KeyGen

Category: Reverse Engineering
Created: Mar 23, 2021 5:17 PM
Solved: Yes
Subjective Difficulty: 🔥🔥🔥🔥🔥

WriteUp:

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This was a challenge in the CSCG2021 Competition.

📜 Challenge Description:

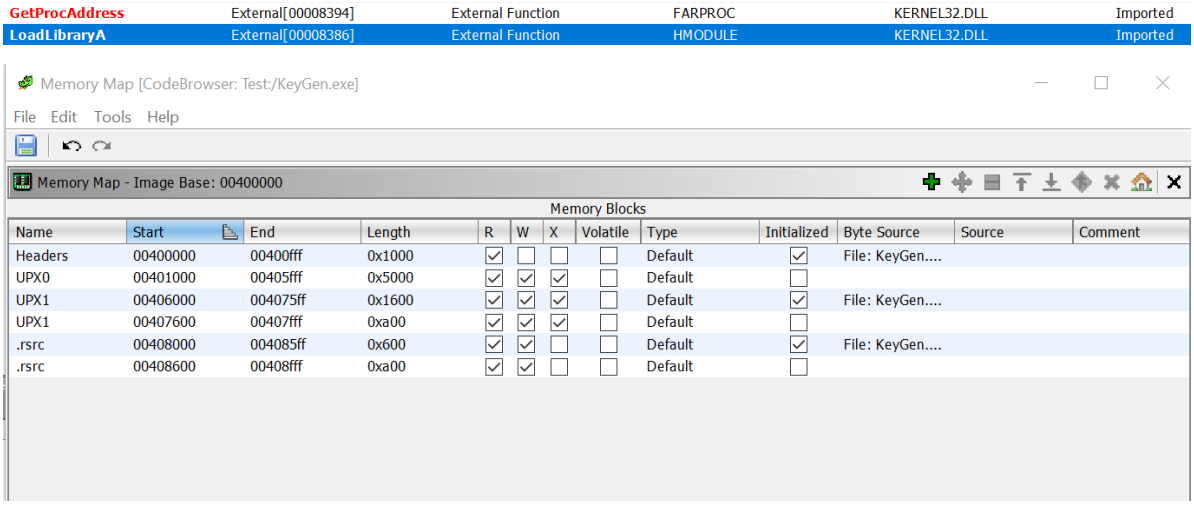
Do you remember these times, where Key Generators where a thing? Pls provide me a nice and oldschool Key Generator for the attached file and use the Service to test your KeyGenerator.

🔎 Research:

I first wanted to solve this challenge with `angr`, but as the input can be anything and we simply need the associated serial, this was a infinite possibility end. WE COULD set the name in stdin at angr and let the symbolic execution gives us the serial as well as WE COULD simply input the name and let an debugger automatically retrieve the serial in the process memory, but i wanted to practice my reverse engineering skills and with an own written algorithm the results are also faster.

I didn't googled some constants but if i did i would have found out that this algorithm actually implements the Mersenne Twister.

When analyzing the given binary we can see that it is packed with the UPX packer:



to decompress it we run this command:

```
upx -d -o KeyGenDecompressed.exe KeyGen.exe
```

Now we are ready to finally inspect the binary.

When running the program, it asks for a name and a serial-key. It looks like each name has a specific serial-key that we have to generate. When giving the wrong Serial, the program prints out `N0P3N0P3`. Okay, so lets dive deep into the assembler code.

Vulnerability Description:

As the given binary contains the algorithm to check for a valid serial, we can also use it to write a serial key generator. This is also the goal of this challenge.

Exploit Development:

So i simply started to read and translate the assembler line per line. You can see my notes further down in the *Notes* section. In the following i will explain the serial generation based on my own python implementation.

First, the name was repeatedly extended to fit whole `0x20` bytes.

```
class Name():
    def __init__(self, initial_name):
        self.name = self._extend_name(list(initial_name.encode("utf-8")))

    def _extend_name(self, name):
        rel = len(name)
        for i in range(len(name), 0x20):
            name.append(name[i-rel])
        return name
```

Second, the `name_key` is generated with the first `4` bytes of the name as a seed.

```
        def get_name_key(self):
                name_key = [] # starting at [esp+0x28]
                name_iv = self.name_iv
                for i in range(1, 0x270):
                    name_iv = ((name_iv>>0x1e) ^ name_iv) & 0xFFFFFFFF
                    name_iv = (name_iv * 0x6c078965) & 0xFFFFFFFF
                    name_iv += i
                    name_key.append(name_iv)
                return name_key

    def _hex(self, bytes_):
        return "".join([hex(i)[2:] for i in bytes_])

    @property
    def hex(self):
        return self._hex(self.name)

    @property
    def name_iv(self):
        return bitstring.BitArray(hex=self._hex(self.name[:4][-1::-1])).uint
```

Then, the name is scrambled based on the `name_key` .

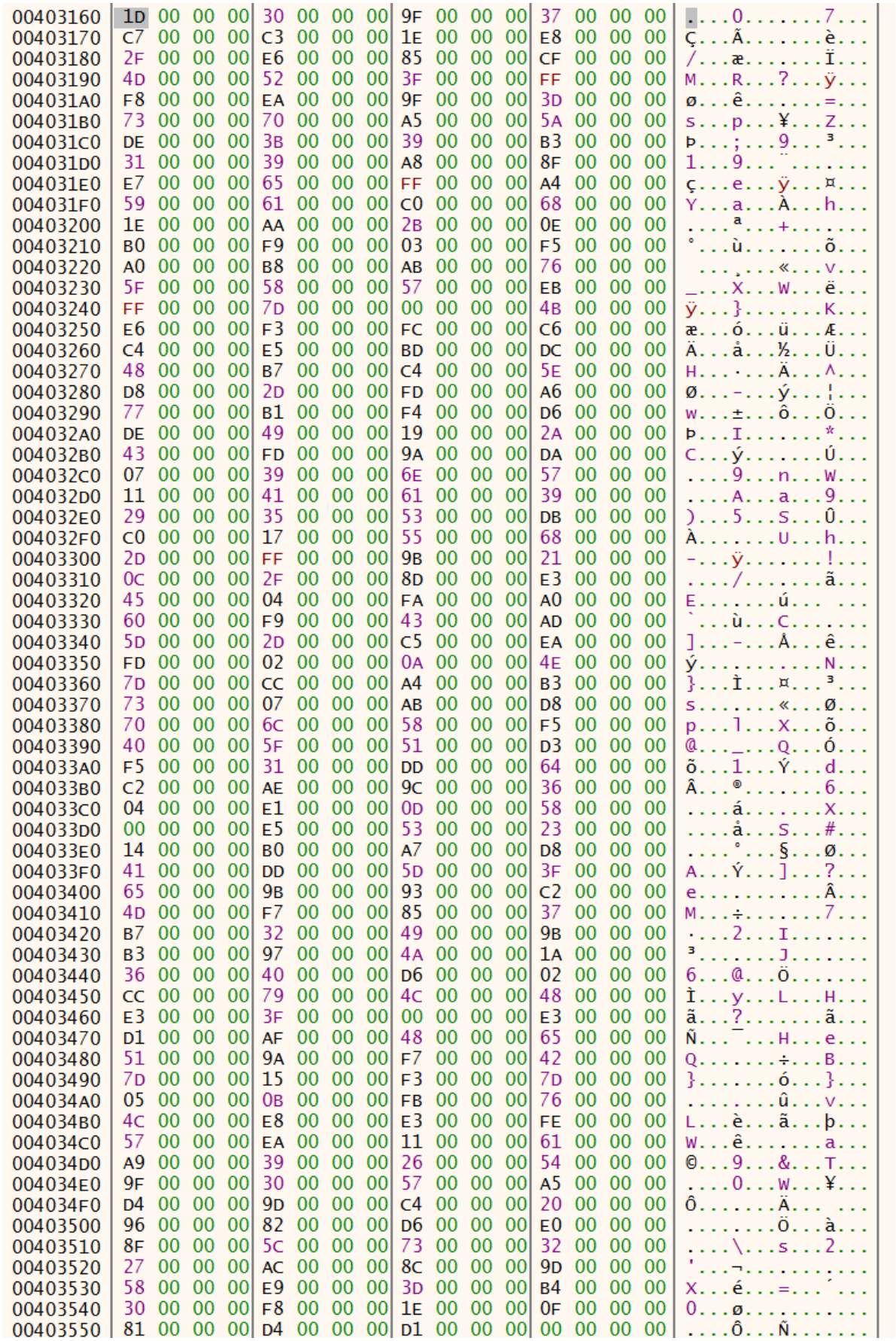
```
    def scramble_name(self, name_key, counter=0x270, nn=0xFFFFFFFF):
        for i in range(len(self.name)):
            name_key, eax = some_encryption(counter, nn, name_key, self.name_iv)
            index = eax % 0xff
            self.name[i] = self.name[i] ^ alphabet_table[index+1]
            counter += 1
```

The `some_encryption` fucntions looks like this:

```
def some_encryption(counter, nn, orig_name_key, name):
    if(counter==0x270):
        name_key = [name] + orig_name_key
        for i in range(counter):
            ecx = name_key[i] ^ name_key[i+1]
            ecx = ecx & 0x7fffffff
            ecx = ecx ^ name_key[i]
            eax = ecx
            b = bool(bitstring.BitArray(uint=eax, length=4*8)[-1])
            if(b):
                eax = 0x9908b0df
            else:
                eax = 0x0
            ecx = ecx>>0x1
            eax = eax ^ name_key[i+397]
            eax = eax ^ ecx
            name_key.append(eax)
        eax = counter
    elif(counter>=0x4e0): # DEAD CODE
        pass
    else:
        name_key = orig_name_key

    nc = name_key[counter] # edx -> 0x9bc -> start of new generated above
    return name_key, (((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) ^ ((((nc ^ (nn &
(nc >> 0xb)) & 0xFFFFFFFF) & 0xff3a58ad) << 0x7)) & 0xFFFFFFFF) ^ ((((nc ^ (nn &
(nc >> 0xb)) & 0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) &
0xff3a58ad) << 0x7)) & 0xFFFFFFFF) & 0xffffdf8c) << 0xF)) & 0xFFFFFFFF)>>0x12) ^
((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) &
0xFFFFFFFF) & 0xff3a58ad) << 0x7)) & 0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) &
0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) & 0xff3a58ad) << 0x7)) &
0xFFFFFFFF) & 0xffffdf8c) << 0xF)) & 0xFFFFFFFF)
```

On its first call (with counter set to `0x270`), the `name_key` will be doubled in size with values based on the initial `name_key`. After this and on every next call this function basically just takes the entry of `name_key` at index `counter`, and returns a value from a big calculation at the end. This value is then used in the `scramble_name` function to determine the entry of the `alphabet_table` with which the name is xored. The alphabet_table is a predefined table of characters with `0xff` entries. You can find it in the memory dump:



```
00403160 1D 00 00 00 30 00 00 00 9F 00 00 00 37 00 00 00 .....0.......7...
00403170 C7 00 00 00 C3 00 00 00 1E 00 00 00 E8 00 00 00 Ç...Ã.........è...
00403180 2F 00 00 00 E6 00 00 00 85 00 00 00 CF 00 00 00 /...æ.........Ï...
00403190 4D 00 00 00 52 00 00 00 3F 00 00 00 FF 00 00 00 M...R...?...ÿ...
004031A0 F8 00 00 00 EA 00 00 00 9F 00 00 00 3D 00 00 00 ø...ê.......=...
004031B0 73 00 00 00 70 00 00 00 A5 00 00 00 5A 00 00 00 s...p...¥...Z...
004031C0 DE 00 00 00 3B 00 00 00 39 00 00 00 B3 00 00 00 Þ...;...9...³...
004031D0 31 00 00 00 39 00 00 00 A8 00 00 00 8F 00 00 00 1...9...¨.......
004031E0 E7 00 00 00 65 00 00 00 FF 00 00 00 A4 00 00 00 ç...e...ÿ...¤...
004031F0 59 00 00 00 61 00 00 00 C0 00 00 00 68 00 00 00 Y...a...À...h...
00403200 1E 00 00 00 AA 00 00 00 2B 00 00 00 0E 00 00 00 ....ª...+.......
00403210 B0 00 00 00 F9 00 00 00 03 00 00 00 F5 00 00 00 °...ù.........õ...
00403220 A0 00 00 00 B8 00 00 00 AB 00 00 00 76 00 00 00  ...¸...«...v...
00403230 5F 00 00 00 58 00 00 00 57 00 00 00 EB 00 00 00 _...X...W...ë...
00403240 FF 00 00 00 7D 00 00 00 00 00 00 00 4B 00 00 00 ÿ...}.........K...
00403250 E6 00 00 00 F3 00 00 00 FC 00 00 00 C6 00 00 00 æ...ó...ü...Æ...
00403260 C4 00 00 00 E5 00 00 00 BD 00 00 00 DC 00 00 00 Ä...å...½...Ü...
00403270 48 00 00 00 B7 00 00 00 C4 00 00 00 5E 00 00 00 H...·...Ä...^...
00403280 D8 00 00 00 2D 00 00 00 FD 00 00 00 A6 00 00 00 Ø...-...ý...¦...
00403290 77 00 00 00 B1 00 00 00 F4 00 00 00 D6 00 00 00 w...±...ô...Ö...
004032A0 DE 00 00 00 49 00 00 00 19 00 00 00 2A 00 00 00 Þ...I.......*...
004032B0 43 00 00 00 FD 00 00 00 9A 00 00 00 DA 00 00 00 C...ý.........Ú...
004032C0 07 00 00 00 39 00 00 00 6E 00 00 00 57 00 00 00 ....9...n...W...
004032D0 11 00 00 00 41 00 00 00 61 00 00 00 39 00 00 00 ....A...a...9...
004032E0 29 00 00 00 35 00 00 00 53 00 00 00 DB 00 00 00 )...5...S...Û...
004032F0 C0 00 00 00 17 00 00 00 55 00 00 00 68 00 00 00 À.......U...h...
00403300 2D 00 00 00 FF 00 00 00 9B 00 00 00 21 00 00 00 -...ÿ.........!...
00403310 0C 00 00 00 2F 00 00 00 8D 00 00 00 E3 00 00 00 ..../.........ã...
00403320 45 00 00 00 04 00 00 00 FA 00 00 00 A0 00 00 00 E.......ú...  ...
00403330 60 00 00 00 F9 00 00 00 43 00 00 00 AD 00 00 00 `...ù...C.......
00403340 5D 00 00 00 2D 00 00 00 C5 00 00 00 EA 00 00 00 ]...-...Å...ê...
00403350 FD 00 00 00 02 00 00 00 0A 00 00 00 4E 00 00 00 ý...........N...
00403360 7D 00 00 00 CC 00 00 00 A4 00 00 00 B3 00 00 00 }...Ì...¤...³...
00403370 73 00 00 00 07 00 00 00 AB 00 00 00 D8 00 00 00 s.......«...Ø...
00403380 70 00 00 00 6C 00 00 00 58 00 00 00 F5 00 00 00 p...l...X...õ...
00403390 40 00 00 00 5F 00 00 00 51 00 00 00 D3 00 00 00 @..._...Q...Ó...
004033A0 F5 00 00 00 31 00 00 00 DD 00 00 00 64 00 00 00 õ...1...Ý...d...
004033B0 C2 00 00 00 AE 00 00 00 9C 00 00 00 36 00 00 00 Â...®.......6...
004033C0 04 00 00 00 E1 00 00 00 0D 00 00 00 58 00 00 00 ....á.........X...
004033D0 00 00 00 00 E5 00 00 00 53 00 00 00 23 00 00 00 ....å...S...#...
004033E0 14 00 00 00 B0 00 00 00 A7 00 00 00 D8 00 00 00 ....°...§...Ø...
004033F0 41 00 00 00 DD 00 00 00 5D 00 00 00 3F 00 00 00 A...Ý...]...?...
00403400 65 00 00 00 9B 00 00 00 93 00 00 00 C2 00 00 00 e...........Â...
00403410 4D 00 00 00 F7 00 00 00 85 00 00 00 37 00 00 00 M...÷.......7...
00403420 B7 00 00 00 32 00 00 00 49 00 00 00 9B 00 00 00 ·...2...I.......
00403430 B3 00 00 00 97 00 00 00 4A 00 00 00 1A 00 00 00 ³.......J.......
00403440 36 00 00 00 40 00 00 00 D6 00 00 00 02 00 00 00 6...@...Ö.......
00403450 CC 00 00 00 79 00 00 00 4C 00 00 00 48 00 00 00 Ì...y...L...H...
00403460 E3 00 00 00 3F 00 00 00 00 00 00 00 E3 00 00 00 ã...?.......ã...
00403470 D1 00 00 00 AF 00 00 00 48 00 00 00 65 00 00 00 Ñ...¯...H...e...
00403480 51 00 00 00 9A 00 00 00 F7 00 00 00 42 00 00 00 Q.......÷...B...
00403490 7D 00 00 00 15 00 00 00 F3 00 00 00 7D 00 00 00 }.......ó...}...
004034A0 05 00 00 00 0B 00 00 00 FB 00 00 00 76 00 00 00 ........û...v...
004034B0 4C 00 00 00 E8 00 00 00 E3 00 00 00 FE 00 00 00 L...è...ã...þ...
004034C0 57 00 00 00 EA 00 00 00 11 00 00 00 61 00 00 00 W...ê.......a...
004034D0 A9 00 00 00 39 00 00 00 26 00 00 00 54 00 00 00 ©...9...&...T...
004034E0 9F 00 00 00 30 00 00 00 57 00 00 00 A5 00 00 00 ....0...W...¥...
004034F0 D4 00 00 00 9D 00 00 00 C4 00 00 00 20 00 00 00 Ô.......Ä...  ...
00403500 96 00 00 00 82 00 00 00 D6 00 00 00 E0 00 00 00 ........Ö...à...
00403510 8F 00 00 00 5C 00 00 00 73 00 00 00 32 00 00 00 ....\...s...2...
00403520 27 00 00 00 AC 00 00 00 8C 00 00 00 9D 00 00 00 '...¬.........
00403530 58 00 00 00 E9 00 00 00 3D 00 00 00 B4 00 00 00 X...é...=...´...
00403540 30 00 00 00 F8 00 00 00 1E 00 00 00 0F 00 00 00 0...ø.........
00403550 81 00 00 00 D4 00 00 00 D1 00 00 00 00 00 00 00 ....Ô...Ñ.......
```

I converted these entries to a list and stored it as a variable in my python script:

```
alphabet_table = [0x00, 0x1d, 0x30, 0x9f, 0x37, 0xc7,  0xc3, 0x1e, 0xe8, 0x2f,
0xe6, 0x85, 0xcf, 0x4d, 0x52, 0x3f, 0xff, 0xf8, 0xea, 0x9f, 0x3d, 0x73, 0x70,
0xa5, 0x5a, 0xde, 0x3b, 0x39, 0xb3, 0x31, 0x39, 0xa8, 0x8f, 0xe7, 0x65, 0xff,
0xa4, 0x59, 0x61, 0xc0,  0x68, 0x1e, 0xaa, 0x2b, 0x0e, 0xb0, 0xf9,  0x03, 0xf5,
0xa0, 0xb8, 0xab, 0x76, 0x5f, 0x58, 0x57, 0xeb, 0xff, 0x7d, 0x00, 0x4b, 0xe6,
0xf3, 0xfc, 0xc6, 0xc4, 0xe5, 0xbd, 0xdc, 0x48, 0xb7, 0xc4, 0x5e, 0xd8, 0x2d,
0xfd, 0xa6, 0x77, 0xb1, 0xf4, 0xd6, 0xde, 0x49, 0x19, 0x2a, 0x43, 0xfd, 0x9a,
0xda, 0x07, 0x39, 0x6e, 0x57, 0x11, 0x41, 0x61, 0x39, 0x29, 0x35, 0x53, 0xdb,
0xc0, 0x17, 0x55, 0x68, 0x2d,  0xff, 0x9b, 0x21, 0x0c, 0x2f, 0x8d, 0xe3, 0x45,
0x04, 0xfa, 0xa0, 0x60, 0xf9, 0x43, 0xad, 0x5d, 0x2d, 0xc5,  0xea, 0xfd, 0x02,
 0x0a, 0x4e, 0x7d, 0xcc, 0xa4, 0xb3, 0x73, 0x07, 0xab, 0xd8, 0x70, 0x6c, 0x58,
0xf5, 0x40,  0x5f, 0x51, 0xd3, 0xf5,  0x31, 0xdd,  0x64, 0xc2, 0xae, 0x9c, 0x36,
0x04, 0xe1, 0x0d, 0x58, 0x00, 0xe5, 0x53, 0x23, 0x14, 0xb0, 0xa7, 0xd8, 0x41,
0xdd, 0x5d,  0x3f, 0x65, 0x9b, 0x93, 0xc2, 0x4d, 0xf7, 0x85, 0x37, 0xb7, 0x32,
0x49,  0x9b, 0xb3, 0x97, 0x4a, 0x1a, 0x36, 0x40,  0xd6,  0x20,  0xcc, 0x79,
 0x4c, 0x48, 0xe3, 0x3f, 0x00, 0xe3, 0xd1, 0xaf, 0x48, 0x65, 0x51, 0x9a, 0xf7,
0x42, 0x7d, 0x15, 0xf3, 0x7d, 0x05, 0x0b, 0xfb, 0x76, 0x4c, 0xe8, 0xe3, 0xfe,
0x57, 0xea, 0x11, 0x61, 0xa9, 0x39, 0x26, 0x54, 0x9f, 0x30, 0x57, 0xa5, 0xd4,
0x9d, 0xc4, 0x20,  0x96, 0x82, 0xd6, 0xe0, 0x8f, 0x5c, 0x73, 0x32, 0x27, 0xac,
0x8c, 0x9d, 0x58, 0xe9, 0x3d, 0xb4, 0x30, 0xf8, 0x1e, 0x0f, 0x81, 0xd4, 0xd1]
```

At this point, we are ready to calculate the serial.

```
    def calculate_serial(self):
        serial = b""
        for i in range(len(self.name)-1, 0, -1):
            if((len(serial)+1)%9 == 0 and i!=len(self.name)-1):
                serial += b'-'
            idx = self.name[i] % 0x21
            serial += int.to_bytes(ascii_alphabet[idx], 1, "little")
        return serial
```

Note that the serial consists of 4 blocks each containing 8 characters except the last one with 7 chararcters. These blocks are seperated by a hyphen. The characters in each block have to match the specific entry of the `ascii_alphabet` table at index specified by the `scrambled_name`. The `ascii_alphabet` table is just another array containing these characters:

```
ascii_alphabet = b"ABCDEFGHJKLMNPQRSTUWQYZ0123456789!"
```

This table can be also found in the strings table of the executable.

Overall it was very time consuming and i struggled a little bit with some array offsets, but in the end i was able to generate my own serial for any given username:

```
tizian@tizian-vm1:~/CTF/CSCG2021/rev/keygen$ python3 generator.py
Name: tibotix
serial: b'LGGH8MDC-P97631PU-PH2C0ZT3-K6QGUDW'
tizian@tizian-vm1:~/CTF/CSCG2021/rev/keygen$
```

Exploit Programm:

generator.py:

```
import bitstring
bitstring.bytealigned = True
```

```
alphabet_table = [0x00, 0x1d, 0x30, 0x9f, 0x37, 0xc7,  0xc3, 0x1e, 0xe8, 0x2f,
0xe6, 0x85, 0xcf, 0x4d, 0x52, 0x3f, 0xff, 0xf8, 0xea, 0x9f, 0x3d, 0x73, 0x70,
0xa5, 0x5a, 0xde, 0x3b, 0x39, 0xb3, 0x31, 0x39, 0xa8, 0x8f, 0xe7, 0x65, 0xff,
0xa4, 0x59, 0x61, 0xc0,  0x68, 0x1e, 0xaa, 0x2b, 0x0e, 0xb0, 0xf9,  0x03, 0xf5,
0xa0, 0xb8, 0xab, 0x76, 0x5f, 0x58, 0x57, 0xeb, 0xff, 0x7d, 0x00, 0x4b, 0xe6,
0xf3, 0xfc, 0xc6, 0xc4, 0xe5, 0xbd, 0xdc, 0x48, 0xb7, 0xc4, 0x5e, 0xd8, 0x2d,
0xfd, 0xa6, 0x77, 0xb1, 0xf4, 0xd6, 0xde, 0x49, 0x19, 0x2a, 0x43, 0xfd, 0x9a,
0xda, 0x07, 0x39, 0x6e, 0x57, 0x11, 0x41, 0x61, 0x39, 0x29, 0x35, 0x53, 0xdb,
0xc0, 0x17, 0x55, 0x68, 0x2d,  0xff, 0x9b, 0x21, 0x0c, 0x2f, 0x8d, 0xe3, 0x45,
0x04, 0xfa, 0xa0, 0x60, 0xf9, 0x43, 0xad, 0x5d, 0x2d, 0xc5,  0xea, 0xfd, 0x02,
 0x0a, 0x4e, 0x7d, 0xcc, 0xa4, 0xb3, 0x73, 0x07, 0xab, 0xd8, 0x70, 0x6c, 0x58,
0xf5, 0x40,  0x5f, 0x51, 0xd3, 0xf5,  0x31, 0xdd,  0x64, 0xc2, 0xae, 0x9c, 0x36,
0x04, 0xe1, 0x0d, 0x58, 0x00, 0xe5, 0x53, 0x23, 0x14, 0xb0, 0xa7, 0xd8, 0x41,
0xdd, 0x5d,  0x3f, 0x65, 0x9b, 0x93, 0xc2, 0x4d, 0xf7, 0x85, 0x37, 0xb7, 0x32,
0x49,  0x9b, 0xb3, 0x97, 0x4a, 0x1a, 0x36, 0x40,  0xd6,  0x20,  0xcc, 0x79,
 0x4c, 0x48, 0xe3, 0x3f, 0x00, 0xe3, 0xd1, 0xaf, 0x48, 0x65, 0x51, 0x9a, 0xf7,
0x42, 0x7d, 0x15, 0xf3, 0x7d, 0x05, 0x0b, 0xfb, 0x76, 0x4c, 0xe8, 0xe3, 0xfe,
0x57, 0xea, 0x11, 0x61, 0xa9, 0x39, 0x26, 0x54, 0x9f, 0x30, 0x57, 0xa5, 0xd4,
0x9d, 0xc4, 0x20,  0x96, 0x82, 0xd6, 0xe0, 0x8f, 0x5c, 0x73, 0x32, 0x27, 0xac,
0x8c, 0x9d, 0x58, 0xe9, 0x3d, 0xb4, 0x30, 0xf8, 0x1e, 0x0f, 0x81, 0xd4, 0xd1]
ascii_alphabet = b"ABCDEFGHJKLMNPQRSTUWQYZ0123456789!"

def some_encryption(counter, nn, orig_name_key, name):
    if(counter==0x270):
        name_key = [name] + orig_name_key
        for i in range(counter):
            ecx = name_key[i] ^ name_key[i+1]
            ecx = ecx & 0x7fffffff
            ecx = ecx ^ name_key[i]
            eax = ecx
            b = bool(bitstring.BitArray(uint=eax, length=4*8)[-1])
            if(b):
                eax = 0x9908b0df
            else:
                eax = 0x0
            ecx = ecx>>0x1
            eax = eax ^ name_key[i+397]
            eax = eax ^ ecx
#            print("[{0}] appening: {1}\n".format(hex(counter-i),hex(eax)))
            name_key.append(eax)
        eax = counter
    elif(counter>=0x4e0): # DEAD CODE
        pass
    else:
        name_key = orig_name_key

    nc = name_key[counter] # edx -> 0x9bc -> start of new generated above
    return name_key, (((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) ^ ((((nc ^ (nn &
(nc >> 0xb)) & 0xFFFFFFFF) & 0xff3A58Ad) << 0x7)) & 0xFFFFFFFF) ^ ((((nc ^ (nn &
(nc >> 0xb)) & 0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) &
0xff3A58Ad) << 0x7)) & 0xFFFFFFFF) & 0xffffdf8C) << 0xF)) & 0xFFFFFFFF)>>0x12) ^
((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) &
0xFFFFFFFF) & 0xff3A58Ad) << 0x7)) & 0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) &
0xFFFFFFFF) ^ ((((nc ^ (nn & (nc >> 0xb)) & 0xFFFFFFFF) & 0xff3A58Ad) << 0x7)) &
0xFFFFFFFF) & 0xffffdf8C) << 0xF)) & 0xFFFFFFFF)

class Name():
```

```
    def __init__(self, initial_name):
        self.name = self._extend_name(list(initial_name))

    def _extend_name(self, name):
        rel = len(name)
        for i in range(len(name), 0x20):
            name.append(name[i-rel])
        return name

    def get_name_key(self):
        name_key = [] # starting at [esp+0x28]
        name_iv = self.name_iv
        for i in range(1, 0x270):
            name_iv = ((name_iv>>0x1e) ^ name_iv) & 0xFFFFFFFF
            name_iv = (name_iv * 0x6c078965) & 0xFFFFFFFF
            name_iv += i
            name_key.append(name_iv)
        return name_key

    def scramble_name(self, name_key, counter=0x270, nn=0xFFFFFFFF):
        for i in range(len(self.name)):
            name_key, eax = some_encryption(counter, nn, name_key, self.name_iv)
            index = eax % 0xff
            self.name[i] = self.name[i] ^ alphabet_table[index+1]
            counter += 1

    def calculate_serial(self):
        serial = b""
        for i in range(len(self.name)-1, 0, -1):
            if((len(serial)+1)%9 == 0 and i!=len(self.name)-1):
                serial += b'-'
            idx = self.name[i] % 0x21
            serial += int.to_bytes(ascii_alphabet[idx], 1, "little")
        return serial

    def _hex(self, bytes_):
        return "".join([hex(i)[2:] for i in bytes_])

    @property
    def hex(self):
        return self._hex(self.name)

    @property
    def name_iv(self):
        return bitstring.BitArray(hex=self._hex(self.name[:4][-1::-1])).uint

def keygen(name):
    name = Name(name)
    name_key = name.get_name_key()
    name.scramble_name(name_key)
    serial = name.calculate_serial()
    return serial

if(__name__ == "__main__"):
    name = input("Name: ")
    serial = keygen(name.encode("utf-8"))
    print("serial: {0}".format(str(serial)))
```

exploit.py:

```
from pwn import *
import sys
import generator

initial_name = b"tibotix"
initial_serial = b"LGGH8MDC-P97631PU-PH2C0ZT3-K6QGUDW"

if(len(sys.argv)<3):
    print("Usage: python3 exploit.py <host> <port>")
    sys.exit(0)

host = sys.argv[1]
port = int(sys.argv[2])

p = remote(host, port, ssl=True)

p.recvuntil("Name: ")
p.sendline(initial_name)
p.recvuntil(b"Serial: ")
p.sendline(initial_serial)

p.recvuntil("'")
name = p.recvuntil("'")[:-1]
print(str(name))
serial = generator.keygen(name)
p.sendline(serial)
p.recvline()
flag = p.recvline()

print("[+] Flag found: {0}".format(str(flag)))
```

Run Exploit:

```
tizian@tizian-vm1:~/CTF/CSCG2021/rev/keygen$ python3 exploit.py 7b0000005e5c1a7d11f1700a-keygen.challenge
g.live 31337
[+] Opening connection to 7b0000005e5c1a7d11f1700a-keygen.challenge.broker.cscg.live on port 31337: Done
b'CCx8KMaOx8jiftBG'
[+] Flag found: b'CSCG{0ld_sch00l_k3y5_4r3_th3_b35t_k3y5}\n'
tizian@tizian-vm1:~/CTF/CSCG2021/rev/keygen$
```

FLAG: CSCG{0ld_sch00l_k3y5_4r3_th3_b35t_k3y5}

Possible Prevention:

Offline key validation are always a bad idea. As long as the program is offline and performs the key validation algorithm, this algorithm can be reversed to generate an own valid key. Certainly one could make things harder by adding more obfuscation and encryption to the algorithm but that does not give you a fully protection. When only checking for one universal serial number you could of course use a hash function and store the hash in the binary. But when you want to check a key for any given user, an online based solution is the way to go. Using this approach one should have a centralized database containing the serial keys. When validating a key for a given user, the program sends a validation request to the server with the given serial and namet that will be checked. The server then responds with a failure or success massage. This response should obviously be signed by the servers private key and be verified by the server public key, which will be stored in the binary, and should contain some random nonce to prevent replay attacks.

🗄 Summary / Difficulties:

In the beginning try to let the program do the algorithm. Overall it was not difficult but rather very "noisy" with this many steps we had to reverse. Anyways i enjoyed this challenge a lot and i definitely learned and practiced a lot new stuff.
However on new rev challenges i would overthink my stategy to solve it.

📚 Further References:

[Using reverse engineering techniques to see how a common malware packer works]

[angr]

🔨 Used Tools:

- x32dbg
- pwntools

Notes:

- main address `0x004010A0`

```
#alphabet_table is at [0x403160]

xmm0 = "ABCDEFGHJKLMPQRSTUWQYZ0123456789!\x00\x00" # at 0x403108
ax = "9!"
ecx = &[esp+0x13D4] # beginning of literals+digits alphabet
[esp+0x13F4] = ax
edx = &"!" # end of alphabet
al = [0x40312A] -> 0x00
add esp, 0x4
[esp+0x13D0] = xmm0 # store the literals+digits alphabet (byte-swapped)
[esp+0x13F2] = al # terminate the alphabet

[esp+0xF] = 0x1
al = byte ptr:[ecx]
[esp+0x18] = "!"

vfscanf("%32s", name) # name is at [esp+0x13AC] (byte-swapped)

edx = len(name)
edi = 0x20-edx
for i in range(edi):
    name[i+edx] = name[i] #will append to name so name fills 0x20 bytes

edi = name #name is now that repeated orig name
name += '\x00' #add null terminator
ecx = name[1:]
edi=len(name) -> 0x20??

vfscanf("%36s", serial) # serial is at [esp+1400]

[esp+0x13A4] = 0xFFFFFFFF
edx = name
[esp+0x24] = edx #only first 4 bytes (byte-swapped)
```

```
for i in range(1, 0x270+1):
    edx = (eax>>0x1E ^ edx) * 0x6c078965
    edx += i
    [esp+0x24+(i*4)] = edx #append edx to the stream beginning at [esp+0x24]
# this will fill the [esp+0x24] value with an initial key
[esp+0x20] = 0x270

edi = 0xff
esi = 0

for i in range(4):
    ecx = &[esp+0x20] #-> 0x270 ->? address of this stack value this with the
prepared data at beginning is maybe some key

    some_encryption() #this will set eax
    edx = 0
    ecx = &[esp+0x20] # -> now is 0x271
        edx = eax % edi # edi = 0xff
    byte ptr:[&name+(i*8)] ^ alphabet_table[edx] # byte ptr:[edx*4 + 0x403160]

    some_encryption() #this will set eax
    edx = 0
    ecx = &[esp+0x20]
        edx = eax % edi # edi = 0xff -> so this will return values between
[0;254] -> alphabet table index
    byte ptr:[&name+1+(i*8)] ^ alphabet_table[edx]

    some_encryption() #this will set eax
    edx = 0
    ecx = &[esp+0x20]
        edx = eax % edi # edi = 0xff
    byte ptr:[&name+2+(i*8)] ^ alphabet_table[edx]

    [...]

    some_encryption() #this will set eax
    edx = 0
    ecx = &[esp+0x20]
        edx = eax % edi # edi = 0xff
    byte ptr:[&name+8+(i*8)] ^ alphabet_table[edx]
    #this will set the 32 name bytes with bytes from the alphabet table in an
order specified by some_encryption


edi = [esp+0x14] -> 0x20 from top
esi = 0
edi = edi - 1 # len(name) -1
if(edi>0):
    [esp+0x14] = 0x9
    edx = 1 - &serial
    [esp+0x10] = edx
    #------
    while(edi>0):
        ecx = &serial
        ecx = ecx + esi
        eax = &[ecx+edx] # -> 1
        cdq # if eax is negative, set edx=0xffffffff -> extends value to 64bit
using edx
```

```
        idiv [esp+0x14] # edx:eax / [esp+0x14] (edx:eax / 0x9)
            edx = edx:eax % [esp+0x14]
        if(edx==0 and esi>0):
            eax = "0x000000" + byte ptr:[esp+0xF]
            if(byte ptr:[ecx]==0x2D): edx = eax
            al = dl
            byte ptr:[esp+0xF] = al
        else:
            eax = "0xffffff" + byte ptr:[&name+edi]
            edx = 0
            eax = "0x000000" + al
            edi -= 1
            div [esp+0x18] # [esp+0x18] -> '!' -> 0x21
                edx = edx:eax % [esp+0x18]
            xor byte ptr:[ecx], byte ptr:[&lit_dig_alphabet+edx] # [ecx] ->
serial
            edx = 0
            cl = byte ptr:[ecx]
            eax = "0x000000" + byte ptr:[esp+0xF]
            if(cl==0): edx = eax
            al = dl
            byte ptr:[esp+0xF] = dl
        edx = [esp+0x10]
        esi += 1
    if(al==0):
        esi = [esp+0x10] = "0xffffff" + [esp+0x13EA]
        ecx = [esp+0x18] = "0xffffff" + [esp+0x13DD]
        edx = [esp+0x14] = "0xffffff" + [esp+0x13E7]
        eax = "0xffffff" + [esp+0x13DC]
        edi = eax
        goto CALLKEYGEN

edx = [esp+0x1c] = "0xffffff" + byte ptr:[esp+0x13e7]
eax = [esp+0x14] = "0xffffff" + byte ptr:[esp+0x13d2]
ecx = "0xffffff" + byte ptr:[esp+0x13df]
edi = "0xffffff" + byte ptr:[esp+0x13ea]
esi = ecx
[esp+0x18] = "0xffffff" + byte ptr:[esp+13e1]
[esp+0x10] = "0xffffff" + byte ptr:[esp+13f1]

CALLKEYGEN:
call keygen.401020("%c%c%c%c%c%c%c%c", eax, edx, ecx, esi, edi, [esp+0x1c],
[esp+0x18], [esp+0x10])

ecx = [esp+0x1460]
eax = 0
pop edi
pop esi
ecx = ecx ^ esp
call keygen.4015D4

# edx = last remainder
# ecx is some counter at [esp+0x20]
def some_encrytion(param_1):
    push ecx, esi, edi # to restore those constants afterwards
    edi = ecx
    [ebp-0x4] = edi
    eax = dword ptr:[edi]
```

```
    if(dword ptr:[edi] == 0x270):
        edx = &[edi+0x8]
        for esi in range(eax, 0x0, -1): #while(esi!=0):
            ecx = dword ptr:[edx-0x4]
            edx = &[edx+0x4]
            ecx = ecx ^ [edx-0x4]
            ecx = ecx  & 0x7fffffff
            ecx = ecx ^ [edx-0x8]
            eax = ecx
            al = al & 0x1 # entweder 1 oder 0
            eax = "0x000000" + al
            eax = -eax # CF = 0 if (eax==0) else 1
            eax = -CF # eax = 0x00 if (eax==0) else 0xff
            ecx = ecx>>0x1
            eax = eax & 0x9908b0df
            eax = eax ^ dword ptr:[edx+0x62c]
            eax = eax ^ ecx
            [edx+0x9B8] = eax
        eax = dword ptr:[edi]
    elif(dword ptr:[edi]>=0x4e0):
        eax = [edi+0x9c4]
        push ebx
        ebx = edi+0x9c4
        for edi in range(0xe3, 0x1, -1):
            ecx = [ebx+0x4]
            edx = ebx+0x4
            ecx = ecx ^ eax
            ecx = ecx & 0x7fffffff
            ecx = ecx ^ eax
            eax = ecx
            al = al & 0x1
            eax = "0x000000" + al
            eax = -eax
            eax = -CF
            ecx = ecx>>0x1
            eax = eax & 0x9908b0df
            eax = eax ^ [ebx+0x634]
            eax = eax ^ ecx
            [ebx+0x9c0] = eax
            ebx = edx
            eax = [edx]
        ebx = [ebp-0x4]
        ebx = ebx + 0xd50
        eax = dword ptr:[ebx]
        for edi in range(0x18c, 0x0, -1):
            ecx = eax
            edx = ebx+0x4
            ecx = ecx ^ dword ptr:[edx]
            ecx = ecx & 0x7fffffff
            ecx = ecx ^ aex
            eax = ecx
            al = al & 0x1
            eax = "0x000000" + al
            eax = -eax
            eax = -CL
            ecx = ecx>>0x1
            eax = eax & 0x9908b0df
            eax = eax ^ [ebx-0xd4c]
```

```
            eax = eax ^ ecx
            [ebx-0x9c0] = eax
            ebx = edx
            eax = [edx]
        edi = [ebp-0x4]
        pop ebx
        ecx = [edi+0x1380]
        ecx = ecx ^ [edi+0x4]
        ecx = ecx & 0x7fffffff
        ecx = ecx ^ [edi+0x1380]
        eax = ecx
        al = al & 0x1
        eax = "0x000000" + al
        eax = -eax
        eax = -CF
        ecx = ecx>>0x1
        eax = eax & 0x9908b0df
        eax = eax ^ [edi+0x634]
        eax = eax ^ ecx
        [edi+0x9c0] = eax
        eax = 0
        [edi] = 0



    edx = [edi+eax*4+0x4]
    eax += 1
    [edi] = eax
    ecx = edx
    eax = [edi+0x1384]
    ecx = ecx >> 0xB
    eax = eax & ecx
    edx = edx ^ eax
    eax = edx
    eax = eax & 0xff3A58Ad
    eax = eax << 0x7
    edx = edx ^ eax
    eax = eax & 0xffffdf8c
    eax = eax << 0xF
    edx = edx ^ eax
    eax = edx
    eax = eax >> 0x12
    eax = eax ^ edx
    pop edi
    pop esi



def keygen.401020():
    vfprintf(0x24, 0x00, STDOUT, param1, 0, param2) # 0x404380 ->
0x7AADA0CBFFFFFFFF

    #restore edi
    #restore esi
```