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25 Comments

Linux Reverse Engineering CTFs for Beginners

After a while, I decided a write a short blog post about Linux binary reversing CTFs in general. How to approach a binary and solving for beginners. I personally am not a fan of Linux reverse engineering challenges in general, since I focus more time on Windows reversing. I like windows reverse engineering challenges more. A reason me liking Windows is as a pentester daily I encounter Windows machines and it's so rare I come across an entire network running Linux. Even when it comes to exploit development it's pretty rare you will manually develop an exploit for a Linux software while pentesting. But this knowledge is really

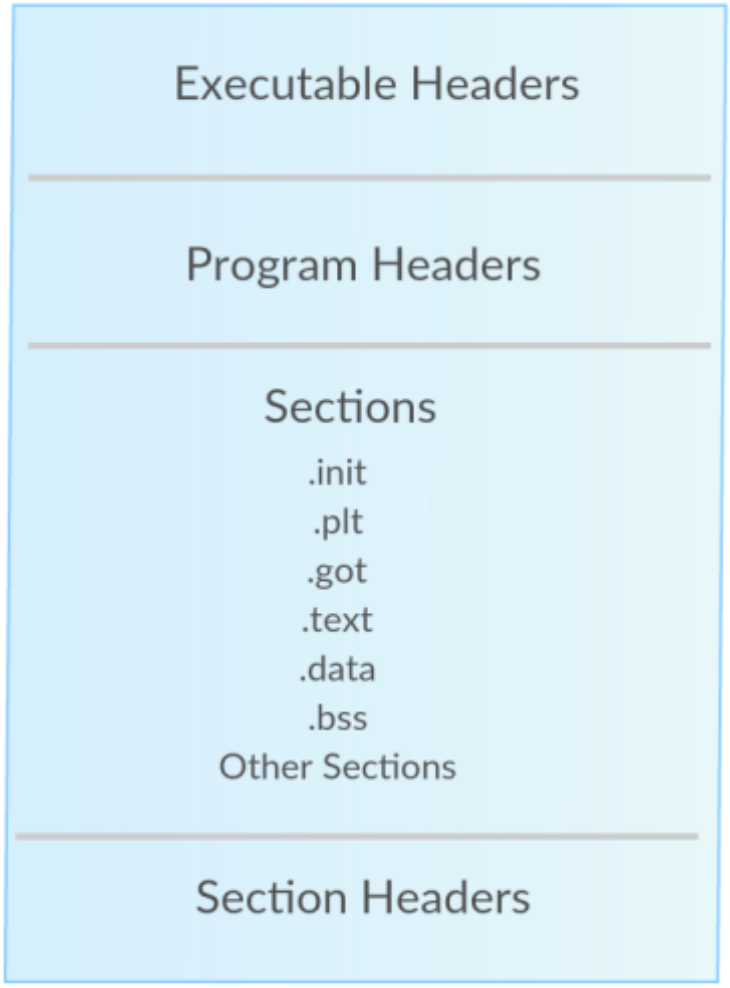
useful when it comes to IoT, since almost many devices are based on Linux embedded. If you want to begin reverse engineering and exploit development starting from Linux would be a good idea. I too started from Linux many years ago. Saying that since some people when they see a reverse engineering challenge they try to run away. So if you are a newbie I hope this content might be useful for you to begin with.

The ELF Format

Let's first have a look at the ELF headers. The best way to learn more about this in detail is to check the man pages for ELF.

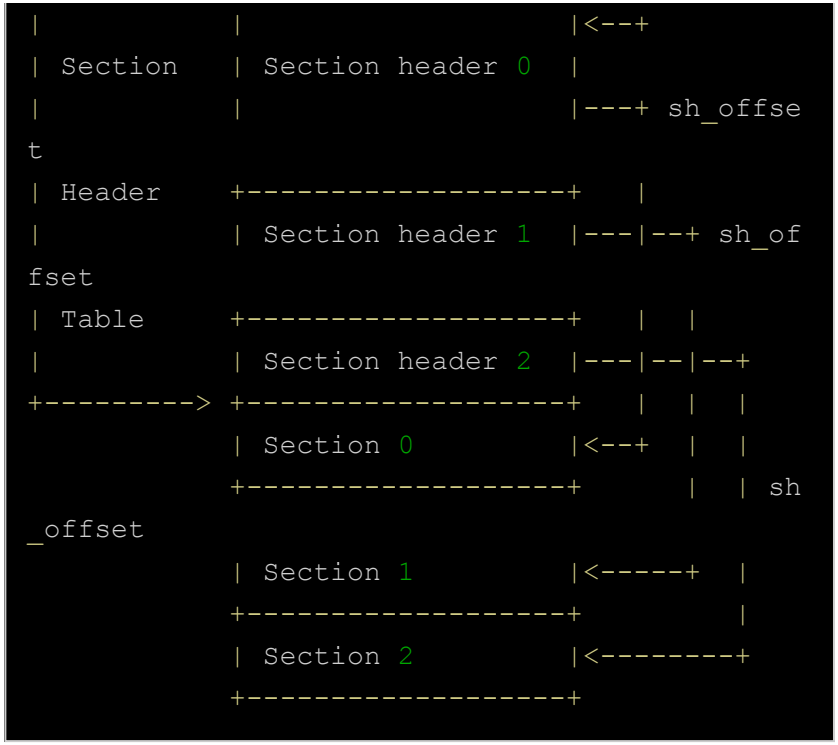
CATEGORY CLOUD

Certs Exploits Malware Mobile Pentesting Programming Raspberry Pi Reversing tools Uncategorized Web Application Security XSS



Here's in more detail. The "e_shoff" member holds the offset to the section header table. The "sh_offset" member holds the address to the section's first byte.

```
            +--------------------+
            | ELF header         |---+
+---------> +--------------------+   | e_shoff
```



Executable Header

Any ELF file starts with an executable header. This contains information about which type of an ELF file, the offsets to different headers. Everything is self-explanatory if you look at the comments. For this example, I am using 32-bit structures. For x86_64 the sizes may change and the naming convention would start with “Elf64_”.

```
1  #define EI_NIDENT (16)
2
3  typedef struct {
4    unsigned char e_ident[EI_NIDENT];     /*
5    Elf32_Half    e_type;                 /*
6    Elf32_Half    e_machine;              /*
```

```
    Elf32_Word    e_version;              /*
    Elf32_Addr    e_entry;                /*
    Elf32_Off     e_phoff;                /*
    Elf32_Off     e_shoff;                /*
    Elf32_Word    e_flags;                /*
    Elf32_Half    e_ehsize;               /*
    Elf32_Half    e_phentsize;            /*
    Elf32_Half    e_phnum;                /*
    Elf32_Half    e_shentsize;            /*
    Elf32_Half    e_shnum;                /*
    Elf32_Half    e_shstrndx;             /*
} Elf32_Ehdr;
```

This is an example using readelf.

```
# readelf -h /bin/ls
ELF Header:
  Magic:   7f 45 4c 46 02 01 01 00 00 00 00 00
 00 00 00 00
  Class:                             ELF64
  Data:                              2's compl
ement, little endian
  Version:                           1 (curren
t)
  OS/ABI:                            UNIX - Sy
stem V
  ABI Version:                       0
  Type:                              DYN (Shar
ed object file)
  Machine:                           Advanced
 Micro Devices X86-64
  Version:                           0x1
  Entry point address:               0x6130
  Start of program headers:          64 (bytes
```

```
 into file)
  Start of section headers:          137000 (b
ytes into file)
  Flags:                             0x0
  Size of this header:               64 (bytes
)
  Size of program headers:           56 (bytes
)
  Number of program headers:         11
  Size of section headers:           64 (bytes
)
  Number of section headers:         29
  Section header string table index: 28
```

To calculate the size of the entire binary we can use the following calculation

```
size = e_shoff + (e_shnum * e_shentsize)
size = Start of section headers + (Number of section headers * Size of section headers)
size = 137000 + (29*64) = 138856
```

As you can see our calculation is correct.

```
# ls -l /bin/ls
-rwxr-xr-x 1 root root 138856 Aug 29 21:20 /bi
n/ls
```

Program Headers

These headers describe the segments of the binary which important for the loading of the binary. This information is useful for the kernel to map the segments to memory from disk. The members of the structure are self-explanatory. I won't be explaining in depth about this for this post as I try to keep things basic. However, every section is important to understand in doing cool things in reverse engineering in ELF 🙂

```
typedef struct {
  Elf32_Word    p_type;                 /*
  Elf32_Off     p_offset;               /*
  Elf32_Addr    p_vaddr;                /*
  Elf32_Addr    p_paddr;                /*
  Elf32_Word    p_filesz;               /*
  Elf32_Word    p_memsz;                /*
  Elf32_Word    p_flags;                /*
  Elf32_Word    p_align;                /*
} Elf32_Phdr;
```

Section Headers

These headers contain the information for the binary's segments. It references the size, location for linking and debugging purposes. These headers are not really important for the execution flow of the binary. In some cases, this is stripped and tools like gdb, objdump are useless as they rely on these headers to locate symbol information.

```
typedef struct {
  Elf32_Word    sh_name;                /*
  Elf32_Word    sh_type;                /*
  Elf32_Word    sh_flags;               /*
  Elf32_Addr    sh_addr;                /*
  Elf32_Off     sh_offset;              /*
  Elf32_Word    sh_size;                /*
  Elf32_Word    sh_link;                /*
```

```
  Elf32_Word    sh_info;                /*
  Elf32_Word    sh_addralign;           /*
  Elf32_Word    sh_entsize;             /*
} Elf32_Shdr;
```

Sections

As any binary, these are the sections. Some sections are familiar with the PE's headers. However, I won't be discussing all the sections as I try to keep it basic.

.bss Section

This section contains the program's uninitialized global data.

.data Section

This section contains the program's initialized global variables.

.rodata Section

This section contains read-only data such as strings of the program used.

.text Section

This section contains the program's actual code, the logic flow.

```
# readelf -S --wide /bin/ls
There are 29 section headers, starting at offs
et 0x21728:
```

```
Section Headers:
  [Nr] Name              Type            Addre
ss          Off    Size   ES Flg Lk Inf Al
  [ 0]                   NULL            00000
00000000000 000000 000000 00      0   0  0
  [ 1] .interp           PROGBITS        00000
000000002a8 0002a8 00001c 00   A  0   0  1
  [ 2] .note.ABI-tag     NOTE            00000
000000002c4 0002c4 000020 00   A  0   0  4
  [ 3] .note.gnu.build-id NOTE            0000
0000000002e4 0002e4 000024 00   A  0   0  4
  [ 4] .gnu.hash         GNU_HASH        00000
00000000308 000308 0000c0 00   A  5   0  8
  [ 5] .dynsym           DYNSYM          00000
000000003c8 0003c8 000c90 18   A  6   1  8
  [ 6] .dynstr           STRTAB          00000
00000001058 001058 0005d8 00   A  0   0  1
  [ 7] .gnu.version      VERSYM          00000
00000001630 001630 00010c 02   A  5   0  2
  [ 8] .gnu.version_r    VERNEED         00000
00000001740 001740 000070 00   A  6   1  8
  [ 9] .rela.dyn         RELA            00000
000000017b0 0017b0 001350 18   A  5   0  8
  [10] .rela.plt         RELA            00000
00000002b00 002b00 0009f0 18  AI  5  24  8
  [11] .init             PROGBITS        00000
00000004000 004000 000017 00  AX  0   0  4
  [12] .plt              PROGBITS        00000
00000004020 004020 0006b0 10  AX  0   0 16
  [13] .plt.got          PROGBITS        00000
000000046d0 0046d0 000018 08  AX  0   0  8
```

```
  [14] .text             PROGBITS         00000
000000046f0 0046f0 01253e 00  AX  0   0 16
  [15] .fini             PROGBITS         00000
00000016c30 016c30 000009 00  AX  0   0  4
  [16] .rodata           PROGBITS         00000
00000017000 017000 005129 00   A  0   0 32
  [17] .eh_frame_hdr     PROGBITS         00000
0000001c12c 01c12c 0008fc 00   A  0   0  4
  [18] .eh_frame         PROGBITS         00000
0000001ca28 01ca28 002ed0 00   A  0   0  8
  [19] .init_array       INIT_ARRAY       00000
00000021390 020390 000008 08  WA  0   0  8
  [20] .fini_array       FINI_ARRAY       00000
00000021398 020398 000008 08  WA  0   0  8
  [21] .data.rel.ro      PROGBITS         00000
000000213a0 0203a0 000a38 00  WA  0   0 32
  [22] .dynamic          DYNAMIC          00000
00000021dd8 020dd8 0001f0 10  WA  6   0  8
  [23] .got              PROGBITS         00000
00000021fc8 020fc8 000038 08  WA  0   0  8
  [24] .got.plt          PROGBITS         00000
00000022000 021000 000368 08  WA  0   0  8
  [25] .data             PROGBITS         00000
00000022380 021380 000268 00  WA  0   0 32
  [26] .bss              NOBITS           00000
00000022600 0215e8 0012d8 00  WA  0   0 32
  [27] .gnu_debuglink    PROGBITS         00000
00000000000 0215e8 000034 00      0   0  4
  [28] .shstrtab         STRTAB           00000
00000000000 02161c 00010a 00      0   0  1
Key to Flags:
  W (write), A (alloc), X (execute), M (merge)
```

```
, S (strings), I (info),
  L (link order), O (extra OS processing requi
red), G (group), T (TLS),
  C (compressed), x (unknown), o (OS specific)
, E (exclude),
  l (large), p (processor specific)
```

Solving a Basic CTF Challenge

Now that you have a basic understanding about the headers, let's pick a random challenge CTF and explire. Download the binary from here.

When we pass in some random string we get `[+] No flag for you. [+]` text displayed.

```
# ./nix_5744af788e6cbdb29bb41e8b0e5f3cd5 aaaa

[+] No flag for you. [+]
```

Strings

Let's start by having a look at strings and see any interesting strings.

```
# strings nix_5744af788e6cbdb29bb41e8b0e5f3cd5

/lib/ld-linux.so.2
Mw1i#'0
libc.so.6
_IO_stdin_used
exit
sprintf
puts
strlen
__cxa_finalize
__libc_start_main
GLIBC_2.1.3
Y[^]
[^_]
UWVS
[^_]
Usage: script.exe <key>
Length of argv[1] too long.
[+] The flag is: SAYCURE{%s} [+]
[+] No flag for you. [+]
%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c
;*2$"
GCC: (Debian 8.2.0-8) 8.2.0
crtstuff.c
```

We found all the strings printed out from the binary. The “%c” is the format string where our flag gets printed, we can determine the flag must be of 15 characters.

```
Usage: script.exe
Length of argv[1] too long.
[+] The flag is: SAYCURE{%s} [+]
[+] No flag for you. [+]
%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c%c
```

We can get a better view of these strings if we look at the '.rodata' section with the offsets.

```
# readelf -x .rodata nix_5744af788e6cbdb29bb41e8b0e5f3cd5

Hex dump of section '.rodata':
  0x00002000 03000000 01000200 55736167 653a2073 ........Usage: s
  0x00002010 63726970 742e6578 65203c6b 65793e00 cript.exe <key>.
  0x00002020 4c656e67 7468206f 66206172 67765b31 Length of argv[1
  0x00002030 5d20746f 6f206c6f 6e672e00 5b2b5d20 ] too long..[+]
  0x00002040 54686520 666c6167 2069733a 20534159 The flag is: SAY
  0x00002050 43555245 7b25737d 205b2b5d 0a000a5b CURE{%s} [+]...[
  0x00002060 2b5d204e 6f20666c 61672066 6f722079 +] No flag for y
  0x00002070 6f752e20 5b2b5d00 25632563 25632563 ou. [+].%c%c%c%c
  0x00002080 25632563 25632563 25632563 25632563 %c%c%c%c%c%c%c%c
```

```
  0x00002090 25632563 256300
   %c%c%c.
```

Checking for Symbols

By checking the symbols of the binary we can realize it uses `printf, puts, sprintf, strlen` functions.

```
# nm -D nix_5744af788e6cbdb29bb41e8b0e5f3cd5
         w __cxa_finalize
         U exit
         w __gmon_start__
00002004 R _IO_stdin_used
         w _ITM_deregisterTMCloneTable
         w _ITM_registerTMCloneTable
         U __libc_start_main
         U printf
         U puts
         U sprintf
         U strlen
```

Tracing System Calls

We can use tools such as strace to trace the system calls used by the program.

```
# strace ./nix_5744af788e6cbdb29bb41e8b0e5f3cd
5 aaaa
```

```
execve("./nix_5744af788e6cbdb29bb41e8b0e5f3cd5
", ["./nix_5744af788e6cbdb29bb41e8b0e"..., "aa
aa"], 0x7ffd5ff92d18 /* 46 vars */) = 0
strace: [ Process PID=59965 runs in 32 bit mod
e. ]
brk(NULL)                               = 0x56
f14000
access("/etc/ld.so.nohwcap", F_OK)      = -1 E
NOENT (No such file or directory)
mmap2(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PR
IVATE|MAP_ANONYMOUS, -1, 0) = 0xf7ef0000
access("/etc/ld.so.preload", R_OK)      = -1 E
NOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|
O_CLOEXEC) = 3
fstat64(3, {st_mode=S_IFREG|0644, st_size=2204
71, ...}) = 0
mmap2(NULL, 220471, PROT_READ, MAP_PRIVATE, 3,
 0) = 0xf7eba000
close(3)                                = 0
access("/etc/ld.so.nohwcap", F_OK)      = -1 E
NOENT (No such file or directory)
openat(AT_FDCWD, "/lib/i386-linux-gnu/libc.so.
6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\1\1\1\3\0\0\0\0\0\0\0\3\0\3
\0\1\0\0\0 \233\1\0004\0\0\0"..., 512) = 512
fstat64(3, {st_mode=S_IFREG|0755, st_size=1930
924, ...}) = 0
mmap2(NULL, 1940000, PROT_READ, MAP_PRIVATE|MA
P_DENYWRITE, 3, 0) = 0xf7ce0000
mprotect(0xf7cf9000, 1814528, PROT_NONE) = 0
mmap2(0xf7cf9000, 1359872, PROT_READ|PROT_EXEC
```

```
, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x19
000) = 0xf7cf9000
mmap2(0xf7e45000, 450560, PROT_READ, MAP_PRIVA
TE|MAP_FIXED|MAP_DENYWRITE, 3, 0x165000) = 0xf
7e45000
mmap2(0xf7eb4000, 12288, PROT_READ|PROT_WRITE,
 MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1d3
000) = 0xf7eb4000
mmap2(0xf7eb7000, 10784, PROT_READ|PROT_WRITE,
 MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) =
 0xf7eb7000
close(3)                                = 0
set_thread_area({entry_number=-1, base_addr=0x
f7ef10c0, limit=0x0fffff, seg_32bit=1, content
s=0, read_exec_only=0, limit_in_pages=1, seg_n
ot_present=0, useable=1}) = 0 (entry_number=12
)
mprotect(0xf7eb4000, 8192, PROT_READ)   = 0
mprotect(0x5664d000, 4096, PROT_READ)   = 0
mprotect(0xf7f1e000, 4096, PROT_READ)   = 0
munmap(0xf7eba000, 220471)              = 0
fstat64(1, {st_mode=S_IFCHR|0620, st_rdev=make
dev(0x88, 0x2), ...}) = 0
brk(NULL)                               = 0x56
f14000
brk(0x56f35000)                         = 0x56
f35000
brk(0x56f36000)                         = 0x56
f36000
write(1, "\n", 1
)                       = 1
write(1, "[+] No flag for you. [+]\n", 25[+] N
```

```
o flag for you. [+]
) = 25
exit_group(26)                          = ?
+++ exited with 26 +++
```

To get a better understanding, we can use ltrace to trace the library calls made by demangling C++ function names. We can see there is a string length check being done.

```
# ltrace -i -C ./nix_5744af788e6cbdb29bb41e8b0
e5f3cd5 aaaaaaaa
[0x565570e1] __libc_start_main(0x565571e9, 2,
 0xffe3a584, 0x56557400 <unfinished ...>
[0x56557249] strlen("aaaaaaaa")

                            = 8
[0x565572ca] puts("\n[+] No flag for you. [+]"
[+] No flag for you. [+]
)
                            = 26
[0xffffffffffffffff] +++ exited (status 26) ++
+
```

Disassembling the Text Section

Let's have a look at the .text section's disassembly and try to understand. In this binary the symbols are not stripped so we can

see the function names which makes it easier to understand. If you can read assembly by now you will have figure out what is happening. If not let's do some live debugging and try to understand better.

```
root@Omega:/mnt/hgfs/shared/Linux RE# objdump
-D -M intel -j .text nix_5744af788e6cbdb29bb41
e8b0e5f3cd5

nix_5744af788e6cbdb29bb41e8b0e5f3cd5:     file
 format elf32-i386


Disassembly of section .text:

000010b0 <_start>:
    10b0:       31 ed                   xor
 ebp,ebp
    10b2:       5e                      pop
 esi
    10b3:       89 e1                   mov
 ecx,esp
    10b5:       83 e4 f0                and
 esp,0xfffffff0
    10b8:       50                      push
 eax
    10b9:       54                      push
 esp
    10ba:       52                      push
 edx
    10bb:       e8 22 00 00 00          call
```

```
10e2 <_start+0x32>
   10c0:       81 c3 40 2f 00 00       add
ebx,0x2f40
   10c6:       8d 83 60 d4 ff ff       lea
eax,[ebx-0x2ba0]
   10cc:       50                      push
eax
   10cd:       8d 83 00 d4 ff ff       lea
eax,[ebx-0x2c00]
   10d3:       50                      push
eax
   10d4:       51                      push
ecx
   10d5:       56                      push
esi
   10d6:       ff b3 f8 ff ff ff       push
DWORD PTR [ebx-0x8]
   10dc:       e8 9f ff ff ff          call
1080 <__libc_start_main@plt>
   10e1:       f4                      hlt

   10e2:       8b 1c 24                mov
ebx,DWORD PTR [esp]
   10e5:       c3                      ret

   10e6:       66 90                   xchg
ax,ax
   10e8:       66 90                   xchg
ax,ax
   10ea:       66 90                   xchg
ax,ax
   10ec:       66 90                   xchg
```

```
 ax,ax
    10ee:       66 90                   xchg
 ax,ax

... Output Omitted ...

000011e9 <main>:
    11e9:       8d 4c 24 04             lea
 ecx,[esp+0x4]
    11ed:       83 e4 f0                and
 esp,0xfffffff0
    11f0:       ff 71 fc                push
 DWORD PTR [ecx-0x4]
    11f3:       55                      push
 ebp
    11f4:       89 e5                   mov
 ebp,esp
    11f6:       56                      push
 esi
    11f7:       53                      push
 ebx
    11f8:       51                      push
 ecx
    11f9:       83 ec 1c                sub
 esp,0x1c
    11fc:       e8 ef fe ff ff          call
 10f0 <__x86.get_pc_thunk.bx>
    1201:       81 c3 ff 2d 00 00       add
 ebx,0x2dff
    1207:       89 ce                   mov
 esi,ecx
    1209:       c7 45 e4 00 00 00 00    mov
```

```
DWORD PTR [ebp-0x1c],0x0
   1210:       c7 45 dc 07 00 00 00    mov
DWORD PTR [ebp-0x24],0x7
   1217:       83 3e 02                cmp
DWORD PTR [esi],0x2
   121a:       74 1c                   je
1238 <main+0x4f>
   121c:       83 ec 0c                sub
esp,0xc
   121f:       8d 83 08 e0 ff ff       lea
eax,[ebx-0x1ff8]
   1225:       50                      push
eax
   1226:       e8 15 fe ff ff          call
1040 <printf@plt>
   122b:       83 c4 10                add
esp,0x10
   122e:       83 ec 0c                sub
esp,0xc
   1231:       6a 01                   push
0x1
   1233:       e8 28 fe ff ff          call
1060 <exit@plt>
   1238:       8b 46 04                mov
eax,DWORD PTR [esi+0x4]
   123b:       83 c0 04                add
eax,0x4
   123e:       8b 00                   mov
eax,DWORD PTR [eax]
   1240:       83 ec 0c                sub
esp,0xc
   1243:       50                      push
```

```
eax
   1244:       e8 27 fe ff ff          call
1070 <strlen@plt>
   1249:       83 c4 10                add
esp,0x10
   124c:       83 f8 0f                cmp
eax,0xf
   124f:       76 1c                   jbe
126d <main+0x84>
   1251:       83 ec 0c                sub
esp,0xc
   1254:       8d 83 20 e0 ff ff       lea
eax,[ebx-0x1fe0]
   125a:       50                      push
eax
   125b:       e8 f0 fd ff ff          call
1050 <puts@plt>
   1260:       83 c4 10                add
esp,0x10
   1263:       83 ec 0c                sub
esp,0xc
   1266:       6a 01                   push
0x1
   1268:       e8 f3 fd ff ff          call
1060 <exit@plt>
   126d:       c7 45 e0 00 00 00 00    mov
DWORD PTR [ebp-0x20],0x0
   1274:       eb 1a                   jmp
1290 <main+0xa7>
   1276:       8b 46 04                mov
eax,DWORD PTR [esi+0x4]
   1279:       83 c0 04                add
```

```
eax,0x4
   127c:       8b 10                   mov
edx,DWORD PTR [eax]
   127e:       8b 45 e0                mov
eax,DWORD PTR [ebp-0x20]
   1281:       01 d0                   add
eax,edx
   1283:       0f b6 00                movzx
eax,BYTE PTR [eax]
   1286:       0f be c0                movsx
eax,al
   1289:       01 45 e4                add
DWORD PTR [ebp-0x1c],eax
   128c:       83 45 e0 01             add
DWORD PTR [ebp-0x20],0x1
   1290:       8b 45 e0                mov
eax,DWORD PTR [ebp-0x20]
   1293:       3b 45 dc                cmp
eax,DWORD PTR [ebp-0x24]
   1296:       7c de                   jl
1276 <main+0x8d>
   1298:       81 7d e4 21 03 00 00    cmp
DWORD PTR [ebp-0x1c],0x321
   129f:       75 1a                   jne
12bb <main+0xd2>
   12a1:       e8 33 00 00 00          call
12d9 <comp_key>
   12a6:       83 ec 08                sub
esp,0x8
   12a9:       50                      push
eax
   12aa:       8d 83 3c e0 ff ff       lea
```

```
eax,[ebx-0x1fc4]
   12b0:       50                      push
eax
   12b1:       e8 8a fd ff ff          call
1040 <printf@plt>
   12b6:       83 c4 10                add
esp,0x10
   12b9:       eb 12                   jmp
12cd <main+0xe4>
   12bb:       83 ec 0c                sub
esp,0xc
   12be:       8d 83 5e e0 ff ff       lea
eax,[ebx-0x1fa2]
   12c4:       50                      push
eax
   12c5:       e8 86 fd ff ff          call
1050 <puts@plt>
   12ca:       83 c4 10                add
esp,0x10
   12cd:       90                      nop
   12ce:       8d 65 f4                lea
esp,[ebp-0xc]
   12d1:       59                      pop
ecx
   12d2:       5b                      pop
ebx
   12d3:       5e                      pop
esi
   12d4:       5d                      pop
ebp
   12d5:       8d 61 fc                lea
esp,[ecx-0x4]
```

```
    12d8:       c3                      ret


000012d9 <comp_key>:
    12d9:       55                      push
 ebp
    12da:       89 e5                   mov
 ebp,esp
    12dc:       57                      push
 edi
    12dd:       56                      push
 esi
    12de:       53                      push
 ebx
    12df:       83 ec 7c                sub
 esp,0x7c
    12e2:       e8 09 fe ff ff          call
 10f0 <__x86.get_pc_thunk.bx>
    12e7:       81 c3 19 2d 00 00       add
 ebx,0x2d19
    12ed:       c7 45 e4 00 00 00 00    mov
 DWORD PTR [ebp-0x1c],0x0
    12f4:       c7 45 a8 4c 00 00 00    mov
 DWORD PTR [ebp-0x58],0x4c
    12fb:       c7 45 ac 33 00 00 00    mov
 DWORD PTR [ebp-0x54],0x33
    1302:       c7 45 b0 74 00 00 00    mov
 DWORD PTR [ebp-0x50],0x74
    1309:       c7 45 b4 73 00 00 00    mov
 DWORD PTR [ebp-0x4c],0x73
    1310:       c7 45 b8 5f 00 00 00    mov
 DWORD PTR [ebp-0x48],0x5f
```

```
   1317:       c7 45 bc 67 00 00 00    mov
DWORD PTR [ebp-0x44],0x67
   131e:       c7 45 c0 33 00 00 00    mov
DWORD PTR [ebp-0x40],0x33
   1325:       c7 45 c4 74 00 00 00    mov
DWORD PTR [ebp-0x3c],0x74
   132c:       c7 45 c8 5f 00 00 00    mov
DWORD PTR [ebp-0x38],0x5f
   1333:       c7 45 cc 69 00 00 00    mov
DWORD PTR [ebp-0x34],0x69
   133a:       c7 45 d0 6e 00 00 00    mov
DWORD PTR [ebp-0x30],0x6e
   1341:       c7 45 d4 32 00 00 00    mov
DWORD PTR [ebp-0x2c],0x32
   1348:       c7 45 d8 5f 00 00 00    mov
DWORD PTR [ebp-0x28],0x5f
   134f:       c7 45 dc 52 00 00 00    mov
DWORD PTR [ebp-0x24],0x52
   1356:       c7 45 e0 33 00 00 00    mov
DWORD PTR [ebp-0x20],0x33
   135d:       8b 55 e0                mov
edx,DWORD PTR [ebp-0x20]
   1360:       8b 75 dc                mov
esi,DWORD PTR [ebp-0x24]
   1363:       8b 45 d8                mov
eax,DWORD PTR [ebp-0x28]
   1366:       89 45 a4                mov
DWORD PTR [ebp-0x5c],eax
   1369:       8b 4d d4                mov
ecx,DWORD PTR [ebp-0x2c]
   136c:       89 4d a0                mov
DWORD PTR [ebp-0x60],ecx
```

```
   136f:       8b 7d d0                mov
edi,DWORD PTR [ebp-0x30]
   1372:       89 7d 9c                mov
DWORD PTR [ebp-0x64],edi
   1375:       8b 45 cc                mov
eax,DWORD PTR [ebp-0x34]
   1378:       89 45 98                mov
DWORD PTR [ebp-0x68],eax
   137b:       8b 4d c8                mov
ecx,DWORD PTR [ebp-0x38]
   137e:       89 4d 94                mov
DWORD PTR [ebp-0x6c],ecx
   1381:       8b 7d c4                mov
edi,DWORD PTR [ebp-0x3c]
   1384:       89 7d 90                mov
DWORD PTR [ebp-0x70],edi
   1387:       8b 45 c0                mov
eax,DWORD PTR [ebp-0x40]
   138a:       89 45 8c                mov
DWORD PTR [ebp-0x74],eax
   138d:       8b 4d bc                mov
ecx,DWORD PTR [ebp-0x44]
   1390:       89 4d 88                mov
DWORD PTR [ebp-0x78],ecx
   1393:       8b 7d b8                mov
edi,DWORD PTR [ebp-0x48]
   1396:       89 7d 84                mov
DWORD PTR [ebp-0x7c],edi
   1399:       8b 45 b4                mov
eax,DWORD PTR [ebp-0x4c]
   139c:       89 45 80                mov
DWORD PTR [ebp-0x80],eax
```

```
   139f:       8b 7d b0                mov
edi,DWORD PTR [ebp-0x50]
   13a2:       8b 4d ac                mov
ecx,DWORD PTR [ebp-0x54]
   13a5:       8b 45 a8                mov
eax,DWORD PTR [ebp-0x58]
   13a8:       83 ec 0c                sub
esp,0xc
   13ab:       52                      push
edx
   13ac:       56                      push
esi
   13ad:       ff 75 a4                push
DWORD PTR [ebp-0x5c]
   13b0:       ff 75 a0                push
DWORD PTR [ebp-0x60]
   13b3:       ff 75 9c                push
DWORD PTR [ebp-0x64]
   13b6:       ff 75 98                push
DWORD PTR [ebp-0x68]
   13b9:       ff 75 94                push
DWORD PTR [ebp-0x6c]
   13bc:       ff 75 90                push
DWORD PTR [ebp-0x70]
   13bf:       ff 75 8c                push
DWORD PTR [ebp-0x74]
   13c2:       ff 75 88                push
DWORD PTR [ebp-0x78]
   13c5:       ff 75 84                push
DWORD PTR [ebp-0x7c]
   13c8:       ff 75 80                push
DWORD PTR [ebp-0x80]
```

```
   13cb:       57                      push
edi
   13cc:       51                      push
ecx
   13cd:       50                      push
eax
   13ce:       8d 83 78 e0 ff ff       lea
eax,[ebx-0x1f88]
   13d4:       50                      push
eax
   13d5:       8d 83 30 00 00 00       lea
eax,[ebx+0x30]
   13db:       50                      push
eax
   13dc:       e8 af fc ff ff          call
1090 <sprintf@plt>
   13e1:       83 c4 50                add
esp,0x50
   13e4:       8d 83 30 00 00 00       lea
eax,[ebx+0x30]
   13ea:       8d 65 f4                lea
esp,[ebp-0xc]
   13ed:       5b                      pop
ebx
   13ee:       5e                      pop
esi
   13ef:       5f                      pop
edi
   13f0:       5d                      pop
ebp
   13f1:       c3                      ret
```

```
    13f2:       66 90                   xchg
 ax,ax
    13f4:       66 90                   xchg
 ax,ax
    13f6:       66 90                   xchg
 ax,ax
    13f8:       66 90                   xchg
 ax,ax
    13fa:       66 90                   xchg
 ax,ax
    13fc:       66 90                   xchg
 ax,ax
    13fe:       66 90                   xchg
 ax,ax

... Output Omitted ...
```

Debugging Live

I will use GDB-Peda for this which makes it easier to understand. Let's first check the functions in the binary. We can see functions such as `main, comp_key`

```
gdb-peda$ info functions
All defined functions:

Non-debugging symbols:
0x00001000  _init
0x00001040  printf@plt
```

```
0x00001050  puts@plt
0x00001060  exit@plt
0x00001070  strlen@plt
0x00001080  __libc_start_main@plt
0x00001090  sprintf@plt
0x000010a0  __cxa_finalize@plt
0x000010a8  __gmon_start__@plt
0x000010b0  _start
0x000010f0  __x86.get_pc_thunk.bx
0x00001100  deregister_tm_clones
0x00001140  register_tm_clones
0x00001190  __do_global_dtors_aux
0x000011e0  frame_dummy
0x000011e5  __x86.get_pc_thunk.dx
0x000011e9  main
0x000012d9  comp_key
0x00001400  __libc_csu_init
0x00001460  __libc_csu_fini
0x00001464  _fini
```

This is how you debug a program. We will hit a break point at the main function. Use `n` to step and `ni` to step each instruction. If you don't know assembly, in a basic challenge like this, look for jumps, compare instructions. Try to understand what check the program does and build the logic in your mind. There are many good crash courses on assembly and I would recommend reading few.

```
gdb-peda$ break main
Breakpoint 1 at 0x11f9
gdb-peda$ run aaaaaaaa
```

```
Starting program: /mnt/hgfs/shared/Linux RE/ni
x_5744af788e6cbdb29bb41e8b0e5f3cd5 aaaaaaaa

[----------------------------------registers--
--------------------------------]
EAX: 0xf7f95dd8 --> 0xffffd2f0 --> 0xffffd4d1
("NVM_DIR=/root/.nvm")
EBX: 0x0
ECX: 0xffffd250 --> 0x2
EDX: 0xffffd274 --> 0x0
ESI: 0xf7f94000 --> 0x1d5d8c
EDI: 0x0
EBP: 0xffffd238 --> 0x0
ESP: 0xffffd22c --> 0xffffd250 --> 0x2
EIP: 0x565561f9 (<main+16>:     sub    esp,0x1
c)
EFLAGS: 0x282 (carry parity adjust zero SIGN t
rap INTERRUPT direction overflow)
[-----------------------------------code-----
--------------------------------]
   0x565561f6 <main+13>:        push   esi
   0x565561f7 <main+14>:        push   ebx
   0x565561f8 <main+15>:        push   ecx
=> 0x565561f9 <main+16>:        sub    esp,0x1
c
   0x565561fc <main+19>:        call   0x56556
0f0 <__x86.get_pc_thunk.bx>
   0x56556201 <main+24>:        add    ebx,0x2
dff
   0x56556207 <main+30>:        mov    esi,ecx
   0x56556209 <main+32>:        mov    DWORD P
TR [ebp-0x1c],0x0
```

```
[-----------------------------------stack-----
----------------------------------]
0000| 0xffffd22c --> 0xffffd250 --> 0x2
0004| 0xffffd230 --> 0x0
0008| 0xffffd234 --> 0xf7f94000 --> 0x1d5d8c
0012| 0xffffd238 --> 0x0
0016| 0xffffd23c --> 0xf7dd79a1 (<__libc_start
_main+241>:     add    esp,0x10)
0020| 0xffffd240 --> 0xf7f94000 --> 0x1d5d8c
0024| 0xffffd244 --> 0xf7f94000 --> 0x1d5d8c
0028| 0xffffd248 --> 0x0
[-----------------------------------------------
----------------------------------]
Legend: code, data, rodata, value

Breakpoint 1, 0x565561f9 in main ()
1: main = {<text variable, no debug info>} 0x5
65561e9 <main>
2: puts = {<text variable, no debug info>} 0xf
7e25e40 <puts>
gdb-peda$
```

If you play with gdb for a little you realize how it works. Let's try to understand the logic part by part.

The program first tries to compare the number of arguments. It's stored in ecx register and moved to esi and it's used to compare the value with 0x2. You can use gdb to go through the assembly instructions and understand better.

```
   0x56556207 <+30>:    mov    esi,ecx
   0x56556209 <+32>:    mov    DWORD PTR [ebp-
0x1c],0x0
   0x56556210 <+39>:    mov    DWORD PTR [ebp-
0x24],0x7
   0x56556217 <+46>:    cmp    DWORD PTR [esi]
,0x2
   0x5655621a <+49>:    je     0x56556238 <mai
n+79>
   0x5655621c <+51>:    sub    esp,0xc
   0x5655621f <+54>:    lea    eax,[ebx-0x1ff8
]
   0x56556225 <+60>:    push   eax
   0x56556226 <+61>:    call   0x56556040 <pri
ntf@plt>
   0x5655622b <+66>:    add    esp,0x10
   0x5655622e <+69>:    sub    esp,0xc
   0x56556231 <+72>:    push   0x1
   0x56556233 <+74>:    call   0x56556060 <exi
t@plt>
```

We can write pseudo code like this.

```
1  if(argc != 2) {
2     printf("Usage: script.exe <key>");
3     exit(1);
4  }
```

```
   0x56556238 <+79>:    mov    eax,DWORD PTR [
esi+0x4]
   0x5655623b <+82>:    add    eax,0x4
   0x5655623e <+85>:    mov    eax,DWORD PTR [
```

```
eax]
   0x56556240 <+87>:    sub    esp,0xc
   0x56556243 <+90>:    push   eax
   0x56556244 <+91>:    call   0x56556070 <str
len@plt>
   0x56556249 <+96>:    add    esp,0x10
   0x5655624c <+99>:    cmp    eax,0xf
   0x5655624f <+102>:   jbe    0x5655626d <mai
n+132>
   0x56556251 <+104>:   sub    esp,0xc
   0x56556254 <+107>:   lea    eax,[ebx-0x1fe0
]
   0x5655625a <+113>:   push   eax
   0x5655625b <+114>:   call   0x56556050 <put
s@plt>
   0x56556260 <+119>:   add    esp,0x10
   0x56556263 <+122>:   sub    esp,0xc
   0x56556266 <+125>:   push   0x1
   0x56556268 <+127>:   call   0x56556060 <exi
t@plt>
```

After translating:

```
1  if(strlen(argv[1]) > 15) {
2      puts("Length of argv[1] too long.");
3      exit(1);
4  }
```

If you check this code we can see there is a loop going through iterating each character of our supplied string.

```
   0x5655626d <+132>:   mov    DWORD PTR [ebp-
0x20],0x0
   0x56556274 <+139>:   jmp    0x56556290 <mai
n+167>
   0x56556276 <+141>:   mov    eax,DWORD PTR [
esi+0x4]
   0x56556279 <+144>:   add    eax,0x4
   0x5655627c <+147>:   mov    edx,DWORD PTR [
eax]
   0x5655627e <+149>:   mov    eax,DWORD PTR [
ebp-0x20]
   0x56556281 <+152>:   add    eax,edx
   0x56556283 <+154>:   movzx  eax,BYTE PTR [e
ax]
   0x56556286 <+157>:   movsx  eax,al
   0x56556289 <+160>:   add    DWORD PTR [ebp-
0x1c],eax
   0x5655628c <+163>:   add    DWORD PTR [ebp-
0x20],0x1
   0x56556290 <+167>:   mov    eax,DWORD PTR [
ebp-0x20]
   0x56556293 <+170>:   cmp    eax,DWORD PTR [
ebp-0x24]
   0x56556296 <+173>:   jl     0x56556276 <mai
n+141>
   0x56556298 <+175>:   cmp    DWORD PTR [ebp-
0x1c],0x321
   0x5655629f <+182>:   jne    0x565562bb <mai
n+210>
   0x565562a1 <+184>:   call   0x565562d9 <com
p_key>
```

```
   0x565562a6 <+189>:   sub    esp,0x8
   0x565562a9 <+192>:   push   eax
   0x565562aa <+193>:   lea    eax,[ebx-0x1fc4
]
   0x565562b0 <+199>:   push   eax
   0x565562b1 <+200>:   call   0x56556040 <pri
ntf@plt>
   0x565562b6 <+205>:   add    esp,0x10
   0x565562b9 <+208>:   jmp    0x565562cd <mai
n+228>
   0x565562bb <+210>:   sub    esp,0xc
   0x565562be <+213>:   lea    eax,[ebx-0x1fa2
]
   0x565562c4 <+219>:   push   eax
   0x565562c5 <+220>:   call   0x56556050 <put
s@plt>
   0x565562ca <+225>:   add    esp,0x10
   0x565562cd <+228>:   nop
   0x565562ce <+229>:   lea    esp,[ebp-0xc]
   0x565562d1 <+232>:   pop    ecx
   0x565562d2 <+233>:   pop    ebx
   0x565562d3 <+234>:   pop    esi
   0x565562d4 <+235>:   pop    ebp
   0x565562d5 <+236>:   lea    esp,[ecx-0x4]
   0x565562d8 <+239>:   ret
```

Up to how many characters does it loop? Here's how I found it. Basically, our password must be of 7 characters in length.

```
[----------------------------------registers--
--------------------------------]
```

```
EAX: 0x6
EBX: 0x56559000 --> 0x3efc
ECX: 0x6
EDX: 0xffffd4c6 ("1234567890")
ESI: 0xffffd250 --> 0x2
EDI: 0x0
EBP: 0xffffd238 --> 0x0
ESP: 0xffffd210 --> 0xf7f943fc --> 0xf7f95200
--> 0x0
EIP: 0x56556293 (<main+170>:    cmp    eax,DWO
RD PTR [ebp-0x24])
EFLAGS: 0x206 (carry PARITY adjust zero sign t
rap INTERRUPT direction overflow)
[-------------------------------------code----
---------------------------------]
   0x56556289 <main+160>:       add    DWORD P
TR [ebp-0x1c],eax
   0x5655628c <main+163>:       add    DWORD P
TR [ebp-0x20],0x1
   0x56556290 <main+167>:       mov    eax,DWO
RD PTR [ebp-0x20]
=> 0x56556293 <main+170>:       cmp    eax,DWO
RD PTR [ebp-0x24]
   0x56556296 <main+173>:       jl     0x56556
276 <main+141>
   0x56556298 <main+175>:       cmp    DWORD P
TR [ebp-0x1c],0x321
   0x5655629f <main+182>:       jne    0x56556
2bb <main+210>
   0x565562a1 <main+184>:       call   0x56556
2d9 <comp_key>
[-------------------------------------stack----
```

```
--------------------------------]
0000| 0xffffd210 --> 0xf7f943fc --> 0xf7f95200
 --> 0x0
0004| 0xffffd214 --> 0x7
0008| 0xffffd218 --> 0x6
0012| 0xffffd21c --> 0x135
0016| 0xffffd220 --> 0x2
0020| 0xffffd224 --> 0xffffd2e4 --> 0xffffd487
 ("/mnt/hgfs/shared/Linux RE/nix_5744af788e6cb
db29bb41e8b0e5f3cd5")
0024| 0xffffd228 --> 0xffffd2f0 --> 0xffffd4d1
 ("NVM_DIR=/root/.nvm")
0028| 0xffffd22c --> 0xffffd250 --> 0x2
[-----------------------------------------
--------------------------------]
Legend: code, data, rodata, value
0x56556293 in main ()
gdb-peda$ print $ebp-0x24
$24 = (void *) 0xffffd214
gdb-peda$ x/x 0xffffd214
0xffffd214:     0x00000007
```

After translating to high-level code, it would look something similar to this.

```
1  for (i = 0; i < 7; i++) value += argv[1][i];
2  if (value != 801) return puts("\n[+] No flag
3  return printf("[+] The flag is: SAYCURE{%s}
```

Basically, the sum of each byte of our password must be equal to 801. Givens us 7 characters, we can sum up like this. You can use any calculation which sums up to 801. After this check is done it

calls the comp_key function and prints out the flag. We don't really need to dig the com_key function as it directly gives us the flag.

```
114 * 6 + 117 = 801
```

Let's check those characters in the ASCII table. 114 is 'r' and 117 is 'u'.

```
Dec Hex    Dec Hex    Dec Hex  Dec Hex  Dec He
x  Dec Hex   Dec Hex   Dec Hex
  0 00 NUL  16 10 DLE  32 20    48 30 0  64 40
 @  80 50 P   96 60 `  112 70 p
  1 01 SOH  17 11 DC1  33 21 !  49 31 1  65 41
 A  81 51 Q   97 61 a  113 71 q
  2 02 STX  18 12 DC2  34 22 "  50 32 2  66 42
 B  82 52 R   98 62 b  114 72 r
  3 03 ETX  19 13 DC3  35 23 #  51 33 3  67 43
 C  83 53 S   99 63 c  115 73 s
  4 04 EOT  20 14 DC4  36 24 $  52 34 4  68 44
 D  84 54 T  100 64 d  116 74 t
  5 05 ENQ  21 15 NAK  37 25 %  53 35 5  69 45
 E  85 55 U  101 65 e  117 75 u
  6 06 ACK  22 16 SYN  38 26 &  54 36 6  70 46
 F  86 56 V  102 66 f  118 76 v
  7 07 BEL  23 17 ETB  39 27 '  55 37 7  71 47
 G  87 57 W  103 67 g  119 77 w
  8 08 BS   24 18 CAN  40 28 (  56 38 8  72 48
 H  88 58 X  104 68 h  120 78 x
  9 09 HT   25 19 EM   41 29 )  57 39 9  73 49
 I  89 59 Y  105 69 i  121 79 y
 10 0A LF   26 1A SUB  42 2A *  58 3A :  74 4A
```

```
 J  90 5A Z  106 6A j  122 7A z
 11 0B VT   27 1B ESC  43 2B +  59 3B ;  75 4B
 K  91 5B [  107 6B k  123 7B {
 12 0C FF   28 1C FS   44 2C ,  60 3C <  76 4C
 L  92 5C \  108 6C l  124 7C |
 13 0D CR   29 1D GS   45 2D -  61 3D =  77 4D
 M  93 5D ]  109 6D m  125 7D }
 14 0E SO   30 1E RS   46 2E .  62 3E >  78 4E
 N  94 5E ^  110 6E n  126 7E ~
 15 0F SI   31 1F US   47 2F /  63 3F ?  79 4F
 O  95 5F _  111 6F o  127 7F DEL
```

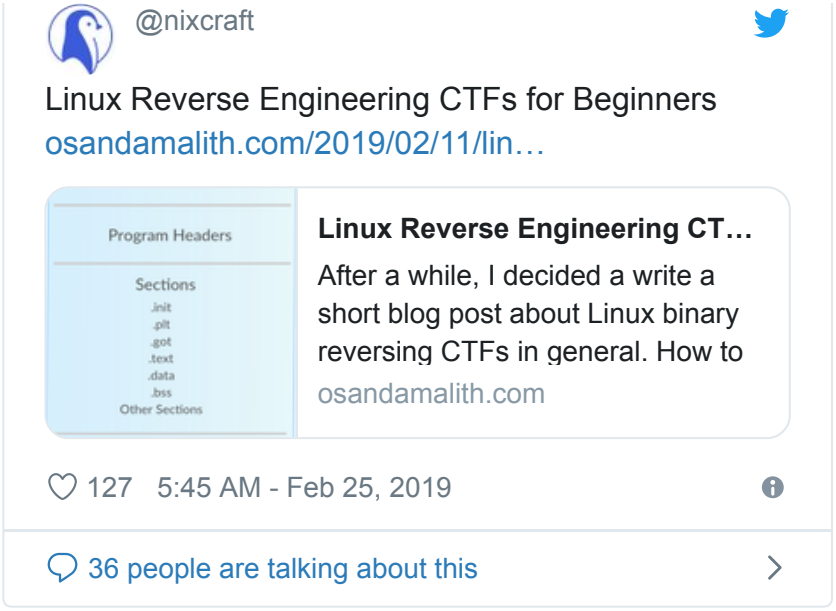
That's it! We just solved a very simple binary 🙂

```
# ./nix_5744af788e6cbdb29bb41e8b0e5f3cd5 rrrrr
ru
[+] The flag is: SAYCURE{L3ts_g3t_in2_R3} [+]
```

Check out my previous CTF solution posts here
Birthday Crackme/
Rootme No software breakpoints Cracking Challenge
Solving Root-me Ptrace challenge
https://asciinema.org/~Osanda

References

http://www.cirosantilli.com/elf-hello-world/



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Anon

Febru ary 14, 20 19

Can’t download the binary from link :- https://ufile.io/blvpm
Tried using wget & Firefox. Failed. Firefox just keeps on loading the page forever. wget just stands at Connecting to uploadfiles.io (uploadfiles.io)|218.248.255.164|:443…

Location: India
Date: 14 Feb

Reply

Osanda Malith Ja yathissa

Febr uary 14, 2019

Can you try on Chrome?

Reply

Rashi

February 14, 2019

Good Article.
a typo here,

114 * 6 + 177 = 801 should be 114 * 6 + 117 = 801

Reply

Osanda Malith Jayathissa

February 14, 2019

Yep Thanks 🙂

Reply

TheLearner

February 19, 2019

Thanks for the article! How did you get colorized, terminal output for readelf, ltrace/strace, and objdump?

Reply

CSS 🙂

Osanda Malith Jayathissa

Marc h 26, 201 9

Reply

Great article! The executable is not available for free anymore. Any chance you could make it available again please? 🙂

Phil

Marc h 26, 201 9

Reply

Thank you! Sorry mate, didn't see that.
Here you go:
https://drive.google.com/open?id=1ikHJC97UzG26nYV8Lay4zFR-5FXHJLk6

Osanda Malith Ja

yathissa

Reply

Marc
h 26, 201
9

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