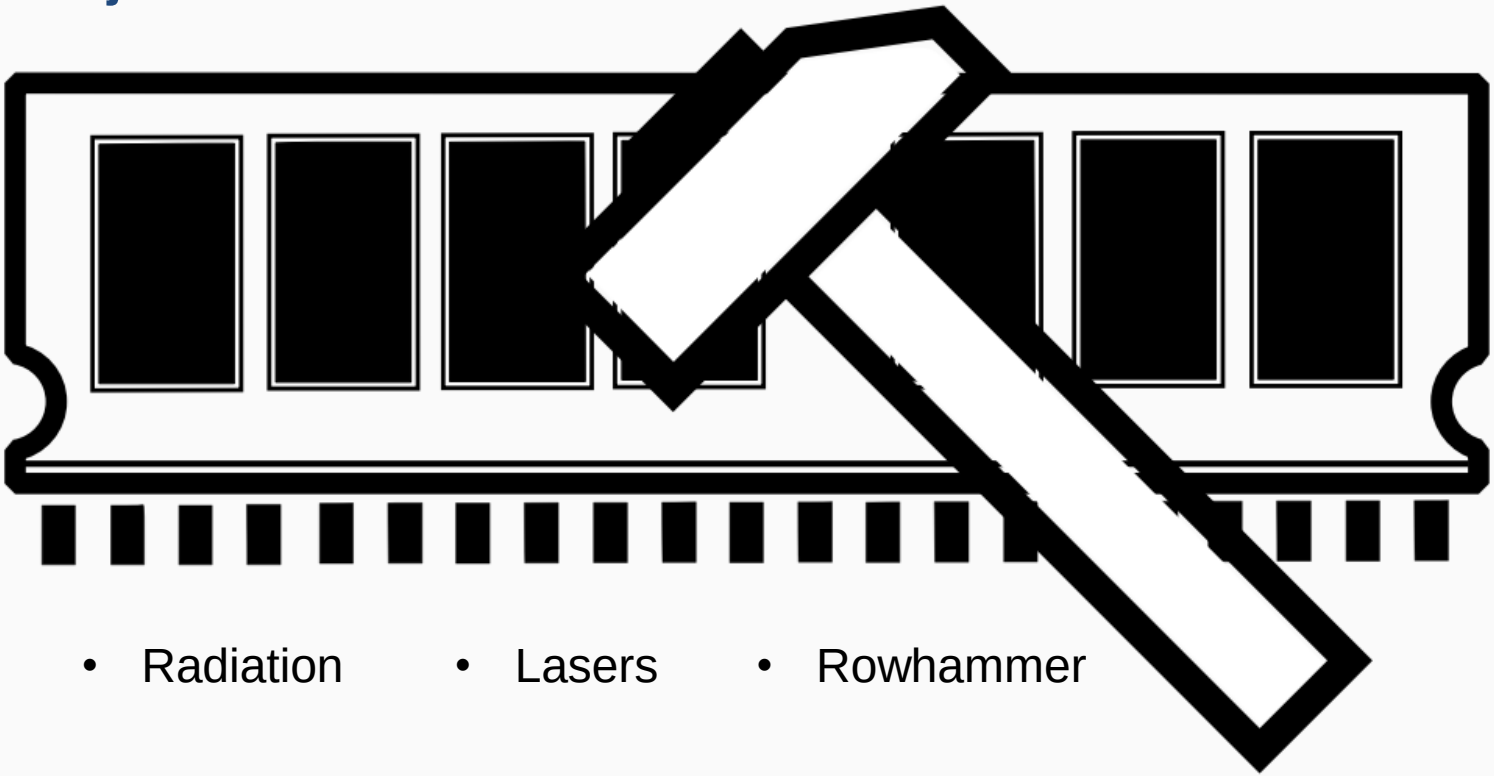
Fault Injection Attacks



- Radiation
- Lasers
- Rowhammer

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Error Detection Codes

Idea: Add redundant information to check for bit flips.

Example Residue Code:

$$enc(8) = 0000\ 1000 \mid 010_b$$

original data
$0000\ 1000_b = 8$

redundant bits
$8\ mod\ 6 = 010_b$

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Arithmetic Error Detection Codes

- *Idea:* Add redundant information to check for bit flips
- Arithmetic codes are homomorphic over arithmetic operations

$$enc(x) + enc(y) = enc(x + y)$$

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Arithmetic Error Detection Codes

- *Idea:* Add redundant information to check for bit flips
- Arithmetic codes are homomorphic over arithmetic operations

$$enc(x) + enc(y) = enc(x + y)$$

$$enc(8) + enc(7) = (8 \mid 8\ mod\ 6) + (7 \mid 7\ mod\ 6)$$
$$= (15 \mid 15\ mod\ 6) = encode(15)$$

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Checks

- Checks detect invalid code words → detect certain bit flips

$$check(x|x_R)\text{: } assert(x_R == x \; mod \; 6)$$

$$check(0000\;1000 \mid 010)\text{: } assert(2 == 8 \; mod \; 6)$$

✓ passed

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Checks

- Checks detect invalid code words → detect certain bit flips

$$check(x|x_R)\colon\ assert(x_R == x\ mod\ 6)$$

$$check(0000\ 1000\ |\ 010)\colon\ assert(2 == 8\ mod\ 6)$$

✓ passed

$$check(0000\ 1001\ |\ 010)\colon\ assert(2 == 9\ mod\ 6)$$

✗ not passed → bit flip detected

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Checks

- Checks detect invalid code words → detect certain bit flips

$$check(x|x_R)\text{: } assert(x_R == x \; mod \; 6)$$

$$check(0000\;1000 \mid 010)\text{: } assert(2 == 8 \; mod \; 6)$$

✓ passed

$$check(0000\;1001 \mid 010)\text{: } assert(2 == 9 \; mod \; 6)$$

✗ not passed → bit flip detected

$$check(0000\;1001 \mid 011)\text{: } assert(3 == 9 \; mod \; 6)$$

✓ passed → bit flips not detected

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Checks

- Checks detect invalid code words → detect certain bit flips

$$check(0000\ 1001|\ 011): assert(3 == 9\ mod\ 6)$$

✓ passed → bit flips not detected

→ Maximum number of bit flips detectable “$d_{min} - 1$”

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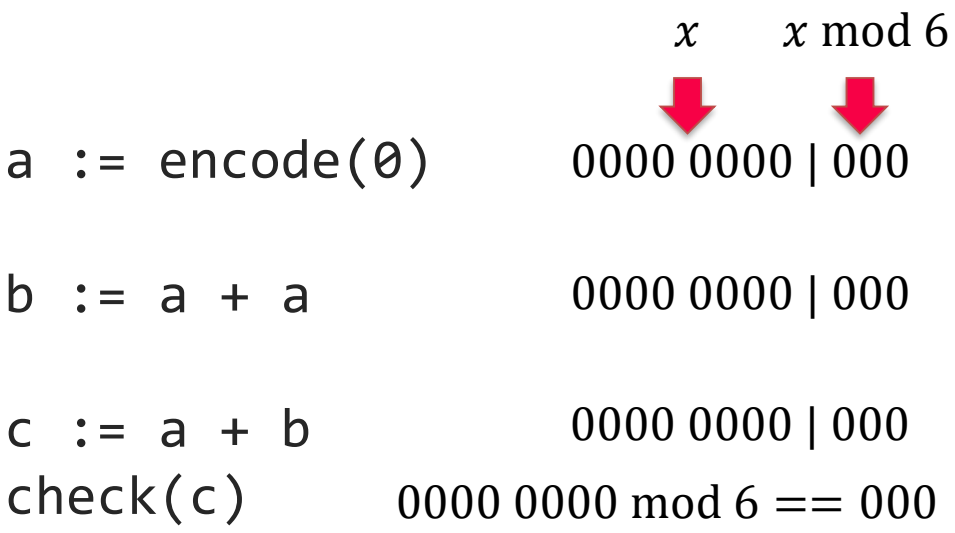
Error Masking



No bit has been flipped and check passes

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Error Masking

Attacker injects bit flip on a

```
a := encode(0)
b := a + a
c := a + b
check(c)
```

x $x \bmod 6$

$0000\ 0000 \mid 000$

$0000\ 0010 \mid 000$

$0000\ 0100 \mid 000$

$0000\ 0110 \mid 000$

$0000\ 0110 \bmod 6 == 000$

One bit has been flipped, errors accumulated and as a result check passes despite the bit flip.

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Error Masking Robustness Requires Intermediate Checks

Attacker injects bit flip on a

```
a := encode(0)

b := a + a
check(b)
c := a + b
check(c)
```

x $x \bmod 6$

0000 0000 | 000

0000 0001 | 000

0000 0010 | 000

0000 0010 mod 6 ≠ 000

One bit has been flipped and the intermediate check detects the bit flip.

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Model Checking of Error Masking Robustness

- A lot of variables!

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Model Checking of Error Masking Robustness

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- Even more possibilities for flips!

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Model Checking of Error Masking Robustness

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- Conditional Jumps / Loops?

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Model Checking of Error Masking Robustness

- A lot of variables!
- Even more possibilities for flips
- Conditional Jumps / Loops?

→ Complex!

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Model Checking of Error Masking Robustness

- A lot of variables!
- Even more possibilities for flips
- Conditional Jumps / Loops?

→ Requires too much memory & time!

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What can we do about it?

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Remember SLAM!

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→ We can discard not required information!

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How can we build an abstract program for this?

→ Next Presentation

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