Inside the AMD Microcode ROM - (Ab)Using AMD Microcode for fun and security

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Outline

- Crash course: Micro-architecture basics and Microcode
- Reconstructing the Microcode ROM
- Application examples
- Framework overview

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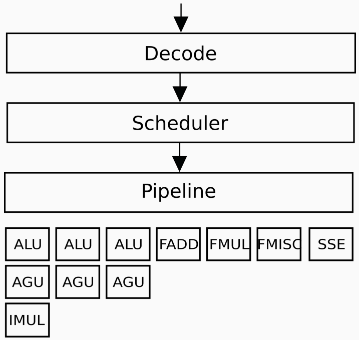
    - Complex features (Intel SGX)
- **Update capabilities**

x86 Instruction Decoding



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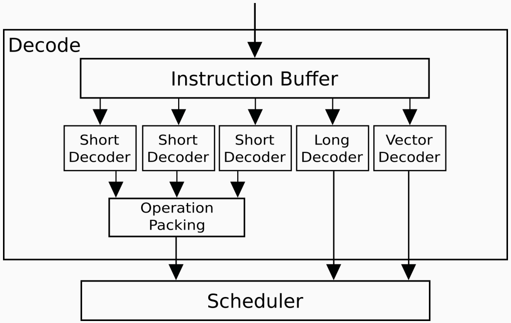
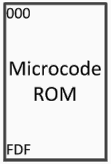


Microcode Engine (Vector Decoder)



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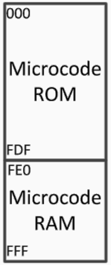

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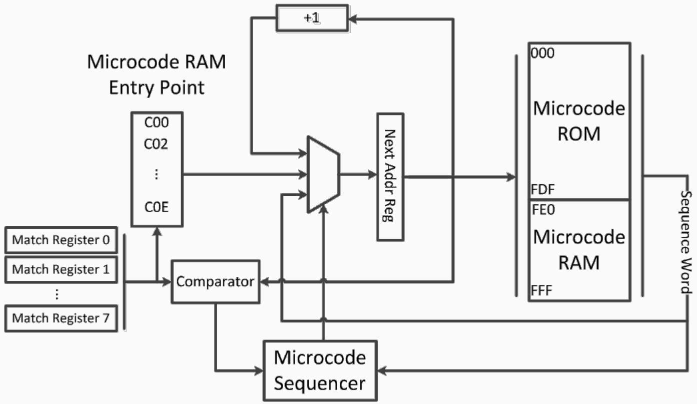

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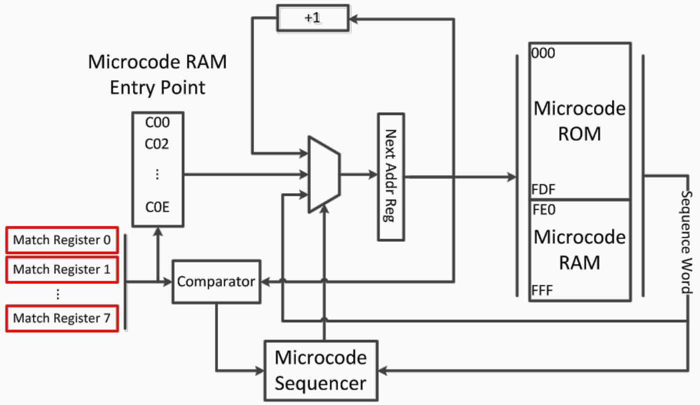

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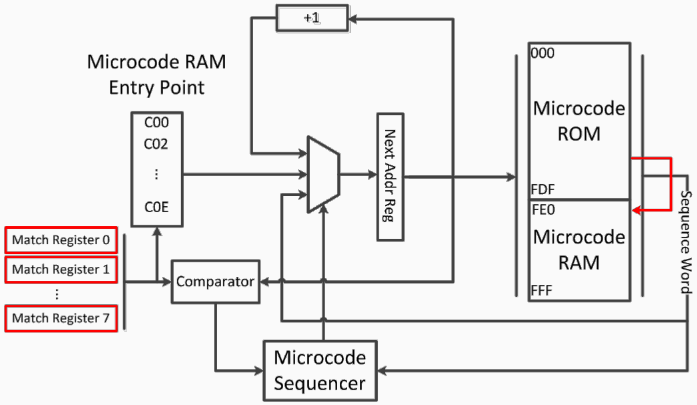

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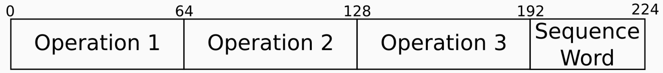

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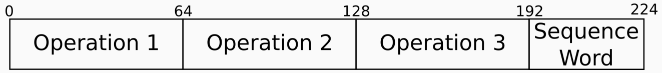

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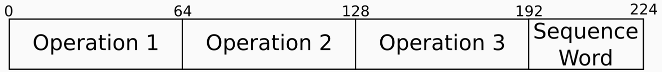

- Updates protected by weak authentication
- Only one update may be loaded at a time

Microcode RTL

```
sub eax, edx
sub.C t56q, rcx, 0x100
jcc ECF, 1
.sw_next // implied sequence word if omitted

ld t1d, [eax]
st [edx], t1d
mov eax, eax
.sw_complete

mov eax, 1
sub.Q rax, rcx
add.EP t56d, eax, ecx
.sw_branch 0xF01
```

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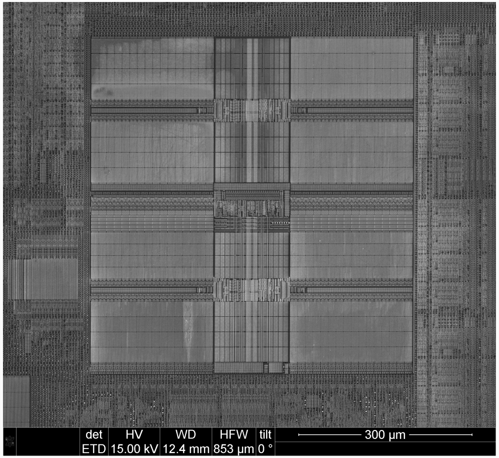
Hardware Analysis



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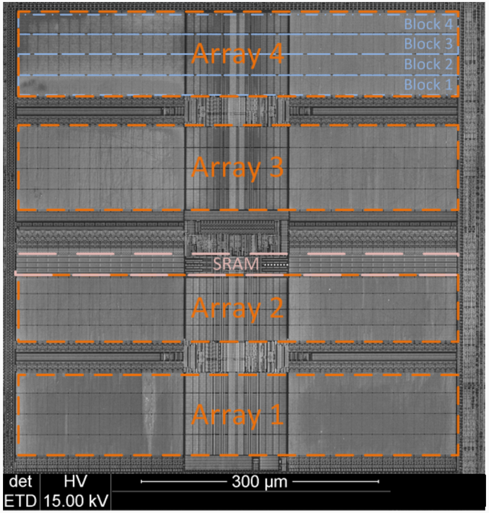
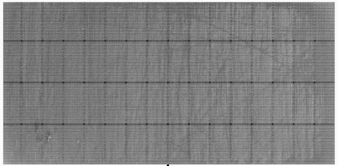
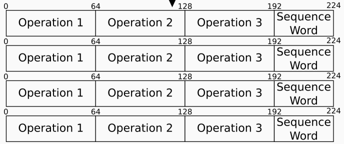


ROM - Recovery Process Overview



```
010101001010010010010
111101000001100010000
110010001010010001100
001001010110000001110
010001110100100100010
001010100100110100001
100001010110011000100
```



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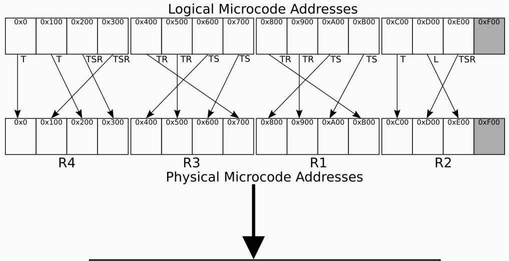

```
mov t1d, eax
xor.Z t1d, 0x23
jcc nEZF, 0x40
.sw_branch 0x96
xor.Z t1d, 0x64
jcc EZF, 0x30
xor eax, eax
```

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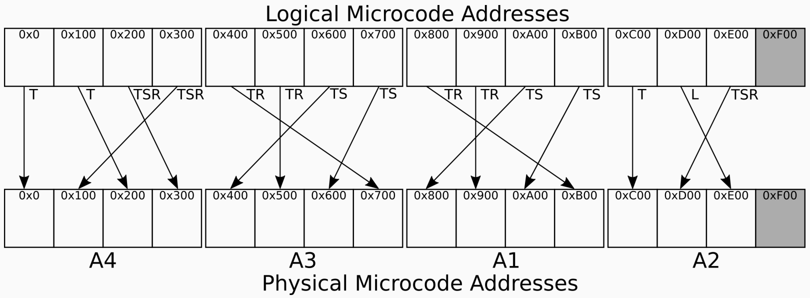
- Emulation yielded 54 additional address pairs

ROM - Mapping Result



ROM - Implementation of Instructions

- SHRD - 0xACA
- RDTSC - 0x318
- WRMSR - 0x6A9

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- Enclave-like execution environment

HWASAN Background

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```
CheckAddressAndCrashIfBad(Addr, kSize) {
  ShadowAddr = (Addr >> 3) + kOffset;
  if (kSize < 8) {
    Shadow = LoadByte(ShadowAddr);
    if (Shadow && Shadow <= (Addr & 7) + kSize - 1)
      ReportBug(Addr);
  } else {
    Shadow = LoadNBytes(ShadowAddr, kSize / 8);
    if (Shadow) ReportBug(Addr);
  }
}
```

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  - Runtime configuration

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- Micro benchmark shows performance advantage (106 vs. 129 cycles)

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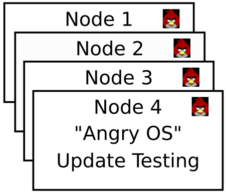

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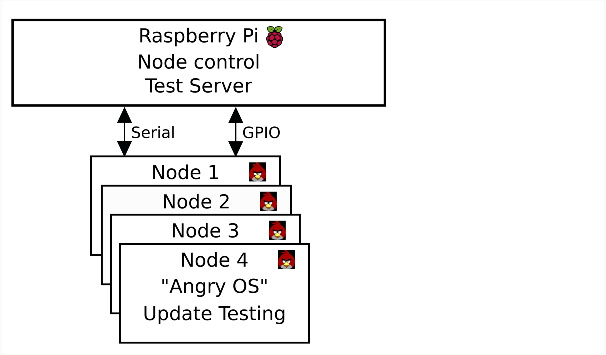
Raspberry Pi
Node control
Test Server
Serial
GPIO
Node 1
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Node 3
Node 4
"Angry OS"
Update Testing

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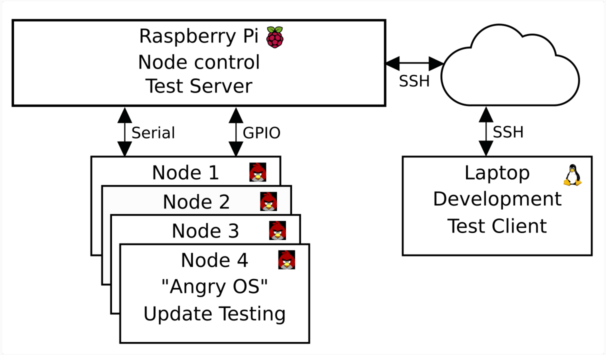
Raspberry Pi
Node control
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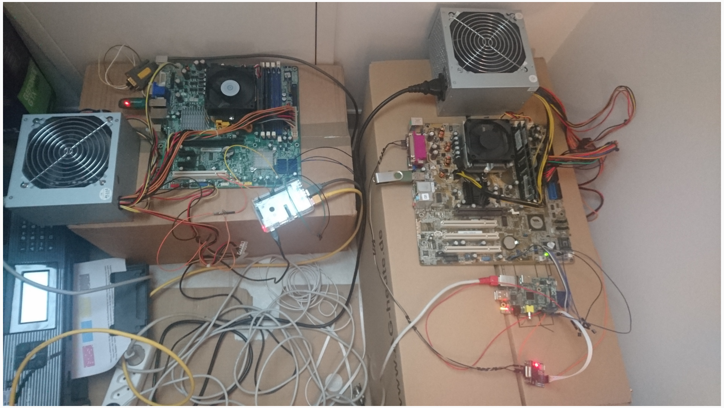

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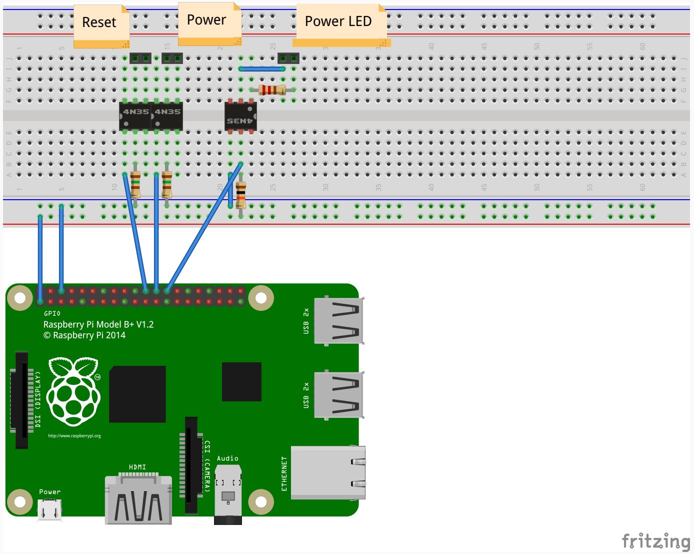
Reset
Power
Power LED
4N35
4N35
4N35
GPIO
Raspberry Pi Model B+ V1.2
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http://www.raspberrypi.org
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CSI (CAMERA)
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USB 2x
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- Apply updates, run streamed test code, error reporting

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- Control Angry OS node via serial and GPIO
- Remote execution wrapper

Conclusion

- Reversing of the ROM opens up many more possibilities
- Lots left to do, if you want to help, contact us!
- Framework, Angry OS, example programs and more available on Github

`https://github.com/RUB-SysSec/Microcode`

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