ECE 6504

Embedded and Controls Systems Security: Stack Smashing IV

Reading:

T: *Code Injection Attacks on Harvard-Architecture Devices* and *Can DREs Provide Long-Lasting Security?*

N: *kBouncer, ROPGuard, ROPecker,* and *Evaluating the Effectiveness of Current Anti-ROP Defenses*

“I intend to live forever, or die trying.”

–Groucho Marx

return-oriented programming (ROP)

setup stack to point to instructions that end in return

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SP replaces IP
(we ‘execute’ on the stack)

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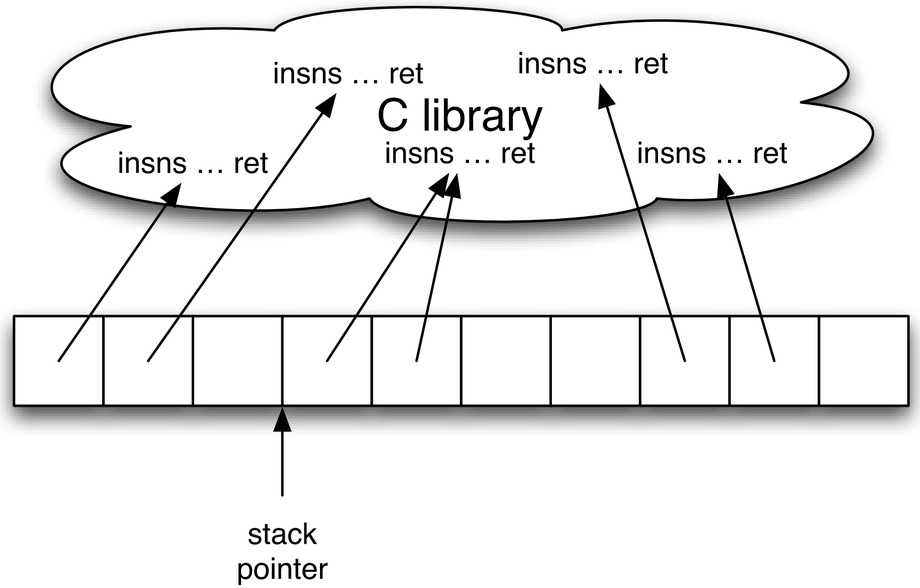

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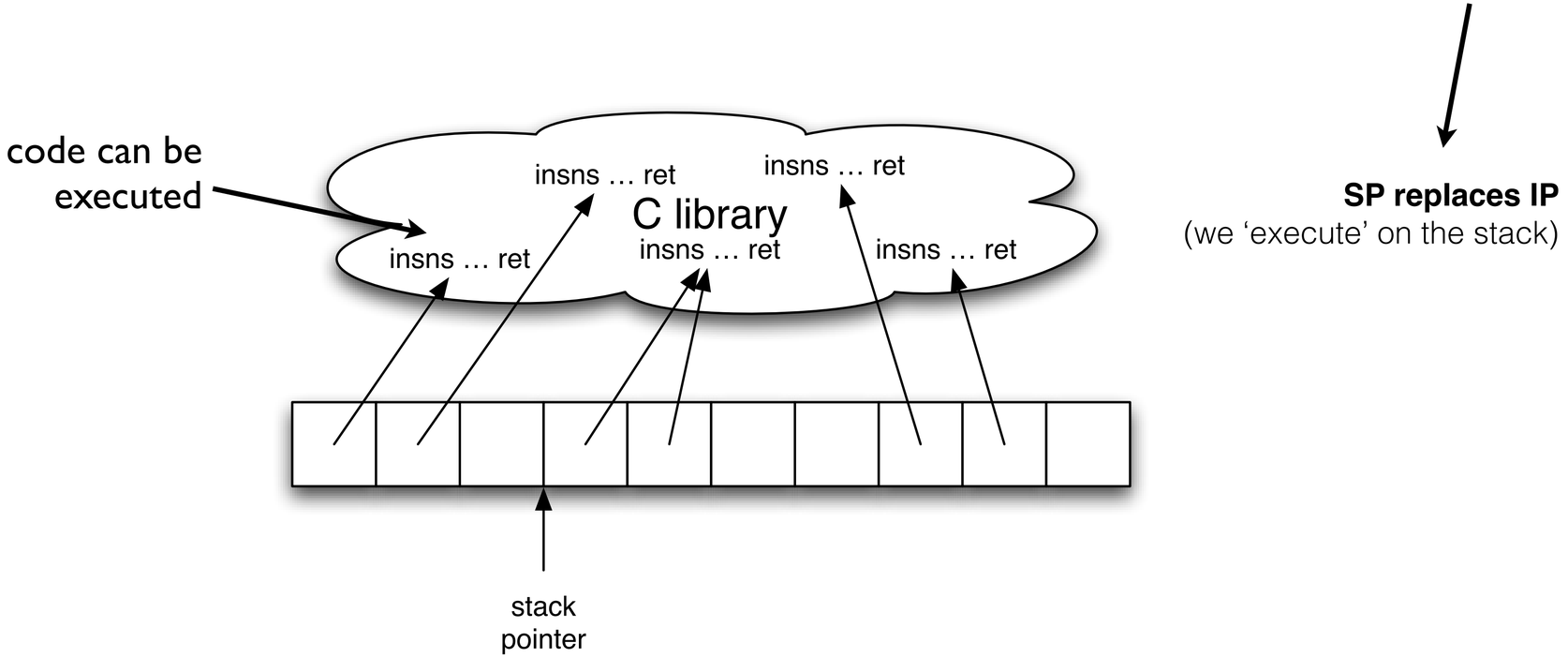

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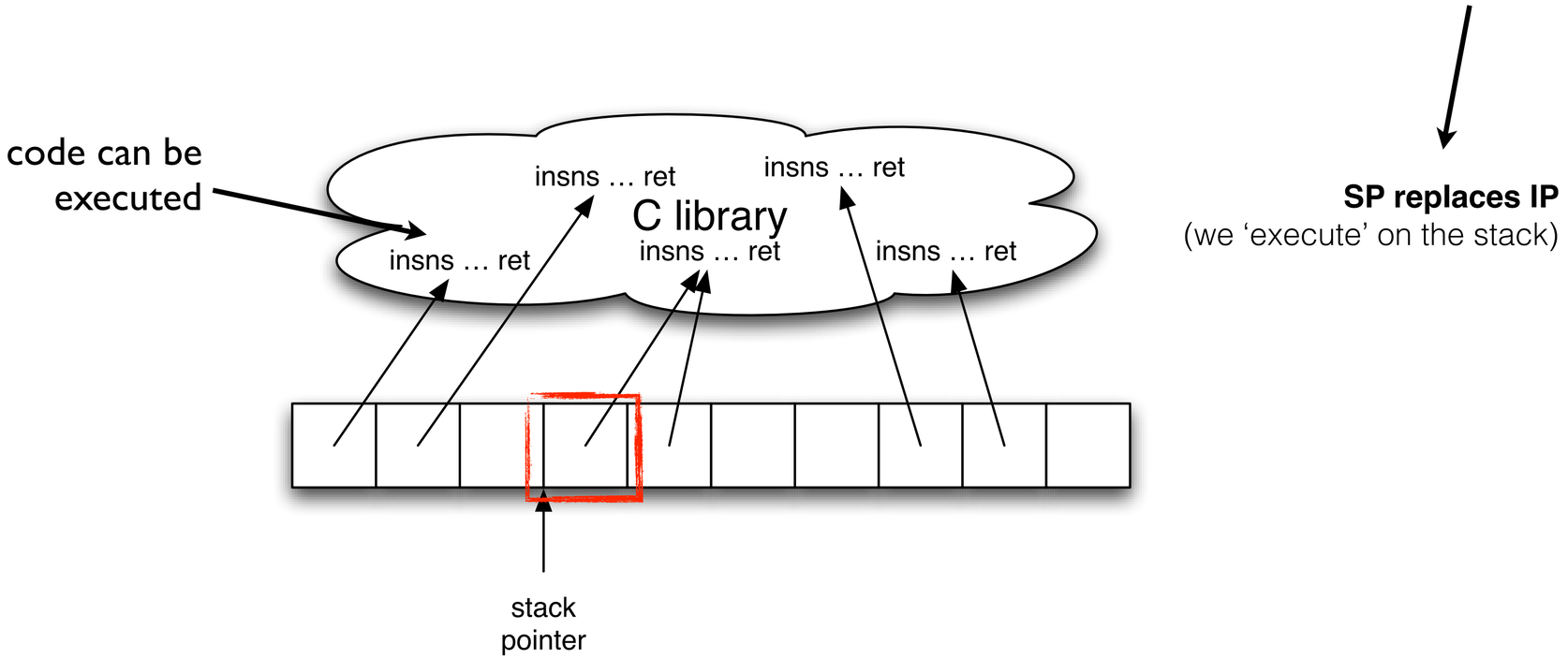

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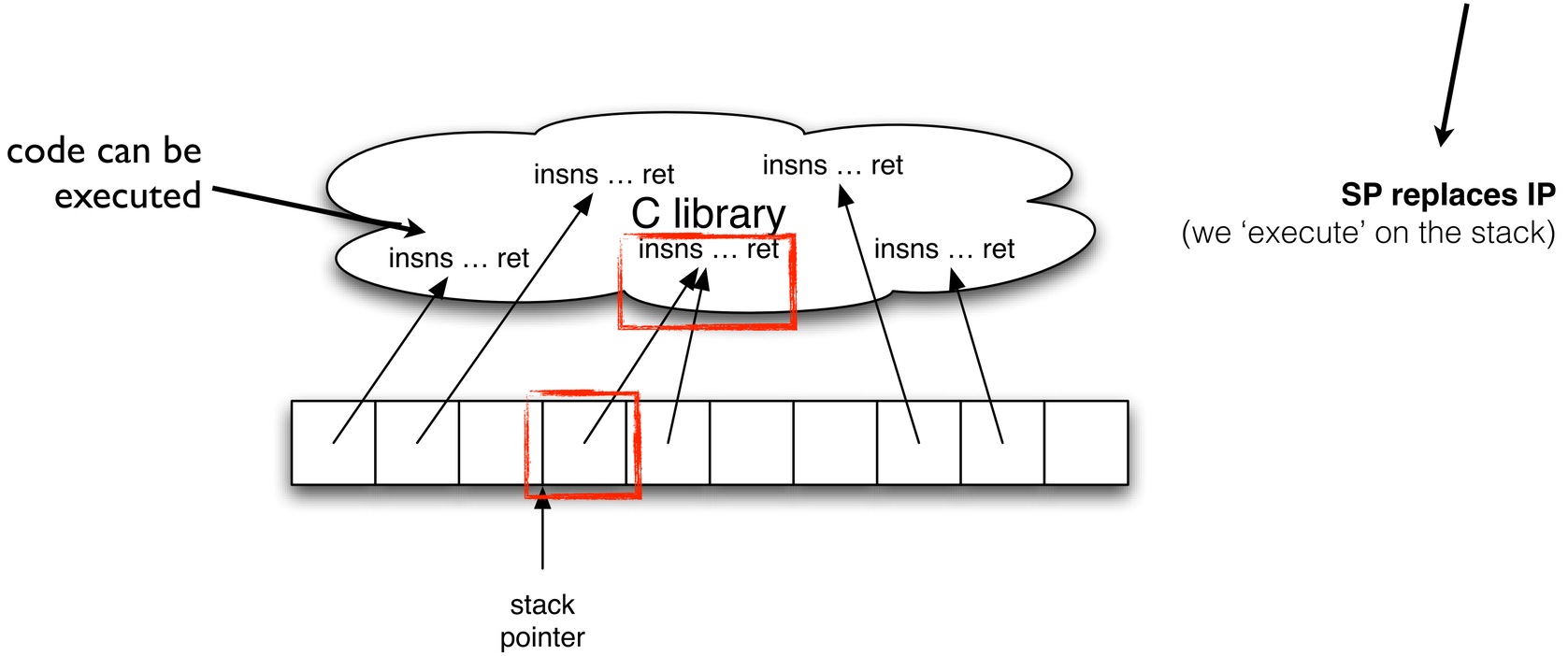

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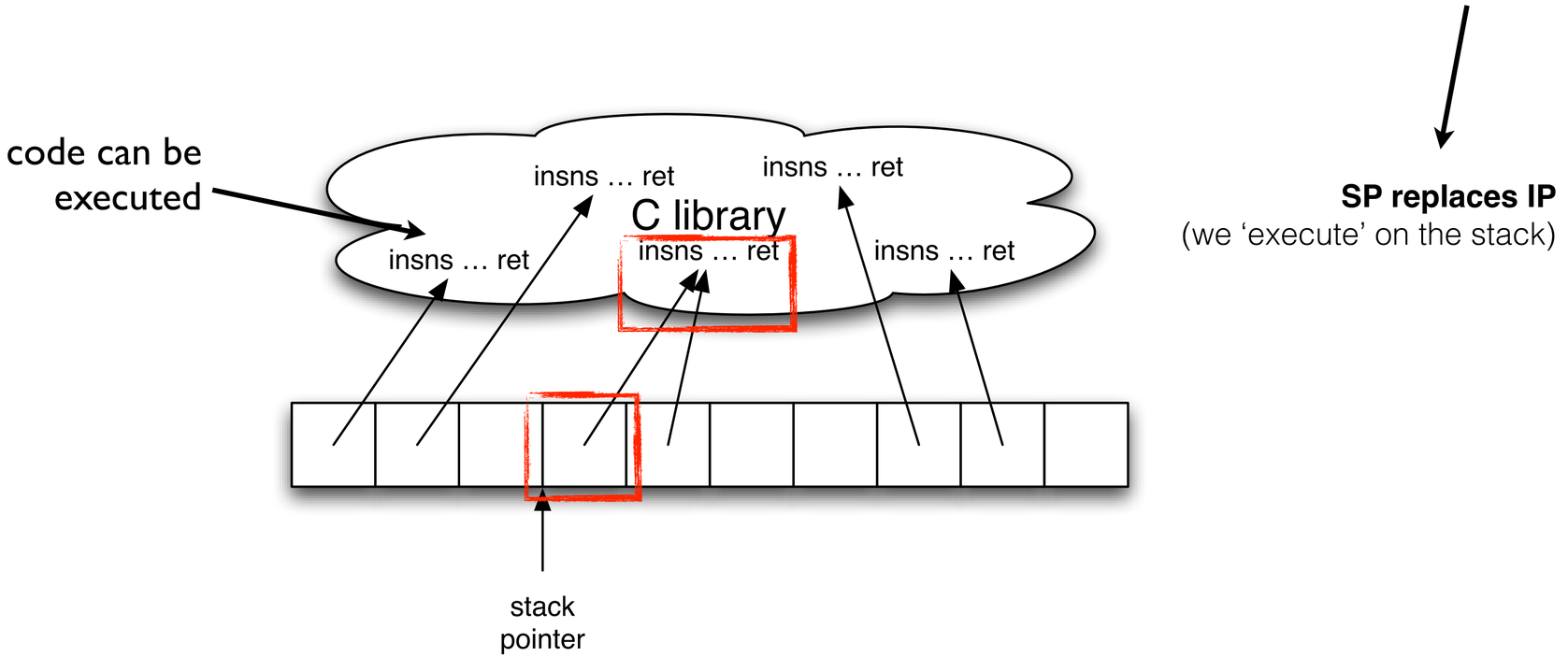
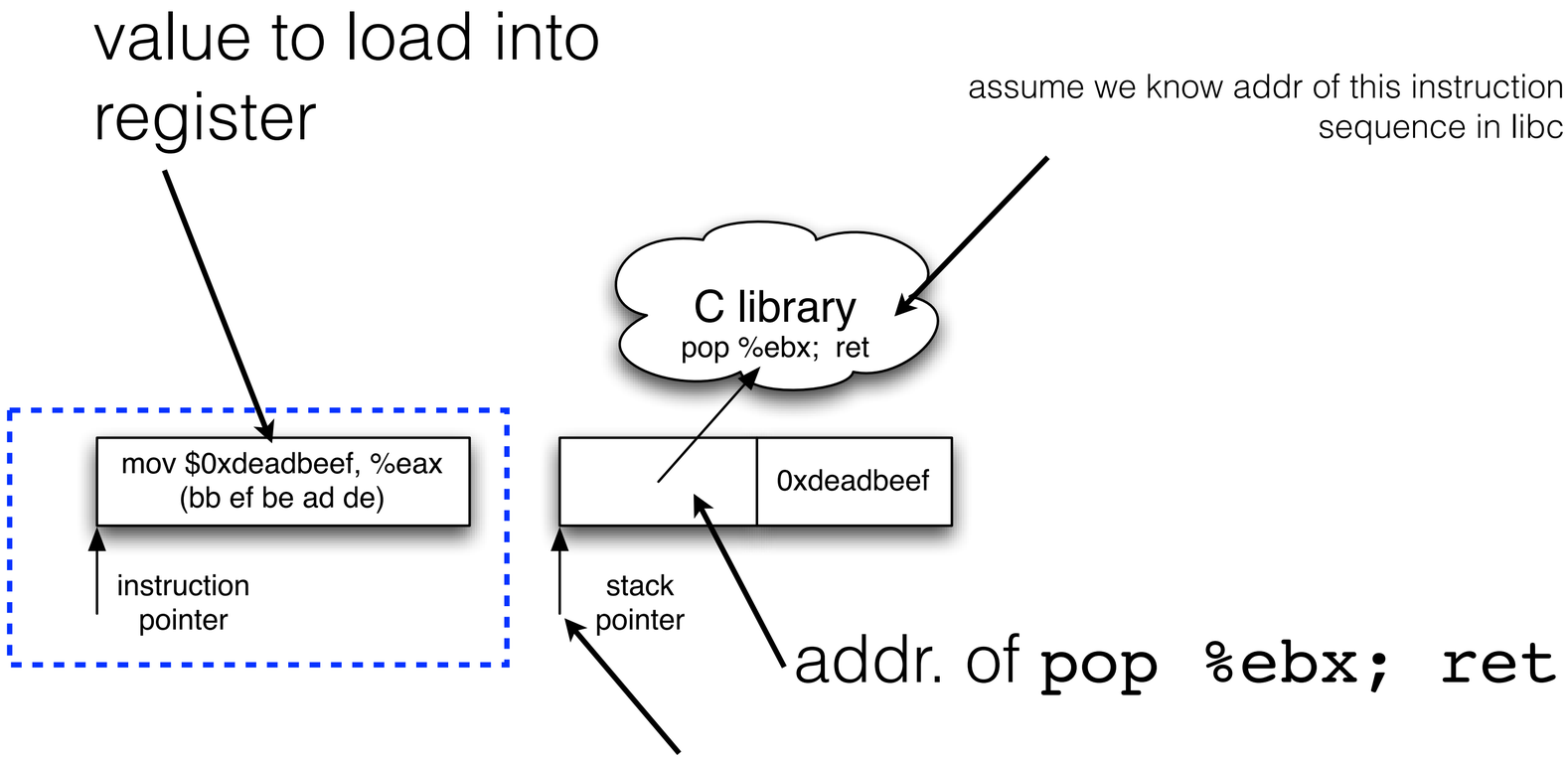


procedure:

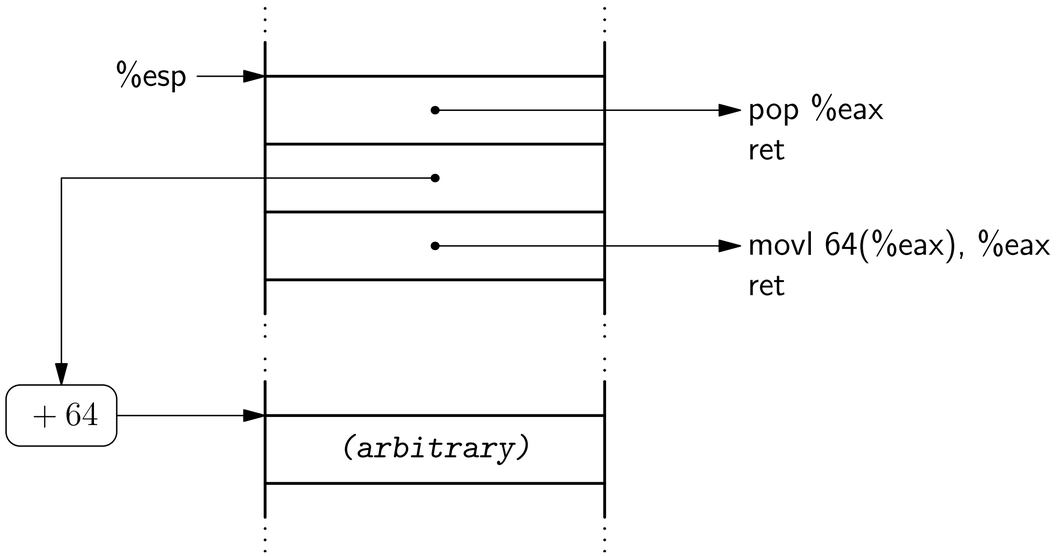
1. setup stack via buffer overflow
2. issue return
3. pop addr from stack
4. IP executes instruction at addr

ROP immediate load



1. `ret` issued with SP here
2. IP pointed at addr of `pop`...
3. SP moved right one word
4. `pop` puts 0xdeadbeef into `ebx`
5. SP moved right one word

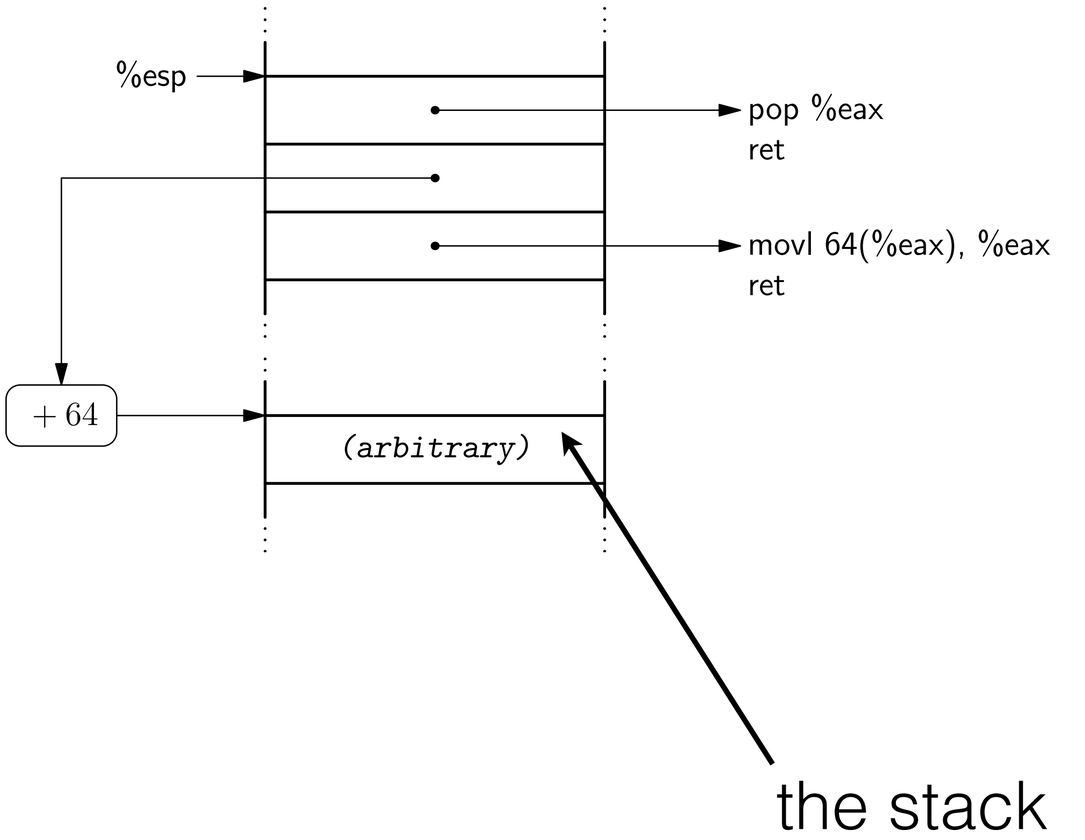
ROP word load



dot represents constructed stack

ROP word load

word into `%eax`



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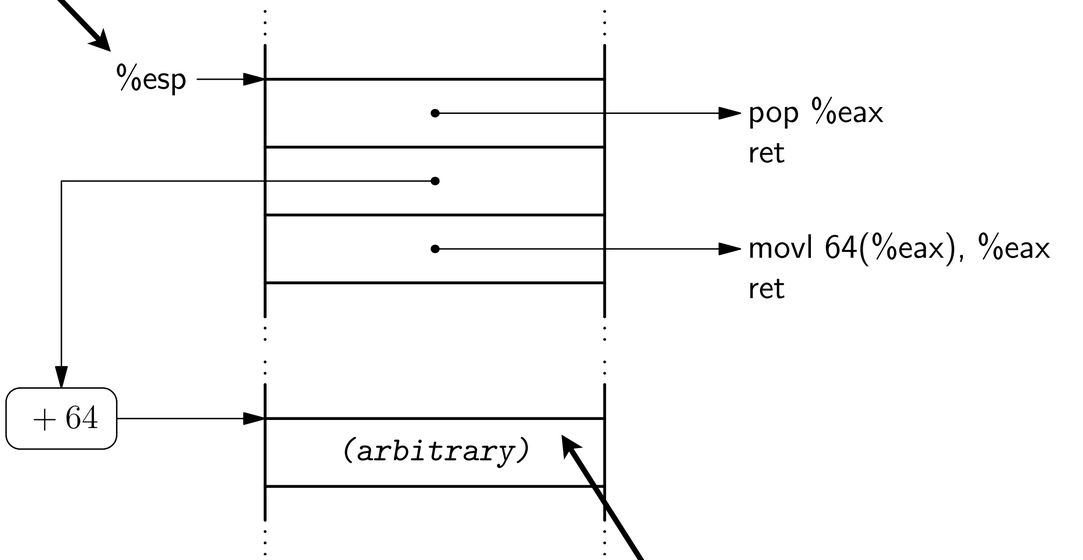

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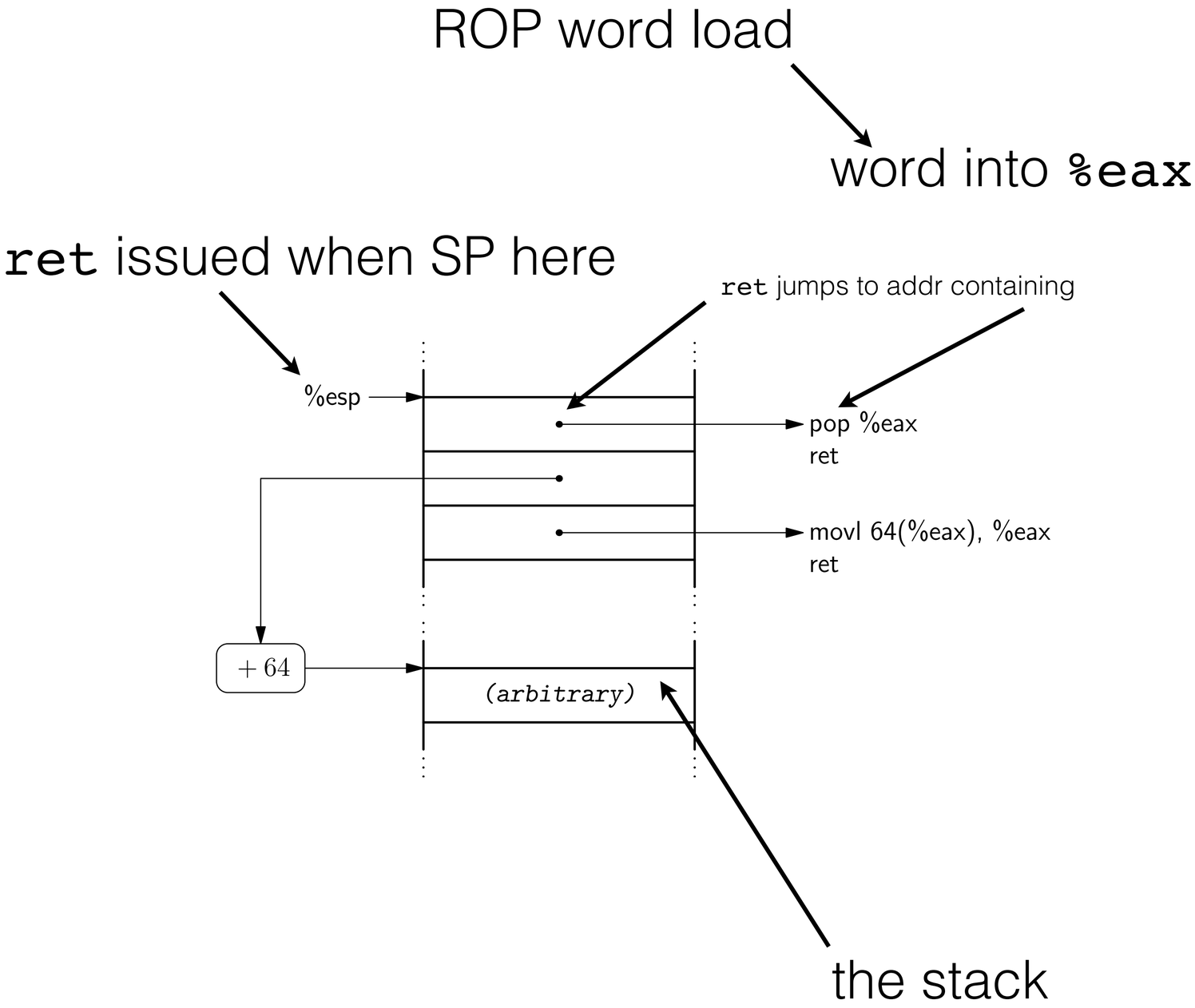

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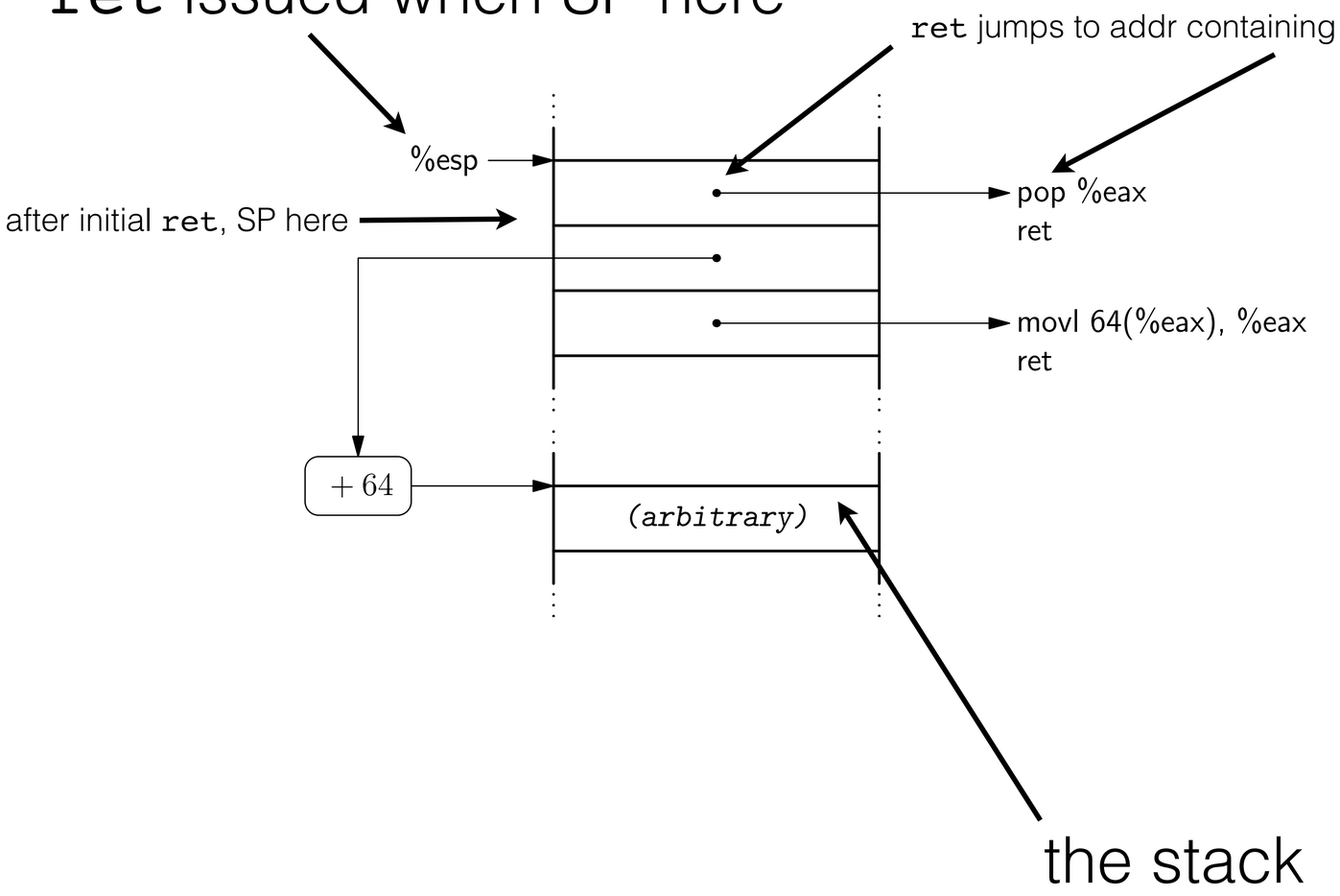

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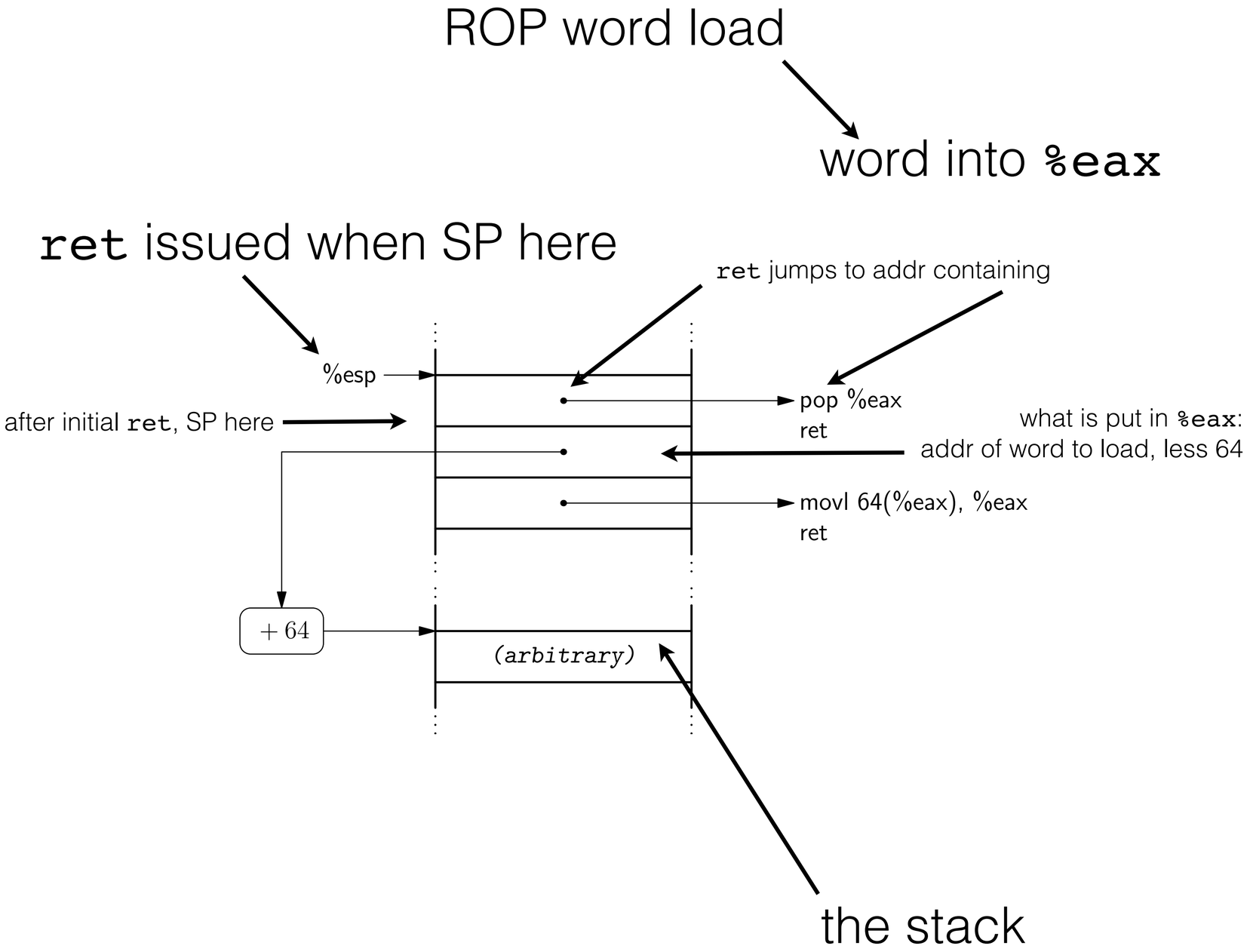

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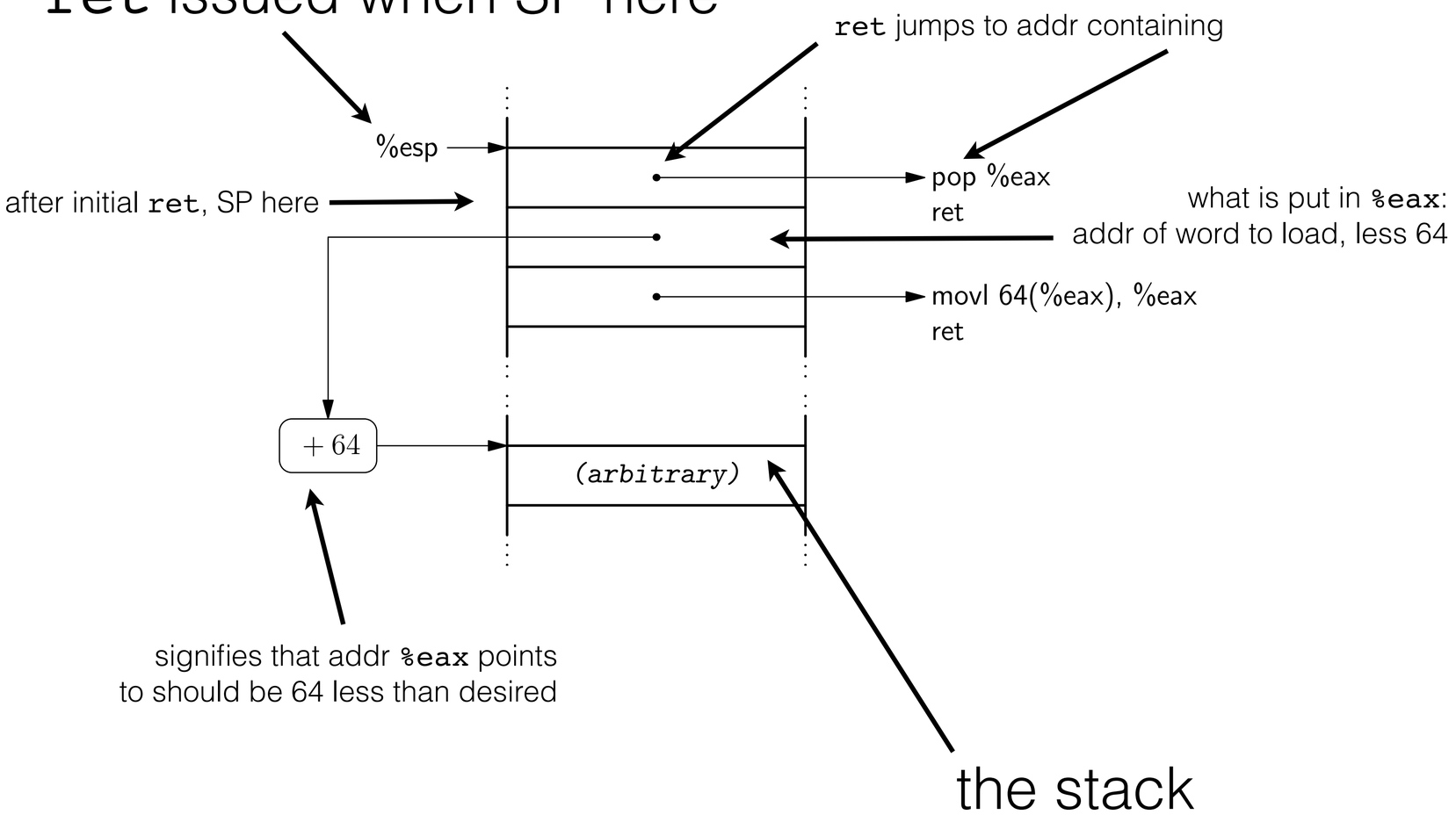

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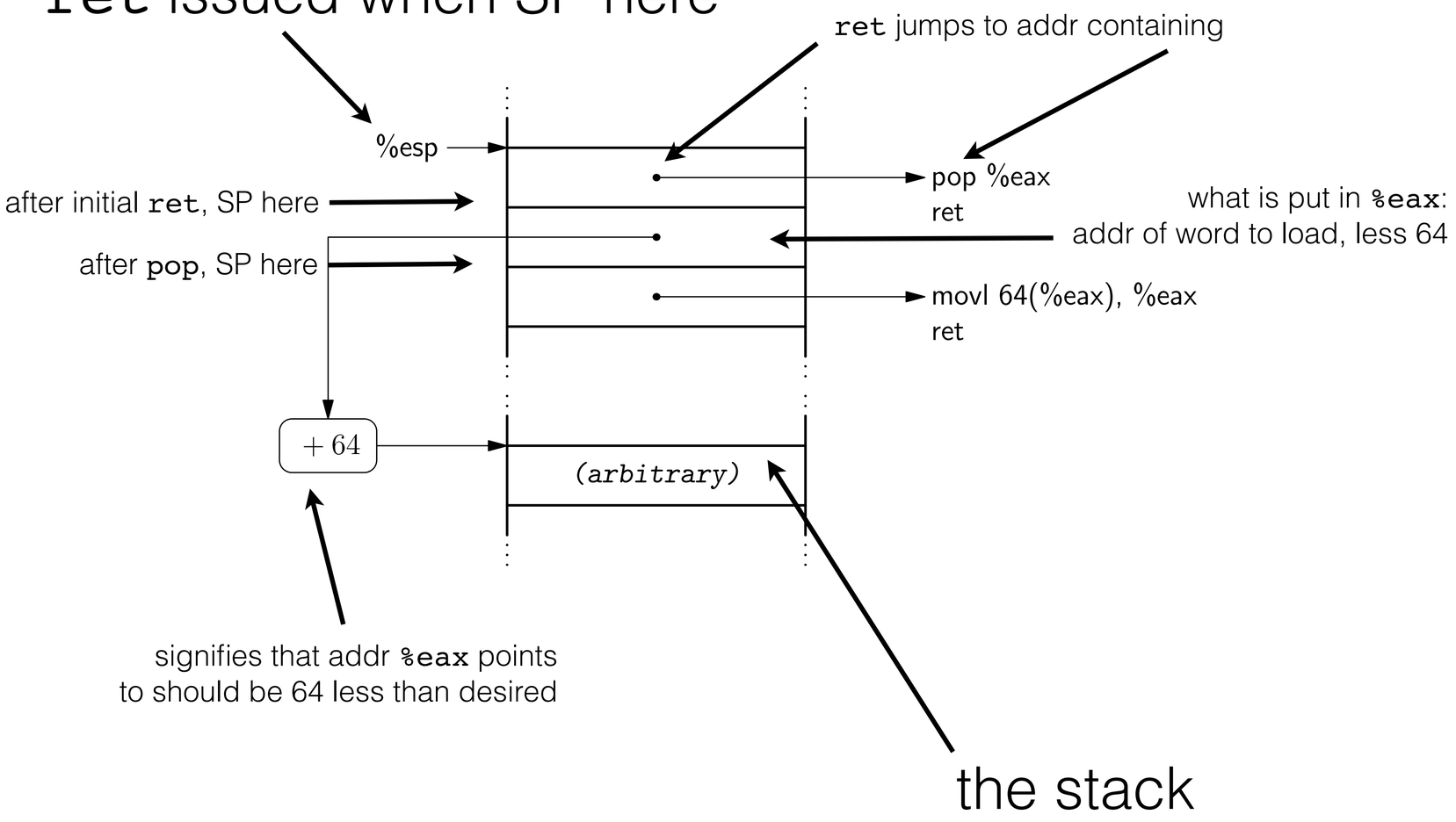

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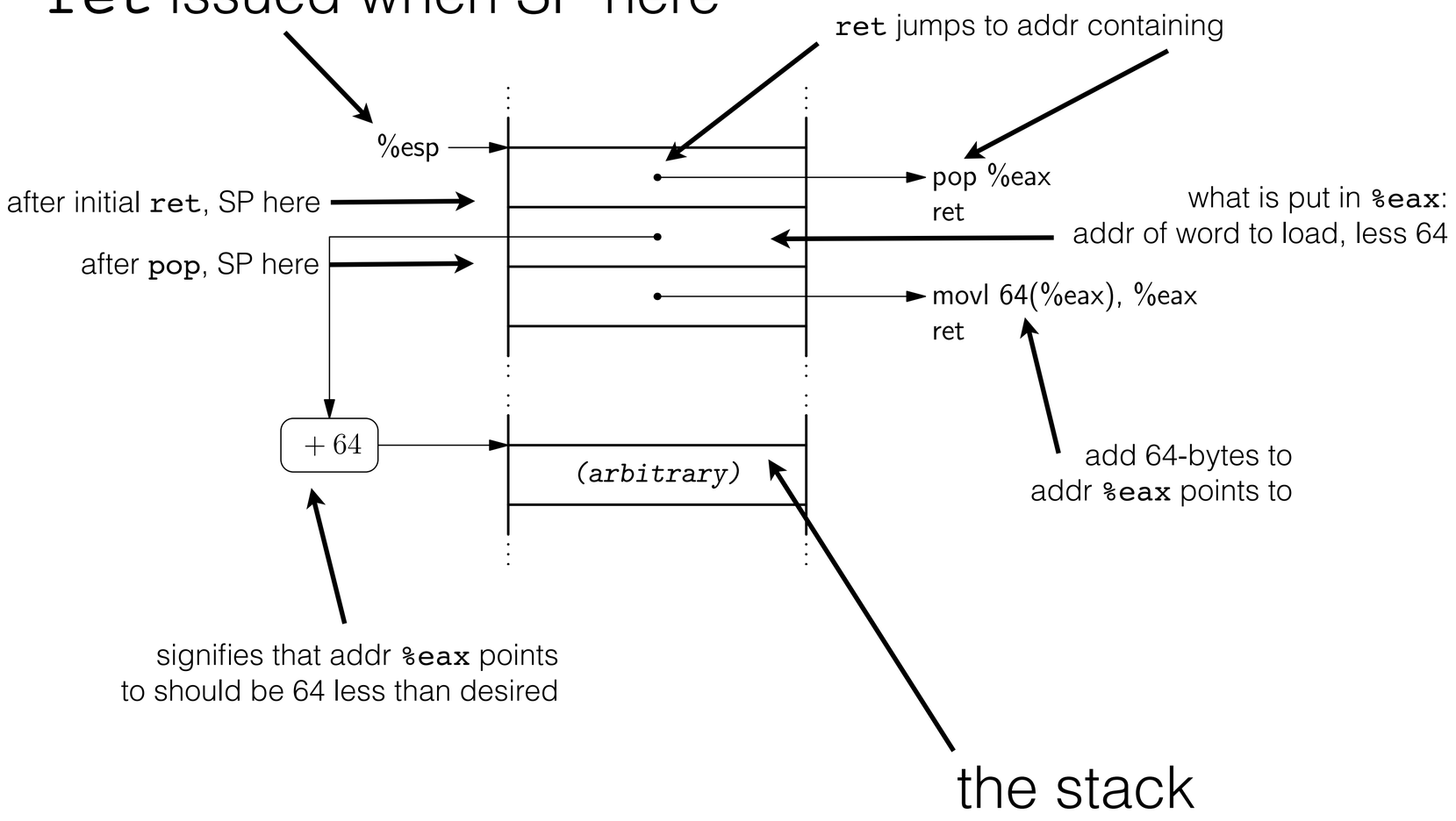

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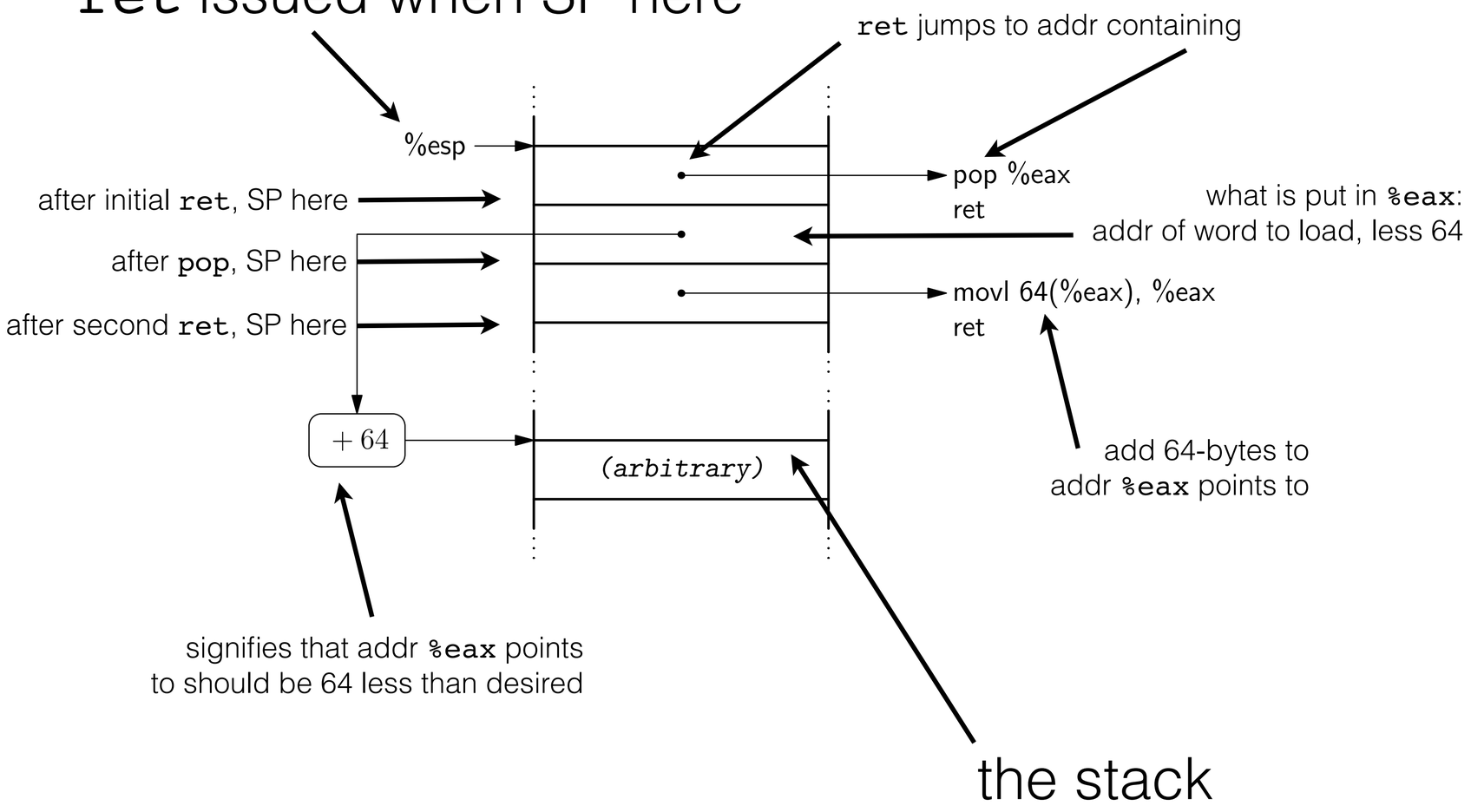

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A: no, let's build gadgets for what we need (shellcode)

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system calls

`umask` system call:

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8b 5c 24 04             movl 4(%esp), %ebx
b8 3c 00 00 00          mov $0x0000003C, %eax
65 ff 15 10 00 00 00    lcall %gs:0x10(,0)
89 d3                   mov %edx, %ebx
c3                      ret
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system call wrappers in **`libc`**

system calls

`umask` system call:

arguments
(passed via register)

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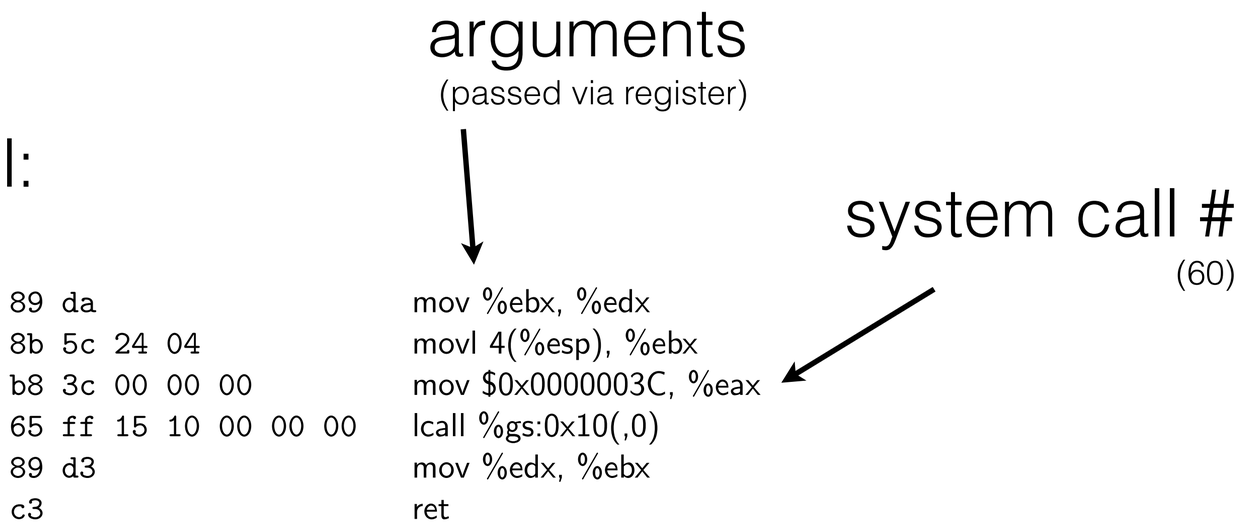

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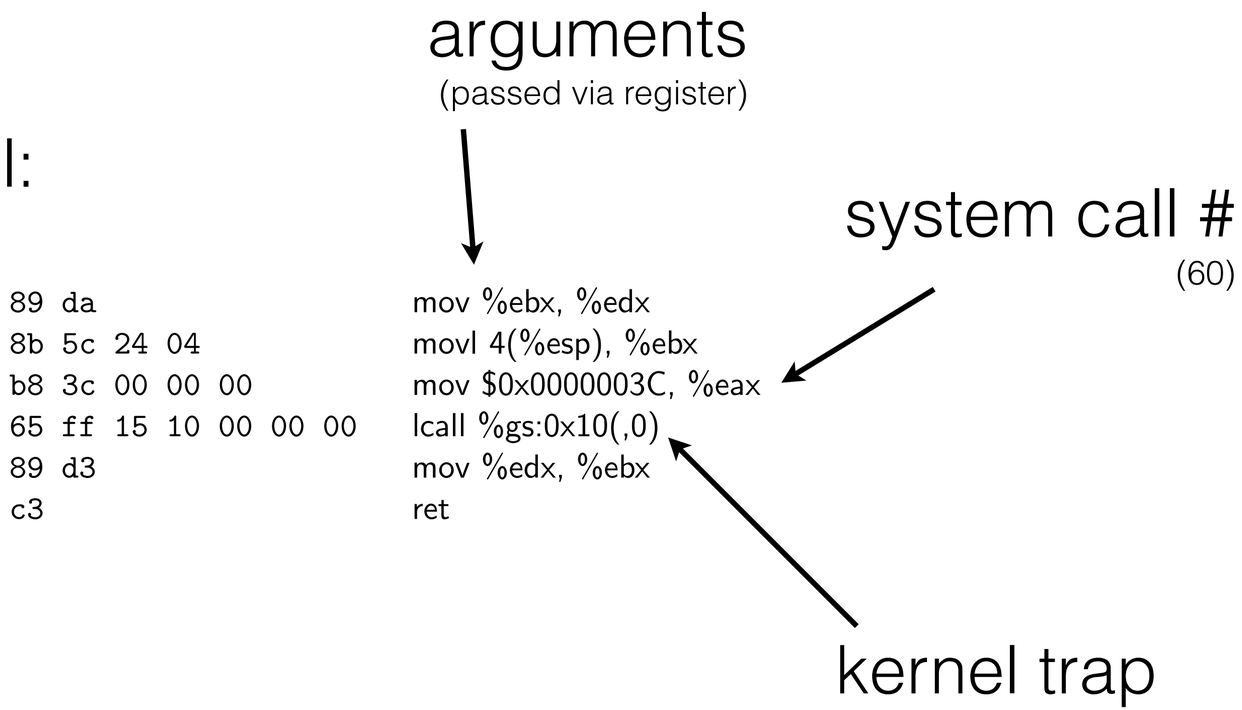

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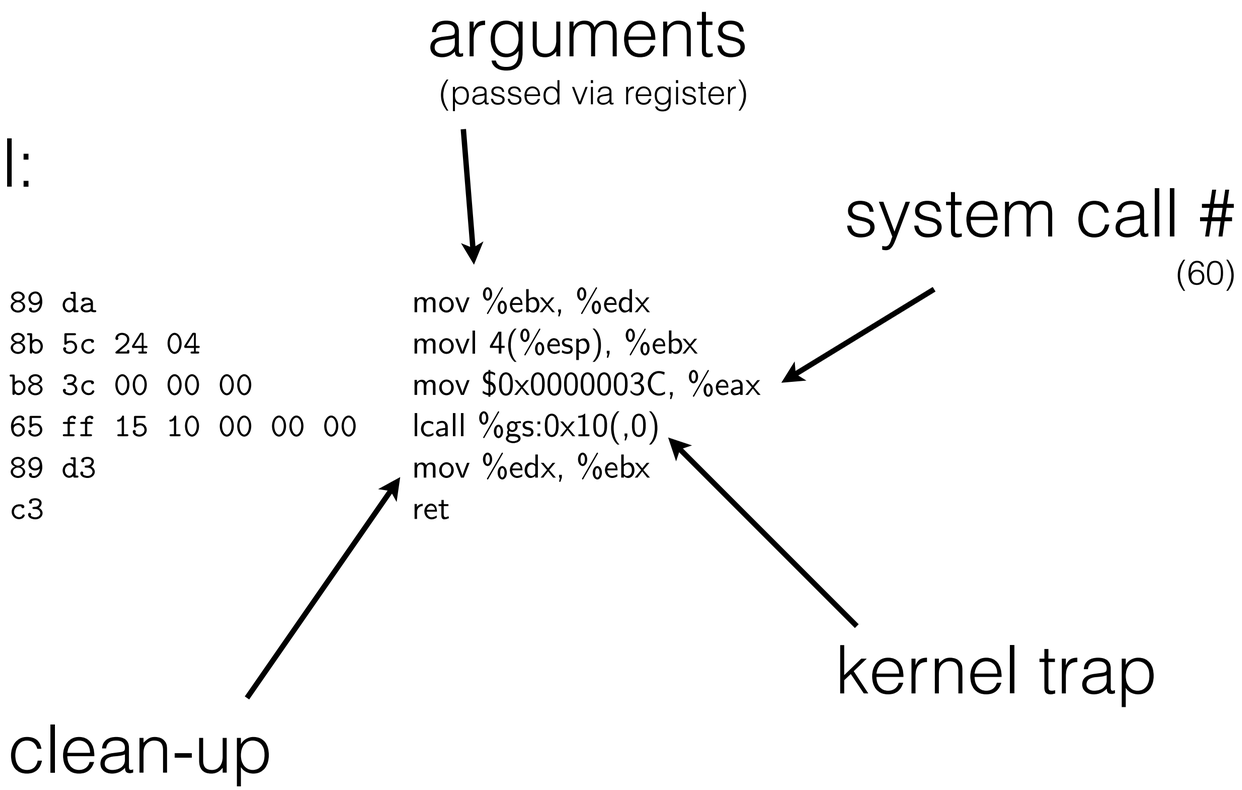

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constructing ROP shellcode

system call number 11

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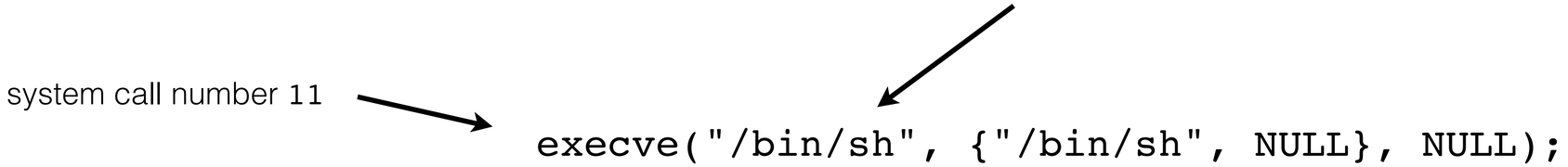

NOTE: `int execve(const char *path, char *const argv[], char *const envp[])`

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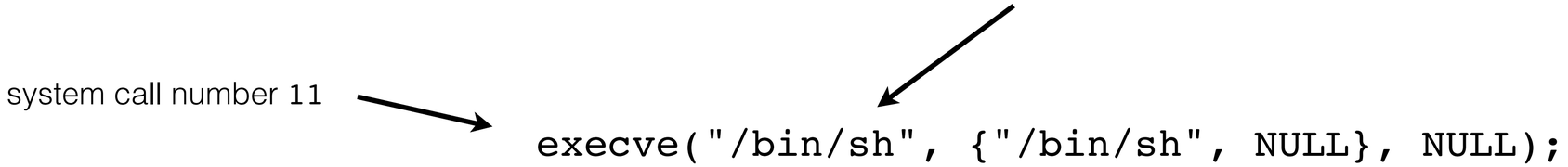

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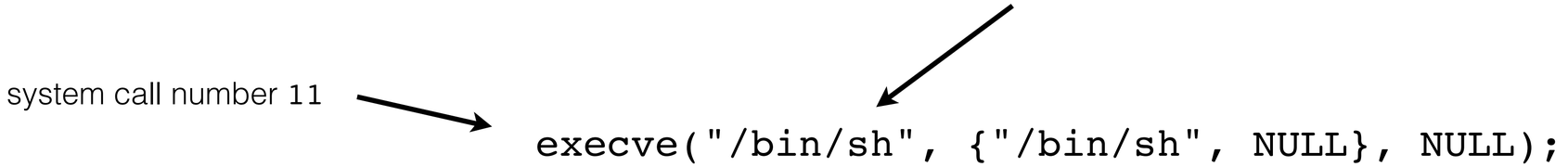

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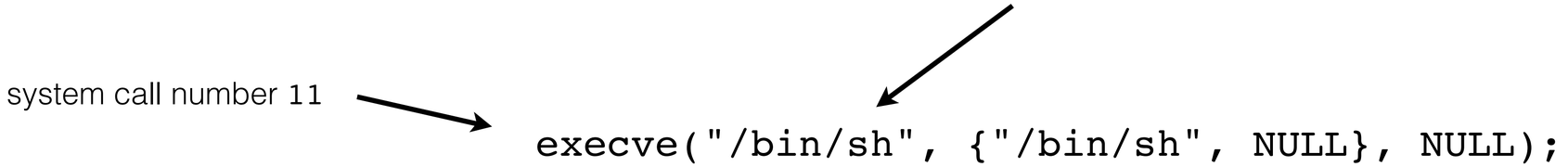

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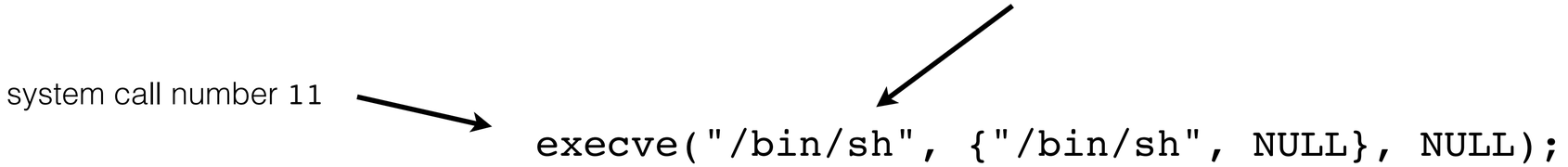

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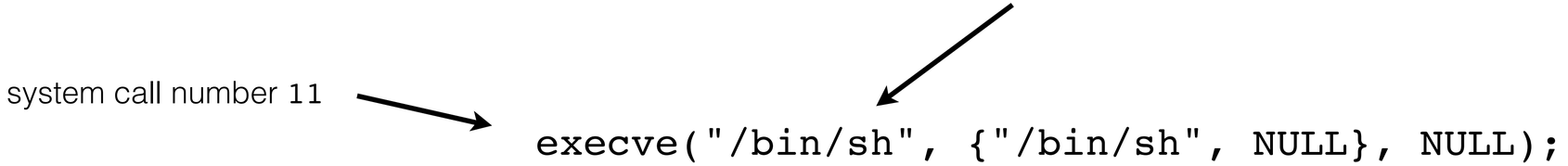

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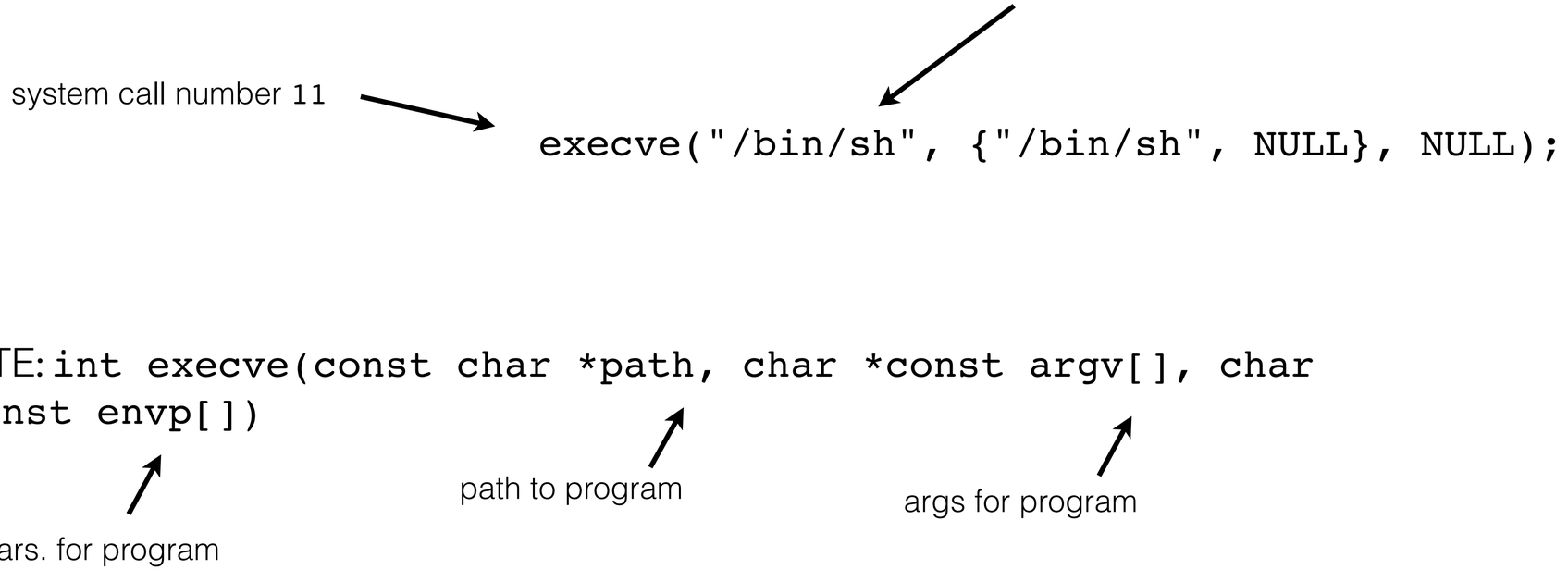

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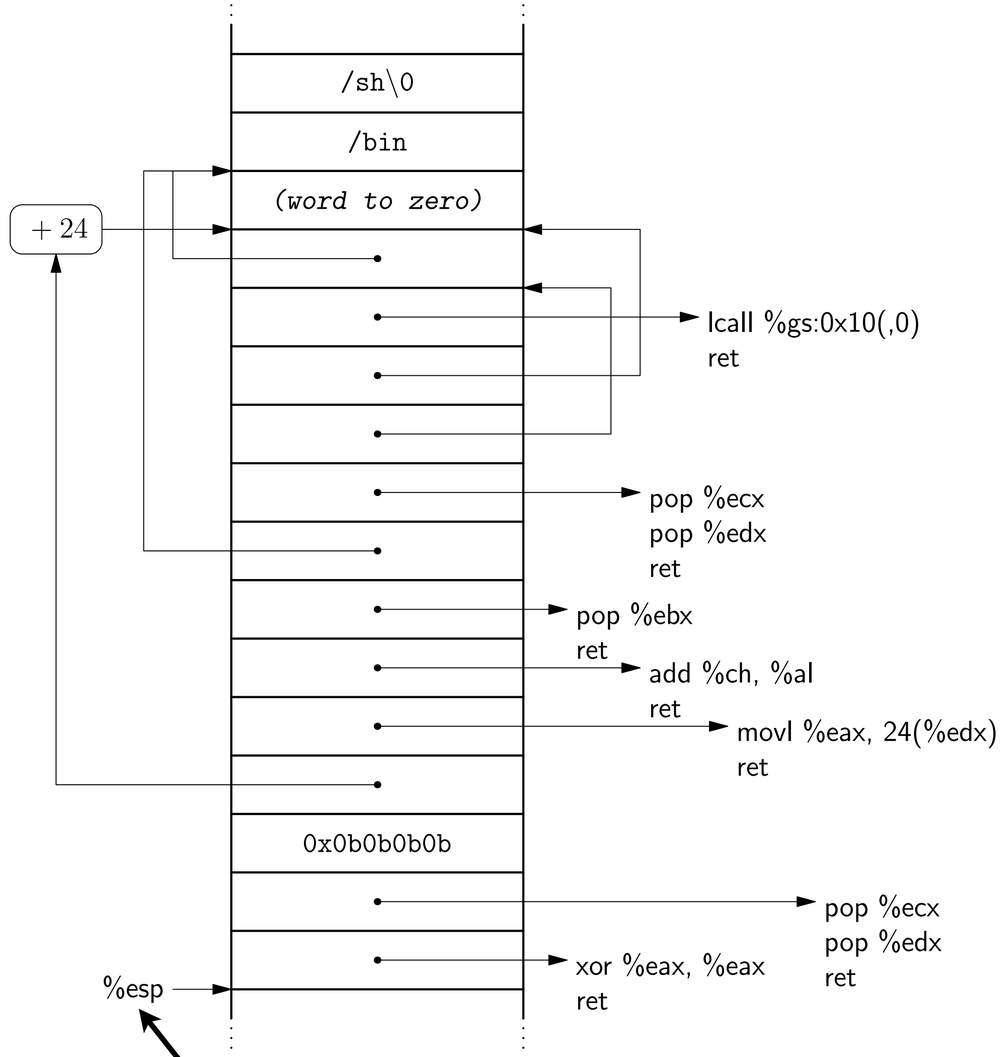
stack via buffer overflow



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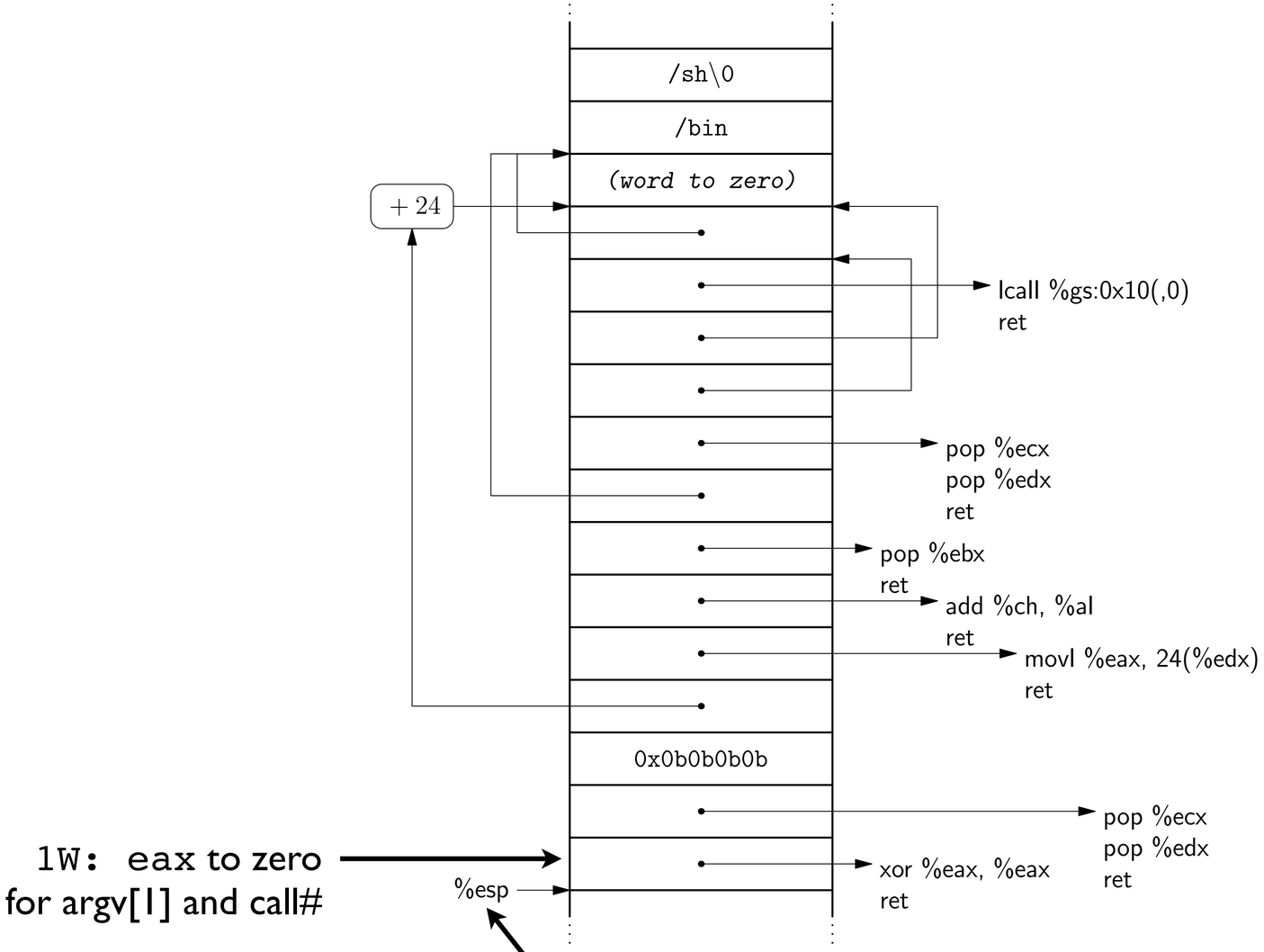

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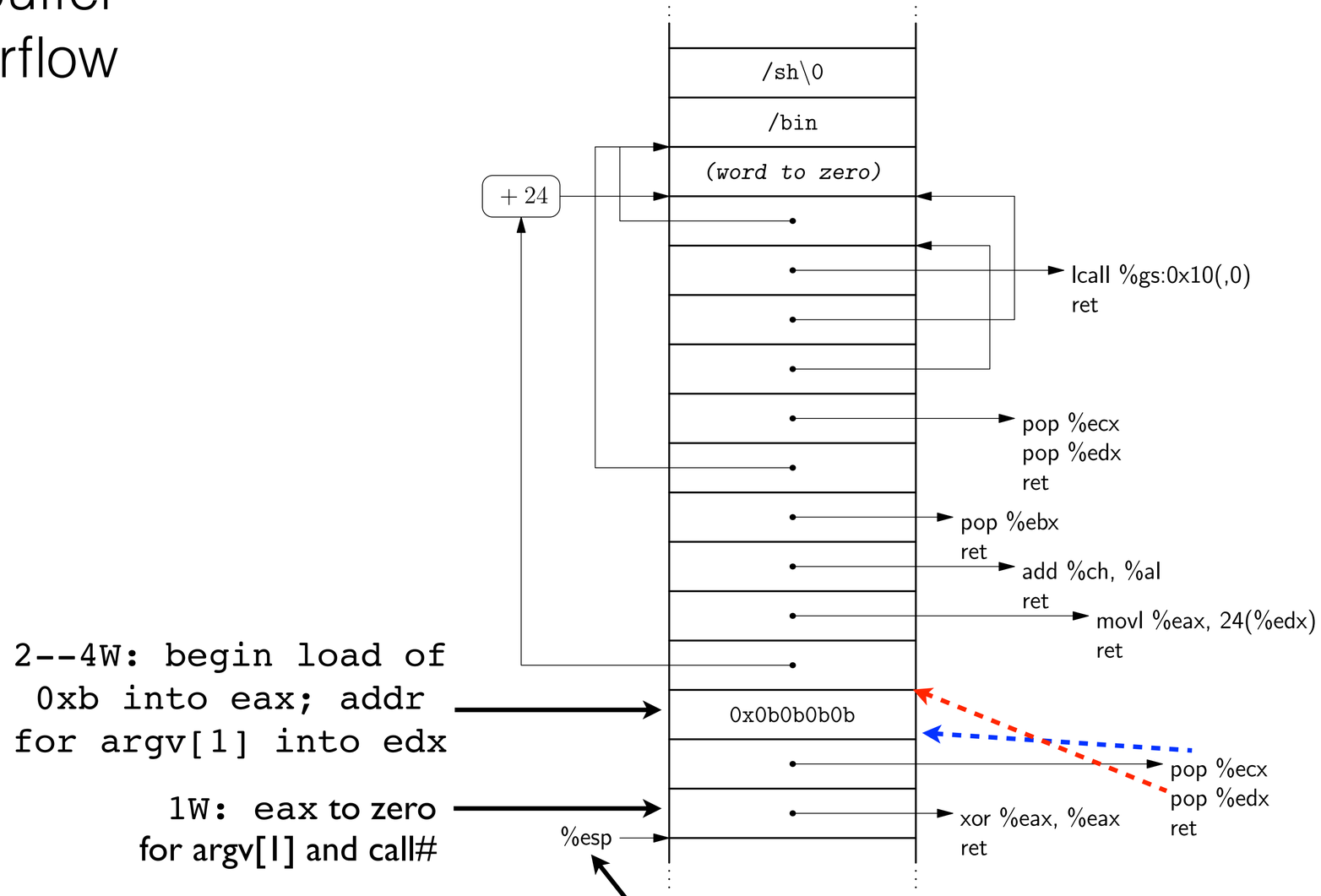

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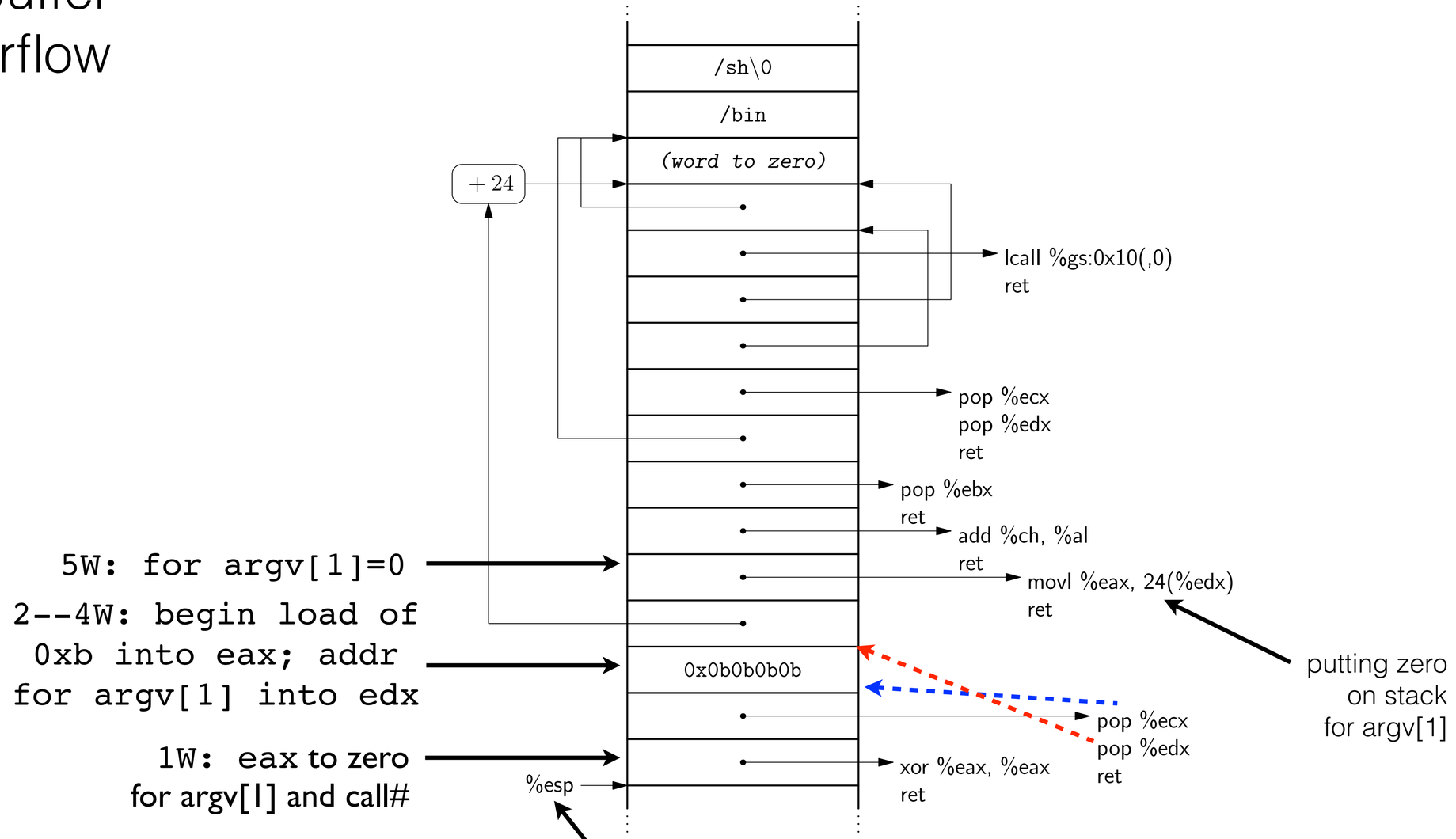

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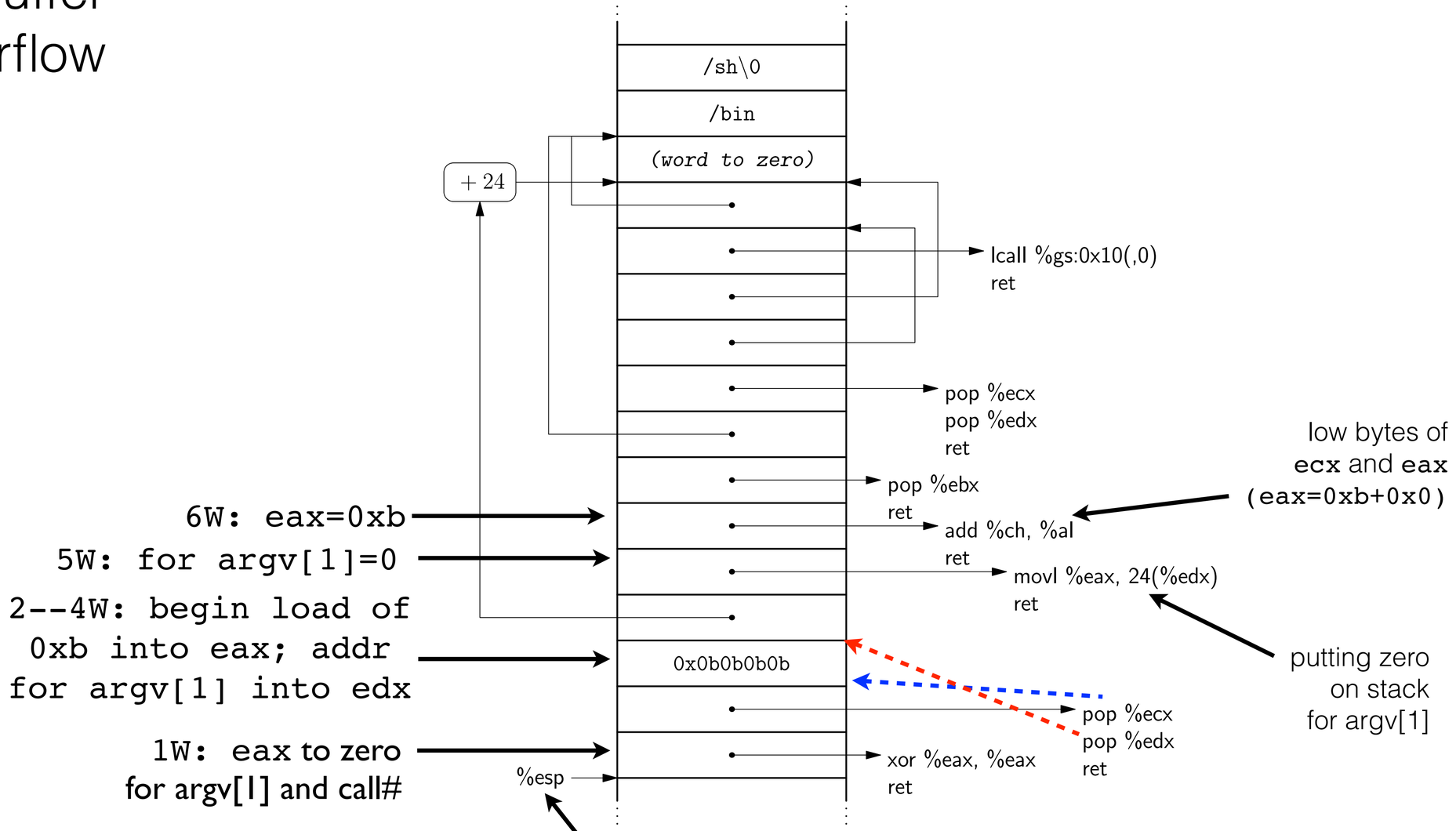

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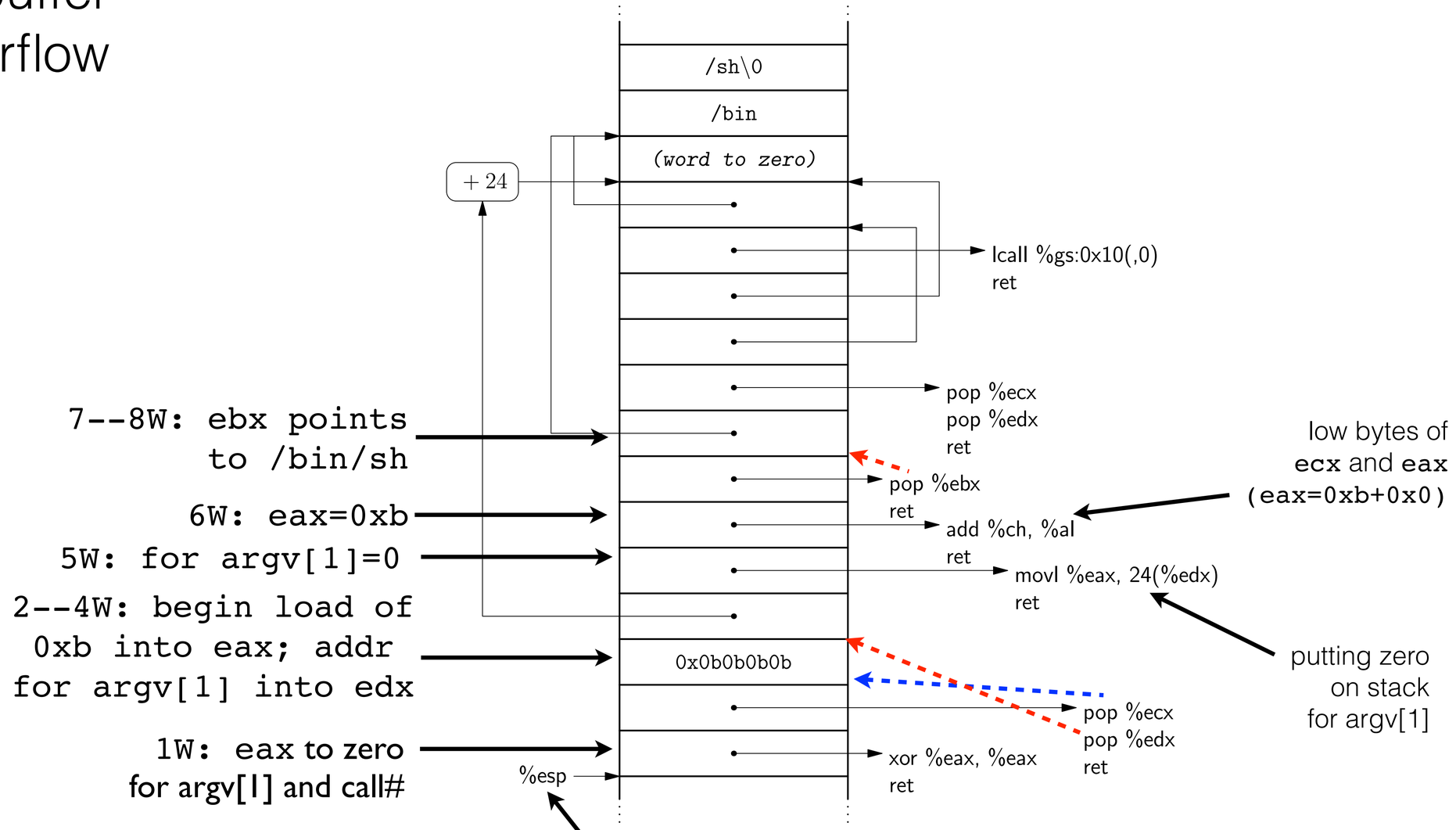

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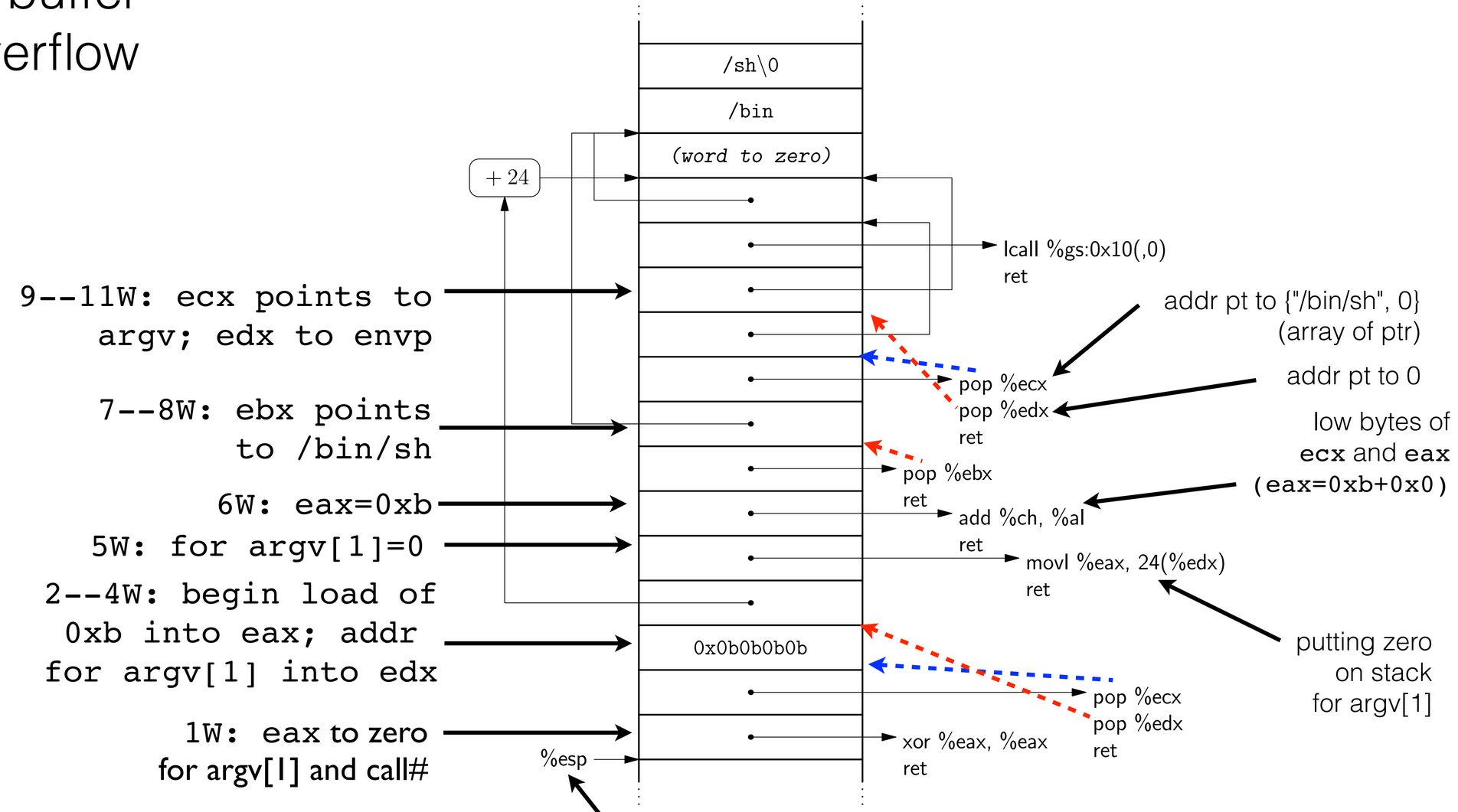

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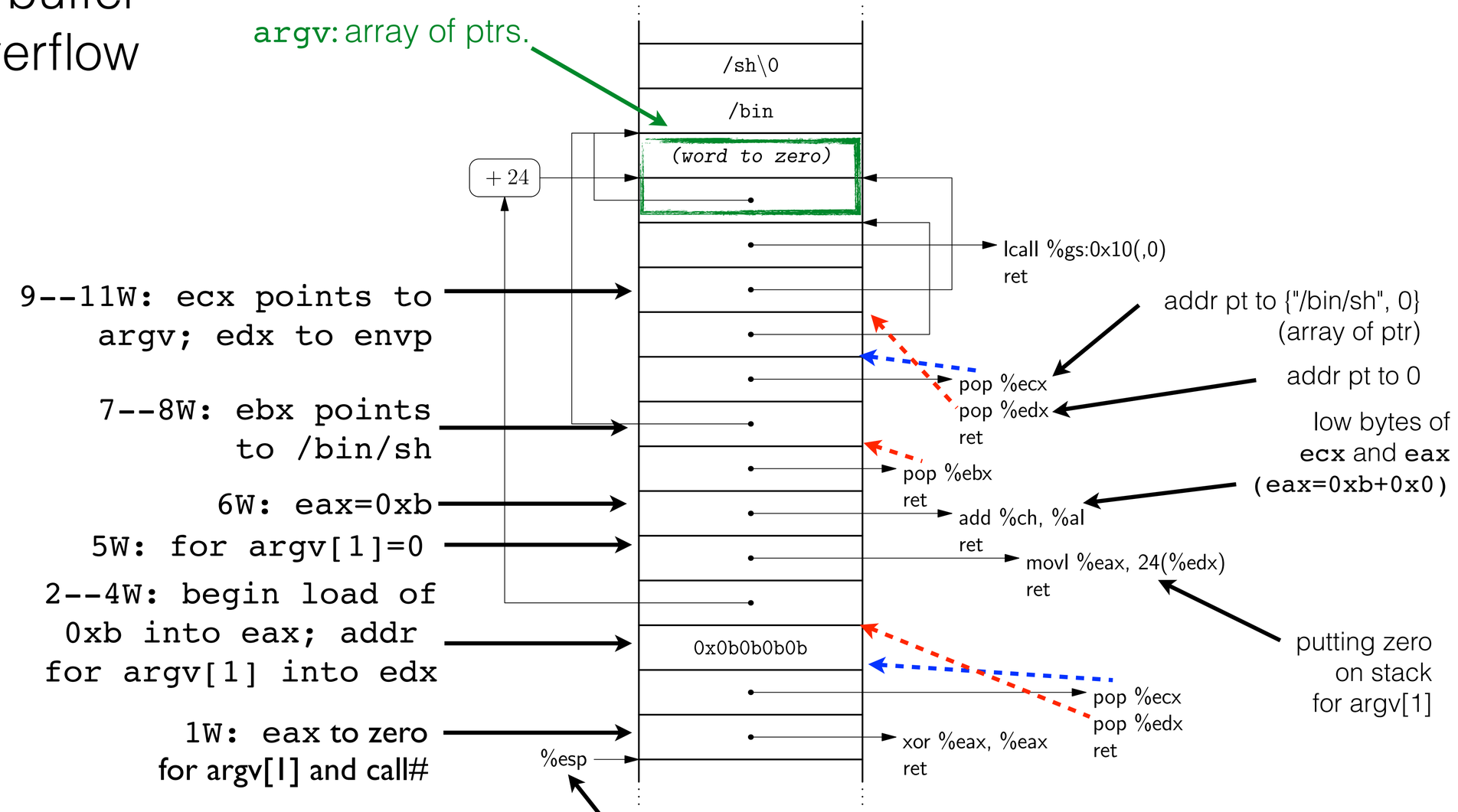

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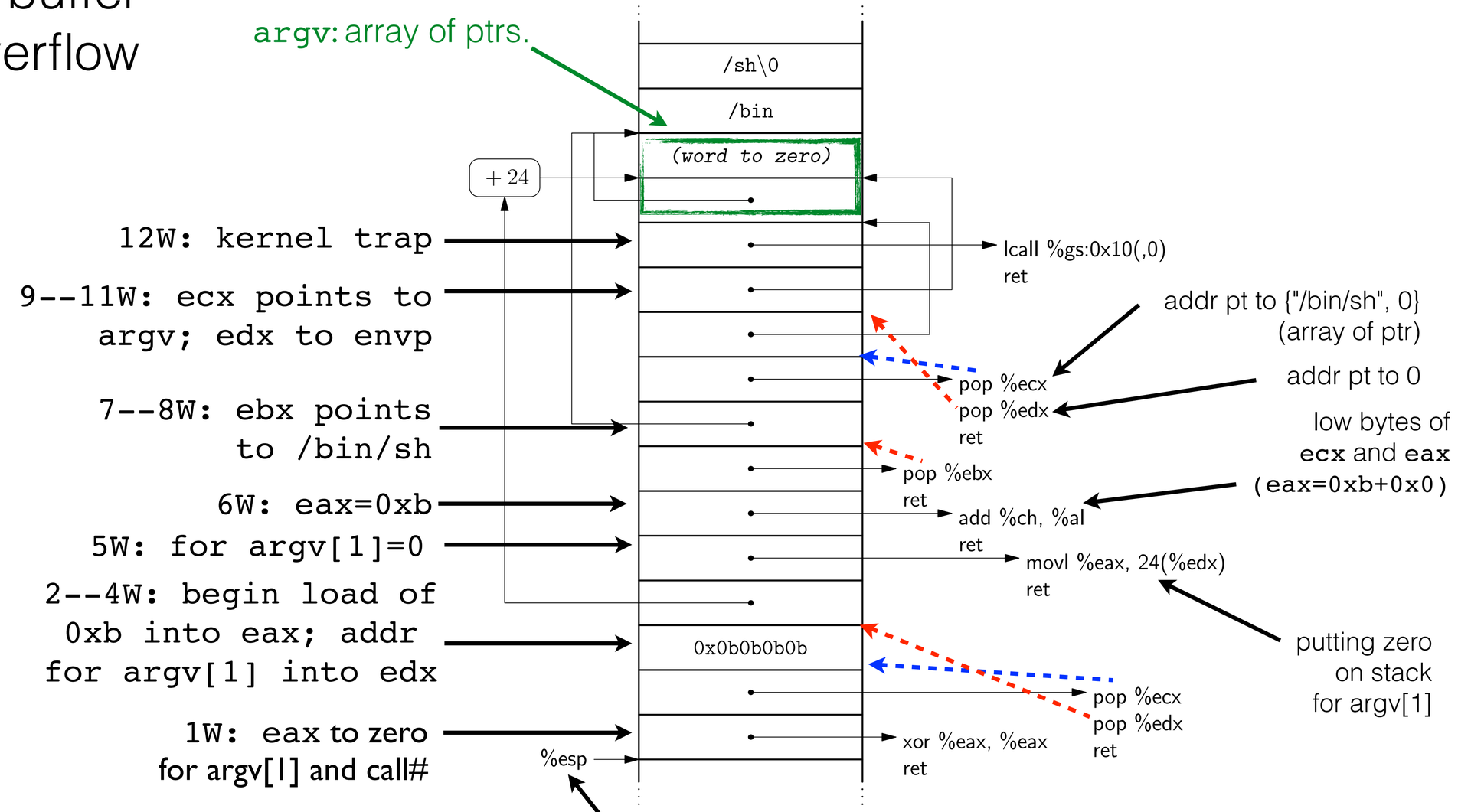

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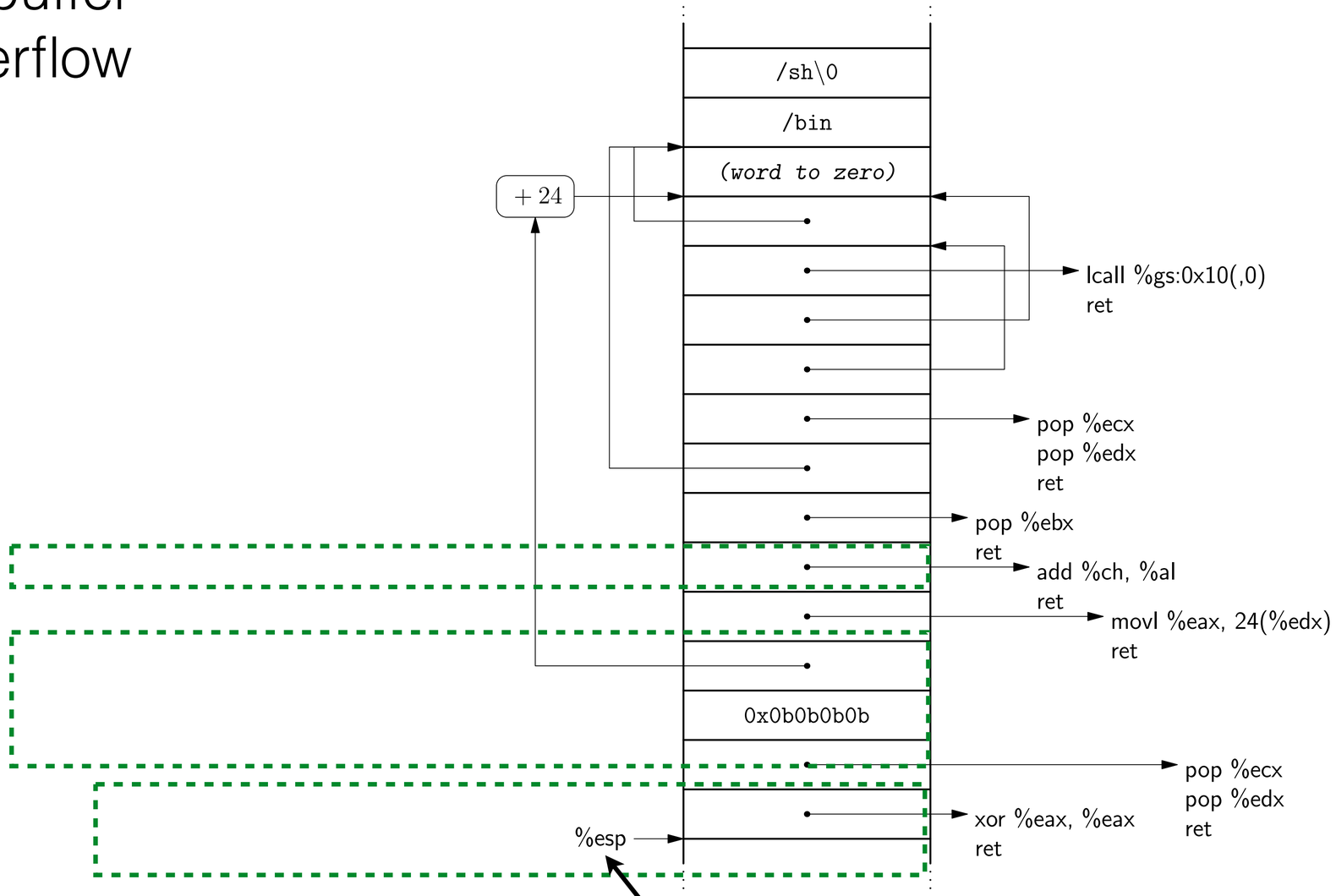

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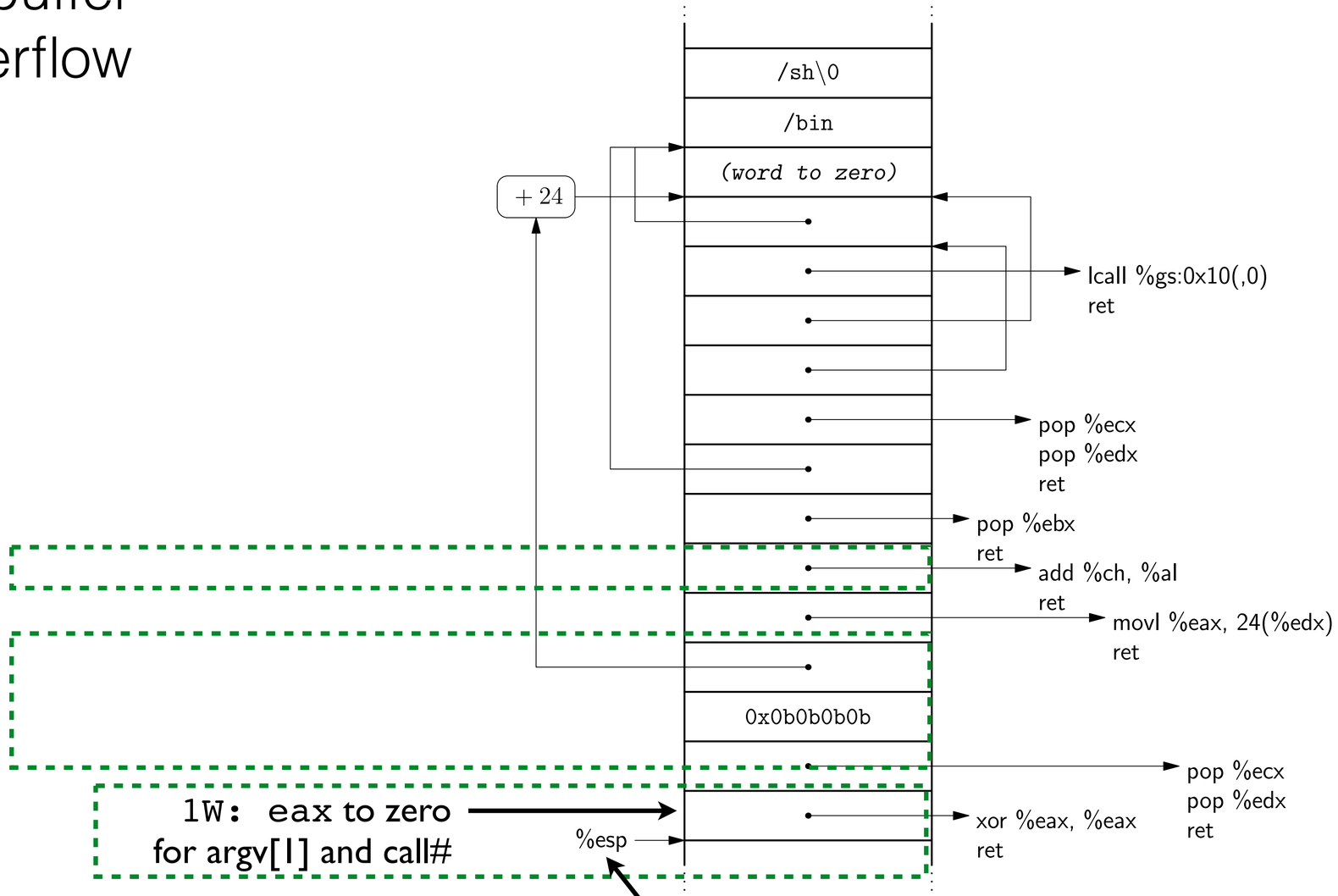

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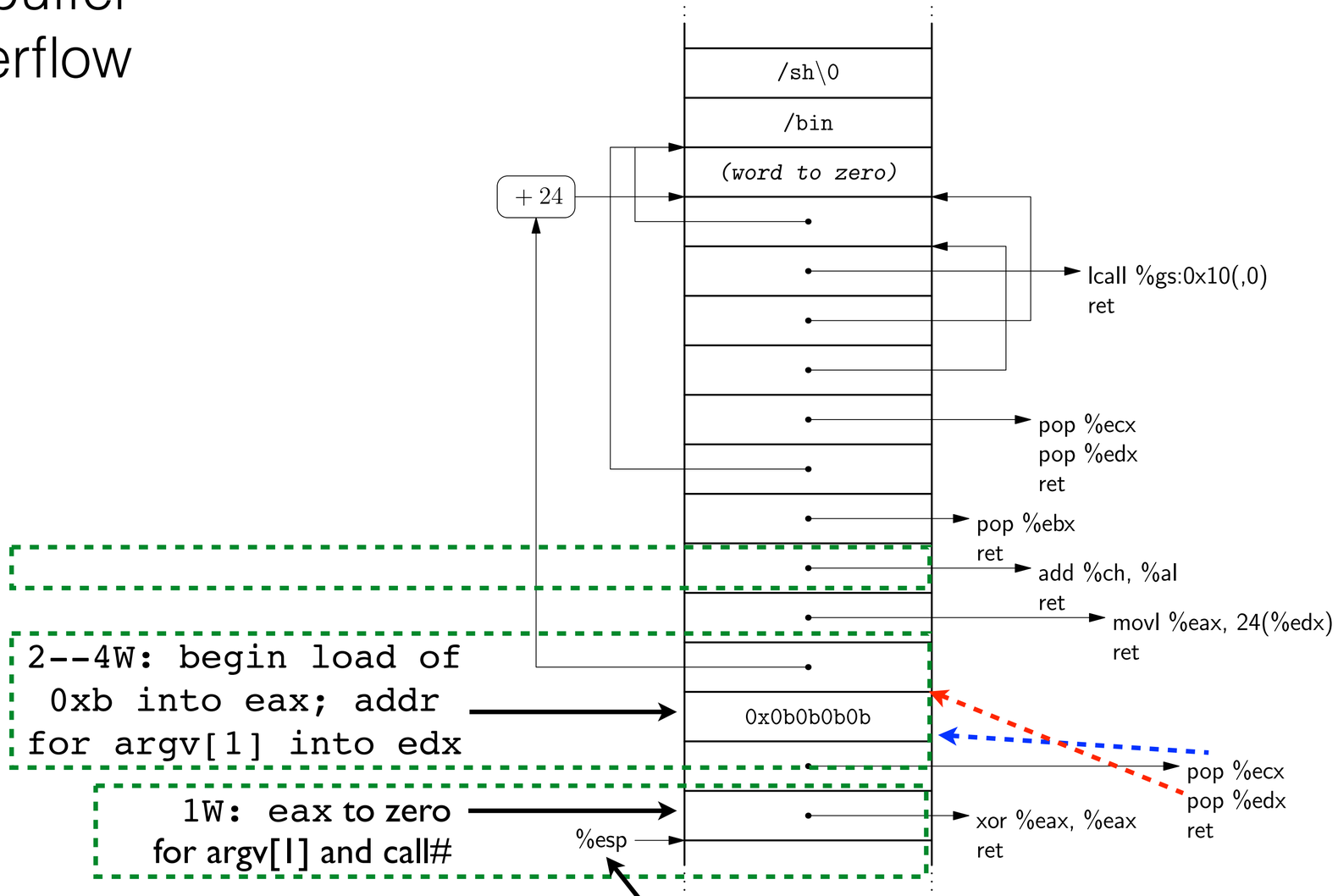

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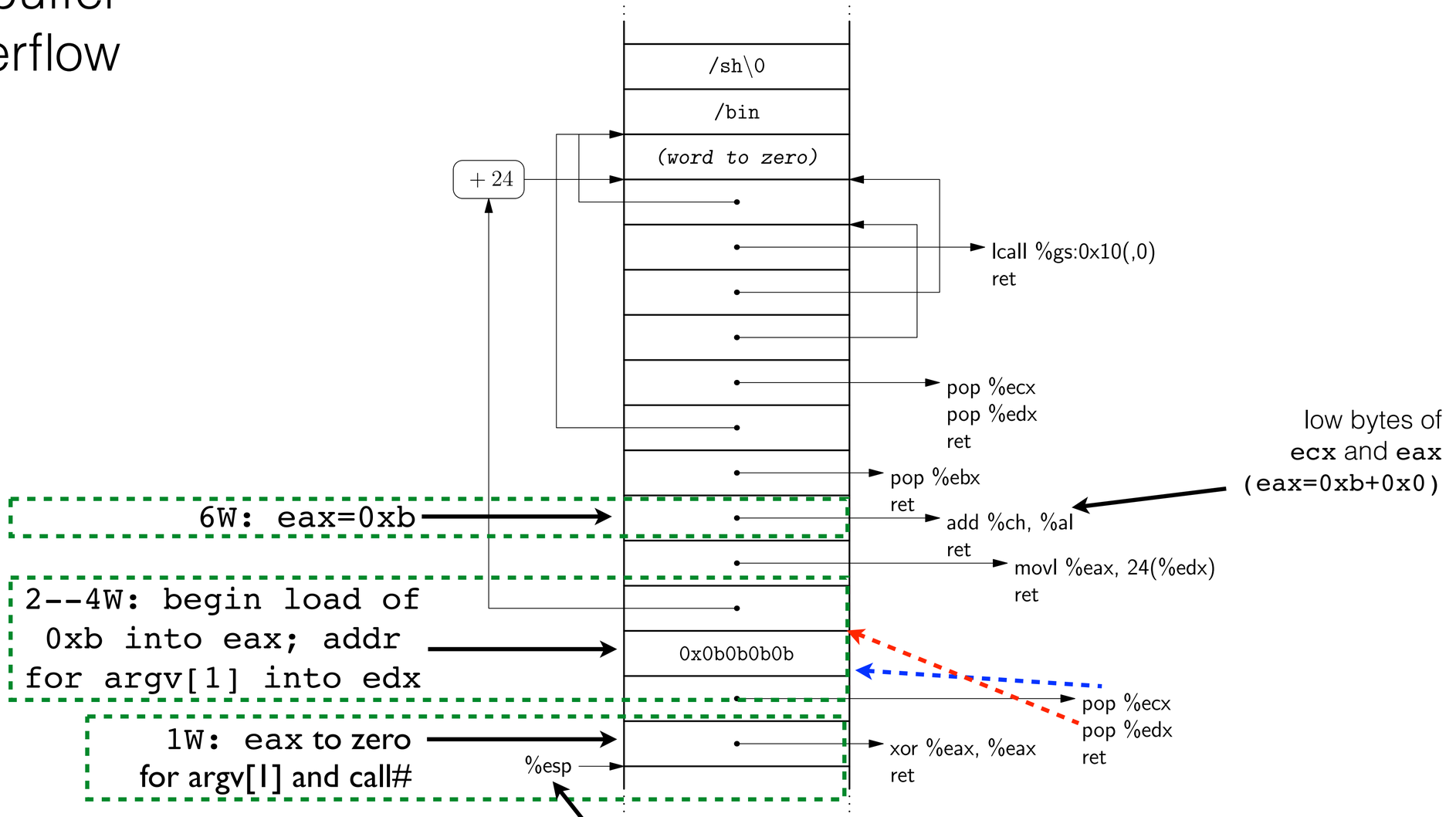

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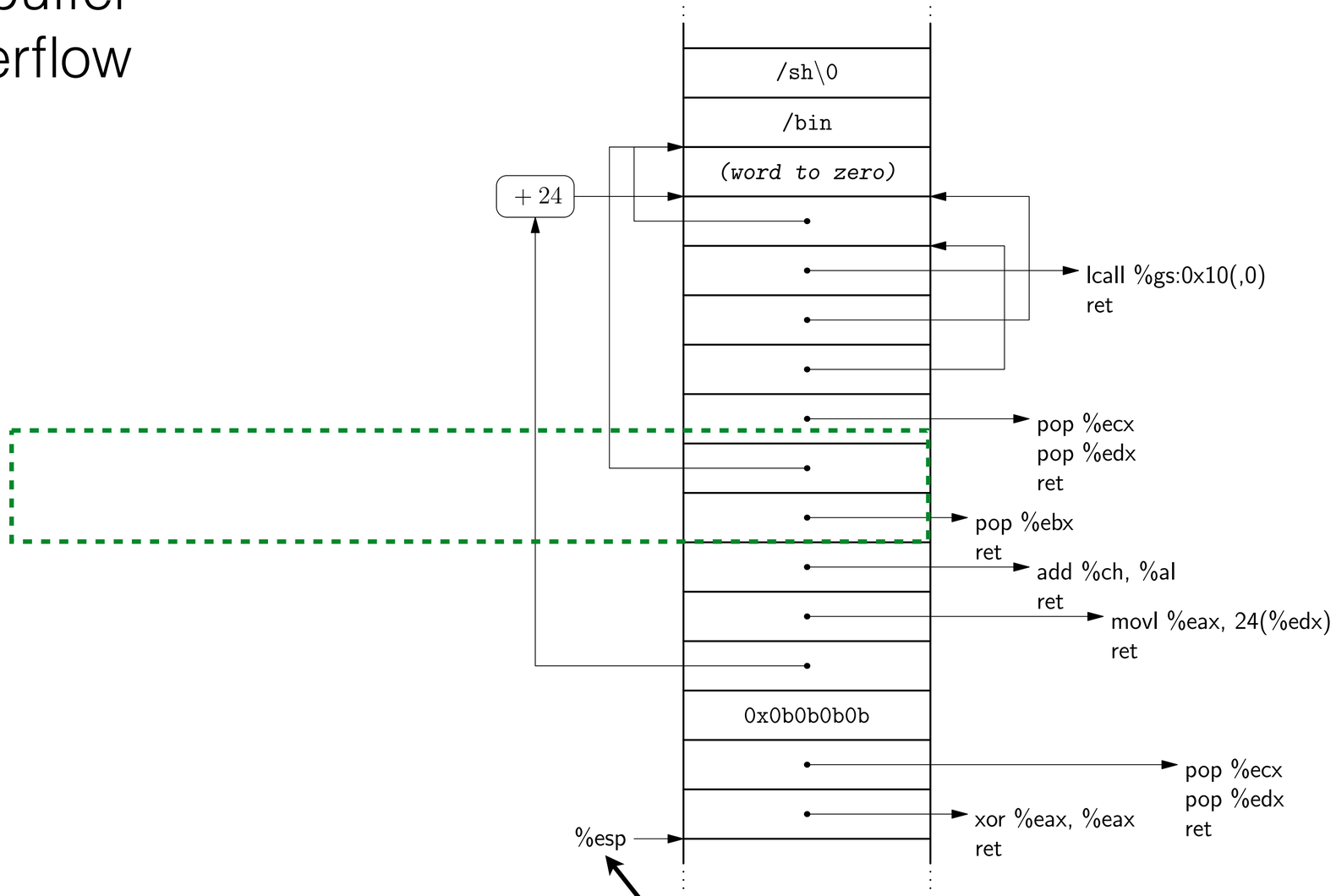

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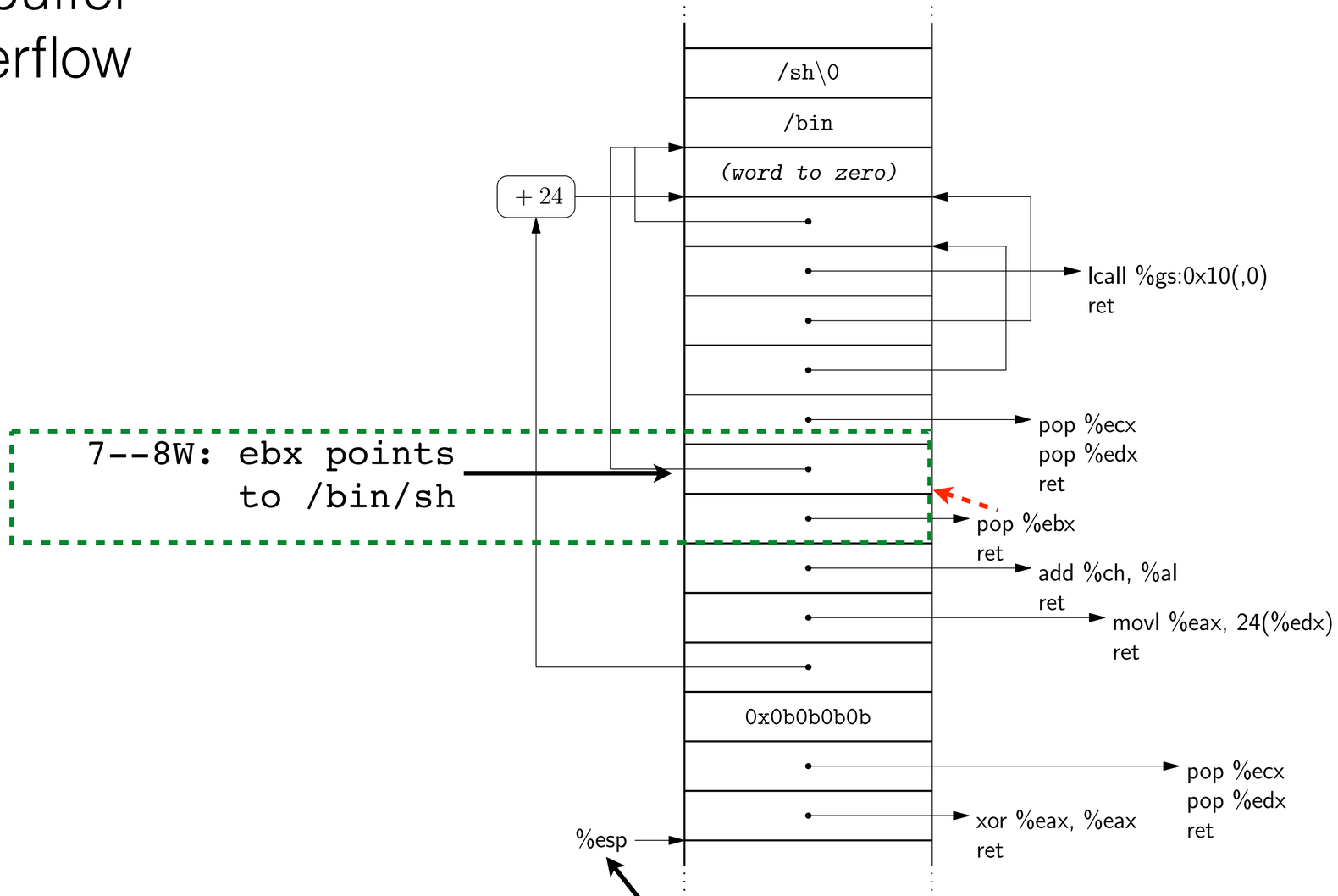

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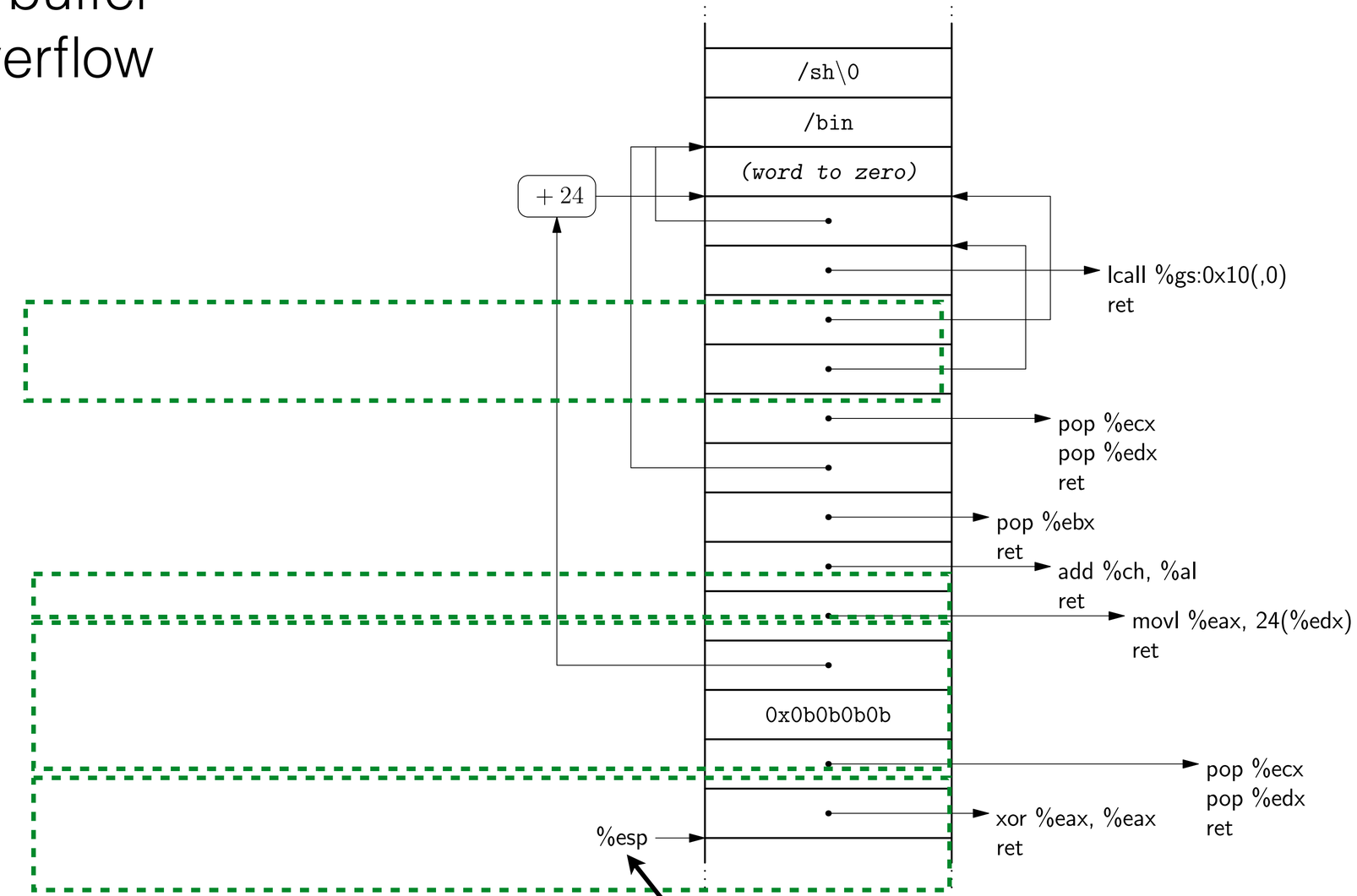

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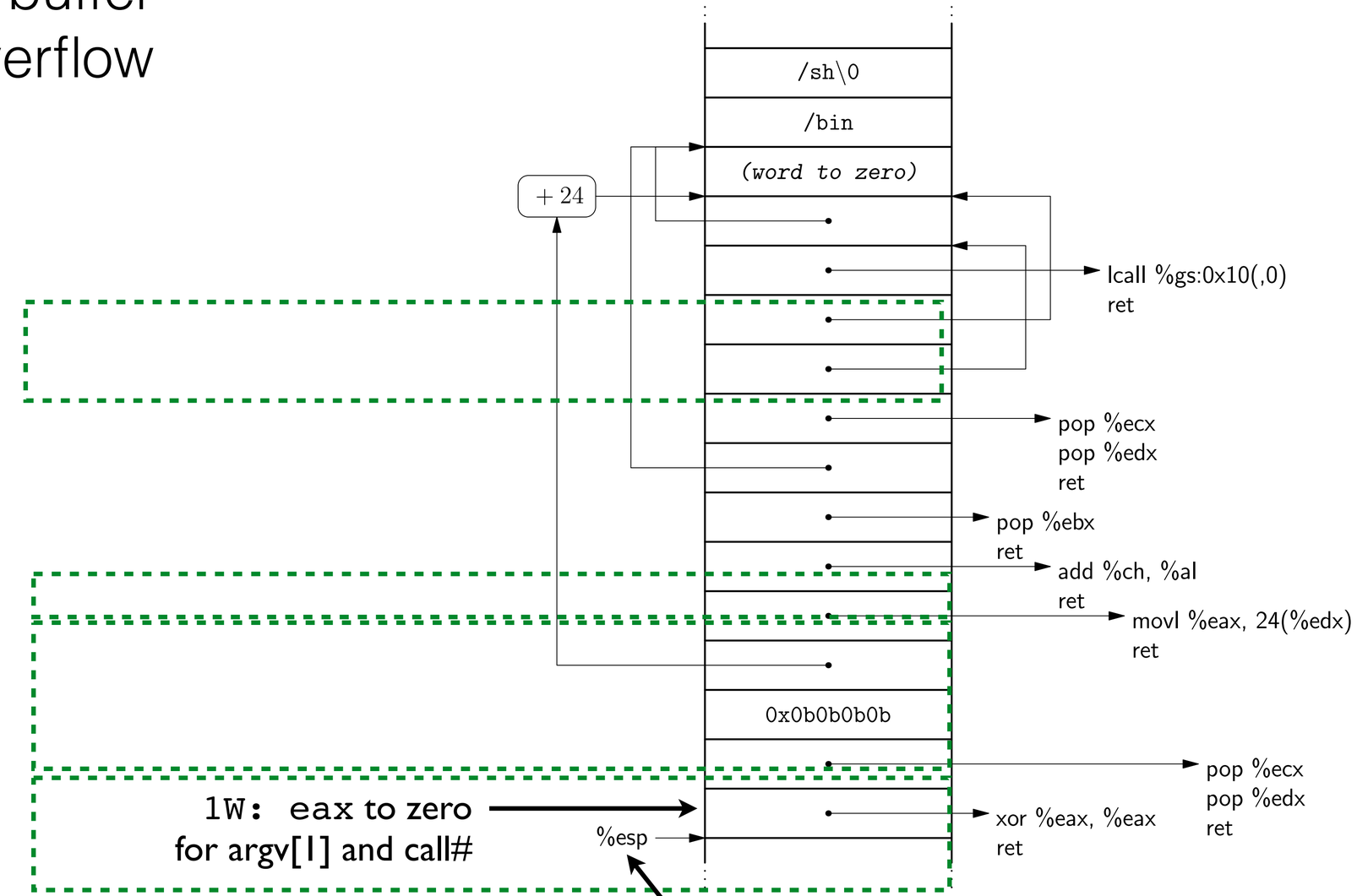

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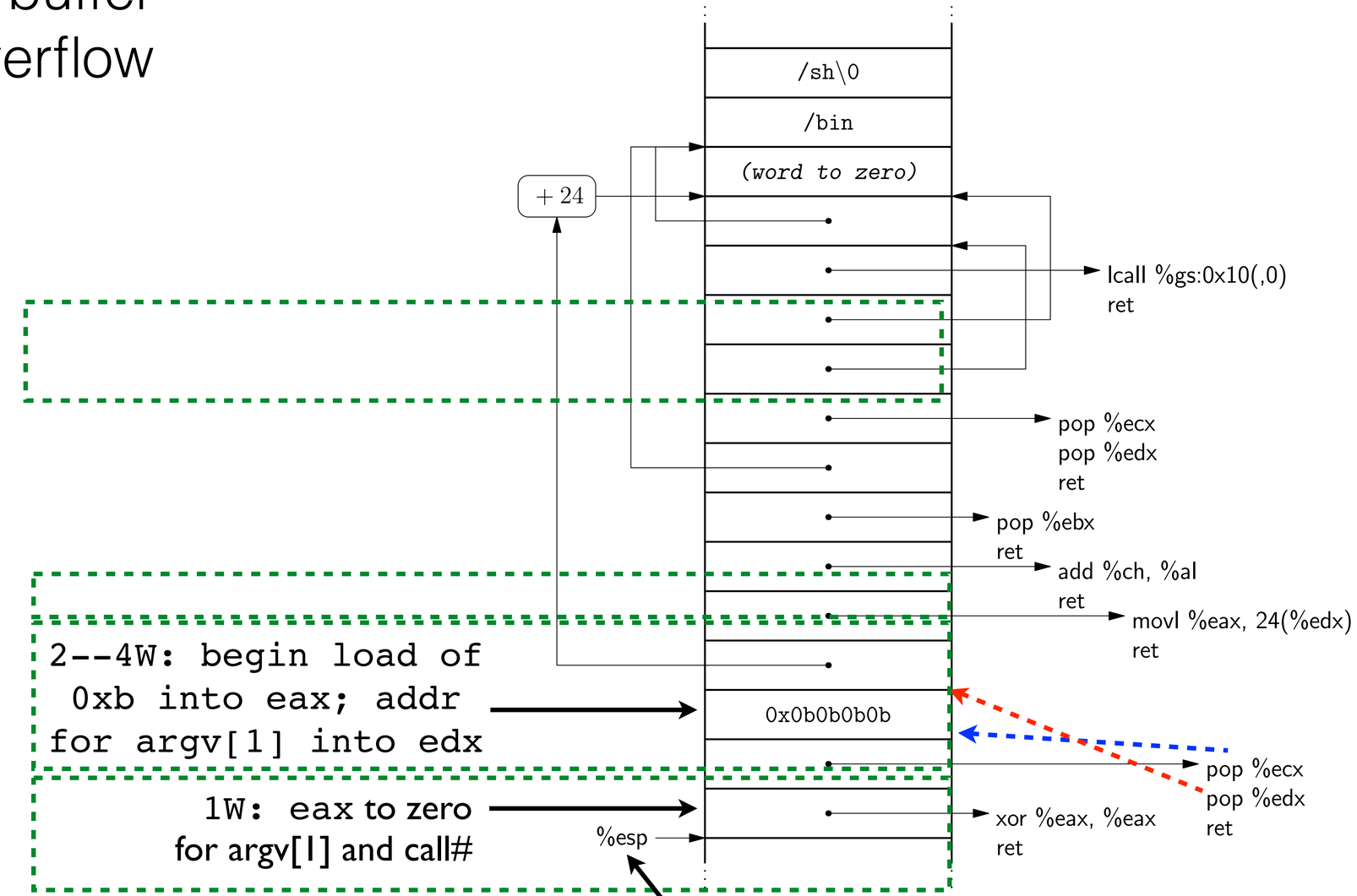

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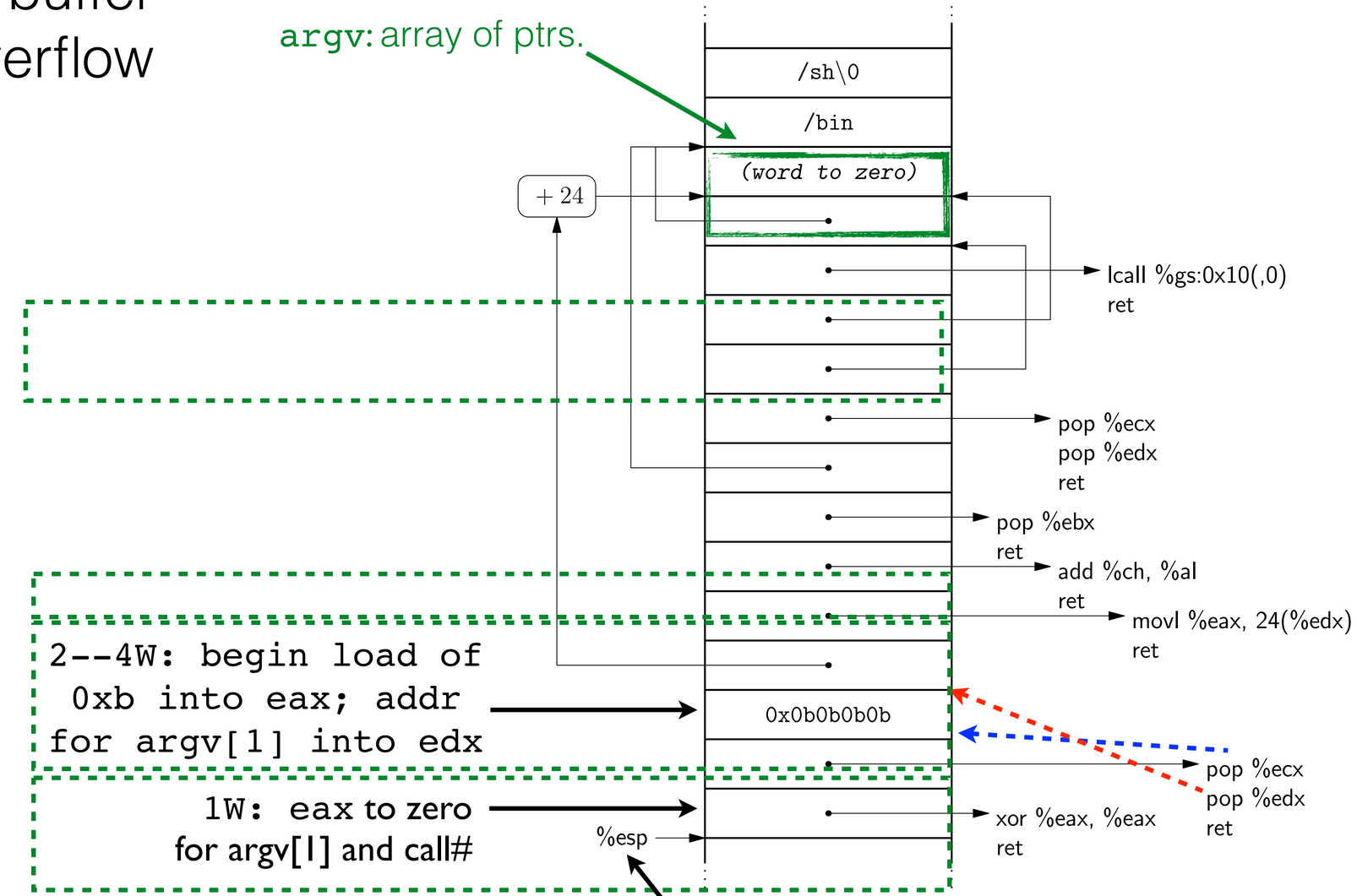

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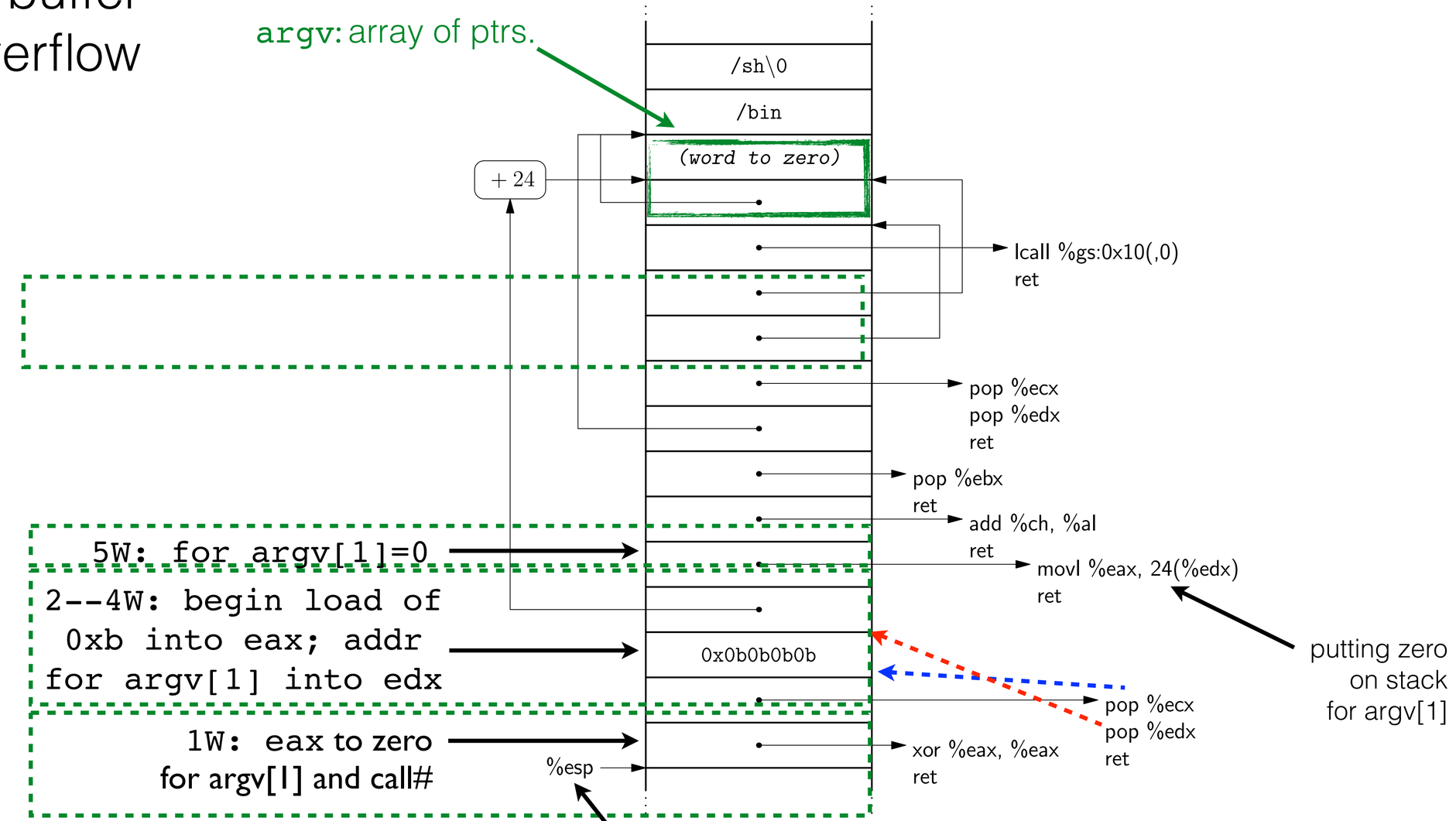

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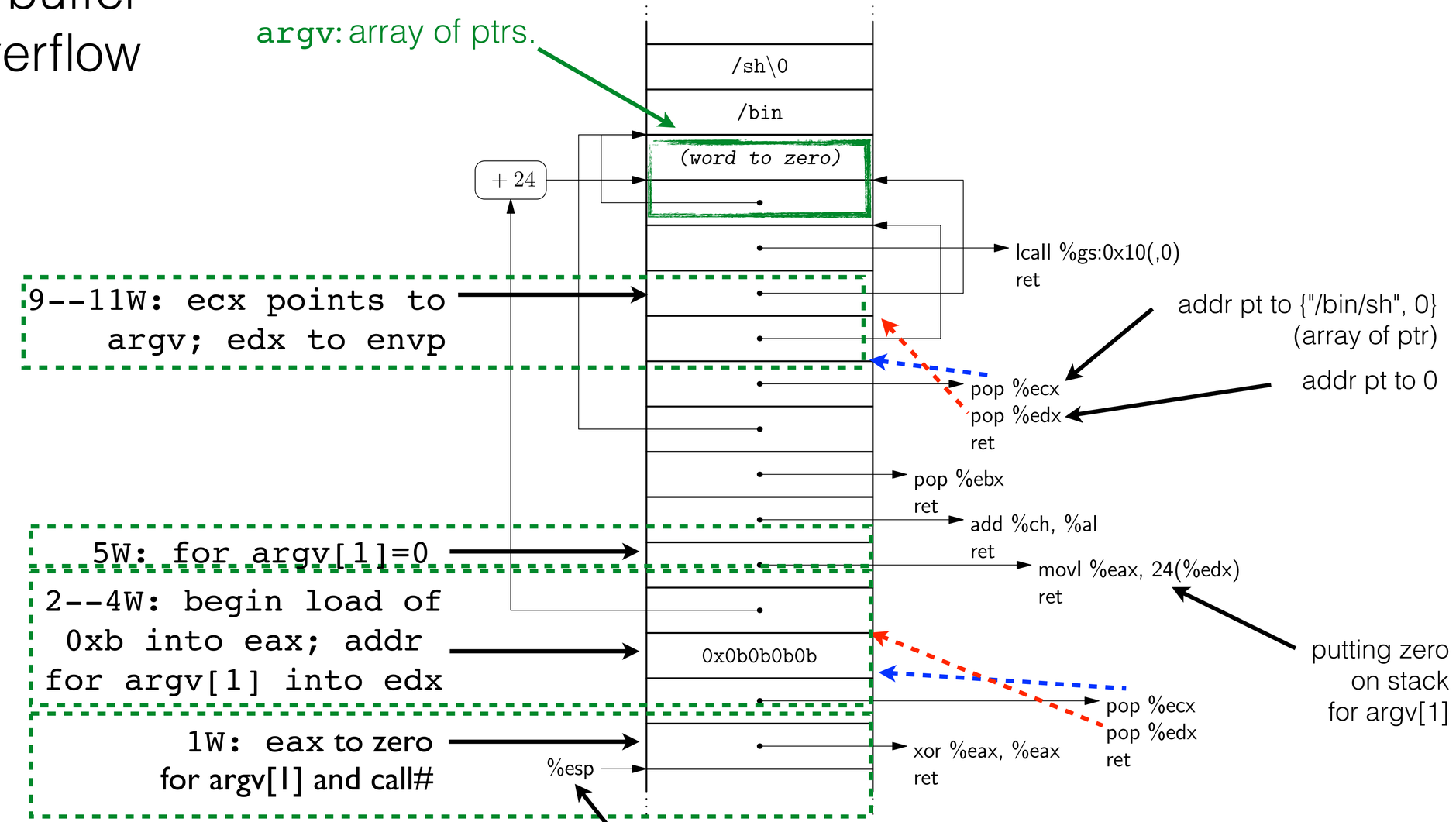

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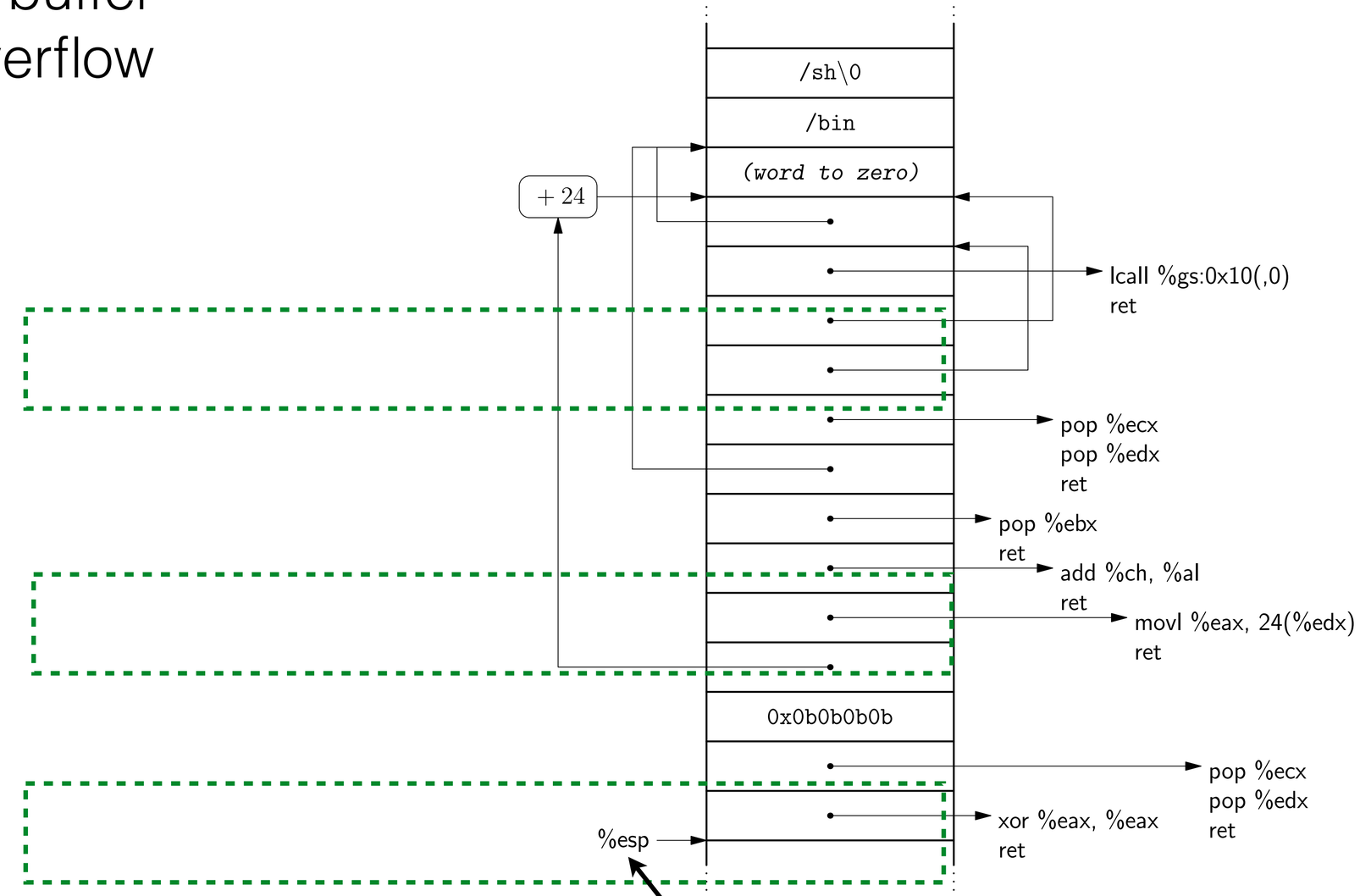

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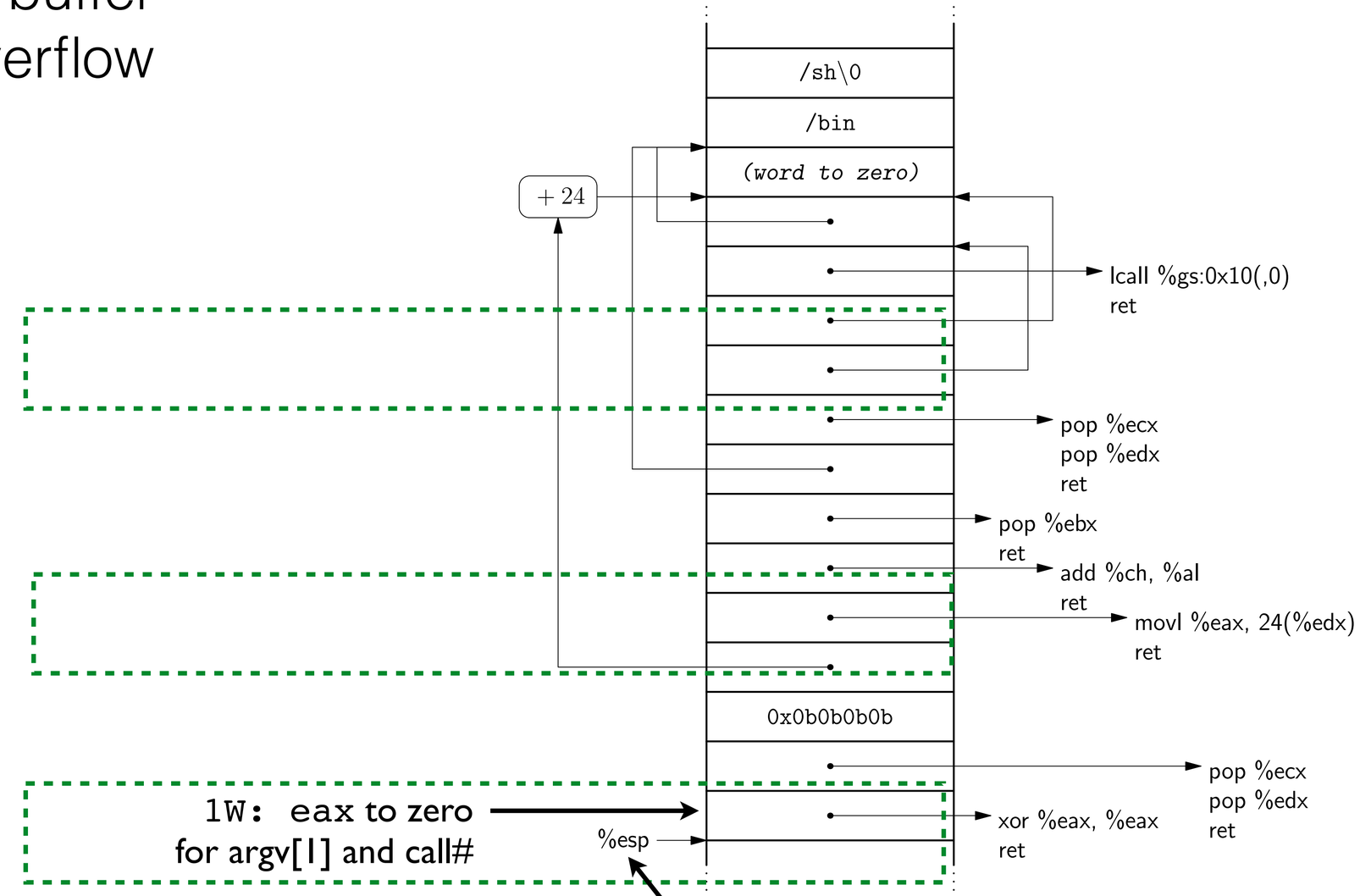

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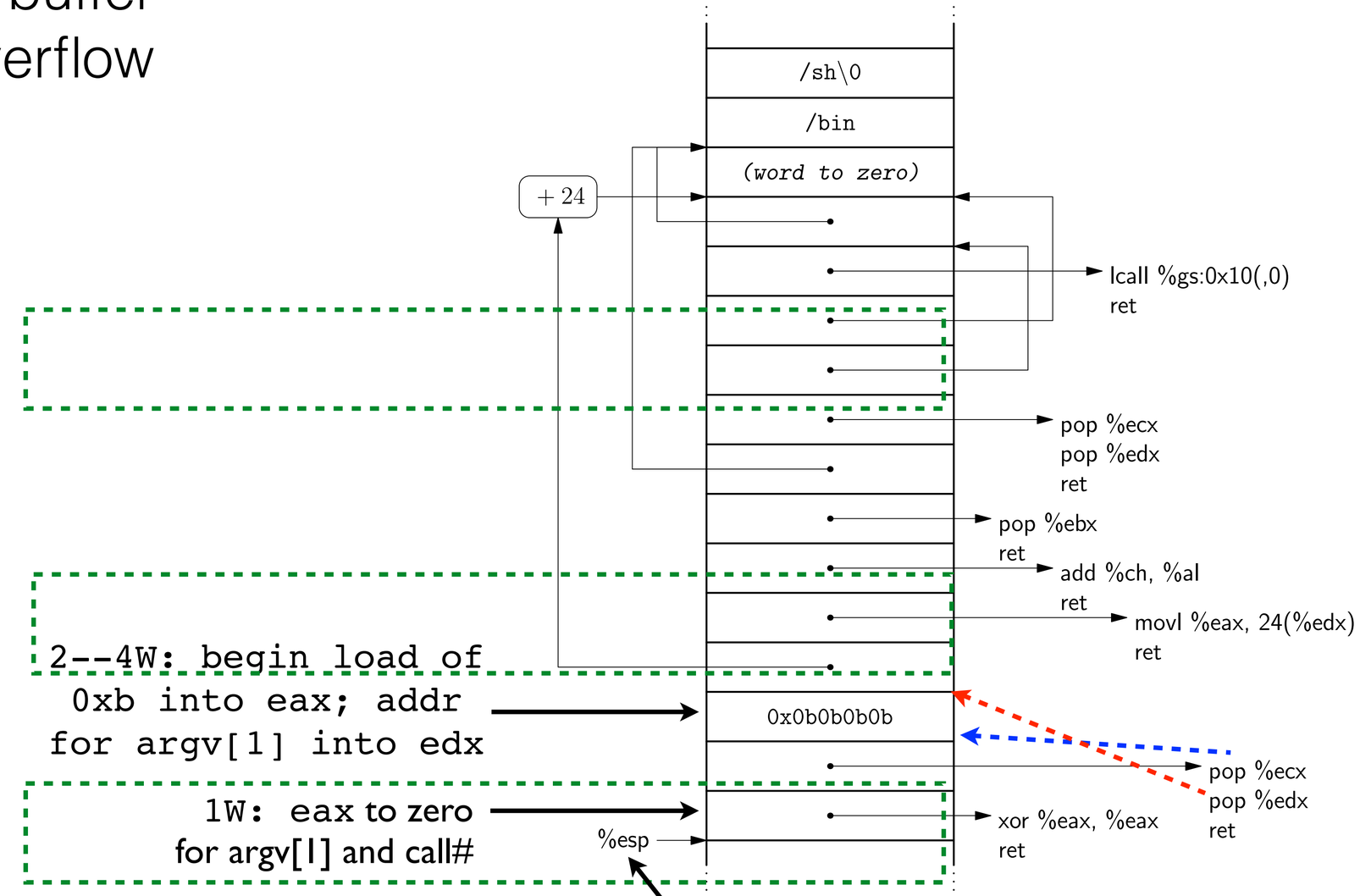

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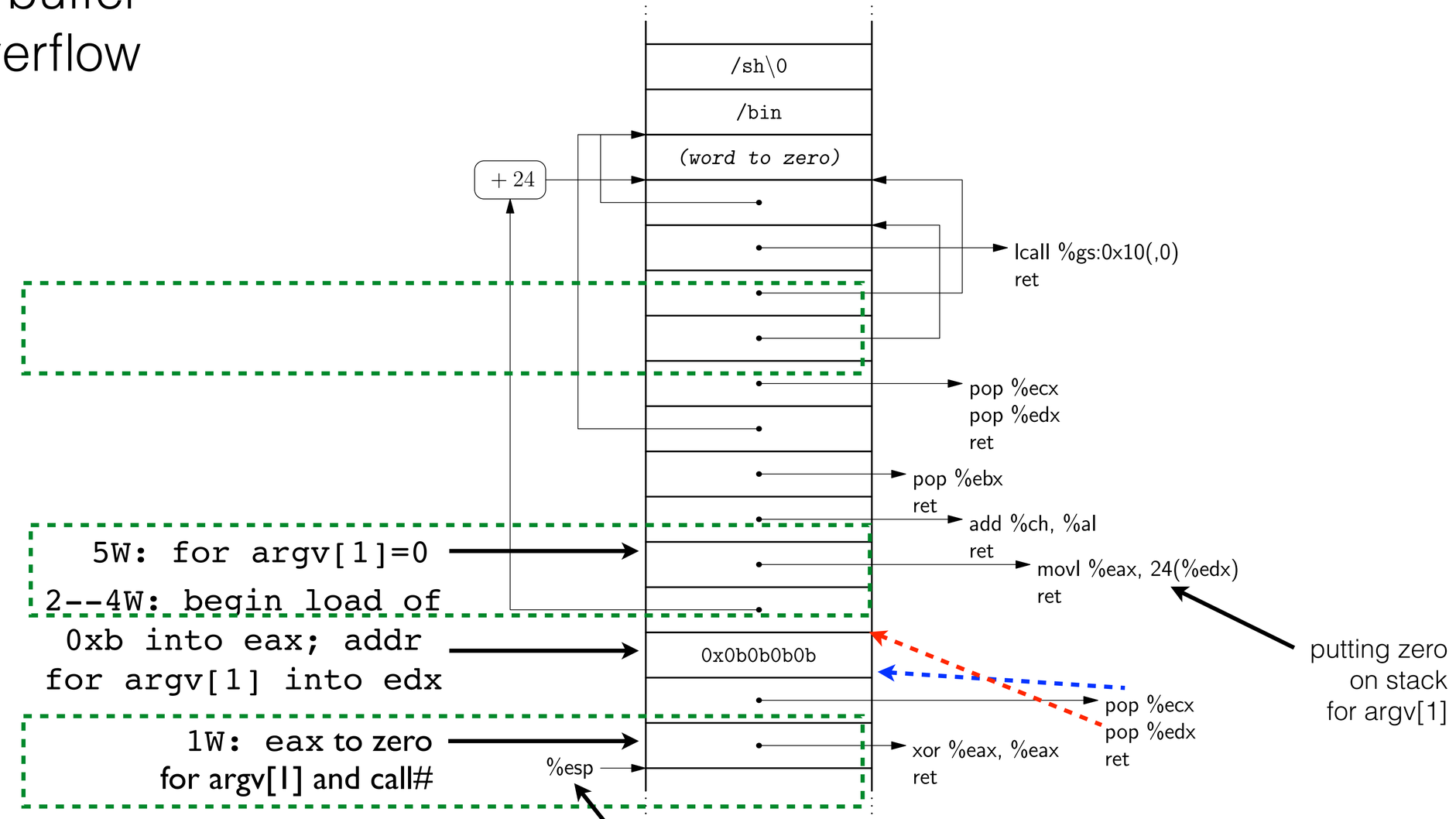

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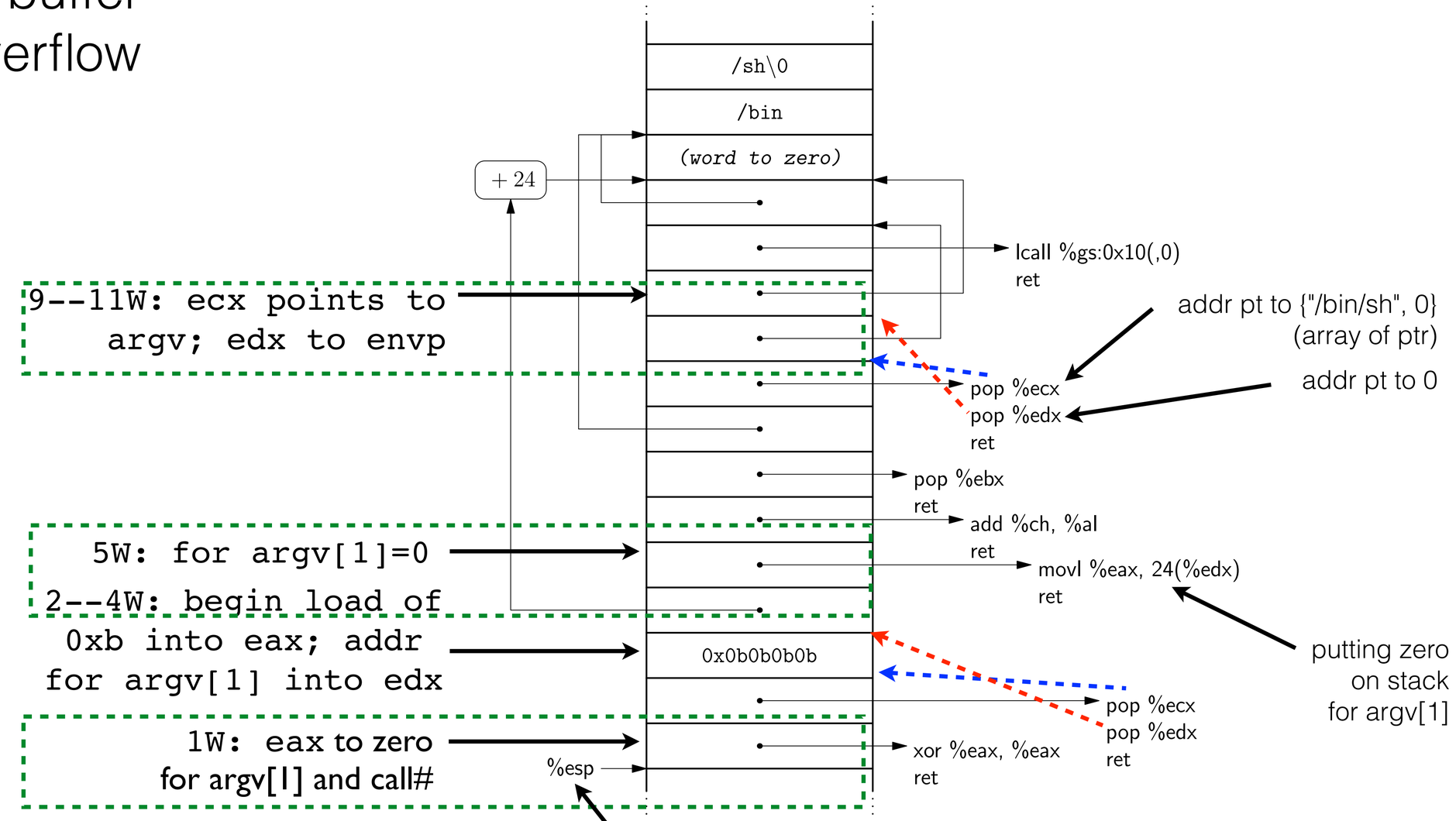

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Virginia Tech
Invent the Future

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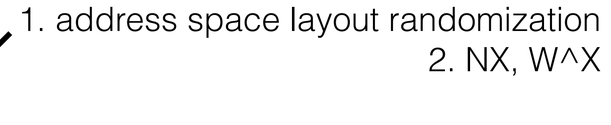

stack protection methods:

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1. address space layout randomization
2. NX, W^X

1. shadow stack
2. StackGuard

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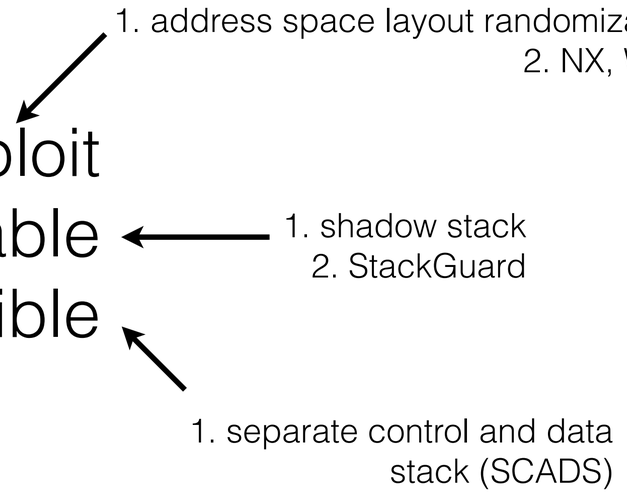

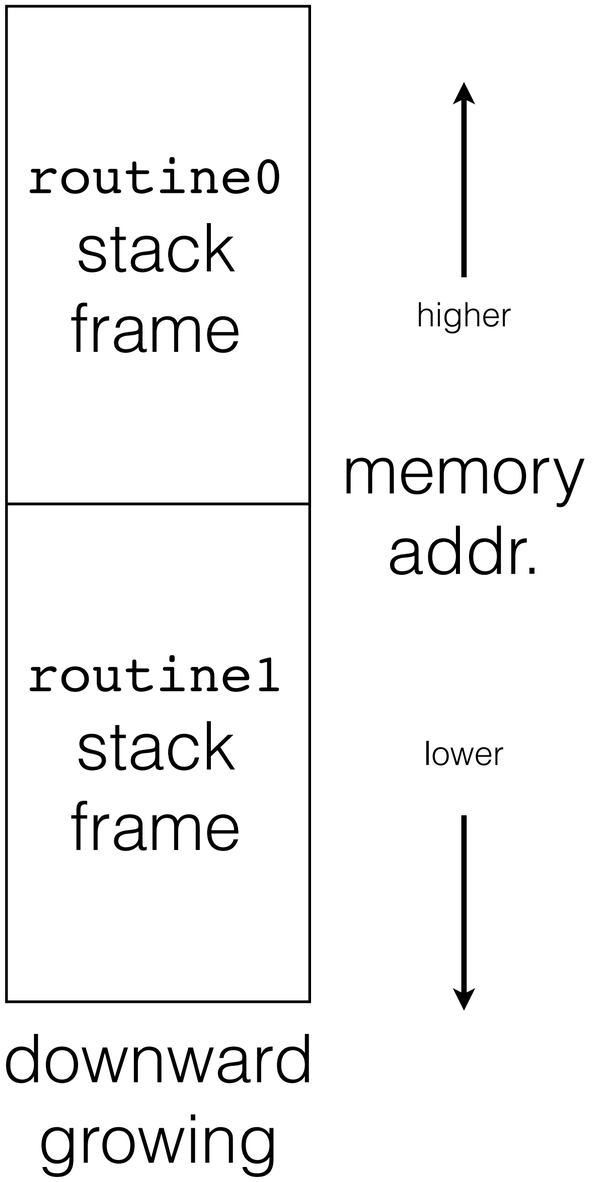

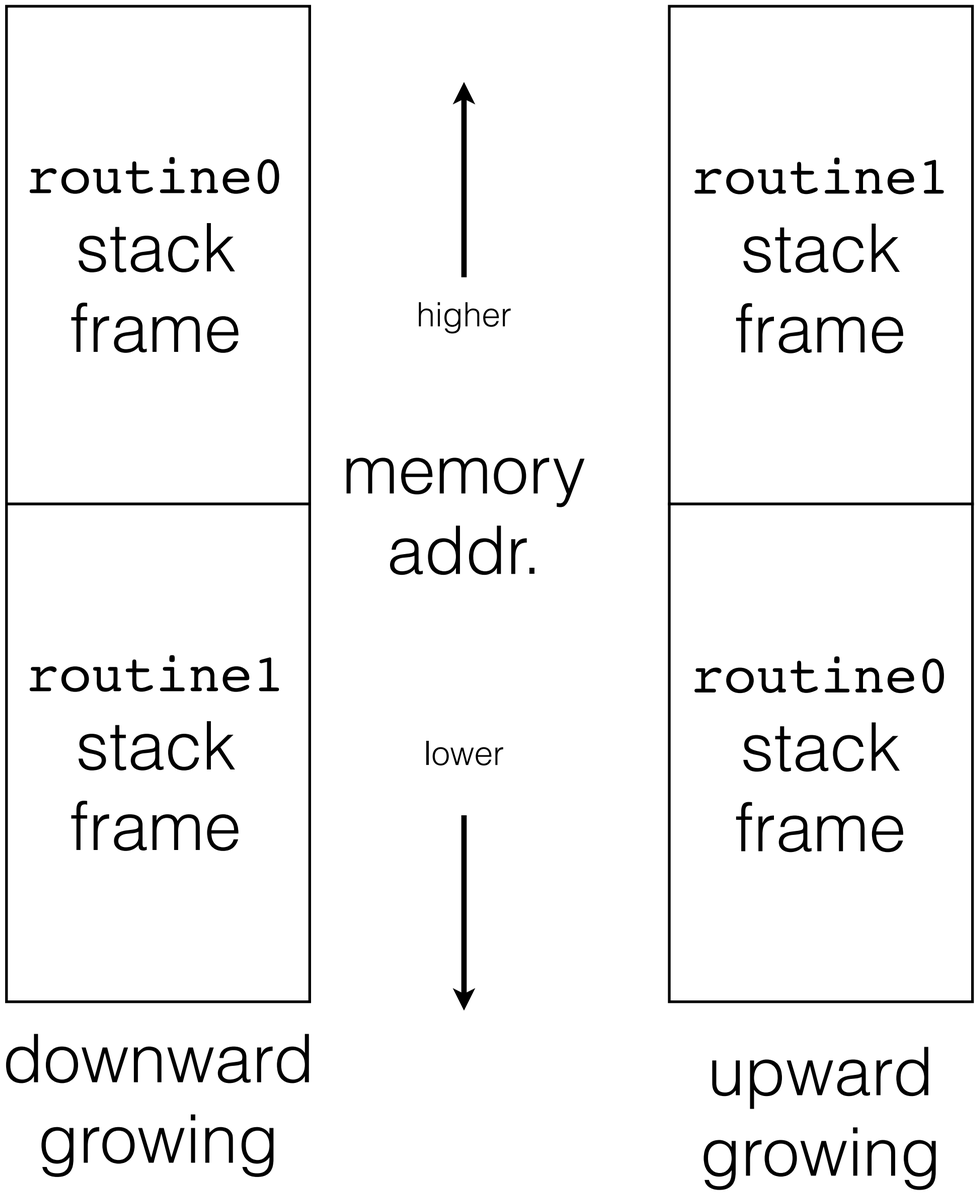

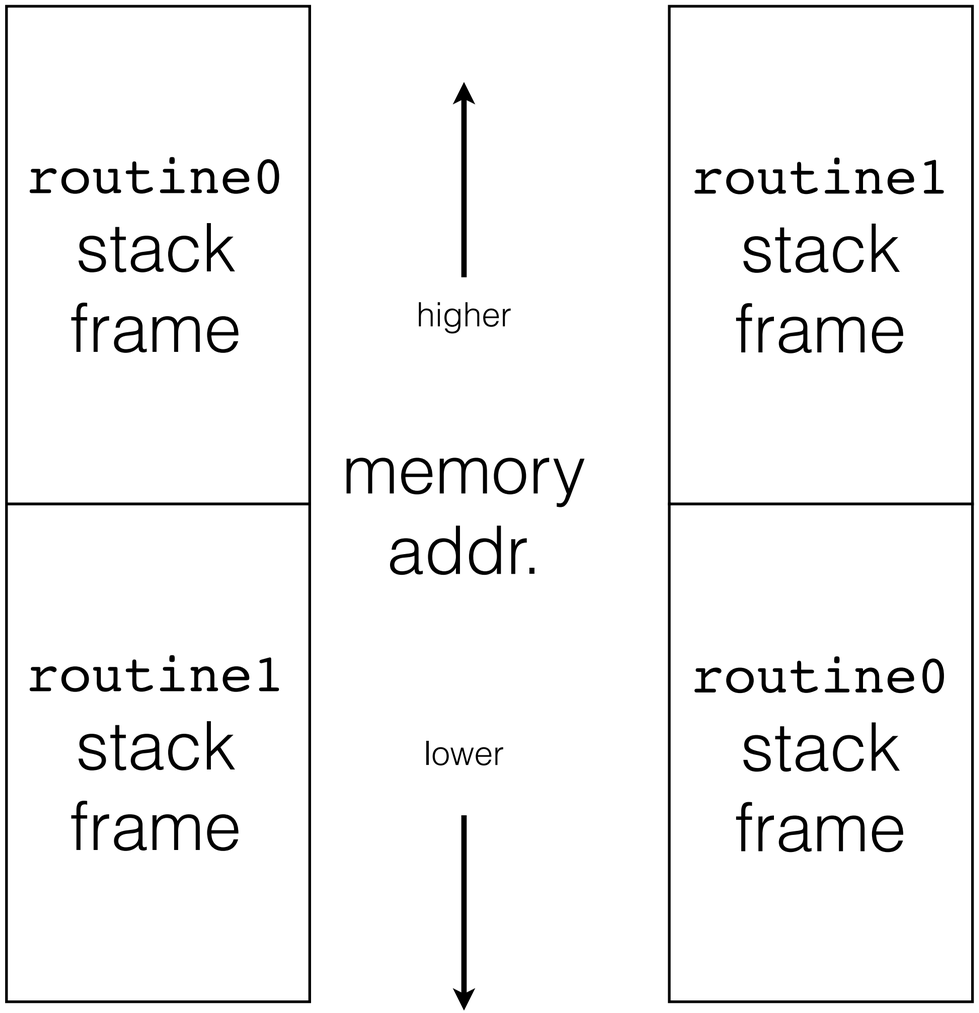

Q: would an upward growing stack prevent exploit of buffer overflow?

upward growing stack buffer overflow

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void function(char *str) {
   char buffer[16];

   strcpy(buffer,str);
}

void main() {
  char large_string[256];
  int i;

  for( i = 0; i < 255; i++)
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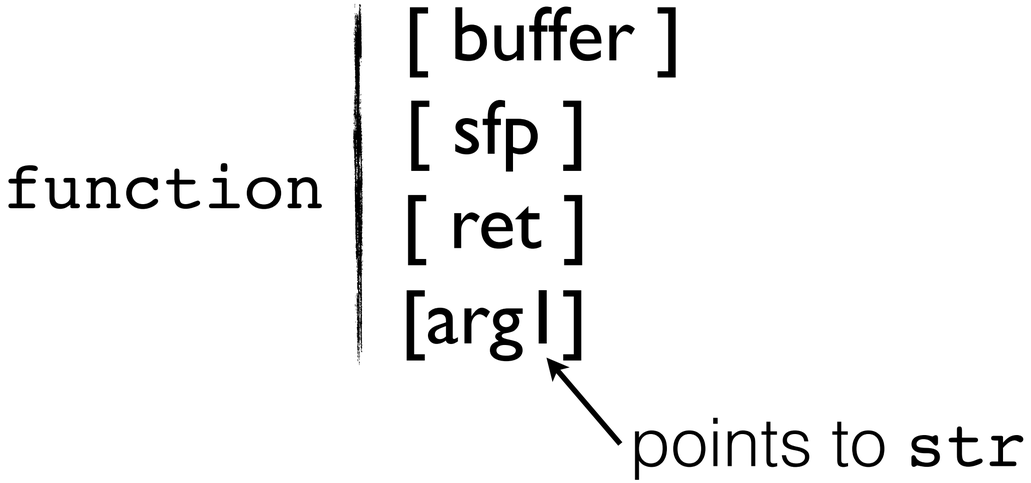

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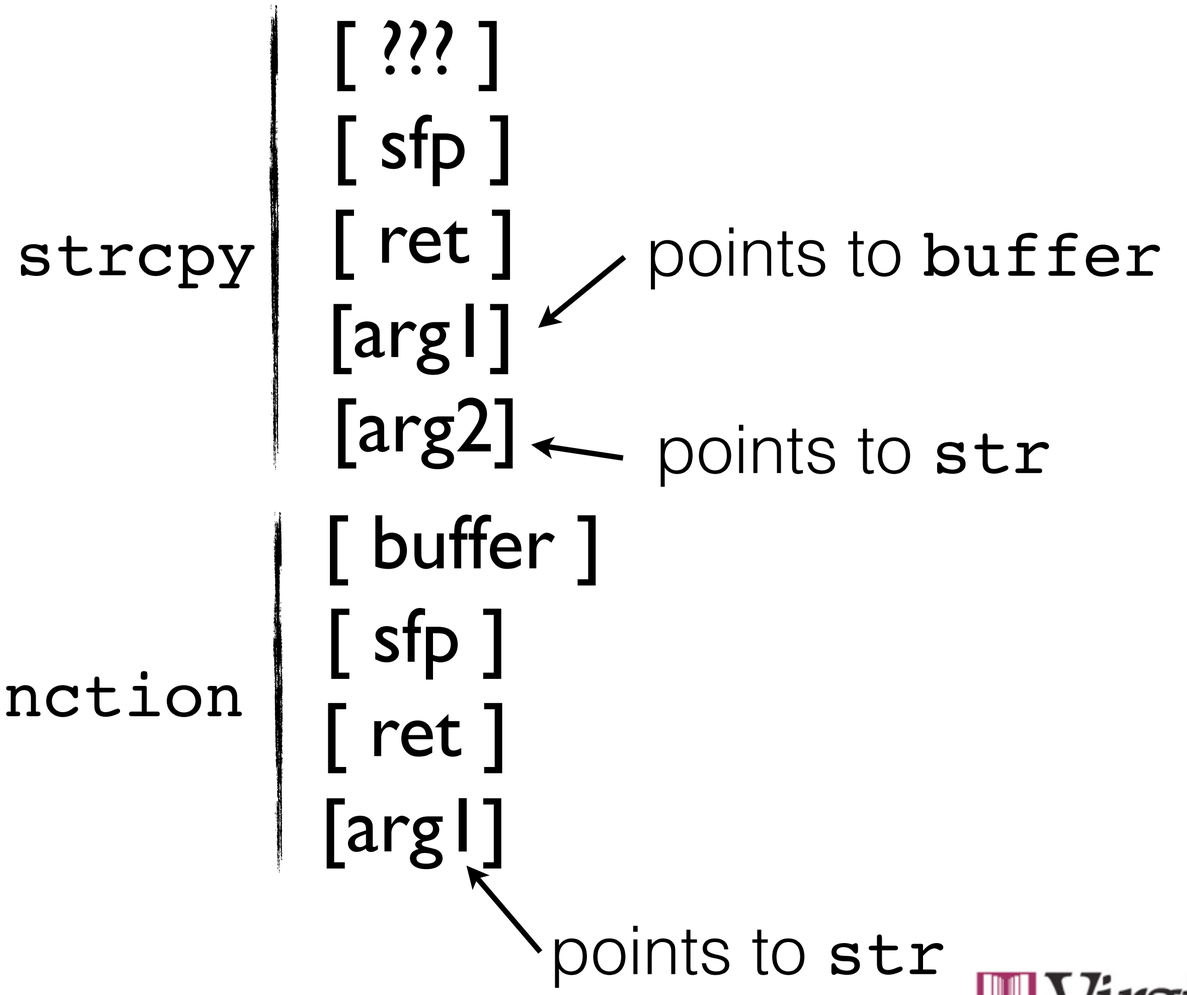

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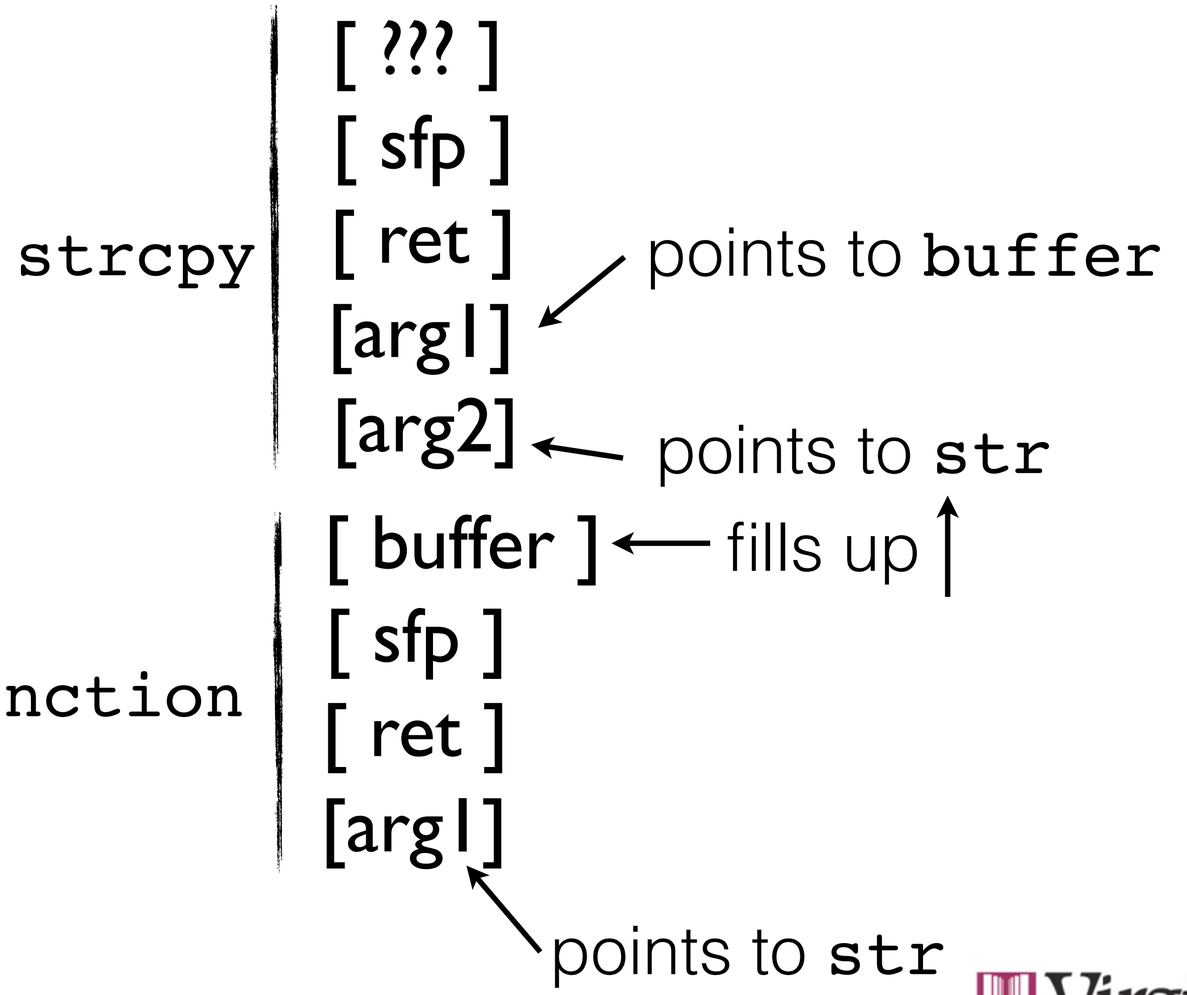

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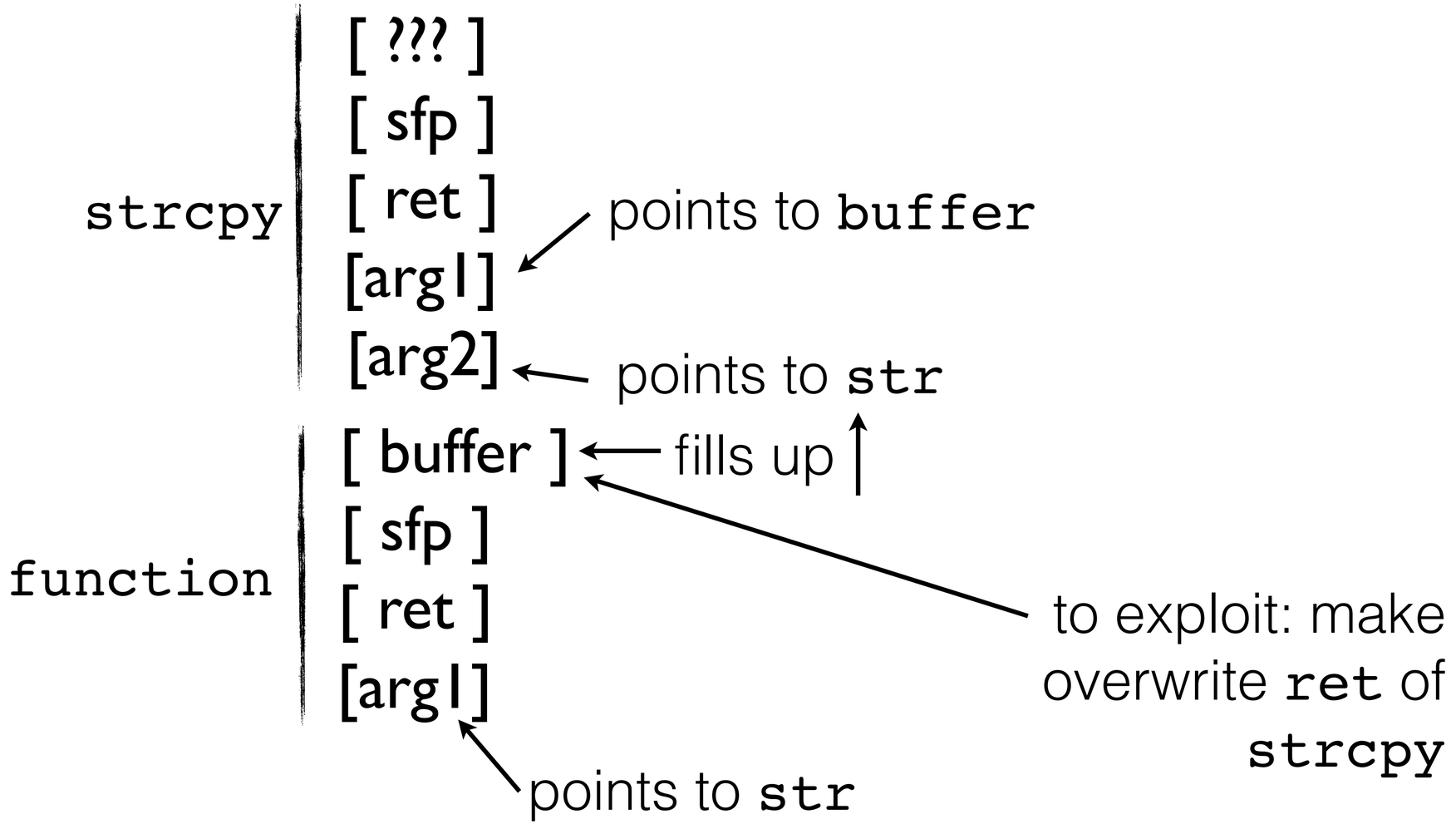


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position independent executable/code

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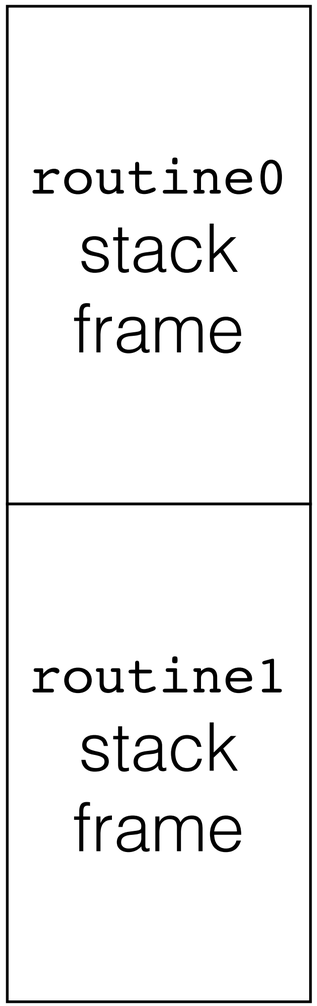
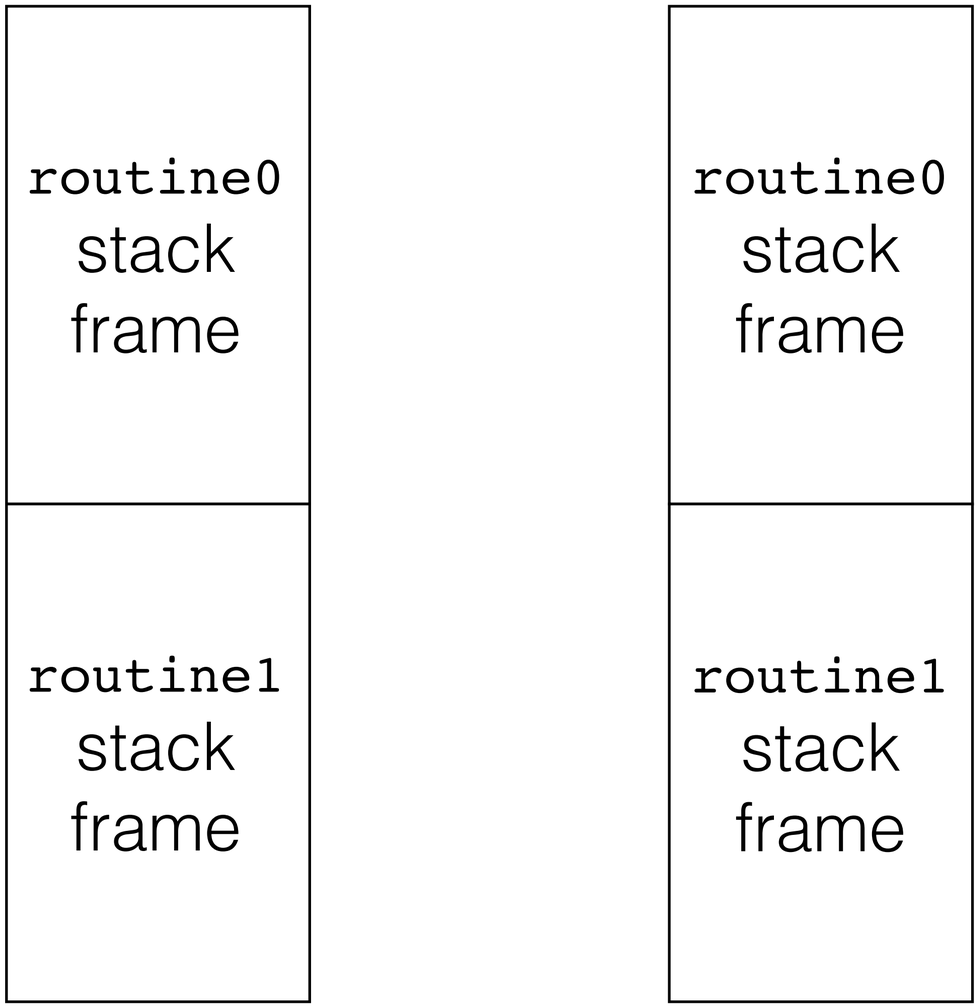


working stack

(overflow occurs here)

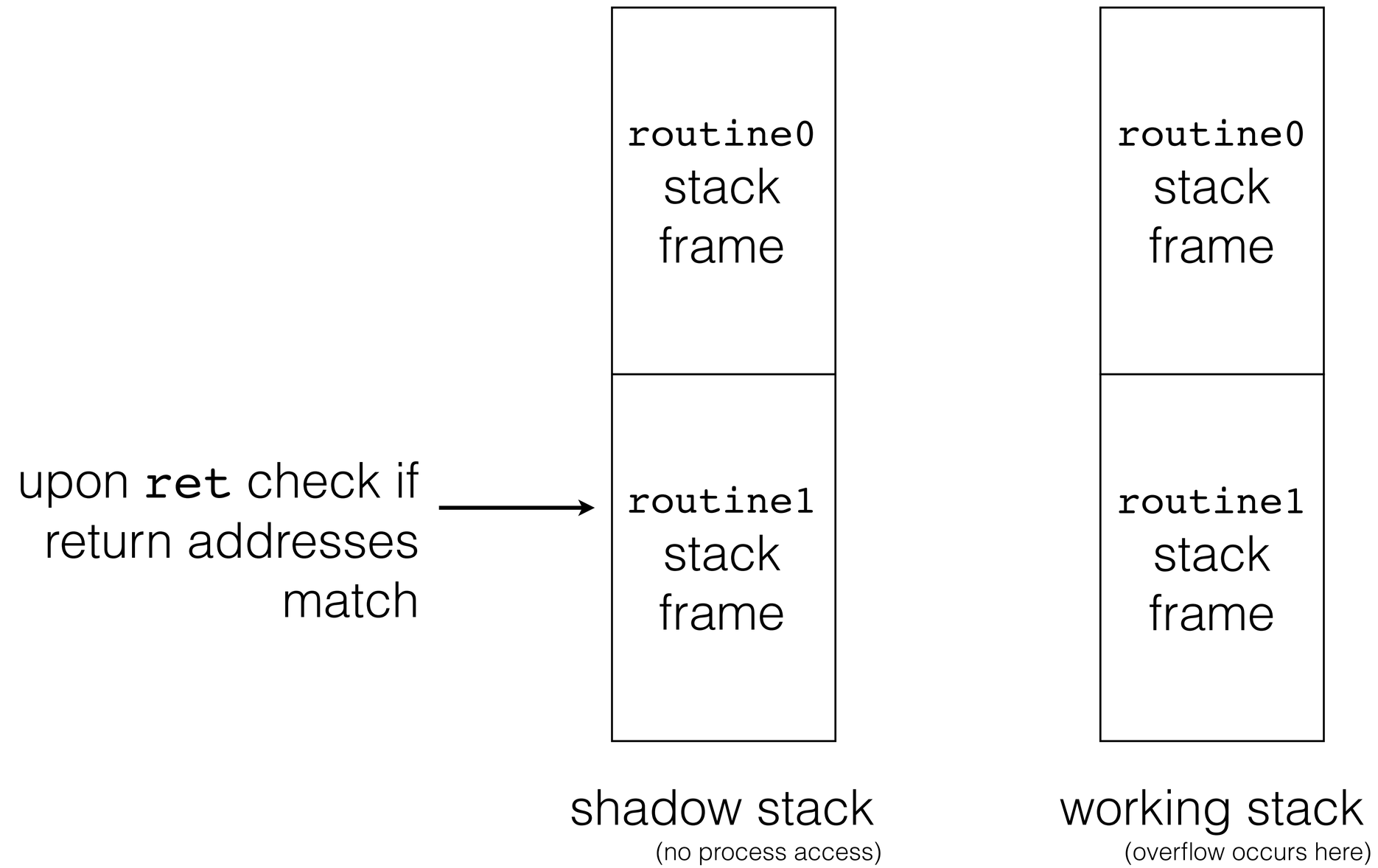
shadow stack



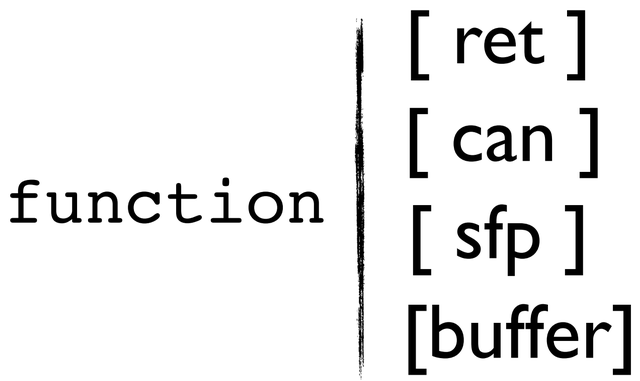
shadow stack
(no process access)

working stack
(overflow occurs here)

shadow stack



StackGuard (canary)



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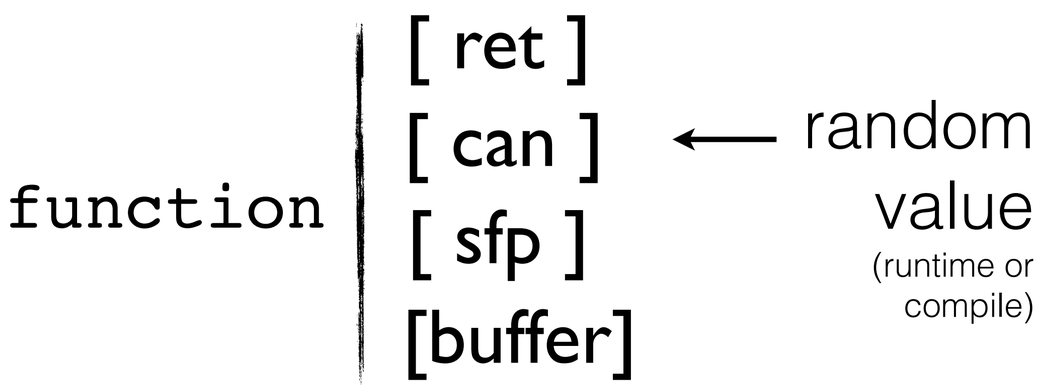
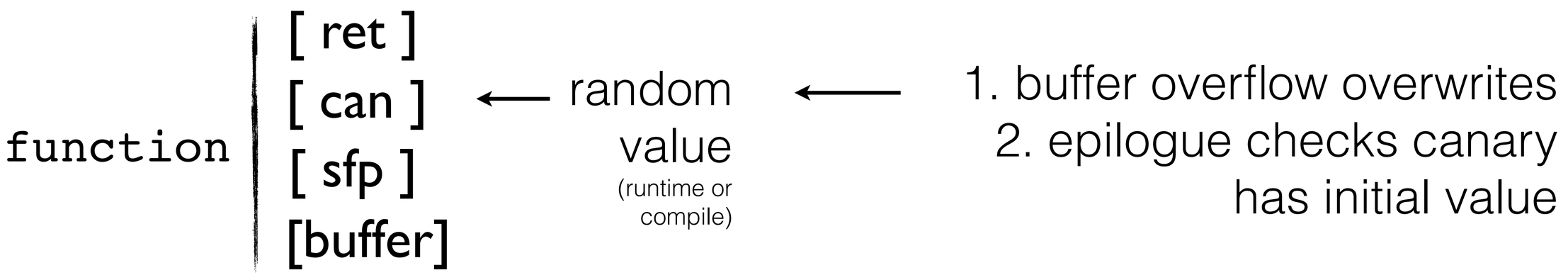
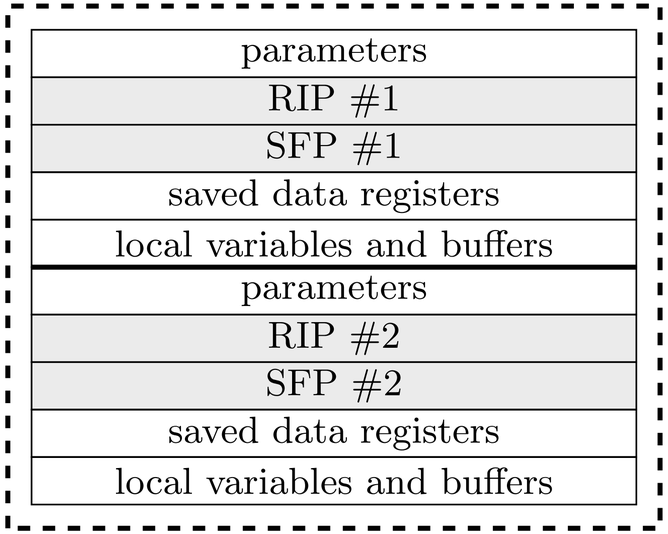


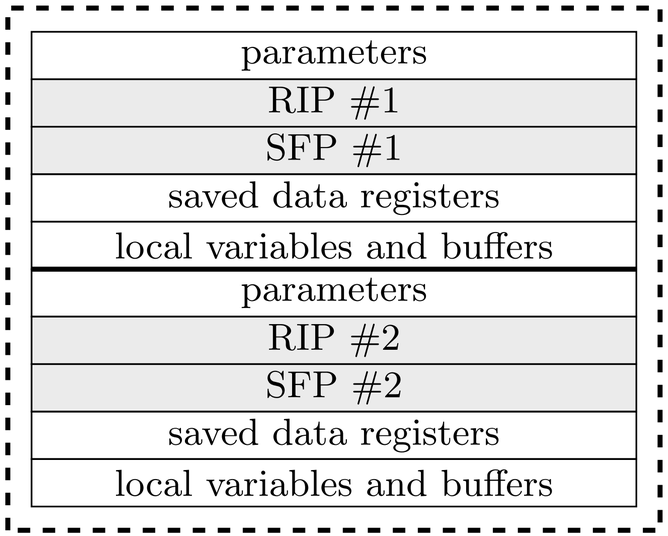
StackGuard (canary)



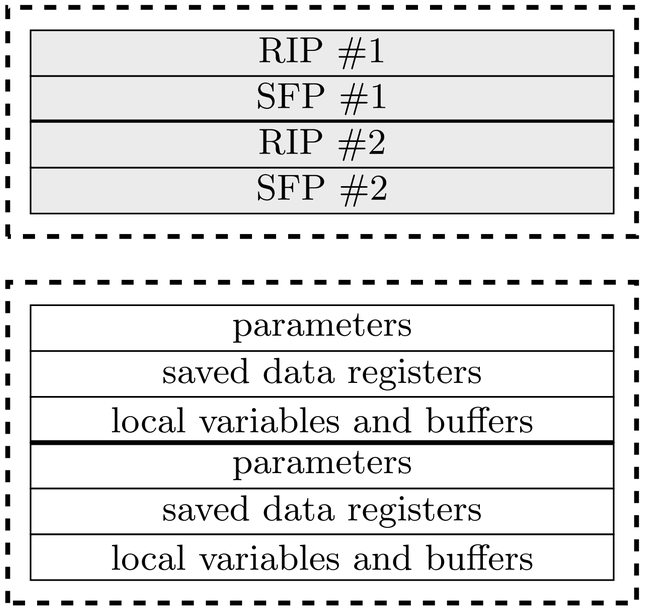
SCADS



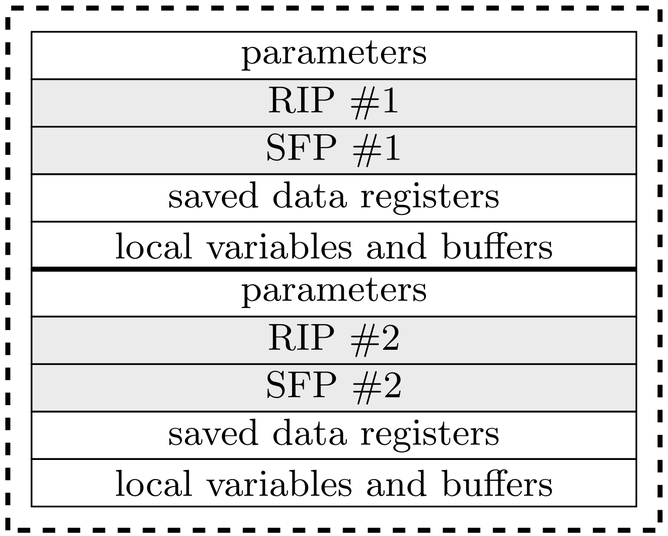
(a) Single call stack.



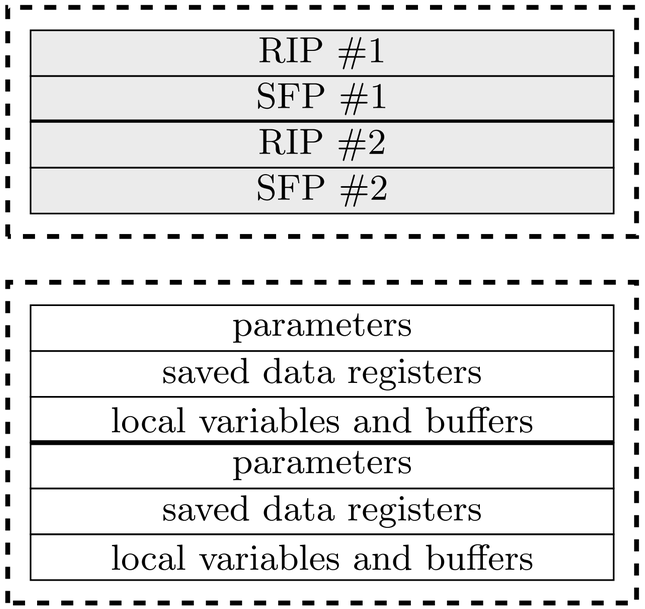
(a) Single call stack.



(b) Separated CS and DS.



(a) Single call stack.



(b) Separated CS and DS.

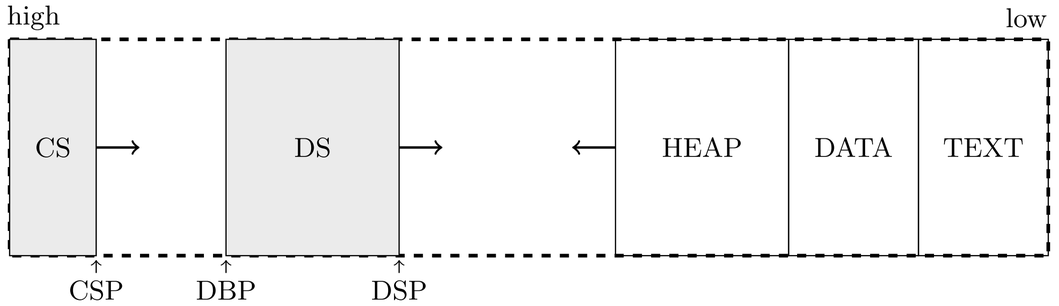


Fig. 2. Virtual address space layout of a user mode process compiled with SCADS.